Trishna's

The IIT Foundation Series

CHEMISTRY

CLASS 9

ALWAYS LEARNING

PEARSON

CHEMISTRY CLASS 9

The IIT Foundation Series

(Third Edition)

PEARSON

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Detailed Contents

Class 9

Preface to the Third Edition

Nothing succeeds like success. In today's highly competitive world a student has to withstand immense pressure in order to succeed. Students who aspire to get into the pre-eminent educational institutes to pursue the best courses—be it in Engineering, Medicine or Sciences—will be appearing for some of the most demanding entrance examinations and compete with the country's best minds for those few coveted seats. Only students with thorough understanding of the fundamental concepts and exceptional problem solving skills are able to succeed in that.

The *IIT-Foundation Guide* series of books is designed to provide students with a comprehensive understanding of fundamental concepts, teach them the application of these concepts and develop their problem-solving skills. The objective of these guides is to ensure that the student is able to look beyond the constraints of the regular school syllabus and get a fundamental understanding of Mathematics, Physics and Chemistry.

Irrespective of the field of study that the student may choose to take up later, it is important to understand that Mathematics and Science form the basis for most modern day activities. Hence, it is imperative for each student to have a sound conceptual grounding in Mathematics and Science. This book is intended to serve as a source of learning that goes beyond the usual school curriculum and also form the back bone of the student's preparation for a range of competitive exams.

A distinctive feature of this book is that it is not written by any single individual, unlike most other reference books found in the market. It is in fact written by a team of well qualified faculty members who are all very experienced in teaching sound fundamentals at along with their applications. We are sure that you will find the book very useful in your preparation for various exams.

Preface

As the old adage goes, "nothing succeeds like success." The truth in this maxim cannot be overstated in today's competitive world. The present-day student is under immense pressure to thrive and emerge triumphantly in examinations. Students aspire to get into pre-eminent educational institutes to pursue the best courses–be it in engineering, medicine, arts or sciences–to enable them to prepare for careers at the global level. Their performance in entrance examinations are often the cornerstones that determine if they would be admitted into these hallowed halls of learning. With most of these exams being designed to challenge the innate talent and ingenuity of students, it is only natural that they find these tests most demanding and that they find themselves competing with the country's best minds for those few coveted seats. Only those students with a thorough understanding of the fundamental concepts and exceptional problem-solving skills pass out with flying colours in these tests.

The "IIT Foundation Series" books are designed to provide students with a comprehensive understanding of the fundamental concepts, to teach them the application of these concepts and to hone their problem-solving skills.

The objective of the IIT Foundation Series books is to ensure that students are able to delve beyond the restrictions of their regular school syllabus and get a fundamental understanding of Mathematics, Physics and Chemistry. The books are designed to kindle student interest in these subjects and to encourage them to ask questions that lead to a firm grip on the principles governing each concept.

Irrespective of the field of study that the student may choose to take up later, it is imperative that he or she develops a sound understanding of Mathematics and Science, since it forms the basis for most modern-day activities. Lack of a firm background in these subjects may not only limit the capacity of the student to solve complex problems but also lessen his or her chances to make it into top-notch institutes that provide quality education.

This book is intended to serve as the backbone of the student's preparation for a range of competitive exams, going beyond the realms of the usual school curriculum to provide that extra edge so essential in tackling a typical question paper.

About the IIT Foundation Series

This book is a perfect companion not only for the students of 9th Grade, but also for higher grades. It will help them achieve the much-needed conceptual clarity in the topics which form the basis for their higher study.

Some of the important features of the book are listed below:

- Builds skills that will help students succeed in school and various competitive examinations.
- The methodology is aimed at helping students thoroughly understand the concepts in Mathematics, Physics and Chemistry.
- Helps develop a logical approach to Mathematics, Physics and Chemistry, thereby enabling more effective learning.
- Lays stress on questions asked by board/school examinations as well as application of concepts.
- The concepts are explained in a well structured and lucid manner, using simple language. This aids learning.
- A large number of examples have been included to help reinforce the concepts involved.
- Different levels of practice exercises have been provided which help students develop the necessary application and problem-solving skills.
- The exercises have been designed keeping in mind the various board/school examinations and competitive examinations, such as the NTSE, NLSTSE, Science Olympiad and Cyber Olympiad.
- The book will not only help the students in better understanding of what is taught in regular school classes (and hence enable them to do well in board examinations) but will also help in developing the acumen, resulting in a distinctive edge over their peers.
- Given below are a few examples that demonstrate how the course will help students in understanding the fundamentals:

How does a kingfisher catch fish?

The kingfisher flies vertically over the position of the fish, then plunges into the water at a 90^0 angle. The concept here is that the normally incident rays do not undergo refraction, hence the fish lies exactly where it appears to be. At any other angle, the apparent location of the fish would be different from its real location.

Why do we normally swing our arms while walking, and why not when we carry a load in our hands?

The center of gravity of a body depends on the distribution of mass in the body. As we walk, the movement of the legs tends to cause a shift in the centre of gravity. To compensate for this shift we swing our arms. When we are carrying a load in the hands, however, the effective C.G is lower, making it easier to maintain balance.

Why does salt become damp when kept exposed during the rainy season and not when kept exposed during summer?

In the rainy season humidity in the atmosphere is very high, i.e., there is a lot of moisture in the atmosphere. Thus, calcium chloride, which is the impurity present in common salt, absorbs this moisture and makes the salt damp. In summer, however, as the temperature is high, calcium chloride tends to loose moisture through the process of evaporation, and the salt is left free-flowing.

Structure of the IIT Foundation Series

The IIT Foundation Series is available in Mathematics, Physics and Chemistry. Each chapter in the book is divided into three parts, namely, theory, test your concepts and concept application.

➤ **Theory:**

The theory part deals with the various concepts in Physics/Chemistry/Mathematics, which is a part of the syllabus prescribed by major boards for Class X. The concepts are explained in a lucid manner, and diagrams have been provided, wherever necessary, to illustrate these concepts.

➤ **Test your Concepts:**

This exercise is provided at the end of the theory section of each chapter. These exercises are a collection of very short-answer, short-answer and essay type of descriptive questions. It is intended to provide students with model questions that they may face in the board examination.

Students are expected to prepare for these questions before they attempt any examination based on that particular chapter. Towards the end of the book, the students will find key points for selected questions of the exercise. These key points provide students with an idea of the points that should be a part of an answer for such a question.

➤ **Concept Application:**

This is a collection of exercises in four different classes: Class 7, Class 8, Class 9 and Class 10.

Class 8 consists of basic objective questions. These questions test the basic knowledge of students and enable them to gauge their understanding of concepts when they start solving this exercise. The key for this exercise is provided at the end of the respective chapter.

Classes 9 and 10 consist of descriptive questions of a higher level of difficulty. These questions help students to *apply the concepts* that they have learnt. Key points for selected questions of these exercises have been provided at the end of each chapter in order to help students solve these questions.

These books are available for 7th, 8th, 9th and 10th classes separately for Mathematics, Physics and Chemistry.

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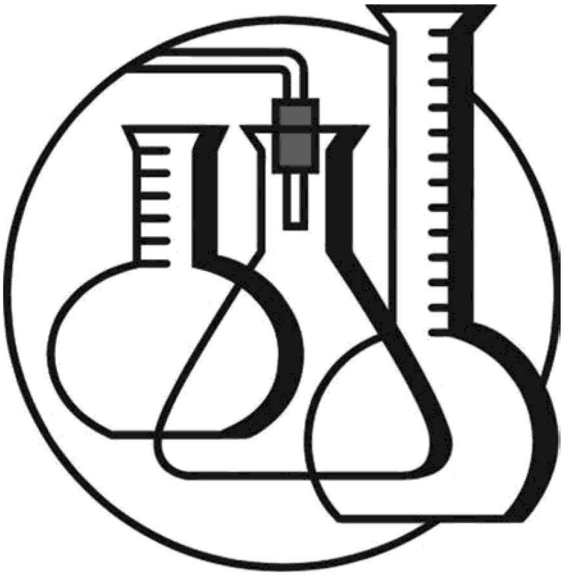
Nature of Matter



INTRODUCTION

The subject of chemistry basically deals with the study of matter in different perceptions. One of the important aspect of study of matter pertains to the various physical states in which matter exists. Another equally important perspective of study is the structure and molecular composition of matter. In addition to these two areas, study of matter is also significant with reference to the type of transformations matter undergoes under various conditions.

Matter basically exists in three states namely solids, liquids and gases. Irrespective of the state of matter, the basic units of matter are only molecules. The three states of matter differ with respect to the pattern of molecular arrangement which brings about change in physical behaviour of the substances in their respective states. The various characteristics of matter which determine the physical behaviour are envisaged in kinetic molecular theory of matter.

Postulates of Kinetic Molecular Theory of Matter

1. Matter is composed of small, tiny particles called molecules.
2. The empty spaces existing between the molecules are called intermolecular spaces.
3. Molecules have forces of attraction between them known as intermolecular forces of attraction. The force of attraction between similar molecules is called **cohesive force** and that between dissimilar molecules is called **adhesive force**.
4. The molecules possess kinetic energy due to their ceaseless motion.

Different states of matter and their properties

The matter around us can be classified into three different states—solids, liquids and gases. The comparison of the three states of matter is tabulated in the next page.

Mass	definite mass	definite mass	definite mass
Volume	definite volume	definite volume	no definite volume
Shape	definite shape	no definite shape, take the shape of the container	no definite shape
Density	high density	lesser density than solids	least density
Compressibility	incompressible	slightly compressible	highly compressible
Rigidity	rigid (cannot flow)	fluid (can flow)	fluid (can flow)
Free surfaces	any number of free surfaces	one free surface i.e., only the upper surface	no free surfaces
Thermal expansion	very low	higher than solids	much greater than both solids and liquids
Diffusion	do not diffuse	some liquids can diffuse spontaneously into another (e.g., water and alcohol), but others do not diffuse. (e.g., Oil and water)	gases diffuse spontaneously and rapidly

The following table gives a comparative study of molecular arrangements in solids, liquids and gases, based on the kinetic molecular theory.

packing of molecules	closely packed	loosely packed.	very loosely packed.
intermolecular space	very low	more than those in solids.	the highest
intermolecular force of attraction	strong intermolecular force of attraction	moderate force of attraction, less than that in solids	negligible intermolecular force of attraction
molecular movement	possess only vibratory motion, but the mean position is fixed	possess translatory and rotatory motion in addition to vibratory motion in one motion	possess translatory, rotatory and vibratory motion in all directions
kinetic energy	very low kinetic energy	high kinetic energy, more than that of solids	the highest kinetic energy

Interconversion of states of matter

Since the physical behaviour of matter in various states depends upon the molecular arrangement which can be changed by changing the conditions of temperature and pressure, matter can be converted from one state to another state under suitable conditions. This is also termed as phase transition.

Interconversion between solid state and liquid state

The process of conversion of solid state to liquid state is called melting or fusion and the opposite process from liquid state to solid state is called freezing. Melting is carried out by supplying heat energy to the solid substance and freezing is carried out by extracting heat energy from the liquid substance.

Melting: When the substance in solid state is subjected to heating, the molecules absorb heat energy which increases the kinetic energy of molecules. This results in increase of kinetic energy of the molecules which in turn leads to increase in temperature, further supply of heat energy does not raise the kinetic energy of molecules. Instead, the heat energy is stored in the form of potential energy. With increase in potential energy, the intermolecular forces of attraction decreases which results in increase in intermolecular spaces. The molecular arrangement of the solid changes to that of liquid. The temperature at which a solid gets converted to liquid state at the atmospheric pressure is called melting point of the solid.

Though each substance has a specific value of melting point under normal atmospheric conditions, certain factors affect the melting point of solids.

Factors affecting melting point

(i) Effect of pressure

The effect of pressure on the melting point of solids depends upon the nature of solid.

For solids which expand on melting, increase in pressure increases the melting point. This is because increase in pressure opposes expansion.

☛ *Examples* Paraffin wax, silver, gold, copper.

For solids which contract on melting, increase in pressure decreases the melting point. This is because increase in pressure favours contraction.

☛ *Examples* Ice, cast iron, brass.

The principle of **regelation** is based on the above concept. Since ice is a solid which contracts on melting, its melting point decreases. When two ice cubes are pressed together, the ice at the interface melts due to the application of slight pressure. When pressure is released, it solidifies again thereby joining the two ice cubes. This principle is called regelation.

(ii) Effect of addition of impurities

Addition of impurities to a solid decreases the melting point of solid thereby allowing the substance to melt at a lower temperature.

Example Rose's metal—alloy of tin, lead and bismuth.

Melting point of this alloy → 94.5°C

Melting point of Pb → 327°C

Melting point of Sn → 231.9°C

Melting point of Bi → 271°C

Freezing: The process of conversion of liquid state to solid state is called freezing. It is the opposite process of melting. This is carried out by extracting heat from a liquid.

When a substance in liquid state is subjected to cooling, heat is extracted from the liquid. Then kinetic energy of molecules decreases which results in decrease in temperature. On reaching a certain temperature, further extraction of heat from the liquid results in decrease in potential energy instead of decreasing kinetic energy. Decrease in potential energy leads to increase in intermolecular forces of attraction and hence decrease in intermolecular spaces. The molecular arrangement of the liquid changes to that of solid. The temperature at which a liquid converts into solid at the atmospheric pressure is called freezing point of the liquid. Freezing point of the liquid is equal to the melting point of the solid for the same substance.

Therefore, the factors which affect the melting point of a substance obviously affect the freezing point. For example, the addition of impurities to the solids decreases the melting point of solid and at the same time decreases the freezing point of the liquid to the same extent. The above principle can be made use of in the preparation of freezing mixtures. A mixture of 3 parts of ice and 1 part of common salt is called freezing mixture which is used to produce a lower temperature of –21°C. Freezing mixtures are used for preservation of food stuffs especially perishables such as fish and meat.

Interconversion between liquid state and gaseous state

Vapourization

The process of conversion of liquid state to gaseous state is called vapourisation. When the liquid is subjected to heating, kinetic energy of molecules increases which results in increase in temperature. At a particular temperature, there is no further increase in kinetic energy of molecules. The heat energy supplied increases the potential energy of molecules. As a result, the intermolecular forces of attraction decreases. The molecules move apart and the substance passes from liquid state to gaseous state. This process is called boiling and the temperature at which the conversion of liquid state to vapour state takes place at normal atmospheric pressure is called boiling point.

Factors affecting boiling point

Though every liquid is characterised by specific value for boiling point, it depends on some factors.

Effect of pressure

The boiling point of a liquid increases with increase in external pressure. This is the reason why water boils at a lower temperature than 100°C at higher altitudes.

This principle is made use of in the working of pressure cooker.

In a pressure cooker, water is subjected to heating in a closed vessel in confined space. The steam generated in fixed volume increases the pressure beyond the normal atmospheric pressure.

Since the external pressure is more, the boiling point of water raises beyond 100°C. The temperature of cooking medium being greater than the normal boiling point, food gets cooked at a faster rate thus saving time and fuel.

Effect of impurities

When any solid substances are dissolved in a liquid, the boiling point of liquid raises beyond the normal boiling point. For example, when common salt is dissolved in water, the solution boils at a temperature greater than 100°C.

Conversion of liquid state to gaseous state can also be brought about even without supplying heat energy to the liquid. In a liquid, the surface molecules possess higher kinetic energies than the molecules in the bulk of the liquid. Due to this reason, the molecules break away from the forces of attraction of the other molecules and go into vapour state. This process of conversion of a liquid state into vapour state at a temperature below the boiling point is called evaporation.

In contrast to boiling, evaporation is considered as a surface phenomenon since it is confined to only surface molecules. It is also a slow process taking place over a period of time at any temperature whereas boiling takes place rapidly at a specific temperature. Vapourization is a common term applicable for both evaporation and boiling.

Factors affecting evaporation

(i) Surface area: Increase in surface area increases the rate of evaporation.
(ii) Temperature: Increase in temperature increases the rate of evaporation.
(iii) Humidity: The amount of water vapour which the atmospheric air holds is called humidity. Higher humidity decreases the rate of evaporation.
(iv) Wind speed: Increase in wind speed increases the rate of evaporation.

Condensation: The conversion of gaseous substance into liquid state is called condensation. This can be carried out by cooling the gas below a particular temperature.

When heat is extracted from the gas, the kinetic energy of molecules decreases and hence temperature falls. When sufficiently low temperature is reached further extraction of heat from the gas does not reduce the kinetic energy. This in turn results in increase in intermolecular forces of attraction bringing the molecules closer. At this point, the gas passes into liquid state.

The conversion of gaseous state to liquid state can also be brought about by the application of pressure. The gases have to be cooled below a certain temperature and then subjected to application of high pressure. This entire process is called liquefaction. Every gas requires a certain minimum temperature for passing into liquid state. That means, above that minimum temperature, application of any amount of pressure cannot bring about the transformation from gaseous state to liquid state. This temperature above which a gas cannot be liquefied howsoever high pressure is applied is called critical temperature. Every gas is associated with a specific critical temperature.

CO_2	31.1°C
NH_3	132°C
O_2	–118°C
N_2	–147°C
H_2	–165°C
He	–240°C
SO_2	20°C

Effects of condensation on climate

The formation of dew, fog and clouds are the applications of condensation.

When the temperature is high, water in water bodies evaporates and during day times the process goes on continuously and the air does not become saturated with water vapour. When the temperature falls during night time, the air becomes saturated with water vapour. The temperature at which the atmospheric air becomes saturated with water vapour is called dew point. On further lowering of temperature, some of the water vapour condenses and the water droplets condense as dew. If the condensation of water vapour takes place on floating dust particles, it results in the formation of fog or mist. In the upper part of atmosphere, the condensed water droplets appear as clouds.

Apart from these inter conversions, the conversion of solid state to gaseous state is also possible in some cases. This process of conversion of solid state into vapour state directly without passing through intermittent liquid state is called sublimation. The vapours when condensed give back the solids. Such solids formed from the vapour is called sublimate. Only some solids undergo sublimation.

☛ *Examples* camphor, naphthalene, ammonium chloride, iodine.

Latent Heat

The change of state of a substance is invariably associated with absorption or liberation of heat. However, the change is not associated with a change in temperature of the substance in any process. It is considered that the heat energy gets hidden into the substances involved in the process and is called latent heat.

For example, when ice melts, the temperature of ice remains constant only at the melting point until the entire process is completed. The entire heat absorbed during the process is utilised to carry out the change. Therefore, the amount of heat energy required to convert 1 kg of a solid into liquid at atmospheric pressure at its melting point is known as the latent heat of fusion. For ice, it is equal to 80 cal per gm.

☛ *Example* When water is subjected to boiling, the temperature of water remains constant at the boiling point until all the water is converted to steam. The heat energy supplied during the process is stored in the steam and this is called latent heat of vapourisation. For steam this equal to 540 cal per gram.

Applications of latent heat

Cooling produced due to evaporation

The liquid molecules absorb energy from the surroundings and overcome the forces of attraction thereby going into vapour state. Since surroundings lose energy, it becomes cold. This principle is made use of in various daily life activities.

(i) Cool sensation produced when alcohol is poured on palm.
(ii) Cotton clothes producing cooling effect during summer.
(iii) Formation of water droplets on the outer surface of glass containing ice cold water.
(iv) Cooling of water in earthen pots during summer.

The basic units of matter in any state are considered as molecules as far as the physical behaviour of matter in different states and their interconversion under different conditions are concerned. This is because molecule is considered as the smallest particle of matter which has an independent existence. However, when focus is laid on the chemical behaviour of matter, the classification of matter with respect to molecular composition becomes inevitable. This is because a molecule is broken down into smaller particles called atoms which take part in chemical reactions.

Classification of Matter on the Basis of Chemical Composition

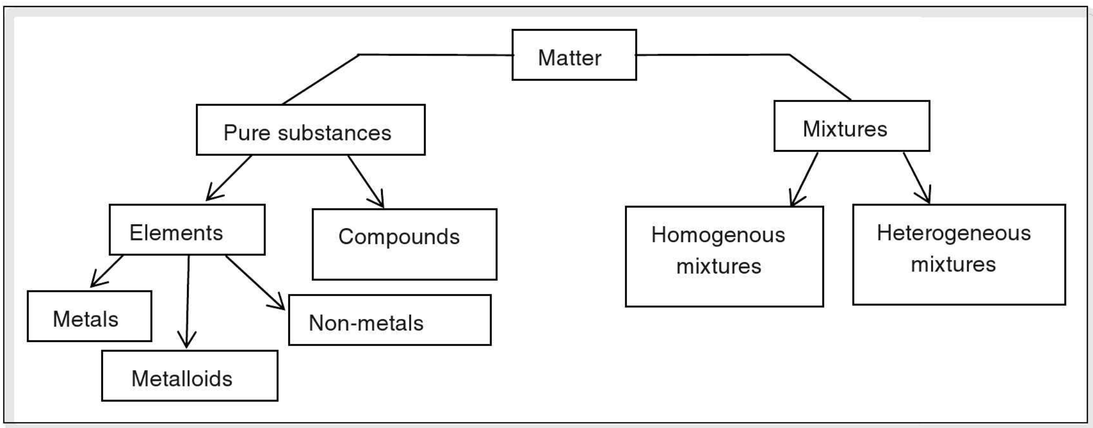


Figure 1.1

A pure substance is the one which is made up of molecules containing same kind of atoms. For example, in case of pure water all the molecules are made up of two hydrogen atoms and one oxygen atom.

In case of a pure substance, the molecule may contain similar atoms or dissimilar atoms. The first category of pure substances in which a molecule is made up of atoms of the same kind are called elements. For example, in hydrogen gas a molecule of hydrogen is made up of two hydrogen atoms. The second category of substances are called compounds. A molecule of carbon dioxide is made up of one carbon atom and two oxygen atoms.

Mixtures are those substances which contain two or more kinds of molecules. For example, common salt solution contains molecules of NaCl and molecules of water. Mixtures may have constituents as elements, an element and a compound or only compounds.

Depending on the distribution of the different kinds of molecules within the mixture, they are classified into two types. Homogeneous mixtures have uniform distribution of the different types of molecules in the mixture. Heterogeneous mixtures have non uniform distribution of the different types of molecules. For example, aqueous solution of glucose is a homogeneous mixture and muddy water is a heterogeneous mixture.

Characteristics of elements

I. Based on their nature, elements are classified as metals, non-metals and metalloids.

☛ *Example* Na, Mg, Al, Cu etc., are metals.

H_2, O_2, He, S etc., are non-metals.

As, Sb, Se, Te, Ge are metalloids.

II. Elements can also be classified on the basis of their atomicity. The number of atoms present in the molecule of an element is called atomicity.

(i) Monoatomic elements: The molecule of the element is made up of only one atom. All metals, noble gases and some non-metals are monoatomic.

☛ *Example* Ag, Al, Au

He, Ne

B, C

(ii) Diatomic elements: The molecule of the element is made up of two atoms. Only some gaseous non-metal are diatomic.

☛ *Example* H_2, O_2, N_2

(iii) Polyatomic elements: The molecule of the element is made up of more than two atoms. Very few elements are polyatomic.

☛ *Example* O_3, P_4, S_8

Characteristics of Compounds

(i) The constituents elements are present in a fixed proportion by weight.

☛ *Example* In CO_2, carbon and oxygen are in the ratio of 12 : 32 (3 : 8)

(ii) The elements do not retain their properties.

☛ *Example* The properties of water are entirely different from those of hydrogen and oxygen.

(iii) The constituent elements can be separated only by chemical methods.

☛ *Example* Water can be decomposed into hydrogen and oxygen by electrolysis method.

(iv) All compounds are invariably homogenous.

(v) The formation of a compound is generally associated with significant energy changes.
$C + O_2 \rightarrow CO_2 - 94$ k cal

Characteristics of mixtures

(i) The constituents may be present in any proportion.

(ii) The constituents retain their individual properties.

☛ *Example* Aqueous solution of sugar.

(iii) Separation of constituents is carried out by physical methods.

(iv) Mixtures can be either heterogeneous or homogeneous.

(v) Formation of a mixture does not involve significant energy change.

Classification of mixtures

Solid–Solid	Stainless steel, Brass Bronze	Iron and sulphur
Solid–Liquid	NaCl in water Iodine in CCl_4	Sulphur in water
Liquid–Liquid	Alcohol and water Benzene and toluene	Oil and water
Liquid–Gas	Liquor ammonia, soda water	–
Gas–Gas	Air	–
Solid–Gas	–	Hydrogen gas adsorbed on Pd

Separation of mixtures

Most of the substances available in nature are not pure substances and they are mixtures. The useful component present in the mixture can be obtained only by separating the individual components of the mixture by following suitable method. The method of separation employed depends upon the nature of components in the mixture.

Separation of solid–solid mixtures

Solvent extraction	Solubility of one component in a solvent.	A mixture of sulphur and sand. Sulphur is soluble in CS_2 and sand is insoluble.
Magnetic separation	Magnetic property of one component.	Mixture of iron ore and sand. Iron ore is attracted by magnet and sand is left behind.
Gravity method	Difference in densities of components.	Mixture of sand and chalk powder. Sand being heavier than chalk powder sinks in water whereas chalk powder floats on water.
Sublimation	Ability of one component to sublime.	Mixture of iodine and sand. On heating iodine sublimes leaving behind sand. The vapours on cooling give solid iodine.
Fractional crystallisation	Difference in solubility of the components in the same solvent.	Mixture of KNO_3 and NaCl. KNO_3 being more soluble than NaCl, when the aqueous solution of this mixture is subjected to heating, the more soluble KNO_3 escapes out along with water vapour and less soluble NaCl is left behind and crystallises out.

Separation of solid–liquid mixtures

Sedimentation and decantation	High density of insoluble solid Component.	Mixture of sand and water Sand being heavier settles at the bottom and liquid is slowly transferred into another container.
Filtration	Size of the particles of insoluble solid component.	Mixture of $BaSO_4$ and H_2O on passing through filter paper, water passes through and $BaSO_4$ remains on the filter paper.
Evaporation	The ability of solid to remain undecomposed when solution is heated up to the boiling point of the liquid component.	Mixture of sugar and water. Water evaporates on heating leaving behind crystals of sugar.
Distillation	Heating the solution to the boiling point of liquid component followed by condensation of the vapours.	Mixture of NaCl and water. Water evaporates and condenses back to water and NaCl is left behind in the distillation flask.
Centrifugation	Size of density of solid particles in comparison to the size of liquid particles.	Milk contains solid fat particles in water. Size of solid particles is less and hence they pass through the filter paper. When this is subjected to centrifugation heavier fat particles settle down at the bottom leaving behind lighter water on the top.

Separation of liquid–liquid mixtures

Separating funnel	Difference in densities of the two liquid components.	Kerosene oil and water are immiscible liquids. When the mixture is taken in the separating funnel, the lighter liquid (kerosene) forms top layer and the heavier liquid (water) settles down.
Fractional distillation	Difference in boiling points of the liquids.	Distillation carried out by including a fractionating column. E.g., Ethyl alcohol + water. Ethyl alcohol has a lower boiling point than water and hence vapourizes. On passing through fractionating column the vapours condense to give alcohol in a receiver. Water is left behind in the distillation flask.

Separation of gas–gas mixtures

Diffusion	Difference in densities of component gases.	The gas with lower molecular weight diffuses faster than the gas with higher molecular weight. E.g. H_2 and CH_4 He and SO_2
Dissolution in suitable solvents	Difference in solubility of component gases in a given solvent.	A mixture of CO_2 and CO. CO_2 is soluble in KOH leaving behind CO. In a mixture of NH_3 and N_2, NH_3 is soluble in water and N_2 is insoluble.
Preferential liquefaction	Difference liquifaction of component gases under pressure.	A mixture of NH_3 and H_2. Ammonia gets liquified under high pressure and hydrogen gas is left behind.
Fractional evaporation	Difference in boiling points of the component gases.	When air is liquefied, the major components of air, N_2 and O_2 can be separated by subjecting the liquid to evaporation. N_2 has a lower boiling point and hence boils off O_2 has a higher boiling point and remains behind.

Separation of liquid–gas mixtures

Heating	Decrease in solubility of a gas with increase in temperature.	When a solution containing a gas is subjected to slight heating below the boiling point of the liquid, the gas escapes out leaving behind the liquid component. E.g. Separation of dissolved O_2 by heating water.
Lowering the pressure	Difference in solubility of gas in the liquid at different pressures.	E.g. Soda water. When soda water bottle is opened, the pressure inside the bottle decreases. CO_2 gas fizzes out of the bottle.

Paper chromatography

Apart from all different methods of separation of mixtures, there is a special technique for separation and identification of the constituents in the mixture.

Principle: Based on difference in adsorption of constituents by a surface of an appropriate adsorbent material or solid medium (stationary phase). The rate of adsorption of a particular constituent depends upon its solubility in the solvent (moving phase)

☛ *Example* Separation of coloured constituent in a mixture of ink by paper chromatography.

Process: A filter paper is taken which generally absorbs water. It acts as stationary phase. The mixture containing different constituents is taken on the filter paper which is then dipped in another solvent called moving phase. If the constituent has more affinity for the adsorbent material, it moves slowly on the filter paper. If the constituent has more affinity for the solvent acting as moving phase, it moves rapidly on the filter paper. Therefore, depending on the relative affinities of the various constituents with the stationary phase and moving phase, spots or lines appear on the filter paper at different positions.

☛ *Example* Separation of coloured constituents in a mixture of ink.

Matter, has an inherent tendency to undergo transformation under suitable conditions. The transformations are basically of two types. Firstly, the changes which do not involve any change in molecular composition of the substance. They are termed as physical changes. Secondly, the changes which involve changes in molecular composition of the substance. These are termed as chemical changes.

Conditions required for chemical changes

(i) **Physical contact between reactants:** A chemical reaction takes place only when the two reactants come in contact with each other. For example, sodium on exposure to water or even moisture react to give sodium hydroxide and hydrogen and hence sodium catches fire. Due to this reason only sodium is stored in kerosene.

(ii) **Heat:** Generally, chemical reaction involve absorption or release of heat energy. Based on the heat changes, the reactions are classified as exothermic and endothermic reactions. The change in energy is represented as ΔH.

Many compounds decompose on absorption of heat. These are endothermic reactions. ΔH is positive.

☛ *Example* $KNO_3 \xrightarrow{\Delta} KNO_2 + O_2 \quad \Delta H = 244.7\ KJ$

$CaCO_3 \xrightarrow{\Delta} CaO + CO_2 \quad \Delta H = 178\ KJ$

Certain chemical reactions such as combustion are associated with release of heat energy. These are exothermic reactions. ΔH is negative.

☛ *Example* $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \quad \Delta H = -890.4\ KJ$

(iii) **Light:** Certain chemical reactions take place with the help of light energy. These are called photochemical reactions.

☛ *Example* $H_2 + Cl_2 \xrightarrow{\text{Light}} 2HCl$.

$6CO_2 + 6H_2O \xrightarrow{\text{electric}} C_6H_{12}O_6$ (photosynthesis)

Some chemical reactions are also associated with release of light energy.

☛ *Example* $Mg + O_2 \rightarrow 2MgO$ + Light

(iv) **Pressure:** There are some chemical reactions which require high pressure condition for the reaction to take place at reasonable rate.

☛ *Example* $2SO_2 + O_2 \xrightarrow{V_2O_5} 2SO_3$ (manufacture of H_2SO_4 by contact process)

$Pb + S \rightarrow PbS$

(v) **Catalyst:** Catalyst is a substance which alters the rate of a chemical reaction. Generally, a catalyst speeds up a chemical reaction. These are termed as positive catalysts in contrast to the negative catalysts which deteriorate the rate of chemical reaction.

☛ *Example* $N_2 + 3H_2 \xrightarrow{\text{Fe}} 2NH_3$

450 °C 200 atm

For the manufacture of ammonia by Haber process, iron acts as a positive catalyst.

☛ *Example* $H_2O_2 \rightarrow H_2O + O_2$

Acetanilide acts as a negative catalyst for the decomposition of H_2O_2 and hence acts as a stabiliser for the solution of H_2O_2.

Since there are vast number of chemical reactions, the study of these reactions becomes easier and convenient by classifying them into various types.

[redacted]		
Chemical combination	Combination of two or more substances.	$N_2 + O_2 \rightarrow 2NO$ (synthesis) $2CO + O_2 \rightarrow 2CO_2$ (compound–element) $NH_3 + H_2O \rightarrow NH_4OH$ (compound–compound)
Chemical decomposition	Splitting of a compound into two or more simpler substances.	$2NaNO_3 \xrightarrow{\Delta} 2NaNO_2 + O_2$ (Thermal decomposition) $2HgO \xrightarrow{\Delta} 2Hg + O_2$ $2HOCl \xrightarrow{\text{Light}} 2HCl + O_2$ (photolytic decomposition) $2H_2O \xrightarrow{\text{electric}} 2H_2 + O_2$ arc (Electrolyte decomposition)

(Continued on following page)

Double decomposition	The radicals of the reactants are interchanged. A double decomposition reaction between acid and base is called neutralisation reaction. Precipitation reactions also are double decomposition reactions.	$Na_2SO_4 + Zn(NO_3)_2 \rightarrow 2NaNO_3 + ZnSO_4$ $2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$ $CaBr_2 + K_2SO_4$ $\downarrow$ $CaSO_4 + 2KBr$
Displacement	Less reactive element is displaced by more reactive element.	$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$ $2KCl + F_2 \rightarrow 2KF + Cl_2$

Since the displacement reaction depends upon the relative reactivities of various metals, they are arranged in decreasing order of reactivity.

Displacement reaction

In a displacement reaction, the more reactive element displaces the less reactive element from its compound.

Representation: $AB + C \rightarrow CB + A$

$$XY + Z \rightarrow XZ + Y$$

The ability of an element to displace another element is known by its relative position in the reactivity series.

Metal reactivity series

Potassium	K	(Most reactive metal)
Sodium	Na	
Calcium	Ca	
Magnesium	Mg	
Aluminium	Al	
Zinc	Zn	Reactivity decreases
Iron	Fe	
Nickel	Ni	
Tin	Sn	
Lead	Pb	
Hydrogen	H	
Copper	Cu	
Mercury	Hg	
Silver	Ag	
Gold	Au	
Platinum	Pt	(Least reactive metal)

The more reactive metal displaces the less reactive metal from its compound.

☛ *Example* $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$

(copper Sulphate) ferrous sulphate

As iron is more reactive than copper, it displaces copper from copper sulphate solution, thereby forming ferrous sulphate.

Similarly, halogens also can be arranged in the order of reactivities which represents their relative abilities for displacement from the respective compounds.

Halogen reactivity series

F_2	↓ Reactivity decreases	(Most reactive halogen)
Cl_2		
Br_2		
I_2		(Least reactive halogen)

The more reactive halogen displaces, the less reactive halogen from its compound.

☛ *Example* $2NaBr + Cl_2 \rightarrow 2NaCl + Br_2$

test your concepts

Very short-answer type questions

1. What is the effect of addition of impurities on freezing point and boiling point of a substance?
2. What is a freezing mixture? Give an example.
3. Define melting point. What is the effect of pressure on melting point?
4. What are cohesive forces and adhesive forces?
5. Cotton clothes producing cooling effect during summer is an application of ______.
6. Why do the wet clothes dry faster on windy day?
7. Is it possible to liquify CO_2 gas at 50 °C? Give reason.
8. A mixture of sand and NH_4Cl can be separated by _____ method.
9. Define latent heat of fusion. Give its value for ice.
10. What is meant by atomicity of an element? Give some examples of polyatomic elements.
11. "All pure substances are homogenous. But, all homogenous substances are not pure". Justify
12. Distinguish between filtration and centrifugation.
13. Silver is a substance which expand on melting so its melting point _____ when pressure is raised.
14. Give an example each for solid-liquid and solid–solid homogenous mixtures.

15. The atomicity of element phosphorus is _____.

16. _____ is the method of separating heavier fat particles of milk from lighter water.

17. A metal 'A' reacts with a metallic chloride of 'B' to give metal 'B'. But, metallic chloride of 'A' cannot give metal 'A' on reaction with metal 'B'. What conclusion can you draw from this?

18. Solubility of a gas in a liquid _____ with rise of temperature.

19. Give an example for a liquid–liquid heterogeneous mixture. Suggest a method of separation for it.

20. The forces of attraction existing between similar molecules are _____.

21. How do you separate a mixture of

(a) CO_2 and O_2 (b) H_2 and O_2

22. The formation of phosphorus pentachloride from phosphorus trichloride and chlorine gas is a _____ type of combination reaction.

23. The addition of MnO_2 to $KClO_3$ decreases the temperature at which $KClO_3$ decomposes because MnO_2 added acts as a ______ catalyst.

24. What is paper chromatography?

25. A mixture of NH_3 and H_2 can be separated by applying pressure, because of their high difference in _____.

26. Why is sodium stored in kerosene?

27. A compound is always _____.

28. A reaction of decomposition of a compound AB is accompanied by absorption of some heat energy. What is the sign of ΔH?

29. The temperature above which no amount of pressure can cause a gas to liquify is _____.

30. What is sublimation? Give some examples.

Short-answer type questions

31. Suggest a method of separation for a mixture of sodium chloride and ammonium chloride. Explain the process.

32. When two ice cubes are pressed, they join together. Explain the principle involved.

33. Why are cotton clothes preferable in summer?

34. How is liquefaction different from condensation?

35. Distinguish between evaporation and boiling.

36. When a glass of ice cold water is taken in a glass, water drops are formed on the outer surface of the glass. Give reason.

37. What is double decomposition reaction? Give an example each for neutralisation and precipitation reaction.

38. Why is it not possible to displace fluorine from metallic fluorides by any other halogen?

39. How is oxygen prepared from air?

40. Explain the process of condensation with respect to kinetic molecular theory.

41. What is critical temperature? How does it affect the liquefaction of gas?

42. Why does steam cause more burns than boiling water?

43. List out the differences between physical and chemical changes.

44. Why do solids have any number of free surfaces and gases have no free surfaces at all? Also compare with liquids.

45. What are the different types of combination reactions? Give an example of each.

Essay type questions

46. Suggest the possible methods of separation of liquid gas mixtures. Explain each method with an example.

47. Explain the factors affecting
    (a) melting point
    (b) boiling point
    (c) evaporation

48. Give the postulates of kinetic molecular theory of matter. Explain the process of melting on the basis of this theory.

49. Explain the process of separation of different constituents in coloured ink.

50. Explain the following methods of separation with an example each.
    (a) Fractional crystallization
    (b) Sedimentation and decantation
    (c) Preferential liquefaction
    (d) Fractional distillation

CONCEPT APPLICATION

Concept Application Level—1

Direction for questions 1 to 7: State whether the following statements are true or false.

1. Boiling point of rainwater is less than that of sea water.

2. Liquid has only one free surface.

3. The rate of evaporation decreases with increase in humidity.

4. During melting of a solid, there is no change in the kinetic energy of molecules.

5. The reaction of sodium chloride with bromine gas is a chemical displacement reaction.

6. The strong intermolecular forces of attraction are responsible for high rigidity of solids.

7. Burning of a piece of magnesium wire is a synthesis reaction.

Direction for questions 8 to 14: Fill in the blanks.

8. A mixture of SO_2, H_2 and Cl_2 can be separated by __________ followed by __________.

9. A liquid wets the given surface if, ___________ forces are predominant over _________forces

10. A mixture contains nitre, common salt and silver chloride as the components. The different separation techniques involved are ___________, ____________ and __________.

11. The reactions of a compound KX with fluorine, chlorine, bromine in three different reactions are given below:

$2KX + F_2 \rightarrow 2KF + X_2$

$2KX + Cl_2 \rightarrow 2KCl + X_2$

$2KX + Br_2 \rightarrow 2KBr + X_2$

then KX is _____________.

12. In two closed containers, substances A and B are present. After sometime, the lid of the container containing substance A alone got off with a lot of pressure. This is because substance A ________.

13. If cold water is poured on a flask containing very hot distilled water and water vapour, the water inside the flask started to boil below 100°C, the principle involved is ___________.

14. Three solid substances x, y, z are heated, the number of free surfaces of substances x, y decreases to zero and one respectively. The number of free surfaces of z does not change. The substances associated with an increase in PE in substances is/are ___________.

Direction for question 15: Match the entries in column A with the appropriate ones in column B.

15.

A	Photolysis	( )	a.	$Fe + S \rightarrow FeS$
B	Electrolysis	( )	b.	$2KI + Cl_2 \rightarrow 2KCl+I_2$
C	Element–element combination	( )	c.	$CaO + H_2O \rightarrow Ca(OH)_2$
D	Compound–compound combination	( )	d.	$PCl_3 + Cl_2 \rightarrow PCl_5$
E	Chemical displacement	( )	e.	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
F	Double decomposition	( )	f.	$2H_2O \rightarrow 2H_2 + O_2$
G	Element–compound combination	( )	g.	$Pb(NO)_2 + 2HCl + PbCl_2+2HNO_3$
H	Combustion	( )	h.	$CaO + CO_2 \rightarrow CaCO_3$
I	Hydrolysis	( )	i.	$AgBr_2 \rightarrow Ag + Br_2$

Direction for questions 16 to 45: For each of the questions, four choices have been provided. Select the correct alternative.

16. The bulb of a thermometer when dipped in petrol and then taken out, the level of the mercury thread in the thermometer

(1) starts falling
(2) starts rising
(3) remains at the same level
(4) initially falls and then rises

17. The high diffusibility of gases is due to

(1) high intermolecular forces of attraction
(2) high KE of molecules
(3) restricted translatory motion in upward direction
(4) All the above

18. Water kept in an earthen pitcher, during summer days becomes very cold due to

(1) condensation (2) evaporation (3) freezing (4) fusion

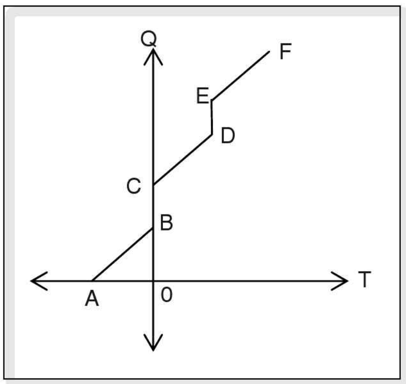
19. The electric bulb on long use forms a black coating on its inner surface. The process associated with this is

(1) melting of tungsten (2) sublimation of tungsten
(3) oxidation of tungsten (4) reduction of tungsten

20. Identify a physical change among the following.

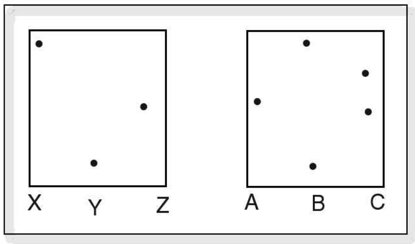
(1) Respiration (2) Digestion of food
(3) Burning of wax (4) Glowing of an electric bulb

21. During a phase transition of a substance the temperature (T) versus heat energy (Q) graph is shown below. Identify the regions of the graph which show an increase in only PE.



(1) AB, BC (2) BC, DE
(3) CD, EF (4) All the regions in the given graph.

22. Chromatogram of pure samples of food colours X, Y and Z is given in fig 1. Three samples of same food materials A, B, C are analysed for purity, with the help of the chromatogram in fig 2. Identify the impure sample.



(1) A (2) B (3) C (4) A and C

23. Maximum intermolecular forces of attraction exists in

(1) bromine (2) air (3) oxygen (4) copper

24. A gaseous mixture of A, B and C is passed through water. The gaseous mixture B and C remains. If this gaseous mixture of B and C is subjected to sudden expansion followed by application of high pressure, B liquifies leaving behind C. Identify the set of gases.

(1) SO_3, NO_2, O_2 (2) Cl_2, SO_2, H_2 (3) CO_2, CO, N_2 (4) NH_3, N_2, H_2

25. Identify the element from the following.

(1) Air (2) Iodine vapour (3) Water (4) Amalgam

26. In which of the following cases, cooking is very slow?

(1) Pressure cooker at sea level (2) Pressure cooker at higher altitude

(3) Open vessel at sea level (4) Open vessel at higher altitude

27. Which of the following reaction is not a combination reaction?

(1) Reaction of iodine with white phosphorus (2) Reaction of iron with sulphur

(3) Addition of water to lime (4) Addition of concentrated sulphuric acid to sugar

28. A mixture of three liquids X, Y and Z when subject to fractional distillation, the order in which the vapours condense back to liquid state in fractionating tower is Y, X and Z. Arrange them in the correct order of vapour pressures.

(1) Z < X < Y (2) Y < X < Z

(3) X < Z < Y (4) X < Y < Z

29. Grease spots from garments can be separated by a method of

(1) chromatography (2) solvent extraction

(3) sublimation (4) dissolution in suitable solvents

30. Which of the following involves both neutralization as well as precipitation?

(1) Reaction between baking powder and H_2SO_4. (2) Reaction between $BaCl_2$ and Na_2SO_4.

(3) Reaction between $AgNO_3$ and HCl. (4) Reaction between slaked lime and H_2SO_4.

31. Arrange the following changes of energy during following phase transition in a proper order.

Ice (0°C) → water (50°C) → ice (0°C)

(a) Potential energy increases and kinetic energy remains constant.

(b) Potential energy decreases and kinetic energy remains constant

(c) Potential energy increases and kinetic energy increases

(d) Potential energy decreases and kinetic energy decreases.

(1) d b c a (2) a c b d

(3) a c d b (4) c d a b

32. For the separation of red ink from blue ink a technique is used which is described below. Arrange the statements in a proper sequence.

(a) The blue and red ink form spots at certain distances on the paper.

(b) Paper chromatography is used for the separation.

(c) Paper and solvent are taken as stationary and mobile phases respectively.

(d) A narrow strip of paper with a line drawn is cut and a mixture of red and blue ink with the help of capillary is placed on the line marked on the paper.

(e) The paper is suspended in the closed jar with the help of hook.

(1) b d c e a (2) b e c a d

(3) b c d e a (4) a d e c b

33. Among the following, identify the substance in which molecules possess vibratory, rotatory motions and translatory motion in all directions except in one direction.

(1) Bromine (2) Iodine (3) Ammonia (4) Silicon dioxide

34. At Darjeeling, distilled water boils at a temperature

(1) above 373K (2) above 473K (3) below 373K (4) at 373K

35. At melting point,

(1) kinetic energy remains constant and potential energy increases.

(2) kinetic energy increases and potential energy remains constant.

(3) both potential energy and kinetic energy increase.

(4) potential energy increases with a decrease in kinetic energy

36. Which among the following statements is true?

(1) The rate of evaporation in a coastal area is less when compared to a non coastal area.

(2) The rate of evaporation in a non coastal area is less when compared to a coastal area.

(3) In both the areas the rate of evaporation is the same.

(4) None of the above

37. Which among the following is not a homogeneous mixture?

(1) Solder (2) Aqueous solution of NaCl

(3) Sulphur in carbon disulphide (4) Sulphur in water

38. Gun powder is a ______

(1) solid-liquid homogeneous mixture
(2) solid-liquid heterogeneous mixture
(3) solid-solid homogeneous mixture
(4) solid-solid heterogeneous mixture

39. Which of the following gases can be separated completely from a mixture by using water as a solvent?

(1) CO_2 and O_2 (2) N_2 and NH_3 (3) CO_2 and NH_3 (4) H_2 and N_2

40. Identify the mixture which can be separated by magnetic separation method.

(1) Chalk powder + sand (2) Iron + sand (3) Common salt + sand (4) Sulphur + sand

41. Which among the following is true?

(1) Air is a bad conductor of heat and thermal expansion of solids is more than that of gases.
(2) Air is a good conductor of heat and thermal expansion of solids is less than that of gases.
(3) Air is a bad conductor of heat and thermal expansion of solids is less than that of gases.
(4) Air is a good conductor of heat and thermal expansion of solids is more than that of gases.

42. Which of the following phenomena is based on the principle that cooling results due to evaporation?

(1) Formation of water drops on the surface of cold drink bottle.
(2) Formation of crystals of ice on the inner surface of the lid of an ice cream box in freezer.
(3) White foggy appearance on the surface of large ice blocks.
(4) Stretching out of tongues by dogs during summer season.

43. Which among the following is the false statement?

(1) Water boils below 100°C on mountain peaks.
(2) Ice undergoes sublimation on surface of moon.
(3) Ice melts above 0°C on mountain peaks
(4) Cooking of food is faster on mountain peaks

44. The order of vapour pressures of four solids is P << R < Q < S. Which of the following has the maximum tendency to sublime?

(1) P (2) Q (3) R (4) S

45. Identify the methods by which the individual components of mixture containing water, potassium nitrate, sodium chloride, alcohol and carbon tetrachloride (CCl_4) can be separated.

(1) Separating funnel, fractional distillation, fractional crystallisation, distillation.
(2) Fractional distillation, distillation, fractional crystallization.
(3) Separating funnel, fractional distillation, filtration, distillation.
(4) Separating funnel, fractional distillation, sedimentation and decantation.

Concept Application Level—2

1. Can water be made to boil in a paper cup without the paper being burnt. Explain

2. "How is the principle of regelation applicable for welding." Explain.

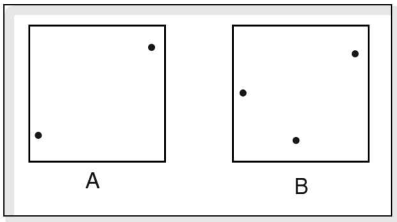
3. Why molten silver cannot be used to make sharp castings?

4. A tarnished silver rod when kept in water containing magnesium bars regains its lustre. Justify.

5. In summer season, Khus Khus mats are used for reducing the heating effect. Explain the principle involved in this.

6. A statue coated with chemical substance X on long exposure to polluted atmosphere becomes black. This colour can be restored by treatment with H_2O_2. Identify element X and also the types of chemical changes involved.

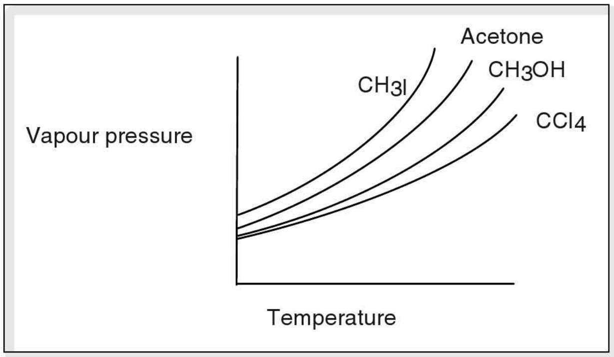
7. A mixture of X and Y on subjecting to paper chromatography gave the chromatogram 'A'. When the same mixture is subjected to heating, chromatogram B was obtained. What do you infer from the chromatograms?



8. Why is solid $CaCl_2$ spread on roads in cold countries, during winter season?

9. Explain the separation techniques involved in the separations of constituents in gun powder. What type of reactions are involved in the explosion of gun powder.

10. Sodium cannot be preserved in water. However, sodium amalgam can be kept in water. Justify.



11. When a mixture of these four liquids is taken, how can they be separated? Justify.

12. Explain why N_2O supports combustion more vigorously than air.

13. A copper rod is placed in $AgNO_3$ solution and $FeSO_4$ solution. What changes do you observe? What type of reactions takes place? Justify your observation.

14. H_2SO_4 is always diluted by adding it to water but not by adding water to it. Justify.

15. What type of reaction is involved in the usage of AgBr in photography? The positive print developed is dipped in $AuCl_3$ solution at the end to impart beautiful appearance to the photograph. Explain the reaction involved in this. Justify.

Directions for questions 16 to 25: Application Based Questions

16. In a chemistry lab, Rina took some mercury and water in two test tubes separately. Then she drained off both the liquids and on observing the empty test tubes, found some difference. Can you guess what the difference is? Explain with appropriate reasons.

17. If we keep a box of ice cream in the freezer for too long, crystals of ice are formed inside the box Give reasons.

18. Pressure cooker reduces the cooking time. Explain the principle involved.

19. Fish and meat can be preserved for a longer time in ice if common salt is added to it. Give reason.

20. Why are cotton clothes preferred in summer?

21. What happens when water is kept in a plastic bottle wrapped with a wet towel?

22. Small pieces of steel and some powdered rust are taken in two test tubes separately. What will you observe when concentrated hydrochloric acid is poured into both the test tubes? Justify your observation.

23. Explain how individual gases can be separated from a gaseous mixture of O_2, H_2 and CO_2.

24. The critical temperature of CO_2 gas and N_2 gas is 31°C and –147°C. Which gas is liquefied easily and why?

25. Can water be boiled below 100°C temperature? If yes, give reason.

Concept Application Level—3

1. When glass of water is freezed, formation of ice starts from the top layer but melting of ice starts from the bottom. Justify
2. Solids generally undergo melting on heating. But, only certain specific solids like naphthalene camphor undergo sublimation. Give reason.
3. Fractional distillation of ethyl alcohol–water mixture gives a mixture of 95.6% ethyl alcohol and 4.4% water. Further separation can be brought about either by the addition of CaO or by the addition of a water soluble salt such as potassium acetate. Justify the formation of pure ethyl alcohol in both the cases.
4. In cold countries, ethylene glycol is used in car radiators for both winter as well as summer seasons. Explain.
5. A mixture of three miscible liquids is subjected to fractional distillation liquid B is obtained in the receiver flask. The remaining mixture on further fractional distillation, A is left behind in the distillation flask. On the basis of the results, comment on the critical temperatures of A, B and C when they are in gaseous state.

Directions for questions 6 to 10: Application Based Questions

6. Dicky, Micky and Vicky had three liquids, A, B and C respectively. They mixed these liquids and observed that they form a homogeneous mixture. They were unable to separate the liquids and asked their teacher to separate these for them. The teacher subjected the given mixture to fractional distillation. Liquid B was obtained in the receiver flask. On further distillation, A was left behind in the distillation flask. On the basis of the results, comment on the critical temperatures of A, B and C in their respective gaseous states.

7. Two ice blocks of 10 g each are placed in 2 ℓ distilled water at 273 K. One of the ice blocks is made up of sea water and other one is made up of distilled water. What will you observe if the ambient temperature is also 273 K? Give reasons to support your observation.

8. Can phase transition be used to test the purity of gold?

9. The melting point of a nonsublimable solid is 100°C. What do you observe when a small piece of this solid is taken in a test tube and placed in boiling water?

10. What is the shape of the meniscus observed when water and mercury are taken in two different capillary tubes and why?

key points for selected questions

Very short-answer type questions

1. Elevation in boiling point and depression in freezing point.
2. Salt in water
3. Temperature involved in the conversion of solid to liquid.
4. Forces existing between molecules.
5. latent heat
6. Increase in rate of evaporation.
7. Critical temperature of carbon dioxide 31.1°C.
8. sublimation
10. Number of atoms in a molecule.
11. Composition of pure substance and mixture.
12. Possibility of separation through filter paper.
13. increases
14. Salt in water and alloys.
15. 4
16. centrifugation
17. Displacement of less reactive metal by more reactive metal.
18. decreases
19. Oil in water, separating funnel.
20. cohesive forces
21. Diffusion.
22. compound–element
23. positive
24. Separation technique, based on difference in adsorption and solubility in the solvent.
25. critical temperatures
26. Reactivity of sodium.
27. homogenous
28. Positive.
29. critical temperature
30. Conversion of solid to gas.

Short-answer type questions

31. Sublimable nature of ammonium chloride.
32. Decrease in melting point of ice with increase in pressure.
33. (i) Nature of cotton clothes to absorb sweat from the body.
    (ii) Evaporation of sweat.
    (iii) Loss of energy and cooling of surroundings.
34. Conversion of gas to liquid by applying pressure at particular temperature.
35. (i) Rate of process.
    (ii) Surface phenomenon and bulk phenomenon.
    (iii) Temperature at which the process takes place.
36. (i) Decrease in temperature due to the cold water glass.
    (ii) Condensation of water vapour.
37. Exchange of radicals among reactants.
38. High reactivity of fluorine among halogens.
39. (i) Difference in boiling points of components in air.
    (ii) Lower boiling point of N_2 than O_2.
    (iii) Fractional evaporation of liquid air.
40. (i) Extraction of heat from gas.
    (ii) Decrease in potential energy.
    (iii) Increase in intermolecular forces of attraction.
41. (i) Minimum temperature required for liquefaction of gas.
    (ii) High critical temperature and easy liquefaction of gas.
42. (i) Lower potential energy associated with molecules of boiling water.
    (ii) Higher potential energy associated with molecules of steam.
43. (i) Change in molecular composition in chemical changes.
    (ii) Temporary and reversible nature of physical and chemical changes.
    (iii) Net gain or loss of energy in chemical change.
44. (i) Difference in molecular movement of solids, liquids, gases.

key points for selected questions

(ii) Vibratory motion in solids.

(iii) Vibratory, translatory and rotatory motions in gases.

(iv) Differences between liquids and gases with respect to translatory motion.

45. (i) Element–element combination reactions.

(ii) Element–compound combination reactions.

(iii) Compound–compound combination reactions.

Essay type questions

46. (i) Solubility of gas decreases with the rise in temperature.

(ii) Effect of reduced pressure on solubility of gas.

47. (i) The effect of pressure on the melting point and boiling point.

(ii) Nature of solid opposition to expansion with increase in pressure.

(iii) Decrease in melting point and increase in boiling point by addition of impurities.

(iv) Temperature.

(v) Humidity.

48. (i) Molecules.

(ii) Inter molecular spaces.

(iii) Inter molecular force of attraction.

(iv) Cohesive forces and adhesive force.

(v) Kinetic energy of molecules due to ceaseless motion.

(vi) Supply of heat and increase in potential energy.

(vii) Decrease in intermolecular forces of attraction.

(viii) Conversion to liquid state.

49. (i) Paper chromatography.

(ii) Stationary phase and moving phase.

(iii) Adsorption of constituents and affinity of constituents to two phases.

50. (i) To separate solid–solid mixture by fractional crystallization, solubility of both components in a solvent.

(ii) Difference in solubility of two components.

(iii) Liquefaction of a gas under high pressure.

(iv) Difference in boiling point of two components

KEY

Concept Application Level—1

True or false

1. True

2. True

3. True

4. True

5. False

6. True

7. True

Fill in the blanks

8. diffusion, fractional evaporation

9. adhesive forces, cohesive forces

10. solvent extraction, filtration, fractional crystallisation

11. KI

12. sublimes at normal atmospheric pressure.

13. Decreasing pressure decreases the boiling point.

14. x, y

Match the following

15. A : i
B : f
C : a
D : h
E : b
F : g
G : d
H : e
I : c

Multiple choice questions

16. Choice (1)
17. Choice (2)
18. Choice (2)
19. Choice (2)
20. Choice (4)
21. Choice (2)
22. Choice (3)
23. Choice (4)
24. Choice (4)
25. Choice (2)
26. Choice (4)
27. Choice (4)
28. Choice (3)
29. Choice (2)
30. Choice (4)
31. (i) Potential energy increases and kinetic energy remains constant.
(ii) Potential energy increases and kinetic energy increases
(iii) Potential energy decreases and kinetic energy decreases
(iv) Potential energy decreases and kinetic energy remains constant

Choice (3)

32. (i) Paper chromatography is used for the separation.
(ii) Paper and solvent are taken as stationary and mobile phases respectively.
(iii) A narrow strip of paper with a line drawn is cut and a mixture of red and blue ink with the help of capillary is placed on the line marked on the paper.
(iv) The paper is suspended in the closed jar with the help of hook.
(v) The blue and red ink is separated on the paper by adsorption technique.

Choice (3)

33. Bromine is a liquid. The molecules of liquid possess vibratory and rotatory motion and translatory motion in all directions except in upward direction.

Choice (1)

34. Pressure decreases with increase in altitude and hence boiling point decreases. Since Darjeeling is at higher attitude water boils below 373K that is below 100°C.

Choice (3)

35. Kinetic energy does not change but potential energy increases at melting point.

Choice (1)

36. The more the humidity, the lesser is the rate of evaporation. In coastal areas humidity is more and hence the rate of evaporation is less.

Choice (1)

37. Sulphur is insoluble in water and forms a solid-liquid heterogeneous mixture.

Choice (4)

38. Gunpowder is a heterogeneous mixture of KNO_3, C and S.

Choice (4)

39. Among the given gases, ammonia can dissolve readily in water. Therefore, it can be separated by using water as solvent.

Choice (2)

40. Since iron is magnetic in nature iron and sand mixture can be separated by magnetic separation.

Choice (2)

41. Conduction of heat in matter takes place via the molecules. One molecule absorbs heat and passes it to the other molecule. As in gaseous state the molecules are vary far away from each other, the heat cannot be transferred from molecule to molecule and thus there is no conduction of heat through air which is a mixture of gases.

In case of solids the molecules are closely packed and the intermolecular forces of attraction are maximum. Therefore, on heating, the molecules cannot move freely there by showing less expansion than gases in which the forces of attraction between molecules is less and hence on heating K.E of molecules increases and therefore the volume increases.

Choice (3)

42. Dogs stretch out their tongues during summer season because the surface area of tongue provides scope for evaporation which protects the body from over heating during summer. This is because they can not sweat like human beings. All other phenomenon are due to the condensation of water vapour due to very low temperature.

Choice (4)

43. With increasing altitude, pressure decreases and hence boiling point of water also decreases. As a result cooking of food is delayed on mountain peaks.

Choice (4)

44. Rate of sublimation is directly proportional to vapour pressure. And hence "S" undergo sublimation more easily at room temperature.

Choice (4)

45. Both KNO_3, NaCl are soluble in water forming a homogeneous solution which is soluble in alcohol and forming a mixture. This mixture is insoluble in CCl_4. And hence CCl_4 is separated by separating funnel. Alcohol is separated by fractional distillation. As KNO_3 is more soluble than NaCl in water it is separated by fractional crystallization. NaCl from water is separated by distillation.

Choice (1)

Concept Application Level—2

Key points

1. (i) Conditions required for burning.
(ii) Utilization of heat energy supplied.

2. (i) Process of welding.
(ii) Changes in pressure during the process
(iii) Effect of change in pressure on melting point.

3. (i) Durable characteristics of the metal for proper casting.
(ii) Change observed in silver during phase transition.

4. (i) Comparison of reactivity of Ag and Mg.
(ii) Conditions required for the ions to get displaced.

5. (i) Structure of khus-khus mats to exhibit capillary action.
(ii) Changes accruing in water due to large surface area of mats.
(iii) Changes observed in the surrounding.

6. (i) Metal present in paints which gets darkened (black) on long exposure to polluted air.
(ii) Nature of H_2O_2
(iii) Change in the colour of the compound when washed with H_2O_2

7. (i) Principle involved in chromatography
(ii) Changes observed in Chromatogram B.
(iii) Reason for the change.

8. Effect of addition of $CaCl_2$ on freezing point of H_2O.

9. (i) Components of gun powder.
(ii) Solubility of the components in water and CS_2.
(iii) Products obtained on oxidation of constituents of gunpowder.
(iv) Constituent of gun power acting as oxygen provider.

10. (i) Predicting the order of vapour pressure of given compounds.
(ii) Changes occurring when metal is preserved in water.
(iii) Properties of sodium in amalgam.
(iv) Effect of water on sodium amalgam.

11. (i) Relation between vapour pressure and boiling point.
(ii) Methods of separation of liquids varying in boiling points.
(iii) Relation between vapour pressure and boiling point.
(iv) Methods of separation of liquids varying in boiling points.

12. (i) Requisite to support combustion.
(ii) Products formed on decomposition of N_2O
(iii) Volume of one of the product in air which supports combustion.
(iv) Comparison of volumes of the component in air and product of N_2O which supports combustion.

13. (i) Requisite for displacement of one metal by the other.
(ii) Relative positions of Ag, Cu and Fe in activity series.

14. (i) Energy changes involved in the reaction between H_2SO_4 and H_2O.
(ii) Conditions required for controlling the reaction.

15. (i) Effect of light on AgBr.
(ii) Comparison of reactivity of Ag and Au.

16. Water droplets are found on the inner surface of one test tube while the other test tube is completely dry. In the case of water, adhesive forces are more than cohesive forces but in case of mercury cohesive forces are more than adhesive forces. Due to stronger adhesive force, water droplets stick to the test tube.

17. Due to very low temperature in the freezer the water vapour gets deposited as crystals of ice. Therefore we get crystals of ice inside the box if kept in freezer for longer time.

18. In a pressure cooker, water is subjected to heating in a closed vessel in confined space. The steam generated in fixed volume increases the pressure beyond the normal atmospheric pressure. Since the pressure is more, the boiling point of water rises beyond 100°C. The temperature of cooking medium being greater than the normal boiling point, food gets cooked at a faster rate thus saving time and fuel.

19. Addition of common salt to ice reduces the freezing point of ice to below 0°C. A mixture of 3 parts of ice and one part of common salt called freezing mixture can produce a much lower temperature (–21°C). Thus, fish and meat can be prevented from spoilage for a longer time in the freezing mixture.

20. People wear cotton clothes to keep themselves cool in summer. Cotton fabric absorb sweat more due to greater adhesive forces between cotton and water and also allows the sweat to be evaporated at a faster rate. The sweat absorbs heat energy equal to the latent heat of vapourisation from the body and gets evaporated, thus keeping the body cool.

21. During the evaporation of water from the wet towel, heat is absorbed from the bottle and its content. Due to this the water present in the bottle becomes cool.

22. Steel is an alloy, that is a mixture in which iron is the major component and it retains its property in steel. Hence pieces of steel will liberate hydrogen and effervescence will be observed. However rust being a compound of iron does not exhibit the chemical property of iron. Rust dissolves in hydrochloric acid due to the formation ferric chloride and no effervescence will be observed in that test tube.

23. When a mixture of O_2, H_2 and CO_2 is present, the mixture can first be passed through KOH as it will dissolve the CO_2. This CO_2 can be obtained back from KOH by adding dilute HCl. The left over mixture contains O_2 and H_2. As the molecular weight difference is high they can be separated by diffusion, where H_2 will come out first.

24. Since the critical temperature of CO_2 is high, the intermolecular forces of attraction among CO_2 molecules is more when compared to N_2. Hence CO_2 will liquefy easily.

25. Yes, water can be boiled below its boiling point as the boiling point of the water decreases with decrease in pressure.

Concept Application Level—3

1. (i) Movement of water when water undergoes freezing.
(ii) Effect of pressure on the melting point of ice.

2. (i) Comparison of vapour pressure of solids which undergo sublimation to normal solids.
(ii) Cause of sublimation
(iii) Requisite of vapour pressure of solid to sublime.

3. (i) Method of separation.
(ii) Changes in the boiling point of water on addition of water soluble salt.
(iii) Method of separation.
(iv) Method of separation.
(v) Changes in the boiling point of water on addition of water soluble salt.
(vi) Method of separation.

4. (i) Boiling point of ethylene glycol.
(ii) Changes observed in the radiator of car during summer and winter.
(iii) Effect a addition of ethylene glycol to water of radiator.

5. (i) Relation between intermolecular forces of attraction and boiling point.
(ii) Relation between critical temperature and boiling point.
(iii) Relation between intermolecular forces of attraction and boiling point.
(iv) Relation between critical temperature and boiling point.

6. Fractional distillation is employed to separate miscible liquids which have a difference in their boiling points. In this process of separation, the liquid with a low boiling point that is a high vapour pressure, distills off. Therefore from the given data, it can be said that the boiling point of B is less than that of C which is less than that of A. For liquids with high boiling points the intermolecular forces of attraction are also high and hence they have high critical temperatures. Therefore, the critical temperature of A is greater than that of C which is greater than that of B.

7. After sometime one ice block will disappear and the other one remains intact. The ice block which is made up of sea water melts because of lowering of melting point due to presence of dissolved salts.

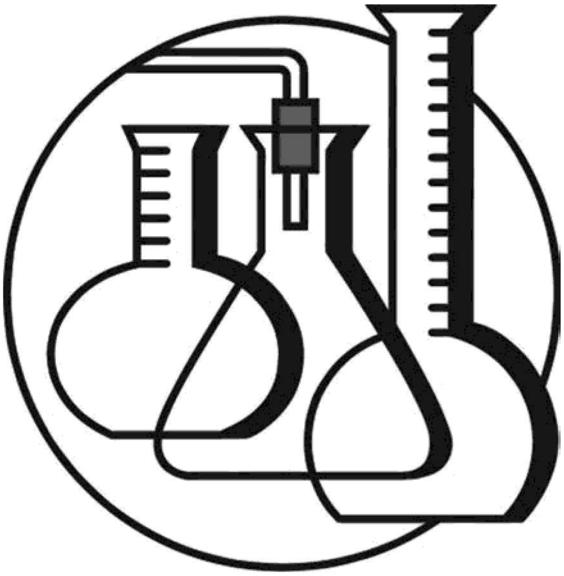
8. Yes, the melting point of pure solid is always constant. The purity of gold can be measured with the help of its melting point. However if the gold is not pure then it does not have a sharp melting point, because the presence of impurities reduce the melting point of a pure gold.

9. The solid remains as it is. Water boils at 100°C. Transmission of heat takes place as long as the temperature of the solid is below 0°C. As soon as the temperature of the solid reaches 100°C, transmission of heat from water to the solid stops. Hence it does not melt.

10. Mercury shows a convex miniscues as mercury has higher cohesive forces than adhesive forces with glass. Water, on the other hand, shows a concave miniscues as the adhesive forces between water and glass are higher than cohesive forces between water molecules.

2

Atomic Structure



INTRODUCTION

The concept that atoms are the fundamental building blocks of matter dates back to very ancient times. However, the ideas regarding atoms of those times had no experimental evidence and remained as mere speculation. Therefore, these ideas had to lay dormant for a long period until John Dalton proposed his atomic theory on the basis of certain observations and experimental results. The basic principle of his theory was that it regarded an atom as the ultimate particle of matter.

Dalton's atomic theory has been successful in giving a convincing explanation for the various laws of chemical combination such as the law of conservation of mass, the law of definite proportions and the law of multiple proportions. However, Dalton's idea that the atom is an indivisible particle of matter has been disproved by later discovery of radioactivity. Several series of experiments on radioactivity which were carried out in later years proved the presence of various subatomic particles in an atom. Atoms are found to be mainly composed of three types of fundamental particles, namely, positively charged protons, neutral particles known as neutrons and negatively charged electrons. The discovery of these fundamental particles paved the way for further research on the internal structure of an atom which obviously explains the enormous diversity of chemistry involved in a wide range of chemical reactions.

DISCOVERY OF FUNDAMENTAL PARTICLES

The electron was the first fundamental particle that was discovered. The credit for the discovery of the electron goes to J. J. Thomson based on his experiments carried out in a discharge tube.

Sir William Crookes was the first scientist who designed the discharge tube which was called the Crooke's discharge tube or Cathode Ray Tube. It is a long glass tube having two metal plates connected to the oppositely charged poles of a battery. The pressure inside the discharge tube can be adjusted by means of an exhaust pump.

This discharge tube was later slightly modified by J.J.Thomson.When high voltage was applied between the cathode and the anode with a small hole at the centre of a partially evacuated tube at a pressure of 0.01 mm of Hg, a bright spot of light was formed on the zinc sulphide screen kept at the opposite end of the discharge tube. This was caused by the rays which originated from the cathode called cathode rays.

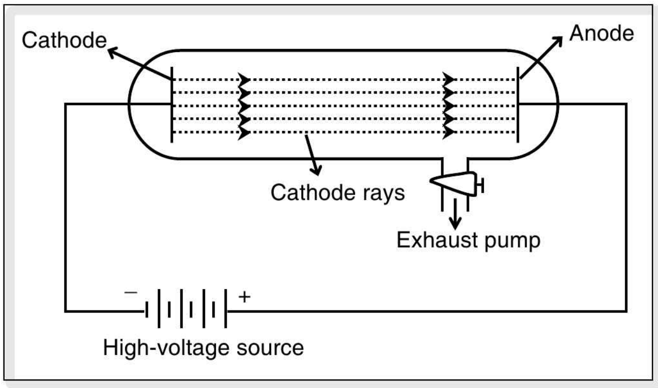


Figure 2.1 Cathode Ray Tube

J. J. Thomson conducted some experiments with a discharge tube for studying the properties of cathode rays.

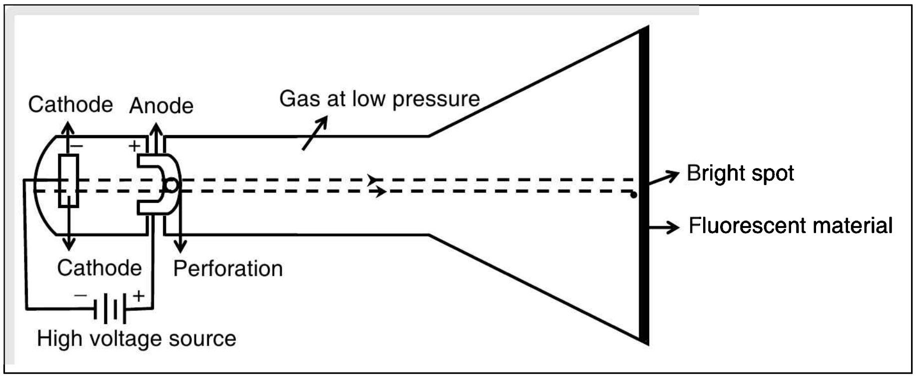
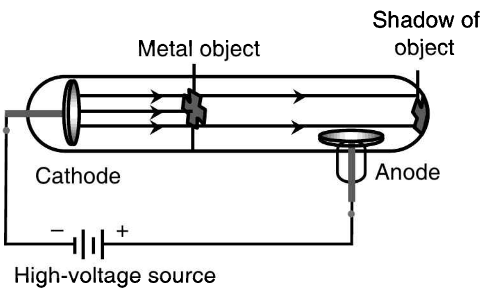


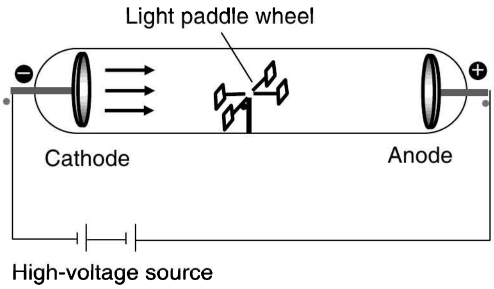
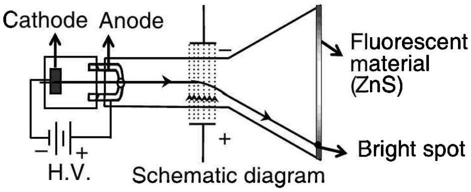
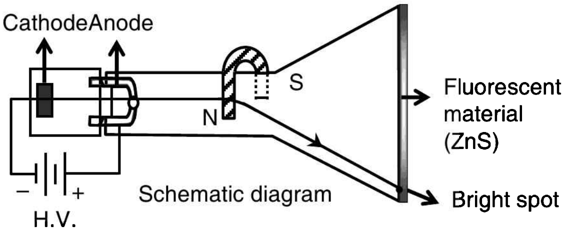
Figure 2.2 J. J. Thomson's Cathode ray tube

Placing a small object in between the cathode and anode.



Formation of a shadow of the object on the opposite side of the cathode.
Cathode rays travel in straight lines.

(Continued on following page)

<table>
<tr><td></td><td></td></tr>
<tr><td>Placing a light paddle wheel between cathode and anode.

</td><td>Rotation of light paddle wheel. Small particles having mass and kinetic energy.</td></tr>
<tr><td>Passing through electric field.

</td><td>Bending of rays towards the positive plate. Negatively charged particles.</td></tr>
<tr><td>Passing through magnetic field applied perpendicular to the path of the cathode rays.

</td><td>Deflection perpendicular to the applied magnetic field.</td></tr>
<tr><td>The above experiments were carried out with different gases in the discharge tube.</td><td>No change in properties.
The properties do not depend on the nature of gas taken in the discharge tube.
Specific charge (e/m value) remains same.</td></tr>
</table>

The discovery of negatively charged electron was later followed by the experiment conducted by Robert Millikan in 1909 to determine the quantity of charge on an electron.

Millikan's oil drop experiment

Some fine oil droplets were allowed to be sprayed into the chamber by an atomizer. The air in the chamber is subjected to ionization by X-rays. The electrons produced by the ionization of air attach themselves to the oil drops. When sufficient amount of electric field is applied which can just balance the gravitational force acting on an oil drop, the drop remains suspended in the air.

From this experiment, Millikan observed that the smallest charge found on them was approximately 1.59×10^{-19} coulombs and the charge on each drop was always an integral multiple of that value.

On the basis of this observation, he concluded that 1.59×10^{-19} coulomb is the smallest possible charge and considered that value as the charge of the electron.

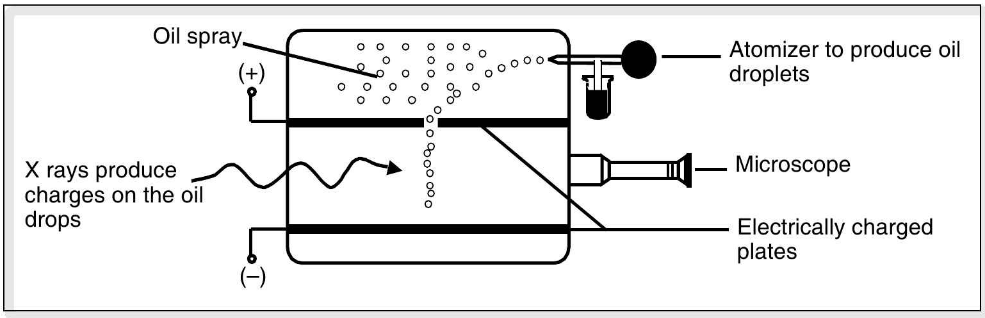


Figure 2.3 A schematic representation of the apparatus used by Millikanto determine the charge of an electron

DISCOVERY OF PROTONS

The presence of positively charged particles in an atom has been predicted by Goldstein based on the electrical neutrality of an atom.The discovery of proton by Goldstein was done on the basis of the cathode ray experiment conducted by using a perforated cathode.

Just like cathode rays, some rays were found to emanate from an anode. These are called anode rays or canal rays.

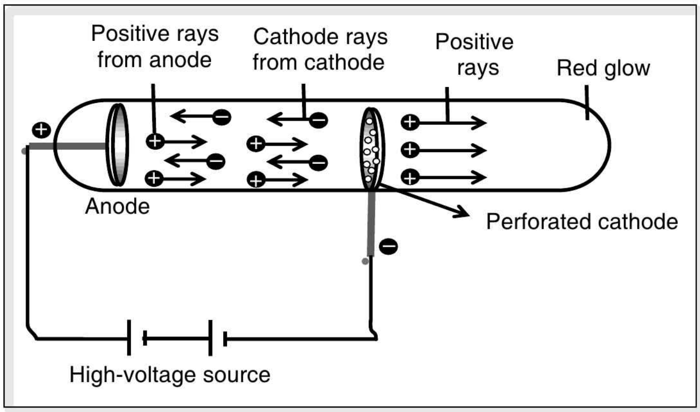


Figure 2.4

Anode rays were found as a stream of positively charged particles in contrast to cathode rays.When hydrogen gas is taken in a discharge tube, these positively charged particles were found to be protons.

Properties of anode rays

1. Anode rays travel in straight lines.
2. Anode rays possess positive charge since they were found to deflect towards negatively charged electrodes.
3. The properties of anode rays depend upon the nature of the gas taken in the discharge tube.
4. The mass of the particles was same as the atomic mass of the gas inside the discharge tube.

The discovery of electrons and protons as sub atomic particles inside the atom lead to the conception of atomic models which depict the arrangement of fundamental particles in an atom.

Various atomic models have been proposed by different scientists like J. J. Thomson, Rutherford, Bohr and Sommerfeld.

Thomson's Atomic Model

J. J. Thomson proposed his atomic model soon after his discovery of electrons.

1. An atom contains negatively charged particles called electrons embedded uniformly throughout a thinly spread positively charged mass.
2. Since the atom is electrically neutral, the total negative charge of electrons is balanced by the total positive charge.

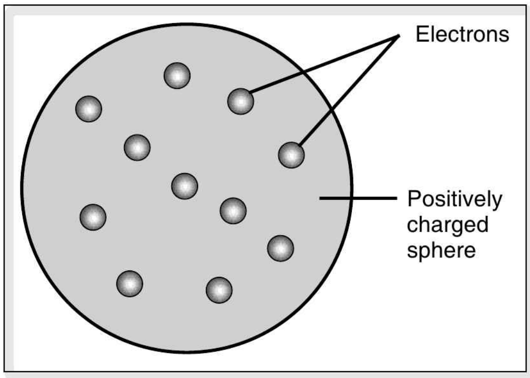


Figure 2.5

Thomson's model of an atom is popularly known as plum pudding model or apple pie model or watermelon model.

Validity of Thomson's model

Thomson's model could successfully explain the electrical neutrality of atom. However, it failed to explain how the positively charged particles are shielded from the negatively charged electrons without getting neutralized.

Rutherford's α-ray scattering experiments

In order to test the validity of Thomson's atomic model, Rutherford conducted α-ray scattering experiment.

In this experiment, α particles were allowed to pass through a pair of positively charged parallel plates and the resultant narrow beam of α- particles was allowed to strike the gold foil which was surrounded by zinc sulphide screen.

The observations or results of this experiment completely disproved Thomson's model.

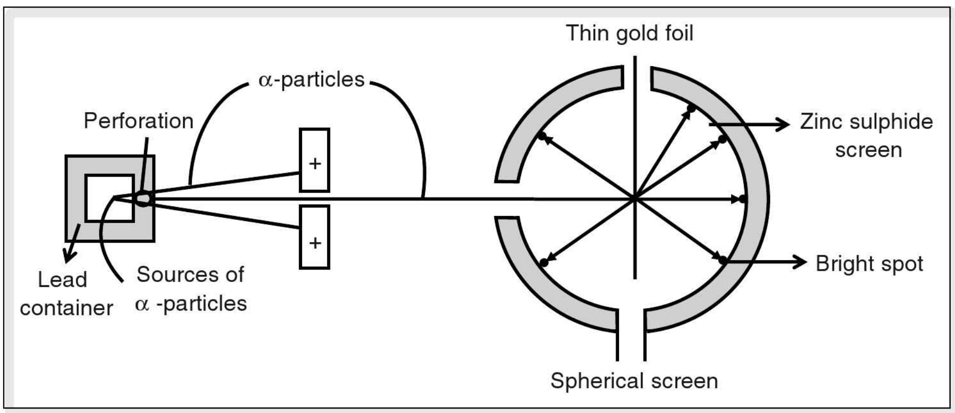


Figure 2.6

Most of the particles passed straight through the gold foil without any deflection.	Presence of large empty space in an atom.
Very few α particles completely rebounded and few α particles showed large deflection.	Presence of central positively charged core known as nucleus.

Rutherford's Atomic Model

The atom is mostly composed of empty space. The entire positive charge and mass of the atom is concentrated in small central part known as nucleus. The size of the nucleus is so small that its diameter is 10^5 times less than that of an atom. The diameter of the nucleus has been estimated by Rutherford as 10^{-13}cm in contrast to that of an atom to be 10^{-8}cm. The electrons present outside the nucleus revolve round the nucleus with high velocities.

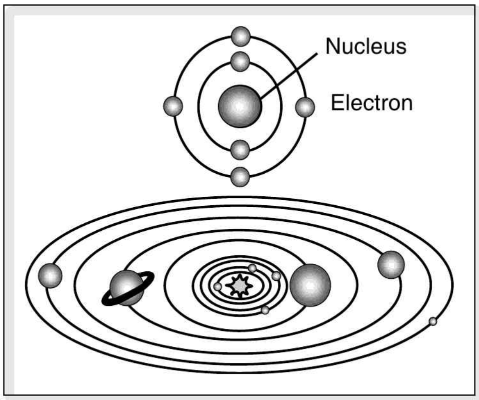


Figure 2.7 The solar system

The electrons revolve round the nucleus with high velocities to counterbalance the electrostatic forces of attraction between protons and electrons. Rutherford's atomic model resembles the planetary motion in solar system. Therefore, Rutherford's model of an atom is also called planetary model.

Validity of Rutherford's atomic model

Rutherford's atomic model could very well explain the presence of positively charged nucleus and presence of electrons outside the nucleus in an atom. However, the failure of Rutherford's theory stemmed from two major objections.

Firstly,

(i) This model is in contradiction to the principle of classical electrodynamics. According to this, any charged particle in circular motion radiates energy continuously. The electron being a charged particle in circular motion loses energy. This should ultimately result in its spiral path towards nucleus and the atom should then collapse.

(ii) The second major objection for Rutherford's model came from the pattern of atomic spectra.

When light passes through the prism, it gets split up into its components of different wave lengths like visible, ultraviolet, infrared light etc. The arrangement of component light energies according to their wavelengths is called spectrum and spectroscope is the instrument designed to observe the spectra.

Since white light is composed of lights of different wavelengths, a continuous band of different wave lengths is obtained which is called continuous spectrum. Light from the sun or incandescent bulb gives such type of spectra.

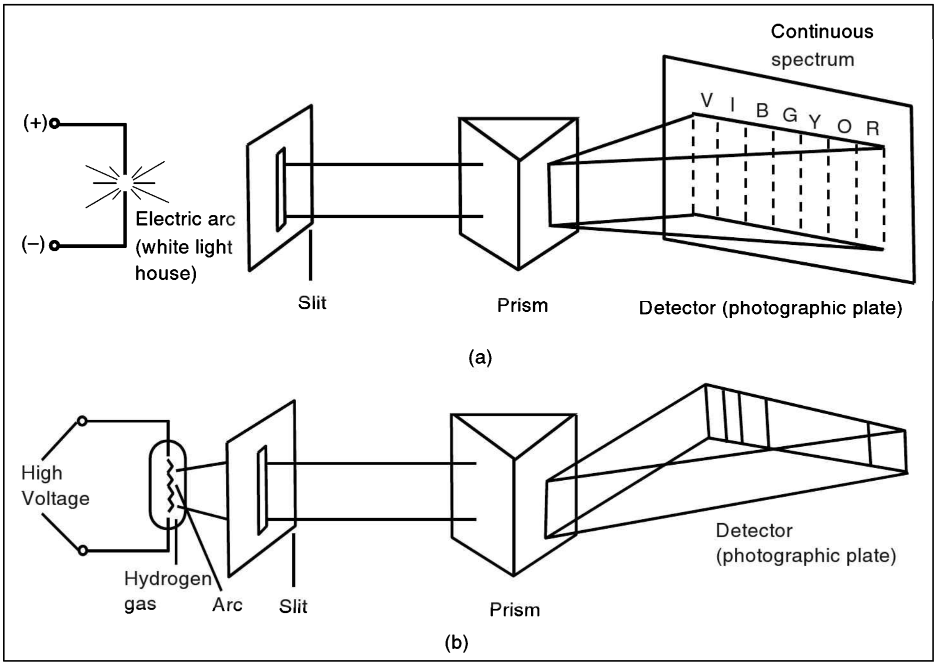


Figure 2.8 (a) shows the spectrum produced by the white light.

But when the spectrum is taken for the atoms of the gas present in the discharge tube, it is found to consist of discrete lines of different colours. This is called line spectrum, which is a discontinuous spectrum.

Figure (b) shows the atomic spectra of hydrogen gas.

According to Rutherford's atomic model, electrons revolving around the nucleus should lose energy continuously. Hence the spectra of atom should be a continuous spectrum whereas the observed atomic spectrum was a line spectrum.

In 1913, Danish scientist, Neils Bohr could overcome the limitation of Rutherford's atomic model successfully based on the quantum theory of radiation proposed by Max Planck.

Quantum Theory of Radiation

At the end of the 19th century, physicists had an idea that matter and energy are distinctly different. Matter consists of particles which have mass and have specific positions in space.

Energy is the form of electromagnetic radiation which has no mass and doesn't have any specific position in the space.

Matter can absorb or emit any quantity of energy.

But in the beginning of the 20th century, these ideas were proved to be incorrect on the basis of some experimental results.

German Physicist, Max Planck, in 1901 carried out the first important experiment by studying the radiation emitted by solid bodies heated to incandescence.

He concluded from his experimental observation that energy can be absorbed or radiated by a body in the form of small packets of energy called quanta which are whole number multiples of the quantity hν where

h = Planck's constant = 6.625×10^{-34} joule-sec.

ν = frequency of the radiation

This theory proves the particle nature of energy.

On the basis of this theory, Bohr proposed his atom model.

Bohr's Model of an Atom

(a) Electrons revolve around the nucleus in specified circular paths called orbits or shells.

(b) Each orbit or shell is associated with a definite amount of energy. Hence these are also called energy levels and are designated K, L, M, N respectively.

(c) The energy associated with a certain energy level increases with the increase of its distance from the nucleus. Hence if the energy associated with the K, L, M, N shells are E_1, E_2, E_3 .... respectively, then $E_1 < E_2 < E_3$ .... etc.

(d) As long as the electron revolves in a particular orbit, the electron does not lose it's energy. Therefore, these orbits are called stationary orbits and the electrons are said to be in stationary energy states.

(e) An electron jumps from a lower energy level to a higher energy level, by absorbing energy, but when it jumps from a higher to lower energy level, the energy is emitted in the form of electromagnetic radiation. The energy emitted or absorbed (ΔE) is an integral multiple of 'hν'.

(f) The electron can revolve only in the orbit in which the angular momentum of the electron (mvr) is quantised, i.e., mvr is a whole-number multiple of $h/2\pi$. This is known as principle of quantization of angular momentum.

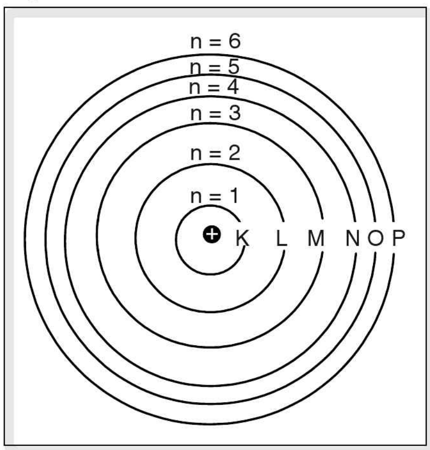


Figure 2.9 Stationary orbits of an atom

The angular momentum is written as

$$mvr = \frac{nh}{2\pi},$$

where, n is an integer (n = 1, 2, 3, 4, ...) and is called principal quantum number.

m = mass of the electron.

v = velocity of an electron in its orbit.

r = distance of the electron from the nucleus.

By applying the concept of quantization of energy, Bohr calculated the radii and energy of the n^{th} orbit of hydrogen atom.

$$r_n = \frac{n^2h^2}{4\pi^2me^2}, E_n = \frac{-2\pi^2me^4}{n^2h^2}$$

With the help of these expressions, Bohr gave a satisfactory explanation for the spectra of hydrogen and hydrogen like species (ions having one electron e.g., He^+, Li^{+2}, Be^{+3}) etc.

Limitations of Bohr's atomic model

1. Bohr could not explain the spectral series for the multi-electron atoms.
2. Bohr's model couldn't give a satisfactory justification for the assumption that electrons can revolve in those orbits where their angular momentum (mvr) is a whole number multiple of $nh/2\pi$ i.e. he could not justify quantization of angular momentum.
3. According to Heisenberg's uncertainty principle, it is impossible to determine simultaneously with certainty the exact position and the momentum of the particle. Bohr assumed that an electron of an atom is located at a definite distance from the nucleus and revolves around the nucleus with a definite velocity i.e., the momentum of the electron is fixed which is against Heisenberg's uncertainty principle.
4. The atomic spectral lines split into a number of closely packed lines in the presence of a magnetic field and an electric field. These effects are called **Zeeman effect** and **Stark effect** respectively. Bohr failed to explain these effects.
5. When the hydrogen spectrum was observed with the spectroscope of high resolving power, it was found that the individual lines in the spectrum consisted of several fine lines lying close to each other. This is called fine spectrum and he failed to explain the fine structure of the spectrum.

DISCOVERY OF NEUTRONS

The electrons being particles having negligible mass and massive protons concentrated inside the nucleus, it could be predicted that the mass of an atom has to be equal to the mass of the total number of protons present in the atom. However, this was found to be true only in case of a hydrogen atom.

The difference in the predicted mass and actual mass of the atom has been found to be equal to the mass of the proton or multiples of the mass of a proton. These particles are supposed to have neutral charge since the atom is electrically neutral. They were called neutrons and they were discovered by James Chadwick by an experiment involving the bombardment of beryllium nucleus with α particles.

The discovery of fundamental particles has ultimately resulted in the establishment of a basic atomic model. The basic model of an atom comprises small positively charged nucleus at the centre of the atom and the electrons revolving round the nucleus in orbits.

Characteristics of fundamental particles

[redacted]				
1.	Electron (e)	-1.6×10^{-19} C -4.8×10^{-10} e.s.u	9.1×10^{-31} kg (or) 0.00055 amu	-1
2.	Proton (p)	$+ 1.6 \times 10^{-19}$ C $+ 4.8 \times 10^{-10}$ e.s.u	1.67×10^{-27} kg (or) 1.0078 amu	$+1$
3.	Neutron (n)	0	1.72×10^{-27} kg (or) 1.0083 amu	0

Atomic number and mass number

[redacted]			
Atomic number	Z	The number of protons in an atom	Cl atom has 17 protons in its atom Z = 17
Mass number	A	The total number of nucleons I.C. number of protons and neutrons in an atom	Cl atom has 17 protons and 18 neutrons in its nucleus. $\therefore$ A = 17 + 18 = 35

An element when represented along with its atomic number and mass number is represented as $_{Z}X^{A}$. Elements are found to exist in their isotopic forms. Isotopes are the atoms of the same element having different mass number. Based on their percentage abundance of each isotopic form average atomic mass of an element is calculated.

☛ *Example* $_{1}H^{1}$, $_{1}H^{2}$, $_{1}H^{3}$.

It is also found that atoms of different elements have same mass number. These are called isobars.

☛ *Example* $_{18}Ar^{40}$, $_{20}Ca^{40}$.

Electronic configuration

The systematic arrangement of electrons in the various shells or orbits in an atom is called electronic configuration.

The electrons are arranged in an atom in the various shells around the nucleus. The last shell or the outermost shell from the nucleus with electrons is called the valence shell. The shell inner to this is called the penultimate shell and the one inner to penultimate shell is called the anti penultimate shell.

The filling of electrons in various shells can be done according to Bohr–Bury scheme. According to this, the maximum number of electrons that can be accommodated in any shell is given by $2n^2$, where n represents the number of the shell.

shell	$2n^2$
K	2
L	8
M	18
M	32
O	50

The maximum number of electrons that can be filled in the valence shell is 8, that in the penultimate shell is 18 and the anti penultimate shell has a maximum capacity of 32 electrons. The filling of electrons till atomic number 30 follows the following pattern.

K	L	M	N
2			
2	8		
2	8	8	
2	8	8	2
2	8	18	2

test your concepts

Very short-answer type questions

1. Which postulate of Dalton's atomic theory is considered to be correct even today?
2. "Like atoms are identical in all respects". This statement of Dalton's atomic theory is contradicted. What discovery contradicts this?
3. What was the basis for the proposal of Dalton's atomic theory?
4. The value of the Planck's constant 'h' in erg-sec is ______.
5. Why was a gas at low pressure taken by Thomson while conducting the experiment?
6. Why is Rutherford's model called the nuclear model?
7. Mass of the electron is calculated from ____ and ____ values of electron.
8. Give the mass and charge of fundamental particles of an atom.
9. What is an atomic model?
10. The equation for the calculation of energy of n^{th} orbit of hydrogen atom derived by Bohr is ______.

11. Who discovered protons? Based on what experiment was he able to discover these protons?

12. What was the mathematical equation given by Max Planck?

13. Who discovered neutrons? How was the discovery made?

14. Neutrons were discovered by bombarding beryllium with _____ particles.

15. What name did Max Planck give to energy packets?

16. What is Heisenberg's uncertainty principle?

17. According to ________, the charges in an atom are arranged like the pulp and seeds of a watermelon.

18. Which theory supported the particle nature of an electron?

19. Give the value of Planck's constant in

    (1) erg-sec

    (2) joule-sec

20. Give the equation to calculate

    (a) the radius of the nth orbit of hydrogen atom.

    (b) energy of the nth orbit of hydrogen atom.

21. What happens when an electron jumps from lower energy level to higher energy level?

22. What is Zeeman effect?

23. What is Stark effect?

24. With the increase in the radius of the orbit, the energy of an electron ______________.

25. What is an α particle?

26. What is a continuous spectrum?

27. The circular paths in which electrons revolve are called ______.

28. Why are light rays known as electromagnetic waves?

29. The ______ consists of well defined lines of definite frequencies.

30. In the formula $E = h\nu$, E is ______ and ν is ______.

Short-answer type questions

31. "Electrons jump from one orbit to another orbit". Justify this statement on the basis of Bohr's theory.

32. On what basis did Bohr propose his atomic model?

33. What are orbits and why are they called stationary orbits?

34. Mention the properties of anode rays.

35. What is the amount of energy needed to remove an electron from a Hydrogen atom to produce an H+ ion? Explain.

36. If Rutherford's atomic model is correct, then the atom should collapse. Why?

37. Describe Millikan's oil drop experiment in brief.

38. According to Rutherford's atomic model, where are the protons and electrons located in an atom?
39. Why was the presence of neutrons in an atom predicted? How were neutrons discovered?
40. Describe J. J. Thomson's atomic model.
41. Define angular momentum. In the relation $mvr = \frac{nh}{2\pi}$, what do m, v, r and h denote?
42. On what basis did Bohr assume the concept of stationary orbits for an electron?
43. The wavelength of particular radiation is 700 nm (1 nm = 10^{-9} m). Find its frequency (ν).
44. Distinguish between continuous spectrum and discontinuous spectrum. Give some examples of sources for these spectra.
45. An electron revolving round in an orbit has angular momentum equal to $\frac{h}{2\pi}$. Can it lose energy?

Essay type questions

46. Explain Bohr's atomic model.
47. What are the observations and conclusions drawn by J. J. Thomson while conducting experiments with a discharge tube for studying the properties of cathode rays?
48. What are the drawbacks of Rutherford's atomic model?
49. Describe Rutherford's atomic model.
50. State the limitations of Bohr's model.

CONCEPT APPLICATION

Concept Application Level—1

Direction for questions 1 to 7: State whether the following statements are true or false.

1. According to Thomson's atomic model, electrons revolve round the nucleus.
2. In a discharge tube, anode rays originate when electrons collide with gas molecules.
3. ${}_8O^{16}$ and ${}_8O^{18}$ are isotopes while ${}_{20}Ca^{40}$ and ${}_{18}Ar^{40}$ are isobars.
4. Energy is absorbed when the electron jumps from K to L energy shell.
5. α–ray scattering experiment proved that the positive particles are present in the extra nuclear part of an atom.
6. Characteristic spectra of atoms is line spectra.
7. An electron in the excited state of an atom is highly unstable.

Direction for questions 8 to 14: Fill in the blanks.

8. Anode rays are deflected towards the negative plate in the presence of electric field because they consist of ______ particles.
9. Some of the α–rays deflect in acute and obtuse angles due to the presence of the _______ in the center of the atom.
10. According to classical electrodynamics, if an electrically charged particle revolves in a circular path, it continuously _______ energy.
11. The energy of an electron present in the first orbit of an atom is _________ than the energy of electron in the other orbits.
12. Splitting of spectral lines in the presence of magnetic field is known as ______ effect.
13. The kinetic energy of an electron present in the first orbit of an atom is ________ than that of the electron in the last orbit.
14. The spectra produced by the de-excitation of an electron is called ________________.

Direction for question 15: Match the entries given in column A with appropriate ones from column B.

15.

A.	$\frac{e}{m}$ value varies with the nature of gas	( )	a.	$h\nu$
B.	Plum pudding model	( )	b.	Rutherford's atomic model
C.	Mass of the atom is concentrated at the centre of atom	( )	c.	Sun rays
D.	Continuous spectrum	( )	d.	Bohr's stationary orbit
E.	$mvr = \frac{nh}{2\pi}$	( )	e.	Thomson's atomic model
F.	Quantum	( )	f.	Anode rays

Direction for questions 16 to 45: For each of the questions, four choices have been provided. Select the correct alternative.

16. Which of the following concepts was not considered in Rutherford's atomic model?
    (1) The electrical neutrality of atom.
    (2) The quantization of energy.
    (3) Electrons revolve around nucleus at very high speeds.
    (4) Existence of nuclear forces of attraction on the electrons.
17. When alpha particles are sent through a thin metal foil only one out of ten thousand of them rebounded. This observation led to the conclusion that
    (1) positively charged particles are concentrated at the centre of the atom.
    (2) more number of electrons are revolving around the nucleus of the atom.
    (3) unit positive charge is only present in an atom.
    (4) a massive sphere with more negative charge and unit positive charge is present at the centre of the atom.

18. Canal ray experiment lead to the discovery of ______.

(1) protons (2) neutrons (3) electrons (4) nucleus

19. In which of the following pairs of shells, energy difference between two adjacent orbits is minimum?

(1) K, L (2) L, M (3) M, N (4) N, O

20. Assertion A: An electron in the inner orbit is more tightly bound to the nucleus.

Reason B: The greater the absolute value of energy of an electron the more tightly the electron is bound to the nucleus.

(1) Both A and B are true but B is not the appropriate reason for A.
(2) Both A and B are individually correct and B is the correct reason for A.
(3) A is correct but B is not correct.
(4) Both A and B are not correct.

21. The electron revolves only in the orbits in which

(1) $mvr > \frac{nh}{2\pi}$ (2) $mvr \geq \frac{nh}{2\pi}$

(3) $mvr = \frac{nh}{2\pi}$ (4) $mvr < \frac{nh}{2\pi}$

22. Which among the following pairs are having different number of valence electrons?

(1) Na^{+}, Al^{+3} (2) P^{-3}, Ar (3) Mg^{+2}, Ar (4) O^{-2}, $\bar{F}$

23. If two naturally occurring isotopes of an element are $7^{X^{15}}$, $7^{X^{11}}$ what is the percentage composition of each isotope of X occurring respectively if the average atomic weight accounts to 14?

(1) 95, 5 (2) 80, 20 (3) 75, 25 (4) 65, 35

24. According to quantum theory of radiation which is false?

(1) Radiations are associated with energy
(2) Radiation is neither emitted nor absorbed discontinuously.
(3) The magnitude of energy associated with a quantum is dependent on frequency
(4) Photons are quanta of radiation.

25. Select True/False among the following statements.

(i) Bohr's theory successfully explained stability of the atom.

(ii) Atoms give line spectra.

(iii) Velocity of electromagnetic waves depends on the frequency.

(iv) Bohr introduced the concept of orbital.

(1) (i) T, (ii) T, (iii) F, (iv) F (2) (i) T, (ii) F, (iii) T, (iv) T

(3) (i) F, (ii) T, (iii) F, (iv) F (4) (i) F, (ii) F, (iii) T, (iv) T

26. Which of the following particles do not produce electronic spectra?

(1) Li^{+2} (2) He^{+2} (3) Be^{+2} (4) Na^{+}

27. An element has two isotopes with mass numbers 16 and 18. The average atomic weight is 16.5. The percentage abundance of these isotopes is ______ and ______ respectively.

(1) 75, 25 (2) 25, 75 (3) 50, 50 (4) 33.33, 66.67

28. Which among the following are isobars?

(1) ${}_{b}X^{a}$, ${}_{b}Y^{a+1}$ (2) ${}_{b}X^{a}$, ${}_{c}Y^{b}$

(3) ${}_{b}X^{a}$, ${}_{b+1}Y^{a}$ (4) ${}_{b}X^{a}$, ${}_{b-1}Y^{a-1}$

29. Some of the elements have fractional atomic masses. The reason for this could be

(1) the existence of isobars.

(2) the existence of isotopes.

(3) the nuclear reactions.

(4) the presence of neutrons in the nucleus.

30. Which of these pairs has almost similar masses?

(1) proton–electron (2) neutron–electron

(3) electron–${}_{1}H^{1}$ (4) neutron–${}_{1}H^{1}$

31. The energy of electron revolving in 3rd orbit of Be^{+3} ion is __________ ev

(1) – 10.2 (2) – 13.6

(3) – 24.2 (4) – 18.1

32. Which of the following concepts, was not considered in Rutherford's atomic model?

(1) The electrical neutrality of atom.

(2) The quantization of energy.

(3) Electrons revolve around the nucleus at very high speeds.

(4) Existence of nuclear forces of attraction on the electrons.

33. ${}_{7}X^{15}$, ${}_{7}X^{11}$ are two naturally occurring isotopes of an element X. What is the percentage of each isotope of X if the average atomic mass is 14?

(1) 95, 5 (2) 80, 20 (3) 75, 25 (4) 65, 35

34. A trinegative ion of an element has 8 electrons in its M shell. The atomic number of the element is

(1) 15 (2) 18 (3) 20 (4) 16

35. Arrange the following statements given by various scientists in chronological order.

(a) Calculation of energy and radius of orbit

(b) Atoms of the same elements are identical in all respects.

(c) Calculation of diameter of the nucleus and the atom

(d) Assumption of thinly spread positively charged mass

(1) d c a b (2) d b c a (3) b d c a (4) c d b a

36. What is the ratio of radii of the first successive odd orbits of hydrogen atom?

(1) 9 : 1 (2) 1 : 9 (3) 1 : 3 (4) 3 : 1

37. An electron revolves round the nucleus in 3rd orbit and jumped to a higher orbit 'X' showing a difference in angular momentum equal to $\frac{h}{\pi}$. The value of 'X' could be

(1) 4 (2) 6 (3) 5 (4) 7

38. Rutherford's α – particle scattering experiment eventually led to the conclusion that

(1) mass and energy are related.

(2) the point of impact with matter can be precisely determined.

(3) neutrons are buried deep in the nucleus.

(4) electrons are distributed in a large space around the nucleus.

39. Arrange the following steps which are carried out in μ–ray experiment in the correct sequence

(a) Passage of μ particles through a slit

(b) Bombardment of μ particles with a gold foil

(c) Deflection of μ particles

(d) Production of μ particles.

(1) dabc (2) dacb (3) adbc (4) adcb

40. Which among the following pairs are having different number of total electrons?

(1) Na^{+}, Al^{+3} (2) P^{-3}, Ar (3) Mg^{+2}, Ar (4) O^{-2}, F^{-}

41. The postulates of Bohr's atomic model are given below. Arrange them in the correct sequence.

(a) As long as the electron revolves in a particular orbit, the electron does not lose its energy. Therefore, these orbits are called stationary orbits and the electrons are said to be in stationary energy states.

(b) Electrons revolve round the nucleus in specified circular paths called orbits or shells.

(c) The energy associated with a certain energy level increases with the increase of its distance from the nucleus.

(d) An electron jumps from a lower energy level to a higher energy level by absorbing energy. But when it jumps from a higher to lower energy level, energy is emitted in the form of electromagnetic radiation.

(e) Each orbit or shell is associated with a definite amount of energy. Hence these are also called energy levels and are designated as K, L, M, N respectively.

(1) a c d e b (2) b c e a d (3) b e c a d (4) b a d c e

42. The ratio of atomic numbers of two elements A and B is 1 : 2. The number of electrons present in the valence shell (3^{rd}) of A is equal to the difference in the number of electrons present in the other two shells. Steps involved for the calculation of ratio of number of electrons present in a penultimate shell to antepenultimate shell of B are given below. Arrange them in the correct sequence.

(a) Calculation of atomic number of B.

(b) Calculation of valence electrons present in A.

(c) Calculation of atomic number of A.

(d) Calculation of number of electrons present in the penultimate and anti penultimate shells of B.

(e) Writing electronic configuration of B.

(1) b c d a e (2) b c a e d (3) d e b c a (4) d b a c e

43. The equation given by Bohr to calculate radius of n^{th} orbit of hydrogen atom is

(1) $r_n = \dfrac{n^2h^2}{4\pi^2 me}$ (2) $r_n = \dfrac{n^2h^2}{4\pi^2 me}$ (3) $r_n = \dfrac{nh^2}{4\pi^2 me}$ (4) $r_n = \dfrac{n^2h^2}{4\pi^2 m^2e}$

44. The number of electrons present in the valence shell of an atom with atomic number 38 is
(1) 2 (2) 10 (3) 1 (4) 8

45. The mass number of an atom whose unipositive ion has 10 electrons and 12 neutrons is
(1) 22 (2) 23(3) 21 (4) 20

Concept Application Level—2

1. When the same isotopic gas is taken in two discharge tubes, the angle of deflection is found to be different though the strength of the external electric field applied is the same. Explain.

2. In a canal ray experiment, different gases were found to produce canal rays with the same specific charge. Explain.

3. When canal rays experiment is conducted with hydrogen gas, scientists were found to give particles with different $\frac{e}{m}$ values. Justify.

4. Energy of the electron in the atom is negative. Explain?

   Hint : Energy of a free electron is taken as zero.

5. If the energy released when an electron jumped from the 4th orbit to the 3rd orbit of hydrogen is 'x', then what would be the energy difference when it jumps from the 3rd orbit to the 2nd orbit?

6. Electronic spectra can distinguish isobars but not isotopes. Justify.

7. If the energy difference between the orbits when an electron in H atom gets excited to higher energy orbit from its ground state is 12.1 eV/atom, calculate the frequency of radiation emitted ($1\ eV = 1.602 \times 10^{-19} J$) when electron comes back to second energy level.

8. Is the energy difference between successive orbits the same for all orbits? Justify your answer.

9. Though there is only one electron in a hydrogen atom, the spectrum of hydrogen contains a number of lines. How do you explain this?

10. What is the ratio of the radius of the 1st orbit to 2nd orbit, if the velocity of the electron in the first orbit is twice that of the second orbit.

11. A particular atom has the 4th shell as its valence shell. If the difference between the number of electrons between K and N shell and L and M shell is zero, find the atomic number of the element and electronic configuration of its stable ion.

12. A stable unipositive ion of an element contains three fully filled orbits. What is the atomic number of the element?

13. Explain why a blackened platinum strip when placed at the radius of curvature turns red hot, only when the cathode taken has concave shape.

14. The average atomic mass of two isotopes with mass numbers A and A + 2 is A + 0.25. Calculate the percentage abundance of the isotopes.

15. Spectral line given by an atom is a kind of signature of the respective atom. Comment on this statement.

    Hint: The nuclear charge of different atoms are different.

Directions for questions 16 to 25: Application Based Questions

16. Why was a spherical sulphide screen used in α-ray scattering experiment?

17. Why is the source of α-particles kept inside the lead block?

18. If Thomson's model is considered to be correct, what would be the observation of Rutherford's α-ray scattering experiment?

19. The ratio of the atomic numbers of two elements A and B is 2 : 3. A is an inert gas with the first 3 orbits completely filled. Identify A and B and write their electronic configurations.

20. A stable dipositive ion and a dinegative ion are isoelectronic with an octet configuration in the second shell of their atoms. Identify the preceding and succeeding elements and write their electronic configurations.

21. Predict the possible atomic number(s) of an atom in which the third shell is incompletely filled and maximum 3 more electrons can be added in that shell?

22. The radius of n^{th} orbit of a single electron species is $0.132\ n^2$ A°. Identify the element.

23. What is the frequency of light emitted when an electron in a hydrogen atom jumps from 3^{rd} orbit to 2^{nd} orbit?

24. An electron having an angular momentum of 1.05×10^{-34} joules jumps to another orbit such that it has an angular momentum of 4.20×10^{-34} joules. Explain the possible transitions.

25. The mass number of a particular element which has equal number of protons and neutrons is 32. What is the electronic configuration of the atom and its stable ion?

Concept Application Level—3

1. In Millikan's oil drop experiment, the distance between the metal plates, A and B to which electric potential is applied such that A is positive and B is negative is 5 mm. An oil drop is found to be suspended at a distance of 2 mm from B. Predict the change in the position of the oil drop when there is a sudden drop or rise in potential. Justify.

2. Different gases in the discharge tube produce different colours under suitable conditions of pressure and voltage. Explain.

   [Hint: Each element has it's own characteristic atomic spectrum].

3. Is the velocity of an electron in all orbits the same for an atom of a particular element? How does it vary for different single electron species? Give reasons in support of your answer.

4. What is the ratio of distance between successive orbits of 1 and 2 to 2 and 3 of hydrogen atom?

   [Hint: radius of nth orbit in hydrogen is $0.529 \times n^2$ A°]

5. If ${}^{y}_{x}A^{+1}$ or ${}^{y-2}_{x-1}B^{+1}$ were to be used instead of α particles in Rutherford's experiment, which would be better and why?

Directions for questions 6 to 10: Application Based Questions

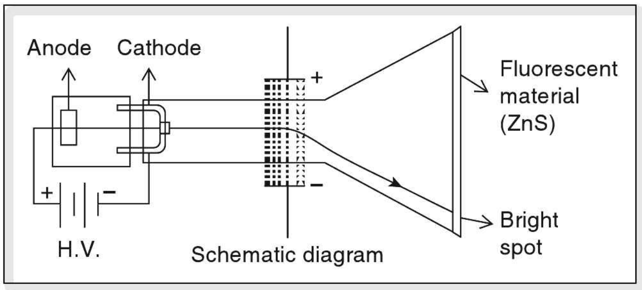
6. Draw a comparison between the potential energy and kinetic energy of electrons in the 1^{st} orbits of hydrogen and He^{+} ion. Also comment on the total energy of the electrons in the above cases.

7. Though the kinetic energy of electrons decreases with an increase in the distance from the nucleus, the potential energy of the electron increases. How do you account for this?

8. Why is high voltage and low pressure maintained in the discharge tube?

9. If canal ray experiments are conducted with different isotopes of hydrogen gas, do the canal rays produced show the same deflection under the external electric field? Give reasons to support your answer.

10.



If the given schematic diagram represents Thomson's experiment and the corresponding observation, what would be his atomic model?

key points for selected questions

Very short-answer type questions

1. Atoms are the tiniest particle of matter that take part in the chemical reaction.
2. Discovery of isotopes.
3. Laws of chemical combination.
4. 6.625×10^{-27}
5. Less intermolecular force of attraction.
6. Discovery of nucleus
7. e and $\frac{e}{m}$
8.

[redacted]		
Electron	-1.6×10^{-19}c	9.1×10^{-28} g
Proton	1.6×10^{-19}c	1.67×10^{-24} g
Neutron	0	1.67×10^{-24} g

9. Arrangement of the fundamental particles.
10. $\frac{-2\pi^2 me^4}{n^2h^2}$
11. Goldstein, Discharge tube
12. $E = h\nu$
13. James Chadwick by an experiment involving the bombardment of beryllium nucleus with α–particles
14. α–particles
15. Quanta
16. Impossible to determine simultaneously the position and momentum of the particle.
17. Thomson's model
18. Planck's quantum theory
19. 6.626×10^{-27} erg sec

    6.626×10^{-34} J sec

20. $r_n = \dfrac{n^2h^2}{4\pi^2 me^2}, E_n = \dfrac{-2\pi^2me^4}{n^2h^2}$

21. Absorption of energy

22. Splitting of spectral lines in the presence of magnetic field.

23. Splitting of spectral lines in the presence of electric field.

24. increases

25. Doubly ionised He ion.

26. A continuous band of different wavelengths.

27. orbits

28. Formed by vibration of mutually perpendicular electric and magnetic components

29. line spectrum

Short-answer type questions

32. Planck's quantum theory.

33. (i) Specified paths of electrons.
(ii) Energy remains constant.

34. (i) Direction of propagation
(ii) Deflection in the presence of electric field
(iii) Deflection in the presence of magnetic field

36. (i) An accelerating charged particle loses energy.
(ii) Spiral path of electron.
(iii) Collapse of the atom.

37. (i) Balancing of oil drop.
(ii) Calculation of the velocity of the drop.
(iii) Calculation of mass.
(iv) Basic charge of an electron.

38. (i) Center of the atom
(ii) Extra nuclear part.

39. (i) The difference in the predicted mass and actual mass.
(ii) bombardment of beryllium nucleus with – particles.

40. (i) Uniformly distributed positive charge.
(ii) Electrons embedded.

41. (i) Mass of electron.
(ii) velocity of electron
(iii) Radius of the orbit.
(iv) Planck's constant.

43. $C = \nu\lambda$

44. (i) Because of quantisation of energy.
(ii) When electrons jump from one orbit to another they emit or absorb only a certain amount of energy.

Essay type questions

46. (i) Specified paths of electrons orbit.
(ii) Definite amount of energy.
(iii) Increase in energy of orbit with the increase in distance from nucleus.
(iv) Stationary orbits.
(v) Change in energy of electron during movement from one orbit to another.
(vi) Quantization of angular momentum.

47. (i) Formation of shadow-travel in straight lines.
(ii) Rotation of paddle wheel-mass and kinetic energy.
(iii) Bending of rays in electric and magnetic field-charged particles.
(iv) Properties do not depend on the nature of gas and cathode.

48. (i) Continuous radiation of energy by electron.
(ii) Spiral path of electron towards nucleus.
(iii) Collapse of atom.

49. (i) Mostly empty space.
(ii) Nucleus.
(iii) Electrons revolve around the nucleus in circular paths.

50. (i) Spectral series of most atoms.
(ii) Quantization of angular momentum.
(iii) Definite location and definite velocity of electron.
(iv) Zeeman effect and Stark effect.
(v) Fine spectrum.

Concept Application Level—1

True or false

1. False
2. True
3. True
4. True
5. False
6. True
7. True

Fill in the blanks

8. positively charged
9. positive charge
10. loses
11. less
12. Zeeman
13. more
14. emission spectrum

Match the following

15. A : f
    B : e
    C : b
    D : c
    E : d
    F : a

Multiple choice questions

16. Choice (2)
17. Choice (1)
18. Choice (1)
19. Choice (4)
20. Choice (1)
21. Choice (3)
22. Choice (3)
23. Choice (3)
24. Choice (2)
25. Choice (1)
26. Choice (2)
27. Choice (1)
28. Choice (3)
29. Choice (2)
30. Choice (4)
31. Engergy $E_n = \frac{-13.6Z^2}{n^2}$ eV

$$E_3 = \frac{-13.6 \times 16}{9} \text{eV} = -24.2 \text{ eV}$$

Choice (3)

32. According to Rutherford's theory, an atom is electrically neutral and electrons revolve around the nucleus. Nuclear forces of attraction exist between the nucleus and electrons. The only assumption that Rutherford did not consider is quantisation of energy.

Choice (2)

33. Let the percentage of ${}_7X^{15}$ is x.

$\therefore$ The percentage composition of ${}_7X^{11}$ is $100 - x$

$$\text{Average atomic weight} = 14 = \frac{x(15) + (100 - x)11}{100}$$

$\Rightarrow 1400 = 15x + 1100 - 11x$

$\Rightarrow 1400 = 4x + 1100 \Rightarrow 4x = 300$

$$x = \frac{300}{4} = 75$$

$\therefore$ The percentage of ${}_7X^{11} = 100 - x$

$= 100 - 75 = 25$ and that of ${}_7X^{15}$ is 75.

Choice (3)

34. Since electronic configuration of the trinegative ion is 2, 8, 8 the electronic configuration of the neutral atom is 2, 8, 5 and its atomic number is 15.

Choice (1)

35. (i) Atoms of the same elements are identical in all respects.

(ii) Assumption of thinly spread positively charged mass

(iii) Calculation of the diameters of the nucleus and the atom

(iv) Calculation of energy and radius of orbit

Choice (3)

36. $r_n = 0.529 \times n^2$ A°

Successive first odd orbits are 1 and 3

$$\frac{r_1}{r_3} = \frac{0.529 \times 1^2}{0.529 \times 3^2} = \frac{1}{9} = 1:9$$

Choice (2)

37. Angular momentum in third orbit is given by

$$mvr = \frac{3h}{2\pi} \rightarrow (1)$$

Angular momentum in X orbit is given by

$$mvr = \frac{Xh}{2\pi} \rightarrow (2)$$

$$\frac{Xh}{2\pi} - \frac{3h}{2\pi} = \frac{h}{\pi}$$

$$(X-3)\frac{h}{2\pi} = \frac{h}{\pi} \Rightarrow X = 5$$

Choice (3)

38. The α–ray scattering experiment led to the discovery of nucleus which in turn helped him conclude that electrons revolve around the nucleus to overcome the strong electrostatic force of attraction.

Choice (4)

39. (i) Production of $\propto$ particles.

(ii) Production of a narrow beam of $\propto$ particles

(iii)Bombardment of $\propto$ particles with gold foil

(iv) Deflection of $\propto$ particles

Choice (1)

40. The electronic configuration of Mg^{+2} is 2, 8

$\therefore$ Total no. of electrons = 10

The electronic configuration of Ar is 2, 8, 8

$\therefore$ Total no. of electrons = 18.

Hence Mg^{+2}, and Ar are having different number of total electrons.

Choice (3)

41. (i) Electrons revolve around the nucleus in specified circular paths called orbits or shells.

(ii) Each orbit or shell is associated with a definite amount of energy. Hence these are also called energy levels and are designated as K, L, M, N respectively.

(iii) The energy associated with a certain energy level increases with the increase of its distance from the nucleus.

(iv) As long as the electron revolves in a particular orbit, the electron does not lose its energy. Therefore, these orbits are called stationary orbits and the electrons are said to be in stationary energy states.

(v) An electron jumps from a lower energy level to a higher energy level by absorbing energy. But when it jumps from a higher to lower energy level, energy is emitted in the form of electromagnetic radiation.

Choice (3)

42 . (i) Calculation of valence electrons present in A.

(ii) Calculation of atomic number of A.

(iii) Calculation of atomic number of B.

(iv) Writing electronic configuration of B.

(v) Calculation of number of electrons present in the penultimate and antepenultimate shells of B.

Choice (2)

43. The equation given by Bohr to calculate radii of n^{th} orbit of hydrogen atom is

$$r_n = \frac{n^2h^2}{4\pi^2me^2}$$

Choice (2)

44. Z = 38, electronic configuration = 2, 8, 18, 8, 2
$\therefore$ Two valence electrons.

Choice (1)

45. Mass number = 11 + 12 = 23

Choice (2)

Concept Application Level—2

Key points

1. (i) Factors which affect angle of deflection in an electric field.
(ii) Conditions for changing the factors which affect the angle of deflection

2. (i) Factors affecting specific charge.
(ii) Conditions where different gases can have the same specific charge.

3. (i) e/m depends on number of protons and neutrons.
(ii) Existence of isotopes
(iii) Variation in e/m for isotopes

4. (i) Comparing energy of free electron and energy of electron in an atom.
(ii) Change in energy when an electron is brought closer to the atom
(iii) Reason for the change in the energy of an electron

6. (i) Fundamental particle responsible for the spectra.
(ii) Relation between fundamental particle and structure of spectra.
(iii) Difference in number of the above particles between isobars and isotopes.
(iv) Effect of this on structure of spectra.

7. (i) Relation between energy and n.
(ii) Calculation of n_2 value from the difference in energy.
(iii) Calculation of frequency from energy.
(iv) Calculation of energy difference based on n values.
(v) Calculation of frequency .
(vi) $\nu = 0.456 \times 10^{15}$ sec^{-1}

8. (i) Factors affecting deflection.
(ii) The effect of atomic number on deflection
(iii) The effect of kinetic energy on deflection

9. (i) Bohr's model of atom.
(ii) Relation between energy absorbed and excitation
(iii) Relation between the path of electron during de-excitation and energy emitted
(iv) Relation between energy emitted and spectrum

10. (i) Comparing the angular momentum of electron in the orbits.
(ii) Comparison of radius.
(iii) $r_1 : r_2 = 1 : 4$.

11. (i) Number of electrons in K, L shell when N shell is the valence shell.
(ii) Calculation of number of electrons in K, L, M, N shells.
(iii) Calculation of atomic number.
(iv) Number of electrons to be lost to form stable ion.
(v) Atomic number = 20

12. (i) Maximum number of electrons present in an orbit. (Bohr-Bury scheme)
(ii) Electronic configuration of neutral atom.
(iii) 37

13. (i) Factors responsible for the strip to turn red hot.
(ii) The path in which the electrons travel from concave cathode.

14. (i) $(n_1 \times A) + (n_2 \times (A + 2)) = (n_1 + n_2)$ $(A + 0.25)$ form
(ii) 87.5% and 12.5%

15. (i) Calculation of energy of electrons in He^+ and Li^{+2} ions.

(ii) 4 : 9

16. To observe scintillations even if the α-rays get deflected at a large angles.

17. α-particles cannot penetrate lead, but β and γ rays can. In order to screen α-particles, from β and γ-rays lead block was used.

18. If Thomson's model is correct, all the α-particles would have penetrated the gold foil and their angle of deflection would be insignificant.

19. A $\rightarrow$ electronic configuration – 2, 8, 18, 8.
Thus, the atomic number = 36

A : B = 2 : 3

$$\therefore B = \frac{36 \times 3}{2} = 54$$

The electronic configuration of B = 2, 8, 18, 18, 8.

20. Let the dipositive ion be X^{+2} and dinegative ion is Y^{-2}.

The octet in the second shell $\rightarrow$ 2, 8

The number of electrons in X = 10 + 2 = 12.

The number of electrons in Y = 10 – 2 = 8.

X is magnesium with an electronic configuration 2, 8, 2. Y is oxygen with a configuration 2, 6.

The element preceding magnesium is sodium and the succeeding one is aluminium. They have electronic configurations 2, 8, 1 and 2, 8, 3 respectively. The elements preceding and succeeding for oxygen are nitrogen and fluorine which have electronic configurations 2, 5 and 2, 7 respectively.

21. Electronic configuration of the atom which can accommodate three more electrons in the 3rd shell could be 2, 8, 5 and 2, 8, 15, 2 Hence the probable atomic numbers are 15 and 27.

22. $$r_n = \frac{Kn^2}{Z}$$

$$\therefore 0.132n^2 = \frac{0.529 \times n^2}{Z}$$

$$\therefore Z = \frac{0.529}{0.132} = 4$$

Since the atomic number is 4, the element is beryllium.

23. $$E_3 - E_2 = -21.72 \times 10^{-19}\left(\frac{1}{9} - \frac{1}{4}\right)$$

$$= 21.72 \times 10^{-19 \times \frac{5}{36}}$$

$\therefore$ Difference in energy, $E_3 - E_2 = 3.01 \times 10^{-19}$ J
According to Plank's equation $\Delta E = h\nu$
$3.01 \times 10^{-19} = 6.625 \times 10^{-34}\ \nu$

$$\text{Frequency } (\nu) = \frac{3.01 \times 10^{-19}}{6.625 \times 10^{-34}} = 4.5 \times 10^{14}\ s^{-1}$$

24. Angular momentum of an orbit

$$mvr = \frac{nh}{2\pi}$$

Initial angular momentum = 1.05×10^{-34} joules

$$1.05 \times 10^{-34} = \frac{n \times 6.625 \times 10^{-34}}{2 \times 3.14}, n = 1$$

The electron is present in the 1st orbit originally.
When the electron gets excited, the angular momentum
= 4.20×10^{-34} joules.

$$4.20 \times 10^{-34} = \frac{n \times 6.625 \times 10^{-34}}{2 \times 3.14}, n = 4$$

An electron can lose energy when it is present in 4th orbit and not from 1st orbit.
The possible transitions are 4 $\rightarrow$ 3, 4 $\rightarrow$ 2, 4 $\rightarrow$ 1, 3 $\rightarrow$ 2, 3 $\rightarrow$ 1 and 2 $\rightarrow$ 1.

25. Mass number = 32
No. of protons = No. of neutrons = 16
$\therefore$ Electronic configuration = 2, 8, 6
Element is sulphur and stable ion S^{-2}
Electronic configuration of S^{-2} is 2, 8, 8.

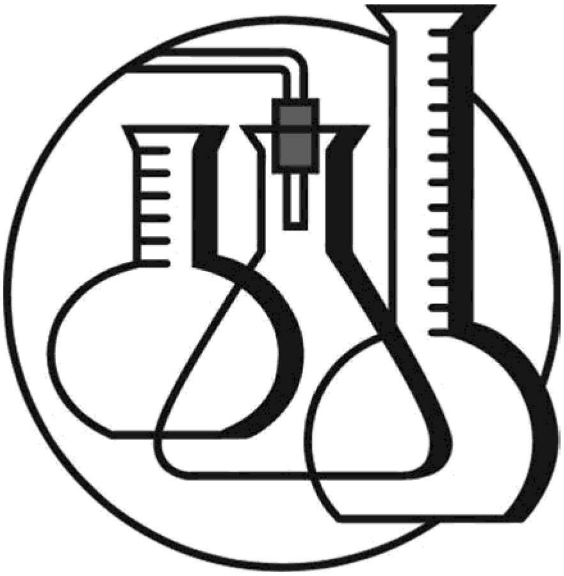
Concept Application Level—3

Key points

1. (i) Charge acquired by oil drop.
   (ii) Different forces acting on the charged oil drop when it is at a distance of 2 mm form B.
   (iii) Relation between position of oil drop and different forces.
   (iv) Effect of a particular force on the position of oil drop.
   (v) Change in position of oil drop with change in potential.
2. (i) Energy of electron
   Excitation and de-excitation.
   (ii) Factors affecting the energy of electron
   (iii) Comparison of the energy emitted during the de-excitation of electron in different atoms
3. (i) Forces acting on moving electron.
   (ii) Position of the electron in the orbit.
   (iii) Relationship between position, forces and velocity.
   (iv) Comparison of nuclear charge in different single electron species.
4. (i) Effects of high voltage and low pressure on the gas molecules in the discharge tube.
   (ii) The effect of velocity of electrons on ionisation
   (iii) Relation between the voltage and the velocity of electrons
   (iv) Relation between the pressure and the number of gas molecules
   (v) The effect of the number of gas molecules on the impact of collision
5. (i) The factors affecting angle of deflection.
   (ii) The characteristics in which the two particles differ.
6. The electrons revolve round the nucleus with high velocities to counterbalance the nuclear force of attraction. As nuclear force of attraction in 1st orbit of He^+ is more than that in 'H' atom. Kinetic energy of electron in He^+ is more (due to greater velocity) than in 'H' atom. When an electron approaches towards an atom, it loses potential energy because it works towards the force of attraction. The greater the force of attraction, the more is the loss of potential energy. Hence the electron in He^+ has lesser potential energy than the electron in H atom. But the loss of P.E is more significant than the change in K.E. Hence total energy helium is less than that of hydrogen.
7. The kinetic energy of an electron is proportional to its velocity. With the increase in distance from the nucleus, the velocity of the electron decreases as the electron has to overcome a lesser nuclear force of attraction. An electron loses its potential energy when it approaches towards an atom that is a nucleus because it works towards the force of attraction during this process. Hence the potential energy of the electron decreases with decrease in distance between the nucleus and the electron and increases with increase in distance between the nucleus and electron.
8. Low pressure means that less number of gas molecules are present in the discharge tube. If the number of molecules is very less, the collisions between the electrons which move towards the anode with a high velocity and the gas molecules become effective. These collisions lead to the dislodge of electrons from gaseous molecules and formation of cathode rays takes place. Moreover, high voltage increases the kinetic energy of the electrons which in turn increases the probability of removal of electrons from the gaseous molecules.
9. Protium (${}_1H^1$), deuterium (${}_1H^2$) and tritium (${}_1H^3$) are naturally occurring isotopes of hydrogen. Unipositive ions of protium,

deuterium and tritium differ in their mass. Thus their e/m ratio is different. Therefore, they deflect at different angles in an external electric field.

10. Since in the given experiments it is observed that positively charged particles are detached from the molecules under low pressure and high voltage, Thomson's model would be other way round that is positively charged particles would be embedded in a thinly spread negatively charged mass.



3

Periodic Table

INTRODUCTION

Elements such as gold, silver, tin, copper, lead and mercury have been known since antiquity. The first scientific discovery of element occurred in 1649 and it was the discovery of phosphorus by Henning Brand. The discovery of elements then continued and the scientists started recognizing the similarities and dissimilarities among the elements in order to make the study of the elements easy and systematic.

A series of efforts for the classification of elements depending on the pattern of their properties eventually led to the construction of the periodic table presently comprising of 111 elements. Periodic table is a tabular arrangement of elements, which depicts the trend of their physical behaviour and chemical properties of all the elements.

German chemist Johann Dobereiner made first significant effort in the development of periodic table. In 1817 he noticed that a group of three elements like (Ca, Sr, Ba) showed similar chemical properties and there was a regular trend in their physical properties. When these elements are arranged in increasing order of atomic weight. The atomic weight of strontium is approximately equal to the average of the atomic weights of calcium and barium.

Later on, in 1829, he discovered the halogen triad and alkali metal triad consisting of (Cl, Br, I) and (Li, Na, K) and proposed that nature contained triads of elements with similar chemical properties and the atomic weight of the second element of the triad is the average of the other two.

In 1864, English chemist John Newland arranged the then known 56 elements in an increasing order of their atomic weights. He noticed that atomic weights of many pairs of elements which differed by 8 or a multiple of 8 exhibited similarities in their chemical properties. Based on this observation he proposed the **Law of Octaves**.

Newland's Arrangement of Elements in Octaves

Li	Na	K	Cu	Rb	Ag	Cs	Tl
Be	Mg	Ca	Zn	Sr	Cd	Ba/V	Pb
B	Al	Cr	Y	Ce/La	U	Ta	Th
C	Si	Ti	In	Zr	Sn	W	Hg
N	P	Mn	As	Di/Mo	Sb	Nb	Bi
O	S	Fe	Se	Ro/Ru	Te	Au	Os

The law states that the **8th element starting from a given one, is a kind of repetition of the first like the eighth note of an octave of music**. Newland's system of classification failed to explain similarities in higher elements.

Dobereiner, Newland and many other scientists contributed significantly for the systematic classification of elements. Their efforts ultimately enabled **Russian chemist Mendeleeff** to construct his periodic table **in 1869**.

He stated in his famous periodic law **that physical and chemical properties of elements are periodic functions of their atomic weights**.

Like Newland, he also arranged the then known 63 elements in the increasing order of their atomic weights in his periodic table in 8 vertical columns and 6 horizontal rows called groups and periods respectively.

After the discovery of noble gases and radioactive elements another version of Mendeleeff's periodic table was published in 1905. In this version '0' group was added to accommodate the noble gases and the 7th period for the radioactive elements of 1905.

Previous attempts of classification show the similarities only in small units like a triad or in a small group, but this table represents the relationship in the entire network, i.e., in vertical columns and in horizontal rows.

Mendeleeff's Periodic table

[redacted]

1	—	Hydrogen H 1.008	—	—	—	—	—	—				
2	Helium He 4.0	Lithium Li 7.03	Beryllium Be 9.1	Boron B 11.0	Carbon C 12.0	Nitrogen N 14.04	Oxygen O 16.00	Fluorine F 19.0				
3	Neon Ne 19.9	Sodium Na 23.05	Magnesium Mg 24.3	Aluminium AI 27.0	Silicon Si 28.4	Phosphorus P 31.0	Sulphur S 32.06	Chlorine CI 35.45				
4	Argon Ar 38	Potassium K 39.1	Calcium Ca 40.1	Scandium Sc 44.1	Titanium Ti 48.1	Vanadium V 51.4	Chromium Cr 52.1	Manganese Mn 55.0	Iron Fe 55.9	Cobalt Co 59	Nickel Ni 59	(Cu)
5		Copper Cu 63.6	Zinc Zn 65.4	Gallium Ga 70.0	Germanium Ge 72.3	Arsenic As 75	Selenium Se 79	Bromine Br 79.95				
6	Krypton Kr 81.8	Rubidium Rb 85.4	Strontium Sr 87.6	Yttrium Y 89.0	Zirconium Zr 90.6	Niobium Nb 94.0	Molybdenum Mo 96.0	—	Ruthenium Ru 101.7	Rhodium Rh 103.0	Palladium Pd 106.5	(Ag)
7	Silver Ag 107.9	Cadmium Cd 112.4	Indium In 114.0	Tin Sn 119.0	Antimony Sb 120.0	Tellurium Te 127	Iodine I 127					
8	Xenon Xe 128	Caesium Cs 132.9	Barium Ba 137.4	Lanthanum La 139	Cerium Ce 140	—	—	—	—	—	—	
9		—	—	—	—	—	—	—				
10	—	—	—	Ytterbium Yb 173	—	Tantalum Ta 183	Tungsten W 184	—	Osmium Os 191	Iridium Ir 193	Platinum Pt 194.9	(Au)
11		Gold Au 197.2	Mercury Hg 200.0	Thallium TI 204.1	Lead Pb 206.9	Bismuth Bi 208	—	—				
12	—	—	Radium Rd 224	—	Thorium Th 232	—	Uranium U 239					
					HIGHER SALINE OXIDES							
	R	R_2O	RO	R_2O_3	RO_2	R_2O_5	RO_3	R_2O_7		RO_4		
					HIGHER GASEOUS HYDROGEN COMPOUNDS							
					RH_4	RH_3	RH_2	RH				

Previous attempts of classification show the similarities only in small units like a triad or in a small group, but this table represents the relationship in the entire network, i.e., in vertical columns and in horizontal rows.

Merits of Mendeleeff's periodic table

1. Mendeleeff left some gaps in his periodic table for some of the then unknown elements based on the properties of the other elements present in the same group. He named these missing elements as Eka boron, Eka aluminium and Eka silicon. Later on, these elements were discovered and named as scandium, gallium and germanium respectively.
2. Mendeleeff corrected the doubtful atomic weights of some elements. For example, the atomic weight of indium, i.e., 76 was based on the assumption that indium oxide had the formula InO. This atomic weight placed indium, which has metallic properties, among the non metals. Mendeleeff corrected the formula of indium oxide from InO to In_2O_3. Based on this corrected formula, the atomic weight of indium is 113. He also corrected the atomic weights of the elements beryllium and uranium.

Limitations of Mendeleeff's periodic table

1. Anomalous pairs: In Mendeleeff's periodic table, there are some pairs of elements in which the element with a higher atomic weight is placed before that of the lower atomic weight element in order to maintain the similarity in chemical properties of the elements belonging to the same group.

The pairs are :	(i) Co	Ni	(ii) Te	I	(iii) Ar	K
	58.9	58.6	127.6	126.9	39.94	39.10

2. Position of hydrogen: The position of hydrogen is not justified.
3. Positions of isotopes: The isotopes of an element have different atomic weights. But there is no position for the isotopes in Mendeleeff's periodic table.
4. Position of lanthanides and actinides: Two sets of 14 elements each (lanthanides and actinides respectively), which follow Lanthanum and Actinium in the order of atomic weights, have not been provided regular or separate places in the periodic table. They have just been put together along with lanthanum and actinium respectively.
5. Position of elements of group VIII: Three triads of the transition elements are placed in group VIII of the periodic table. They should have been given separate positions.
6. Anomalous placement of the transition and coinage metals
   (i) Transition elements were placed along with typical elements under the same group.
   (ii) Coinage metals were placed with alkali metals.

Owing to these limitations and the later discovery of atomic structure, Mendeleeff's periodic table has no practical significance at present. Nevertheless, its significance lies in the fact that the concept of periodicity in properties and the resultant arrangement of elements in a periodic table originated from Mendeleeff's classification of elements.

Modern periodic table–the long form of the periodic table

In 1913, H. G. J Moseley worked on X-ray spectra of elements and established that the atomic number is equal to the total nuclear charge and it is a more fundamental characteristic of an element than atomic weight.

Moreover, it was found that some of the major defects of Mendeleeff's periodic table like the anomalous position of some pairs of elements (Co-Ni, Te–I, Ar–K), placements of isotopes, etc. would automatically disappear, if atomic number, i.e., the total nuclear charge is used as the basis of the compilation of the periodic table instead of the atomic weight. Based on these observations, Moseley proposed the modern periodic law which states that **"the physical and chemical properties of elements are the periodic functions of their atomic numbers".**

Thus, according to the modern periodic law, if the elements are arranged in the order of their increasing atomic numbers, the elements with similar properties are repeated after certain regular intervals.

DESCRIPTION

Description of modern or the long-form of the periodic table

The long form of the periodic table (also called Bohr's table) consists of horizontal rows called periods and vertical columns called groups or families.

There are 7 periods and 16 groups in the periodic table. The groups from I to VII are divided into sub groups 'A' and 'B'. VIII group consists of 3 vertical columns. All noble gases are kept in zero group.

According to the recent recommendation of IUPAC, the groups are numbered from 1 to 18 (18 groups) instead of subdivision of groups into A and B sub-groups.

Different portions of long form of periodic table

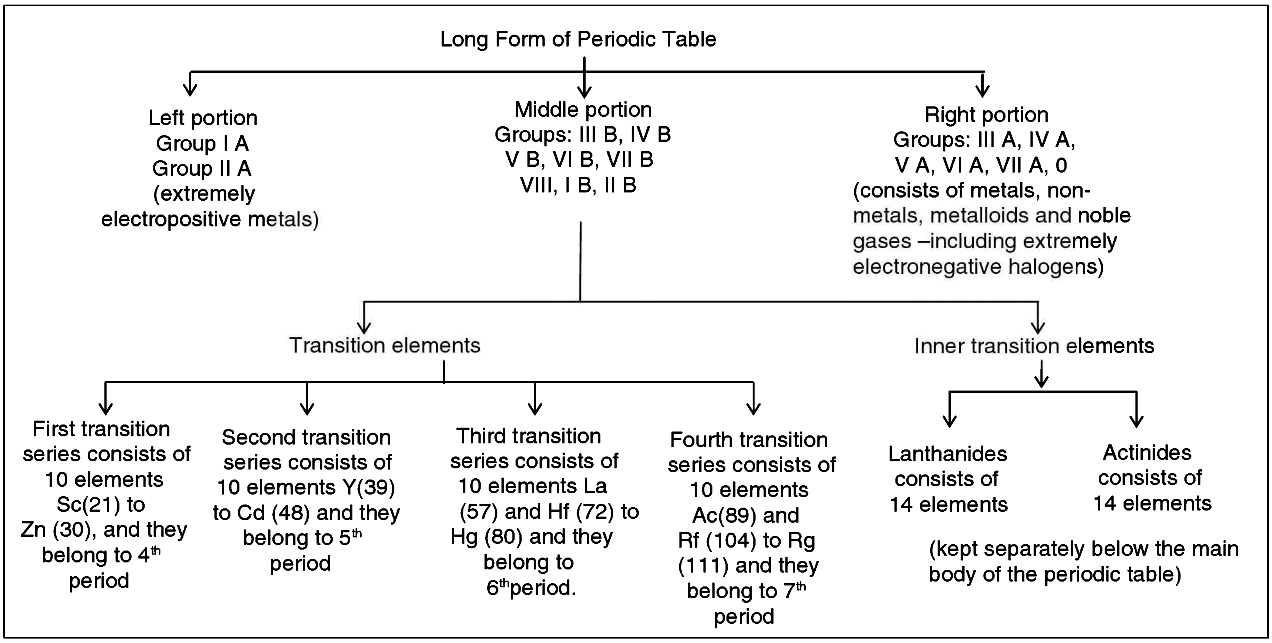


Figure 3.1

Periods

First period	This period has only two elements, hydrogen and helium which have only one energy level or shell. This period is called very short period.
Second period	Elements have two shells. It has 8 elements Li 3 to Ne 10. The elements of this period are called bridge elements.
Third period	This period also has 8 elements–Na 11 to Ar 18. The second and third period are called short periods. These elements have 3 shells. The elements of this period are called typical elements
Fourth period	This period has 18 elements–(K 19 to Kr 36). They have 4 energy levels or 4 shells.
Fifth period	This period also has 18 elements (Rb 37 to Xe 54). They have 5 energy levels or 5 shells.
Sixth period	This period has 32 elements (Cs 55 to Rn 86). They have six energy levels or 6 shells. The fourth, fifth and sixth periods are called long periods.
Seventh period	This is an incomplete period which at present has 19 elements which starts with Fr 87. All these elements are radioactive. Out of these, the naturally occurring radioactive elements are Fr 87, Ra 88, Ac 89, Th 90, Pa 91, and U 92 while the remaining elements after uranium, i.e., Np 93 to Db 105 are artificially prepared radioactive elements and these are called transuranic elements. Atoms of these elements have 7 energy levels or 7 shells.

Groups

1. Groups IA, IIA, IIIA, IVA, VA, VIA, VIIA contain metals, non-metals and metalloids. These elements are called representative elements because their valence electrons represent their group numbers.
2. Groups IB, IIB, IIIB (only Sc, Y, La and Ac), IV B, V B, VI B, VII B and VIII contain only transition metals.
3. In group III B except Sc, Y, La, Ac, the other elements are called inner transition metals and are placed separately in two rows under the periodic table. They belong to 6^{th} period (Ce to Lu) and 7th period (Th to Lr)
4. The '0' group contains noble gases.

Merits of the long form of periodic table

1. The classification is based on the atomic number of elements, which is more fundamental than the atomic weight.
2. In this periodic table, the position of an element is related to the electronic configuration of the atom. Elements belonging to the same group possess same number of electrons in their valence shells and show similar chemical characteristics.

Periodic table

1
1 **H** 1.008

1 ← Atomic number, Z
H ← Element symbol
1.008 ← Relative atomic mass, A_r

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.008																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.01	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.54	30 **Zn** 65.41	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.91	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 98.91	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.40	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.30
55 **Cs** 132.91	56 **Ba** 137.34	**La–Lu**	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.19	83 **Bi** 208.98	84 **Po** 210	85 **At** 210	86 **Rn** 222
87 **Fr** 223	88 **Ra** 226.03	**Ac–Lr**	104 **Rf** [261]	105 **Db** [262]	106 **Sg** [266]	107 **Bh** [264]	108 **Hs** [277]	109 **Mt** [268]	110 **Ds** [271]	111 **Rg** [272]	112 **Uub** [285]						

Lanthanoids	57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 146.92	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.92	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
Actinoids	89 **Ac** 227.03	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** 237.05	94 **Pu** 239.05	95 **Am** 241.06	96 **Cm** 244.07	97 **Bk** 249.08	98 **Cf** 252.08	99 **Es** 252.09	100 **Fm** 257.10	101 **Md** 258.10	102 **No** 259	103 **Lr** 262

☛ *Examples*

Alkali metals	Li	3	2	2, 1	1
	Na	11	3	2, 8, 1	1
	K	19	4	2, 8, 8, 1	1
	Rb	37	5	2, 8, 18, 8, 1	1
	Cs	55	6	2, 8, 18, 18, 8, 1	1
	Fr	87	7	2, 8, 18, 32, 18, 8, 1	1
Halogens	F	9	2	2, 7	7
	Cl	17	3	2, 8, 7	7
	Br	35	4	2, 8, 18, 7	7
	I	53	5	2, 8, 18, 18, 7	7
	At	85	6	2, 8, 18, 32, 18, 7	7

3. Variation of chemical properties along a period is correlated with gradual filling of electrons in a particular shell in the period.
4. In this table, inert gases are placed at the end of each period which is very logical because valence shells have octet configuration. So, their inertness can also be explained in terms of the electronic configuration.
5. Due to the separation of the two subgroups, dissimilar elements (e.g., alkali and coinage metals) do not fall together.
6. Different types of elements like

(i) active metals, (ii) transition metals, (iii) non-metals and metalloids (iv) noble gases and (v) inner transition elements (lanthanides and actinides) have their separate locations in this periodic table.

Defects of the long-form of the periodic table

1. Even after the compilation of the modern periodic table, the position of hydrogen remained controversial. This is because hydrogen with one electron in its valence shell shows similarities with both alkali metals and halogens. Therefore, placing hydrogen in IA group is not completely justifiable.
2. The elements lanthanides and actinides could not be placed in the main body of the modern periodic table.
3. This periodic table does not reflect the exact distribution of electrons of some of the transition and inner-transition elements.

Periodicity

The regular gradation in the properties of elements and their repetition at regular intervals is called periodicity. The properties which show such regular trend are called periodic properties. Some of the periodic properties are:

(a) Atomic size (b) Ionization potential (c) Electron affinity
(d) Electronegativity (e) Electropositive character (f) Oxidizing/reducing capacity
(g) Metallic/non-metallic character

(a) Atomic size

The size of an atom depends on the distance between the valence shell and the nucleus i.e., the atomic radius.

Variation of atomic size along a period and a group in the periodic table

Period

The atomic radii generally decrease from left to right across a period. When we proceed along a period, electrons are added to the subshells of the same main energy level. With the addition of each electron, the nuclear charge increases by 1. Hence, the increased nuclear charge attracts the electrons more strongly and the size of the atom decreases.

Group

On moving down a group, the atomic radii of the elements increase with an increase in the atomic number. On proceeding downward in a group, the electrons are added to the next main energy level which are farther from the nucleus. This effect decreases the electrostatic force of attraction between the nucleus and the valence shell electrons. Consequently, the atomic radii of the atoms of the elements increase along a group from top to bottom.

(b) Ionization energy

Ionization energy of an element is the minimum amount of energy required to remove the most loosely held electron from the outermost shell of an isolated neutral gaseous atom of that element in its lowest energy state to produce a cation.

Successive ionization potentials

The amount of energy required to remove the first electron from a neutral atom is called the **first ionization energy**.

The energy required to remove the electron from a unipositively charged ion is called the **second ionization energy**.

Similarly, the third and the fourth ionization energy or ionization potentials can be defined in the same way.

If the first ionization energy is considered as I_1 and the second is I_2 and so on then, $I_1 < I_2 < I_3 < I_4 < \ldots\ldots$

The successive increase in these values is due to the fact that it is relatively more difficult to remove an electron from a cation having higher positive charge than from a cation having lower positive charge than from a neutral atom.

Variation of ionization potential along a period and a group of the periodic table

In the period

Ionization energy generally increases from left to right along a period because the atomic size of the elements gradually decreases due to the increase in the atomic number.

In the group

Ionization energy decreases from top to bottom in a group because of the increase in the atomic radius which is due to the increase in the number of shells.

(c) Electron affinity

The amount of energy released when an electron is added to an isolated neutral gaseous atom in its lowest energy state to produce an anion is called its electron affinity.

Factors influencing the magnitude of electron affinity are

(i) atomic size (ii) effective nuclear charge

Variation of electron affinity along a period and along a group of the periodic table

Period

Electron affinity values generally increase on moving from left to right along a period due to the decrease in the atomic size and the increase in its effective nuclear charge.

Group

Electron affinity gradually decreases from top to bottom of a group. This is due to the steady increase in the atomic radius and the decrease in the effective nuclear charge of the elements.

(d) Electronegativity

Electronegativity of an element is defined as the relative tendency or ability of the atom of an element present in a molecule to attract the shared electron pair towards itself.

Variation of electronegativity along a group and a period of the periodic table

Period

Electronegativity increases on moving along a period from left to right. This is due to the increase in nuclear charge and decrease in atomic size, as a result of which shared electron pair can be attracted more towards itself.

Group

Electronegativity decreases from top to bottom in a group due to an increase in the atomic size, as a result of which the shared electron pair is attracted less towards itself.

(e) Electropositive character

Electropositive character of an element is its ability to lose one or more electrons to form a positively charged ion.

Variation of electropositivity along a period and a group in a periodic table

Period

Electropositive character decreases from left to right along a period due to the increase in ionization potential.

Group

Electropositive character increases from top to bottom along a group due to the decrease in ionization potential.

(f) Oxidizing and reducing property

The higher the value of electron affinity of the element, the greater would be its capacity to accept an electron, i.e., the element behaves as a strong oxidizing agent.

The lower the value of the ionization potential of an element, the greater would be its capacity to lose electrons, i.e., the element behaves as a strong reducing agent.

Variation of oxidizing and reducing property along a period and a group in a periodic table

Period

Due to the increase in electron affinity from left to right of a period, the oxidising capacity of the elements increases and the reducing capacity decreases from left to right along a period.

Group

Due to the decrease in ionization potential as well as electron affinity from top to bottom of a group, oxidizing capacity of the element decreases whereas its reducing capacity increases on descending a group.

(g) Metallic and non metallic property

Non-metals generally have high electronegativity and metals, low electronegativity.

Variation of metallic and non-metallic character along a period and a group of the periodic table

Period

Electronegativity increases from left to right along a period in the periodic table. Consequently, the metallic character along a period decreases from left to right and the non-metallic character increases.

Group

Since electronegativity decreases from top to bottom along a group in the periodic table, the metallic character of an element increases on descending a group and non-metallic character decreases.

This trend is very much prominent in the case of elements of IVA and VA groups. These groups begin with non-metals (C and N) respectively and end with metals (Pb and Bi) respectively.

test your concepts

Very short-answer type questions

1. What was the need to classify elements?
2. The element in between lithium and potassium in Dobereiner's classification is ________ .
3. What was the basis of Dobereiner's classification of the elements?
4. In Newland's classification, elements are arranged in an increasing order of their ______.
5. Mendeleeff placed coinage metals with _________ metals.
6. What is Newland's law of octaves?
7. The Mendeleeff's periodic table, Ar and ________ form the anomalous pair.
8. What is Mendeleeff's periodic law?
9. Name the element whose atomic weight was corrected by Mendeleeff.
10. Name some elements whose properties were predicted by Mendeleeff prior to their discovery.
11. Lanthanides and actinides are called ________ elements.
12. Which group contains the inner transition elements?
13. What is the modern periodic law?
14. What is the basis of the modern periodic table?
15. Which periods are called the short periods and which periods are called long periods? Why?
16. The elements in the very short period are __________ and _________.
17. What do you mean by representative elements? Give example.
18. Where are the extremely electropositive metals positioned in the periodic table?
19. What type of elements does the right portion of the periodic table contain?
20. What is meant by atomic radius?
21. An increase in atomic radius results in ________ in the electron affinity of an element.
22. Which group contains the noble gases and what are the special characteristics of these gases?
23. Which elements are called transuranic elements?
24. _______ group elements have a greater tendency to form cations.
25. Define ionization potential?
26. Describe the trend of the metallic and non-metallic character of the elements in a group.
27. Define electronegativity. What are its units?
28. Give the number of valence electrons of (a) Alkali elements (b) Halogens
29. How does ionisation potential vary in a group and in a period?
30. Describe the trend of the metallic and non-metallic character of the elements of a period.

Short-answer type questions

31. What are the advantages of the classification of elements?

32. Give some examples of Dobereiner's triads. Explain how they are grouped as triads.

33. What are the achievements and the limitations of Newland's classification?

34. Give the limitations of Dobereiner's classification.

35. Give brief description of Mendeleeff's periodic table.

36. What is the basic difference between Mendeleeff's periodic table and modern periodic table?

37. Why are the lanthanides and the actinides given a separate position in the modern periodic table?

38. Why is there an increase in successive I.P. values?

39. Why do the elements of the same group show identical property? Explain.

40. How does electronegativity vary along a group and along a period? Give reasons and explain with examples.

41. How does the atomic size vary along a group and a period? Give reasons and explain with the help of an example.

42. What is the difference between electronegativity and electropositivity?

43. Why is the modern periodic table also referred as Bohr's table?

44. Why do the chemical properties along a period vary?

45. How do the oxidizing and reducing capacity of an element depend on the ionization potential and electron affinity?

Essay type questions

46. What are the merits and the limitations of Mendeleeff's periodic table?

47. Explain in detail about the different periods of the modern periodic table.

48. What is meant by periodicity? What are the various periodic properties? Explain how and why atomic radius varies in a group and period. Give an example.

49. What are the merits and limitations of the long form of periodic table?

50. How does ionization potential, electron affinity, electropositivity, oxidizing and reducing capacity vary along a group and a period? Give reasons

CONCEPT APPLICATION

Concept Application Level—1

Direction for questions 1 to 7: State whether the following statements are true or false.

1. In Dobereiner's classification, the atomic weight and the properties of the first element are almost equal to the average of those of the 2nd and 3rd elements of a triad.
2. Atomic numbers of the isotopes of an element are different.
3. Differentiating electrons enter anti-penultimate shell in transition elements.
4. Along a period, atomic volume of the elements gradually increases from left to right due to an increase in the number of valence electrons.
5. The element with atomic number 17 has the least size among all the elements of that period.
6. The lower is the value of ionization potential of an element, the greater is its reducing power.
7. Among all the groups, the maximum number of elements is found in IIIB group.

Direction for questions 8 to 14: Fill in the blanks.

8. In the modified Mendeleeff's periodic table, ________ groups and ________ periods are present, whereas in modern periodic table, _____ groups and _____ periods are present.
9. If three elements X, Y and Z form a triad and atomic weights of X and Z are 9 and 40 respectively, then the atomic weight of an element Y is _____.
10. Mendeleeff named certain undiscovered elements as eka boron and eka aluminum which when later discovered were called ______and________.
11. According to Newland's classification, the properties of the 3rd element will find similarity with those of the______ element.
12. Extremely electropositive metals are present in ________ and ________ groups.
13. The atomic number of an element that belongs to the IV A group and 4th period is ___________.
14. Good reducing agents are found in _____ and _____ groups.

Direction for question 15: Match the entries given in column A with appropriate ones in column B.

15.

	Column A			Column B
A.	Calcium	( )	a.	Modern periodic table
B.	Sodium	( )	b.	Naturally occurring radioactive element
C.	Uranium	( )	c.	II A
D.	Lanthanides and actinides	( )	d.	Alkali metal
E.	18 groups and 7 periods	( )	e.	8 elements
F.	2nd and 3rd period in modern periodic table	( )	f.	III B

Direction for questions 16 to 45: For each of the questions, four choices have been provided. Select the correct alternative.

16. Atomic weights of three elements in a Doberenier traid are x, 81, 127. Find the missing atomic weight.

(1) 104 (2) 35 (3) 46 (4) 23

17. The properties which increase on going down the group are__________.

(1) ionization energy and electro negativity (2) atomic size and ionization energy
(3) electro negativity and atomic size (4) metallic character and reducing power

18. Which of the following belong to the same group.

A^{3+} (Number of electrons = 10)
B^{2+} (Number of electrons = 10)
C (Number of electrons = 5)
D (Number of electrons = 31)

(1) ABC (2) BCD (3) ACD (4) ADB

19. Which of the following is not true?

(1) All the fourth period elements have the 4th shell as the valence shell.
(2) In all 4th period elements differentiating electrons enter 4th shell.
(3) In 4th period elements differentiating electrons enter either 4th shell or to 3rd shell.
(4) 1st transition series elements are present in 4th period.

20. The values of the second electron affinities of elements are positive. Which of the following could be the appropriate reason?

(1) Work has to be done against the force of repulsion of the valence electron of the uninegative ion.
(2) Work has to be done against the force of attraction of the nucleus.
(3) The electron loses its energy since it has to work against the repulsive force.
(4) In uninegative ions, the effective nuclear force of attraction towards the valence electrons becomes more.

21. Why is the ionization energy of sulphur less than that of phosphorous, though sulphur is next to phosphorous in the period?

(1) Atomic radius of sulphur is greater than that of phosphorous.
(2) Sulphur has half filled electronic configuration.
(3) Phosphorus has half filled electronic configuration.
(4) In the 3rd period the ionization energy decreases along the period.

22. The element which accepts electrons readily to form anion belongs to

(1) VII A group and 2nd period. (2) VII A group and 3rd period.
(3) O group and 3rd period. (4) VIA group and 3rd period.

23. Identify the oxide which forms the strongest base.

(1) MgO (2) Al_2O_3 (3) Na_2O (4) CaO

24. The formula of the oxide of an element M is M_2O_3. The first four ionization energies of the element M can be in the order:

(1) 120 kcal, 270 kcal, 400 kcal and 5098 kcal
(2) 210 kcal, 150 kcal, 370 kcal and 590 kcal.
(3) 70 kcal, 100 kcal, 105 kcal and 120 kcal
(4) 560 kcal, 410 kcal, 320 kcal and 290 kcal

25. The chemistry of alkali metals is essentially the chemistry of unipositive ions because,

(1) they have low ionization energy values
(2) they have strong tendency to lose single valence electron.
(3) second ionization energy values is very high.
(4) All the above

26. Na^+, F^- and Mg^{+2} ions have the same

(1) size (2) electronic configuration
(3) ionization energy (4) nuclear charge

27. Gallium is more electronegative than aluminum even though electronegativity of the elements decreases down the group. It is due to ______.

(1) increase in the atomic size (2) increase in the ionization energy
(3) increase of effective nuclear charge (4) All the above

28. The total number of inner transition elements are ________.

(1) 14 (2) 28
(3) 20 (4) 15

29. Which one of the following doesn't come under zero group?

(1) He (2) K
(3) Ne (4) Ar

30. The atomic numbers of 4 elements A, B, C, D are 8, 9, 10 and 11 respectively. The order of their atomic volume is

(1) A > B > C < D (2) A < B < C > D
(3) A > B < C < D (4) A < B > C > D

31. Arrange the following statements in a chronological order.

(a) Some elements be grouped in sets of three elements in the increasing order of their atomic weights in which the atomic weight of the middle element was found to be the arithmetic mean of the atomic weights of the other two elements.
(b) The physical and chemical properties of elements are periodic functions of their atomic numbers.
(c) The physical and chemical properties of elements are periodic functions of their atomic weights.
(d) When elements are arranged in the increasing order of their atomic weights, the eighth element resembles the first in physical and chemical properties just as the eighth note on a musical scale resembles the first one.

(1) adcb (2) acdb (3) dbac (4) bdca

32. The electron affinity increases on moving from left to right along a period. Arrange the reasons in a proper sequence.

(a) The amount of energy released during the addition of an electron increases from left to right along a period.

(b) Effective nuclear charge of the elements increases from left to right.

(c) The atomic size of the elements decreases from left to right.

(d) The tendency to gain electrons and form anion increases from left to right.

(1) acbd (2) cbda (3) cadb (4) dcba

33. X belongs to IA or 1st group and 5th period and Y succeeds X in the group. Z succeeds Y in the period. Arrange the suitable statements in the correct sequence in order to arrange X, Y and Z in the increasing order of their atomic sizes.

(a) Effect of number of valence electrons and number of shells on the atomic size.

(b) Identification of the elements X, Y, Z.

(c) Determination of the number of shells and the number of valence electrons present in X, Y and Z.

(d) Determination of the positions of Y and Z in the periodic table based on the position of X.

(1) dbca (2) bdca (3) cad (4) dca

34. Among 3rd period elements halogen and alkaline earth metals are respectively

(1) Cl, Na (2) S, Na (3) S, Mg (4) Cl, Mg

35. Which among the following pair of elements have maximum and minimum electron affinity values respectively?

(1) Be, Cl (2) He, K (3) Be, S (4) Cl, Cs

36. Which of these triads could not be justified as Dobereiner's triad?

(1) Li, Na, K (2) Cl, Br, I (3) C, N, O (4) Ca, Sr, Ba

37. An element belongs to IIIA group and 4th period in the modern periodic table. What could be the probable atomic number of that element?

(1) 23 (2) 49 (3) 31 (4) 13

38. The formula of ion formed by an element A is A^{+2}. The element A can probably belong to which of the following groups?

(1) IIIA (2) VIIA (3) IIA (4) IA

39. The anomalous pairs in Mendeleeff's periodic table is/are __________.

(1) Co, Ni (2) Te, I (3) Ar, K (4) All the above

40. Which of the following triads do not follow Dobereiner's law of triads?

(1) Li, Na, K (2) Ca, Sr, Ba (3) Be, Mg, Ca (4) Cu, Ag, Au

41. Which of the following elements don't belong to group IIA or 2nd group?

(1) Be (2) Mg (3) Li (4) Ca

42. Which of the following is not a transition element?
(1) Mn (2) Fe (3) Cu (4) K

43. Element X has twelve protons in its nucleus. To which group in the periodic table would it belong?
(1) IVA (14) (2) IIA (2) (3) IIIA (13) (4) VIA (16)

44. Element X has twelve neutrons in its nucleus. To which group in the periodic table would it belong?
(1) 1 (2) 2
(3) 3 (4) Cannot be predicted

45. If I_1 is the 1st ionization potential, I_2 is the 2nd ionization potential, I_3 is the 3rd ionization potential and I_4 is the fourth ionization potential of an element, then which of the following has the least value?
(1) I_1 (2) I_2 (3) I_3 (4) I_4

Concept Application Level—2

1. Why is the positive ion always smaller than the corresponding neutral atom?
2. Alkaline earth metals are denser than the corresponding alkali metals. Comment on the statement.
3. Why is the zero group present at the right hand side of the periodic table?
4. Why is it not possible to form Na^{+2} ion? Explain with respect to periodic properties?
5. If the atomic numbers of some elements in the modern periodic table are 8, 7, 11, 12, 13 and 9, what type of ions do they form? Arrange the ions in the increasing order of their size and justify.
6. "The densities of transition metals are greater than those of the alkali and alkaline earth metals". Justify.
7. An element R belongs to IVA group and 3rd period in the periodic table. Arrange the elements that are placed below 'R' and towards right in the periodic table in increasing order of atomic size and ionisation potential.
8. Predict the position of the elements which form the largest cation and the smallest anion in the modern periodic table?
9. Why do transition metals show catalytic behaviour?
10. Predict the position and properties like metallic/non-metallic character and oxidizing/reducing capacity of an element with atomic number 35 in the periodic table.
11. Elements with more non-metallic character are good oxidizing agents and those with more electro-positive character are good reducing agents. Explain.
12. An element 'X' belongs to group II A and 4th period in the periodic table. Find out the atomic number of 'X' and the element which is placed just below 'X' in the periodic table.
13. Explain why the addition of an electron to a neutral atom is associated with release of energy?
14. The first four ionization energies of an element R are 580, 640, 1000, and 2700 k cal/mole respectively. Find the group number of R and write formulae of its chloride and oxide.

15. B and Al belong to the same group, but the nature of oxides formed by them are different, whereas Be, Al form same type of oxides although they belong to different groups. Comment.

Directions for questions 16 to 25: Application Based Questions

16. Chlorine, Y and Iodine form a Dobereiner's triad. Identify the atomic weight of Y.

17. Three elements X, Y and Z form a Dobereiner triad. The ratio of the atomic weight of X to that of Z is 7 : 25. If the sum of the atomic weights of X and Z is 160, find the atomic weights of X, Y and Z.

18. The total number of electrons present in first two and last two shells is the same for an atom of an element X. The sum of the electrons present in second, fourth and fifth shells is equal to the number of electrons present in third shell and fifth shell is valence shell. Identify X and predict its position in the periodic table.

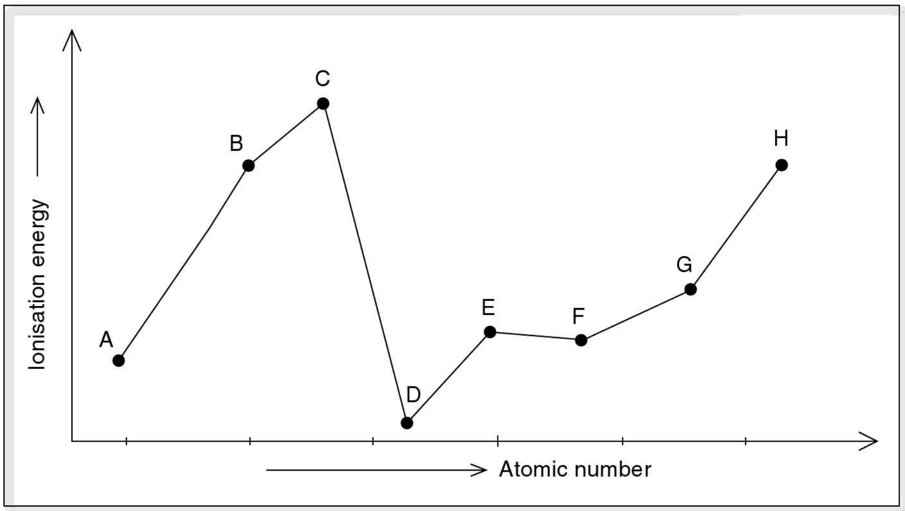
19. The atomic number of elements X, Y and Z are (A – 2), A and (A + 2) respectively. Y is a noble gas (not helium) then

(a) Predict the group to which X, Y and Z belong.

(b) Predict the formula of a molecule formed by X and Z.

20. Consider the isotopes of carbon. i.e., C – 12, C – 13, C – 14, would you place them in same or different slots in the periodic table? Give reason.

21. Given below is the graph representing the ionisation energies of a few elements, A to H with successive atomic numbers.



(a) Identity the noble gas

(b) Which of the following elements could D be?

(i) Ne (ii) Ca (iii) Na

(c) Which element has the highest electron affinity?

(d) Which element has the strongest metallic character?

(e) Write the unit of ionisation energy.

22. A physical science teacher said that work is directly proportional to force and displacement. One of the student who attended the "T.I.M.E IIT" foundation course said that work done in removing an electron from cation is directly proportional to the charge on it. Teacher appreciated the student and explained the above concept. What was her explanation?

23. Elements A, B and C with atomic numbers z, z + 1, z + 2 form positive ions having equal number of electrons. Compare and contrast the sizes of the respective ions.

24. Elements with higher electronegativity are good oxidizing agents. Give reasons.

25. If the atomic numbers of some elements in the modern periodic table are 8, 7, 11, 12, 13 and 9, what type of ions do they form? Arrange the ions in the increasing order of their size and justify.

Concept Application Level—3

1. Write the electronic configuration of the most stable cation of the element having the lowest ionization potential value and belonging to the 4th period. Justify your answer.
2. "Generally, electron affinity values of elements decrease from top to bottom in group of non metallic elements. However, elements of 2nd period have lower electron affinity values than do the corresponding elements of 3rd period". Comment on this statement.
3. Why do alkali metals tarnish on exposure to air?
4. Electron affinity values of noble gases are zero whereas they are negative for alkaline earth metals. How do you account for this?
5. Explain how the density changes across a period from K to Ni and compare it with the change down the group from K to Cs respectively.

Directions for questions 6 to 10: Application Based Questions

6. Which elements can be used in solar cells and why?
7. Explain the energy changes involved in the formation of F^- and O^{2-} from their respective atoms.
8. "Addition of an electron to a uninegative ion (except to VIA group elements) is an endothermic process where as the formation of uninegative ion from its neutral atom is an exothermic process". Comment.
9. A, B, C and D are four 9^{th} class students. Their chemistry teacher conducted a role play in the class which is as given below. She assumed that A is a metal and B is a nonmetal. C and D need to carry out two separate experiments. For this purpose, C needs an oxidizing agent and D needs a reducing agent. Accordingly they have to form two groups consisting of two students each. How will they form the group? Explain this with appropriate reasons.
10. Three elements A, B and C have successive atomic numbers in increasing order. A attains stability when an electron is added to 3^{rd} shell which is the valence shell. Identify A, B and C and predict the respective elements possessing the maximum ionisation energy, oxidising power, reducing power, electron affinity and atomic size.

key points for selected questions

Very short-answer type questions

1. Easy and systematic study.
2. Sodium
3. Atomic weight
4. Atomic weights
5. alkali
6. 8th element starting from a given one is a kind of repetition of the first just like the eighth note of an octave of music.
7. K
8. Properties of elements are periodic functions of their atomic weights
9. Indium
10. Scandium, gallium and germanium
11. inner transition elements
12. III B
13. Periodic function of their atomic number
14. Atomic number
15. 2nd and 3rd, 4th and 5th
16. Hydrogen, helium
17. Incompletely filled valence shells.
18. IA
19. Nature of elements

    Non-metals
20. Distance from centre of nucleus to the outermost orbit
21. decrease
23. Artificially prepared radioactive elements
24. IA
25. Minimum energy required for removal of valence electron
26. Down a group–metallic character increases non-metallic character decreases.
27. Tendency to attract the shared pair of electrons, it is a relative property.
28. 1, 7
29. Decreases from top to bottom in a group and increases from left to right along a period.
30. Along a period–metallic character decreases non-metallic character increases

Short-answer type questions

32. (i) Ca, Sr, Ba
    (ii) Cl, Br, I
    (iii) Li, Na, K.
    Similar chemical properties.
36. (i) Mendeleeff's periodic table–Atomic weight.
    (ii) Modern periodic table–Atomic number.
37. Electronic configuration.
38. Effective nuclear charge increases.
39. Valence electrons.
40. (i) Along a period—atomic radii decreases.
    (ii) Along a group—atomic radii increases.
41. (i) Group—Number of shells change
    (ii) Period—Number of electrons in the valence shell change
42. (i) Tendency of an atom of an element present in a molecule to attract shared electron pair more towards itself
    (ii) Tendency of an atom of an element to lose one or more electrons to form a positively charged ion.
44. Due to difference in the number of valence electrons.
45. (i) Effect of ionization potential and electron affinity on losing and gaining electrons.
    (ii) Effect of losing and gaining electrons on oxidizing and reducing nature.

Essay type questions

46. **Merits**
    (i) Atomic weights.
    (ii) Missing elements.
    (iii) Correction of atomic weights.

key points for selected questions

Limitations

(i) Anomalous pairs.
(ii) Position of hydrogen.
(iii) Positions of isotopes.
(iv) Position of lanthanides and actinides.
(v) Anomalous placement of the transition and coinage metals.

47. First period : only 2 elements, very short period
Second period : 8 elements, bridge elements.
Third period : 8 elements, typical elements.
Fourth period : 18 elements.
Fifth period : 18 elements
Sixth period : 32 elements, very long period
Seventh period : incomplete, radioactive

48. (i) Periodicity : Trend
(ii) In a period : Atomic radii: As electrons are added to the same energy levels, nuclear charge increases.
(iii) In a group: Addition of an extra shell.

49. Merits

(i) Atomic numbers.
(ii) Position related to electronic configuration.
(iii) Variation of physical and chemical properties.
(iv) Placement of inert gases.

Defects

(i) Position of hydrogen.
(ii) Position of lanthanides and actinides.

50. Along a period – Electron affinity, Ionization potential, oxidizing capacity increases, reducing capacity decreases

Along a group – Electron affinity, oxidizing capacity, ionization potential decreases, reducing capacity increases.

KEY

Concept Application Level—1

True or false

1. False
2. False
3. False
4. False
5. True
6. True
7. True

Fill in the blanks

8. 8, 7, 18, 7
9. 24.5
10. Scandium, gallium
11. 10th
12. IA and IIA
13. 32
14. IA, IIA

Match the following

15. A : c
B : d
C : b
D : f
E : a
F : e

Multiple choice questions

16. Choice (2)

17. Choice (4)

18. Choice (3)

19. Choice (2)

20. Choice (1)

21. Choice (3)

22. Choice (2)

23. Choice (3)

24. Choice (1)

25. Choice (4)

26. Choice (2)

27. Choice (3)

28. Choice (2)

29. Choice (2)

30. Choice (3)

31. (i) Some elements be grouped in sets of three elements in the increasing order of their atomic weights in which the atomic weight of the middle element was found to be the arithmetic mean of the atomic weights of the other two elements.

(ii) When the element are arranged in the increasing order of their atomic weights, the eighth element resembles the first in physical and chemical properties just as the eighth note on a musical scale resembles the first one.

(iii) The physical and chemical properties of elements are periodic functions of their atomic weights.

(iv) The physical and chemical properties of elements are periodic functions of their atomic numbers.

Choice (1)

32. (i) The atomic size of the elements decreases from left to right.

(ii) Effective nuclear charge of the elements increases from left to right.

(iii) The tendency to gain electrons and form anions increases from left to right.

(iv) The amount of energy released during the addition of an electron increases from left to right along period.

Choice (2)

33. (i) Determination of the positions of Y and Z in the periodic table based on the position of X.

(ii) Determination of the number of shells and the number of valence electrons present in X,Y and Z

(iii) Effect of number of valence electrons and number of shells on atomic size.

Choice (4)

34. Among the 3rd period elements halogen and alkaline earth metal are chlorine and magnesium respectively.

Choice (4)

35. Inert gases have zero electron affinity due to their stable octet configuration, whereas IA group elements have minimum electron affinity value due to large atomic size. Halogens have high electron affinity due to small atomic size. Hence Cl and Cs have maximum and minimum electron affinity values respectively.

Choice (4)

36. According to Dobereiner's classification, the elements of the triads (Li, Na, K; Cl, Br, I; Ca, Sr, Ba) have similar chemical properties. Elements C, N and O do not show similar properties.

Choice (3)

37. Elements in IIIA group are B, Al, Ga, In, Tl and in this B belongs to the 2nd period.

$\therefore$ The element in IIIA group and 4th period is Ga (gallium), whose atomic number is 31.

Choice (3)

38. The formula of ion formed by A is A^{+2}

$\Rightarrow$ Valency of A is 2.

$\therefore$ A belongs to II A group

Choice (3)

39. Anomalous pairs in mendeleeff's periodic table are Cu, Ni; Te, I; Ar, K.

Choice (4)

40. Since the atomic weight of Ag is not equal to the mean of the atomic weights of Cu and Au, Hence (Cu, Ag, Au) triad do not follow Dobereiner's law of triads.

Choice (4)

41. Lithium belongs to IA(1) group.

Choice (3)

42. Potassium belong to IA(1) group called alkali metal, but not transition element.

Choice (4)

43. The atomic number of X = 12.

Its electronic configuration = 2, 8, 2

$\therefore$ X belongs to IIA(2) group since there are two electrons in the valence shell.

Choice (2)

44. The position of the element in the periodic table cannot be predicted based on the number of neutrons present in the nucleus.

Choice (4)

45. Ionization Potential values increases in the following order:

$I_1 < I_2 < I_4 < \ldots\ldots$

Choice (1)

Concept Application Level—2

Key points

1. (i) Difference between cation and neutral atom.
(ii) comparison of number of electrons in neutral atom to cation.
(iii) comparison of number of protons in neutral atom and cation.
(iv) comparison of effect of nuclear charge in neutral atom and cation.

2. (i) comparison of nuclear charge in alkali and alkaline earth metals.
(ii) Relation and comparison between nuclear charge and atomic size of alkali and alkaline earth metals
(iii) comparison of atomic mass of corresponding elements of IA and IIA
(iv) Relation between mass, size and density

3. (i) comparison of electronic configuration of zero group elements with elements other group.
(ii) Characteristics of zero group elements.

4. (i) Electronic configuration of sodium.
(ii) Position of sodium in the periodic table.
(iii) Periodic properties of these elements.

5. (i) Identification of the number of valence electrons in each element
(i) Tendency of an atom of an element to lose or gain based on number of valence electrons.
(ii) Type of ions formed
(iii) Variation of size of an ion with charge

6. (i) Transition metals come to the right of the respective alkali and alkaline earth metals in the period.
(ii) Factors that effect the density.
(iii) comparison of the variation in mass in alkali, alkaline and transition metals.
(iv) comparison of the variation in volume.

7. (i) Identification of R.
(ii) Position of an element 'R' in periodic table
(iii) comparison of effect of nuclear charge on valence electrons across a period and down the group
(iv) Relation between nuclear charge, size and ionization potential.

8. (i) Cations are smaller than their corresponding atoms and anions are larger than their corresponding atoms.
(ii) Trend of atomic size along a period and down a group.

(iii) Position of the largest atom which can form cation.
(iv) Position of the smallest atom which can form anion.

9. (i) Requisite for catalytic behaviour.
(ii) Electronic configuration of metals
(iii) Relation between electronic configuration and bonding

10. (i) Electronic configuration of the element.
(ii) Prediction of atomic size and ionization potential.
(iii) Relation between ionization potential and metallic/non-metallic and oxidizing/ reducing nature.

11. (i) Nature of metal and non-metals.
(ii) Oxidizing agent and reducing agent in terms of electronic concept
(iii) Relation between metals, non-metals, oxidizing and reducing agents

12. (i) Electronic configuration of X.
(ii) Atomic number of X based on periodic arrangement of elements.
(iii) Electronic configuration of element below X.
(iv) Atomic number of element below X.

13. (i) Type of forces present between an added electron and neutral atom.
(ii) The type of forces responsible for addition of electrons
(iii) Energy changes involved when electrons are added

14. (i) Identification of valence shell electronic configuration from the given I.P. values.
(ii) Identification of respective group number from the valence electrons
(iii) Writing the formulae of its chloride and oxide

15. (i) Position of B, Be, Al in periodic table.
(ii) Comparison of size and ionisation potential of B, Be and Al
(iii) Relation between size, I.P. and nature of the oxides formed

16.

Triad	Chlorine	Y	Iodine
Atomic weights	35.5	–	127

Mean atomic wt $= \dfrac{35.5 + 127}{2} \Rightarrow 81.25$

$\therefore$ atomic weight of Y = 81.25

17. Let the atomic weights of X,Y and Z be Z_x, Z_y and Z_z respectively.

$$\therefore \frac{Z_x}{Z_z} = \frac{7}{25} \Rightarrow Z_x = \frac{7}{25} . Z_z \rightarrow (1)$$

Given that $Z_x + Z_z = 160$

$$\therefore \frac{7}{25} . Z_z + Z_z = 160 \Rightarrow Z_z = 125$$

From equation (1)

$$Z_x = \frac{7}{25} . 125 = 35$$

$$\text{Atomic weight of Y is } Z_y = \frac{35 + 125}{2} = 80.$$

[$\because$ X,Y, Z form Dobereiner triad]

18. Electronic configuration of element X is

K	L	M	N	O
2	8	18	8	2

The element X is strontium with atomic number 38. It belongs to fifth period and second group (IIA) or group 2.

19. (a) As Y is a noble gas, the group of y is eighteenth group or zero group.

X = A – 2; group of X is 16th group or VI A.

Z = A + 2; group of Y is 2nd group or II A

(b) X $\Rightarrow$ Valency = 2 (electronegative)

Z $\Rightarrow$ Valency = 2 (electropositive)

Hence the formula is ZX

20. They should be placed in the same slot i.e they belong to IVA or 14 group and 2nd period as they have same atomic number.

21. (a) The noble gas is C.

(b) D is an alkali metal i.e., Na.

(c) B has the highest electron affinity.

(d) D has the strongest metallic character.

(e) The unit of ionisation energy is kJ / mole.

22. As the positive charge increases, the effective nuclear charge on the outer most electron increases. So work done for removing an electron increases with the increase of charge on the cation.

23. As the positive ions have equal number of electrons, A, B and C must be isoelectronic and form unipositive, dipositive and tripositive ions. With the increase in nuclear charge, the effective nuclear force of attraction on the outermost electrons increases. Therefore, the ionic size decreases from A^+, B^{+2} and C^{+3}.

24. Elements with higher electronegativity has greater tendency to attract the shared pair of electrons present in a compound. An atom which undergoes reduction is an oxidizing agent. The greater the electronegativity value, the more is its tendency to undergo reduction. So it acts as a good oxidizing agent.

25. The elements with atomic numbers 8, 7, 11, 12, 13 and 9 are oxygen, nitrogen, sodium, magnesium, aluminium and fluorine respectively. These elements belong to VIA(16), VA(15), IA(1), IIA(2), IIIA(13) and VIIA(17) groups. Generally these elements form O^{-2}, N^{-3}, Na^+, Mg^{+2}, Al^{3+} and F^- ions. The order of ionic size is

$N^{-3} > O^{-2} > F^- > Na^+ > Mg^{+2} > Al^{3+}$.

Concept Application Level—3

1. (i) Trend of I.P. value along a period

(ii) Trend of ionization potential along a period.

(iii) The group that has elements with lowest ionization potential in their respective periods.

(iv) Electronic configuration of the element and cation.

2. (i) Comparison of atomic size of 2nd and 3rd period elements.

(ii) Effect of numbers of electrons on size

(iii) Energy changes that take place by the addition of an electron in III shell and II shell

3. (i) Reactivity of alkali metals

(ii) Electronic configuration of alkali metals.

(iii) Ionization potential of alkali metals.

(iv) Effect of ionization potential on reactivity.

(v) Relating reactivity and tarnishing.

4. (i) Valence shell electronic configuration of noble gases and alkaline earth metals.

(ii) Relation between valence shell electronic configuration and stability in both the cases

(iii) Types of forces existing between an electron going to be added to a noble gas

(iv) Energy change involved when an electrons is added to a noble gas element

5. (i) Comparison between different electrons entering different shells.

(ii) Variation of nuclear charge on the size of the elements from K to Ni

(iii) Variation of the nuclear charge on elements K to Cs down the group

(iv) Effect of nuclear charge on size

(v) Relation between mass, size and density

6. The metals which belong to alkali metal groups such as K, Cs, Rb can be used in solar cells. The reason is that these metals have very low first ionization energy. Hence they can lose electron easily when exposed to sunlight.

7. Though F^- and O^{-2} are isoelectronic species, the formation of F^- is exothermic while O^{-2} is endothermic. Elements (or) ions having inert gas configuration are highly stable. For attaining nearest inert gas configuration fluorine has one electron less. So it readily accepts electrons and the formation of F^- takes place. In this process, a large amount of energy is released. But in the case of the formation of O^{-2} repulsions exist between the added electron and already existing O^{-1} ion. So this process requires supply of energy to overcome this repulsion. Hence, the formation of O^{-2} is an endothermic process.

8. Addition of an electron to uninegative ion involves repulsion between the electron and negatively charged ion. So energy is required to add an electron to a uninegative ion. Hence it is endothermic process. When an electron is added to a neutral atom, it works towards the force of attraction exerted by the nucleus of the neutral atom and hence energy is released during this process.

9. Oxidising agent is the substance which oxidizes the other substances but also undergoes reduction itself i.e. it accepts electrons from the others. The more the non-metallic character of an element, the more is its tendency to accept electrons and thus acting as a good oxidizing agent.

Reducing agent is the substance which reduces the other substances but itself undergoes oxidation. That means, it gives up its electrons. The more the metallic character, the more is the tendency of losing electrons. Hence metals are good reducing agents. The pairing should be A and D, B and C.

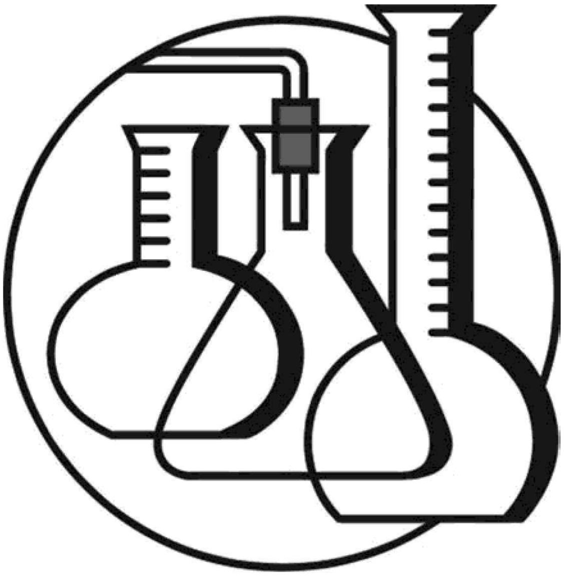
10. As A attains stability by gaining an electron it must form a uninegative ion. The third shell being the valence shell of A, the electronic configuration of A is 2, 8, 7. So the atomic number is 17. A, B and C have successive atomic numbers. So the atomic number of B is 18 and that of C is 19. A, B and C are chlorine, argon and potassium respectively.

Group	**VIIA(17)**	**0(18)**	**IA(1)**
	A	B	C
	Cl	Ar	K
Z	17	18	19
Electronic Configuration	2,8,7	2,8,8	2,8,8,

Since Cl has the highest electron affinity, it gains an electron and attains stability, thus it has greater oxidising power. K which belongs to IA(1) group and 4th period possesses greater atomic size, lower ionisation potential and greater reducing power. Atomic size gradually increases from Cl to K. Ar which belongs to 18th group possesses maximum ionisation potential due to stable octet configuration.

4

Chemical Bonding



INTRODUCTION

Nature is associated with innumerable chemical reactions. A chemical reaction involves change in molecular composition of a substance. It has been established that atom is the smallest particle of matter which takes part in a chemical reaction. Molecule is the smallest constituent particle of matter which has an independent existence and which represents the properties of the respective elements or compounds. Most of the elements in nature have been found to exist in combined state. However, there are some atoms which have independent existence and are considered to be highly stable atoms. Except those of a few elements, the atoms of most of the elements have an inherent tendency to combine and form molecules. The combining atoms may belong to the same element or different elements. Within the molecules, the atoms are held together by attractive forces. Study of the types of bonds, the conditions required for bond formation and the energy changes involved in chemical bond formation are some aspects of study of chemical bonding.

Reasons for the formation of a chemical bond

Noble gases are mono atomic. They do not combine either with their own atoms or atoms of other substances. These are the unique gases having 8 electrons (except helium) in their respective valence shells and is called the **octet configuration**. Helium has only two electrons as it has only one main energy level. This is called **duplet configuration**.

Except noble gases, atoms of all other elements have 1 to 7 electrons in their valence shells. The octet of the noble gases and the pair of electrons in helium are so stable that atoms of other elements also strive to attain the same electronic configuration to become stable.

In order to satisfy this urge, atoms unite to form molecules, their electrons get rearranged and a bond is said to be formed. During the formation of a bond, energy of the participating atoms gets reduced and thereby the molecules become stable.

Types of chemical bonds

The various types of bonds are:

1. Ionic bond
2. Covalent bond
3. Co-ordinate bond
4. Metallic bond

Ionic Bond

A chemical bond is formed between two atoms by complete transfer of one or more electrons from one atom to the other as a result of which the atoms attain their nearest inert gas configuration. The electrostatic force of attraction which holds the two oppositely charged ions together is called ionic bond.

During the formation of an ionic bond, one atom loses electron(s) forming positively charged ion called cation while the other atom gains electron(s) forming negatively charged ion called anion. The cation and anion are held together by strong electrostatic forces of attraction. The resulting compounds formed are called ionic compounds.

Example for ionic bond formation

Formation of potassium chloride

Electronic configuration of

Potassium (19) - 2, 8, 8, 1

Chlorine (17) - 2, 8, 7

Potassium has a tendency to lose its one valence electron to attain the nearest inert gas configuration of argon.

$K - e^- \rightarrow K^+$

Chlorine has a tendency to accept an electron from potassium to attain the electronic configuration of argon.

$Cl + e^- \rightarrow Cl^-$

$K^+ + Cl^- \rightarrow KCl$

Lewis dot formula

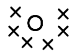
To explain the various types of bonds and to visualise the shift in the valence electrons, G. N. Lewis proposed the Lewis dot formula. In this, the valence electrons of the participating atoms are shown in the form of dot or cross. The valence electron of one of the participating atoms is represented as dot and that of the other one as cross.

Representation of some ionic compounds by Lewis dot formulae

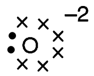
Formation of magnesium oxide

Electronic configuration of

Magnesium (12) 2, 8, 2 

Oxygen (8) 2, 6. 

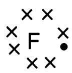
Magnesium loses two electrons from its valence shell while oxygen gains these two electrons such that both the elements attain the nearest inert gas configuration of neon.

Mg^{+2}  Formula: MgO

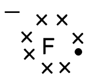
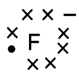
Formation of calcium fluoride

Electronic configuration of

Calcium (20) $\rightarrow$ 2, 8, 8, 2 

Fluorine (9) $\rightarrow$ 2, 7 

Calcium loses two electrons from its valence shell while fluorine can gain only one electron to attain its nearest inert gas configuration. Hence the two electrons lost by one calcium atom are accepted by two fluorine atoms.

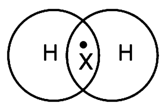
 Ca^{+2}  Formula: CaF_2

Covalent Bond

Covalent bond is a bond formed when two atoms share one or more electron pairs. Each atom contributes equal number of electron(s) towards the bond formation.

Formation of hydrogen molecule

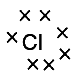
Hydrogen has one electron. It shares this electron with another atom of hydrogen, attaining the duplet configuration. Hence the two hydrogen atoms share the electron pair and thereby a covalent bond is formed between the two hydrogen atoms.



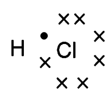
Formation of hydrogen chloride

Electronic configuration of

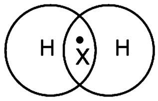
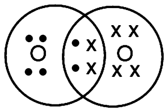
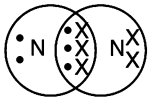
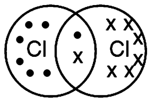
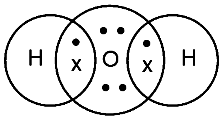
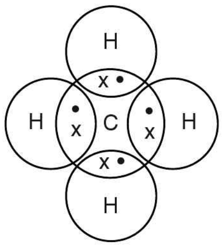
H (Z = 1) $\rightarrow$ 1 H •

Cl (Z = 17) $\rightarrow$ 2, 8, 7 

The pair of electrons (one is contributed by hydrogen and another one by chlorine) is shared by both hydrogen and chlorine atoms. Thus hydrogen attains its stable duplet configuration and chlorine attains its stable octet configuration.



Some examples of covalent molecules using Lewis dot symbols

Hydrogen(H_2)	**1**		1 shared pair
Oxygen(O_2)	**6**		2 shared pairs
Nitrogen(N_2)	**5**		3 shared pairs
Chlorine(Cl_2)	**7**		1 shared pair
Water(H_2O)	**H → 1, O → 6**		2 shared pairs
Methane(CH_4)	**C → 4, H → 1**		4 shared pairs

Factors responsible for the formation of ionic and covalent bond

Ionization energy	The lower the value of ionization potential of the element, the higher is the probability of cation formation. Likewise, higher ionization potential values lead to anion formation. Hence, if the difference of ionization potential between the two atoms is more, ionic compounds are formed.	Atoms with higher ionization potential are unable to lose their valence electrons and hence prefer to form covalent bonds by sharing of electrons.
Electron affinity	Atoms with very low electron affinity form ionic bond with the atoms of higher electron affinity.	The formation of a covalent bond is favoured when the combining atoms have almost equal electron affinity.

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Electronegativity	The greater is the difference in electronegativities between the two combining atoms, the greater are the chances of transfer of electron(s) from one atom to another. Hence, greater electronegativity difference between the two combining atoms leads to the formation of an ionic bond.	If the electronegativities of the combining atoms do not differ much, then the bond formed between them is likely to be covalent.
Metallic–Non-metallic character	If one of the atoms is metallic and the other one is non-metallic, then the difference in ionization potential, electron affinity and electronegativity becomes more which leads to the formation of an ionic bond.	If both the atoms are non-metallic, then the difference in ionization potential, electron affinity and electronegativity is very less, this leads to the formation of a covalent bond.

Energy changes during covalent bond formation

☛ *Example* Formation of hydrogen molecule.

When two hydrogen atoms approach each other, attractive forces develop between the electrons of one atom and the nucleus of the other atom. At the same time, repulsive forces also exist between the nuclei of the two atoms and the electrons of the two atoms. As the two atoms are brought closer to each other, at some distance, the proton electron attraction just balances the electron electron repulsion and proton proton repulsion. The bond formation takes place at this distance which corresponds to minimum possible energy state and the system becomes stable. This distance between the two nuclei is called the bond length.

The total energy of this system is a function of distance between hydrogen nuclei as shown in the graph.

In the hydrogen molecule, the electrons reside in the space between the two nuclei where they are attracted simultaneously by the protons present in both the nuclei of the two hydrogen atoms.

Since the bonding between two hydrogen atoms is associated with equitable sharing of electrons between the bonded atoms, this does not result in any charge separation within the molecule. These types of bonds are called **non-polar covalent bonds**.

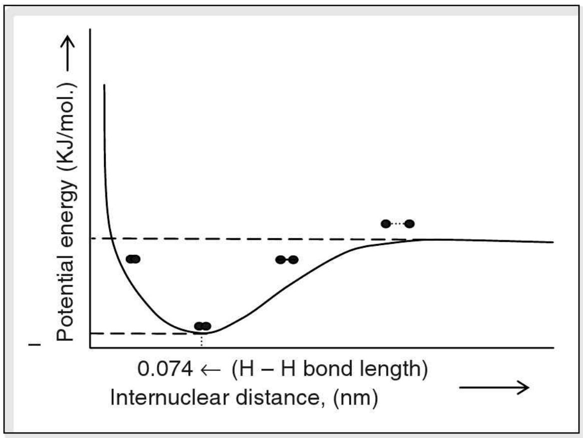


Figure 4.1

Polar Covalent Bond

Polar covalent bond is a type of covalent bond formed between two non-identical atoms. Since the two atoms differ in their capacity to attract the shared electron pair, unequal sharing of electrons results. Due to the unequal sharing of electrons, fractional positive and negative charges are developed on the bonded atoms and the bond is said to be polar. Though it is a covalent bond, a slight ionic character is imparted to the bond due to the electronegativity difference between the two bonded atoms.

Comparative study between polar and non-polar covalent bonds

Sharing of electrons	Electron pairs contributed by both the bonded atoms of the molecule are unequally shared.	Electron pairs contributed by both the bonded atoms forming the covalent molecule are equally shared.
Development of charge	Slight positive and negative charges are developed on the bonded atoms	No charge is developed due to equal sharing of electrons.
Constituent atoms	Formed between the atoms having difference in their electronegativities. Example: H_2O, HF, HCl, NH_3.	Formed by identical atoms. Example: Cl_2, O_2, N_2 etc.

Comparative study of the properties of ionic and covalent compounds

Physical state	Most of the ionic compounds are crystalline solids. X-ray studies of the ionic compound have revealed that the constituent particles of the crystals are ions, not molecules. The cations and anions are held together very strongly by electrostatic force of attraction. Hence, the ions cannot be displaced from their position and thus the ionic compounds are generally hard solids.	Generally liquids or gases. This is because kinetic energy of the molecules easily overcomes the weak intermolecular (electrostatic) forces between the polar covalent molecules.	Generally liquid or gas. This is because kinetic energy of the molecules easily overcomes the weak van der Waal's forces acting between the non-polar covalent molecules.
Melting and boiling points	All the ionic compounds have high melting and boiling points. Considerable heat energy is required to overcome the electrostatic force of attraction between the ions of an electrovalent compound and make the ions mobile. Hence they have high melting and boiling points.	Have low melting and boiling points because a small amount of energy is sufficient to overcome the weak electrostatic force of attraction or the H-bonding between the polar covalent molecules.	Have low melting and boiling points because a small amount of energy is sufficient to overcome the weak van der Waal's forces acting between the molecules.

(Continued on following page)

Solubility	Ionic compounds are generally soluble in polar solvents like water, but insoluble in non-polar organic solvents. Molecules of the polar solvent like water can overcome the force of attraction between the ions in the crystal of the ionic solute. As a result, the ions become mobile and disperse in all directions in the polar solvent. Non-polar organic solvents cannot overcome the force of attraction between the ions of the ionic compound. Hence, ionic compounds do not dissolve in non-polar organic solvents.	Soluble in polar solvent due to the presence of partial charges. Also soluble in non-polar covalent liquids, due to similar forces between the molecules.	Insoluble in polar solvents like water because they don't ionize, but soluble in non-polar covalent liquids like benzene, carbon tetra-chloride, due to similar forces.
Density	The oppositely charged ions in an ionic compound are held closely by electrostatic force of attraction. Hence the number of ions per unit volume in an ionic compound is more and thereby their density is high.	Generally, they exist in the form of liquid or in gaseous states due to weak inter molecular forces. Hence the number of molecules per unit volume is less, thereby leading to low density.	Generally, they exist in liquid or gaseous states due to weak inter molecular forces. Hence the number of molecules per unit volume is less, thereby leading to low density.
Electrical conductivity	Electrovalent compounds conduct electricity either in the fused state or in their aqueous solutions, due to the presence of mobile ions. Since the ions are charged particles, they move towards the respective electrodes under the influence of an electric field and conduct electricity.	These compounds ionize in water and the ions help in conducting electricity.	These compounds do not ionize and hence do not conduct electricity.

Co-ordinate Covalent Bond

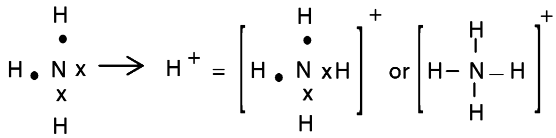
Co-ordinate bonds are those covalent bonds where the electron pair is provided by only one of the bonded atoms, but shared by both the atoms.

This atom which donates the electron pair is called the donor and the other atom which accommodates the shared pair of electrons is called the acceptor.

The co-ordinate bond is represented by a one sided arrow '→' where the arrow head points towards the acceptor and the tail towards the donor.

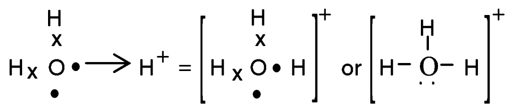
☛ *Examples*

(i) Formation of ammonium ion



The lone pair of electrons is donated by N-atom of ammonia and it is accepted by H^+. Hence N-atom is donor and H^+ is acceptor.

(ii) Formation of hydronium ion



O-atom of water molecule is donor and H^+ is acceptor.

Forces acting between the covalent molecules

(i) van der Waal's forces

The weak forces which exist between the covalent molecules are known as van der Waal's forces.

There is an electrostatic force of attraction between the nucleus of one molecule and the electrons of the other. This is largely, but not completely neutralized by the electrostatic force of repulsion of electrons of one molecule by the electrons of the other or the nucleus of one molecule by the nucleus of the other. The resultant weak forces of attraction between the two molecules are called van der Waal's forces.

(ii) Dipole–dipole attractions

In polar covalent molecules, the unequal sharing of bonded electron pair results in partial charge separation within the molecule. The molecule with opposite partial charges is called dipole. The opposite charges of adjacent dipoles align with each other and the forces of attraction existing between these oppositely charged ends of the adjacent dipoles are called dipole–dipole attractions. The dipole–dipole attractions are much stronger than van der Waal's forces of attractions.

☛ *Example* In HCl molecule $H^{\delta+}$ and $Cl^{\delta-}$ charges are formed within molecule. In a sample of HCl, $Cl^{\delta-}$ of one HCl molecule attracts $H^{\delta+}$ of other molecule and these attractions are known as dipole – dipole attractions.

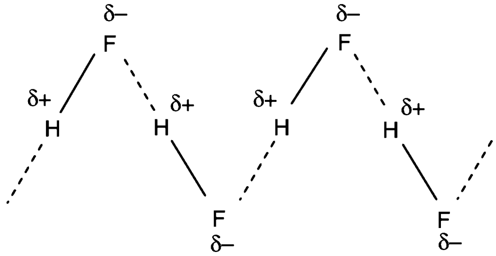
Hydrogen bonding

Polar covalent molecules which have a highly electronegative atom bonded to a hydrogen atom become strongly polar. Some examples of such molecules are HF, H_2O, NH_3.

In such types of polar covalent molecules, the H-atom of one molecule gets attracted to the strongly electronegative atom of the other molecule due to the formation of the slight positive charge on the hydrogen atom and the slight negative charge on the more electronegative atom.

This force of attraction that holds the hydrogen atom of one molecule to the highly electronegative atom of the other molecule is called hydrogen bond.

1.



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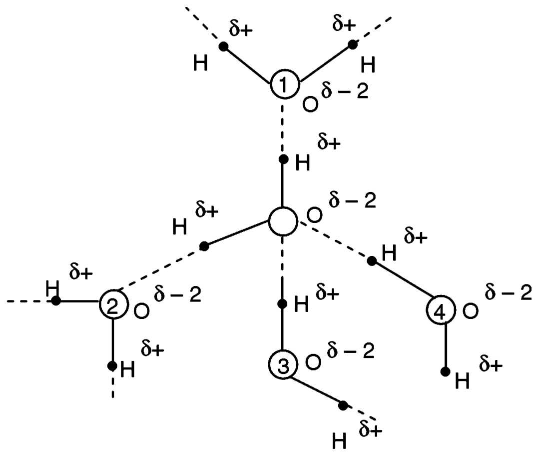

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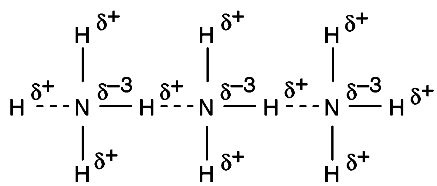


Metallic Bond

Any metal is a crystalline substance. A metal atom generally has either 1, 2 or 3 electrons in its valence shell. It can easily lose these electrons and gain stability. Metals are thus highly electropositive in nature. These electrons lost by the metal are called free electrons. The free electrons of all the metal atoms form an electron pool. The resulting positively charged metal ions are believed to be held together by the electron pool.

The force of attraction that exists between the mobile electrons and the metal ions is known as metallic bond.

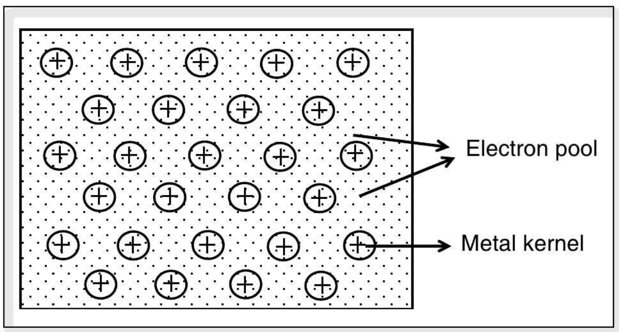


Figure 4.2 Schematic illustration of metallic bond in 'electron sea model'

Redox reactions

In a chemical reaction, if loss and gain of electron(s) takes place by the atoms or the ions, then the phenomenon can be defined in terms of loss and gain of electrons.

Oxidation

During a chemical reaction, if an atom or an ion loses one or more electrons, then the atom or the ion is said to be oxidized and this process is called oxidation.

Reduction

During a chemical reaction, if an atom or an ion gains one or more electrons, then the atom or the ion is said to be reduced and this process is called reduction.

Redox reaction

A chemical reaction in which loss and gain of electrons take place simultaneously is called a redox reaction.

Oxidizing agent: In the redox reaction, the atom or the ion that gains electron(s) is called an oxidizing agent.

Reducing agent: In the redox reaction, the atom or the ion that loses electron(s) is called a reducing agent.

Explanation of redox reactions with the help of some example

(i) When zinc granules are dipped into dilute H_2SO_4, H_2 gas is liberated with the formation of $ZnSO_4$.

$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$ (g)

In the above chemical reaction, the zinc atom loses two electrons and forms Zn^{+2} ion and each of the two hydrogen atoms gain an electron each.

$Zn - 2e^{-1} \rightarrow Zn^{+2}$

$2H^{+} + 2e^{-1} \rightarrow H_2$

In this reaction, zinc is oxidized and acts as a reducing agent. H^{+} is reduced and acts as an oxidizing agent.

(ii) When iron powder and sulphur are mixed and heated, they form ferrous sulphide (FeS).

$Fe + S \rightarrow FeS$

In this reaction, Fe loses two electrons and forms Fe^{+2} whereas S gets converted to S^{-2} by gaining two electrons. Hence, Fe is oxidized and S is reduced. Sulphur is an oxidizing agent whereas iron is a reducing agent.

test your concepts

Very short-answer type questions

1. How many types of chemical bonds are there? What are they?
2. Name one solvent in which most of the ionic compounds dissolve.
3. During the formation of ___________ electron transfer takes place from one atom to the other.
4. In which state do the electrovalent compounds generally conduct electricity?
5. Why do the non-polar covalent compounds not conduct electricity?
6. What type of chemical bonds are found in each of the following compounds?
   (a) potassium chloride (b) carbon dioxide
   (c) hydrogen chloride (d) water
   (e) magnesium oxide (f) calcium fluoride
   (g) methane (h) sodium chloride
   (i) ammonia (j) phosphorus-penta chloride
   (k) sulphur hexafluoride
7. Ionic compounds are insoluble in __________ solvents.
8. In what type of solvents do the
   (a) polar compounds and
   (b) non-polar compounds dissolve?
9. The atoms of an element with electronic configuration 2, 8 are held by __________ forces of attraction.
10. Why are the molecules more stable than the atoms?
11. __________ compounds conduct electricity in fused state or in aqueous solution.
12. What are the criteria due to which a covalent bond becomes polar or non-polar?
13. What are the two opposing forces that start acting between two hydrogen atoms when they are brought together?
14. The nature of bond in H_2S is ___________.
15. Why are the fractional positive and negative charge developed within a polar covalent molecule?
16. What is a coordinate covalent bond?
17. What are van der Waal's forces of attraction?
18. The electrical conductivity of ionic compounds in molten state is due to the presence of ________.
19. Define
    (a) polar covalent compound and
    (b) non-polar covalent compound

20. Give some examples in which coordinate covalent bond formation takes place.

21. Write two effects of van der Waal's forces of attraction.

22. Metallic lustre is due to the presence of __________.

23. Give some examples of the compounds where hydrogen-bond exists.

24. In the ___________ bond, the contribution of an electron pair is one-sided, but the sharing is equitable.

25. Draw the Lewis dot formulae for the bond formations in the following compounds.

(a) NaCl (b) CaF_2 (c) H_2 (d) O_2

(e) N_2 (f) H_2O (g) NH_3 (i) CH_4

26. In a covalent bond, ___________ of electrons takes place between the two atoms.

27. The chemical reaction in which loss and gain of electrons take place, is called ___________ reaction.

28. Define the following terms on the basis of electron transfer.

(a) Oxidation
(b) Reduction
(c) Redox reaction
(d) Oxidizing agent
(e) Reducing agent

29. In ammonium ion, the lone pair of electrons is donated by __________ and it is accepted by __________. Hence __________ is called donor and __________ is called acceptor.

30. In the reaction $2Mg + CO_2 \rightarrow 2MgO + C$, oxidizing and reducing agents are respectively ________ and ____________.

Short-answer type questions

31. Why is helium considered to be a noble gas though it has only two valence electrons unlike the other noble gases?

32. What are the factors responsible for the formation of covalent bond and ionic bond?

33. Why do the noble gases not take part in a chemical reaction?

34. What type of bond formation takes place between

(a) a metal and a non-metal and
(b) two non-metals?

35. Why do most of the ionic compounds exist in solid state while the covalent compounds are mostly in gaseous or liquid state?

36. What is the role of ionization potential and electron affinity of the elements in the formation of ionic bond and covalent bond?

37. Why is the density of the ionic compounds high and that of covalent compounds low?

38. Why are the melting points and boiling points of the ionic compounds high and those of covalent compounds low?

39. Why do the pure covalent compounds not conduct electricity?

40. Why are the ionic compounds soluble in water?

41. Why do polar covalent compounds dissolve in water?

42. Explain the hydrogen bond formation with the help of a diagram in the following compounds

(a) hydrogen fluoride (b) ammonia (c) water.

43. What types of bonds exist in the following ions?

(a) ammonium ion

(b) hydronium ion

Explain in brief their formation with a diagram.

44. Write in short about van der Waal's forces.

45. Mention the oxidizing agent, reducing agent in the following redox reactions and give reason in support of your answer.

(i) $Mg + 2HCl \rightarrow MgCl_2 + H_2$

(ii) $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$

(iii) $2KMnO_4 + 16HCl \rightarrow 2KCl + 2MnCl_2 + 8H_2O + 5Cl_2$

(iv) $2H_2S + SO_2 \rightarrow 2H_2O + 3S$

(v) $4HCl + O_2 \rightarrow 2H_2O + Cl_2$

Essay type questions

46. Write in detail about metallic bond.

47. Complete the following table:

Molecules	No. of valence electrons of the constituent atoms	Structure of the molecule (Present diagrammatically the sharing of electrons for covalent bond formation)
Chlorine		
Methane		
Water		
Nitrogen		

48. Differentiate between ionic and covalent bonding on the basis of the following parameters:

(a) formation
(b) physical state
(c) melting point and boiling point
(d) solubility
(e) electrical conductivity

49. Describe hydrogen bonding with the help of examples.

50. Describe the formation of co-ordinate bond and present diagrammatically the formation of coordinate bond in ammonium and hydronium ions.

CONCEPT APPLICATION

Concept Application Level—1

Direction for questions 1 to 7: State whether the following statements are true or false.

1. Atoms are less stable than molecules.
2. Sharing of electrons takes place in calcium fluoride.
3. In a nitrogen molecule, only one pair of electrons are shared between the two nitrogen atoms.
4. Metallic bond is unidirectional.
5. Covalent compounds conduct electricity since they have free electrons.
6. In a redox reaction, the oxidizing agent itself gets reduced.
7. In HF, unsymmetrical distribution of shared pair of electrons takes place.

Direction for questions 8 to 14: Fill in the blanks.

8. In calcium fluoride, ____________ bond formation takes place between calcium and fluorine.
9. The total number of chemical bonds present in hydronium ion is __________.
10. The distance where the energy of the atoms taking part in the bond formation is minimum, is called the ___________.
11. If the shared pair of electrons is present nearer to one of the bonded atoms, then the nature of the bond is ______________.
12. Covalent compounds having giant molecules are virtually ___________ in all solvents.
13. In water molecule ____________ bond formation takes place between hydrogen and oxygen.
14. The nature of bonds formed between atoms of elements X and Y with higher ionization potential is __________.

Direction for question 15: Match the entries given in column A with appropriate ones in column B.

15.

A.	Ionic bond	( )	a.	Weak forces existing between molecules.
B.	Polar covalent bond	( )	b.	2 shared pairs of electrons
C.	Co-ordinate covalent bond	( )	c.	Electron transfer takes place from one atom to another
D.	Reducing agent	( )	d.	Attraction between positive ions and surrounding free mobile electrons
E.	Nitrogen	( )	e.	1 shared pair of electrons.
F.	Oxygen	( )	f.	Loses electron in a chemical reaction
G.	Chlorine	( )	g.	Shared pair of electrons is attracted towards the more electronegative atom
H.	Metallic bond	( )	h.	Forces of attraction between bonded hydrogen and a highly electronegative atom.
I.	H-bonding	( )	i.	3 shared pairs of electrons
J.	van der Waal's force	( )	j.	Contribution of pair of electrons by a single atom.

Direction for questions 16 to 45: For each of the questions, four choices have been provided. Select the correct alternative.

16. Among the following hydrides, ionic hydride is ________.

(1) MgH_2 (2) SiH_4 (3) BH_3 (4) PH_3

17. When one highly electropositive element A reacts with a highly electronegative element B, the compound formed will be

(1) an ionic compound.

(2) a polar covalent compound.

(3) a co-ordinate covalent compound.

(4) a non-polar covalent compound.

18. The covalency of nitrogen in ammonium ion is ________.

(1) 3 (2) 4 (3) 5 (4) 2

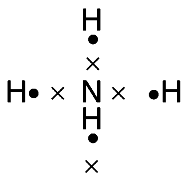
19. Which of the following substances is associated with the weakest electrostatic forces of attraction?

(1) HCl (2) NaCl (3) Na (4) Cl_2

20. The force of attraction acting between cation and anion of an ionic compound is

(1) electrostatic force of attraction (2) metallic bond
(3) hydrogen bond (4) None of these

21. The Lewis dot diagram representing ammonia molecule is

(1)


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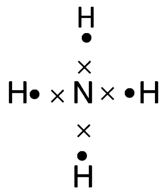

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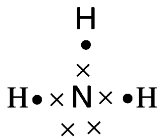
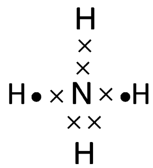


(4)


22. In the following reaction, $SO_2 + 2H_2S \rightarrow 3S + 2H_2O$

(1) sulphur is oxidized and hydrogen is reduced.
(2) hydrogen is oxidized and sulphur is reduced.
(3) sulphur is both oxidized and reduced.
(4) sulphur is reduced and oxygen is oxidized.

23. Though HCl, NH_3 are covalent molecules, their aqueous solutions conduct electricity, this is due to

(1) the presence of free electrons.
(2) the formation of free ions.
(3) the formation of hydrated compounds.
(4) formation of dative bond.

24. The strength of ionic bond is more when there is

(1) no difference in the atomic radii of the constituent atoms.
(2) less difference in the ionization potential of the atoms.
(3) less difference in the electronegativity of the atoms.
(4) greater difference in the metallic character of constituents atoms.

25. Why is the boiling point of ethyl alcohol (C_2H_5OH) higher than that of the corresponding hydrocarbon (C_2H_6)?

(1) Ionic bonds exist in ethyl alcohol molecule.
(2) Hydrogen bonds exist between ethyl alcohol molecules.
(3) Covalent bonds exist between ethyl alcohol molecules.
(4) None of the above

26. Which of the following solutions does not have a hydrogen bond?

(1) H_2S (2) C_2H_5OH (3) HF (4) NH_3

27. Which among the following is not attracted towards a charged plate?

(1) Water (2) Ammonia (3) Hydrochloric acid (4) Bromine

28. Assertion (A): Iron is harder than potassium.

Reason (R): Iron is more metallic than potassium due to its higher electropositivity.

(1) Both A and R are true and R is the correct explanation of A.

(2) Both A and R are true but R is not the correct explanation of A.

(3) A is true, R is false.

(4) A is false, R is true.

29. The nature of bonds present in sodium hydroxide are

(1) ionic, covalent and co-ordinate covalent.

(2) ionic and covalent.

(3) covalent and co-ordinate covalent.

(4) ionic and co-ordinate covalent.

30. If two atoms A and B of a molecule are brought closer than their minimum inter nuclear distance, then potential energy of the system

(1) remains constant at minimum value (2) starts increasing

(3) remains constant at maximum value (4) starts decreasing

31. Which among the following liquids shows convex meniscus in a glass tube?

(1) Water

(2) Hydrochloric acid

(3) Alcohol

(4) Carbon tetrachloride

32. The electronic configurations of two elements A and B are 2, 8, 8, 2 and 2, 6 respectively. Then the formula of the compound formed between them is _____ and its nature is _____.

(1) AB, covalent (2) AB, ionic (3) A_2B, covalent (4) A_2B, ionic

33. P, Q, R and S are four substances. P conducts electricity in the solid state, Q conducts electricity only in the solution state, R conducts electricity in the molten state and S is a bad conductor of electricity either in the molten state or in the solution state. Then P, Q, R and S may be ______.

(1) P = Aluminium, Q = $MgCl_2$, R = HCl, S = Br_2

(2) P = Aluminum, Q = HCl, R = Na_2O, S = Glucose

(3) P = KCl, Q = HCl, R = Iron, S = Glucose

(4) P = KCl, Q = HF, R = Na_2O, S = Br_2

34. Which among the following can form the strongest hydrogen bond?

(1) HF (2) H_2O (3) NH_3 (4) CH_4

35. A molecule in which the central atom is associated with contracted octet is

(1) NH_3 (2) PH_3 (3) $AlCl_3$ (4) CH_4

36. Covalency of N in NH_3, NH_4^+, NH_4Cl are ____, ____ and ______ respectively

(1) 3, 4, 5 (2) 3, 4, 4 (3) 3, 3, 3 (4) 3, 3, 4

37. Which among the following can form the strongest metallic bond?

(1) Sodium (2) Potassium

(3) Magnesium (4) Aluminium

38. Arrange the following in sequence for the representation of NH_3 molecule by Lewis dot diagram.

(a) Determination of the nature of bond between the constituents

(b) Electronic configuration of the constituents

(c) Representation of valence electrons as cross or dots

(d) Identification of the atomic numbers of the constituent elements

(1) dbca (2) dbac (3) bdac (4) dbca

39. "The strength of ionic bond in $MgCl_2$ is greater than in NaCl". Arrange the following key points that are essential to explain the above said statement in a correct sequence.

(a) Comparison of sizes of respective ions of Na and Mg.

(b) Factors affecting strength of ionic bond.

(c) Effect of size and electronegativity difference on the strength

(d) Comparison of electronegativity difference of the respective constituents in both the compounds

(1) d c b a (2) b c a d (3) b a d c (4) d a c b

40. Metals are lustrous in nature, having shiny appearance. Arrange the reasons given below in a sequence.

(a) Emission of radiation or light energy by excited electrons makes a metal shiny in appearance

(b) The electrostatic forces of attraction between metal ions and the mobile electrons is called metallic bond.

(c) The positive metal ions are surrounded by pool of electrons.

(d) When light falls on the crystal, electrons get excited

(1) c b a d (2) c b d a (3) b c a d (4) b d c a

41. The element which can never attain octet configuration in any of its compounds is _______

(1) K (2) Li (3) F (4) O

42. In the formation of AlF_3, aluminium atom has to lose ______ electrons.

(1) 1 (2) 2 (3) 3 (4) 4

43. Which of the following is a true statement?

(1) In polar compounds shared pair of electrons is away from the more electronegative atom.

(2) Polar compounds are good conductors of electricity in their vapour state.

(3) In polar compounds separation of charges take place.

(4) Polar compounds are good conductors of electricity in solid state.

44. In which of the following molecules partial charge separation does not take place?

(1) Chlorine (2) Hydrochloric acid

(3) Water (4) Ammonia

45. Ionic compounds do not conduct electricity in solid state. Identify the correct reason.

(1) Absence of oppositely charged ions in solid state

(2) Absence of mobile ions in solid state

(3) Absence of forces of attraction between ions in solid state

(4) Absence of free electrons in solid state

Concept Application Level—2

1. Explain the nature of the different types of bonds present in a NH_4Cl molecule.

2. The potential energy curve is not symmetrical about the minimum energy point. Justify.

3. Why is water called a universal solvent?

4. Comment on the intensity of charge of an electric field when HF and dry air are placed between two charged parallel plates.

5. Why are metals malleable and ductile?

6. Water shows capillary action in a narrow glass tube. Give appropriate reasons.

7. Between NaCl and CsCl, which has greater strength of ionic bond? Justify.

8. On decreasing the temperature, the conductivity of metals gradually increases. However below a particular temperature, the increase is found to be drastic. How do you account for this?

9. Which one of the two substances should have a higher boiling point–Br_2 or ICl? Give reasons in support of your answer.

10. The electrical conductivity of silicon increases by replacing a fraction of silicon atoms by arsenic atoms. Give appropriate reasons to support the statement.

11. Compound 'x' conducts electricity in the aqueous solution or molten state. Compound 'y' conducts electricity in the aqueous solution only. Compound 'z' does not conduct electricity in the molten state or in aqueous solution. Predict the nature of bonds in x, y and z.

12. Diamond, silicon carbide and silica can be used as abrasives. How do you account for the above said property?

13. "Though nitrogen and chlorine have almost equal electronegativity values, nitrogen forms hydrogen bonding, chlorine does not". Justify.

14. The leaves of aquatic plants do not decay though these are completely submerged. Explain.

15. What type of bond formation takes place in liquor ammonia? Explain.

Directions for questions 16 to 25: Application Based Questions

16. HF in the vapour state is associated covalent molecules while aqueous HF is ionic. Explain.
17. "Covalent bond is directional whereas ionic bond is not". Justify.
18. Compare NaCl and CsCl with respect to ease of formation and also the strength of the ionic bond.
19. Nitrogen and oxygen are the major components in air. However, they do not combine at all to form nitric oxide under normal conditions. Give reasons.
20. Intermolecular forces do not exist in ionic compounds. Justify the statement.
21. Compare and contrast the metallic character and hardness of sodium and iron. Justify.
22. Although the molecular mass of H_2S is more than that of H_2O, H_2O is a liquid whereas H_2S is a gas. Justify the statement.
23. Explain why when equal volumes of both ethyl alcohol and water are mixed, the volume of the resulting solution is less than the sum of the volumes of water and alcohol.
24. The leaves of aquatic plants do not decay though these are completely submerged in water. Explain
25. Identify redox reaction among the following

    (1) Acid – base neutralisation (2) Precipitation reaction

    (3) Metal displacement reaction (4) All the above

Concept Application Level—3

1. Why are ionic compounds hard and brittle?
2. Graphite is a good conductor of electricity whereas diamond cannot conduct electricity. Explain.
3. Density of water is maximum at 4°C. Explain.
4. Graphite is used as a solid lubricant. Why?
5. $SnCl_4$ is liquid while $SnCl_2$ is solid. Explain.

Directions for questions 6 to 10: Application Based Questions

6. Pure iron is relatively soft, ductile and malleable. But its hardness increases by diffusing carbon atoms in it. Explain with appropriate reasons.
7. Both zinc and mercury belonging to the same group in which differentiating electron enters into d-subshell of penultimate shell. But, zinc is a solid while mercury is a liquid. How do you justify this?
8. Three gases methane, ammonia and water vapour which have comparable molecular masses are liquefied at the same temperature. However, the pressure required to be applied is different for the three gases. Justify.
9. Among the various inorganic acids like HNO_3, $HClO_4$ and H_2SO_4, sulphuric acid is highly syrupy in nature. Explain.
10. Molten $AlCl_3$ is a poor conductor of electricity while hydrated $AlCl_3$ is a very good conductor. How do you account for this? Also explain the nature of bonding in the product.

key points for selected questions

Very short-answer type questions

1. Nature of forces of attraction

2. Any polar solvent

3. Ionic bond

5. Absence of charged species

6. Electro negativity, I.P., E.A. difference exist between constituent elements.

7. non-polar

10. Stability of lower energy state

11. Ionic

12. Charge separation

13. Attractive and repulsive forces

14. polar covalent bond

15. Difference in electronegativity

17. Weak forces existing between covalent molecules

18. mobile ions

20. NH_4^+ H_3O^+

21. (1) Boiling point (2) physical state

22. free electrons

23. H_2O, HF

24. co-ordinate covalent

25. Representation of
- (i) valence electrons
- (ii) sharing and transfer of electrons

26. sharing

27. Redox

28.
- (i) Loss of electrons
- (ii) Gain of electrons
- (iii) Mutual transfer of electrons
- (iv) The substance that gains electrons
- (v) The substance that loses electrons

Short-answer type questions

31. Only one shell (K shell).

32. Ionization potential and electron affinity

33. The presence of 8 electrons in valence shell.
- (i) Ionization potential
- (ii) Electron affinity and
- (iii) Electronegativity

34.
- (a) complete transfer of electrons–ionic bond
- (b) sharing of electrons–covalent bond.

35. Ionic compounds–strong electrostatic forces of attraction–solid.

Covalent compounds–weak electrostatic forces of attraction–liquid or gas.

36.

[redacted]		
(a) I.P.	Large difference	High for both atoms
(b) E.A.	Large difference	Small difference

37. Strong electrostatic forces of attraction.

38. Ionic compounds–strong electrostatic forces of attraction.

39. Do not ionize.

40. They exist in the form of ions.

41. Charge separation.

42.
- (i) partial charge separation takes place on constituent atoms.
- (ii) electrostatic force of attraction exist between $H^{+\delta}$ and more electronegative element.

43.
- (i) Nitrogen donates its pair of electrons to H^+
- (ii) Oxygen donates its pair of electrons to H^+

44. Weak electrostatic forces of attraction.

45.
- (i) loss of oxygen/gain of hydrogen–reduction
- (ii) gain of oxygen/loss of hydrogen–oxidation.

key points for selected questions

Essay type questions

46. (i) Electropositive nature of metals
(ii) Free electrons
(iii) Electrostatic force of attraction

47. (i) Atomic number
(ii) Maximum number of electrons in a shell $= 2n^2$

48. (i) Nature of bond
(ii) strength of bonds.

49. (i) Hydrogen bonded to electronegative atom
(ii) Charge separation
(iii) Electrostatic force of attraction

50. (i) Transfer of pair of electrons
(ii) Sharing
(iii) Donor, acceptor

KEY

Concept Application Level—1

True or false

1. True
2. False
3. False
4. False
5. False
6. True
7. True

Fill in the blanks

8. ionic
9. three
10. bond length
11. polar covalent
12. Insoluble
13. polar covalent bond
14. covalent

Match the following

15.

A	:	c
B	:	g
C	:	j
D	:	f
E	:	i
F	:	b
G	:	e
H	:	d
I	:	h
J	:	a

Multiple choice questions

16. Choice (1)
17. Choice (1)
18. Choice (2)
19. Choice (4)
20. Choice (1)
21. Choice (3)
22. Choice (3)
23. Choice (2)
24. Choice (4)
25. Choice (2)
26. Choice (1)
27. Choice (4)
28. Choice (3)
29. Choice (2)
30. Choice (2)

31. Glass is made up of silicates which are ionic in nature. CCl_4 is covalent in nature, as a result, CCl_4 shows convex meniscus in a glass tube.

Choice (4)

32. Element B gains two electrons to attain octet configuration forming B^{-2}. Whereas element A loses two electrons to attain octet configuration and forms A^{+2}. Between A^{+2} and B^{-2}, there exists strong electrostatic forces of attraction (ionic bond) and forming AB.

Choice (2)

33. Generally, metals conduct electricity in solid state. Ionic compounds conduct electricity in the molten state as well as in the solution state. Polar covalent compounds conduct electricity in the solution state.
Non-polar covalent compounds conduct electricity neither in the molten state nor in the solution state and hence P = Al, Q = HCl, R = Na_2O, S = Glucose.

Choice (2)

34. The strength of hydrogen bond depends on size and electronegativity of an atom. The more the electronegativity and lesser the atomic size, the more is the strength of hydrogen bond. Hence HF can form the strongest hydrogen bond.

Choice (1)

35. In $AlCl_3$ central atom Al possess six electrons in its valence shell. Hence $AlCl_3$ is a molecule with contracted octet.

Choice (3)

36. Number of electron pairs involved in sharing will gives the covalency of an atom of an element. Hence covalency of 'N' in NH_3, NH_4^+ NH_4Cl are 3, 4, 4 respectively.

Choice (2)

37. The strength of metallic bond depends on number of valence electrons and size of metal kernel. The more the number of valence electrons and less the size of metal kernel, the more is the strength of metallic bond. Hence Al can form the strongest metallic bond.

Choice (4)

38. (i) Identification of atomic numbers of the constituents
(ii) Electronic configuration of the constituents
(iii) Determination of the nature of bond between the constituents
(iv) Representation of the valence electrons as crosses or dots

Choice (2)

39. (i) Factors affecting strength of ionic bond.
(ii) Effect of size and electronegativity difference on the strength.
(iii) Comparison of sizes of respective ions of Na and Mg.
(iv) Comparison of electronegativity difference of the constituents in both the compounds.

Choice (2)

40. (i) The positive metal ions are surrounded by a pool of electrons.
(ii) The electrostatic forces of attraction between metal ions and the mobile electrons is called metallic bond.
(iii) When light falls on the crystal, electrons get excited
(iv) Emission of radiation or light energy by excited electrons makes a metal shiny in appearance

Choice (2)

41. Li, as it attains stable electronic configuration of duplet in its compounds.

Choice (2)

42. Aluminium has to lose three electrons to form Al^{3+} ion.

Choice (3)

43. Due to electronegativity difference between the constituents in polar compounds separation of charges take place.

Choice (3)

44. In case of non-polar molecules separation of charge does not take place. Chlorine is non-polar.

Choice (1)

45. Though ionic compounds contain ions in solid state in their crystal lattices, they do not conduct electricity because the ions are at fixed positions and they are not mobile. Therefore, they do not act as charge carriers.

Choice (2)

Concept Application Level—2

Key points

1. Formation of ammonia molecule, ammonium ion and ammonium chloride.

2. (i) Intensity of force before bond formation.
(ii) Intensity of force at the minimum potential energy.
(iii) Intensity of force at where atoms move closer than bond length.

3. (i) Water has oxygen which is lightly electronegative.
(ii) Nature of solvent
(iii) Mechanism of dissolution

4. (i) Effect of field on polar molecules.
(ii) Orientation of polar molecules.
(iii) Effect of their orientation on electric field.

5. (i) Presence of free electrons.
(ii) Movement of free electrons
(iii) Directionality of metallic bond
(iv) Effect of directionality on malleability and ductility

6. (i) Type of molecules in glass and water.
(ii) Comparison of nature of bonds in water and glass
(iii) Forces acting between these molecules

7. (i) Factors affecting ionic bond strength.
(ii) Comparision of radius of cation
(iii) Effect of radius on electrostatic force of attraction

8. (i) Particles responsible for electrical conductivity in metals.
(ii) Factors that affect conductivity.
(iii) Relation between temperature and vibration of metal atoms.
(iv) Relation between vibration of metal atoms and conductivity.

9. (i) Inter molecular forces.
(ii) Comparing electronegativity of Br and Cl.
(iii) Nature of bonds in Br_2 and ICl based on electronegativity.
(iv) Effect of nature of bonds on intermolecular forces of attraction.

10. (i) Number of valence electrons in Arsenic.
(ii) Comparison of number of valence electrons in silicon and arsenic
(iii) Bonding in presence and absence of arsenic
(iv) Dependence of electrical conductivity on free electrons

11. (i) Co-ordinate compounds being covalent in nature, do not ionize.
(ii) Prediction of compound z
(iii) Comparing properties of x and y
(iv) Prediction of compounds x and y
(v) Predicting nature of bonds from type of compounds

12. (i) Nature of bonding in diamond, SiC and SiO_2.
(ii) Strength of the bond.
(iii) Requisite for abrasive nature.

13. (i) Sharing of electrons and transfer of electrons.
(ii) Comparison of atomic size of nitrogen and chlorine.
(iii) Effect of size on strength of hydrogen bond.

14. (i) Components and nature of outer layer of aquatic plants.
(ii) Bonding in water.
(iii) Forces between water and aquatic plants.

15. Formation of ammonium hydroxide.

16. Due to the greater difference in the electronegativity between 'F' and 'H' in HF the strength of H–bonding is strong even in the vapour state it exists in the associated form. (of 2 to 6 HF molecules).

But, HF in water exists in the form of ions because of high dielectric constant of H_2O, i.e. due to the high charge separation between O and H in H_2O, it breaks the polar covalent forces between H and F in HF and thus aqueous HF is an ionic compound.

17. Strong electrostatic forces of attraction exist between ions in all directions in the ionic bond. Hence it is non-directional in nature whereas electron pair is localized between the atoms in covalent bond which gives proper shape to the molecule and is directional in nature.

18. Ionic compounds are formed easily between larger cation and smaller anion. This is because an atom whose atomic radius is large can form a cation easily and an atom which has a small atomic radius can form an anion easily. Cs^+ ion can be formed more easily than Na^+ ion. Formation of CsCl is easier than the formation of NaCl. Among NaCl and CsCl, as the anion is the same i.e., Cl^-, the cations are compared. Cs has a larger atomic radius than sodium. Thus the strength of ionic bond is more in NaCl than CsCl.

19. N_2 is formed by sharing of three electron pairs, that is a triple covalent bond is present between two nitrogen atoms in N_2. The bond strength is very high since under normal conditions N_2 cannot react with any of the components present in air. Thus N_2 doesn't react with O_2 to form NO. High temperature favours the formation of NO.

20. Ionic compounds exist in the form of oppositely charged ions even in solid state. Therefore in ionic compounds, intermolecular forces do not exist, only interionic forces exist. These forces are so strong that the ions come together to form the crystal lattice.

21. Sodium belongs to IA group and has lower IP value than iron. Therefore, it can lose electrons more easily than iron. Hence it is more electropositive and more metallic than iron. Strength of the metallic bond increases with an increase in the number of valence electrons and effective nuclear charge. Thus iron is harder than sodium which contains only one valence electron and has less effective nuclear charges.

22. H_2O is a liquid while H_2S is not because oxygen being more electronegative than sulphur, can involve in the formation of hydrogen bonding in water. Thus water is a liquid while in H_2S there is no hydrogen bonding due to less electronegativity of sulphur and the molecules are far apart and hence H_2S is a gas.

23. The extent of intermolecular H–bonding between water and ethyl alcohol is greater compared to the extent of intermolecular H–bonding between ethyl alcohol molecules, i.e. aqueous or diluted ethyl alcohol has H–bonding to a greater extent compared to pure ethyl alcohol. Since each water molecule can form 4 H–bonds, many ethyl alcohol molecules get surrounded by it and thus more number of ethyl alcohol molecules are associated with water molecules thus decreasing the intermolecular spaces. Hence when equal volumes of both are mixed, the net volume is less than the sum of the two volumes taken. Thus, the ethyl alcohol molecules are brought closer in water due to greater extent of H–bonding.

24. The texture of aquatic plants (leaves, hydrocarbons stem, etc) is soft and waxy as they are made up of organic compounds, which are non-polar in nature. Since water molecules are highly polar, they hardly come in contact with the waxy surface of the leaves.

25. Only metal displacement reactions are redox reductions.

Choice (3)

Concept Application Level—3

1. (i) Forces of attraction in ionic compounds.
   (ii) Type of constituents.
   (iii) Arrangement of constituents.
   (iv) Effect of this arrangement on directionality.

2. (i) Number of bonds formed by each carbon in graphite and diamond.
   (ii) Number of valence electrons in carbon.
   (iii) Comparison of the number of carbon atoms each carbon is bonded to in diamond and graphite.
   (iv) Comparison of structure of diamond and graphite.

3. (i) Bonding in ice.
   (ii) Change in bonding on melting.
   (iii) Change in the position of molecules on increasing temperature up to 4°C.

4. (i) Structure of graphite.
   (ii) Bonding in graphite.
   (iii) Bonding which helps in lubricative action.
   (iv) Melting point of graphite.

5. (i) Comparison of charges on positive radial of $SnCl_2$ and $SnCl_4$.
   (ii) Comparison of nuclear charge.
   (iii) Effect of charge and nuclear charge on size.
   (iv) Relation between size and intermolecular force of attraction.

6. Pure iron has metallic bond which is omnidirectional. When pressure is applied layers of metal kernels slide over the other layers and hence the metal can be made into thin sheets and wires. Therefore pure iron is malleable and ductile. When some amount of carbon is added a covalent compound Fe_3C (cementite) between iron and carbon is formed. Since covalent bonds are directional, layers of metal kernels can not slide easily. Hence the hardness of metal increases by the addition of carbon due to the formation of these bonds.

7. Zinc belongs to 4th period and '3d' series of transition metals. The electronic configuration of zinc is 2, 8, 18, 2. It can contribute 2 electrons for metallic bond. Thus, strong metallic bond in zinc imparts hardness to the metal which makes its physical state to be solid. Mercury belongs to 6th and '5d' series of transition metals. The electronic configuration of Hg is 2, 8, 18, 32, 18, 2. Due to the poor screening effect of 14 'f' electrons, the effective nuclear force of attraction on the outermost shell increases. Therefore, the electrons contributed for metallic bond are less which results in the formation of a thinner electron pool and hence weaker metallic bond. As a result of this, mercury is a liquid.

8. In H_2O and NH_3, there is hydrogen bonding and hence the intermolecular forces of attraction are stronger. Between NH_3 and H_2O, H_2O has stronger intermolecular forces of attraction than NH_3 due to stronger hydrogen bonding with oxygen. CH_4, being a non-polar molecule, has only van der waal's forces of attraction, which are weak. Therefore the order of critical temperatures is $CH_4 < NH_3 < H_2O$. The pressure required to be applied is in the order $H_2O < NH_3 < CH_4$. The greater the intermolecular force of attraction, the lower is the pressure required to liquify it.

79.
```
H – O – S – O – H ..... O – S – O – H .....
        ||                  ||
        O                   O
```

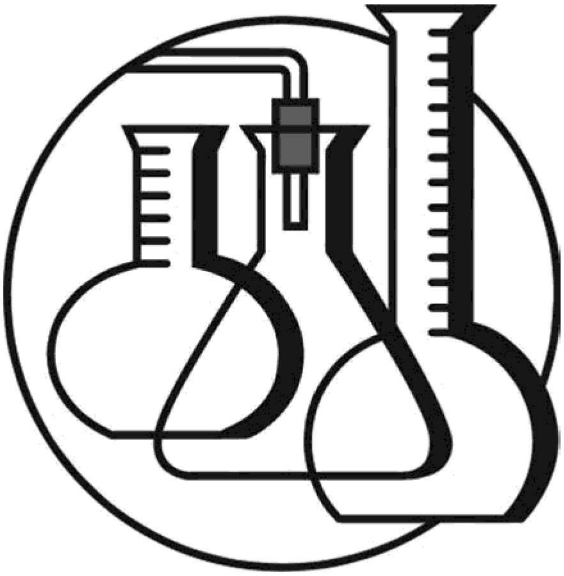
Since the electronegativity difference between S and O is more compared with N and O in HNO_3, Cl and O in $HClO_4$, the intensity of negative charge is more on oxygen and thus the hydrogen bonded to such oxygen can form hydrogen bonds more effectively. Thus H_2SO_4 molecules are associated with stronger H–bonding and form a syrupy liquid, i.e. a liquid with high viscosity.

10. $AlCl_3$ is covalent in nature because of small size and high nuclear charge of Al^{+3}.

But when $AlCl_3$ is put in water, Al^{+3} ions get surrounded by water molecules by means of coordinate covalent bonds in which a lot of energy is liberated.

$AlCl_3 + 6H_2O \rightarrow [Al(H_2O)_6]^{+3}$

Thus $AlCl_3$ gets dissolved in aqueous medium in which mobile hydrated aluminium and chloride ions are present and hence it conducts electricity due to the mobility of these ions in an electrical field. However, molten $AlCl_3$ exists as a molecule and thus is a bad conductor of electricity.



5

Mole Concept, Stoichiometry and Behaviour of Gases

INTRODUCTION

Chemistry is the branch of science which deals with the study of matter. Though the study of matter involves various aspects, the most important aspect is the study of chemical reactions. A chemical reaction involves transformation of matter associated with change in molecular composition. For the sake of convenience and universal application, the chemical reactions are represented in the form of chemical equations. In these chemical equations, the various substances involved in the reactions are written in the form of symbols and formulae which are the short hand notations of the respective elements and compounds. The study of naming various compounds and derivation of formulae for the compounds is an inevitable part in the study of chemical reactions, which is considered the language of chemistry.

Symbols and Formulae

There are 111 elements discovered till now and all of them have been given symbols on the basis of their English names or Latin names. A symbol represents an atom of an element.

Examples of symbols

[redacted]

Chlorine	Cl	Aurum	(Gold)	Au
Carbon	C	Argentum	(Silver)	Ag
Beryllium	Be	Stannum	(Tin)	Sn
Magnesium	Mg	Plumbum	(Lead)	Pb

The formulae of elements and compounds are written by making use of the symbols of the respective elements. It represents the actual number of atom(s) of each element present in one molecule of the substance (element or compound).

Examples of Formulae

[redacted]	
Nitrogen	N_2
Ozone	O_3
Barium sulphate	$BaSO_4$

Radicals or ions

An atom or a group of atoms gets converted to the corresponding ions or radicals by losing or gaining electrons. These are called positive and negative radicals respectively. Based on the amount/number of charge on the radicals, they are categorized as monovalent, bivalent, trivalent and tetravalent ions or radicals.

Some important positive radicals

[redacted]		
Monovalent	H^+	Hydrogen
Monovalent	Na^+	Sodium
Monovalent	K^+	Potassium
Monovalent	Cu^+	Cuprous
Monovalent	Hg^+	Mercurous
Monovalent	NH_4^+	Ammonium
Monovalent	Ag^+	Argentous
Bivalent	Zn^{+2}	Zinc
Bivalent	Mg^{+2}	Magnesium
Bivalent	Cu^{+2}	Cupric
Bivalent	Fe^{+2}	Ferrous
Bivalent	Ca^{+2}	Calcium
Bivalent	Ba^{+2}	Barium
Bivalent	Hg^{+2}	Mercuric
Bivalent	Sn^{+2}	Stannous
Bivalent	Pb^{+2}	Plumbous
Bivalent	Ag^{+2}	Argentic
Trivalent	Al^{+3}	Aluminium
Trivalent	Fe^{+3}	Ferric
Tetravalent	Sn^{+4}	Stannic
Tetravalent	Pb^{+4}	Plumbic

Some important negative radicals

Monovalent	OH	Hydroxyl
Monovalent	F^-	Fluoride
Monovalent	Cl	Chloride
Monovalent	Br	Bromide
Monovalent	I^-	Iodide
Monovalent	NO_2	Nitrite
Monovalent	NO_3	Nitrate
Monovalent	ClO	Hypochlorite
Monovalent	ClO_2^-	Chlorite
Monovalent	ClO_3	Chlorate
Monovalent	ClO_4	Perchlorate
Monovalent	CH_3COO	Acetate
Monovalent	HCOO	Formate
Monovalent	HS	Bisulphide
Monovalent	HSO_3	Bisulphite
Monovalent	HSO_4	Bisulphate or Hydrogen sulphate
Monovalent	H	Hydride
Monovalent	HCO_3	Bicarbonate or Hydrogen carbonate
Bivalent	S^2	Sulphide
Bivalent	SO_4^2	Sulphate
Bivalent	CO_3^2	Carbonate
Bivalent	O^2	Oxide
Bivalent	O_2^2	Peroxide
Bivalent	SO_3^2	Sulphite
Trivalent	PO_4^3	Phosphate

Derivation of formulae of compounds

Two basic principles are followed in writing the formula of the compounds. Firstly, the more electropositive element (positive radical) is written first followed by the electronegative element or negative radical. Secondly, the total charge on the positive radicals should be balanced by the total charge on the negative radicals since a molecule is electrically neutral.

K^+Cl^- 1 1 1 1	KCl
Fe^{+2} O^{-2} 2 2	FeO
Fe^{+3} O^{-2} 3 2 2 3	Fe_2O_3
Si^{+4} O^{-2} 4 2 2 1 1 2	SiO_2
Ca^{+2} NO_3^- 2 1 1 2	$Ca(NO_3)_2$

Naming of compounds

Binary compounds

The compounds that are formed by the combination of two elements are called binary compounds.

In naming binary compounds, the **electropositive atom** (generally metal) is specified first by giving its **ordinary English name**. The name of the second element which is generally a **non-metal** is obtained by adding the **suffix 'ide'** to its name.

☛ *Examples*

$MgCl_2$	Magnesium chloride
$CaCl_2$	Calcium chloride
BaO	Barium oxide
H_2S	Hydrogen sulphide

In case of metals showing **variable valency**, it is necessary to specify which of the positive ions are present.

☛ *Examples*

FeO	Ferrous oxide or Iron(II)oxide
Fe_2O_3	Ferric oxide or Iron(III)oxide
$CuCl$	Cuprous chloride or Copper(I)chloride
$CuCl_2$	Cupric chloride or Copper(II)chloride

For binary covalent compounds, generally formed by two **non-metallic elements,** it is required to specify the number of atoms of **more electronegative element** with the help of a meaningful **prefix**.

The less electronegative element is specified first, followed by the more electronegative element. The **prefix** is generally added to the more electronegative element to specify its number of atoms.

SO_2	Sulphur dioxide
N_2O_5	Nitrogen pentoxide
SF_6	Sulphur hexafluoride
PCl_3	Phosphorus trichloride
CO	Carbon monoxide

One	Mono
Two	Di
Three	Tri
Four	Tetra
Five	Penta
Six	Hexa
Seven	Hepta
Eight	Octa
Nine	Nona
Ten	Deca

Naming of acids

Acids usually contain hydrogen ion (H^+) as the positive radical. Hence the name of the acid is determined by the constituent(s) of its negative radical.

Binary acid	Negative radical consists of a single non metal Example: HCl, HBr	'ic' (prefix hydro) Hydrochloric acid Hydrobromic acid

(Continued on following page)

Oxy acid	Negative radical consists of a non metal and oxygen. The name of the oxy acid is determined by the percentage of the oxygen associated with a specific non metal.	
	Acids with comparatively less percentage of oxygen.	
	Example: H_2SO_3, HNO_2, H_3PO_3	'ous' Sulphurous acid, Nitrous acid Phosphorous acid
	Acids with comparatively more percentage of oxygen.	
	Example: H_2SO_4, HNO_3, H_3PO_4	'ic' Sulphuric acid, Nitric acid Phosphoric acid

If the acid contains lesser number of oxygen atoms than the corresponding 'ous' acid, 'hypo' prefix is given to the negative radical whereas 'per' prefix is given to the negative radical when the acid contains greater number of oxygen atoms than the corresponding 'ic' acid.

☛ *Examples*

Hypochlorous acid	$HClO$
Chlorous acid	$HClO_2$
Chloric acid	$HClO_3$
Perchloric acid	$HClO_4$

Naming of bases

Bases generally contain hydroxyl radical (OH^-) as the negative radical and a metal ion as its positive radical. While writing the name of the base, the name of the metal is written first followed by hydroxide.

☛ *Examples*

Calcium hydroxide	$Ca(OH)_2$
Magnesium hydroxide	$Mg(OH)_2$
Sodium hydroxide	$NaOH$
Aluminium hydroxide	$Al(OH)_3$

Naming of salts

The positive radical present in the salt comes from the corresponding base and the negative radical comes from the corresponding acid.

The name of the salts starts with the name of the metal present as positive radical which is followed by the name of the negative radical. The name of the negative radical is determined by the name of the acid from which the salt is produced.

1. 'ous' acid	'ite'	
Example:	$CaSO_3$	Calcium sulphite
Sulphurous acid (H_2SO_3)	$Zn(NO_2)$	Zinc nitrite
Nitrous acid (HNO_2)	$Mg(PO_3)_2$	Magnesium phosphite
Phosphorous acid (H_3PO_3)		
2. 'ic' acid	'ate'	
Example:	$ZnSO_4$	Zinc sulphate
Sulphuric acid (H_2SO_4)	$NaNO_3$	Sodium nitrate
Nitric acid (HNO_3)	$AlPO_4$	Aluminium phosphate
Phosphoric acid (H_3PO_4)		

If NH_4^+ is present as positive radical in the base or in the salt, ammonium is written in place of the name of the metal.

☛ *Example*

Ammonium hydroxide (base)	NH_4OH
Ammonium phosphate (salt)	$(NH_4)_3PO_4$

A chemical formula gives scope for the study of matter with respect to the molecular composition. The other aspect of the study of matter involves the study with respect to the three distinct physical states. The three physical states, namely, solids, liquids and gases are basically distinguished on the basis of their molecular arrangement.

Solids are characterized by closely packed molecular arrangement which gives them definite shape. Therefore the intermolecular forces of attraction are very high in solids. In liquids, the molecules are relatively loosely packed and hence they exhibit less inter-molecular forces of attraction. Matter in gaseous state is characterized by a very loosely packed arrangement of molecules. Due to this molecular arrangement, there are negligible intermolecular forces of attraction in gaseous state. Consequently, in gaseous state, molecules behave independently and hence it is considered the simplest state of matter.

Characteristics of gases based on the kinetic theory of gases

The postulates of kinetic theory of gases are:

(i) Gases contain large number of tiny particles known as molecules.
(ii) The force of attraction between the molecules is very low.
(iii) The intermolecular space is large.
(iv) Molecules of gas are in a state of random motion resulting in continuous collisions among themselves and with the walls of the container, exerting pressure.
(v) The kinetic energy of molecules is proportional to the temperature.

From the kinetic theory of gases, we can conclude that the following are the characteristics of gases:

(i) Gases do not possess definite volume and shape.
(ii) Gases possess low density compared to liquids and solids.

(iii) Gases exert pressure equally in all directions.
(iv) Gases are capable of great expansion. They occupy the entire volume of any given container.
(v) Gases are highly compressible compared to liquids and solids.
(vi) Gases exhibit the property of diffusion.

The volume and physical behaviour of a given mass of a gas depend on its temperature and pressure over it.

Based on experiments certain relations among the variables of gas (volume, temperature and pressure) are established. These are stated as **gas laws**.

Boyle's Law

The volume of a given mass of a gas is inversely proportional to its pressure at constant temperature.

If a given mass of a gas occupies a volume V at pressure P and temperature T, then from Boyle's law:

$V \propto \frac{1}{P}$ (T is constant);

$V = \frac{K}{P}$ or

PV = K (K is proportionality constant)

If at constant temperature, a certain mass of a gas occupies a volume V_1 at pressure P_1, and a volume V_2 at pressure P_2, then from Boyle's law, $\mathbf{P_1V_1 = P_2V_2}$, at constant temperature.

Graphical representation of Boyle's law

(i) Volume (V) vs Pressure (P)

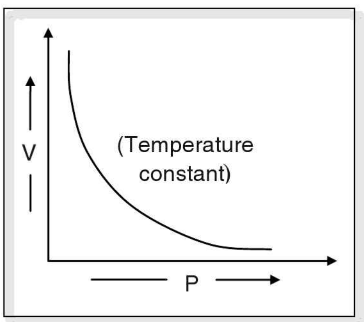


Figure 5.1

(ii) Volume (V) vs $\frac{1}{\text{Pressure (P)}}$

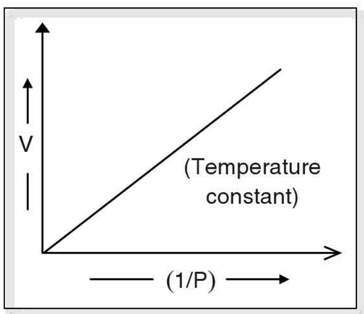


Figure 5.2

(iii) The product of Pressure and Volume (PV) vs Pressure (P)

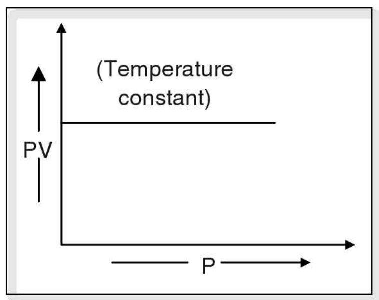


Figure 5.3

☛ *Numerical Problems*

1. What will be the volume of a given mass of a gas at a pressure of 38 cm of Hg, if it occupies 250 ml at a pressure of 114 cm of Hg keeping the temperature constant?

Solution

According to Boyle's law, at constant temperature,

$P_1V_1 = P_2V_2$

P_1 = Initial Pressure

P_2 = Final Pressure

V_1 = Initial Volume V_2 = Final Volume.

P_1 = 38 cm of Hg P_2 = 114 cm of Hg

V_1 = ? V_2 = 250 ml

$38\ V_1 = 114\ \ 250$

$$V_1 = \frac{114 \times 250}{38} = 750 \text{ ml}$$

Charles' Law

At constant pressure, the volume of a given mass of a gas increases or decreases by (1/273) of its volume at 0°C for every 1°C increase or decrease in temperature respectively,

$$\text{i.e.}\, V_t = V_0\left(1 + \frac{t\ °C}{273}\right)$$

Let the volume of a given mass of gas at 0°C be V_0. Its volume increases to V_t at t °C under constant pressure.

Hence from Charles' law,

$$V_t = V_0\left(\frac{273 + t\ °C}{273}\right)$$

$$V_t = V_0\left(\frac{T}{273}\right); \text{T is the absolute temperature}$$

$$V \propto T \text{ , as } \frac{V_0}{273} = \text{constant}$$

Hence Charles' law can also be stated as follows:

For a fixed mass of gas, the volume of a gas (V) is directly proportional to the absolute temperature (T), (Kelvin temperature) at constant pressure, i.e.,

$V \propto T$ (P is constant)

or $\frac{V}{T}$ = K (K is the proportionality constant).

If at constant pressure, a certain mass of a gas occupies a volume V_1 at temperature T_1 and a volume V_2 at temperature T_2, then according to Charles' law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \text{ (at constant pressure).}$$

Graphical representation of Charle's law

(i) Volume (V) vs absolute temperature (T)

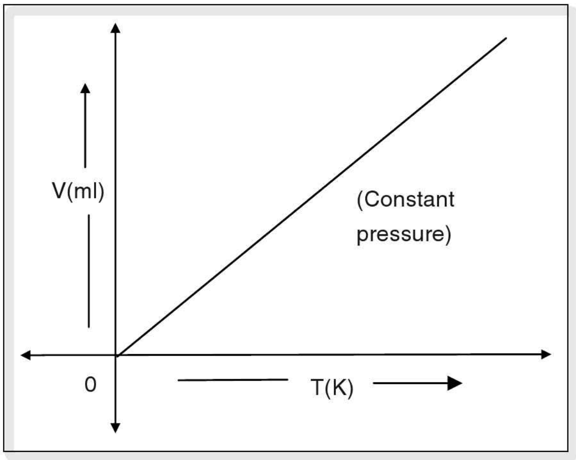


Figure 5.4

(ii) Volume (V) vs temperature(t) in celsius scale

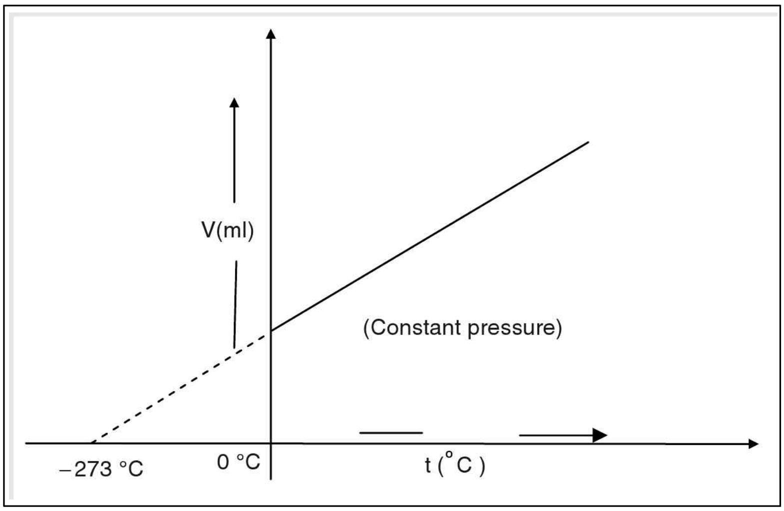


Figure 5.5

From Charle's law

$$V_t = V_o\left(\frac{273 + t\,°C}{273}\right)$$

As 't' in this equation approaches 273°C, the volume approaches zero. Below 273°C, the volume of a gas would become negative which is an impossible result.

Therefore 273°C is the lowest temperature that can be attained theoretically. However, practically before reaching this temperature itself all gases either get liquefied or solidified. Therefore 273°C is taken as zero point on a new temperature scale called absolute temperature scale.

Temperature in Kelvin scale can be obtained by adding 273 to the temperature measured in celsius scale.

T(Kelvin) = 273 + C (Celsius)

Numerical Problems

1. At what temperature will a given mass of a gas occupy a volume of 75 ℓ, if it occupies a volume of 100 ℓ at a temperature of 27°C, pressure remaining constant?

Solution

According to Charle's law at constant pressure

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Where

V_1 = Initial Volume V_2 = Final Volume

T_1 = Initial Temperature T_2 = Final Temperature

Given,

$V_1 = 75\ \ell$ $V_2 = 100\ \ell$

$T_1 = ?$ $T_2 = 300$ K

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{75}{T_1} = \frac{100}{300} \quad ; \quad T_1 = \frac{300 \times 75}{100} = 225 \text{ K}$$

The gas equation

For a given mass of a gas, the gas equation gives a relationship among the volume, pressure and temperature and can be derived by combining Boyle's law and Charles' law.

The volume of a given mass of a gas is V at temperature T and pressure P.

Applying Boyle's law: $V \propto \frac{1}{P}$ (T is constant)(i)

Applying Charles' law: $V \propto T$ (P is constant)(ii)

Combining (i) and (ii),

$V \propto \frac{1}{P}\ T$ [when both T and P change]

$$V = K\ \frac{T}{P}$$

$$\frac{PV}{T} = K \text{ (K is a proportionality constant)}$$

If the volume of a given mass of a gas changes from V_1 to V_2, pressure from P_1 to P_2 and temperature from T_1 to T_2, then from the gas equation, we have $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

☛ *Numerical Problems*

1. A given mass of a gas occupies 143 cm³ at 17°C and 700 mm of Hg pressure. What will be its volume at 27°C and 280 mm of Hg pressure?

Solution

From gas equation:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$P_1 = 700$ mm $P_2 = 280$ mm

$V_1 = 143$ cm³ $V_2 = ?$

$T_1 = 290$ K $T_2 = 300$ K

$$\frac{700 \times 143}{290} = \frac{280 \times V_2}{300}$$

$$V_2 = \frac{300 \times 700 \times 143}{280 \times 290} = \frac{2100 \times 143}{28 \times 29} = 369.8 \text{ cm}^3$$

Standard Temperature and Pressure (STP) or Normal Temperature and Pressure (NTP)

Temperature and pressure have great influence on the volumes of gases. It is necessary to choose a suitable value of each as standards to refer to the volume of gas.

The conditions of standard temperature and pressure are given below.

Standard temperature = 0°C = 273 K

Standard pressure = 760 mm of Hg (mercury)

= 76 cm of Hg = 1 atm

A gas which strictly obeys the gas equation under all the conditions of temperature and pressure is called an ideal gas. However, in nature all gases are real gases i.e., they do not perfectly obey the gas equation under all the conditions of temperature and pressure.

The behaviour of gases can be expressed by Boyle's law and Charles' law when the gases are subjected to change in pressure and temperature. Another law namely Gay-Lussac's law of combining volumes describes the relationship among the volumes of gaseous reactants and products.

Gay-Lussac's Law of combining volumes of gases

When gases react chemically, they do so in volumes which bear a simple whole number ratio to each other and to the volumes of the products, provided the products are also in the gaseous state and the temperature and pressure of the reactant and product gases are the same.

☛ *Example*

In the reaction of carbon monoxide with oxygen, two volumes of carbon monoxide react with one volume of oxygen to give two volumes of carbon dioxide.

$$\underset{2\text{vol}}{CO + CO} + \underset{1\text{vol}}{O_2} \longrightarrow \underset{2\text{vol}}{CO_2 + CO_2}$$

The volume ratio of carbon monoxide, oxygen and carbon dioxide is 2 : 1 : 2.

In 1811, Amedo Avogadro established a relationship between the volumes of gases and the number of molecules present in them provided the volumes are measured at similar conditions of temperature and pressure.

Avogadro's Law: Under similar conditions of temperature and pressure, equal volumes of all gases contain equal number of molecules.

Explanation: Under similar conditions of temperature and pressure, one litre of any gas, hydrogen, helium or hydrogen chloride contain the same number of molecules.

From Avogadro's law, the number of particles present in a given mass of a substance (solid, liquid or gas) and the volume of the substance, if it is in gaseous state, was calculated.

The mass of a substance is nothing but the total mass of its constituent particles i.e., atoms or molecules.

Measurement of the mass of atoms and molecules

Atomic Weight or relative atomic mass

The mass of $\frac{1}{12}$th of carbon –12 isotope has been taken as the standard. The mass of the atoms of other elements are calculated with respect to the number of times an atom of an element is heavier than $\frac{1}{12}$th part of a carbon –12 isotope. This is called the atomic weight or the relative atomic mass. Since the weight of $\frac{1}{12}$th part of a carbon –12 is called atomic mass unit, the relative atomic mass is expressed in amu.

Gram atomic weight or gram atom

The relative atomic mass expressed in grams is called **gram atomic weight or gram atom.**

☛ *Example* Atomic weight of oxygen = 16 amu.

Gram atomic weight of oxygen = 16 grams.

Molecular weight or relative molecular mass

Molecular weight is a number which indicates how many times, a molecule of a substance is heavier in comparison to $\frac{1}{12}$th the mass of one carbon 12 isotope.

Gram molecular weight

Molecular weight expressed in grams is called **gram molecular weight.**

The molecular weight of the substance can be easily determined from its formula by adding up the atomic weights of its constituent atoms.

☛ *Example*

Calculation of molecular weight of calcium carbonate ($CaCO_3$).

Atomic weight of calcium is 40 amu

Atomic weight of carbon is 12 amu

Atomic weight of oxygen is 16 amu

Molecular weight of calcium carbonate

$= 40 + 12 + (16 \quad 3) = 100$ amu

Gram Molecular Volume (GMV): One gram molecule of any dry gas at STP occupies the same volume i.e., 22.4 ℓ or 22.4 dm^3. This is called as Gram Molecular Volume or GMV.

☛ *Example*

1 gram molecule of dry chlorine gas occupies 22.4 litres at STP.

Since GMW of chlorine is 71 g, 71 g of chlorine gas occupies 22.4 litres at STP.

Avogadro's number and mole concept

Mole is the unit of amount of substance and it is a number just like dozen. By using mole as a unit of amount of substance, it is possible to calculate the number of atoms, molecules and ions of a given mass of a substance.

Mole

Mole is defined as the amount of substance that contains the same number of units (atom, molecules or ions) as there are atoms in exactly 12 grams of carbon –12 isotope. This number is called Avogadro number. One mole of any substance contains Avogadro number of chemical units.

Experimentally, it was found that this number is 6.023×10^{23}.

From the concept of mole, it can be concluded that:

(i) 1 gram atom of any substance is equivalent to one mole of atoms of that substance and contains avogadro number of atoms.

(ii) 1 gram molecule of any substance is equivalent to one mole of molecules of that substance and contains avogadro number of molecules.

☛ *Examples*

(i) One mole of hydrogen atoms
- 6.023×10^{23} hydrogen atoms
- 1 g of hydrogen

(ii) One mole of carbon atoms
- 6.023×10^{23} carbon atoms
- 12 g of carbon

(iii) One mole of NaCl
- 6.023×10^{23} Na^+ ions and 6.023×10^{23} Cl^- ions
- 58.5 g of NaCl

(iv) One mole of ammonia gas
- 6.023×10^{23} ammonia molecules
- 17 g of NH_3

(v) One mole of sodium
- 6.023×10^{23} sodium atoms
- 23 g of sodium

(vi) One mole of hydrogen
- 6.023×10^{23} hydrogen molecules
- 2 g of hydrogen

Relation between GMV, mole and Avogadro number: 1 gram molecule of any dry gas occupies 22.4 ℓ volume at STP. Hence 22.4 ℓ of a dry gas at STP is equivalent to 1 mole of that gas and contains 6.023×10^{23} molecules i.e., avogadro number of molecules.

☛ *Example* 1 gram molecule or 32 grams or 1 mole of dry oxygen gas occupies 22.4 ℓ at STP and contains 6.023×10^{23} molecules of oxygen.

☛ *Example* 1 gram molecule or 4 gram or 1 mole of dry helium gas occupies 22.4 ℓ at STP and contains 6.023×10^{23} atoms because helium is a monoatomic gas.

For all solid and liquid substances, mole can be converted into weight or number of atoms or molecules. For gaseous substances, mole can also be converted into volume in addition to weight and number of particles.

☛ *Example* One mole of bromine liquid
- 6.023×10^{23} bromine molecules
- 160 g of bromine

One mole of chlorine gas
- 6.023×10^{23} chlorine molecules
- 71 g of chlorine
- 22.4 ℓ chlorine at STP

Schematic representation of different relationships for mole

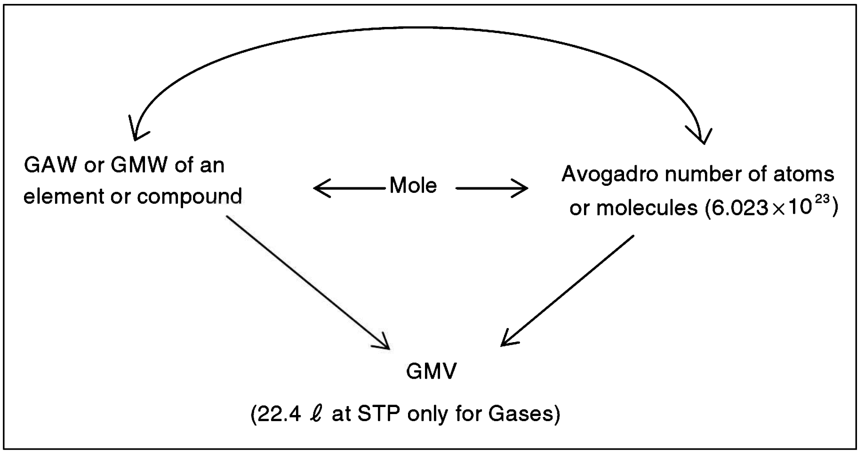


Figure 5.6

Numerical Problems

1. Calculate the number atoms present in 112 grams of N_2 and also find its volume at STP

Solution

Gram Molecular weight of N_2 = 28 grams.

112 grams of N_2 is equivalent to $\frac{112}{28}$ = 4 moles of nitrogen

112 grams N_2 contains 4 6.023×10^{23} molecules = 24 10^{23} (approx) molecules

The volume of the given mass N_2 = (4 22.4) ℓ = 89.6 ℓ at STP

2. Calculate the mass of water which contains the same number of molecules as that of 667.5 g of aluminium chloride.

Solution

Molecular weight of aluminium chloride ($AlCl_3$) = 133.5

667.5 grams of aluminium chloride is equivalent to $\frac{667.5}{133.5}$ = 5 moles of aluminium chloride.

Numbers of molecules present in 667.5 grams of aluminium chloride is equivalent to that present in 5 moles of water.

The mass of 5 moles of water = 18 × 5 = 90 grams.

Another characteristic property shown by gases is the process of diffusion.The spreading of the fragrance of perfumes in a specific area can be attributed to this property of gases.

The volume of the gas diffused in unit time at certain temperature and pressure through unit area is called 'rate of diffusion of the gas'.

Thomas Graham based on his observations, established a quantitative relationship between the rate of diffusion of gases and their densities.

Graham's law of diffusion states that the rates of diffusion of different gases are inversely proportional to the square roots of their densities, under similar conditions of temperature and pressure

Graham's law of diffusion

$$r \quad \frac{1}{\sqrt{d}} \quad \text{(temperature and pressure constant)}$$

$$\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{M_2}{M_1}}$$

Numerical Problems

1. 480 cc of methane gas diffused in 40 minutes. If 1440 cc of another gas diffused in 60 minutes under similar condition of temperature and pressure then find out the molecular mass of the gas.

Solution

Rate of methane and unknown gas can be given as

$$r_{methane} = \frac{V_{methane}}{time} \qquad r_x = \frac{V_x}{time}$$

$$r_{methane} = \frac{480}{40} = 12 \text{ cc/min}$$

$$r_x = \frac{1440}{60} = 24 \text{ cc/min}$$

$$\frac{r_{CH_4}}{r_x} = \sqrt{\frac{M_x}{M_{CH_4}}}$$

$$= \sqrt{\frac{M_x}{16}} = \frac{12}{24}$$

$$= M_x = \frac{12^2}{24^2} \times 16 = 4 \text{ g}$$

Gram Molecular Mass of gas = 4 g

2. Find out the relative rates of diffusion of oxygen and sulphur dioxide gases under similar conditions of temperature and pressure.

Solution

$$\frac{r_{O_2}}{r_{SO_2}} = \sqrt{\frac{M_{SO_2}}{M_{O_2}}} = \sqrt{\frac{64}{32}} = \sqrt{2} : 1$$

Stoichiometry

The chemical reactions are represented in the form of chemical equations. Since these chemical equations should comply with the law of conservation of mass, they should be balanced with respect to the number of atoms of each element involved in the reaction. Therefore, a quantitative relationship can be established between the various reactants and products. The area of study pertaining to the study of this quantitative relationship among reactants and products is called stoichiometry.

Example of balanced chemical equation: $NaOH + HCl \rightarrow NaCl + H_2O$

One atom of sodium	One atom of sodium
One atom of chlorine	One atom of chlorine
One atom of oxygen	One atom of oxygen
Two atoms of hydrogen	Two atoms of hydrogen

Balancing of chemical equations by trial and error method

(i) The number of times an element appears on the reactant side and the product side of the equation is counted.

(ii) The element which appears the least number of times is balanced first.

(iii) The other elements are balanced in the increasing order of their frequency.

(iv) In case any two or more elements have the same frequency, the metallic element is balanced first in preference to the non metallic element.

☛ *Example*

Skeleton equation

$KI + H_2SO_4 + MnO_2 \rightarrow KHSO_4 + MnSO_4 + H_2O + I_2$

Balancing sulphur

$2KI + 3H_2SO_4 + MnO_2 \rightarrow 2KHSO_4 + MnSO_4 + H_2O + I_2$

Balancing oxygen and hydrogen

$2KI + 3H_2SO_4 + MnO_2 \rightarrow 2KHSO_4 + MnSO_4 + 2H_2O + I_2$

A balanced chemical equation provides

(i) weight-weight relationship of the reactants and products.

(ii) weight-volume relationship when some of the reactants and products are in gaseous state.

(iii) volume-volume relationship when all the reactants and products are in gaseous state.

Chemical calculations based on weight–weight relationship

☛ *Example*

What is the amount of NH_3 formed when 14 g of N_2 combines with 6 g of H_2?

Solution

N_2	+	$3H_2$	$\rightarrow$	$2NH_3$
1 mol		3 mol		2 mol
28 g		3 2 g		2 17 g

From the balanced equation, 1 mol of N_2 reacts with 3 mol of H_2 or 28 g of N_2 reacts with 6 g of hydrogen. The amount of nitrogen is less than that required for complete reaction with H_2. Hence, N_2 is called limiting reactant or limiting reagent. H_2 is excess reactant.

28 g of N_2 forms 34 g of NH_3

14 g of N_2 forms $\frac{14 \times 34}{28}$ g of NH_3

Amount of ammonia formed = 17 g

Chemical calculations based on weight–volume relationship

☛ *Example*

When calcium carbonate is strongly heated, 28 grams of calcium oxide is obtained. Calculate the volume of CO_2 liberated at STP.

$$\xrightarrow{\Delta} \quad CaCO_3 \ CaO + CO_2$$

Solution

The above chemical equation shows that 1 mole of $CaCO_3$ decomposes to form 1 mole of CaO and 1 mole of CO_2.

Hence, if 56 g of CaO is obtained by heating $CaCO_3$, the volume of CO_2 liberated is 22.4 ℓ or dm^3 at STP.

Therefore, when 28 of CaO is obtained, the volume of CO_2 is $\left(22.4 \times \frac{28}{56}\right) \ell = 11.2\ \ell$ or dm^3.

Calculations based on volume-volume relationship

☛ *Example*

Calculate the volume of CO_2 at STP, when 22.4 ℓ of CO under STP completely burns in presence of excess oxygen.

$2CO + O_2 \ 2CO_2$

Solution

The above chemical equation shows that 2 gram-molecular volume of CO reacts with 1 gram-molecular volume of O_2 and 2 gram-molecular volume of CO_2 is produced.

Hence, (22.4 2) = 44.8 ℓ of CO at STP burns in oxygen and produces (22.4 2) = 44.8 ℓ of CO_2 at STP

Therefore, 22.4 ℓ of CO at STP on complete combustion gives 22.4 ℓ of CO_2.

Calculation of empirical and molecular formulae of compounds

Another important aspect of stoichiometry is the elemental analysis of a substance. The proportion by mass of each element present in a compound is called its **percentage composition**. The elemental analysis helps to determine the mass of each element present in 100 g, of known compound and it also establishes the chemical formula of unknown compound.

Percentage of an element by mass present in a compound

$$= \frac{\text{mass of element in one mole of the compound}}{\text{gram molecular mass of the compound}} \times 100$$

The chemical formula of the compound that can be calculated from the elemental analysis data (percentage by mass of each element in the compound) is called the empirical formula.

Empirical formula represents the simplest whole number ratio of the atoms of different constituent elements present in one molecule of the compound. The molecular formula of a compound can be calculated if both the empirical formula and the molecular mass are known.

Molecular formula represents the actual number of atoms of different constituent elements present in one molecule of the compound.

The molecular and empirical formula of any chemical compound are related as

n Empirical formula = Molecular formula, where 'n' is positive integer

$$n = \frac{\text{Molecular mass of compound}}{\text{Empirical formula mass}}$$

Numerical Problems

1. Calculate the percentage composition of calcium bicarbonate.

   GMM of calcium bicarbonate $[Ca(HCO_3)_2] = 162$

   Amount calcium in 162 g of calcium bicarbonate = 40

   Amount of calcium in 100 g of calcium bicarbonate = $\frac{40 \times 100}{162} = 24.7\%$

   Amount of hydrogen in 162 g of calcium bicarbonate = 2 g

   Amount of hydrogen in 100 g of calcium bicarbonate = $\frac{2 \times 100}{162} = 1.23\%$

   Amount of carbon in 162 g of calcium bicarbonate = 24 g

   Amount of carbon in 100 g of calcium bicarbonate = $\frac{24 \times 100}{162} = 14.8\%$

   Amount of oxygen in 162 g of calcium bicarbonate = 96 g

   Amount of oxygen in 100 g of calcium bicarbonate = $\frac{96 \times 100}{162} = 59.2\%$

Percentage composition of calcium bicarbonate

Percentage of calcium	24.7%
Percentage of hydrogen	1.23%
Percentage of carbon	14.8%
Percentage of oxygen	59.2%

2. An organic compound on analysis has been found to have following percentage composition.

   Percentage of carbon = 40%

   Percentage of hydrogen = 6.66%

   If the vapour density of the compound is 30, find out the molecular formula of the compound.

Solution

Carbon	40	12	$40/12 = 3.33$	$\frac{3.33}{3.33} = 1$
Hydrogen	6.66	1	$\frac{6.66}{1} = 6.66$	$\frac{6.66}{3.33} = 2$
Oxygen	53.34	16	$\frac{53.34}{16} = 3.33$	$\frac{3.33}{3.33} = 1$

Empirical formula CH_2O

V.D. = 30 Mol.wt = 2 V.D = 30 2 = 60

Empirical formula wt = 30

$$\text{Molecular formula} = CH_2O \ \frac{60}{30} = CH_2O \ 2$$

$$= C_2H_4O_2.$$

test your concepts

Very short-answer type questions

1. State Charle's law.
2. State Avogadro's law.
3. State Graham's law of diffusion.
4. 1 mm of Hg = _______ torr.
5. What is the difference between a Kelvin scale and a Celsius scale?
6. Give the values for the following
   (i) Amount of sodium in 1 mole of sodium.
   (ii) Amount of nitrogen in 1 mole of nitrogen.
7. Calculate the number of moles present in
   (i) 32 g of sulphur dioxide.
   (ii) 34 g of ammonia.
8. Calculate the volume occupied by 0.8 g of methane at STP.
9. Calculate the molecular weight of
   (i) Ammonium sulphate $[(NH_4)_2 SO_4]$
   (ii) Cryolite $[Na_3AlF_6]$
10. The temperature at which molecular motion ceases is _____°C or _____ K.
11. What is STP? Give the values of temperature and pressure at STP.
12. Pressure of gas molecules is due to _____.

Direction for questions 13 to 17: In each of the following questions, a positive and a negative radical is listed. Using the criss cross method, write the formula for the compound that is formed and name the compound.

13. Ag^{+1} Br^{-1}

14. K^{+1} OH^{-1}

15. NH_4^{+1} HPO_4^{-2}

16. Ca^{+2} HSO_4^{-1}

17. Sn^{+4} S^{-2}

18. The S.I. unit of temperature is _____.

Direction for questions 19 to 24: Balance the following chemical equations.

19. $NaNO_3 \rightarrow NaNO_2 + O_2$.

20. $BeO + NaOH \rightarrow Na_2BeO_2 + H_2O$.

21. $LiNO_3 \rightarrow Li_2O + NO_2 + O_2$

22. $KI + H_2SO_4 \rightarrow K_2SO_4 + SO_2 + I_2 + H_2O$

23. $NaBr + H_3PO_4 \rightarrow Na_3PO_4 + HBr$

24. $SO_2 + H_2S \rightarrow H_2O + S$

Direction for questions 25 to 29: For each of the following reactions, identify the products formed and balance the equations.

25. $Na_2O_2 + H_2O \rightarrow$

26. $S + HNO_3 \rightarrow$

27. $MnO_2 + HCl \rightarrow$

28. $HNO_3 + CaCO_3 \rightarrow$

29. $Fe_2(SO_4)_3 + NaOH \rightarrow$

30. Empirical formula of a compound is C_2H_4O. If its empirical formula weight is equal to its vapour density, calculate the molecular formula of the compound.

Short-answer type questions

31. Explain the statement "Gases have neither a fixed shape nor a fixed volume".

32. How do gases differ from solids and liquids?

33. Mention the factors on which the rate of diffusion of gases depend. Why are similar conditions of temperature and pressure necessary?

34. Calculate the percentage of
   (i) magnesium in magnesium carbonate.
   (ii) oxygen in calcium hydroxide.

35. State Gay-Lussac's law of combining volumes of gases? Give an example.

36. $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$.
60 dm^3 of ethane is mixed with 448 dm^3 of pure oxygen at STP If the mixture is ignited and reacts as illustrated in reaction, calculate the volume of CO_2 formed?

37. The relation between gram molecular mass and gram molecular volume is established by Avogadro's law. Explain.

38. Calculate the weight of following gases which occupy a volume 3.36 dm^3 at S.T.P.
    (i) Nitrogen
    (ii) Hydrog en
    (iii) Helium

39. Calculate the number of moles in
    (i) 29.4 g of H_2SO_4
    (ii) 31.9 g of hydrated copper sulphate
    (iii) 5 g of $CaCO_3$

40. Calculate the weight (in g) of 5×10^{24} molecules of nitrogen dioxide.

41. Two flasks A and B of equal volumes are kept under similar conditions of temperature and pressure. If flask A holds 16.2 g of gas X while flask B holds 1.35 g of hydrogen, calculate the relative molecular mass of gas X.

42. A gaseous hydrocarbon of vapour density 14 contains 85.2% of carbon. Calculate its molecular formula.

43. Calculate the amount of mercury obtained by the decomposition of 2.16 kg of mercuric oxide.

44. Give the values for the following
    (a) Gram molecule of Helium = __________ g of Helium.
    (b) Gram atom of Chlorine = __________ g of Chlorine.
    (c) Gram atom of Potassium = __________ g of Potassium.

45. Calculate the amount of potassium chloride obtained by the thermal decomposition of 12.25 kg of potassium chlorate.

Essay type questions

46. 47 g of impure Al_2O_3 is reduced electrolytically to give aluminium and oxygen. Calculate the amount of aluminium produced.

47. Calculate the empirical and molecular formula of an organic compound whose percentage composition is C = 70.54%, H = 5.87%, O = 23.52%.The molecular weight of compound is 136.

48. Calculate the empirical and molecular formula of a compound whose molecular weight is 120 and has the following percentage compositions.
Mg = 19.68%; S = 26.24%, O = 52.48%

49. Calculate the volume of CO_2 formed at STP and the weight of zinc oxide formed in grams, when 2.32 g of zinc carbonate decomposes with no further loss in weight.

50. Calculate the volume of CO_2 formed at STP and weight of calcium oxide formed, in grams, when 5.5 g of calcium carbonate crystals decompose with no further loss in weight.

CONCEPT APPLICATION

Concept Application Level—1

Direction for questions 1 to 7: State whether the following statements are true or false

1. Pressure of a gas is measured using a barometer.
2. Volume of the given mass of a gas is directly proportional to pressure at constant temperature.
3. The number of molecules present in 16 g of sulphur dioxide are 3×10^{23}.
4. The volume of 32 grams of oxygen at S.T.P is 224 ℓ.
5. Under similar conditions of temperature and pressure the ratio of rate of diffusion of methane and sulphur dioxide is 2 : 1.
6. The vapour density of hydrogen peroxide is equal to molecular weight of NH_3.
7. Real gases obey gas laws under all conditions.

Direction for questions 8 to 14: Fill in the blanks.

8. 9.2 g of sodium contains _____ atoms.
9. Marsh gas in coal mines is detected by using ______ law.
10. The volume of 5 gram-molecules of methane gas is __________at STP
11. 1 mole of argon gas contains _____ number of fundamental particles.
12. The ratio of a gram-atomic weight of nitrogen and oxygen is __________.
13. Empirical formula of a compound is C_2H_5 and its molecular weight is 58, then its molecular formula is _____.
14. The measurable properties of a gas are _____, _____ and _____.

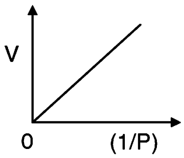
Direction for question 15: Match the entries given in column A with appropriate ones in column B.

15.

	Column A			Column B
A.	Avogadro number	( )	a.	25.8%
B.	Percentage weight of oxygen in Na_2O	( )	b.	75%
C.	Empirical formula of oxalic acid	( )	c.	6023×10^{23}
D.	Empirical formula of acetic acid	( )	d.	CHO_2
E.	Percentage of carbon in methane	( )	e.	CH_2O

Direction for questions 16 to 45: For each of the questions, four choices have been provided. Select the correct alternative.

16. Which of the following graphs is true for the given mass of a gas at constant temperature?

(1)


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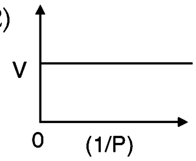
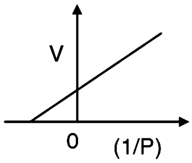
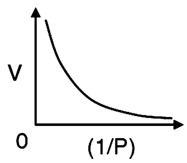
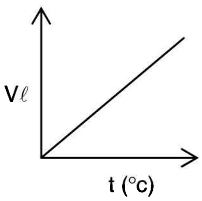
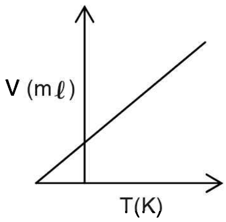


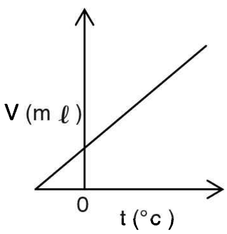
(3)


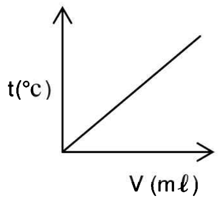
(4)


17. Which of the following graphs is true for a given mass of a gas at constant pressure?

(1)


(2)


(3)


(4)


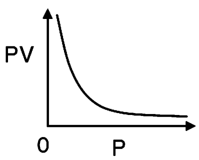
18. At constant temperature, when the volume of a gas is reduced to (1/3)rd, the pressure will increase ________.

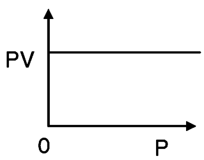
(1) 1 time (2) 2 times (3) 3 times (4) 4 times

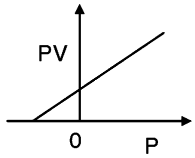
19. A monovalent positive radical, combines with chromate radical; identify the formula of the compound formed.

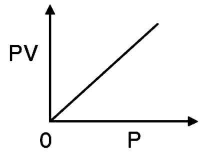
(1) $XCrO_4$ (2) X_2CrO_4 (3) $X_2Cr_2O_7$ (4) $X(Cr_2O_7)_2$

20. Which of the following graphs is true for the given mass of a gas at constant temperature?

(1)


(2)


(3) 

(4) 

21. The formula of calcium dihydrogen phosphate is

(1) CaH_2PO_4 (2) $Ca(HPO_4)_2$ (3) $Ca(H_2PO_4)_2$ (4) $Ca_3(PO_4)_2$

22. The number of oxygen atoms present in 0.25 moles of magnesium perchlorate.

(1) 4 N (2) 8 N (3) 6 N (4) 2 N

23. Vapour density of SO_3 is ________.

(1) 80 (2) 48 (3) 32 (4) 40

24. If equal volumes of two gases, CH_4 and $O_{2,}$ are allowed to diffuse, then the time taken for diffusion of CH_4 is found to be

(1) $\frac{1}{2}$ times that of O_2. (2) $\frac{1}{\sqrt{2}}$ times that of O_2.

(3) $\sqrt{2}$ times that of O_2. (4) 2 times that of O_2.

25. If the rate of diffusion of a gas is r and its density is d, then under similar conditions of pressure and temperature ________.

(1) $r \propto d$ (2) $r \propto \sqrt{d}$ (3) $r \propto \frac{1}{\sqrt{d}}$ (4) $r \propto \frac{1}{d}$

26. The volume of CO_2 liberated at STP on burning 24 g of carbon in excess oxygen is ________.

(1) 22.4 ℓ (2) 44.8 ℓ (3) 16.8 ℓ (4) 67.2 ℓ

27. Which among the following contain 43.4% of sodium?

(1) sodium bicarbonte (2) sodium nitrate

(3) sodium carbonate (4) sodium chloride

28. The number of atoms present in 16 grams of O_2 is ________.

(1) 6.023×10^{23} (2) 3.011×10^{23}

(3) 12.046×10^{23} (4) 3.011×10^{22}

29. In which of the following cases, empirical formula is the same as molecular formula?

(1) Sucrose (2) C_6H_6

(3) C_2H_5COOH (4) Glucose

30. 50 g of magnesium on treatment 40 g of carbon dioxide gives magnesium oxide. In this amount of excess reagent taken is

(1) 8.5 g (2) 6.37 g

(3) 5.5 g (4) 7.5 g

31. Identify the correct sequence of relevant steps to write the formula of cupric bisulphate.

(a) Writing the symbol of negative radical as HSO_4^{-2}

(b) Writing the symbol of positive radical as Cu^{+2}

(c) Writing symbol of negative radical as HSO_4^-

(d) Writing symbol of positive radical as Cu^+

(e) Interchanging the valencies of positive and negative radicals and writing subscripts as 1 and 2.

(f) Interchanging the valencies of positive and negative radicals and writing subscripts as 2 and 1.

(g) Keeping HSO_4 in parenthesis

(h) Keeping Cu in parenthesis.

(1) baeh (2) bceg (3) dcfh (4) dafg

32. Arrange the relevant points in proper sequence to explain why gases exert pressure.

(a) Gas molecules are in random motion.

(b) Kinetic energy of gas molecules is proportional to absolute temperature.

(c) Gas is made up of tiny particles called molecules.

(d) Intermolecular forces of attraction are negligible in gases.

(e) During random motion, the gas molecules collide with each other.

(f) During random motion, the gas molecules collide with the walls of container.

(1) cadef (2) cbdfe (3) cdaf (4) cdaef

33. Arrange the relevant points in the proper sequence for explaining why Kelvin scale is preferred to Celsius scale in the study of gases.

(a) – 273°C is the least possible temperature.

(b) A graph of volume vs temperature is a straight line passing through origin.

(c) A graph of volume vs temperature (°C) is a straight line which intersects volume axis at some point.

(d) Extrapolation of straight line touches the volume axis at – 237°C

(e) – 237°C is called absolute zero or 0 K.

(f) All values of temperature are positive in Kelvin scale.

(g) Usage of negative values for temperature gives negative values for other properties like pressure and volume.

(1) cdaef (2) bdaef (3) cdfeag (4) bdfeab

34. The ratio of phosphorus atoms present in calcium phosphide and magnesium phosphate is

(1) 1 : 2 (2) 2 : 1 (3) 1 : 3 (4) 1 : 1

35. For which of the following reactions, is Gay Lussac's law not applicable?

(1) Formation of HI from its constituents

(2) Formation of NH_3 from its constituents

(3) Formation of CO_2 from its constituents

(4) Formation of SO_3 from SO_2 and O_2

36. The ratio of number of molecules present in a given mass of oxygen and sulphur trioxide is

(1) 2 : 1 (2) 5 : 2 (3) 2 : 5 (4) 1 : 2

37. In which of the following cases, is the empirical formula same as the molecular formula?

(1) $C_{12}H_{22}O_{11}$ (2) C_6H_6 (3) C_3H_5COOH (4) $C_6H_{12}O_6$

38. Which of the following reactions is associated with same volume ratio as the reaction of formation of CO_2 from CO and O_2?

(1) Synthesis of ammonia (2) Synthesis of HCl

(3) Formation of SO_3 from SO_2 and O_2 (4) Synthesis of nitric oxide

39. At constant temperature, a gas is at a pressure of 940 mm of Hg. At what pressure, its volume decreases by 40%?

(1) 564 mm of Hg (2) 1860 mm of Hg (3) 2350 mm of Hg (4) 1567 mm of Hg

40. The number of molecules present in 2.8 g of nitrogen is

(1) 6.023×10^{23} (2) 6.023×10^{22} (3) 6.023×10^{21} (4) 6.023×10^{20}

41. If the formula of a metallic nitrate is $M(NO_3)_2$, then what will be the formula of the nitride of that metal.

(1) MN_2 (2) M_3N_2 (3) M_2N (4) M_2N_3

42. The ratio of rates of diffusion of two gases X and Y is $4 : \sqrt{11}$. If the molecular mass of Y is double to the molecular mass of oxygen X is

(1) CO (2) SO_3 (3) CO_2 (4) NO

43. 160 ml of carbon monoxide is mixed with 100 ml of oxygen and the mixture is ignited. What volume of oxygen is left behind? (Assume that all volumes are measured under same conditions)

(1) 80 ml (2) 60 ml (3) 20 ml (4) 40 ml

44. Assertion (A): One gram molecule of any gas occupies 22.4 ℓ volume at STP

Reason (R): Under similar conditions of temperature and pressure equal masses of all gases occupy equal volumes.

(1) Both A and R are correct and R is the correct explanation for A

(2) Both A and R are correct but R is not the correct explanation for A

(3) A is correct, but R is wrong

(4) A is wrong, but R is correct

45. What is the volume of oxygen liberated at STP when 24.5 g of potassium chlorate is subjected to heating?

(1) 3.36 ℓ (2) 5.6 ℓ (3) 6.72 ℓ (4) 16.8 ℓ

Concept Application Level—2

1. Why is temperature in Kelvin scale always positive? Also explain why Kelvin temperature is used only in studying gas laws.

2. A certain amount of a gas is filled in a tank of volume 63000 ℓ and 42 atm. If this gas is transferred to a cylinder of volume of 1260 ℓ, find the number of cylinders that can be filled with the given gas at STP? (assume complete evacuation of cylinder)

3. One mole of hydrocarbon is subjected to combustion. The product obtained is condensed and the resulting gaseous product occupied a volume of 89.6 ℓ at STP. Oxygen required for this combustion is 145.6 ℓ at STP. What should be the molecular formula of x?

4. How many molecules of hydrogen chloride can be synthesized from 896 ℓ of chlorine gas at STP?

5. How many grams of magnesium nitrate should be heated to produce oxygen which is just sufficient to form 15.3 g of alumina?

6. The ratio of nitrogen and oxygen by mass present in a colourless gas is 7 : 8. When this colourless gas combines with O_2, it produces 44800 cm^3 of brown coloured gas at STP Find out the number of moles of oxygen that have taken part in the reaction.

7. In an organic compound the percentage of carbon and hydrogen are 40 and 6.7 respectively. If the vapour density of the compound is 30, what is the molecular formula of the compound?

8. How many grams of oxygen contain the same number of molecules as present in 352 g of CO_2?

9. The volume occupied by oxygen at STP obtained on heating the 490 g of $KClO_3$ is 130 ℓ. Calculate the percentage purity of $KClO_3$ [$KClO_3$ on heating produces KCl and O_2].

10. Balance the following chemical reactions by identifying the products.

(1) $CuSO_4 + HI \rightarrow CuI_2$ ___ (2) $PCl_5 + H_2O \rightarrow H_3PO_4 +$ ____

(3) $Fe_3O_4 + HCl \rightarrow FeCl_2 + FeCl_3$ _____ (4) $Al_2O_3 + N_2 + C \rightarrow AlN +$ ____

11. How many moles of water are required to be dissociated to produce oxygen which is just sufficient to form 800 grams of magnesium oxide by burning magnesium? (Atomic weight of Mg is 24)

12. The mass of 256 ml of triatomic elemental gas at 27C and 4 atm is 2 g. Calculate the weight of one atom.

13. 710 g of chlorine gas contains X atoms of chlorine. Calculate the mass of sodium chloride which contains X number of chloride radicals. (Atomic weight of Na is 23 g)

14. Two gases A and B, which do not chemically react, are taken in two one litre containers. They are found to exert pressures P_1 and P_2 respectively. When the mixture of the gases A and B is taken in another 1 litre container, the pressure exerted is found to be ($P_1 + P_2$). How can you justify this on the basis of kinetic molecular theory?

15. A particular compound contains only nitrogen and hydrogen. The percentage of nitrogen in that compound is 875%. 96 grams of that compound contains 18×10^{23} molecules of that substance. Find out the molecular formula of that compound.

Directions for questions 16 to 25: Application Based Questions

16. The ratio of nonmetal atoms to the number of atoms of two nonmetallic oxides A and B are 0.33 and 0.25 respectively. Find the valencies of nonmetals present in those nonmetallic oxides.

17. 2 moles of chlorine atoms are present in how many grams of chlorine gas?

18. A cylinder is filled with a mixture of equal number of molecules of oxygen, carbon dioxide and helium. When leakage occurs, do equal amounts of gases come out? Give reason.

19. At what centigrade temperature, will the volume of a given mass of a gas at 0°C triple itself if pressure is kept constant?

20. Two gases A and B are kept in two cylinders and allowed to diffuse through a small hole. If the time taken by gas A is four times the time taken by gas B for diffusion of equal volume of gas under similar conditions of temperature and pressure, what will be the ratio of their molecular masses?

21. If the volume occupied by a certain mass of gas is decreased by 60%, what would be the percentage change in pressure at the same temperature?

22. The percentage of a trivalent metal in a metallic oxide is 53%. How many grams of this metallic oxide should be required to produce 22.8 g of salt when treated with excess sulphuric acid?

23. 448 ℓ of ammonia at STP on decomposition gives X g of nitrogen. How many molecules of oxygen are required to produce NO_2 from X g of nitrogen?

24. Calculate the number of molecules of gaseous product obtained on heating 8.8 g of CO_2 with coke if the conversion of CO_2 is 80% by mass.

25. The volume occupied by oxygen at STP obtained on heating the 490 g of $KClO_3$ is 130 l. Calculate the percentage purity of $KClO_3$ [$KClO_3$ on heating produces KCl and O_2].

Concept Application Level—3

1. There are four different metal halides–A, B, C and D. The ratio of the number of constituent atoms (i.e., metal and halogen atoms present) in one gram-molecule of those metal halides are 1, 05, 025 and 033 respectively. Find the valency of the metals present in those metal halides. Give reasons in support of your answer.

2. 500 ml of monoatomic gas "X" diffuses through a hole at a pressure of 4 atm and 127. 1500 ml of another elemental diatomic gas Y diffuses through the same hole at a pressure of 2 atm and 27C. If the time taken for both the diffusion processes are the same. Compare the atomic weights of two gases.

3. Under what conditions can ideal gases be liquefied? Give reasons to support your answer.

4. The molecular weight of gas 'A' is 10 times greater than the molecular weight of gas 'B'. These two gases are taken in cylinders of 5 ℓ volume at 1 atm pressure and 27°C temperature. Comment on the number of molecules in the two gases. Justify with respect to kinetic molecular theory of gases.

5. Easily liquefiable gases show larger deviations from gas laws. Comment on this statement on the basis of kinetic molecular theory.

Directions for questions 6 to 10: Application Based Questions

6. A certain volume of O_2 gas is kept in a cylinder fitted with a movable piston. If all the O_2 molecules present in that cylinder get converted to O_3 molecules at the same temperature and pressure, will you observe any change in the system? Calculate the percentage change if any change takes place. Justify your answer with appropriate reasons.

7. Equal volumes of CO and O_2 are kept in a closed cylinder under certain temperature and pressure. The mixture is heated till all the CO gets converted to CO_2. Then, the temperature of the gases is brought to the previous temperature. Will there be any change in any parameter of the gas or gases present in the cylinder? Justify your answer with appropriate reasons. If any change takes place, calculate the percentage change.

8. A sample of a mixture of Na_2CO_3 and $NaHCO_3$ is subjected to heating till there is no further loss in weight. Assuming that the loss in weight of the sample is 22% of the initial weight of the mixture due to the evolution of CO_2, find out the relative percentages of the two components in the mixture.

9. A patient Vasu, had to survive for a month on artificial respiration before he passed away. Nurse was instructed to give him 7.5 g of glucose per hour for consumption to meet the energy requirement. What volume of carbogen (95% O_2 + 5% CO_2) had to be supplied for Vasu assuming that he was kept under the conditions of 27°C temperature and normal atmospheric pressure?

10. 64.5% pure sample of zinc when treated with excess of dilute HCl liberated some volume of hydrogen gas at STP. This hydrogen is utilised for the reduction of 23.2 g Fe_3O_4. Find out the amount of iron obtained and also amount of impure zinc taken. [Atomic mass of Zn = 65.5 and Fe= 56].

key points for selected questions

Very short-answer type questions

1. For a given mass of a gas, the volume of a gas (v) is directly proportional to the absolute temperature (T) at constant pressure
2. Under similar conditions of temperature and pressure, equal volumes of all gases contain equal number of molecules.
3. The rate of diffusion of a gas is inversely proportional to the square root of its density at constant temperature and pressure
4. one
5. T (Kelvin) = 273 + °C (Celsius)
6. (i) 23 g (ii) 28 g
7. (i) 0.5 (ii) 2
8. 16 g of methane occupies 22.4 ℓ

   0.8g of methane occupies = $\dfrac{0.8 \times 22.4}{16} = 1.12\ \ell$.
9. (i) 132 g (ii) 210 g
10. –273, 0
11. The standard temperature and pressure which refer to the volume of gas.
    Standard temperature = 0°C = 273 K
    Standard pressure = 1 atm = 760 mm of Hg
    = 76 cm of Hg
12. Collisions on the walls of container
13. AgBr
14. KOH
15. $(NH_4)_2HPO_4$
16. $Ca(HSO_4)_2$
17. SnS_2
18. Kelvin
19. $2NaNO_3 \longrightarrow 2NaNO_2 + O_2$
20. $BeO + 2NaOH \longrightarrow Na_2BeO_2 + H_2O$
21. $4LiNO_3 \longrightarrow 2Li_2O + 4NO_2 + O_2$
22. $2KI + 2H_2SO_4 \longrightarrow K_2SO_4 + SO_2 + I_2 + 2H_2O$
23. $3NaBr + H_3PO_4 \longrightarrow Na_3PO_4 + 3HBr$
24. $SO_2 + 2H_2S \longrightarrow 2H_2O + 3S$
25. $2Na_2O_2 + 2H_2O \longrightarrow 4NaOH + O_2$
26. $S + 6HNO_3 \longrightarrow H_2SO_4 + 6NO_2 + 2H_2O$
27. $MnO_2 + 4HCl \longrightarrow MnCl_4 + 2H_2O$.
28. $2HNO_3 + CaCO_3 \longrightarrow Ca(NO_3)_2 + H_2CO_3$
29. $Fe_2(SO_4)_3 + 6NaOH \longrightarrow 3Na_2SO_4 + 2Fe(OH)_3$
30. Empirical formula weight = 12 2 + 4 + 16 = 44
    Empirical formula weight = Vapour density = 44
    Molecular weight = V.D. 2 = 44 2 = 88
    Molecular formula = $C_4H_8O_2$.

Short-answer type questions

31. (i) Molecular arrangement
    (ii) Intermolecular forces of attraction
    (iii) Molecules are free and independent

key points for selected questions

32. (i) Molecular arrangement
(ii) Intermolecular forces of attraction

33. (i) Molecular weights of gases
(ii) Change in temperature
(iii) Change in pressure

34. (i) Molecular weight of a compound
(ii) Amount of element present in 100 g of the compound = $\frac{\text{Amount of element} \times 100}{\text{Molecular weight}} \times 100$

35. (i) Ratio of volume of reactant and products
(ii) Temperature and pressure

36. (i) Mole ratio = Volume ratio
(ii) Limiting reactants
(iii) Calculate the volume of CO_2, corresponding to the volume of limiting reactant.

38. Relating the mass of a gas and volume at STP.

39. (i) Molecular weight of substance
(ii) Relate molecular weight and number of moles.

40. (i) Molecular weight of gas.
(ii) Weight of Avogadro number of molecules

41. Relation between mass and number of moles.

42. (i) Molecular weight = 2V.D.
(ii) Calculate the simplest ratio of the number of carbons and hydrogens.
(iii) Calculate empirical formula weight
(iv) Calculate molecular formula from empirical formula weight and molecular weight.

43. (i) $2HgO \rightarrow 2Hg + O_2$
(ii) Calculate according to mole ratio.

45. (i) $KClO_3 \rightarrow 2KCl + 3O_2$
(ii) Calculate according to mole ratio

Essay type questions

46. (i) $2Al_2O_3 \rightarrow 2Al^{+3} + 6O^{-2}$
(ii) $2Al^{+3} + 6e^- \rightarrow 2Al$
$6O^{-2} \rightarrow 3O_2 + 12e^-$
(iii) Calculate according to mole ratio

47. (i) Calculate the simplest ratio of the number of constituent atoms.
(ii) Calculate molecular formula from empirical formula and molecular weight.

48. (i) Calculate the simplest ratio of the number of constituent atoms.
(ii) Calculate molecular formula from empirical formula and molecular weight.

49. (i) $ZnCO_3 \rightarrow ZnO + CO_2$
(ii) Calculate according to mole ratio

50. (i) $CaCO_3 \rightarrow CaO + CO_2$
(ii) Calculate according to mole ratio

KEY

Concept Application Level—1

True or false

1. True
2. False
3. False
4. True
5. True
6. True
7. False

Fill in the blanks

8. 2.4×10^{23}
9. Grahams

10. 112 ℓ

11. 54 N

12. 7 : 8

13. C_4H_{10}

14. Pressure, volume, temperature

Match the following

15. A : c

B : a

C : d

D : e

E : b

Multiple choice questions

16. Choice (1)

17. Choice (3)

18. Choice (3)

19. Choice (2)

20. Choice (2)

21. Choice (3)

22. Choice (4)

23. Choice (4)

24. Choice (2)

25. Choice (3)

26. Choice (2)

27. Choice (3)

28. Choice (1)

29. Choice (1)

30. Choice (2)

31. (i) Writing the symbol of positive radical as Cu^{+2}

(ii) Writing the symbol of negative radical as HSO^{-}_{4}

(iii) Interchanging the valencies of positive and negative radicals and writing 1 and 2 as subscripts.

(iv) Keeping HSO_4 in parenthesis

Choice (2)

32. (i) Gas is made up of tiny particles called molecules.

(ii) Intermolecular forces of attraction are negligible in gases.

(iii) Gas molecules are in random motion.

(iv) During random motion, the gas molecules collide with the walls of container.

Choice (3)

33. (i) A graph of volume vs temperature (°C) is a straight line which intersects volume axis at some point.

(ii) Extrapolation of straight line touches the volume axis at -273 °C

(iii) – 273 °C is the least possible temperature.

(iv) – 273°C is called absolute zero or 0 Kelvin.

(v) All values of temperature are positive in Kelvin scale.

(vi) Usage of negative values gives negative values for other properties like pressure and volume.

Choice (1)

34.

Ca_3P_2	$Mg_3(PO_4)_2$
3 Ca atoms	3 Mg atoms
2 P atoms	2 P atoms
	8 O atoms

The ratio of phosphorus atoms is 2 : 2 = 1 : 1

Choice (4)

35. Constituents of CO_2 are carbon and oxygen where carbon is a solid, Gay Lussac's law is applicable for only gaseous reactions.

Choice (3)

36. 32 g of oxygen contains 'N' molecules

32 g of SO_3 contains $\frac{80}{32}$ N molecules

Ratio of number of molecules present in 32 g

of O_2 and $SO_3 = N : \frac{80}{32} N = 2.5 : 1 = 5 : 2$

Choice (2)

37. $C_{12}H_{22}O_{11}$, empirical formula and molecular formula are same

Choice (1)

38. $2CO + O_2 \rightarrow 2CO_2$. The volume ratio is 2 : 1 : 2.

2 vol 1 vol 2 vol.

Formation of SO_3 can be represented as

$2SO_2 + O_2 \rightarrow 2SO_3$ also possesses same volume ratio (2 : 1 : 2)

Choice (3)

39. $P_1 = 940$ mm of Hg, $V_2 = 60\ \ell$
$V_1 = 100\ \ell$, $P_2 = ?$

$$P_2 = \frac{P_1V_1}{V_2} = \frac{940 \times 100}{60} = 1567 \text{ mm of Hg}$$

Choice (4)

40. 28 g of nitrogen contains 6.023×10^{23} molecules

2.8 g of nitrogen contains 6.023×10^{22} molecules.

Choice (2)

41. $M(NO_3)_2 \Rightarrow$ Valency of M is + 2

Metal nitride $M^{+2}\ N^{-3} \Rightarrow M_3N_2$.

Choice (2)

42. $$\frac{r_x}{r_y} = \frac{4}{\sqrt{11}} = \sqrt{\frac{M_y}{M_x}} \Rightarrow \frac{4}{\sqrt{11}} = \sqrt{\frac{M_y}{M_x}} \quad (1)$$

Molecular weight of $O_2 = 32$

$\therefore$ Molecular weight of $Y = 2 \times 32 = 64$

$$\therefore \frac{4}{\sqrt{11}} = \sqrt{\frac{64}{M_x}} \Rightarrow \frac{16}{11} = \frac{64}{M_x} \Rightarrow M_x = 44$$

$\therefore$ Gas X is CO_2

Choice (3)

43. $2CO + O_2 \rightarrow 2CO_2$

2 moles of CO react with 1 mole of O_2

160 ml(moles) of CO react with ? ml (moles) of O_2

$$= \frac{160 \times 1}{2} = 80 \text{ ml of } O_2$$

$\therefore$ Volume of O_2 left = 100 – 80 = 20 ml.

Choice (3)

44. One gram molecule of any gas occupies 22.4 l volume at STP.
According to Avogadro's law, under similar conditions of temperature and pressure equal moles but not equal mass of all gases occupy equal volumes.

Choice (3)

45. $2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2 \uparrow$

2 moles of $KClO_3 \rightarrow$ 3 moles of O_2

$$\frac{24.5}{122.5} = 0.2 \text{ moles} \rightarrow x = \frac{3 \times 0.2}{2}$$

= 0.3 moles of O_2

1 mole $\rightarrow 22.4\ \ell$

$0.3 \rightarrow x = 6.72\ \ell$

Choice (3)

Concept Application Level—2

Key points

1. (i) Charles' law.
   (ii) Determination of Kelvin from Charles law.
   (iii) Relation between change in volume with temperature.
2. (i) Boyle's law.
   (ii) Volume of gas at STP.
   (iii) Determination of number of cylinders.
   (iv) 2100 cylinders
3. (i) Balanced equation for combustion of hydrocarbon.
   (ii) Identification of the product that is condensed.
   (iii) Calculation of number of moles of the gaseous product and oxygen from the given volume.
   (iv) Determination of the molecular formula of the hydrocarbon.
   (v) C_4H_{10}
4. (i) Relation between volume of the gas at STP and number of moles.
   (ii) 48×10^{23} molecules
5. (i) Calculation of amount of oxygen required for the formation of given amount of alumina.
   (ii) Balanced chemical equation for the decomposition of magnesium nitrate.
   (iii) Calculation of mass of magnesium nitrate required to be heated.
   (iv) 66.6 g

6. (i) Identification of the colourless gas.
   (ii) Balanced chemical equation of combustion of colourless gas.
   (iii) Relate volume of products to number of moles of oxygen consumed.
   (iv) 1 mole

7. (i) Calculation of atomic ratio from the percentages of various elements.
   (ii) Determination of empirical formula.
   (iii) Relation between molecular weight and vapour density.
   (iv) Determination of molecular formula.
   (v) $C_2H_4O_2$

8. (i) Relation between the mass and the number of molecules.
   (ii) Number of moles of CO_2.
   (iii) Mass of O_2 containing equal number of moles as CO_2.
   (iv) 256 g

9. (i) Weight–Volume relationship.
   (ii) Balanced chemical equation of decomposition of $KClO_3$.
   (iii) Relating volume of O_2 obtained and mass of $KClO_3$ actually present.
   (iv) Calculation of percentage purity.
   (v) 96.7%

10. (i) Type of chemical reaction.
    (ii) Balancing by keeping appropriate coefficients.

11. (i) Relationship between the mass of reactants and products.
    (ii) Balanced chemical equation for synthesis of MgO.
    (iii) Relating number of moles of oxygen and amount of MgO.
    (iv) Balanced chemical equation for dissociation of water.
    (v) Relating number of moles of oxygen and water.
    (vi) 20 moles

12. (i) Ideal gas equation.
    (ii) Calculation of the volume occupied by the gas at STP.
    (iii) Calculation of the molecular weight of the gas from the mass given.
    (iv) Relation between gram molecular weight and number of molecules.
    (v) Calculation of the weight of one atom.
    (vi) 2.66×10^{23}

13. (i) Calculation of X from the given mass.
    (ii) Relation between gram atomic weight, given mass and number of atoms.
    (iii) 1170 g

14. Relation between the number of molecules of a gas and its pressure.

15. (i) Relation between the number of molecules and the gram molecular weight of a substance.
    (ii) Finding molecular weight relating given mass and number of molecules.
    (iii) Percentage of hydrogen.
    (iv) Empirical formula of compound.
    (v) Relating empirical formula and molecular weight to derive molecular formula.
    (vi) N_2H_4

16. Let the nonmetallic oxide be $X_x O_y$.

$$\therefore \frac{x}{x+y} = 0.33 \Rightarrow x = x(0.33) + y(0.33)$$

$\Rightarrow 0.67x = 0.33y \Rightarrow x:y = 1:2$

And hence the number of oxygen atoms are 2, as the valency of oxygen is two, the valency of nonmetal is four.

Let the nonmetallic oxide be X_xO_y

In B

$$\therefore \frac{x}{x+y} = 0.25 \Rightarrow x = 0.25x + 0.25y$$

$\Rightarrow 0.75x = 0.25y$

$\Rightarrow x:y = 1:3$

Valency of nonmetal =

$$\frac{\text{valency of "O"} \times \text{No. of "O" atoms}}{\text{Number of nonmetal atoms}} = \frac{2 \times 3}{1} = 6$$

17. 1 molecule of chlorine gas consists of two chlorine atoms. Hence 2 atoms of chlorine are present in 1 molecule of chlorine gas that is 71 g of Cl_2.

18. When leakage occurs in a cylinder containing a gaseous mixture containing equal masses of different gases,
equal amounts of gases do not come out. This is because rate of diffusion of a gas depends on its molecular mass. The order of molecular masses of the gases is He < O_2 < CO_2. The rate of diffusion is in the order He > O_2 > CO_2. From the mixture, maximum amount of helium comes out whereas minimum amount of CO_2 comes out .

19. 0°C corresponds to 273 K. Since volume of a gas is directly proportional to absolute temperature at constant pressure, the volume gets tripled when temperature is tripled.

$T_1 = 273$ K, $T_2 = ?$,

$V_1 = V$, $V_2 = 3V$,

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \Rightarrow T_2 = \frac{V_2 T_1}{V_1} = \frac{3V \times 273}{V} = 819 \text{ K}$$

t = 819 – 273 = 546°C

20. Rate of diffusion (effusion)

$$= \frac{\text{Volume of gas diffused (v)}}{\text{time taken (t)}}$$

Let time taken by gas B be 't'.

Then rate of diffusion of

$$B = \frac{\text{Volume of gas B diffused } (V_1)}{t}$$

according to the given data

time taken by gas A = 4 × time taken by gas B
= 4 × t

∴ rate of diffusion of

$$A = \frac{\text{Volume gas A diffused } (V_2)}{4 \times t}$$

Volume of gas B diffused = Volume of gas A diffused

$\therefore V_1 = V_2$

$$\frac{\text{rate of diffusion of A}}{\text{rate of diffusion of B}} = \frac{r_A}{r_B} = \frac{V_1}{4t} \times \frac{t}{V_2} = \sqrt{\frac{M_B}{M_A}}$$

$$\therefore \frac{r_A}{r_B} = \frac{1}{4} = \sqrt{\frac{M_B}{M_A}}$$

Squaring on both sides $= \frac{1}{16} = \frac{M_B}{M_A}$

$M_A : M_B = 16 : 1$

21. $P_1 = P, V_1 = V$

$$V_2 = V - \frac{60V}{100}$$

$P_2 = ?$

$$P_1V_1 = P_2V_2, P_2 = \frac{PV}{V - \frac{60V}{100}} = 2.5P$$

$$\text{Percentage change} = \frac{(2.5P - P)}{P} \times 100 = 150\%$$

22. The formula of metal oxide is M_2O_3.
Let the atomic weight of metal be x.

$$\therefore \left(\frac{2x}{2x + 48}\right)100 = 53 \Rightarrow x = 27.06$$

∴ The metal is Al and formula of oxide is Al_2O_3.

$Al_2O_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$

(54 + 48) g of Al_2O_3 gives [54 + 3(96)]g of $Al_2(SO_4)_3$

? ← 22.8 g of $Al_2(SO_4)_3$

$$= \frac{22.8 \times 102}{342} = 6.8 \text{ g.}$$

23. $2NH_3 \rightarrow N_2 + 3H_2$

2(22.4) ℓ of NH_3 → 22.4 ℓ of N_2

448 ℓ → ?

$$= \frac{448 \times 22.4}{2 \times 22.4} = 224\ \ell$$

28 g of N_2 corresponds to 22.4 ℓ
? corresponds to 224 ℓ

$$= \frac{28 \times 224}{22.4} = 280 \text{ g}$$

∴ X = 280 g

$N_2 + 2O_2 \rightarrow 2NO_2$

28 g of N_2 → 64 g of O_2

280 g → ?

$$= \frac{280 \times 64}{28} = 640 \text{ g}$$

$32\text{ g} \rightarrow 6 \times 10^{23}$ molecules

$640\text{ g} \rightarrow ?$

$= \frac{640 \times 6 \times 10^{23}}{32} = 12 \times 10^{24}$ molecules.

24. $CO_2 + C \rightarrow 2CO$

44 g of $CO_2 \rightarrow 2 \times 6 \times 10^{23}$ molecules of CO

8.8 g of $CO_2 \rightarrow ?$

$= \frac{8.8 \times 12 \times 10^{23}}{44} = 2.4 \times 10^{23}$ molecules

100% conversion $\rightarrow 2.4 \times 10^{23}$ molecules

80% conversion $\rightarrow ?$

$= \frac{80 \times 2.4 \times 10^{23}}{100} = 1.92 \times 10^{23}$ molecules

25. $2\ KClO_3 \rightarrow 2\ KCl + 3O_2$

2×122.5 g of $KClO_3 \rightarrow 3 \times 22.4\ \ell$ of O_2 at STP

$? \leftarrow 130\ \ell$ of O_2 at STP

$= \frac{2 \times 122.5 \times 130}{3 \times 22.4} = 473$ g of $KClO_3$.

% of purity of $KClO_3 = \frac{473}{490} \times 100 = 96.7\%$.

Concept Application Level—3

Key points

1. (i) Relation between the number of constituent atoms present in 1 molecule of the substance and their valency.
   (ii) Number of metal and halogen atoms in A, B, C and D.
   (iii) Valency of metal depending on number of halogens the metal is associated with.
   (iv)

A	:	1
B	:	2
C	:	4
D	:	3

2. (i) Ideal gas equation.
   (ii) Comparison of the volumes of gases X and Y under similar conditions of temperature and pressure.
   (iii) Calculation of the ratio of rate of diffusion of X and Y
   (iv) Determination of the ratio of their molecular weights.
   (v) Comparison of atomic weights from the atomicity of the gases.
   (vi) $(\text{At wt})_y \times 8 = (\text{At wt})_x$

3. (i) Properties of ideal gases.
   (ii) Conditions for liquefaction of any gas.
   (iii) Applying these conditions to ideal gases.
   (iv) Unique nature of ideal gas.

4. (i) The cause of pressure for the gas.
   (ii) Relation between the number of molecules and pressure exerted by the gas provided the volume is kept fixed.
   (iii) Comparison of the number of molecules of the gases under the given condition of temperature.

5. (i) Comparing properties of gas which follow gas laws and easily liquefiable gases.
   (ii) Properties of gas based on kinetic molecular theory which follow gas laws.
   (iii) Property which makes gases easily liquefiable.
   (iv) Comparison of properties of easily liquefiable gases and ideal gases.

6. $3O_2 \rightarrow 2O_3$
   3 moles of O_2 are converted to 2 moles of O_3.
   ∴ The volume will be reduced if the temperature and pressure are kept constant.
   Let the volume of O_2 be x ℓ.
   ∴ The volume of O_3 will be $\frac{2x}{3}\ell$

   ∴ Percentage reduction of volume $= \frac{x - \frac{2x}{3}}{x} \times 100$

   $= \frac{\frac{x}{3}}{x} \times 100 = \frac{x}{3x} \times 100 = 33.33\%$

7. $2CO + O_2 \rightarrow 2CO_2$
   Temperature is brought down to the previous temperature and the volume of the cylinder is fixed.
   ∴ Pressure will be reduced, because the number of molecules will be reduced.

Let 2n molecules of CO and 2n molecules of O_2 be there in that cylinder (an equal volume of any gas contains the same number of molecules under similar conditions of temperature and pressure).

2n molecules of CO combine with n molecules of O_2 and form 2n molecules of CO_2, according to stoichiometric equation.
After the reaction 2n molecules of CO_2 are formed and n molecules of O_2 will be left over.
If T and V are fixed, then pressure is directly proportional to the number of molecules.

$$\therefore \frac{p_1}{p_2} = \frac{4x}{3x}$$

$$\therefore p_2 = \frac{3p_1}{4}$$

Percentage change is equal to

$$= \frac{4x - 3x}{4x} \times 100 = 25\%$$

8. $2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$
Let 100 g be the weight of mixture
amount of CO_2 produced = 22
number of moles CO_2 = 0.5
amount of $NaHCO_3$ present in the mixture
$2 \times 0.5 \times 84 = 84$ g
Amount of Na_2CO_3 present in the mixture
= 16 g
% of $NaHCO_3$ = 84%
% of Na_2CO_3 = 16%

9. $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
Amount of glucose required for 30 days = 7.5 $\times 24 \times 30 = 5400$ g

$$\therefore \text{no. of moles of glucose} = \frac{5400}{180} = 30$$

Volume of O_2 required for combustion at STP
$= 22.4 \times 6 \times 30 = 4032\ \ell$

STP	Given conditions
$T_1 = 273$ K	$T_2 = 300$ K
$P_1 = 1$ atm	$P_2 = 1$ atm
$V_1 = 4032\ \ell$	$V_2 = ?$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\therefore V_2 = \frac{1 \times 4032 \times 300}{273 \times 1} = 4430.76\ \ell$$

$\therefore$ oxygen required = 4430.76 ℓ
95 ℓ of oxygen is present in 100 ℓ of carbogen

$$\therefore 4430.76\ \ell \text{ of } O_2 \text{ is present in} = \frac{100 \times 4430.76}{95}$$

= 4663.95 ℓ of carbogen.

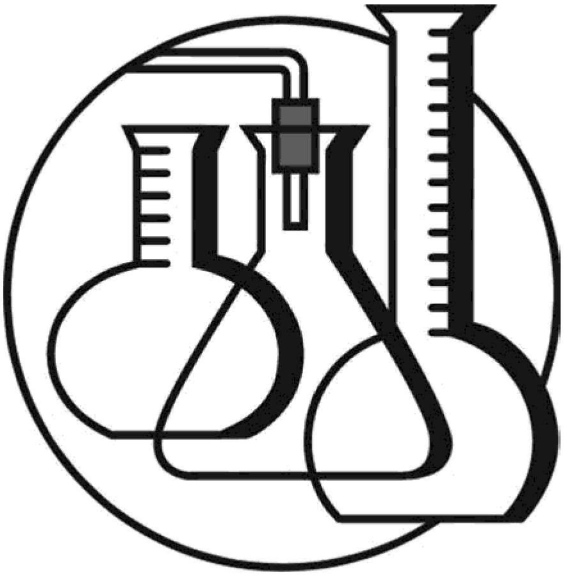
10. $Zn + 2\,HCl \rightarrow ZnC_{12} + H_2$
$Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$

$$\text{Number of moles of } Fe_3O_4 = \frac{23.2}{232} = 0.1$$

23.2 g Fe_3O_4 = 0.1 moles
1 mole Fe_3O_4 requires 4 moles H_2
0.1 mole Fe_3O_4 requires 0.4 moles H_2
To evolve 0.4 moles H_2, 0.4 moles of Zn are required.
Mass of 0.4 moles Zn = $0.4 \times 65.5 = 26.2$ g

$$\text{amount of 64.5\% Zn} = \frac{26.2 \times 100}{65.5} = 40 \text{ g}$$

amount of iron formed = 0.3 moles
$= 0.3 \times 56 = 16.8$ g



6

Chemical Kinetics and Chemical Equilibrium

INTRODUCTION

Earth is the only planet endowed with the gift of bearing a wide variety of flora and fauna. The existence of life on earth owes to the various chemical reactions taking place in nature. Some such reactions closely associated with life are burning of fuel, digestion of food, cooking of food, degradation of organic matter, etc. Henceforth, the study of chemical reactions is an inevitable part of science.

The study of chemical reactions can be done with respect to different aspects. The most important aspects of the study of chemical reactions are the time taken for the completion of the reaction and the favourable conditions required for the respective reactions. The branch of chemistry which deals with the above aspects is called chemical kinetics. The kinetics of reversible reactions is studied as chemical equilibrium.

Classification of Reactions

On the basis of time taken for the completion of the reactions, the chemical reactions can be classified into three categories

(i) Instantaneous reactions
(ii) Slow reactions
(iii) Moderate reactions

The reactions which are completed within a fraction of a second are called **instantaneous reactions**.

☛ *Examples*

(i) When a solution of silver nitrate is added to a chloride salt solution, a precipitate is formed immediately.

(ii) Sodium when exposed to air or water catches fire immediately.

(iii) Acid base neutralization reactions involving strong acids and bases

(iv) Most of the precipitation reactions

(v) Reactions of active metals

(vi) Some biological reactions involving muscle contractions and the transmission of nerve impulses

Contrary to the above category, there are some reactions which take some days or months, or even years in some cases, for their completion. Such reactions are called **slow reactions**.

☛ *Examples*

(i) Rusting of Iron (corrosion of metals)

(ii) Decomposition of biodegradable organic matter

In between these two extremes, we find many reactions requiring time ranging from a few minutes to hours to reach completion. Such types of reactions are called **moderate reactions**.

☛ *Examples*

(i) Digestion of food

(ii) Cooking of food

(iii) Photosynthesis in plants

In this chapter the study is confined to the kinetics of moderate reactions.

Rate of a reaction

During a chemical reaction, the reactants gradually disappear and products are gradually generated. As the reaction proceeds, the concentration of the reactants decreases and that of the products increases. This change in the concentration of products or reactants is measured with respect to time. The change in the concentration of products or reactants in unit time is known as the **rate of reaction**.

$$\text{Rate of reaction} = \frac{\text{Change in the concentration of reactants or products}}{\text{Time interval}}$$

If ΔC is the change in the concentration of reactants or products during the time interval Δt, $r = \frac{\Delta C}{\Delta t}$, where 'r' is the rate of a reaction.

Units of rate of a reaction

Since the change in the concentrations is usually expressed in moles/lt and time interval in seconds, the units of the rate of reaction can be taken as moles lt^{-1} sec^{-1}.

For a reaction $A \rightarrow B$

$r = -\frac{\Delta C_A}{\Delta t}$. where C_A is the concentration of 'A'.

The rate of reaction with respect to reactants is always represented by a negative sign, which indicates decrease in the concentration of reactants with time.

$r = +\frac{\Delta C_B}{\Delta t}$, where C_B is the concentration of 'B'.

The rate of reaction with respect to products is always represented by positive sign, which indicates an increase in the concentration of products with time.

Illustrations for rate of reaction

The rate of reaction with respect to a particular reactant or a product depends upon the stoichiometric coefficient of that substance in a balanced chemical equation.

☛ *Example*

Formation of nitric oxide

$N_2 + O_2 \rightarrow 2NO$

One mole of nitrogen reacts with one mole of oxygen to give two moles of nitric oxide.

Rate of formation of nitric oxide = 2 × Rate of consumption of nitrogen or oxygen.

Rate of consumption of nitrogen or oxygen = $\frac{1}{2}$ × Rate of formation of nitric oxide.

$$\text{Rate with respect to nitrogen} = -\frac{\Delta[N_2]}{\Delta t}$$

$$\text{Rate with respect to oxygen} = -\frac{\Delta[O_2]}{\Delta t}$$

$$\text{Rate with respect to nitric oxide} = +\frac{1}{2}\frac{\Delta[NO]}{\Delta t}$$

$$r = -\frac{\Delta[N_2]}{\Delta t} = -\frac{\Delta[O_2]}{\Delta t} = \frac{1}{2}\frac{\Delta[NO]}{\Delta t}$$

☛ *Example*

$2SO_2 + O_2 \rightarrow 2SO_3$

Two moles of SO_2 react with one mole of oxygen to give two moles of SO_3.

$$\text{Rate with respect to oxide} = -\frac{1}{2}\frac{\Delta[O_2]}{\Delta t}$$

$$\text{Rate with respect to So}_2 = -\frac{1}{2}\frac{\Delta[SO_2]}{\Delta t}$$

$$\text{Rate with respect to So}_3 = +\frac{1}{2}\frac{\Delta[SO_3]}{\Delta t}$$

$$r = -\frac{1}{2}\frac{\Delta[SO_2]}{\Delta t} = +\frac{1}{2}\frac{\Delta[SO_3]}{\Delta t} = -\frac{\Delta[O_2]}{\Delta t}$$

The basic reason why different reactions take place at different rates lies in the collision theory of reaction rates proposed by Svante Arrhenius in 1857. This theory is applicable for reactions involving gaseous reactants as it basically originated from the **kinetic molecular theory of gases**.

Postulates of collision theory of reaction rates

(i) A chemical reaction takes place due to collisions between the reactant molecules.

(ii) The rate of reaction does not correspond to the number of collisions taking place in the reaction. That means, all the collisions do not lead to the formation of products.

(iii) The collisions which finally lead to the transformation of reactants into products are called effective collisions or fruitful collisions.

(iv) For the effective collisions, the colliding molecules should be associated with certain minimum amount of energy called threshold energy. Apart from this, it is also necessary that the colliding molecules are oriented in proper direction. The rest of the collisions are called ineffective collisions as they do not lead to the formation of products.

(v) The reactant molecules which are associated with different energies must gain some energy and reach threshold energy. This energy which the reactant molecules have to acquire in order to lead to the effective collisions is called activation energy.

(vi) The reactions which are associated with low activation energy are fast and the reactions which are associated with high activation energy are slow.

(vii) The molecules which cross the energy barrier and reach threshold energy form an activated complex. This activated complex which is at a high energy state loses energy and forms products.

Factors affecting the rate of reaction

Depending on the magnitude of activation energy, each and every reaction is associated with a characteristic rate. However, the rate of a particular reaction also depends upon other factors. The most important factors which influence the rate of reaction are concentration, temperature and catalyst.

Concentration

In the case of most of the reactions, the rate of a reaction increases with the concentration of the reactants. The reason can be explained on the basis of collision theory. With the increase in the concentration of the reactants, the number of reactant molecules per unit volume increases thereby increasing the number of effective collisions. With the increase in the collision frequency, the rate of reaction increases.

Temperature

In general, the rate of reaction increases with the increase in temperature. With the increase in temperature, the kinetic energy of the reactant molecules increases. Therefore, more number of molecules acquire threshold energy and this results in effective collisions.

Experiment to study the effect of temperature and concentration on the rate of reaction

I. Two boiling test tubes each with 3 g of zinc granules are taken. Graduated syringes are attached to the boiling test tubes. 5 ml of 1M HCl and 5 ml of 2M HCl are respectively added to the two test tubes. The volumes of hydrogen gas evolved in the two syringes at various time intervals are noted. It is observed that the volume of hydrogen gas evolved is more in the second case than in the first case. This shows that the rate of reaction increases with concentration.

II. The same experiment can be repeated by taking the same concentration of HCl at two different temperatures. It is found that the volume of hydrogen evolved is more at higher temperatures.

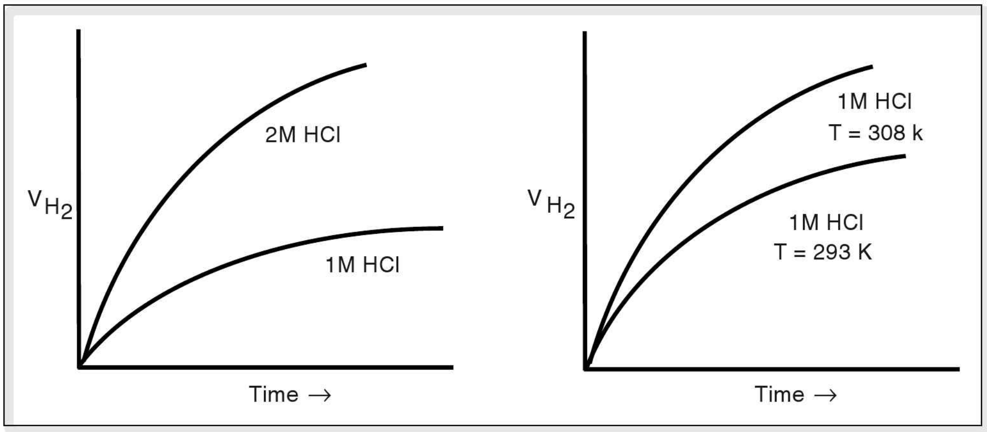


Figure 6.1

Catalyst

A catalyst is a substance which alters the rate of a reaction without undergoing any net change in its composition. A catalyst alters the rate of reaction by making the reaction to take place in an alternative pathway. Generally, most of the catalysts reduce the activation energy of the reaction. Since the alternative reaction path is associated with lower activation energy, more number of effective collisions take place and hence greater is the rate of reaction.

In most of the reactions, catalysts increase the rate of reactions. These are called positive catalysts.

☛ *Example* $N_2 + 3H_2 \quad 2NH_3$

There are few reactions in which catalysts decrease the rate of reaction. There are called negative catalysts.

☛ *Example* $2H_2O_2 \quad 2H_2O + O_2$

Glycerine, urea, acetanilide, sodium pyrophosphate decrease the rate of the decomposition of H_2O_2 and hence act as stabilisers for H_2O_2.

Though it is possible to increase the rate of reaction by increasing the temperature, the use of catalyst has a lot of significance in the industrial processes. This is because carrying out a process at a lower temperature in the presence of catalyst reduces the cost of production to a large extent. Increasing the temperature is not feasible in the case of some reactions.

Chemical equilibrium

It is our common experience that water kept in a closed container undergoes evaporation and so the level of water reduces in the container after some time. However, it is found that the entire water in the container does not evaporate. A stage is reached where there is no further fall in water level in the container. It implies that the number of water molecules going into vapour state becomes equal to the number of vapour molecules coming back to the liquid state and, hence, water level remains steady. This state is called **equilibrium**.

Such an equilibrium is not confined to physical processes alone. There are many chemical reactions which do not go to completion when carried out in a closed system. However, equilibrium is attained in all such reactions at some stage. Such reactions are called reversible reactions.

Reversible and irreversible reactions

Reversible reactions

Reactions in which reactants are converted to products and products are converted back to reactants are called **reversible reactions.**

The reaction in which reactants are converted to products is called the **forward reaction**. The reaction in which products are converted back to reactants is called the **backward reaction**.

Irreversible reactions

Reactions in which reactants are converted to products but products cannot be converted back to reactants are called **irreversible reactions**. They take place only in one direction.

Can take place in both directions.	Can take place in only one direction.
Equilibrium is established.	No equilibrium is established.
Can be made irreversible under certain conditions.	Cannot be made reversible under any condition.
Represented by two half arrows in opposite directions. ($\rightleftharpoons$)	Represented by a full arrow pointing towards the products ($\rightarrow$)
Examples $N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2\,NH_{3\,(g)}$ $H_{2\,(g)} + I_{2\,(g)} \rightleftharpoons 2\,HI_{\,(g)}$ $2SO_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2\,SO_{3\,(g)}$ $PCl_{5\,(g)} \rightleftharpoons PCl_{3\,(g)} + Cl_{2\,(g)}$ $2NO_{\,(g)} + O_{2\,(g)} \rightleftharpoons 2\,NO_{2\,(g)}$ $CaCO_{3\,(s)} \rightleftharpoons CaO_{\,(s)} + CO_{2\,(g)}$	**Examples** $4\,Fe_{\,(s)} + 3O_{2\,(g)} \rightarrow 2\,Fe_2O_{3\,(s)}$ $NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$ $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$ $Sn + 2\,HCl \rightarrow SnCl_2 + H_2$

Dynamic equilibrium

A reversible reaction proceeds in both the directions. The reaction in which reactants are converted to products is called the **forward reaction**. The reaction in which products are converted to reactants is called the **backward reaction**.

It is evident that the rate of a reaction at any instant is proportional to the concentration of the reactants.

In the beginning, the concentration of the reactants is maximum and, hence, the rate of forward reaction is also maximum. As reaction proceeds, the rate of forward reaction decreases with a decrease in the concentration of reactants. In the beginning, the concentration of products is minimum and, therefore, the rate of backward reaction is least. As time proceeds, the concentration of products increases, thereby, increasing the rate of backward reaction.

At some stage, the rate of forward reaction becomes equal to the rate of backward reaction. Once this state is reached, there is no net change in the molar concentrations of reactants and products. That means the system has attained the state of equilibrium.

Consider a relation $A + B \rightleftharpoons C + D$. At equilibrium, the concentrations of A, B, C and D remain constant. When the forward and backward reactions take place with equal speeds, the amount of reactants consumed per unit time becomes equal to the amount of reactants produced per unit time. At this stage also the **composition** of A, B, C and D does not vary further. Such an equilibrium is called **dynamic equilibrium**. All chemical equilibria are dynamic in nature. When the system is at dynamic equilibrium, the reaction appears to have come to a standstill. But, it is not so. The reaction proceeds with no net change in the concentrations of reactants and products.

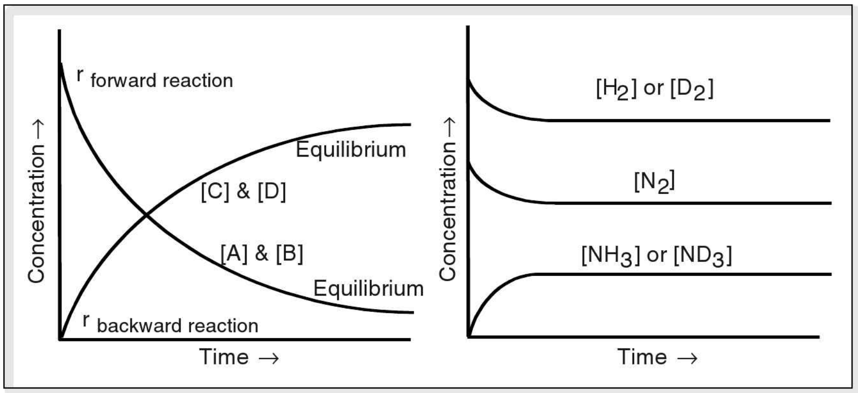


Figure 6.2

Experiment to show the dynamic nature of chemical equilibrium

Two reactions are conducted separately by taking known amounts of nitrogen and hydrogen in the first case and nitrogen and deuterium in the second case. Amounts of NH_3, N_2 and H_2 in the first reaction and amounts of ND_3, N_2 and D_2 in the second reaction are noted at regular intervals. After a certain time, it is found that the composition of reaction mixture remained unaltered with time. This constancy in composition indicates a state of equilibrium. At this stage, the reaction mixtures of both the reactions are mixed together and left for some time. The result of the analysis of mixture showed that the same concentration of ammonia, as well as some deuterium containing forms of ammonia in the reaction mixture. Thus, it can be concluded that the interchange of H and D atoms has taken place because the forward and backward reactions proceeded even after the equilibrium was reached.

Characteristics of dynamic equilibrium

(i) The observable properties such as concentration, density, colour, pressure, etc. remain constant at constant temperature.
(ii) Equilibrium can be attained from either direction.
(iii) Equilibrium is generally attained in a closed system only. This prevents the escape of products from reaction.
(iv) The usage of catalyst does not alter the position of equilibrium.
(v) Equilibrium state proceeds indefinitely unless it is disturbed by external factors.

Identification of equilibrium

The equilibrium stage can be identified by the constancy of some observable properties. Depending on the nature of various substances, a particular property is taken for observation.

☛ *Example* $CaCO_{3(S)} \rightleftharpoons CaO_{(S)} + CO_{2(g)}$

Since there is only one gaseous product in the above reaction, equilibrium can be identified by the constancy of pressure exerted by CO_2.

$NO_{2(g)} + CO_{(g)} \rightleftharpoons NO_{(g)} + CO_{2(g)}$

Since NO_2 is a reddish brown gas, the equilibrium can be identified by the constancy of colour.

Law of chemical equilibrium or Law of mass action

Guldberg and Wage proposed a law in order to establish a quantitative relationship between the concentrations of reactants and products at equilibrium.

The law of mass action states that the rate of a reaction is proportional to the product of molar concentrations of reactants.

For a reversible reaction $A + B \rightleftharpoons C + D$

$r_f \propto [A]^x [B]^y$, where r_f is the rate of the forward reaction.

$r_f = K_f [A]^x [B]^y$

$r_b \propto [C]^m [D]^n$, where r_b is the rate of the backward reaction

$r_b = K_b [C]^m [D]^n$

At equilibrium, $r_f = r_b$

$K_f [A]^x [B]^y = K_b [C]^m [D]^n$

$\frac{K_f}{K_b} = K_c = \frac{[C]^m [D]^n}{[A]^x [B]^y}$, where K_c is called the equilibrium constant

Equilibrium constant (K_c)

It can be defined as the ratio of the product of concentrations of products to the product of the concentrations of reactants with all of them raised to the powers of their coefficients in the balanced chemical equation.

Application of law of mass action to various equilibria

☛ *Example* $H_{2(g)} + I_{2(g)} \rightleftharpoons 2\,HI_{(g)}$

$$K_c = \frac{[HI]^2}{[H_2][I_2]}$$

☛ *Example* $N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2NH_{3\,(g)}$

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

These are all homogenous equilibria where all reactants and products are in one phase, i.e., in gaseous phase.

In case of heterogeneous equilibria, the reactants and products may exist in different phases. In such cases, the molar concentrations of only gaseous substances are taken into consideration for writing equilibrium constant. Concentrations of solids and pure liquids are taken as a unity since the rate of reaction is independent of their concentrations.

☛ *Example* $CaCO_{3\,(s)} \rightleftharpoons CaO_{(s)} + CO_{2\,(g)}\uparrow$

$$K_c = \frac{[CaO][CO_2]}{[CaCO_3]}$$

Since molar concentrations of solids are taken as a unity, $K_c = [CO_2]$

Characteristics of equilibrium constant

(i) Equilibrium constant has a constant value for a particular reaction at constant temperature.

(ii) Equilibrium constant depends on the direction in which the reaction is carried out.

(iii) The value of equilibrium constant varies with variation in the stoichiometric coefficients of the reaction.

(iv) The value of equilibrium constant does not depend on the addition of catalyst to a reaction. It only reduces the time taken to reach equilibrium.

Applications of equilibrium constant

(i) The value of equilibrium constant gives us an idea about the extent of reaction. A greater value of K_c implies that the reaction mostly proceeds towards products, thereby, giving greater yield of products. A lower value of K_c indicates the lesser yield of products.

(ii) K_c values help us to calculate the equilibrium concentrations of various substances in the reaction.

(iii) On the basis of K_c values, we can predict the direction of a reaction.

Factors affecting the equilibrium

There are different factors which affect chemical equilibrium. The factors are concentration of the reactants or products, temperature and pressure. The change in the behaviour of the system at equilibrium due to the alteration of those factors was first enunciated by Le Chatelier.

Le Chatelier principle has been proposed to explain the effect of various factors on equilibrium.

According to this principle, when a system at equilibrium is subjected to a constraint or a change, the system tends to move to that direction in which the effect of the change is nullified.

Effect of concentration

When the concentration of any of the reactants or products in a reaction at equilibrium is changed, the composition of the equilibrium reaction mixture also changes in such a way so as to compensate the effect of concentration change.

☛ *Example* $H_2 + I_2 \rightleftharpoons 2HI$

The addition of hydrogen or iodine at equilibrium disturbs the equilibrium concentration of reactants. Hence, the reaction proceeds in that direction in which large amount of hydrogen or iodine are consumed. That means the equilibrium shifts in the forward direction. The yield of HI increases. The same shift takes place by the removal of HI from the reaction mixture at equilibrium.

However, addition of HI at equilibrium results in the shift of equilibrium in the backward direction.

☛ *Example* $K_2CrO_4 + HCl \rightleftharpoons K_2Cr_2O_7 + KCl + H_2O$

The aqueous solution of potassium chromate which is yellow in colour changes to orange coloured solution of potassium dichromate by the addition of an acid.

The addition of HCl to the reaction mixture at equilibrium shifts the reaction in the forward direction. This is indicated by the intensification of the colour of the reaction mixture. The addition of water to the equilibrium mixture shifts the reaction in the backward direction. This is marked by the fading of orange colour.

Effect of pressure

According to Boyle's law, an increase in pressure leads to a decrease in volume at constant temperature.

When a system at equilibrium is subjected to an increase in pressure, the reaction takes place in that direction which is associated with a decrease in volume. Similarly, the decrease in pressure makes the reaction proceed in that direction which is accompanied by the increase in volume.

Avogadro's law states that equal volumes of all gases contain equal number of moles. The reactions which proceed with a change in the number of moles, involve a change in volume.

Therefore, the effect of pressure is applicable to only those reactions which are accompanied by a change in the number of moles (change in volume). Pressure has no effect on those equilibria which do not involve a change in the number of moles.

☛ *Example* $N_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2\,NO_{(g)}$

$n_R = 2$ $n_p = 2$ $\Delta n = n_p - n_R = 0$

where n_R and n_P represent the number of moles of the reactants and products.

Since the number of moles of reactants is equal to the number of moles of products, change in pressure has no effect on the position of equilibrium. It results in the lower yield of HI.

Reactions associated with a change in the number of moles

Case I

Increase in the number of moles (volume)

☛ *Example* $PCl_{5\,(g)} \rightleftharpoons PCl_{3\,(g)} + Cl_{2\,(g)}$

$n_R = 1$ $n_p = 2$ $\Delta n = n_p - n_R = 2 - 1 = 1.$

The forward reaction proceeds with an increase in the number of moles. That means increase in volume takes place during the reaction. Therefore, decrease in pressure favours the forward reaction and speeds up the dissociation process. An increase in pressure shifts the equilibrium in the backward direction, thereby, suppressing the dissociation process.

Case II

Decrease in the number of moles (volume)

☛ *Example* $N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2NH_{3\,(g)}$

$n_R = 4$ $n_p = 2$ $\Delta n = n_P - n_R = -2$

The forward reaction proceeds with a decrease in the number of moles, i.e., decrease in volume. Hence, an increase in pressure favours the forward reaction and enhances the yield of ammonia. Obviously, the decrease in pressure speeds up the dissociation of ammonia into nitrogen and hydrogen. Due to this reason, high pressure (200 to 1000 atm) is maintained during the process of synthesis of ammonia by Haber process (which is the most favourable condition for getting greater yield of the products).

Effect of temperature

Most of the chemical reactions are associated with either the absorption or evolution of heat. Hence, change in temperature changes the state of equilibrium. Increase in temperature makes the reaction proceed in that direction in which more heat is absorbed. Similarly, decrease in temperature allows the reaction to take place in a direction associated with the release of heat energy.

Case I

Absorption of heat energy

Example $N_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2\,NO_{(g)} - \text{heat}$

Since the absorption of heat takes place in the forward reaction, the increase in temperature shifts the equilibrium in the forward direction. It can be concluded that for all endothermic reactions, high temperature is a favourable condition for greater yield of products.

Case II

Evolution of heat energy.

Example $N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2\,NH_{3\,(g)} + \text{heat}$

Since the forward reaction is accompanied by the release of heat energy, decrease in temperature favours forward reaction. That means for all exothermic reactions, low temperature is a favourable condition.

test your concepts

Very short-answer type questions

1. What are instantaneous reactions? Give two examples.
2. Define a reversible reaction. Give an example.
3. Rusting of iron is a _______ reaction.
4. The rate of reaction, with respect to reactants, ______ as the reaction proceeds.
5. What is meant by irreversible reaction? Give an example.
6. How are the reversible and irreversible reactions represented?
7. How can you make a reversible reaction irreversible? Give an example.
8. Define rate of reaction? How do we represent it mathematically?
9. What is meant by activation energy?
10. During a chemical reaction ______ takes place between the reactant molecules.
11. What are effective collisions?
12. K_c changes with change in _______.
13. What are negative catalysts? Give an example.
14. State Le Chatelier's principle.
15. State the law of mass action.
16. A greater value of K_c indicates a higher rate of the _______ reaction.

17. How does a catalyst influence the rate of a reaction?

18. What is meant by dynamic equilibrium?

19. Explain the dynamic nature of chemical equilibrium.

20. For every 10°C rise in temperature, the rate of reaction is generally ______.

21. Catalyst _____ the activation energy in case of decomposition of HI.

22. The rate of the forward reaction ______ with time.

23. How can you recognize the state of equilibrium?

24. "Pressure has no influence on the following equilibrium." Justify.

$N_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2\,NO_{(g)}$

25. Energy possessed by molecules resulting in effective collisions is called ______.

26. What is meant by threshold energy?

27. Units of equilibrium constant of the reaction $BaO_2(s) \rightleftharpoons BaO(s) + \frac{1}{2}O_2(g)$ is ______.

28. In the formation of SO_3 from SO_2 rate with respect to SO_2 = ______ times the rate of O_2.

29. Define equilibrium constant.

30. The units of rate of reaction are _____________.

Short-answer type questions

31. What are instantaneous reactions, slow reactions and moderate reactions? Give examples

32. How do you represent rate of a reaction with respect to reactants and products? What are the units?

33. What are the characteristics of dynamic equilibrium?

34. State law of mass action. Apply it to the following equilibria.
   (a) $2SO_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2SO_{3\,(g)}$
   (b) $3Fe_{(s)} + 4\,H_2O_{(g)} \rightleftharpoons Fe_3O_{4\,(s)} + 4H_{2\,(g)}$

35. For the reaction $H_2 + I_2 \rightleftharpoons 2HI$, express the rate of reaction with respect to all reactants and products.

36. Apply the law of mass action to the following equilibria
   (a) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$
   (b) $2NO + O_2 \rightleftharpoons 2NO_2$

37. Explain how it is possible to show the dynamic nature of chemical equilibrium by an experiment.

38. Explain the effect of concentration on rate of reaction on the basis of collision theory.

39. What are the characteristics of equilibrium constant?

40. Explain Le Chatelier's principle. Apply it to the following equilibria
   (a) $2SO_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2SO_{3\,(g)}$ + heat
   (b) $N_2O_{4\,(g)} \rightleftharpoons 2\,NO_{2\,(g)}$ - heat

41. Explain the effect of catalyst on the rate of reaction?

42. Give four examples each for reversible and irreversible reactions.

43. Explain the effect of temperature on rate of reaction on the basis of collision theory.

44. List out two applications of equilibrium constant.

45. Give differences between reversible and irreversible reactions.

Essay type questions

46. State and explain the law of mass action. Apply it to the following equilibria.

(i) $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

(ii) $NH_4HS_{(S)} \rightleftharpoons NH_{3(g)} + H_2S_{(g)}$

(iii) $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$

47. State and explain the postulates of the collision theory of reaction rates.

48. State Le Chatelier's principle and apply it to the following equilibria.

(i) $2NH_{3(g)} \rightleftharpoons N_{2(g)} + 3H_{2(g)}$ – heat

(ii) $2NO_{(g)} \rightleftharpoons N_{2(g)} + O_{2(g)}$ + heat

49. One mole of PCl_5 is subjected to heating in a one litre vessel. The number of moles of PCl_3 formed at equilibrium is 0.6. Calculate the equilibrium constant for the dissociation of PCl_5.

50. Explain the effect of temperature and concentration on the rate of reaction by an experiment.

CONCEPT APPLICATION

Concept Application Level—1

Direction for questions 1 to 7: State whether the following statements are true or false.

1. In the formation of NH_3 from nitrogen and hydrogen, rate with respect to H_2 is $\frac{2}{3}$ the rate of NH_3.

2. The rate of reaction with respect to change in the concentration of products is represented as $r = -\frac{\Delta c}{\Delta t}$

3. For the reaction $PCl_5 \rightleftharpoons PCl_3 + Cl_2$, there is no affect of pressure.

4. An exothermic reaction is favoured by increasing the temperature.

5. At equilibrium properties like pressure, concentration, density and colour remain constant.

6. The negative catalyst decreases the activation energy of a reaction.

7. The activation energy for slow reactions is high.

Direction for questions 8 to 14: Fill in the blanks.

8. The rate of reaction is positive when it is measured with respect to _________.

9. Potential energy of the products is _______ than reactants in an endothermic reaction.

10. In the formation of NO from nitrogen and oxygen increase in temperature shifts the reaction to _______.

11. If K_C for the formation of ammonia is 2 moles^{-2} lt^2, K_c for decomposition of ammonia is _______.

12. The rate of an endothermic reaction increases with ______ in temperature.

13. $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$. This reaction becomes irreversible because ________.

14. For the equilibrium reaction, dissociation of calcium carbonate K_c is equal to _________.

Direction for question 15: Match the entries in column A with the appropriate ones in column B.

15.

A.	Formation of nitric oxide	( )	a.	Increase in pressure
B.	Formation of NH_3	( )	b.	Endothermic reaction
C.	Dissociation of PCl_3	( )	c.	No effect of pressure
D.	Formation of HI	( )	d.	Exothermic reaction

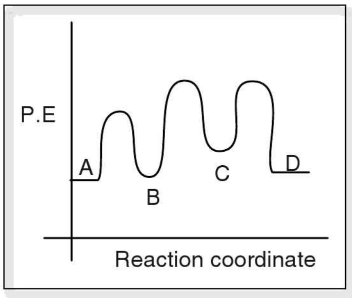
Direction for questions 16 to 45: For each of the questions, four choices have been provided. Select the correct alternative.

16. For the reaction $2X + 3Y \rightarrow 4Z + 6Q$.
   (1) rate of consumption of X is 3 times the rate of formation of Q.
   (2) rate of formation of Q is two times the rate of consumption of Y.
   (3) rate of formation of Z is half of the rate of the consumption of X.
   (4) rate of consumption of X is 3 times the rate of consumption of Y.

17. For the reaction involving the formation of 1 mole of water molecule from hydrogen and oxygen, the rate of reaction with respect to reactants is given as

   (1) $r = \frac{1}{2}\frac{\Delta[H_2]}{\Delta t}$ (2) $r = -\frac{1}{2}\frac{\Delta[H_2]}{\Delta t}$ (3) $r = -\frac{1}{2}\frac{\Delta[O_2]}{\Delta t}$ (4) $r = -\frac{\Delta[H_2]}{\Delta t}$

18. Following graph represents a reaction taking place in three steps. From this, identify the exothermic step of the reaction.



(1) $A \rightarrow B$ (2) $B \rightarrow C$ (3) $C \rightarrow D$ (4) Both (1) and (2)

19. Which of the following expressions can be used to describe the rate of reaction for the equation, $2X + Y \rightarrow X_2Y$?

(1) $\frac{-\Delta[X]}{\Delta t}$ (1) $\frac{-\Delta[X]}{\Delta t}$ (3) $-\frac{1}{2}\frac{\Delta[X]}{\Delta t}$ (4) $\frac{1}{2}\frac{\Delta[X]}{\Delta t}$

20. $2SO_2 + O_2 \rightarrow 2SO_3$ + heat. The favourable conditions for the above reaction are

(1) low pressure, high temperature. (2) high pressure, low temperature.
(3) low pressure, low temperature. (4) high pressure, high temperature.

21. In reversible reactions

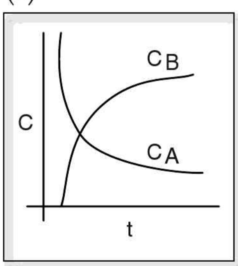
(1) concentration of reactants decreases with time
(2) concentration of products increases with time
(3) concentration of reactants decreases and then increases with time
(4) concentration of reactants and products are constant at equilibrium

22. Consider the reaction $NO + \frac{1}{2}O_2 \rightleftharpoons NO_2$. Which of the following gives the value of K_c for this equilibrium?

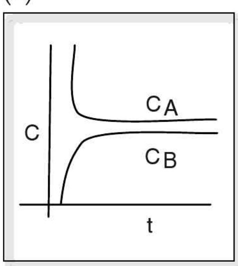
(1) $K_c = \frac{[NO][O_2]^{\frac{1}{2}}}{[NO_2]}$ (2) $K_c = \frac{[NO_2]}{[NO][O_2]}$ (3) $K_c = \frac{[NO_2]}{[NO][O_2]^{\frac{1}{2}}}$ (4) $K_c = \frac{[NO_2]}{[NO]^2[O_2]}$

23. The reaction $2A \rightleftharpoons B$ is started with 2 moles of A in one litre container. Which of the following graphs represents the equibrium of the given reaction, if 40% of the reactant A gets converted to B to attain equilibrium?

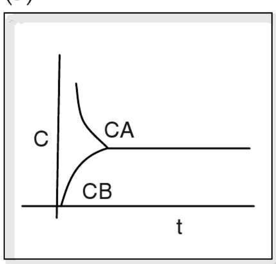
(1)



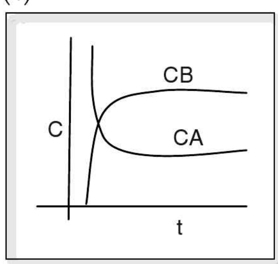
(2)



(3)



(4)



24. Which of the following is true?

(1) Energy of activated complex is more than products and less than reactants.

(2) Sum of threshold energy and minimum potential energy of reactants is equal to activation energy.

(3) For the effective collisions the colliding molecules should be associated with threshold energy.

(4) Energy of the products is always equal to energy of the reactants.

25. Which of the following equilibria can be shifted in backward direction by applying high pressure?

(1) $2NO + O_2 \rightleftharpoons 2NO_2$ (2) $CO + Cl_2 \rightleftharpoons COCl_2$

(3) $2NH_3 \rightleftharpoons N_2 + 3H_2$ (4) None of them

26. If the activation energy of forward reaction is four times the amount of energy released ($\Delta H = -10$ kcal), what could be the activation energy of the backward reaction?

(1) 50 kcal (2) 60 kcal (3) 40 kcal (4) 30 kcal

27. Which of the following factors effect the equilibrium constant?

(1) Concentration (2) Pressure (3) Catalyst (4) Temperature

28. A reaction has an equilibrium constant 22×10^{-2} mole^{-1} ℓ at a certain temperature. Which of the following equilibria corresponds to the above K_c value?

(1) $NO_{2(g)} + CO_{(g)} \rightleftharpoons NO_{(g)} + CO_{2(g)}$

(2) $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

(3) $CO_{(g)} + Cl_{2(g)} \rightleftharpoons COCl_{2(g)}$ (4)

$NH_{3(g)} + H_2S_{(g)} \rightleftharpoons NH_4HS_{(s)}$

29. What happens when temperature of a reaction mixture increases from 20°C to 60°C?

(1) The rate of the reaction increases and rate constant decreases

(2) The rate of reaction and the rate constant, decreases.

(3) The rate of reaction remains unchanged and rate constant increases.

(4) Both rate and rate constant of the reaction increases.

30. Which of the following equilibrium shifts in the backward direction by applying high pressure?

(1) $N_2O_4\,(g) \leftrightarrows 2NO_2\,(g)$ (2) $H_{2(g)} + Cl_{2(g)} \leftrightarrows 2HCl\,(g)$

(3) $N_{2(g)} + 3H_{2(g)} \leftrightarrows 2NH_{3(g)}$ (4) $PCl_{2(g)} + Cl_{2(g)} \leftrightarrows PCl_{5(g)}$

31. $2A + 4B \rightarrow 3C + 5D$

In the given reaction, the rate of reaction with respect to A, B, C and D are

(a) r_A (b) r_B

(c) r_C (d) r_D

Arrange them in the ascending order of their magnitude.

(1) a c b d (2) a d b c

(3) a b c d (4) d b c a

32. From the given graph, arrange the following in ascending order.

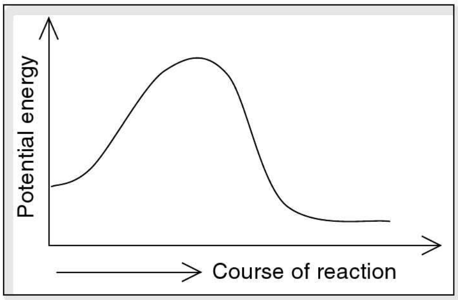
(a) Energy of the reactant

(b) Energy of the product

(c) Threshold energy

(d) Activation energy of the backward reaction

(e) Activation energy of the forward reaction.



(1) b a d e c (2) a b e d c

(3) b e a d c (4) b a e d c

33. $A_{(s)} \rightleftharpoons B_{(s)} + C_{(g)} - \text{heat}$

Arrange the conditions which are given below and applied on the above reaction in the increasing order of the yield.

(a) Low temperature and low pressure

(b) High temperature and low pressure

(c) Continuous removal of the gas C and high temperature

(d) Low temperature and high pressure

(1) a d c b (2) d a b c (3) c b d a (4) a c b d

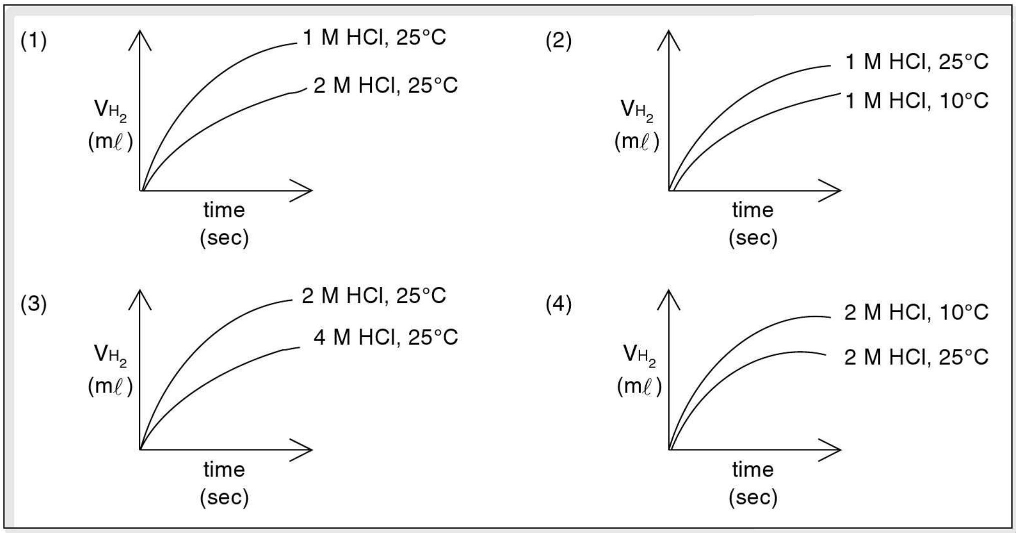
34. (a) $2A_{(g)} \rightleftharpoons 2B_{(g)} + C_{(g)}$ (b) $X_{(g)} \rightleftharpoons Y_{(g)} + Z_{(g)}$

(c) $2P_{(g)} \rightleftharpoons Q_{(g)} + R_{(g)}$ (d) $2R_{(g)} \rightleftharpoons 3S_{(g)} + 2T_{(g)}$

The above reactions are carried out in four separate closed vessels of same volume and same temperature is maintained throughout. If all the reactions are initiated with equal number of moles of the reactants and their degrees of dissociation are same, arrange them in the increasing order of pressure after the reactions attain equilibrium.

(1) c a d b (2) a c b d (3) c a b d (4) b a c d

35. $Zn + 2HCl \rightarrow ZnCl_2 + H_2\uparrow$ for this reaction which among the following graphs is true?



36. For the formation of one mole of nitric oxide from its constituents rate of formation of nitric oxide is __________ the rate of consumption of one of the reactants

(1) $\frac{1}{2}$th (2) $\frac{1}{4}$th

(3) two times (4) four times.

37. Which among the following is true regarding dynamic equilibrium?

(1) The composition of reactants varies but not products.

(2) The composition of products varies but not reactants.

(3) Rate of forward and backward reactions proceed with different speeds.

(4) Rate of forward and backward reactions proceed with equal speeds.

38. For the equilibrium, $N_2+3H_2 \rightleftharpoons$ 2NH3, if deuterium is introduced into the reaction mixture after equilibrium, the final composition of equilibrium mixture is

(1) NH_3, ND_3. (2) NH_3, ND_3, H_2, D_2, N_2.

(3) NH_3, D_2, N_2. (4) ND_3, H_2, N_2.

39. Which among the following reactions is reversible when carried out in closed container?

(1) $3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$ (2) $CaCO_3 \rightarrow CaO + CO_2$

(3) $NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$ (4) Both (1) and (2)

40. K_C for the reaction $\frac{1}{2}N_2(g)+\frac{3}{2}H_2\,(g) \rightleftharpoons NH_{3(g)}$ is

(1) $K_C = \dfrac{[NH_3]}{[N_2][H_2]}$ (2) $K_C = \dfrac{[N_2][H_2]}{[NH_3]}$

(3) $K_C = \dfrac{[NH_3]}{[N_2]^{\frac{1}{2}}[H_2]^{\frac{3}{2}}}$ (4) $K_C = \dfrac{[N_2]^{\frac{1}{2}}[H_2]^{\frac{3}{2}}}{[NH_3]}$

41. $C_{(s)} + CO_{2(g)} \rightleftharpoons 2CO_{(g)}$ – heat. The favourable conditions for the above reaction are

(1) low pressure, high temperature (2) high pressure, low temperature

(3) low pressure, low temperature (4) high pressure, high temperature

42. Which of the following statements regarding catalyst is false?

(1) It may increase or decrease rate of a reaction.

(2) It is highly specific in its action.

(3) It remains unchanged at the end of a chemical reaction.

(4) A catalyst changes the state of equilibrium in a chemical reaction.

43. In a certain reaction $2A + B \Leftrightarrow 4C$, the concentration of A decreases from 5×10^{-3} mol/lit to 2×10^{-3} mol / lit in 30 sec. What is the rate with respect to 'C'?

(1) 5×10^{-5} mole ℓ^{-1} sec^{-1} (2) 5×10^{-5} ℓ^{-1} mole^{-1} sec^{-1}

(3) $2\ \ell\ 10^{-4}$ mole ℓ^{-1} sec^{-1} (4) 2×10^{-4} ℓ^{-1} mole^{-1} sec^{-1}

44. The activation energy for the forward reaction of $A + B \rightleftharpoons C + D$ is 50 kJ/mole. If the energy of the products is 10 kJ/mole more than that of reactants, the activation energy for the formation of reactants from the products is

(1) 60 kJ / mole (2) 30 kJ / mole
(3) 40 kJ / mole (4) 50 kJ / mole

45. **Assertion (A):** In the preparation of oxygen from $KClO_3$, MnO_2 acts as a positive catalyst.

Reason (R): MnO_2 decreases the activation energy of the reaction.

(1) Both A and R are correct and R is the correct explanation of A.
(2) Both A and R are correct and R is not the correct explanation of A.
(3) A is correct and R is wrong.
(4) A is wrong and R is correct.

Concept Application Level—2

1. Draw energy profile diagrams for exothermic and endothermic reactions.

2. If one mole of nitrogen pentoxide undergoes thermal decomposition to form oxide of nitrogen and oxygen, explain how rate of formation of products is related to rate of consumption of reactants.

3. K_c for the reaction $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$ has a value of 0.04. What would be the value of K_c for the reverse reaction?

4. Draw the energy profile diagram and also calculate the activation energy of the forward reaction for a reaction $A + B \leftrightarrows C + D$. Energy released is equal to twice the activation energy of the forward reaction and Ea of the backward reaction is 120 kj/mole.

5. In a hypothetical reaction $X \rightarrow Y$, the activation energy of the forward and backward reactions are 13 kj/mole and 7 kj/mole respectively. Calculate heat of the reaction.

6. For an equilibrium, $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$, if 'x' is the degree of dissociation at equilibrium, derive the value of K_c for the given reaction. Also give K_c for the equilibrium, if the reaction is started with one mole of hydrogen iodide.

7. What is the effect of pressure and volume on the decomposition of HI and also explain the role of catalyst.

8. Predict the effect of pressure on the following equilibria.

(i) $2Cu(NO_3)_{2(s)} \rightleftharpoons 2CuO_{(s)} + 4NO_{2(g)} + O_{2(g)}$
(ii) $C_{(s)} + CO_{2\,(g)} \rightleftharpoons 2CO_{(g)}$
(iii) $I_{2(s)} + 5F_{2(g)} \rightleftharpoons 2IF_{5(g)}$
(iv) $FeO_{(s)} + CO_{(g)} \rightleftharpoons Fe_{(s)} + CO_{2(g)}$

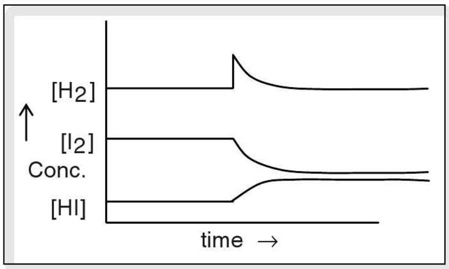
9. 30 moles of PCl_5 is placed in a 2 ℓ reaction vessel and heated. K_c for the reaction is 0.5. What is the composition of the mixture at equilibrium?

$PCl_5 \rightleftharpoons PCl_3 + Cl_2$.

10. Explain the effect of the addition of inert gas to the following equilibria (i) at constant pressure (ii) at constant volume.

(a) $H_{2(g)} + Cl_{2(g)} \rightleftharpoons 2HCl_{(g)}$ (b) $CO_{(g)} + Cl_{2(g)} \rightleftharpoons COCl_{2(g)}$ (c) $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

11. Equilibrium of the reaction of formation of hydrogen iodide from hydrogen and iodine is disturbed. The graph obtained is given below. How can you apply Le Chatelier principle to the equilibrium and explain the graph.



12. Consider the reactions

(i) $CO_{(g)} + H_2O_{(g)} \leftrightarrows CO_{2(g)} + H_{2(g)} \rightarrow K_1$

(ii) $CH_{4(g)} + H_2O_{(g)} \leftrightarrows CO_{(g)} + 3H_{2(g)} - K_2$

(iii) $CO_{4(g)} + 2H_2O_{(g)} \leftrightarrows CO_{2(g)} + 4H_{2(g)} \rightarrow K_3$

Give the relation between K_1, K_2, K_3. [K_1, K_2 and K_3 are the equilibrium constants of the respective reactions.]

13. For the reaction, A + 2B → 5C + 3D the rate of formation of C is 0.06 moles/l/sec and final concentration of B is 0.04 moles/l at 2 sec. Find out the initial concentration of B and also the change in concentration of B.

14. K_c for the reaction in the formation of ammonia is equal to 3×10^{-2}. Predict whether the reaction with the following concentrations is at equilibrium. If not, predict the direction in which the reaction will proceed to reach equilibrium?

$[NH_3] = 0.5 \times 10^{-3}$ M

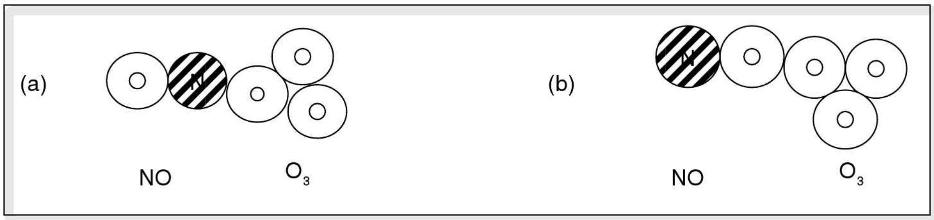
$[N_2] = 0.5 \times 10^{-6}$ M

$[H_2] = 1 \times 10^{-3}$ M

15. How can you distinguish between equilibrium position and equilibrium constant? Give an example.

Directions for questions 16 to 25: Application Based Questions

16. The students of class 9th of City International school were attending an audio-visual session on the collision theory of chemical kinetics. When they were viewing the slides given below, their instructor asked them to guess which of the following could be the effective collision and justify their answer.



17. Teena and Neena while reading books on ozone depletion came across some information which is given below. Both chlorofluorocarbons (freons) and oxides of nitrogen can catalyse the destruction

of ozone in the upper layers of the atmosphere. The activation energies of the reactions which cause ozone depletion are 2.1 kJ/mole in the presence of freons and 11.9 kJ/mole in the presence of the oxides of nitrogen. Based on the above information, Teena and Neena had an argument. According to Teena, freons are more harmful. In Neena's opinion, the oxides of nitrogen cause more harm. Can you justify who is correct?

18. $aX \rightarrow bY$. The initial concentration of X is 0.6 M. After 10 minutes interval of time the concentration of X and Y are found to be 0.3 M and 0.2 M respectively. Calculate the stoichiometric coefficients and rate of reaction with respect to X and Y.

19. In order to avoid spoilage, food is kept in refrigerators. Explain the principle involved.

20. Pinku took two closed vessels for carrying out two different reversible reactions. The first reaction was the thermal decomposition of cupric nitrate and the second reaction was the synthesis of iodine pentaflouride from its constituents. After the reactions reached the state of equilibrium, he changed the pressure on both the reaction mixtures keeping the other parameters unaltered. In the first reaction vessel, he observed that the intensity of brown colour had been decreasing and in the other reaction vessel, the intensity of purple colour had been increasing. Explain the reason behind such observation.

21. Niki, Nita, and Nitu study in the 9th standard. They were carrying out three different reversible reactions. When the reactions attained their state of equilibrium, they measured the concentration of each gas present in the equilibrium mixture and calculated the K_C value of each reaction. They were provided with the energy profile diagrams of each reaction. From this information, they prepared the following table.

From the data given in the table, calculate which reaction will take the maximum time to reach equilibrium and which one will give the maximum yield?

Reaction – 1	14×10^{-3}	25 kJ/mole
Reaction – 2	7×10^{-2}	50 kJ/mole
Reaction – 3	8×10^{-1}	20 kJ/mole

22. PCl_5 can be formed by heating a mixture of Cl_2 and PCl_3. If 1 mole each of Cl_2 and PCl_3 are mixed and the reaction is allowed to take place in a closed container fitted with a pressure gauge, then predict the changes in the pressure gauge and explain with suitable reason.

23. Write KC value for the equilibrium $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ and relate it to the K_C values for the following equilibria.

(a) $\frac{1}{2}N_{2(g)} + \frac{3}{2}H_{2(g)} \rightleftharpoons NH_{3(g)}$ (b) $2N_{2(g)} + 6H_{2(g)} \rightleftharpoons 4NH_{3(g)}$

24. We can prepare nitrogen dioxide gas by the addition of conc. HNO_3 to copper turnings. But the NO_2 gas formed, has a tendency to dimerise to dinitrogen tetroxide and the equilibrium $2NO_2 \rightleftharpoons N2O_4 + 57.2$ kJ is established. Two sealed test tubes containing the reaction mixtures of same composition are kept in water bath separately which are at high temperature and low temperature respectively. What observations are found in the two baths? Explain.

25. Equilibrium concentration of SO_2Cl_2 formed from 3 moles of SO_2 and 4 moles of Cl_2 present in a litre flask is 1.5 mole/lit. Calculate K_C.

Concept Application Level—3

1. In the manufacture of sulphuric acid industrially, the key step involved is formation of SO_3. Higher the yield of SO_3, greater is the yield of sulphuric acid and more over lesser is the pollution effect. K_c at relatively higher temperatures (400°C) is found out to be very high and their values gradually decrease with increase in temperature. Based on the data given, predict the favourable conditions for the better yield of SO_3.

2. For a reaction, the instantaneous rate of reaction with respect to x, y and z is expressed as $r = -\frac{1}{2}\frac{\Delta[x]}{\Delta t} = -\frac{1}{3}\frac{\Delta[y]}{\Delta t} = \frac{1}{2}\frac{\Delta[z]}{\Delta t}$. What would be the stoichiometric equation for the reaction?

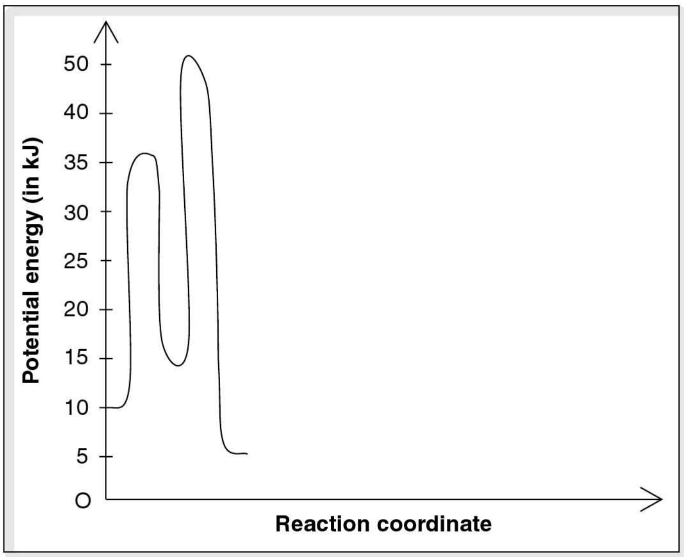
3. What is the relation between equilibrium constant and the stability of reactants? Justify.

4. Reactants A and B can react to give two different products C and D in two different reactions. The two reactions take place in two different mechanisms and D is found to be more energetically stable than C. But, product C was found in larger amounts. How do you account for this?

5. When ammonia is strongly heated with oxygen, the rate of disappearance of ammonia is found to be 2.9×10^{-2} mol $l^{-1}s^{-1}$ during the measured time interval. Calculate the rate of appearance of nitric oxide and water.

Directions for questions 6 to 10: Application Based Questions

6. The following diagram represents the energy profile diagram for a two step reaction. Calculate the ratio of change in heat energy involved in step – I to step – II.



7. The rate for the reaction X $\rightarrow$ Y is studied at 25°C by varying conditions of reaction. In experiment (i) the rate of reaction is found out to be 5×10^{-2} mole ℓ^{-1} sec^{-1}. In experiment (ii) the rate of reaction is found out to be 8×10^{-1} mole ℓ^{-1} sec^{-1}. Account for the variation in rate of reaction.

8. Explain the effect of the addition of inert gas to the following equilibria (i) at constant pressure (ii) at constant volume.

(a) $H_{2(g)} + Cl_{2(g)} \rightleftharpoons 2HCl_{(g)}$

(b) $CO_{(g)} + Cl_{2(g)} \rightleftharpoons COCl_{2(g)}$

(c) $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

9. A 3 ℓ flask contains 0.5 moles of sulphur dioxide at 127°C temperature. Some amount of oxygen is introduced into the flask along with a catalyst. When the pressure reached 8.2 atm, 0.3 moles of SO_3 is formed and there is no further change in the pressure of the reaction mixture. Calculate K_c value for the above reaction.

10. "Melting of ice takes place slowly at higher altitudes". Justify this statement by applying the principle of equilibrium.

key points for selected questions

Very short-answer type questions

1. Reactions completed in fraction of seconds.
   Example: Sodium exposed to air catches fire immediately
   Neutralization reaction between sodium hydroxide and HCl

3. Slow

4. decreases

8. Rate of change of concentration of reactants or products in unit time.
   $$r = \frac{\Delta C}{\Delta T}$$

9. Difference between threshold energy and energy possessed by molecules.

10. Boyles, Charles

11. Collisions leading to the transformation of reactants to products.

12. Temperature

13. Catalyst which decrease the rate of reaction.
    Example: Glycerine retards decomposition of H_2O_2.

14. System at equilibrium is subjected to a constraint or change, the system tends to shift in that direction in which the effect of the change is nullified.

15. Rate of a reaction is proportional to the product of molar concentration of reactants

16. 14 : 3

17. Alters the rate of reaction without undergoing any net change.

18. Both forward and backward reactions proceed with same speed.

20. two times

21. decreases

25. 54 N

26. Minimum energy required by molecules for effective collisions.

27. decreases by 66.67%.

28. C_4H_{10}

29. Ratio of product of concentration of products to the product of concentration of reactants raised to the power of their coefficients.

30. mole ℓ^{-1} sec^{-1}

key points for selected questions

Short-answer type questions

32. (i) Change in concentration per unit time.
(ii) Appropriate sign
(iii) Units of concentration in moles/l and time in seconds.

33. (i) concentration of reactants and products.
(ii) constancy of observable properties
(iii) change in direction.
(iv) addition of catalyst
(v) change in concentration.

35. Relation between rate of reaction and stoichiometric coefficients of reactants and products.

37. (i) Taking a mixture of isotopes of hydrogen (hydrogen and deuterium) along with nitrogen
(ii) Composition at equilibrium

38. Number of molecules per unit volume and number of effective collisions.

39. (i) Constant at constant temperature.
(ii) Direction of reaction
(iii) Stoichiometric coefficients
(iv) Not affected by catalyst.

41. Reaction path and activation energy.

43. (i) Increase in kinetic energy of molecules with increase in temperature.
(ii) Increase in collision frequency.

Essay type questions

46. (i) Rate of reaction and concentration of reactants
(ii) Equilibrium constant–Ratio
(iii) Stoichiometric coefficients–exponents of concentration terms.
(iv) Solid substances should not be included in the expression.

47. (i) Effective collisions and threshold energy.
(ii) Activation energy.
(iii) Activated complex.

48. (i) Shift of equilibrium by changing the external factors.
(ii) Concentration, pressure and temperature.
(iii) Exothermic and endothermic reactions–effect of temperature.

KEY

Concept Application Level—1

True or false

1. False
2. False
3. False
4. False
5. True
6. False
7. True

Fill in the blanks

8 products
9. greater
10. forward direction
11. 0·5 moles^2/l^2
12. increase
13. CO_2 gaseous product escapes out.
14. concentration of carbon dioxide.

Match the following

15. A : b

B : d

C : a

D : c

Multiple choice questions

16. Choice (2)

17. Choice (4)

18. Choice (3)

19. Choice (3)

20. Choice (2)

21. Choice (4)

22. Choice (3)

23. Choice (2)

24. Choice (3)

25. Choice (3)

26. Choice (1)

27. Choice (4)

28. Choice (3)

29. Choice (4)

30. Choice (1)

31. $r = \frac{-1}{2}\frac{\Delta[A]}{\Delta t} = \frac{-1\Delta[C]}{4\,\Delta t} = \frac{1}{3}\frac{\Delta[C]}{\Delta t} = \frac{1}{5}\frac{\Delta[D]}{\Delta t}$

(i) r_A

(ii) r_C

(iii) r_B

(iv) r_D

Choice (1)

32. (i) Energy of the product

(ii) Energy of the reactant

(iii) Activation energy of the forward reaction.

(iv) Activation energy of the backward reaction

(v) Threshold energy

Choice (4)

33. (i) Low temperature and high pressure

(ii) Low temperature and low pressure

(iii) High temperature and low pressure

(iv) Continuous removal of the gas 'C' and high temperature

Choice (2)

34. (i) $2P(g) \rightleftharpoons Q(g) + R(g)$

(ii) $2A(g) \rightleftharpoons 2B(g) + C(g)$

(iii) $X(g) \rightleftharpoons Y(g) + Z(g)$

(iv) $2R(g) \rightleftharpoons 3S(g) + 2T(g)$

Choice (3)

35. Rate of reaction is directly proportional to temperature.

Choice (2)

36. $N_2 + O_2 \rightarrow 2NO$

$$r = \frac{-\Delta[N_2]}{\Delta t} = \frac{-\Delta[O_2]}{\Delta t} = \frac{1}{2}.\frac{\Delta[NO]}{\Delta t}$$

$\Rightarrow$ rate of formation of NO = 2. rate of consumption of N_2 or O_2.

Choice (3)

37. At dynamic equilibrium rate of forward and backward reactions are equal.

Choice (4)

38. $2N_2 + 3H_2 + 3D_2 \rightleftharpoons 2NH_3 + 2ND_3$.

Choice (2)

39. $3Fe + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2$

$CaCO_3 \rightleftharpoons CaO + CO_2$

Choice (4)

40. $\frac{1}{2}N_2 + \frac{3}{2}H_2 \rightleftharpoons NH_3$

$$K_C = \frac{[NH_3]}{[N_2]^{\frac{1}{2}}[H_2]^{\frac{3}{2}}}$$

Choice (3)

41. $C + CO_{2(g)} \rightleftharpoons 2CO_{(g)} - \text{Heat}$

$n_P = 2, n_R = 1$

Since $n_P > n_R \Rightarrow$ low pressure favours forward reaction.

Since the reaction is endothermic high temperature favours forward reaction.

Choice (1)

42. A catalyst does not change the state of equilibrium in a chemical reaction.

Choice (4)

43. The rate of reaction with respect to

$$A = \frac{\text{Change in concentration}}{\text{time}}$$

$$\frac{d[A]}{dt} = \frac{5 \times 10^{-3} - 2 \times 10^{-3}}{30} = \frac{3 \times 10^{-3}}{30}$$

$$= 1 \times 10^{-4} \text{ mol / lit's}$$

reaction is $2A + B \rightarrow 4C$

$$\frac{1}{2}\frac{d[A]}{dt} = \frac{1}{4}\frac{d[C]}{dt}$$

The rate of reaction in term of 'C' is

$$\frac{\Delta[C]}{\Delta t} = \frac{4}{2} \times \frac{\Delta[A]}{\Delta t}$$

$$= 2 \times \frac{d[A]}{dt} = 2 \times 1 \times 10^{-4} = 2 \times 10^{-4} \text{mole}/\ell^{-1}.\text{sec}$$

Choice (3)

44. Activation energy for forward reaction 50 kJ/mole. If the energy of the products is 10kJ/mole is more than that of reactants the activation energy for the formation of reactants from the products is 40 kJ / mole.

Choice (3)

45. Positive catalyst decreases the activation energy of the reaction. Hence the rate of reaction increases.

Choice (1)

Concept Application Level—2

Key points

1. (i) Energy charges during the formation of a product.
(ii) Comparison of energy of the reactant and product in case of endothermic and exothermic reaction.
(iii) Relation among the energy of the reactant, product and activation energy.

2. (i) Balanced chemical equation.
(ii) Relation between rates of reaction of reactants and products from balanced chemical equation.

3. (i) Identification of the colourless gas.
(ii) 25

4. (i) Comparison of energies of reactants and products.
(ii) Determination of empirical formula.
(iii) Relation between molecular weight and vapour density.
(iv) Determination of molecular formula.
(iv) 40 kj/mole

5. (i) Relation between ΔH, E_a and E_b.
(ii) Calculation of heat of reaction from the given E_a and E_b values.
(iii) 6 kj/mole

6. (i) $K_c = \frac{[HI]^2}{[H_2][I_2]}$

$$K_c = \frac{[\text{Products}]^{\text{coefficients}}}{[\text{Reactants}]^{\text{coefficients}}}$$

(ii) Composition at equilibrium.
(iii) Calculation of k_c.

7. (i) Balanced chemical equation.
(ii) Comparison of number of moles of reactants and products.
(iii) Effect of change in pressure and volume on equilibrium.
(iv) Effect of catalyst on equilibrium composition and K_c.

8. (i) Le Chatelier Principle
(ii) Comparison of the number of moles of gaseous reactants and products.
(iii) Effect of number of moles on volume.
(iv) Effect of pressure on volume.
(v) Shift of reaction to decrease the effect of pressure.

9. (i) $K_c = \dfrac{[\text{Products}]^{\text{coefficients}}}{[\text{Reactants}]^{\text{coefficients}}}$

(ii) Calculation of concentration of the reactants and products at equilibrium.

(iii) 5 moles of PCl_3, 5 moles of Cl_2 and 25 moles of PCl_5.

10. (i) Le Chatelier Principle

(ii) Factors affecting equilibria.

(iii) Change in concentration on the addition of inert gas at constant pressure.

(iv) Change in concentration on the addition of inert gas at constant volume.

(v) Effect of change in concentration on the equilibrium.

11. (i) Equilibrium position

(ii) Comparison of the concentration of components before the change in concentration of H_2.

(iii) Sudden change in the concentration of H_2.

(iv) Comparison of the change in concentration of components after the change in concentration of H_2.

(v) Effect of the change in concentration on the equilibrium.

12. (i) Calculation of equilibrium constants for respective reactions.

(ii) Relation between K_1, K_2, K_3 from the calculated K_1, K_2 and K_3.

13. (i) Calculation of rates of a reaction with respect to B and C.

(ii) Relation between rates of reaction with respect to B and C

(iii) Calculation of rate of B with respect to C.

(iv) Calculation of initial concentration from rate of 'B'.

(v) 0.088 mole/ℓ

14. (i) $N_2 + 3H_2 \rightarrow 2\,NH_3$

(ii) Balanced chemical equation.

(iii) Calculation of the ratio of products and reactants where the co-efficients are raised to their powers.

(iv) Comparison of the above ratio with the given K_c.

(v) Concentration of reactants and products.

15. (i) Balanced chemical equation for the formation of SO_3.

(ii) Relation between K_c and temperature.

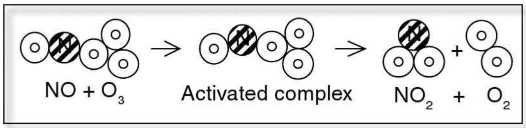
(iii) Type of reaction based on change in K_c with temperature.

(iv) Effect of temperature on equilibrium.

(v) Temperature, pressure conditions required to increase the yield of SO_3.

(vi) Effect of change in concentrations of SO_2, O_2, SO_3 on equilibrium.

16.



The collisions represented by figure (a) are effective collisions. The collisions with threshold energy result in a reaction. Apart from this, the reactants which collide should have a proper orientation. In figure (b), the nitrogen atom of NO is not near enough to make a bond with any of the oxygen atoms of ozone. In figure (a), the NO molecule collides with O_3 where the direction in which both the reactants collide is perfect enough to result in a chemical reaction.

17. Activation energy is the difference between the threshold energy of the reaction and the kinetic energy of the colliding molecules. That means it gives the energy barrier the reactant molecules have to cross in order to result in effective collisions. The reaction with less activation energy can cross the energy barrier easily and hence the reaction takes place at a faster rate. The reaction with a high activation energy has a greater energy gradient. As a result,

the reaction is comparatively slower. In the case of the destruction of ozone in the upper layers of the atmosphere, the activation energy for the reaction catalysed by chlorofluorocarbons is less that is, 2.1 kJ/mole. Hence, it takes place faster when compared to the reaction catalysed by nitric oxide which has a higher activation energy of 11.9 kJ/mole. From this, it is obvious that chlorofluorocarbons are more harmful to the environment with respect to ozone depletion.

18. aX → bY

0.6	0	Initial concentration
0.3	0.2 M	Final concentration

$$r = \frac{-1}{a}\frac{\Delta[X]}{\Delta t} = \frac{1}{b}\frac{\Delta[Y]}{\Delta t} \Rightarrow \frac{-1}{a}\frac{(0.3-0.6)}{10}$$

$$= \frac{1}{b}\frac{(0.2-0.0)}{10}$$

$\Rightarrow \frac{0.3}{a} = \frac{0.2}{b} \Rightarrow$ Least possible values of a and b are 3 and 2 respectively.

Rate with respect to X $= \frac{\Delta[X]}{\Delta t} = \frac{0.3}{10 \times 60}$

$= 0.0005$ mole ℓ^{-1} sec^{-1}

Rate with respect to Y $= \frac{0.2}{10 \times 60}$

$= 0.00033$ mole ℓ^{-1} sec^{-1}

19. The rate of any chemical reaction increases exponentially with temperature. When the food is exposed to hot conditions (in summer) that is high temperatures, due to the increase in rate of biochemical reactions taking place in the food, it gets spoiled. If the food is kept in refrigerators, the low temperature decreases the rates of the biochemical reactions considerably. Hence, they are not spoiled.

20. Decomposition of cupric nitrate

$2Cu(NO_3)_2 \rightleftarrows 2CuO + 4NO_{2(g)} + O_{2(g)}$

Brown

Synthesis of iodine penta fluoride

$I_{2(g)} + 5F_{2(g)} \rightleftarrows 2IF_{5(g)}$

Purple

Since the intensity of brown colour was decreasing in the first reaction, it can be concluded that the pressure on the equilibrium mixture increased.

Since the intensity of purple colour was increasing in the second reaction, it can be concluded that the pressure on the equilibrium mixture decreased.

According to Le Chatelier principle, if the pressure increases, the reaction proceeds in a direction in which the number of moles decreases and vice versa.

21. More the Ea value, more is the time taken for the completion of a reaction. Hence, reaction-2 takes more time for completion.

More the K_C value more is the yield of the products. The yield from reaction–3 is the maximum.

22. $PCl_{3(g)} + Cl_{2(g)} \Leftrightarrow PCl_{5(g)}$. The number of moles of products is half the number of moles of the reactants. If the reaction goes to completion, we should expect that the pressure indicator should show half of the initial pressure. But, the pressure indicator indicates a higher pressure than half of the initial pressure and it is less than the initial pressure. This indicates that the reaction did not go to completion. Later if the pressure indicator shows constant value without further rise or fall in pressure, it implies that the reaction is in equilibrium. The pressure gauge initially shows decrease followed by an increase ultimately reaching a constant position which indicates the equilibrium.

23. $N_2 + 3H_2 \rightleftharpoons 2NH_3$

$$K_{C_1} = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

(a) $\frac{1}{2}N_{2(g)} + \frac{3}{2}H_{2(g)} \rightleftharpoons NH$

$$K_{C_2} = \frac{[NH_3]}{[N_2]^{\frac{1}{2}}[H_2]^{\frac{3}{2}}}$$

$$K_{C_2} = \sqrt{K_{C_1}}$$

(b) $2N_{2(g)} + 6H_{2(g)} \rightleftharpoons 4NH_{3(g)}$

$$K_{C_3} = \frac{[NH_3]^4}{[N_2]^2\,[H_2]^6}$$

$$K_{C_3} = K_{C_1}^2$$

24. $2NO_2 \rightleftharpoons N_2O_4$ + 57.2 kJ is an exothermic reaction. According to Le Chatelier principle, low temperature favours forward reaction. Backward reaction is endothermic. High temperature favours the backward reaction.
A sealed test tube containing the reaction mixture when kept in a hot water bath favours the backward reaction and equilibrium is shifted towards the left. The product mostly consists of NO_2 which is reddish brown in colour.
When a sealed test tube containing the same reaction mixture is kept in water bath of lower temperature, the forward reaction is favourable and equilibrium shifts to the right. The product mostly exists in the form of colourless N_2O_4.
The test tube in the hot water bath has a dark brown coloured product in it. The test tube kept in the water bath of lower temperature has a light coloured product in it.

25.

	SO_2	+ Cl_2	$\rightleftharpoons$ SO_2Cl_2
Initial No. of moles	3	4	0
at equilibrium	3 – x	4 – x	x

Concentration of SO_2Cl_2 at equilibrium is 1.5 moles.
x = 1.5 moles / ℓ
Concentration of SO_2 at equilibrium
= 3 – 1.5 = 1.5 moles / ℓ
Concentration of Cl_2 at equilibrium = 4 – 1.5
= 2.5 moles/lit

$$\therefore K_C = \frac{[SO_2Cl_2]}{[SO_2][Cl_2]} = \frac{1.5}{1.5 \times 2.5} = 0.4\ \ell/\text{mole}$$

Concept Application Level—3

Key points

1. (i) Relation between the stoichiometric coefficients and rate of reaction.
(ii) Identification of the reactants and products.
(iii) Rate of disappearance and appearance of reactants and products.
(iv) Balanced chemical equation.

2. (i) Relation between concentration of products, reactants and K_c.
(ii) Relation between rates of a reaction and stability of the reactants.
(iii) Relation between K_c and stability of reactants.
(iv) Relation between K_c and rate of reaction

3. Activation energy

4. (i) Factors affecting the rate of reaction and the amount of product formed.
(ii) Comparison of activation energy of both mechanisms.
(iii) Effect of activation energy on the amount of product formed.

5. (i) Balanced chemical equation for the reaction involved.
(ii) 4.35×10^{-2} mol lt^{-1} s^{-1}
(iii) Comparison of stoichiometric coefficients of reactants and products in the balanced chemical equation.
(iv) Comparison of the rate of appearance of NO, H_2O with the rate of disappearance of ammonia.
(v) Calculation of rate of appearance of NO and H_2O.

6. First step is endothermic and the amount of the energy absorbed is 15 – 10 = 5 kJ.
Second step is exothermic and the amount of the energy liberated is 15 – 5 = 10 kJ.
$\therefore$ Ratio of energy = 5 : 10 = 1 : 2

7. Rate of reaction depends upon concentration, catalyst etc at a given temperature.

The more the initial concentration of reactant, the more is the rate of reaction. Since in the experiment (ii) the rate is higher the initial concentration of X could be more.

Rate of catalysed reaction is greater than that of uncatalysed reaction. Since in the experiment (ii) the rate of reaction is higher a positive catalyst might have been used.

8. Collisions due to inert gas with reactants does not lead to chemical reactions. The addition of inert gas has no effect on the equilibrium involving no change in the number of moles either at constant pressure or at constant volume.

For equilibrium involving change in the number of moles, addition of inert gas has an effect at constant pressure. However, it has no effect at constant volume. Thus for the reaction

$H_2 + Cl_2 \rightleftharpoons 2HCl$ there is no effect

For the reactions where there is an increase in the number of moles, the addition of inert gas further increases the number of moles but per unit volume there is decrease in number of moles. Hence reaction shift in that direction associated with more number of moles. As a result, the equilibrium shifts towards the right. The forward reaction takes place faster.

Ex : $N_2O_4 \rightleftharpoons 2NO_{2(g)}$

For the reactions where there is a decrease in the number of moles, the addition of inert gas increases the rate of backward direction. As a result, the equilibrium shifts towards left.

Ex : $CO_{(g)} + Cl_{2(g)} \rightleftharpoons COCl_{2(g)}$

9. $V = 3\ \ell$

$P = 8.2$ atm

$R = 0.0821\ \ell$ atm K^{-1} $mole^{-1}$

$T = 127 + 123 = 400$ K

Total number of moles at equilibrium are

$$n = \frac{PV}{RT} = \frac{8.2 \times 3}{0.0821 \times 400} = 0.75$$

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

Number of moles of SO_2

at equilibrium $0.5 - 0.3\ n_{O_2}\ 0.3 = 0.2$

$\therefore$ number of moles of O_2 at equilibrium

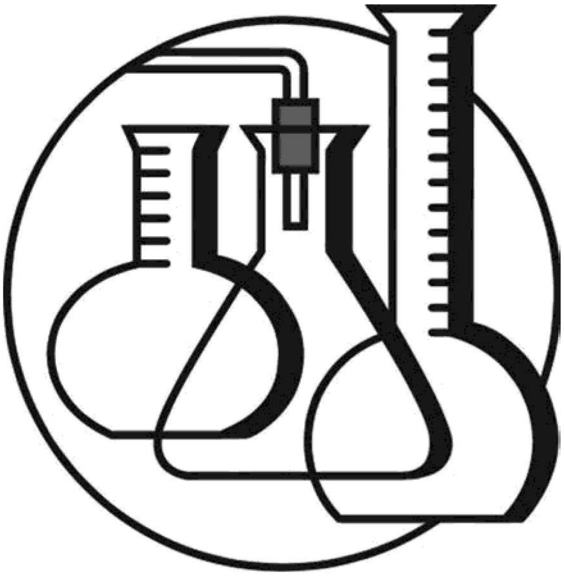
$$n_{O_2} = n - \left(n_{SO_3} + n_{SO_2}\right) = 0.75 - 0.5 = 0.25$$

$$K_c = \frac{(0.3)^2}{(0.2)^2 \times (0.25)} = 9.$$

10. Melting of ice to water is associated with decrease in volume. Since the process is associated with decrease in volume, increase in pressure favours the process. Therefore, melting of ice takes place at a faster rate at higher pressure. But at higher altitudes, the pressure being low, the process takes place slowly since the backward process takes place at a faster rate.

7

Water, Solution, Solubility and Hydrogen



INTRODUCTION

The uniqueness of the planet earth lies in it being inhabited by a wide variety of flora and fauna. Water is one of the most precious natural resources which imparts this uniqueness to the planet. The significant role played by water in the sustenance of life owes not only to its abundance but also to its characteristic properties such as its state of existence, its ability to undergo interconversion to other states and above all to its universal solvent property.

The universal solvent property of water which means the ability to form solutions with a wide range of substances contributes for all life processes occurring in nature. At the same time, the most prevalent hazard of water pollution can also be attributed to the same property. In short, either way water and solutions is considered as an invariable part of chemistry.

Water in the liquid state is found in oceans and seas. Apart from this, liquid water is also found in rivers, lakes, streams and other water bodies. Water available in the above sources is called surface water. Water present in oceans and seas contains appreciable proportions of dissolved salts, predominantly sodium chloride. The presence of these salts imparts salty taste to water and this water is hence called saline water.

In addition to surface water, water is also available under the earth's surface. This is called underground water. This water is stored due to the seepage of rain water through the soil. The underground water may come out in the form of springs. This can be drawn out artificially by digging wells or with the help of tube wells.

Water obtained from different sources contains different salts in dissolved state. The physical properties of water are by and large attributed to the salts dissolved in it. Dissolution of soap and formation of lather in water also depends on the presence of the dissolved salts.

Water that dissolves soap and readily produces lather is known as soft water. Rain water and distilled water are the examples of **soft water**.

Water that produces a curdy substance on the addition of soap and cannot lather easily is known as **hard water**. This happens due to the presence of dissolved salts like chlorides, sulphates and bicarbonates of calcium and magnesium. The constituents of soap are soluble sodium salts of higher fatty acid like palmitic acid, stearic acid or oleic acid. When hard water is treated with soap, reactions take place among the soluble salts of calcium, magnesium present in hard water and the constituent salts of soap producing insoluble palmitate, stearate or oleate of calcium and magnesium in the form of curdy precipitate which prevents the formation of lather.

Hardness of water can be classified into two types depending on the ease of removal of it. These are **temporary hardness** which can be removed by boiling and **permanent hardness** which cannot be removed by simple boiling.

Removal of hardness

(i) Temporary hardness	By boiling: $Ca(HCO_3)_2 \rightarrow CaCO_3 + CO_2 + H_2O$ $Mg(HCO_3)_2 \rightarrow MgCO_3 + CO_2 + H_2O$ Precipitates of insoluble $CaCO_3$ and $MgCO_3$ can be filtered off.
(ii) Temporary and permanent hardness	By passing through ion exchange resins: Removal of cation: $2RCOO^-H^+ + Ca^{+2} \rightarrow (RCOO)_2Ca + 2H^+$ acid resin $2RCOO^-H^+ + Mg^{+2} \rightarrow (RCOO)_2Mg + 2H^+$ acid resin Removal of anion: $RNH_3^+OH^- + Cl^- \rightarrow RNH_3Cl + OH^-$ basic resin $2RNH_3^+OH^- + SO_4^{-2} \rightarrow (RNH_3)_2SO_4 + 2OH^-$ basic resin [acid and basic resins are giant organic molecules where R represents the alkyl group]

After prolonged use, resins lose their activity and are hence required to be reactivated. Acid resin can be regenerated by using a strong acid like H_2SO_4, whereas regeneration of basic resin is carried out by treating it with strong base like NaOH.

$$\underset{\text{acid resin after use}}{(RCOO)_2Ca} + H_2SO_4 \rightarrow \underset{\text{regenerated acid resin}}{2RCOOH} + Ca^{+2} + SO_4^{-2}$$

$$\underset{\text{basic resin after use}}{RNH_3Cl} + NaOH \rightarrow \underset{\text{regenerated basic resin}}{RNH_3OH} + Na^+ + Cl^-$$

Important Properties of Water

Solvent property

The significance of 'solutions' in chemistry originates from the universal solvent property of water. Water can dissolve many substances in it due to its high dielectric constant. Dielectric constant is the property of a solvent to reduce the force of attraction between the ions (cations and anions) of inorganic compounds. It can also dissolve a large number of organic compounds like glucose, sugar, alcohol etc. Due to the ability to dissolve a wide range of substances in it, water is called the universal solvent.

Day to day human activities like washing, cooking, cleaning etc. and all life processes occurring in nature involve the formation of solutions with water. Therefore, the ability of water to form solutions is responsible for sustenance of life. On the other hand, the same characteristic forms the basic cause for adding pollutants to water. In whichever way it is considered, the ability of water to form solutions influences the survival of man on earth.

A solution is a homogeneous mixture of two or more substances. The proportion of the constituents of the solution can be varied within certain limits. The solutions comprising of two components are called binary solutions.

That component of a solution which is in the same physical state (i.e., solid, liquid or gas) as the solution is called solvent, the other component is called the solute.

If both the components are in the same state, the component which is present in larger proportions is called solvent and the one which is present in minor proportions is called solute.

Classification of solutions

Depending on the physical states of the solute and the solvent, solutions can be classified into various types.

	solid	Alloys of metals
Solid	liquid	Hydrated crystalline salts
	gas	Hydrogen gas adsorbed on platinum or palladium
	solid	Common salt in water
Liquid	liquid	Petrol in kerosene
	gas	Aerated water or soft drinks
Gas	gas	Air

When the solvent is a gas and the solute is a solid or a liquid, the resultant mixture becomes heterogeneous. All other solutions being homogeneous are called true solutions. The other two types of mixtures being heterogeneous are called suspensions. Example: fog, mist, dust particles in air.

Solubility

The process of dissolving a substance in the given solvent is called dissolution. The amount of solute dissolved in a definite quantity of a solvent depends upon the nature of solute as well as nature of solvent.

The maximum amount of a particular solute in grams, which can dissolve in 100 grams of solvent at a given temperature is called **solubility**.

$$\text{Solubility} = \frac{\text{Mass of solute}}{\text{Mass of solvent}} \times 100$$

☛ *Example*

Solubility of copper sulphate in water at 20°C is 20.7 and solubility of potassium chloride in water at 20°C is 34.

A given solution may or may not contain the maximum amount of solute in it. The further dissolving capacity of a given solution depends on the amount of solute already present in the solution. On the basis of the capacity of the solution to dissolve certain amount of solute further, the solutions are classified into three types.

Saturated solution

A solution which contains the maximum amount of solute that can be dissolved in the solvent at a given temperature is called **saturated solution** at that particular temperature. This solution can no longer dissolve any more solute under the given conditions.

Unsaturated solution

The solution containing lesser amount of solute than the saturated solution at a given temperature is called an **unsaturated solution**. In an unsaturated solution the solvent has the capacity of dissolving more amount of solute at that particular temperature.

Supersaturated solution

If a solution holds more solute than the saturated solution at a given temperature, it is called a supersaturated solution.

When more solute is made to dissolve in a saturated solution by raising its temperature and then cooling it slowly without causing any disturbances (like shaking), then the resultant solution holds more solute than the saturated solution.

Supersaturated solution is metastable and slight disturbances like shaking, stirring, scratching the wall of the container or adding a solute crystal to the solution make the additional amount of solute to precipitate out, thereby resulting in the formation of a saturated solution again.

Effect of temperature on the solubility

For most of the substances, solubility increases with the increase in temperature. However, the solubility of some substances decreases with increase in temperature. In case of some substances the temperature has no or little effect on the solubility. The solubility of sodium sulphate and calcium sulphate increases with the increase in temperature up to a certain extent and then decreases, whereas solubility of sodium chloride does not show much variation with the increase of temperature.

The solubilities of gases in liquids show a different trend with regard to the effect of temperature. In these solutions, the solubility is also influenced by the pressure.

Effect of temperature

With the increase in temperature, the solubility of a gas in a particular liquid decreases.

Effect of pressure

The effect of pressure on the solubility of a gas in a liquid is given by Henry's law, which states that at constant temperature the increase in pressure on the surface of the liquid increases the solubility of gas in liquid.

Many chemical reactions take place in the solution state. In order to calculate the volume or mass of the solution required to be taken for the reaction, the concentration of the solution should be known. There are different methods for measuring the concentration of solution. Among these, molarity and weight-percentage are the two methods which are commonly used.

Molarity

It is the most convenient and commonly used method for expressing the concentration of a solution.

Molarity can be defined as the number of moles of a solute present in one litre of a solution. It is denoted by 'M'.

If n = number of moles of the solute present in the solution

W = Weight of the solute in grams

GMW = Gram Molecular Weight (mass) of the solute

V = Volume of the solution, then

$$M = \frac{n}{v} = \frac{W}{GMW} \times \frac{1}{v \text{ in } \ell} \text{ or } M = \frac{W}{GMW} \times \frac{1000}{v \text{ in ml}}$$

☛ *Example*

0.4 M sodium carbonate solutions means 0.4 moles of sodium carbonate present in 1000 ml of the solution.

Weight percentage (w/w)

The mass of a solute expressed in grams present in 100 grams of a solution is called the weight percentage of the solute in the solution.

$$\text{Weight percentage of the solute} = \frac{\text{Weight of the solute}}{\text{Weight of the solution}} \times 100$$

☛ *Example*

10% (w/w) sodium hydroxide solution.

10 g of sodium hydroxide is present in 100 g of the solution.

When a saturated solid-liquid solution is cooled slowly, solid solute settles down with a highly regular arrangement of its constituent particles (atoms, molecules or ions). This regular arrangement of component particles in a three-dimensional system is uniform throughout the entire solid. This type of solid is called **crystalline solid**. The smallest unit of this arrangement of particles which gets repeated throughout the crystalline solid is called unit cell. **Unit cell** of each substance has a definite geometric shape.

Hence, crystals can be defined as solids in which the constituent atoms, molecules or ions are packed in a regularly ordered and repeating pattern extending in all three spatial dimensions.

Crystallization is the process of formation of a crystalline solid from the corresponding solution.

Different processes of crystallization

(i) Slow cooling of a hot saturated solution of a solid solute from a higher temperature to a lower temperature.

(ii) Evaporation of an unsaturated solution at moderate temperature.

(iii) Slow cooling of a molten solid.

(iv) Sublimation of the solid followed by condensation of the resultant vapours.

Water of crystallization: When a solid gets crystallized from its respective hot concentrated aqueous solution, a certain fixed number of water molecules also get attached to the solid crystals to form unit cells of the crystals.

The fixed number of water molecules which combine with a crystal and are necessary for the maintenance of crystalline properties, but capable of being lost either at normal temperature or at a higher temperature is called **water of crystallization.**

Examples of such solids (salts) are green vitriol ($FeSO_4\,7H_2O$), blue vitriol ($CuSO_4.5H_2O$), washing soda ($Na_2CO_3\,.10H_2O$) etc.

Hydrated salts and anhydrous salts: The salts which contain water of crystallization are called **hydrated salts**.

When the hydrated salts completely lose their water molecules, it is called **anhydrous salt.** When a hydrated salt gets dehydrated and forms anhydrous salt, the colour of the salt changes. For example $CuSO_4.\,5H_2O$ is blue in colour. It changes to white colour due to the loss of water molecules on heating.

Efflorescence and deliquescence: There are some hydrated crystals which lose some of the water of crystallization or all the water of crystallization on exposure to air at normal temperature. This phenomenon is known as **efflorescence** and the hydrated crystals which lose water molecules are called efflorescent substances.

After the release of the water molecules, efflorescent substances lose their crystalline property and get transformed into a powdery mass.

☛ *Example*

Glauber salt, $Na_2SO_4.10H_2O$ loses all of its water molecules on exposure to air at ordinary temperature.

Some crystalline salts absorb moisture on exposure to air and ultimately dissolve in it to form an aqueous solution. This phenomenon is called **deliquescence** and these crystalline salts are called deliquescent substances.

These salts may or may not contain water of crystallization.

Examples of such salts are hydrated magnesium chloride ($MgCl_2.6H_2O$), hydrated calcium chloride ($CaCl_2.\ 6H_2O$) etc.

Hygroscopic substances and desiccating agents: There are certain substances which absorb moisture from air without changing their physical state.These substances are called hygroscopic substances. They may exist in solid or liquid state under normal temperature and pressure.

Examples of such substances are calcium oxide (solid), concentrated sulphuric acid (liquid) etc.

After absorbing moisture, solid hygroscopic substances remain as solids and liquid substances remain as liquids.

Unlike deliquescent substances, these hygroscopic substances retain their physical states (solids or liquid) on the absorption of moisture.

Hygroscopic substances which are used to remove water from the surroundings are called **desiccating agents**. Examples of desiccating agents are calcium oxide and anhydrous calcium chloride.

Study of solutions is an important and vital part of chemistry because of its various applications. Besides solutions, there are some other mixtures known as colloids and suspensions which also have equal importance in chemistry because of their unique properties. The basic difference in the properties of solution, colloid and suspension is attributed to the variation in size of their constituent particles.

In solution, the size of the solute particles is less than 10 nm and do not settle down on long standing. Whereas in suspension, the size of the suspended particles is more than 1 μm. Hence the suspended particles settle down slowly. The mud particle present in muddy water is an example of suspension.

A colloid is a mixture where one of the constituents is dispersed evenly throughout another. The size of the constituent particles which is dispersed is in between 10 nm to 1 μm and called **dispersed phase**. The medium in which these particles are dispersed is called **dispersion medium**.

Like solutions, colloids can also be classified based on the physical state of the dispersed phase and dispersion medium.

Classification of colloids

Solid	Solid	Solid sol: coloured glass
	Liquid	Gel: jelly, cheese, butter
	Gas	Solid foam: pumice
Liquid	Solid	Sol– paint, blood
	Liquid	Emulsion: milk, face cream
	Gas	Foam: moisture in air, whipped cream
Gas	Solid	Solid aerosol: smoke
	Liquid	Liquid aerosol: fog, mist, clouds

Colloids have some unique properties due to the specific size of the particles of the dispersed phase.

Properties of colloid

Tyndall effect

When a beam of light rays is passed through a colloid, particles of the dispersed phase scatter the light rays and the path of the light becomes visible. The scattering of light by the colloid particles is known as **Tyndall effect**.

True solution is completely transparent to the light rays and in case of suspension the path of the light rays is faintly observed.

Brownian movement

The random movement exhibited by the colloid particles throughout the dispersion medium is known as **Brownian movement**. This type of movement resists the colloid particles to settle down.

Coagulation of colloid particles

Colloid particles can be coagulated by the addition of salt because these particles are charged. Coagulation takes place due to the neutralization of the charge associated with the colloid particles and thus the colloid particles can be settled down.

Action of water on some metals

(i) **Potassium and Sodium:** These two metals reacts with cold water. They even react with moisture (water vapour).

$$2K + 2H_2O \rightarrow 2KOH + H_2$$

$$2Na + 2H_2O \rightarrow 2NaOH + H_2$$

(ii) **Calcium:** This reaction takes place in cold water.

$$Ca + 2H_2O \rightarrow Ca\,(OH)_2 + H_2$$

Electrolysis of water

Water conducts electricity when a few drops acid is added to it. On electrolysis, water gives 2 volumes of H_2 and 1 volume of O_2. Hoffman's voltameter is an apparatus in which acidulated water is electrolysed by using platinum electrodes.

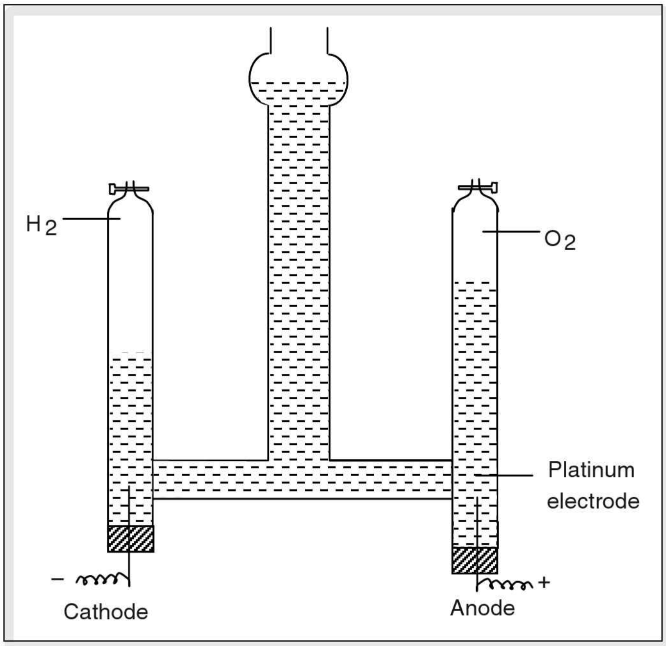


Figure 7.1 Hoffman's voltameter

Mechanism of electrolysis

The process of electrolysis results in the decomposition of an electrolyte and subsequent deposition or liberation of the constituent products at the respective electrodes. However, the quantities of the electrolytic products at the respective electrodes are not same for all the electrolytes.

For the establishment of quantitative relationship between the electricity passed through the electrolyte and the products obtained at the electrodes, Michael Faraday conducted some experiments. The results were given out as Faraday's laws of electrolysis.

Faraday's Laws of Electrolysis

First law

The amount of substance deposited or liberated or dissolved at an electrode is directly proportional to the quantity of electricity passing through the electrolyte.

Mathematical representation

$m \propto Q$ (m = mass of substance deposited at the electrode)

(Q = Quantity of electricity passing through the electrolyte)

$Q = c \times t$ (c = current strength in amperes;

t = time of flow of current in seconds)

$m \propto ct$ or $m = ect$ (e = constant called electrochemical equivalent)

If c = 1 amp; t = 1 sec (or Q = 1 coulomb) then m = e

Therefore, electrochemical equivalent can be defined as the mass of substance which undergoes electrode reaction at an electrode by the passage of one coulomb of electricity through the electrolyte.

Since the charge of an electron is equal to 1.602×10^{-19} coulombs, passage of one mole of electrons through an electrolyte corresponds to passage of $(6.023 \times 10^{23} \times 1.602 \times 10^{-19})$ coulombs of electricity.

Charge of 1 mole of electrons = $6.023 \times 10^{23} \times 1.602 \times 10^{-19}$ = 96,496 coulombs

≈ 96,500 coulombs

96,500 coulombs is called one faraday.

The amount of substance which undergoes electrode reaction by the passage of one faraday (96,500 coulombs) of electricity is equal to the **equivalent weight** of the substance.

Calculation of equivalent weight

The equivalent weight of an element or radical is calculated by dividing its atomic weight/formula weight by its valency. The unit of equivalent weight is **atomic mass unit**.

$$\text{Equivalent weight of an element} = \frac{\text{Atomic weight}}{\text{valency}}$$

$$\text{Equivalent weight of a radical} = \frac{\text{Formula weight of the radical}}{\text{valency}}$$

$$\text{Equivalent weight of aluminium} = \frac{\text{Atomic weight of aluminium}}{\text{valency of aluminium}} = \frac{27}{3} = 9$$

$$\text{Equivalent weight of oxygen} = \frac{\text{Atomic weight of oxygen}}{\text{valency}} = \frac{16}{2} = 8$$

$$\text{Equivalent weight of sulphate radical} = \frac{\text{Formula weight of sulphate radical}}{\text{valency}} = \frac{96}{2} = 48.$$

Therefore the number of equivalents of substance deposited or liberated or dissolved at an electrode is equal to the number of faradays of electricity passed through the electrolyte.

Relation between equivalent weight and electrochemical equivalent

Electrochemical equivalent = $\dfrac{\text{Equivalent weight}}{96500} = \dfrac{\text{Atomic weight}}{z \times 96500}$ (where z = valency of the element)

Second law

For the passage of same quantity of electricity through different electrolytes, the amounts of respective substances deposited at the electrodes is in the ratio of the equivalent weights of the substances.

If m_1, m_2 and m_3 are masses of different substances and E_1, E_2 and E_3 are the equivalent weights of the substances,

$m_1 : m_2 : m_3 = E_1 : E_2 : E_3$ (when quantity of electricity is constant)

☛ *Numerical Problems*

Calculate the weight of aluminum deposited during the electrolysis of molten aluminum chloride by passing 193 amperes of current for 500 minutes.

Solution

$A1^{+3} + 3e^- \rightarrow Al$

Mass of Al deposited(W) $= \dfrac{Mct}{ZF}$

M = molecular weight = 27

c = 193amp.

t = 500 × 60 sec.

Z = 3

F = 96500c

$$W = \frac{27 \times 193 \times 500 \times 60}{3 \times 96500} = 540 \text{ g}$$

A current of 9.65 amperes is passed through three different electrolytes $NaNO_3$, KCl and $ZnSO_4$ for 30 minutes separately. Calculate the mass ratio of the metals deposited at the respective electrodes. Also find out the weights of various metals deposited at the respective electrodes.

Solution

Quantity of electricity passed through the electrolyte = current strength × time of flow = 9.65 × 30 × 60 coulombs

$$m_{Na} : m_K : m_{Zn} = E_{Na} : E_K : E_{Zn}$$

$$E_{Na} = \frac{23}{1} = 23 \qquad (Na^+ + e^- \rightarrow Na)$$

$$E_K = \frac{39}{1} = 39 \ (K^+ + e^- \rightarrow K)$$

$$E_{Zn} = \frac{65}{2} = 32.5 \ (Zn^{+2} + 2e^- \rightarrow Zn)$$

$$m_{Na} : m_K : m_{Zn} = 23 : 39 : 32.5$$

$$\text{Weight of sodium deposited} = \frac{23 \times 9.65 \times 30 \times 60}{96500} = 4.14 \text{ g}$$

$$\text{Weight of potassium deposited} = \frac{39 \times 9.65 \times 30 \times 60}{96500} = 7.02 \text{ g}$$

$$\text{Weight of Zinc deposited} = \frac{32.5 \times 9.65 \times 30 \times 60}{96500} = 5.85 \text{ g}$$

test your concepts

Very short-answer type questions

1. What is meant by soft water?
2. Colloid particles show ________ movement.
3. Name some salts which impart hardness to water.
4. The molarity of a 250 ml solution is 0.5 M. The amount of solute present in it is______ g. (molecular weight of the solute = 58)
5. How does the process of boiling soften water?
6. What is a binary solution? Give one example.
7. Mention the specific property of water due to which it acts as an universal solvent.
8. The smallest unit of crystalline solid is called ________.
9. Define solubility.
10. The dispersion medium in smoke is _________.
11. Give examples of the following solutions:

    (i) Solid in solid (ii) Gas in liquid (iii) Liquid in solid
12. In blood dispersed phase is ________ and dispersion medium is ________.
13. Why do we get a fizzing sound when a cool drink bottle is opened?
14. Effervescence is observed when the water is warmed. What is the reason behind it?
15. Solubility of salt 'A' in water at 25°C is 15. What is the meaning this statement?
16. Name one hygroscopic substance whose physical state does not change by absorbing water.
17. How is a unsaturated solution made from saturated?
18. Solubility of gas _______ with the increase of temperature.
19. What is meant by unit cell of a crystalline solid?
20. Equivalent weight of phosphate radical is equal to ________
21. What happens when blue litmus paper is dipped in water in which a piece of calcium metal has been dropped?
22. Why does the colour of the solid blue copper sulphate become white on heating?
23. What is the relation between coulomb and faraday?
24. What are dispersed phase and dispersion medium?
25. In what ratio by mass, hydrogen and oxygen are produced by the electrolysis of water?
26. Total charge of Avogadro number of electrons = ________.
27. What is the total charge of 2 moles of electrons in faraday?

28. Hydrated copper sulphate on heating turns to _________.

29. What are the equivalent weights of cuprous ion and cupric ion?

30. The number of water molecules present in glauber salt is _________.

Short-answer type questions

31. Find out the mass of the solvent present in 500 g of 30% sodium chloride solution.

32. Differentiate (i) soft and hard water and (ii) temporary and permanent hardness of water.

33. Identify the physical state of the dispersed phase and dispersion medium of the following colloids:
(i) Smoke (ii) Blood (iii) Cheese (iv) Fog (v) Coloured glass

34. How are the resins regenerated after long use?

35. What is the mass of the solute present in 1 litre of 0.2 M sodium carbonate solution?

36. How many grams of potassium chloride is present in 250 g of saturated solution if the solubility of KCl is 35.8 at 25°C?

37. What is the effect of temperature and pressure on the solubility of solids and gases in liquids?

38. Establish the relationship between equivalent weight and electrochemical equivalent.

39. Correlate the bond present in water with its solvent property.

40. If small pieces of sodium and potassium are dropped separately in two beakers containing water, golden and lilac flames are observed on the surface of water in the respective beakers. Justify these observations.

41. What are the different processes of crystallization?

42. Explain molarity and weight percentage.

43. How many moles of electrons are required to liberate 112 litre of oxygen at STP when acidulated water is electrolyzed?

44. Differentiate deliquescence and efflorescence.

45. What is ratio by mass of magnesium and calcium obtained when the electrolysis of their respective chlorides are carried out in the molten state, if the number of moles of both the chlorides taken are same?

Essay type questions

46. Compare and contrast solution, colloid and suspension.

47. State the two laws of electrolysis. Explain with examples.

48. Explain saturated, unsaturated and super saturated solutions and their interconversion without adding any solute in the solution.

49. Explain the different processes of removal of temporary and permanent hardness of water

50. What are the different properties of colloids? Explain.

CONCEPT APPLICATION

Concept Application Level—1

Direction for questions 1 to 7: State whether the following statements are true or false.

1. Temporary hardness of water can be removed by boiling.
2. The molarity of 4 g of NaOH in 100 ml solution is 0.5 M.
3. Calcium oxide retains its physical state on exposure to air.
4. During electrolysis of water hydrogen and oxygen are liberated at cathode and anode respectively.
5. The solvent is in solid state in hydrated salts.
6. 27 g of aluminium is deposited by passing one faraday of electric charge.
7. 144750 C is equal to two faradays.

Direction for questions 8 to 14: Fill in the blanks.

8. In face cream, the dispersion medium and dispersed phase are in ________ and ________ states respectively.
9. Formula of green vitriol is ________.
10. Salts with water of crystallization are known as _____
11. To deposit 216 g of silver _____ faradays of charge is required.
12. Washing soda on exposure to air loses ________ water molecules.
13. Presence of _____ and _____ of _____ and _____ imparts permanent hardness of water.
14. Anhydrous calcium chloride is a _____ agent.

Direction for question 15: Match the entries in column A with the appropriate ones in column B.

15.

	Column A			Column B
A.	RNH_3OH	( )	a.	Particles settle down on long standing
B.	RCOOH	( )	b.	Hygroscopic substance
C.	Washing soda	( )	c.	Coagulation takes place on addition of salt
D.	Sulphuric acid	( )	d.	Acid resin
E.	Suspension	( )	e.	Water of crystallization
F.	Colloid	( )	f.	Basic resin

Direction for questions 16 to 45: For each of the questions, four choices have been provided. Select the correct alternative.

16. Phosphorus pentoxide used in the preparation of N_2O_5 from HNO_3 acts as a

(1) reducing agent (2) catalyst (3) dehydrating agent (4) drying agent

17. Regeneration of RNH_3Cl can be done by

(1) NaOH (2) NaCl (3) HCl (4) H_2SO_4

18. Anhydrous cobalt chloride can be used to remove moisture from the surroundings. Which of the following renders the sample reusable?

(1) Exposure to high humid air

(2) Keeping in air tight container

(3) Exposure to dry air

(4) Keeping in contact with another efflorescent substance

19. Which among the following is having maximum molarity?

(1) 20 g of NaOH in 500 ml solution (2) 49 of H_2SO_4 250 ml solution

(3) 7.4 g of $Ca(OH)_2$ in 100 ml solution (4) 73 g of HCl in 2000 ml solution

20. When NaCl is added to water, columbic force of attractions between

(1) radicals present in NaCl increases

(2) partially charged hydrogen and oxygen of water increases

(3) Cl^- and partially charged hydrogen of water increases

(4) Na^+ and partially charged oxygen of water becomes very weak.

21. Which of the following does not show much variation of solubility with the change of temperature?

(1) Sodium chloride (2) Sodium sulphate

(3) Potassium chloride (4) Potassium sulphate

22. Time required for the deposition of 40 g of calcium by passing 965 amp current through molten calcium chloride is

(1) 100 s (2) 200 s (3) 50 s (4) 150 s

23. The w/w % of 25 g of calcium hydroxide in 50 g of solvent is _______ %

(1) 40 (2) 33.33 (3) 36.3 (4) 30

24. What is the molarity of 24.5% (w/w) sulphuric acid solution. [Density of solution is 1.8 g/cc]

(1) 6 M (2) 3 M (3) 4 M (4) 4.5 M

25. Which of the following changes take place due to the addition of aluminium sulphate to muddy water?

(1) Muddy water becomes free from germs and bacteria

(2) Coagulation of mud particles takes place

(3) Adsorption of mud on aluminium sulphate crystals results in isolation of mud from water

(4) A part of the mud becomes soluble in water.

26. When a small crystal of solute is added to supersaturated solution,

(1) unsaturated solution is formed. (2) saturated solution is formed.

(3) some amount of solute is precipitated. (4) Both (2) and (3)

27. Which among the following is used as a desiccating agent?

(1) Calcium hydroxide (2) Magnesium chloride

(3) Calcium oxide (4) Calcium nitrate

28. Which of the following statements is true?

(1) Solubility of the gases in water decreases with decrease in pressure

(2) Solubility of the gases in water decreases with increase in temperature.

(3) Solubility of the gases at depth of the sea is more than that at it surface

(4) All the above

29. Aqueous solution of a metal salt on electrolysis with 1930 amp current for 20 sec produces 8 g of the metal. The valency of the metal is ____ (atomic weight = 40).

(1) three (2) two

(3) four (4) one

30. In which of the following colloids, both dispersed phase and dispersion medium are liquids?

(1) Blood (2) Smoke

(3) Mist (4) Paint

31. The solubility of a solute A in four solvents P, Q, R and S is 20 g, 30 g, 15 g, 40 g respectively at a given temperature. Arrange the four solvents in the increasing order of their dielectric constant.

(1) $P < Q < R < S$ (2) $R < P < Q < S$

(3) $R < Q < P < S$ (4) $P < Q < S < R$

32. The weight of a china dish with a saturated solution of sodium nitrate at 40°C is 80 g. After evaporating the whole solution the dish's weight along with the crystals is 40 g and the solubility of $NaNO_3$ at 40°C is 20 g. What is the weight of the empty china dish?

(1) 30 g (2) 32 g

(3) 34 g (4) 28 g

33. What is the weight percentage of 4 M calcium hydroxide solution?

[Density of solution = 1.3 g/ml]

(1) 11.6% (2) 48.3%

(3) 38.5% (4) 22.8%

34. Which of the following statements is true?

(1) Solubility of the gases in water decreases with decrease in pressure

(2) Solubility of the gases in water decreases with increase in temperature

(3) Solubility of the gases at deep sea is more than that at its surface

(4) All the above

35. Arrange the solutes, A, B, C and D in decreasing order of amount of solute precipitated when their respective hot saturated solutions are cooled from 100°C to 30°C

	[redacted]			
(a)	A	120	140	160
(b)	B	130	120	150
(c)	C	125	130	140
(d)	D	140	135	130

(1) c b d a (2) a c b d (3) b d c a (4) a b c d

36. Write the steps in sequence for electroplating of brass spoon with silver.

(a) K^+ and H^+ ions are not discharged at cathode due to higher discharge potential than Ag^+.

(b) Silver gets deposited on brass spoon.

(c) A highly cleaned brass spoon which has to be electroplated is taken.

(d) Due to electrolytic dissociation, Ag^+, K^+, H^+, OH^-, CN^- ions are formed.

(1) c d a b (2) a d c b

(3) d a c b (4) a d b c

37. Which among the following elements cause water pollution?

(1) Mercury (2) Lead

(3) Arsenic (4) All the above

38. Which property of water is responsible for water pollution?

(1) High dielectric constant

(2) High specific heat

(3) High specific gravity

(4) All the above.

39. Which among the following has water of crystallization?

(1) Washing soda (2) Baking soda

(3) Common salt (4) Calcium hydroxide

40. Which of the following is not the properties of the colloids?

(1) Brownian movement (2) Tyndall effect

(3) Coagulation (4) Crystallisation

41. Which among the following has minimum molarity?

(1) 20 g of NaOH in 100 ml solution

(2) 24.5 g of H_2SO_4 in 500 ml solution

(3) 14 g of HCl in 100 ml solution

(4) 37 g of $Ca(OH)_2$ in 2000 ml solution

42. Which among the following is a true solution?

(1) Vinegar in water (2) Sulphur in water
(3) Aluminium paint (4) Starch solution

43. Arrange the statements in sequence for the calculation of weight of aluminium deposited during the electrolysis of molten aluminium chloride by passing 'c' amperes of current for 't' minutes.

(a) Find the product of current (c) and time (t).
(b) Convert time in minutes to seconds
(c) Write reduction equation of metal ion.
(d) Conversion of charge into Faradays.
(e) Relation between mass of metal and number of Fardays passed through

(1) b a d c e (2) a b c d e
(3) d b a e c (4) b a d e c

44. Relation between electrochemical equivalent (e) and equivalent mass (E) is given by

(1) $E = \frac{e}{96500}$ (2) $E = \frac{96500}{e}$

(3) $e = \frac{E}{96500}$ (4) $e = \frac{\text{valency}}{96500}$

45. Electrolysis principle is not used in the following process.

(1) Plating of silver on copper
(2) Extraction of metals
(3) Refining of metals
(4) Purification of drinking water

Concept Application Level—2

1. A piece of metal is dropped in cold water, the water slowly becomes turbid and effervescence is observed. What will you observe, if blue litmus paper is dipped into the turbid water? Identify the metal and justify the observation.

2. Explain the role of lime and washing soda for the removal of permanent hardness of water.

3. Why are carbonated beverages kept in sealed container?

4. Some amount of glauber salt, hydrated magnesium chloride and hydrated calcium chloride are separately is kept in three containers. What will you observe, if blue coloured cobalt chloride is introduced in the three containers? Explain with reason.

5. 100 g of 25 % (w/w) sodium hydroxide is prepared in the laboratory. If the density of water is 0.9 g/cc at room temperature, calculate the volume of water taken.

6. 200 ml of pure water contains 60 g of a solute at 60°C. The salt solution is cooled slowly up to 30°C. Based on the data given below calculate the mass of the solute precipitated from the solution.

[redacted]	
60	55
45	30
30	40

7. The amount of solute (H_2SO_4) and solvent present in a solution are 49 g and 90 g respectively. If the specific gravities of the solute and solvent are 1.96 and 0.9 respectively, calculate the molarity of the solution?

8. 5.4 g of trivalent metal is deposited by passing 5 amp current during the electrolysis of its molten chloride. If the atomic weight of the metal is 27, calculate the time taken for the deposition.

9. The density of the particles of the dispersed phase is more than that of the dispersion medium in a colloid. But the colloid particles do not settle down. Give reason.

10. Calculate the molarity of 30 % (w/w) NaOH solution, if the density of the solution is 1.05 g/cc.

11. If 6 g of a metal gets deposited by passing 2 amp of current for 2 hrs 30 min, calculate the equivalent weight of the metal.

12. Why does smoke produced by cigarette appear blue in colour?

13. Why is ferric chloride solution used to stop the bleeding from a wound?

14. Common salt increases in weight on long standing. Justify with appropriate reason.

15. Compare the conductivity of a solution of NaOH in water and in alcohol.

Directions for questions 16 to 25: Application Based Questions

16. Why does the colour of the solid blue copper sulphate becomes white on heating?

17. When equal number of moles of CO_2, SO_3 and nitrogen gases are passed through water under pressure and then heated, which gas is evolved in maximum percentage? Justify.

18. Amount of solutes A, B and C in 400 g of water at 20°C, 40°C and 80°C in their saturated solutions are given below.

[redacted]			
A	120 g	100 g	115 g
B	150 g	180 g	190 g
C	140 g	160 g	150 g

When the hot saturated solutions A, B and C are cooled slowly from 80°C to 20°C, analyse the changes that take place gradually in the given solutions with appropriate reason.

19. A sample X loses its water of crystallization when exposed to dry air, a sample Y absorbs moisture from the atmospheric air. Justify the above action on the basis of vapour pressures of respective substances.

20. 8 g of bivalent metal is deposited by passing 10 amp current during the electrolysis of its molten chloride. If the atomic weight of the metal is 40, calculate the time taken for the deposition.

21. The time taken for the deposition of same number of moles of silver and copper, by the electrolysis of molten silver salt and copper salt respectively is in the ratio 1 : 2 carried out in two electrolytic cells connected in series. Find out the ratio of valences of two metals.

22. What will be the volume of oxygen gas liberated at STP when 15 amp current is passed through acidulated water for 4 hours?

23. Though distilled water is pure water, people prefer potable water for drinking. Justify.

24. Why is ethylene glycol used as an antifreeze?

25. 50 g of 15% (w/w) sodium hydroxide is prepared in the laboratory. Calculate the volume of water utilized if density of water is 0.9 g/cc. at the experimental conditions.

Concept Application Level—3

1. When cupric carbonate is added to dilute sulphuric acid and the resultant mixture is cooled slowly, crystallization takes place. But no crystallization is observed when the same process is carried out by taking dilute nitric acid instead of sulphuric acid. Explain with appropriate reason.

2. NaOH can remove permanent and temporary hardness simultaneously. Explain.

3. Compare the elevation in boiling point of colloid and true solution.

4. A beam of light is passed through three containers containing three different mixtures. The beam of light ray is not visible in the first container, it is brightly visible in the second container and in the third container faint beam of light is visible. Justify your answer with appropriate reasons.

5. Acidulated water is taken in Hoffman voltmeter to carry out the electrolysis process. If a piece of litmus paper is dipped in both the compartments of Hoffman voltmeter, what change will be observed in the colour of the litmus during the electrolysis process?

Directions for questions 6 to 10: Application Based Questions

6. A little amount of $CaCO_3$ is added to two test tubes, containing dilute sulphuric acid and dilute hydrochloric acid respectively and the resultant mixture is cooled slowly. What observation we can make and justify the observation.

7. Anhydrous cobalt chloride is used as a dehumidifying agent for absorbing moisture from highly humid air and again it is made reusable by low humid air. Justify the action of cobalt chloride with respect to its vapour pressure.

8. Find the ratio of time taken for the deposition of the same number of moles of zinc and silver, by the electrolysis of zinc sulphate and silver nitrate respectively carried out in two electrolytic cells connected in series.

9. If small pieces of sodium and potassium are dropped separately in two beakers containing water, golden yellow and lilac flames are observed respectively on the surface of water in the respective beakers. Justify the above observations.

10. Though sodium chloride is not deliquescent, table salt shows deliquescent nature. Justify.

key points for selected questions

Very short-answer type questions

1. Water that dissolves soap and produces lather.

2. brownian

3. Calcium chloride, magnesium sulphate and calcium bicarbonate.

4. 7.25 g

5. By decomposition of calcium and magnesium bicarbonates.

6. Solutions comprising of two components.

7. High dielectric constant.

8. unit cell

9. The maximum amount of a particular solute in grams, which can dissolve in 100 grams of solvent at a given temperature.

10. Gas

11. (i) Alloy (ii) Soft drink (iii) Glauber salt

12. Solid, liquid

13. Due to escaping of gases.

15. 15 g of salt A is dissolved in 100 g of solvent.

16. Calcium oxide

17. By adding solvent.

18. increase

19. The smallest repeating pattern of crystalline solid.

20. 32

21. Nature of the product formed.

22. Loss of water of crystallization.

23. One faraday = 96,500 coulombs.

24. Constituent particle in a solution which is dispersed is in between 10 nm to 1 μm is called dispersed phase and the medium in which dispersed phase is dispersed is called dispersion medium.

25. 1 : 4

26. 96,500

27. Two faraday.

28. colourless

29. 63.5 and 31.75

Short-answer type questions

33.

[redacted]

Smoke	Solid	Gas
Blood	Solid	Liquid
Cheese	Liquid	Solid
Fog	Liquid	Gas
Coloured glass	Solid	Solid

34. (i) By using strong acids.
(ii) By using strong bases.

38. (i) Definition of electrochemical equivalent.
(ii) Definition of equivalent weight.
(iii) Relation between electrochemical equivalent and equivalent weight.

39. (i) Type of bond.
(ii) Effect of this bond on the force of attraction between the ions of compounds.

40. (i) Reaction between sodium and water.
(ii) Reaction between potassium and water.
(iii) Nature of the products.
(iv) Effect of nature of products on the coloured observed.

41. (i) Slow cooling of hot saturated solution.
(ii) Evaporation of an unsaturated solution.
(iii) Slow cooling of a molten solid.

42. (i) Definition.
(ii) Formulae.

43. 20 moles

44. (i) Definition.
(ii) Change in physical state.

45. 3 : 5

key points for selected questions

Essay type questions

46. (i) Comparison of sizes of constituent particles.
    (ii) Comparison of properties.
    (iii) Unique properties of colloids.

47. (i) Relation between amount of substance obtained at the electrode and current passed.
    (ii) Relative weights of various substances obtained at the electrode for the passage of same amount of current.

48. (i) Definition.
    (ii) Shaking.
    (iii) Stirring.
    (iv) Scratching.

49. (i) Boiling
    (ii) Ion exchange resins.
    (iii) Regeneration of resins.

50. (i) Tyndal effect
    (ii) Brownian movement
    (iii) Coagulation

KEY

Concept Application Level—1

True or false

1. True
2. False
3. True
4. True
5. True
6. False
7. False

Fill in the blanks

8. liquid, liquid
9. $FeSO_4.7H_2O$
10. hydrated salts
11. 2
12. 9
13. Sulphates, chlorides, calcium, magnesium
14. drying

Match the following

15. A. : f
    B. : d
    C. : e
    D. : b
    E. : a
    F. : c

Multiple choice questions

16. Choice (3)
17. Choice (1)
18. Choice (3)
19. Choice (2)
20. Choice (3)
21. Choice (1)
22. Choice (2)
23. Choice (2)
24. Choice (4)
25. Choice (2)
26. Choice (4)
27. Choice (3)
28. Choice (4)
29. Choice (2)
30. Choice (4)

31. The higher the dielectric constant of solvent, the more is the solubility of a solute in that particular solvent. And hence increasing order of dielectric constants is R < P < Q < S.

Choice (2)

32. Let the weight of an empty china dish x g.

weight of saturated solution = (80 – x)g

weight of $NaNO_3$ crystals = (40 – x) g

weight of H_2O in saturated solution

= 80 – x – 40 + x = 40

$$\therefore \text{Solubility} = \frac{\text{weight of NaNO}_3}{\text{weight of water}}$$

$$20 = \frac{40 - x}{40} \times 100$$

$$800 = 4000 - 100x$$

$$x = 32 \text{ g}$$

Choice (2)

33. $$M = \frac{w}{Mwt} \times \frac{1000}{V \text{ in ml}}$$

4 M $Ca(OH)_2$ solution means 296 g of $Ca(OH)_2$ is dissolved in 1000 ml of solution.

Mass of the solution = d × v

= 1.3 × 1000

= 1300 g

$$\text{Weight percentage} = \frac{\text{weight of solute}}{\text{weight of solution}} \times 100$$

$$= \frac{296}{1300} \times 100 = 22.8\%$$

Choice (4)

34. Solubility of gases in water decreases with the decrease of pressure and increase of temperature.

Choice (4)

35. A = 160 – 120 = 40 g

B = 20 g

C = 15 g

D = No ppt

Choice (4)

36. (i) A highly cleared brass spoon which has to be electroplated is taken

(ii) Due to electrolytic dissociation Ag^+, K^+, H^+ , OH^-, CN^- ions are formed.

(iii) K^+, H^+ ions are not discharged at cathode due to higher discharge potential than Ag.

(iv) Silver gets deposited on brass spoon.

Choice (1)

37. Mercury, lead and aresenic are the elements which cause water pollution.

Choice (4)

38. High dielectric constant of water is responsible for water pollution. This is because of the ability of water to dissolve large variety of substances.

Choice (1)

39. Washing soda has water of crystallization.

Choice (1)

40. Crystallisation is not the property of colloid.

Choice (4)

41. $$\text{Molarity} = \frac{37}{74} \times \frac{1000}{2000} = 0.25$$

37g of $Ca(OH)_2$ in 2000 ml solution has minimum molarity.

Choice (4)

42. Vinegar in water is a true solution since it is highly soluble in water.

Choice (1)

43. (i) Convert time in minutes to seconds

(ii) Find the product of y current (c) and time (t).

(iii) Conversion of charge into Faradays.

(iv) Write reduction equation of metal ion.

(v) Relation between mass of metal and Faradays passed through.

Choice (1)

44. Relation between electrochemical equivalent (e) and equivalent mass (E) is given by

$$e = \frac{E}{96500}$$

Choice (3)

45. Electrolysis principle is not used in the purification of drinking water.

Choice (4)

Concept Application Level—2

Key points

1. (i) Identification of metal that reacts with cold water but does not produce any flame.
   (ii) Reaction between the metal and water.
   (iii) Product formed in the above reaction.
   (iv) Solubility of the product in water.
   (v) Nature of aqueous solution formed.
   (vi) Identification of changes observed when blue litmus paper is dipped in the above solution.
2. (i) Chemical composition of lime and washing soda.
   (ii) Reasons for the permanent hardness of water.
   (iii) Reaction between components of permanent hard water and lime.
   (iv) Reaction between components of permanent hard water and washing soda.
   (v) Solubility of the products obtained in the above reactions.
   (vi) Relation between the solubility of the products and hardness of water.
3. (i) Constituents of carbonated beverages.
   (ii) Effect of pressure on the solubility of gas in liquid.
4. (i) Comparison of the nature of three given hydrated salts.
   (ii) Effect of the nature of three hydrated salts on cobalt chloride.
   (iii) Change in colour of cobalt chloride.
5. (i) Determination of the mass of sodium hydroxide present in the solution.
   (ii) Calculation of the mass of water taken.
   (iii) Calculation of molarity.
   (iv) Calculation of volume of water taken from the density given.
6. (i) Determination of the nature of the solution at 60°C from the given data.
   (ii) Determination of nature of solution at 45°C.
   (iii) Determination of nature of solution at 30°C.
   (iv) Relation between the nature of the solution and the amount of precipitation.
7. (i) Determination of the volumes of the solute and solvent.
   (ii) Calculation of total volume of the solution.
   (iii) Calculation of number of moles of H_2SO_4.
   (iv) Calculation of molarity of solution.
8. (i) Calculation of number of moles of the metal deposited.
   (ii) Calculation of amount of charge required.
   (iii) Calculation of the time taken for the deposition.
   (iv) 3.22 h
9. (i) Properties of colloid particles.
   (ii) Charge possessed by colloid particles
   (iii) Forces acting between colloid particles.
   (iv) Effect of these forces against coagulation of colloid particles.
10. (i) Calculation of the volume of 100 g of the solution.
    (ii) Calculation of number of moles of NaOH present in the calculated volume of the solution.
    (iii) 7.88 M
11. (i) Calculation of the amount of charge required to deposit the given amount of metal.
    (ii) Calculation of equivalent weight of the metal, based on the amount of charge passed through the electrolyte.
    (iii) 32.2

12. (i) Constituents of smoke.

(ii) Size of the constituent particles and their nature.

(iii) Phenomenon taking place when light rays are incident on these particles.

13. (i) Nature of constituents of blood.

(ii) Charge present on the constituents of blood.

(iii) Forces acting among the constituents which are charged.

(iv) Effect of ferric chloride on the charged constituents.

(v) Phenomenon that takes place due to the above effect.

14. (i) Impurities present in common salt.

(ii) Nature of the impurities present in common salt.

(iii) Effect of nature of the impurities on the increase in weight.

15. (i) Comparison of polar nature of water and alcohol.

(ii) Type of bonds present in sodium hydroxide.

(iii) Relation between polarity and dielectric constant.

(iv) Effect of dielectric constant on solubility.

(v) Comparison of dielectric constants of water and alcohol.

16. Due the loss of water molecules from $CuSO_4 \cdot 5H_2O$.

17. As solubility of nitrogen is very less in water, it is expelled in maximum percentage. CO_2 and SO_3 are soluble in water. Hence they will be expelled in lesser percentage.

18. **Sample A:** When the solution is cooled from 80°C to 40°C solute forms a precipitate of 15 g and when cooled from 40°C to 20°C solubility increases from 100 g to 120 g and the solution becomes unsaturated.

Sample B: When the solution is cooled from 80°C to 40°C, solute forms a precipitate of 10 g and when cooled from 40°C to 20°C solubility decreased from 180 g to 150 g forming 30 g of precipitate.

Sample C: When solution is cooled from 80°C to 40°C solubility increase from 150 g to 160 g forming unsaturated solution and while cooling from 40°C to 20°C solubility decreases from 160 g to 140 g forming 10 g precipitate.

19. A sample X shows efflorescence and sample Y show deliquescence nature.

In sample X vapour pressure of hydrated crystal is lesser than pressure of moisture present in atmosphere.

In sample Y vapour pressure of hydrated crystal is greater than pressure of moisture present in atmosphere.

20. Formula $w = \dfrac{MC.t}{2.96,500} \Rightarrow t = \dfrac{W \times 96,500 \times 2}{M.C}$

$W = 8$ g, $C = 10$ amp

$M = 40$, $Z = 2$

$$\therefore t = \frac{8 \times 2 \times 96500}{40 \times 10} = 3860 \text{ sec}$$

21. According to Faraday's first law

$$W = \frac{Z.C.t}{n \times 96,500} \Rightarrow \frac{n \times 96,500}{C.t} = \frac{Z}{W}$$

$$\Rightarrow \frac{C.t}{n \times 96,500} = \frac{W}{Z} = \text{no.of moles}$$

$$\therefore\ n_{Ag} = \frac{C_{Ag}.t_{Ag}}{n_{Ag} \times 96,500} n_{Cu} = \frac{C_{cu}.t_{cu}}{n_{cu} \times 96,500}$$

Given that $n_{Ag} = n_{Cu}$ and two electrolytic cells are connected in series that is $C_{Ag} = C_{Cu}$

$$\therefore \frac{t_{Ag}}{n_{Ag}} = \frac{t_{Cu}}{n_{Cu}} \Rightarrow \frac{n_{Ag}}{n_{Cu}} = \frac{t_{Ag}}{t_{Cu}}$$

$$\therefore \frac{n_{Ag}}{n_{Cu}} = \frac{1}{2}. = 1 : 2$$

22. $H_2O \rightarrow H^+ + O\bar{H}$

$4O\bar{H} \rightarrow 2H_2O + O_2 + 4\,\bar{e}$

4F of electricity $\rightarrow$ 22.4 ℓ of O_2 at STP

$4 \times 96{,}500$ C $\rightarrow$ 22.4 l of O_2 at STP

$15 \times 4 \times 60 \times 60$ C $\rightarrow$?

$$= \frac{15 \times 4 \times 3600 \times 22.4}{4 \times 96{,}500} = 12.53\ \ell \text{ of } O_2 \text{ at STP.}$$

23. Potable water has a pleasant taste and odour and has dissolved matter like air, CO_2 and minerals which are absent in distilled water. The salts present in our body dissolves in distilled water and causing health problems.

24. The melting point of water decreases by adding of ethylene glycol. Hence within a wide range of temperature it remains in the liquid state. Thus ethylene glycol can conveniently work as an antifreeze for the water used as a coolant in automobiles especially in cold countries.

25. 50 g of 15% $\left(\frac{w}{w}\right)$ sodium hydroxide

$\Rightarrow$ 7.5 g of NaOH is present in 50 g of solution.

$\Rightarrow$ 42.5 g of water is present in 50 g of solution

$$\text{Volume of water} = \frac{\text{mass}}{\text{density}}$$

$$\text{Volume of water} = \frac{42.5}{0.9} = 47.22\ \text{cm}^3$$

Concept Application Level—3

1. (i) Products obtained in the given reactions.
(ii) Product formed when cupric carbonate is treated with dil.H_2SO_4.
(iii) Nature of the product obtained cooling.
(iv) Effect of coding on the product formed.
(v) Product formed when cupric carbonate is treated with dil. HNO_3
(vi) Nature of the product formed.
(vii) Effect of cooling on the product formed.

2. (i) Composition of salts which impart temporary and permanent hardness to water.
(ii) Reaction between NaOH and components of temporary hard water.
(iii) Nature of the products formed.
(iv) Effect of the nature of the products formed on the hardness of water.
(v) Reaction between one of the products formed in the above reaction and the components causing permanent hardness.

3. (i) Comparison of the size of the solute particles and colloid particles.
(ii) Conditions required for a liquid to boil.
(iii) Effect of presence of soluble impurities on the vapour pressure of the liquid.
(iv) Nature of the colloid particles.
(v) Effect of the presence of the colloid particles on the vapour pressure of the dispersed medium (liquid).

4. (i) Comparison of nature of solute, colloid and suspended particles.
(ii) Wavelength of the visible light rays.
(iii) Comparison of this wavelength with the size of the particles present in the three mixtures.
(iv) Effect of the size of the particles on the passage of visible light rays through the mixture.
(v) Phenomena which occur in the three containers when the light rays are incident on them.

5. (i) Product obtained at the electrodes in Hoffman voltmeter.
(ii) Reaction at the cathode.
(iii) Reaction at the anode.
(iv) Comparison of change in number of ions at the respective electrodes.
(v) Effect of the above change on the colour of litmus paper.

6. In first test tube crystallization takes place, in the second test tube no crystallization is observed. In the second test tube calcium chloride is formed which is deliquescente in nature and therefore it does not crystallize.

7. Cobalt chloride is a desiccating material and hence it absorbs water molecules from moisture and turns pink. When cobalt chloride is kept in low humid air, it loses its water molecules and it becomes blue in colour. Vapour pressure of anhydrous cobalt chloride is less than that of water vapour pressure. In low humid air the vapour pressure of hydrated cobalt chloride is comparatively higher than water vapour pressure hence it loses water of crystallization.

8. Ist Cell

$ZnSO_4$ dissociates into Zn^{2+}, SO_4^{2-}

II cell

$AgNO_3$ dissociates into Ag^+, NO_3^-

As per faraday's II law of electrolysis

$$\frac{m_1}{E_1} = \frac{m_2}{E_2}$$

$$W = \frac{MCt}{ZF}$$

$$\frac{m_1}{\frac{AWt}{Valency}} = \frac{m_2}{\frac{AtMt}{Valency}} \Rightarrow \frac{W_1}{M_1} = \frac{C_1t_1}{Z_1F} \quad (1)$$

As same number of moles.

$$\frac{W_1}{M_1} = \frac{W_2}{M_2}$$

As the cells are connected in series

same amount of current flows.

$C_1 = C_2$

From equation (1) and (2)

$$\frac{C_1t_1}{Z_1F} = \frac{C_2t_2}{Z_2F} \Rightarrow \frac{t_1}{z_1} = \frac{t_2}{z_2} \Rightarrow \frac{t_1}{t_2} = \frac{z_1}{z_2}$$

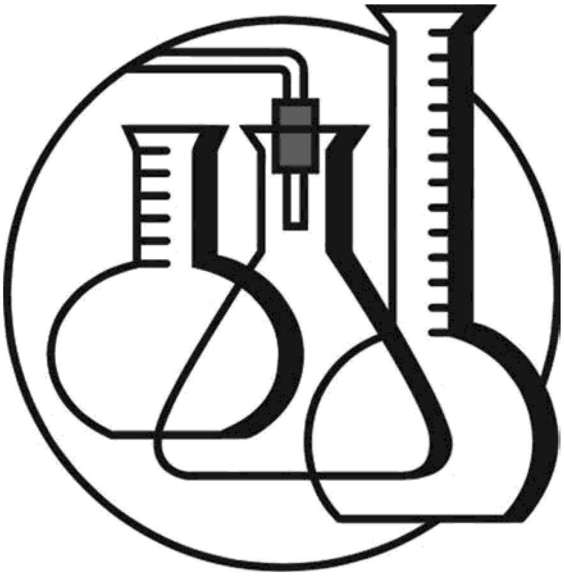
$$\frac{t_1}{t_2} = \frac{2}{1} = 2:1$$

9. Potassium and sodium are two metals which react with cold water producing heat. They can even react with moisture. As they float on water, they burn in oxygen producing flames. Potassium burns with lilac flame and sodium burns with golden yellow flame.

$$2K + 2H_2O \rightarrow 2KOH + H_2$$

$$2Na + 2H_2O \rightarrow 2NaOH + H_2.$$

10. Table salt contains impurities like $CaCl_2$ and $MgCl_2$ in small percentages which absorb moisture from air on account of their deliquescent nature, therefore table salt shows deliquescent nature.



8

Metals and Non-Metals

INTRODUCTION

Metals in nature generally exist in the form of their compounds. The extraction of metals from their respective compounds involves various processes from simple mechanical crushing or grinding to complicated chemical reactions under specific conditions for a better yield. These processes are carried out in well-designed furnaces. Finally, these metals are purified to different extents based on their end use. All these processes come under the purview of **metallurgy**. The properties of metals can be improvised by doping a small amount of another metal or non-metal which makes the same metal usable for a variety of purposes and this area comes under the study of alloy.

Certain useful non-metals like sulphur and carbon, are available in the elemental state under the earth's crust. These non-metals are excavated and refined before using them in various fields. Apart from this, different compounds which consist of various metals and non-metals in different proportions are manufactured in industries in large scale and prepared in the laboratory in small scale depending on their application. The study of these metals, non-metals and their compounds is necessary because of their wide range of applications.

Metallurgy

Some metals like silver, gold, platinum are less reactive and are found in their free states. The other metals being highly reactive are found in their combined states like oxides, carbonates or sulphides. These solid inorganic compounds found in the earth's crust are called minerals.

In certain minerals, the percentage of a particular metal is high and these metals can be extracted from these profitably; such minerals are called **ores**. The impurity associated with the ore is called **gangue**. The process of the extraction of metals from their respective ores is called **metallurgy.**

Metals are extracted from suitable ores through certain **general metallurgical processes** like

(i) Dressing or concentration of ore

(ii) Concentration of ore

(iii) Conversion of ore to oxide

(iv) Extraction of metal

(v) Refining

(i) **Dressing of ore:** The ores are in the form of huge rocks. In this process, the rocks are broken down into small pieces and ground to powder. This powdered form of ore is used for further metallurgical processes.

(ii) **Concentration of ore:** The ore is associated with huge amounts of impurities like sand, other metal compounds, and certain non-metals. The impurities that are associated with the ore is called gangue. In this process, certain amount of gangue is removed from the ore, thus increasing the concentration of metal in the ore. The process by which the gangue is removed depends on the type of ore and gangue.

(a) **Magnetic separation:** This process is carried out for those ores in which either the ore or the gangue is magnetic in nature. The powdered ore is made to fall on a rubber belt which moves horizontally over two pulleys of which one is a strong map net. Magnetic components are retained on the belt and is collected as a separate heap after coming out of the magnetic influence.

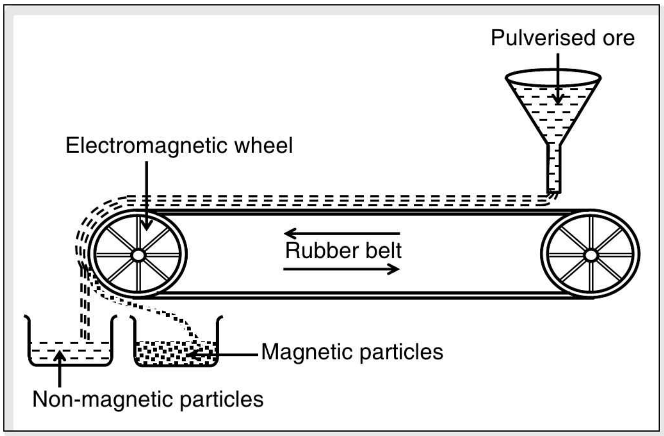


Figure 8.1 Electromagnetic separation

(b) Gravity separation: The ores in which the specific gravity difference between the ore and gangue is high is concentrated by gravity separation. This is generally applicable for iron ore. The ore is taken on a sloping table with ridges and washed with water. The water washes away the lighter gangue particles leaving behind the concentrated ore. This method of separation is applicable to all types of ores except sulphide ores.

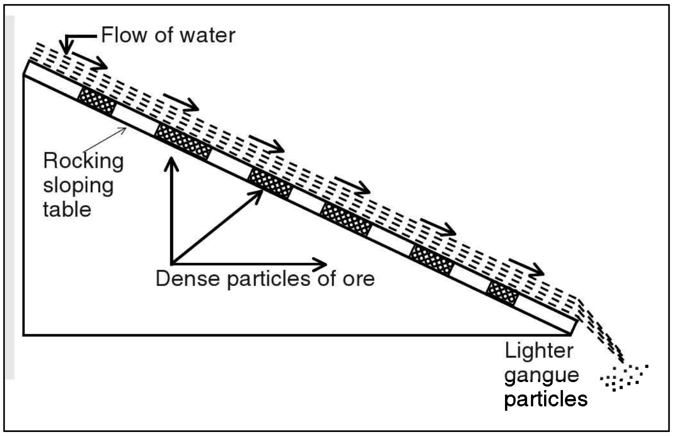


Figure 8.2 Concentration of ore by Gravity Process

(c) Froth floatation: This process is generally followed for sulphide ores. The ore is taken in a tank with oil and water and mixed thoroughly by blowing air. Bubbles of oil are formed. The ore sticks to these bubbles and rises up while the gangue sticks to the water and settles at the bottom. The froth along with the ore is separated.

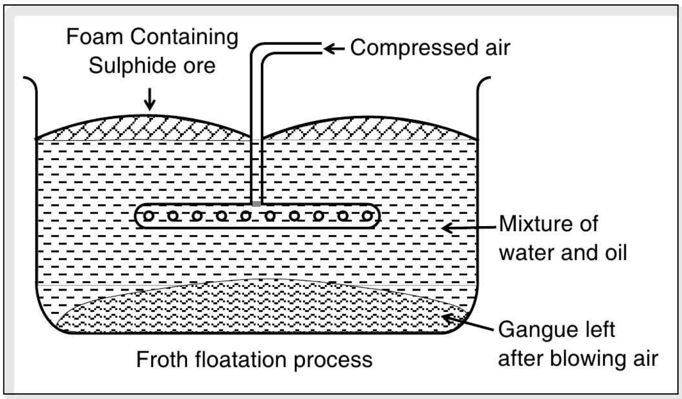


Figure 8.3 Froth floatation process

(iii) **Conversion of ore to oxide:** The conversion of ore to oxide is carried out by two methods.

(a) Roasting: This is generally carried out for sulphide ores. The ore is heated to a temperature below the fusion point of the ore where the ore reacts with the oxygen present in air and forms metal oxide and sulphur dioxide.

$MS + O_2 \rightarrow MO + SO_2$

Volatile impurities present in the ore are removed during this process.

(b) Calcination: This process is carried out specifically for carbonate ores. The main purpose of this process is the removal of CO_2 from the ore. Hence the ore is heated to its decomposition temperature and gets converted to the oxide form. Along with CO_2, volatile impurities are also removed in this process. Apart from carbonate ores, hydrated ores are also subjected to calcination for the removal of water of crystallization.

$MCO_3 \rightarrow MO + CO_2$

(iv) **Extraction of metal:** The oxide ores obtained from the above process are reduced to metals by smelting. During this process flux (a material which combines with gangue) is added. This converts the gangue to slag (the fusible material gangue forms when flux reacts with it), which is separated from the ore. The metal so obtained in this process is not 100% pure and needs to be further purified.

(v) **Purification or refining of metals:** Different methods of the refining of metals are followed for different metals. The method of refining generally depends upon the type of impurities present within the metal.

[redacted]			
(i)	Distillation	Iron, Mercury	The metal is strongly heated above its boiling point in the absence of air. The metal vapourizes, leaving behind the impurities. The vapours are cooled in earthen retorts, to get the metal in the solid or in the liquid form.

(Continued on following page)

[redacted]			
(ii)	Liquation	Lead, Tin (metals with low melting point)	The metal is taken on the upper part of the sloping hearth and heated above its melting point. The metal melts, flows down the hearth and is collected at the bottom.
(iii)	Polling	Copper with cuprous oxide as impurity	Molten copper is stirred with wooden poles. These poles emit wood gas which reduces copper oxide to copper.
(iv)	Oxidation	Iron with oxidizable impurities	Oxygen is blown through molten metal where the impurities get converted to gaseous oxides and are removed. $C + O_2 \rightarrow CO_2 \uparrow$ $S + O_2 \rightarrow SO_2 \uparrow$
(v)	Electrolytic refining	Aluminium	A block of impure metal is taken as anode and a thin strip of pure metal as cathode. The electrolyte is the soluble salt of the metal. On passing the current, the metal ions from the anode dissolve in the electrolyte, go towards the cathode and get discharged there. Electrolysis continues and the cathode becomes a thick block of pure metal.

The extraction of all the metals from the ores follows one of the above processes.

Metallurgy of iron

Iron is a highly reactive metal and is generally found in the oxide state. The most common ores of iron are

Haematite	Fe_2O_3
Limonite	$Fe_2O_3 . H_2O$
Magnetite	Fe_3O_4
Siderite	$FeCO_3$
Iron pyrites	FeS_2
Magnetite	Fe_3O_4

Iron is generally extracted from haematite, limonite, siderite. Among these haematite and limonite are the most preferred ores.

The manufacturing of pig iron is the first step in the metallurgy of iron. This pig iron is further converted to cast iron which is used for the manufacture of steel and wrought iron.

(i) **Dressing and concentration of ore:** The ore is crushed to make smaller pieces from large chunks.

The crushed ore is concentrated by the process of magnetic separation and further concentration is done by gravity separation process.

(ii) **Conversion to oxide:** The concentrated ore is converted to oxide form by the process of roasting which involves heating the ore in the presence of excess of air.

On roasting, the carbonate ore decomposes to oxide giving out carbon dioxide. This process is also associated with other advantages like

(a) the removal of moisture and other volatile impurities.

(b) the removal of impurities like sulphur, phosphorous, arsenic, antimony in the form of gaseous oxides.

(c) the conversion of ferrous oxide to ferric oxide.

(d) inducing porosity in the mass, thus rendering the metal to easy reduction.

(iii) **Reduction of oxide to metal:** The reduction of oxide to metal is carried out with carbon in a blast furnace by the process called smelting.

Smelting in blast furnace

Blast furnace is a huge chimney like structure about 30 m high and 8 m in diameter. It is made of iron plates and lined internally with refractory bricks. On top, it has a double cup and cone arrangement. Below this, there is an outlet for waste gases. A hearth is present at the bottom to collect cast iron and slag, and has separate outlets for each. Hot compressed air is blown into the furnace through pipes called tuyeres which are placed above the hearth.

The ore is mixed with coke, and limestone approximately in the ratio of 8 : 4 : 1. This mixture is called charge.

The charge is lowered into the furnace from the top through the cup and cone arrangement and various reactions take place in the furnace at different levels.

(a) Lower region (1500°C–2000°C)

Coke combines with the heated air coming from the tuyeres and burns to form carbon dioxide. The reaction, being highly exothermic increases the temperature in this zone to 2000°C.

$$C + O_2 \rightarrow CO_2 + 97 \text{ kcal.}$$

This region is also called the combustion zone.

(b) Middle region or fusion zone (1500°C–1000°C)

The carbon dioxide formed in the lower layer moves to the middle layer where it is reduced to carbon monoxide.

$$CO_2 + C \rightarrow 2CO - 39 \text{ kcal}$$

At such a high temperature, the limestone added decomposes into calcium oxide and carbon dioxide.

$CaCO_3 \rightarrow CaO + CO_2 - 43$ kcal

The calcium oxide(quick lime) formed reacts with impurities like sand in the ore and converts them to slag.

$CaO + SiO_2 \rightarrow CaSiO_3$

The slag, calcium silicate goes towards the hearth present at the bottom of the furnace. As the reactions in the middle region are endothermic, the temperature of this zone decreases.

(c) Upper region or reduction zone (1000°C–500°C)

The carbon monoxide formed in the middle region moves to the upper region where it reduces the iron oxide to iron.

$$FeO + CO \xrightarrow{750-600°C} Fe + CO_2$$

$$Fe_3O_3 + 3CO \rightarrow \xrightarrow{600-400°C} 2Fe + 3CO_2$$

The iron formed here melts due to high temperature and then, due to its high density, settles down. Both the slag (calcium silicate) and iron settle down in the hearth. Iron being heavier forms the bottom layer with slag on top. From here, iron and slag are tapped through separate outlets.

The iron obtained from this process is called the pig iron. This is not 100% pure and acts as the basic raw material for cast iron and steel.

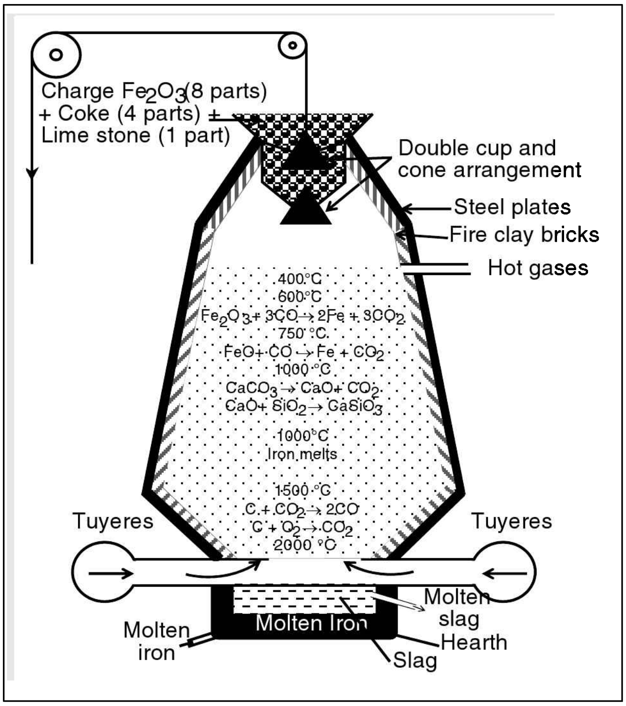


Figure 8.4

Cast iron

This is obtained by re-melting pig iron in a vertical furnace called cupola and thereby gets refined. It is then poured into suitable moulds where it solidifies. This re-melted pig iron is called cast iron.

Wrought iron

This is a comparatively purer form of iron. Cast iron is taken in a reverberatory furnace and stirred at high temperature. This process is called puddling. Most of the impurities are lost during this process due to the high temperature. Iron at this stage is in a semi solid state. This on cooling gives wrought iron.

Steel

Steel is an **alloy of iron** with some amount of carbon in it. The carbon added increases the hardness of iron. Thus steel is harder than iron and the hardness increases with increase in the carbon content. The manufacture of steel is carried out by many processes. The best quality is the however obtained by the **open-hearth process**.

Open-hearth process for making special type of steel

As the name suggests, the shape of the furnace is like a hearth the top of which is open. The charge is pig iron and steel scrap. The process can be carried out in two ways depending on the impurities present in the raw material.

Acid process: In this process, the furnace is lined with acidic refractories, i.e., silica brick.

Basic process: In this process, the furnace is lined with magnesite or dolomite. Basic process is adopted if phosphorus is present as an impurity.

Along with pig iron, steel scrap is added as raw material in this process. To promote the oxidation of the impurities, small amount of iron ore is added to provide additional oxygen.

The temperature on the top of the hearth is generated by hot fuel gas which burns on the hearth and produces a temperature of 1600°C to 1650°C. Carbon starts getting oxidized. Sulphur gets oxidized to sulphur dioxide, silicon to silicon dioxide and phosphorous to phosphorous pentoxide. The silica and phosphorous pentoxide react with manganese and calcium oxide to form slag.

$C + O_2 \rightarrow CO_2$

$2CO_2 + C \rightarrow 2CO$

$P + O_2 \rightarrow P_2O_5$

$Si + O_2 \rightarrow SiO_2$

$MnO + SiO_2 \rightarrow MnSiO_3$

$CaO + P_2O_5 \rightarrow 2Ca_3\,(PO_4)_2$

The final composition of steel is adjusted by adding ferrosilicon and/or ferromanganese alloy. Thus in this process temperature and composition can be controlled. It is a very lengthy process and takes about 5 to 15 hours.

Raw materials used in open-hearth process have low content of phosphorous and sulphur in them, hence the steel made by this process is of better quality.

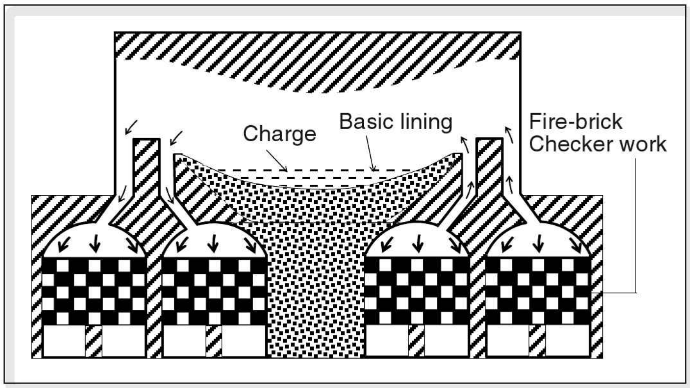


Figure 8.5 An open hearth furnace

Alloying of metal changes its physical properties and thus makes it useful for a variety of purposes depending on the composition of the alloy.

Another important aspect of alloy is prevention of corrosion. Stainless steel, a unique alloy of iron does not get corroded at all.

Corrosion of iron can be prevented in many other ways.

The most common ones are

(i) **Galvanization:** The process of coating a layer of zinc on the metal is called galvanization.

(ii) **Electroplating:** In this process, one metal is deposited over the other metal through an electrolytic process. The metal to be coated is taken as the cathode and the metal with which it is coated is taken as anode. On passing electricity, the anode dissolves in the electrolyte which is generally a salt solution of the anodic metal. The metal ions move towards the cathode where they are discharged and get deposited on the cathode, thus forming a coating over it.

Metals thus have various applications in the from of elements, compounds, alloys etc. Similarly, non-metals also play a very important role in various fields due to their specific properties. Which makes, the study of non-metals also equally significant as that of metals.

Non-metals

Carbon

It is one of the most important non-metallic elements. It is invariably present in all the living organisms in the form of biomolecules.

Occurrence

Carbon occurs both in the free state and in the combined state.

Free state

Carbon exists as the native element in the form of coal in the earth's crust. It occurs in a very small amount in the form of its allotropic forms like diamond and graphite.

Combined state

In the combined state, carbon exists in the form of oxides, (carbon dioxide, carbon monoxide), carbonates (metal carbonates) and many organic compounds (proteins, carbohydrates, etc).

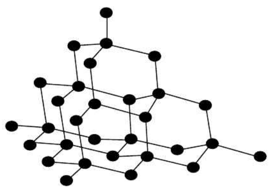
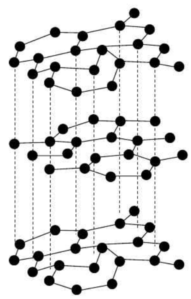
Allotropy

Allotropy is the phenomenon in which an element exhibits different physical forms with similar chemical properties. The different physical forms exhibited by the element are called allotropes. Carbon exhibits various allotropic forms which have a wide variety of applications. The allotropic forms are broadly classified into **crystalline forms and amorphous forms**.

(i) **Crystalline forms**: In these allotropic forms, the carbon atoms have a well defined regular geometrical arrangement.

☛ *Example* Diamond, Graphite

Comparative study of diamond and graphite

Structure	Diamond has a regular tetrahedral arrangement. This is due to the bonding of each atom of carbon with four other carbon atoms covalently, forming a single unit of crystal. These crystal units lie in different planes accounting for a rigid three dimensional structure. Carbon has a valency of four and each carbon is bonded to four other carbon atoms forming a tetrahedral unit. These tetrahedral units lie in different planes, thus forming a rigid three dimensional structure. 	In graphite, each carbon atom is bonded covalently to three other carbon atoms resulting in the arrangement of hexagonal rings in a single plane. The forces of attraction between the atoms of two single crystals, in the parallel planes are weak. Each carbon is bonded to three carbon atoms only leaving behind one free valency. A three dimensional arrangement of hexagonal rings is resulted. These rings lie on a single plane. The entire structure is such that the layers of hexagonal rings are arranged parallel to each other. 

Appearance	A pure diamond is a colourless, transparent, crystal. It is the hardest among naturally occuring solids.	Graphite is a dark grey, very soft solid with metallic lustre.
Conduction	It is a good conductor of heat and bad conductor of electricity.	It is a bad conductor of heat and good conductor of electricity.
Refractive index	It has a high refractive index of 2.5.	It is opaque.
Solubility	It is insoluble in common solvents.	It is insoluble in common solvents.
Density	Density of diamond is 3.5 gm/cm^3, which is the densest form of carbon.	Density is 2.25 gm/cm^3.
Melting Point	The melting point of diamond is about 3700°C.	It has a melting point of about 3600°C.

(ii). **Amorphous allotropes of carbon:** In these forms of carbon, the carbon atoms are not arranged in an orderly manner.

☛ *Example* Coke, wood, charcoal, sugar, lamp black, animal charcoal. etc.

Comparative study of amorphous allotropes

Coke	Coke is prepared by heating coal in the absence of air up to a temperature of 1300°C in huge iron retorts.	It is a grayish black porous solid.	(i) It is used as a household fuel. (ii) It is used extensively in the extraction of metals like copper and lead, from their oxides and sulphide ores as it is an excellent reducing agent. (iii) It is used in the manufacture of graphite and calcium carbide. (iv) It is used in the manufacture of water gas and producer gas.
Lamp black	Lamp black is prepared by burning mustard oil, turpentine oil, petroleum in the absence of oxygen. A clean dry glass slide is placed over the flame of mustard oil lamp. After some time a deep black powdery substance is coated on the slide, which is known as lamp black.	Lamp black is light, powdery black substance, having a velvet touch. It has an oily feel due to the presence of vapours of some amounts of oil.	(i) Lamp black is used as stabilizing filler for rubber in making tyres and plastics. (ii) It is used as a black pigment in inks and paints. (iii) It is used for making black shoe polishes. (iv) It is used in the manufacture of black carbon papers and carbon ribbons for type-writers.

Wood charcoal	A dry hard glass test tube is half filled with wood shavings. The wood shavings are heated in the absence of air using Bunsen burner. Wood shavings get charred, giving off fumes. The charred product formed is wood charcoal.	It is a brittle grey solid and can adsorb gases and liquids.	(i) It is used as a house hold fuel. (ii) For small scale extraction of metals. (iii) As a deodorant. (iv) In gas masks.
Sugar charcoal	It is prepared by the destructive distillation of sugar.	It is a thick black residue.	(i) It is used for extracting metals from their oxides. (ii) It is used as an adsorbent material in place of activated charcoal.
Animal charcoal	Animal bones contain organic matter and calcium phosphate. The crushed fine powder of the animal bones if subjected to destructive distillation produces residue. This residue is called bone charcoal.	It has less percentage of carbon and has the property of adsorption. It has high adsorptive capacity for mercury, arsenic, etc.	(i) Bone charcoal is used to remove colour from sugar cane juice by adsorbing impurities. (ii) It is used in the extraction of yellow phosphorous.

Compounds of Carbon

Carbon, in nature, exists largely in the form of compounds. These compounds exist invariably in the form of organic and inorganic compounds. Some of the important inorganic compounds of carbon are

(i) **Oxides of carbon:** Carbon reacts with oxygen to form two types of oxides, namely carbon monoxide and carbon dioxide.

(a) Carbon monoxide: It is prepared by passing carbon dioxide over heated coke.

$$CO_{2(g)} + \underset{\text{(red hot)}}{C} \rightarrow 2CO_{(g)} - Q$$

Carbon monoxide is a very harmful gas. On breathing, it combines with blood, reacts with haemoglobin forming carboxy haemoglobin thus decreasing the oxygen carrying capacity of the blood.

Uses

(i) It is used in the preparation of fuel gases.
(ii) It is used as reducing agent.
(iii) It is used in the preparation of metal carbonyls.

(b) Carbon dioxide: This is prepared by treating hydrochloric acid with limestone.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$$

Carbon dioxide gas plays a very important role in the atmosphere.

Uses

(i) It is used in the photosynthesis of plants
(ii) It also traps the heat radiation and keeps the earth warm.

The characteristic feature of carbon dioxide gas is seen when it is passed through lime. A milky white precipitate of calcium carbonate is formed, which dissolves on excess passage of carbon dioxide due to the formation of soluble calcium bicarbonate

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$$

(ii) **Carbonates and bicarbonates:** Carbonates and bicarbonates are another important class of compounds of carbon.

All carbonates except sodium and potassium carbonates on thermal decomposition give carbon dioxide. All bicarbonates on heating undergo decomposition to give carbon dioxide. Thus carbonates and bicarbonates act as sources, for the preparation of carbon dioxide.

Nitrogen

Nitrogen is an inactive element and is present in maximum proportion in air. The significance of nitrogen in air is to dilute the activity of oxygen thereby allowing natural processes like respiration and combustion to take place at a moderate rate.

Occurrence

Free state

Nitrogen exists in the free state in the atmospheric air. It is the major constituent of air comprising 78% by volume and 75% by weight.

Combined state

Nitrogen occurs in the combined state in various forms. It is present in the form of minerals like nitre (KNO_3) and chile salt petre ($NaNO_3$). Nitrogen is present in major amounts in organic matter such as proteins, nucleic acids, enzymes and various compounds of biological importance.

Preparation

In the industries, nitrogen is manufactured by isolation from the atmospheric air as it contains nitrogen in abundance. This is done by fractional distillation of liquid air.

Laboratory method of preparation of nitrogen gas

Principle: Ammonium chloride reacts with sodium nitrite to give ammonium nitrite which decomposes thermally to give nitrogen gas.

$$NH_4Cl + NaNO_2 \rightarrow NH_4NO_2 + NaCl$$

$$NH_4NO_2 \rightarrow N_2 + 2H_2O$$

Procedure

Equimolar solutions of ammonium chloride and sodium nitrite are taken in a round bottom flask and heated gently. Ammonium nitrite is formed which decomposes to give nitrogen which is collected by the downward displacement of water.

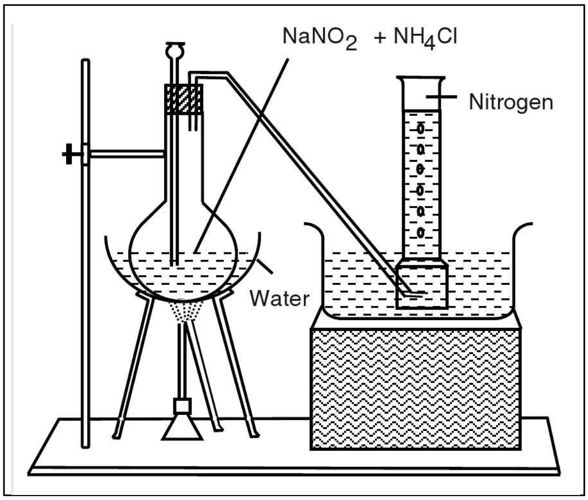


Figure 8.6 Preparation of nitrogen

Physical properties

Physical properties of nitrogen

Solubility	Slightly soluble in water (2.3 vol in 100 vol)
Density	Slightly lighter than air. Vapour density of air = 14.4 Vapour density of N_2 = 14.0
Liquefaction	It can be liquefied to a colourless liquid which boils at –195.8°C
Solidification	It can be solidified under high pressure to a white snow like mass which melts at –209.8°C.
Nature	It is a chemically nonreactive gas. Due to this nonreactive nature, it is used in (i) the filling of electric bulbs to prevent the oxidation of the filament present in it. (ii) and in the preservation of food stuffs

Chemical properties

Reaction with non metals (i) Hydrogen	Nitrogen reacts with hydrogen at high temperature and pressure to give ammonia gas. $N_2 + 3H_2 \rightarrow 2NH_3$
(ii) Oxygen	Nitrogen and oxygen react in equal volumes to form nitric oxide $N_2 + O_2 \rightarrow 2NO$
Reaction with metals (i) magnesium	Magnesium reacts with nitrogen to form magnesium nitride $3Mg + N_2 \rightarrow Mg_3N_2$
(ii) Calcium	$3Ca + N_2 \rightarrow Ca_3N_2$
(iii) Aluminium	$2Al + N_2 \rightarrow 2AlN$
Reaction with compounds (i) Calcium carbide	Heating calcium carbide with nitrogen at 800°C to 1000°C forms a mixture of calcium cyanamide and graphite $CaC_2 + N_2$ $\downarrow$ 800°C $CaCN_2 + C$

Uses

(i) Filling of electric bulbs

(ii) Manufacture of fertilizers

(iii) Storage of canned food

Compounds of nitrogen

Since nitrogen is the most essential element for the growth of plants and most of the plants are incapable of absorbing nitrogen directly from the atmosphere, the manufacture of useful compounds from nitrogen has lot of industrial significance. The most important compounds are ammonia and nitric acid which form the basic raw materials for the manufacture of a number of fertilizers.

Laboratory preparation of ammonia

Principle: Ammonium chloride on reaction with an alkali like calcium hydroxide liberates ammonia gas.

$$NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O + 2NH_3\uparrow$$

Process: Ammonium chloride and calcium hydroxide are taken in 1 : 3 ratio by weight in a round bottom flask and heated gently. The gas evolved is passed through a delivery tube which is connected to the bottom of a tower packed with quick lime. The gas passes through this tower and is collected in an inverted gas jar by downward displacement of air.

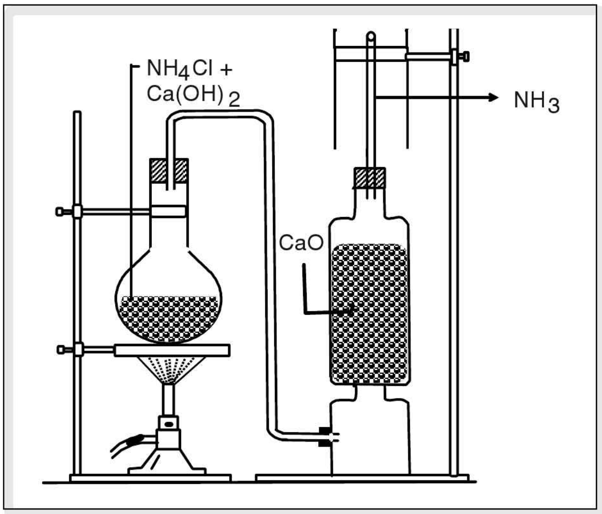


Figure 8.7 Preparation of ammonia

Physical properties

Colour	Colourless
Odour	Pungent smell, causes burning sensation in the upper part of nasal track and brings tears to eyes.
Taste	Bitter in taste
Physiological nature	Poisonous, damages respiratory system
Density	It is lighter than air (vapour density 8.5)
Solubility	Highly soluble in water, so it cannot be collected by the downward displacement of water. 1300 vol of NH_3 can be dissolved in 1 vol. of H_2O at STP.
Boiling point	–33.4°C.
Freezing point	–78°C.

Chemical properties

With non-metals (i) Oxygen	A burning match stick when introduced into a jar containing ammonia and oxygen burns with a pale blue flame. $4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$ When the above mixture of ammonia and oxygen is passed over heated platinum, nitric oxide and water vapour are formed with the evolution of heat. $4NH_3 + 5O_2 \xrightarrow[900°C]{Pt} 4NO + 6H_2O$ $2\ NO + O_2 \rightarrow 2NO_2$ $2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$
(ii) Chlorine	1) Limited amount of Cl_2 White dense fumes of ammonium chloride are formed along with nitrogen. $8NH_3 + 3Cl_2 \rightarrow 6NH_4Cl + N_2$ 2) Excess amount of Cl_2 Nitrogen trichloride and HCl are formed. $NH_3 + 3Cl_2 \rightarrow NCl_3 + 3HCl$
With metals	On reaction with active metals corresponding amides are formed. $2NH_3 + 2Na \rightarrow 2NaNH_2 + H_2$ $2NH_3 + 2K \rightarrow 2KNH_2 + H_2$
With acids	Ammonia being slightly basic reacts with acids to form salts. $NH_3 + HCl \rightarrow NH_4Cl$ $NH_3 + HNO_3 \rightarrow NH_4NO_2$ $2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$
Reducing Property	When Ammonia is passed over hot cupric oxide, gets reduced to copper. $CuO + 2NH_3 \rightarrow N_2 + 3Cu + 3H_2O$

Uses

(i) Manufacture of fertilizers
(ii) As a laboratory reagent
(iii) Manufacture of rayon, plastic, rubber, etc.
(iv) In the preparation of explosives like ammonal (NH_4NO_3 + Al powder) and amatol (NH_4NO_3 + 20% TNT)

Phosphorous

Phosphorous is an important element and is used in the elemental state and in the compound form. It is one of the essential nutrients required in larger amounts (macro nutrient) for plants. It plays a role in photosynthesis.

Occurrence

Phosphorous, being highly reactive, doesn't exist in the free state. In the combined state, it exists in the form of phosphates, in inorganic as well as organic matter.

Inorganic compounds

Chlorapatite	$3Ca_3(PO_4)_2 . CaCl_2$
Fluorapatite	$3Ca_3(PO_4)_2 . CaF_2$
Phosphorite	$Ca_3(PO_4)_2$

Organic matter

It is found in phosphoproteins of yolk, bone marrow, brain, nervous system, bones, teeth, etc.

Preparation

Phosphorous is prepared by the electrolytic reduction of mineral phosphate.

Procedure

The mineral phosphate (calcium phosphate) is mixed with sand and coke. This mixture is taken in an electric furnace with carbon electrodes. The mixture is electrically heated up to 1775K.

The following reactions take place

$$2Ca_3(PO_4)_2 + 6SiO_2 \rightarrow 6CaSiO_3 + P_4O_{10}$$

(sand) (slag)

$$P_4O_{10} + 10C \rightarrow P_4 + 10CO$$

The slag formed settles at the bottom and is removed. Phosphorous vapours and carbon monoxide gas formed are let out of the furnace from the top. The subsequent cooling of these vapours under water results in the condensation of phosphorous into solid phosphorous.

Purification

The phosphorous obtained is purified using potassium dichromate in an acidic medium. The impurities are oxidized and removed as vapours or slag. Pure liquid phosphorous settles at the bottom where it is collected, filtered through chamois leather and sent through water cooled pipes for solidification.

Allotropy

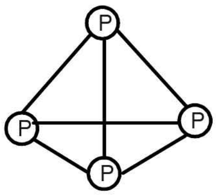
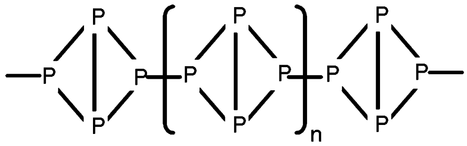
The phenomenon of the existence of an element in more than one form is called allotropy and the different forms of the element are called allotropes. Allotropes have almost same chemical properties but different physical properties.

Phosphorous exists in two important allotropic forms.

(i) White phosphorous.

(ii) Red phosphorous.

Comparative study of white phosphorous and red phosphorous

State	Soft solid	Brittle powder
Colour	White initially, gradually changes to yellow	Dark red
Odour	Garlic smell	Odourless
Density	1.82 gm/cm^3	2.1 gm/cm^3
Melting Point	317 K	–
Boiling Point	553.5 K	Sublimes at 565K
Ignition temperature	308 K	533K
Physiological nature	Poisonous	Non-poisonous
Atomicity	Four	Exists as chains
Structure	 Isolated tetrahedral P_4 units	 Chains of tetrahedral P_4 units linked to each other by P–P bonds.

Chemical properties

(i) With air/oxygen	Phosphorous reacts with oxygen to form two types of oxides P_2O_3 and P_2O_5 $P_4 + 3O_2 \xrightarrow[\text{Limited supply}]{} 2P_2O_3$ $P_4 + 5O_2 \xrightarrow[\text{excess}]{} 2P_2O_5$ These oxides with (excess) water produce oxyacids like HPO_3 H_3PO_4, H_3PO_3 and $H_4P_2O_7$
(ii) With chlorine	Phosphorous reacts with chlorine to form PCl_3 and PCl_5. $P_4 + 6Cl_2 \rightarrow 4PCl_3$ Limited supply $P_4 + 10Cl_2 \rightarrow 4PCl_5$ Excess
(iii) With NaOH	Phosphorous when boiled with NaOH produces a colourless, poisonous gas phosphine $P_4 + 3NaOH + 3H_2O \rightarrow PH_3 + 3NaH_2PO_2$

Uses

(i) Red phosphorous is used in making safety matches.
(ii) Used in making phosphor bronze, an alloy of phosphorous, copper and tin.
(iii) Used in making rat poison (Zinc phosphide).
(iv) Used in making fertilizers.

Phosphorous plays a very vital role in the growth of plants. It is available to plants in the form of phosphate. One of the important constituent of fertilizers is phosphorous. It is given to plants in the form of calcium phosphate, super phosphate of lime, and lime nitrogenous phosphate.

Super phosphate of lime is a widely used phosphatic fertilizer which is prepared by treating calcium phosphate with concentrated sulphuric acid.

$$Ca_3(PO_4)_2 + H_2SO_4 \rightarrow \underbrace{2CaSO_4 + Ca(H_2PO_4)_2}_{\text{Super phosphate of lime}}$$

Oxygen

Oxygen is one of the most important non-metals. It plays a very important role in the life of most of the living organisms.

Occurrence

Oxygen is found in the free state and in the combined state.

Free state

Oxygen is present in free state in the atmospheric air. It comprises about 21% by volume and about 23% by mass of the total air. Water in oceans and other water bodies also contains some amount of oxygen in the dissolved state. Due to the presence of this dissolved oxygen in water, all aquatic species are able to survive in water.

Combined state

Water is the most important compound which contains oxygen in the combined state. Plants and animals also contain 50%–70% of oxygen in the combined state. 50% of oxygen is present in the form of silicates, carbonates, limestone and other ores.

Laboratory preparation of oxygen

In the laboratory, oxygen is prepared by the thermal decomposition of potassium chlorate or lead nitrate or potassium permanganate. The oxygen gas released is collected by the downward displacement of water.

$$2\,KClO_3 \xrightarrow[MnO_2]{\Delta} 2KCl + 3O_2 \uparrow$$

$$2Pb\,(NO_3)_2 \xrightarrow{\Delta} 2PbO + 4NO_2 + O_2 \uparrow$$

$$2KMnO_4 \xrightarrow{\Delta} K_2MnO_4 + MnO_2 + O_2 \uparrow$$

Physical properties

[redacted]	
Colour	Colourless
Taste	No characteristic taste
Odour	No characteristic odour
Physiological nature	Non-poisonous
Density	Vapour density = 16
Solubility	Slightly soluble in water
Liquefaction	–183°C at atmospheric pressure.
Boiling and freezing point	Boiling point is –183°C Freezing point is –218.4°C
Action on litmus	Neutral

Chemical properties

[redacted]	
(i) **With metals**	Metals react with oxygen to form basic or amphoteric oxides. $\left.\begin{array}{l} 2Ca + O_2 \rightarrow 2CaO \\ 2Mg + O_2 \rightarrow 2MgO \end{array}\right\}\text{basic}$ $4Al + 3O_2 \rightarrow 2Al_2O_3$ (amphoteric)
(ii) **With non-metals**	Non-metals react with oxygen to form basic or neutral oxides. $S + O_2 \rightarrow SO_2$ $C + O_2 \rightarrow CO_2$ $2H_2 + O_2 \rightarrow 2H_2O$

If a few drops of acid is added to water, it can be decomposed into its components, i.e., hydrogen and oxygen by passing electricity through it. This process is called **electrolysis of water** and is used for the industrial preparation of hydrogen and oxygen.

Electrolysis of water

If a little amount of sulphuric acid is added to water, the water is called acidulated water. When this is subjected to electrolysis, water decomposes to give hydrogen and oxygen. Hydrogen is liberated at the cathode and oxygen is liberated at the anode.

$$2H_2O \xrightarrow{\text{Electric current}} 2H_{2(g)} + O_{2(g)}$$

Experiment I

Acidulated water is taken in a rectangular tank. Platinum plates are inserted into the tank which are connected to the opposite terminals of the battery. When high voltage is passed through the tank, water electrolyses to give hydrogen gas at the cathode and oxygen gas at the anode.

Advantages

(i) The process is comparatively economical and can be used especially in places where the electricity is available at cheaper rates.

(ii) Hydrogen gas is obtained as a bi-product.

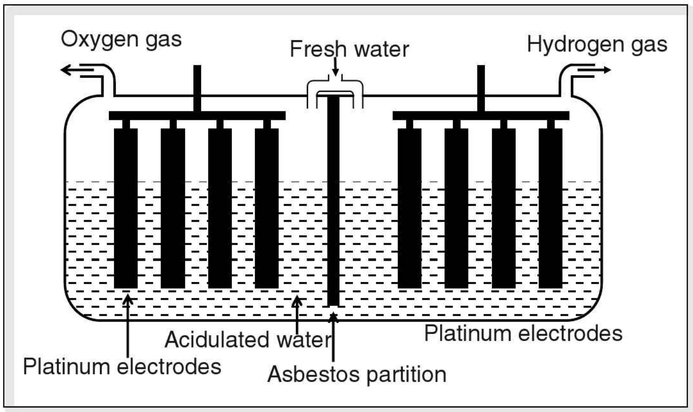


Figure 8.8 Industrial electrolysis of water

Properties of oxygen

Uses of oxygen

(i) Respiration of living organisms.

(ii) Combustion or burning of fuels.

(iii) Manufacture of H_2SO_4 and HNO_3 in industry.

(iv) Explosive: For blasting big rocks in mines, a mixture of coal, petroleum jelly and liquid oxygen is used in the form of cartridge.

(v) Metal extraction: Used in blast furnace for the extraction of iron.

(vi) Welding: A mixture of oxygen and hydrogen on burning gives oxy-hydrogen flame which is at a temperature of 2800°C. In place of hydrogen, when acetylene is used, it becomes oxy-acetylene flame which gives a still higher temperature of 3300°C. Both are used for welding purposes.

(vii) Stimulant for breathing: A mixture of 95% oxygen and 5% CO_2 is called carbogen. It is used for aiding breathing in patients with breathing problems.

(viii) As anaesthetic: A mixture of N_2O and oxygen is used as anaesthetic during surgical operations.

(ix) Rocket fuel: Liquid oxygen is used.

(x) Artificial respiration: Oxygen cylinders are carried by mountaineers, astronauts, miners, divers, submariners, aviators, firemen etc.

Sulphur

Sulphur is an important non metallic element. It reacts with metals thus destroying their metallic properties. Hence its name is derived from the Sanskrit word "sulvari" which means enemy of copper.

Occurrence

In nature, sulphur occurs in both free and combined state.

Free State

Sulphur in the free state is found in the earth's crust in the volcanic regions.

Combined state

Sulphur in the combined state is found in organic matter in the form of many biomolecules (insulin, glucosinolates of plants and animals, natural gas, etc) and in inorganic matter in the form of sulphides (cinnabar–HgS, galena–PbS, Iron pyrites–FeS) and sulphate (gypsum– $CaSO_4.2H_2O$, Epsom salt–$MgSO_4.7H_2O$)

☛ *Extraction* Sulphur is extracted from the earth's crust by the following process:

Frasch process

This process is used to extract sulphur j250which lies 150–400 m below the earth's crust.This process is also called Louisiana process as large deposits of it are found in Louisiana. A direct mining is not possible as sulphur is present in layers of quick sand and gravel.

Process: In this process, three concentric pipes of diameters 25 mm, 76 mm and 152 mm are drilled through the ground to the sulphur deposits. Super heated steam (170°C) under pressure is sent through the outer most pipe. This melts the sulphur below (m.p of sulphur = 112°C). Hot compressed air (up to 35 atm) is sent through the innermost pipe, which froths up the molten sulphur below. The sulphur foam formed rises up the middle pipe and is collected.

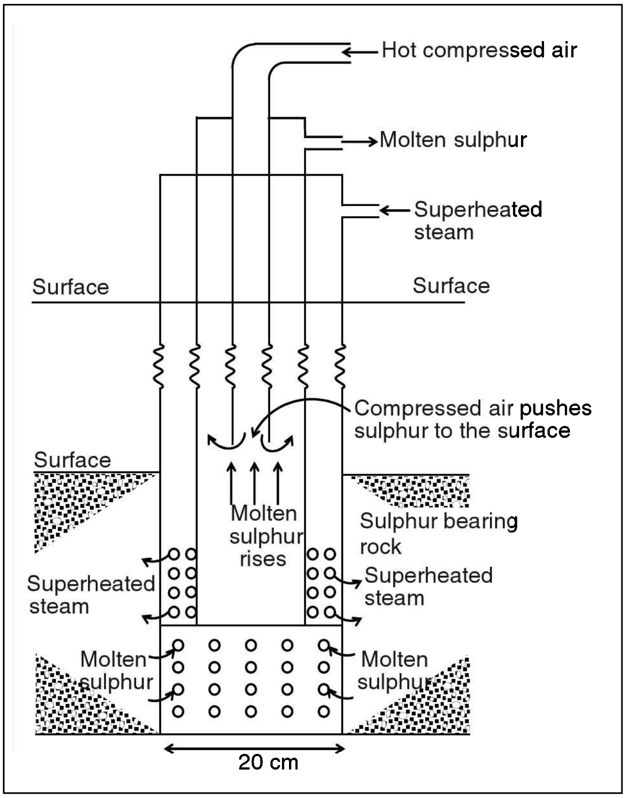


Figure 8.9 The Frasch process for extracting sulphur

Advantage

The sulphur extracted in this process is 99·5% pure and doesn't need further purification.

Allotropes

Allotropes of sulphur

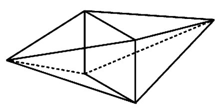
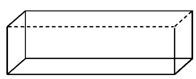
The phenomenon of the existence of an element in more than one physical form is called allotropy; and the other forms of the same element are called allotropes. Sulphur exists in different allotropic forms. Allotropes have same chemical properties but different physical properties.

The three main allotropic forms of sulphur are:

(i) Rhombic sulphur
(ii) Monoclinic sulphur
(iii) Plastic sulphur

Rhombic sulphur and monoclinic sulphur are crystalline whereas plastic sulphur is amorphous.

Comparative study of the allotropic forms of sulphur

Other names	Octahedral sulphur, Alpha-sulphur	Prismatic sulphur, Beta-sulphur	Gamma-sulphur
Preparation	Roll sulphur is dissolved in carbon disulphide. This is allowed to evaporate slowly by slight heating. Rhombic sulphur crystals are left behind.	Roll sulphur is heated on an evaporating dish till it melts to pale yellow liquid. This on cooling forms a crust on the surface. Holes are pierced on the crust and the molten sulphur is drained out. Needle shaped sulphur (monoclinic sulphur) crystals are left behind.	Roll sulphur is heated to above 300°C till it turns to dark brown, this is poured into cold water and the sulphur formed is plastic sulphur.
Colour	Pale yellow	Amber	Dark brown
Shape/ structure	Octahedral 	Needle shaped 	Amorphous
Density	2.08 g/cm^3	1.98 g/m^3	1.92 g/cm^3
Solubility	Soluble in carbon disulphide	Soluble in carbon disulphide	Insoluble in carbon disulphide
Melting point	112.8°C	119°C	No sharp melting point
Conductivity	Sulphur is a bad conductor of heat and electricity		
Boiling point	Sulphur boils at 444°C		

Rhombic sulphur is the most stable form at normal temperature. Monoclinic sulphur and plastic sulphur change to rhombic form on long standing.

Transition between rhombic sulphur and monoclinic sulphur

Rhombic sulphur is stable below 95.6°C and above this temperature, it changes to monoclinic sulphur. Conversely, monoclinic sulphur is stable above 95.6°C, but changes to the rhombic variety below this temperature. Hence 95·6°C is called transition temperature of these two allotropes of sulphur.

Puckered ring structure of sulphur

Both rhombic and monoclinic sulphur exists in the form of S_8 molecules. These S_8 molecules are in the form of a ring. It forms a crown shaped molecule with four atoms on the top and four atoms at the bottom. (Fig 8.10)

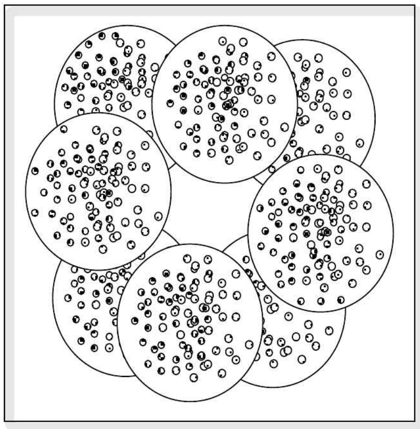


Figure 8.10

The rhombic form and the monoclinic form differ in the arrangement of these S_8 puckered rings. In rhombic sulphur, these rings fit snugly into each other while in monoclinic sulphur the rings are stacked one on top of the other.

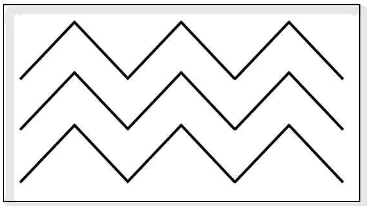


Figure 8.11 Rhombic sulphur

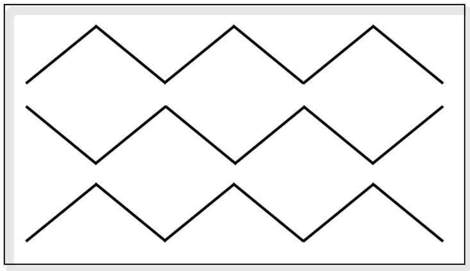


Figure 8.12 Monoclinic sulphur

Action of heat on sulphur

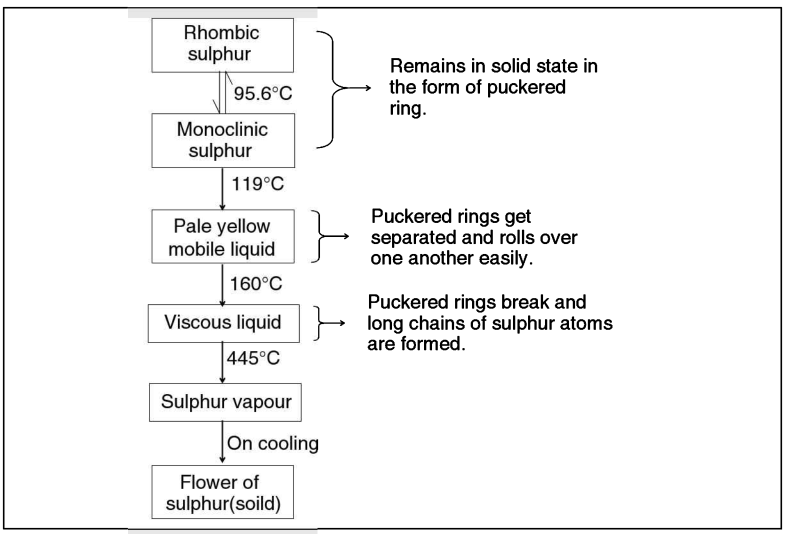


Figure 8.13

Chemical properties

With non-metals	
(i) Oxygen	Sulphur reacts with oxygen above 300°C giving two oxides. $S + O_2 \xrightarrow{800^\circ C} SO_2$ (Sulphur dioxide) $S + O_2 \rightarrow 2SO_3$ (trace amounts) (Sulphur trioxide)
(ii) Hydrogen	Boiling sulphur with hydrogen gas evolves a gas with a bad smell. $H_2 + S \rightarrow H_2S$ (Hydrogen sulphide)
(iii) Carbon	Sulphur vapours when passed over red hot coke forms carbon disulphide $C + S \rightarrow CS_{2(l)}$ (red hot) (carbon disulphide)
With metals	Sulphur vapours when passed over the heated surface of the metals gives the corresponding metal sulphides. $Zn + S \rightarrow ZnS$ $Fe + S \rightarrow FeS$
With acids	Sulphur is oxidized to sulphuric acid and reduces nitric acid to nitrogen dioxide $S + HNO_3 \rightarrow H_2SO_4 + 6NO_2 + 2H_2O$

Uses

Sulphur has a wide variety of uses in various industries.

Rubber industry: It is used for the vulcanization of rubber to make it hard and elastic.

Chemical industry: Used in making chemicals like sulphuric acid, carbon disulphide, etc.

Explosive industry: Sulphur along with charcoal and nitre is used in making gun powder.

Pharmaceutical industry: Sulphur due to its excellent fungicidal activities is used as a fungicide.

Compounds of sulphur

Sulphur forms a wide range of compounds which have applications in various fields.

Sulphur dioxide

This is an oxide of sulphur where one atom of sulphur is associated with two atoms of oxygen.

It is found in exhaust emissions of internal combustion engine, in the industrial areas where coal and petroleum are used as fuels. In nature it is found in volcanic gases.

Preparation

Laboratory preparation of SO_2

Sulphur dioxide is prepared in the laboratory by heating copper turnings with concentrated sulphuric acid.

$Cu + 2H_2SO_4 \rightarrow CuSO_4 + 2H_2O + SO_2\uparrow$

Properties

Physical properties

[redacted]	
Colour	Colourless
Odour	Pungent and suffocating
Taste	Sour
Vapour density	32 (2.2 times heavier than air)
Solubility in water	Fairly soluble
Boiling point	–10°C
Freezing point	–76°C
Physiological nature	Poisonous

Chemical properties

[redacted]	
Acidic nature (i) With litmus (ii) Reaction with water	Sulphur dioxide is acidic in nature and can change blue litmus to red. Sulphur dioxide with water forms unstable sulphurous acid. $H_2O + SO_2 \rightarrow H_2SO_3$
Reducing property	Sulphurdioxide when passed through chlorine water reduces the chlorine to hydrogen chloride. $SO_2 + Cl_2 + H_2O \rightarrow HCl + H_2SO_4$
Bleaching property	Sulphur dioxide is a good bleaching agent. This on reaction with moisture or water, produces nascent hydrogen which helps in the bleaching action. $SO_2\uparrow + H_2O \rightarrow H_2SO_4 + 2[H]$ (reducing agent) The nascent hydrogen produced on being exposed to moisture acts as the bleaching agent. It reduces the coloured matter to colourless. This reaction is reversible. The colourless product on exposure to atmospheric oxygen can get oxidized and thus regains its colour. Coloured vegetable + [H] $\rightarrow$ Colourless product + Water (Bleached product)

Hydrogen sulphide

Hydrogen sulphide gas is well known for its rotten egg smell. In free state it is present in volcanic gases, water of springs, in the air near and around industrial area.

Though the gas has bad smell and pollutes atmosphere, it is still prepared in the laboratory due to its certain unique properties and uses.

Laboratory preparation of hydrogen sulphide

Principle: Ferrous sulphide on reaction with hydrochloric acid gives ferrous chloride, liberating hydrogen sulphide gas.

$FeS + 2HCl \rightarrow FeCl_2 + H_2S \uparrow$

Physical Properties

[redacted]	
Colour	Colourless
Odour	Smell of rotten eggs
Taste	Sour taste
Solubility	Fairly soluble in water
Vapour density	17 (1.2 times heavier than air)

Chemical properties

[redacted]	
Acidic nature	It can change blue litmus to red It reacts with a base to form salt and water $NaOH + H_2S \rightarrow NaHS + H_2O$ (Sodium hydrogen) sulphide) $NaOH + NaHS \rightarrow Na_2S + H_2O$ (Sodium sulphide)
Reducing Property (i) With oxygen	Hydrogen sulphide undergoes combustion during which it reduces oxygen to water. $2H_2S + O_2 \rightarrow 2S + 2H_2O$ It however does not support combustion.
(ii) With chlorine	Chlorine on reaction with hydrogen sulphide is reduced to hydrogen chloride. $H_2S + Cl_2 \rightarrow 2HCl \uparrow + S$
(iii) With $FeCl_3$	H_2S reduces ferric chloride to ferrous chloride $FeCl_3 + H_2S \rightarrow FeCl_2 + HCl + S$

(Continued on following page)

(iv) With acids	H_2S on reaction with Conc. H_2SO_4 and HNO_3 reduces these to their respective oxides. $H_2SO_4 + H_2S \rightarrow SO_2 + S + 2H_2O$ (Conc) $2HNO_3 + H_2S \rightarrow 2NO_2 + S + 2H_2O$

Uses

The most important application of hydrogen sulphide gas is in analytical chemistry.

Hydrogen sulphide on reaction with aqueous solutions of metal salts convert them to metal sulphides. These metal sulphides are in the form of precipitates. The colour of the precipitate depends upon the nature of metal ion. Therefore, hydrogen sulphide is mainly used for the detection of metal cations present in the metal salts.

$$Pb(NO_3)_2 + H_2S \rightarrow \underset{\text{(Black precipitate)}}{PbS} + 2HNO_3$$

$$CuSO_4 + H_2S \rightarrow \underset{\text{Black precipitate)}}{CuS} + H_2SO_4$$

$$ZnSO_4 + H_2S \rightarrow \underset{\text{(White precipitate)}}{ZnS} + H_2SO_4$$

$$MnSO_4 + H_2S \rightarrow \underset{\text{(Flesh coloured)}}{MnS} + H_2SO_4$$

This is the major use of hydrogen sulphide gas.

Chlorine

Chlorine is not only a member of the halogen family, but also considered as the typical halogen. It is diatomic and highly reactive gas. Chlorine generally exists in a combined state rather than in a free state.

Chlorine was first synthesized by Scheele and the elemental nature was established by Davy.

Laboratory method of preparation

Oxidation of hydrochloric acid: Hydrochloric acid on oxidation with MnO_2 or $KMnO_4$ or $K_2Cr_2O_7$ gives chlorine gas. Oxidation of HCl by MnO_2 is the most common method employed for the preparation of chlorine gas in laboratory.

Principle

When manganese dioxide is heated with concentrated HCl. HCl gets oxidized to chlorine gas.

$$MnO_{2+}4HCl \rightarrow MnCl_2+2H_2O+Cl_2$$

Physical properties

Colour	Greenish Yellow
Odour	pungent smell
Solubility	Sparingly soluble in water
Density	Heavier than air. Vapour density 35.5
Atomicity	2

Chemical properties

With non-metals (i) Phosphorous	Chlorine reacts with phosphorous to form phosphorous trichloride which further reacts with chlorine to produce phosphorous pentachloride $2P + 3Cl_2 \rightarrow 2PCl_3$ $PCl_3 + Cl_2 \rightarrow PCl_5$
(ii) Hydrogen	Chlorine has a very high affinity towards hydrogen. It reacts with hydrogen to form hydrogen chloride. $H_2 + Cl_2 \rightarrow 2HCl$ Chlorine reacts with hydrogen in hydrocarbon to form carbon and hydrogen chloride. $C_{10}H_{16} + 8Cl_2 \rightarrow 10C + 16HCl$
With metals	Chlorine reacts with most of the metals. $2Na+Cl_2 \rightarrow 2NaCl$. E.g.: Burning magnesium ribbon reacts with chlorine gas to form. $MgCl_2$ with the evolution of light energy $Mg + Cl_2 \rightarrow MgCl_2$
With water	Chlorine dissolves in water forming a mixture of hydrochlolric acid and hypochlorous acid. This reaction is responsible for the bleaching action of chlorine since HOCl dissociates giving nascent oxygen. $Cl_2 + H_2O \rightarrow HCl + HOCl$ $HOCl \rightarrow HCl + [O]$

Uses

(i) Used in the manufacture of bleaching powder.

Bleaching powder is one of the most important compounds of chlorine which is widely used for the purification of drinking water owing to its disinfectant action. It is prepared by treating slaked lime with chlorine gas.

$Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$

(ii) For bleaching wood pulp, cotton, paper, silk, rayon, etc.

(iii) For preparing poisonous gas like mustard gas (ClC_2H_4-S-C_2H_4Cl), phosgene ($COCl_2$) tear gas (CCl_3NO_2).

(iv) In the preparation of hydrochloric acid.

(v) In the extraction of metals like platinum, gold, titanium, etc.

(vi) In the manufacture of chloroform ($CHCl_3$),carbon tetrachloride (CCl_4), dichloro diphenyl trichloroethane (DDT) etc. and also in rubber, plastic and paint industries.

(vii) In the purification of drinking water.

test your concepts

Very short-answer type questions

1. What is metallurgy?
2. During calcination carbonate ores are converted to ___________.
3. In electroplating process the metal to be coated is taken as ___________.
4. What type of oxides do metals form?
5. __________ is used for making shoe polishes.
6. Discuss any three uses of wood charcoal.
7. What is meant by allotrophy?
8. Name the different allotropes of sulphur.
9. ________ is amorphous form of sulphur.
10. Discuss any two uses of carbon monoxide.
11. How is nitrogen isolated from liquid air?
12. The impurities that are associated with the ore are called ___________.
13. Which is the purest form of iron? How is it useful?
14. What are the catalyst and promoter used in the manufacture of ammonia during Haber's process?
15. What are the various explosives that can be prepared from ammonia?
16. Non-metals react with oxygen to form ___________ or ___________ oxides.
17. Discuss three important uses of graphite.
18. How nitric acid reacts with sulphur?
19. What is the colour of the precipitate formed when H_2S is made to react with lead nitrate?
20. Write the reaction of sulphuric acid with sodium chloride and potassium nitrate.
21. ___________ is the chemical name of bleaching powder.
22. Explain the acidic nature of sulphur dioxide based on its reactivity with water.
23. Explain the chemical reaction of chlorine with hydrogen sulphide.

24. List the allotropes of phosphorous.

25. When carbon dioxide is passed through lime water, a milky white precipitate of ____________ is formed.

26. What is super phosphate of lime?

27. Geometry of alpha-sulphur is ____________.

28. Write the reaction of phosphorous with chlorine.

29. During the manufacture of wrought iron, cast iron is taken in a reverberatory furnace and stirred at high temperature and this process is called _________.

30. ____________ is an alloy of phosphorous, copper, tin.

Short-answer type questions

31. Complete the following table giving a comparison between metals and non-metals.

	Parameter	Metals	Non-metals
1.	Melting point and boiling point		
2.	Conductivity		
3.	Tensile strength		
4.	Density		
5.	Formation of ions		
6.	Formation of oxides		

32. What is the basic purpose of roasting and calcination? Compare these two processes.

33. Explain froth floatation process for concentrating sulphide ores.

34. Discuss the action of hydrogen chloride on ammonia.

35. Distinguish between calcination and roasting?

36. Write the balanced equations for the following preparations

 (i) ammonium sulphate from ammonia.

 (ii) ammonium phosphate from ammonia.

37. Explain with equations the reaction of sulphur with metals and non metals.

38. What are the different processes involved in the dressing of ore? Explain.

39. Differentiate between rhombic sulphur and monoclinic sulphur.

40. In industries, chlorine is used in the manufacture of hydrogen chloride. Explain.

41. How is H_2S used as an analytical reagent?

42. Explain the reaction of ammonia with chlorine.

43. How is ore concentrated in the gravity separation process? Explain.

44. How is chlorine gas prepared?

45. State the reactions that take place at the cathode and anode during the process of electrolytic reduction of alumina.

Essay type questions

46. Describe smelting of iron in blast furnace. Write all the reactions which take place in different zones of blast furnace.

47. Explain with equations how sulphur dioxide is prepared in the laboratory.

48. Describe the structure of diamond.

49. Differentiate between white phosphorous and red phosphorous.

50. Compare cast iron, steel and wrought iron.

CONCEPT APPLICATION

Concept Application Level—1

Direction for questions 1 to 7: State whether the following statements are true or false.

1. Rhombic sulphur is the most stable form of sulphur at normal temperature.
2. The solid, inorganic compounds found in the earth's crust are called minerals.
3. Metals react with oxygen only to form basic oxides.
4. Phosphorous reacts with air and forms P_2O_5.
5. Metallic oxides are produced in calcination and roasting.
6. Colourless gas formed by treating phosphorus with NaOH is phosphine.
7. Burning magnesium ribbon continuously burns in nitrogen atmosphere.

Direction for questions 8 to 14: Fill in the blanks.

8. When carbon dioxide is passed through lime water, a milky white precipitate of ___________ is formed.
9. The reduction of metallic oxide in presence of carbon or carbon monoxide in blast furnace is called _________.

10. Silica acts as __________ in the process of extraction of iron from its oxides.

11. In open hearth process for making steel, the final composition of steel is adjusted by adding __________ alloy.

12. Hydrogen sulphide on reacting with aqueous solution of metal salts converts them to __________.

13. Reaction taking place in lower region of blast furnace is associated with ________ of energy.

14. Hardness of steel increases with the increase of __________.

Direction for question 15: Match the entries in column A with the appropriate ones in column B.

15.

A.	Charcoal	( )	a.	Rat poison
B.	Sulphur	( )	b.	Fertilizers
C.	Phosphorous	( )	c.	Fungicides
D.	Chlorine	( )	d.	Gas masks
E.	Nitrogen	( )	e.	Tear gas

Direction for questions 16 to 45: For each of the questions, four choices have been provided. Select the correct alternative.

16. Pig iron obtained from blast furnace cannot be used for making tools because
   (1) high percentage of impurities decrease malleability.
   (2) high percentage of impurities Increase malleability.
   (3) low carbon content increases hardness.
   (4) low carbon content decreases hardness.

17. Which of the following is the gaseous product obtained in roasting?
   (1) SO_2 (2) O_2 (3) SO_3 (4) H_2S

18. Which of the following reactions does not take place in the smelting process?
   (1) $FeO + CO \rightarrow Fe + CO_2$. (2) $CaO + SiO_2 \rightarrow CaSiO_3$.
   (3) $C + CO_2 \rightarrow 2CO$. (4) $Fe_2O_3.H_2O \rightarrow Fe_2O_3 + H_2O$.

19. Which of the following helps in the bleaching action of sulphurdioxide?
   (1) H_2 (2) O_2 (3) [H] (4) O

20. Graphite is generally used as a refractory material in electric furnaces because
   (1) of its high melting point. (2) it has a layered structure.
   (3) Both (1) and (2). (4) it is lustrous.

21. Reaction: $FeCl_3 + H_2S \rightarrow FeCl_2 + HCl + S$ in the above reaction

(1) H_2S is the reducing agent
(2) $FeCl_3$ undergo oxidation
(3) H_2S acts as oxidizing agent
(4) $FeCl_3$ acts as reducing agent

22. Which would quickly absorb oxygen?

(1) Alkaline solution of pyrogallol
(2) lime water
(3) Conc. H_2SO_4
(4) Alkaline solution of $CuSO_4$.

23. Which of the following changes takes place during the process of calcination of ore?

(1) Thermal decomposition of ore takes place
(2) The mass become porous
(3) Moisture is removed
(4) All the above

24. Which of the following substance is used as lining in Bessemer converter in case of acidic process?

(1) Quick lime
(2) Silica
(3) Slacked lime
(4) Caustic potash

25. The sulphide ores which involve roasting as one of the steps of extraction are concentrated by certain method. Identify the main principle involved.

(1) Adsorption of ore particles to pine oil.
(2) Specific gravity difference between ore and gangue.
(3) Attraction of ore or gangue particles towards the magnet.
(4) Coagulation of gangue particles by the addition of pine oil.

26. Which of the following properties of diamond is not attributed to its rigid giant polymeric tetrahedral structure?

(1) Good thermal conductivity
(2) Good abrasive nature
(3) Poor electrical conductivity
(4) Both (1) and (2)

27. Which of the following oxides react to form slag in open hearth process?

(1) CaO, CO
(2) P_2O_5, CaO
(3) P_2O_5, SiO_2
(4) CaO, CO_2

28. Which of the following negative radical is present in bleaching powder?

(1) Hypochlorite
(2) Chlorate
(3) Chloride
(4) Both (1) and (3)

29. Which of the following compositions is used as a fertilizer?

(1) $CaCN_2 + C$
(2) $CaC_2 + C$
(3) $Ca_3N_2 + C$
(4) $AlN + C$

30. Which of the following salt of calcium is used in the preparation of super phosphate of lime?

(1) $Ca_3(PO_3)_2$
(2) $Ca_3(PO_4)_2$
(3) $Ca(HPO_4)_2$
(4) $CaSO_4$

31. General metallurgical processes are given below. Arrange them in correct sequence.

(a) Conversion of ore to oxide
(b) Refining
(c) Dressing of ore
(d) Extraction of metal
(e) Concentration of ore

(1) eadbc (2) ceadb (3) decba (4) becda

32. Reactions involved in the smelting of iron in the blast furnace are given below. Arrange them in the correct sequence.

(a) $CaCO_3 \rightarrow CaO + CO_2 + 43$ kcal
(b) $CaO + SiO_2 \rightarrow CaSiO_3$
(c) $C + O_2 \rightarrow CO_2 + 97$ kcal
(d) $CO_2 + C \rightarrow 2CO - 39$ kcal
(e) $FeO / Fe_2O_3 + CO \rightarrow Fe + CO_2$

(1) cdabe (2) cadeb (3) edcba (4) bceda

33. Different stages involved in the manufacture of hydrogen gas by Bosch process are given below. Arrange them in the correct sequence.

(a) Removal of unoxidized CO
(b) Preparation of water gas
(c) Removal of CO_2
(d) Removal of water vapour
(e) Removal of CO

(1) cedba (2) cdbae (3) becda (4) bdaec

34. Different stages involved in the nitrogen cycle are given below. Arrange them in correct sequence starting from nitrates.

(a) Conversion of animal protein to excretory product
(b) Conversion of ammonia to nitrites
(c) Conversion of plant protein to animal protein
(d) Conversion of nitrites to nitrates
(e) Conversion of nitrates to plant protein
(f) Conversion of excretory product to ammonia

(1) dbeafc (2) cbdafe (3) efbdca (4) ecafbd

35. Epsom salt is

(1) $MgSO_4.7H_2O$ (2) $KCl.MgCl_2.6H_2O$ (3) Na_3AlF_6 (4) $CaSO_4.2H_2O$

36. Which of the following reactions takes place in the lower region of blast furnace?

(1) $CO_2 + C \rightarrow 2CO - 39$ kcal (2) $C + O_2 \rightarrow CO_2 + 97$ kcal

(3) $FeO + CO \xrightarrow{750-600^{\circ}C} Fe + CO_2$ (4) $CaO + SiO_2 \rightarrow CaSiO_3$

37. When ammonia reacts with excess chlorine it forms

(1) $NH_4Cl + N_2$ (2) $N_2 + HCl$ (3) $NOCl + HCl$ (4) $NCl_3 + HCl$

38. Water gas is a mixture of

(1) $CO + H_2$ (2) $CO_2 + N_2$ (3) $CO + N_2$ (4) $CO_2 + H_2$

39. Which among the following is used in the manufacture of deodorant?

(1) Lamp black (2) Animal charcoal (3) Sugar charcoal (4) Wood charcoal

40. Which of the following compounds is used as the raw material for many fertilizers?

(1) NH_3 (2) H_2S (3) HCl (4) CO_2

41. Which among the following is widely used in the match industry?

(1) N_2 (2) C (3) P (4) Cl_2

42. Which of the following cannot be concentrated by froth flotation process?

(1) Zinc blende (2) Copper pyrites (3) Iron pyrites (4) Limonite

43. Which of the following changes takes place during the process of calcination of an ore?

(1) Thermal decomposition of the ore takes place (2) The mass become porous
(3) Moisture is removed (4) All the above

44. **Assertion (A):** Diamond is a good conductor of heat.

Reason (R): In diamond each carbon atom is bonded strongly to four other carbon atoms.

(1) Both A and R are true and R is the correct explanation for A.
(2) Both A and R are true but R is not the correct explanation for A.
(3) A is true but R is false.
(4) A is false but R is true.

45. **Assertion (A):** Wrought iron is much more malleable than pig iron.

Reason (R): Wrought iron is the purest form of iron.

(1) Both A and R are true and R is the correct explanation for A.
(2) Both A and R are true but R is not the correct explanation for A.
(3) A is true but R is false.
(4) A is false but R is true.

Concept Application Level—2

1. What happens to the conductivity of metals with increase in temperature?
2. Why is the iron obtained from the blast furnace not used for making any articles?
3. An iron piece is kept for some time in concentrated nitric acid and then removed. The iron piece now can neither liberate hydrogen from dilute sulphuric acid nor can it liberate copper to form copper sulphate. Explain with an appropriate reason.
4. During the preparation of artificial diamond can molten copper be used instead of molten iron? Justify.
5. Why are diamonds found in coal mines?

6. H_3PO_4 serves as very important intermediate in fertilizer industry. Justify.

7. Why are the metals sodium and potassium not extracted by the electrolysis of their respective salt solutions?

8. In two containers A and B, NH_3 is allowed to react with Cl_2 under suitable conditions. If the gaseous products formed in A responds to litmus test compare the molar ratio of reactants in both the containers and identify the products formed.

9. Among white phosphorous and red phosphorous which is more preferable for use in match sticks? Give reasons in support of your answer.

10. Turpentine oil when exposed to an atmosphere of chlorine ignites with a black sooty flame. Justify.

11. Two solid non-metals X and Y are taken which are used for the purpose of vulcanization of rubber and for use in sugar industry respectively. A mixture of X, Y and 'Z', which is a salt of an alkali metal of corresponding ic acid of nitrogen can explode on heating even in the absence of oxygen. Justify.

12. "Graphite cannot be used as a lubricant in space". Give reasons.

13. X, Y are the elements which belong to VI A, VII A group or 3rd period. Oxide of an element 'X' and element 'Y' act as a bleaching agents in the presence of water. Explain bleaching action of which one is permanent?

14. What are the different reactions taking place in fusion zone of blast furnace and explain how these reactions affect the temperature of the zone.

15. Phosphor bronze is an alloy of copper with 3·5 to 10% of tin and up to 1% of phosphorous. What is the reason for the addition of phosphorous?

16. Iron exposed to moist air for a long time doesn't liberate hydrogen gas from dilute acids like HCl and $H2SO_4$. Explain.

17. Wrought iron is more malleable than cast iron. Give reasons.

18. Mr. John is working in IICT as a scientist. During the synthesis of a drug in the laboratory by his assistant he found that some impurities were associated with the drug. Mr. John dissolved the drug obtained in the solvent and added charcoal to it. This was then filtered off which on evaporation gave back the pure drug. Then the assistant asked Mr. John the following question 'what is the role of charcoal'? What was Mr. John's answer?

19. A group of students in a school were supposed to demonstrate some experiments in a science exhibition to be conducted on the National Science Day. As a part of planning for the above activity, they gathered in the science laboratory and were discussing their ideas. Smith took a beaker of water and a piece of charcoal. He asked his friends to predict whether it will float or sink in the water. Most of them said that it would float and it actually did. He then asked them whether anybody could make it sink in the water. After a few seconds of silence, Andy came forward and said he could do it by boiling the beaker containing water and charcoal. Then all of them were astonished to see the charcoal slowly sinking in the water. Predict the principle involved in the above experiment.

20. An oxide of a nonmetal 'X' is the mixed anhydride of two oxy acids. Identify 'X' and the other two oxyacids. Also mention how the oxide is formed from the stable hydride of the same element.

21. **(a)** Explains the disadvantage of P_2O_5 as a drying agent though it is known to be a good desiccant.

(b) How can P_2O_5 be used in the preparation of SO_3?

22. Carbon dioxide and water vapour present in air moderates the temperature of the earth. Explain.

23. Anhydrides of sulphurous acid and carbonic acid produce milkiness when passed through a solution of the same substance 'X'. When chlorine gas is made to react with the same solution 'X', it gives a compound 'Y' having disinfectant action. Identify 'Y' and justify its use for the above purpose.

24. **(a)** Account for the changes observed in the surroundings when carbon dioxide gas comes out of a fire extinguisher.

(b) Although CO_2 is generally used as a material in fire extinguisher it can not be used to put out fires caused by metals like Na, Mg, K.

25. A practical examination was being conducted for the students. The examiner, in the viva voice, asked Julie the question "Two salts X and Y are given to you. Salt 'X' is obtained by treating potassium with oxy acid of a non metal with suffix ic which has seven electrons in 'M' shell which is the valence shell. Salt 'Y' is formed between lead and oxy acid of a non metal with five electrons in its valence 'L' shell. Both the salts can give oxygen on thermal decomposition. "Which salt do you prefer for the preparation of pure oxygen and why?". When she answered the question correctly, examiner was very much impressed and awarded her full marks. What was the answer that Julie gave?

Concept Application Level—3

1. Is the property involved in the shining of diamond and lustre of metals the same? Justify.
2. Wrought iron is more malleable than cast iron. Give reasons.
3. Rusted iron is washed with phosphoric acid before soldering. Justify.
4. A bivalent metal forms a salt with the oxy acid of a solid non-metal in which the non-metallic element has +5 oxidation state. The salt formed can not be used as a fertilizer though it contains essential nutrients and is available as mineral in nature. However, the salt when treated with conc. H_3PO_4 gives an important and desirable fertilizer when compared with conc H_2SO_4. Identify the various substances involved and give equations.
5. Burning of coal leads to increase in the acidity of soil. Comment on this statement.
6. Graphite and iodine are the only nonmetals possessing lustre which is actually an important attribute of metals. Comment on the statement with proper justification.
7. How does soda water help in digestion of food after over eating?
8. Metals like platinum, palladium find application in the process of purification of hydrogen. Justify.
9. Mr. Paul, who is working for Asian paints, while constructing a house coated the building with white paint. After a few months his friend Mr. Richard who is working in a chemical laboratory visited the house and noticed a few dark patches on the white paint here and there due to which the building lost its original lustre. He advised his friend to try for restoration of lustre by washing with hydrogen peroxide. Justify the role of hydrogen peroxide.
10. "Metals are good thermal conductors and electrical conductors. How the above said properties vary in case of diamond and graphite, which are allotropes of the non metallic element carbon.

key points for selected questions

Very short-answer type questions

1. Process of the extraction of metals from their respective ores is called metallurgy.
2. Oxide
3. Cathode
4. Basic oxides or amphoteric oxides
5. Lampblack
6. Fuel, deodorant and gas masks
7. Existence of different physical forms of element with almost similar chemical properties.
8. Rhombic sulphur, monoclinic sulphur and plastic sulphur
9. Plastic sulphur
12. Gangue
13. Wrought iron, chains, bolts etc
14. Fe, Mo
15. Ammonal (NH_4NO_3 + Al powder), Amatol (NH_4NO_3 + 20% T.N.T)
16. Acidic, neutral
17. Leads of pencils, moderator in nuclear reactors, making refractory crucibles
18. $S + HNO_3 \rightarrow H_2SO_4 + 6NO_2 + 2H_2O$
19. Black precipitate
20. $H_2SO_4 + 2NaCl \rightarrow Na_2SO_4 + 2HCl$
    $H_2SO_4 + 2KNO_3 \rightarrow K_2SO_4 + 2HNO_3$
21. Calcium chloro hypochlorite
22. $SO_2 + H_2O \rightarrow H_2SO_3$
23. $H_2S + Cl_2 \rightarrow 2HCl\uparrow + S$
24. White and red phosphorous
25. Calcium carbonate
26. $Ca(H_2PO_4)_2H_2O + 2CaSO_4 \cdot 2H_2O$
27. octahedral
28. $2P + 3Cl_2 \rightarrow 2PCl_3$; $PCl_3 + Cl_2 \rightarrow PCl_5$
29. puddling
30. Phosphobronze

Short-answer type questions

33. (i) Set-up
    (ii) Raw materials
    (iii) Procedure
34. $HCl + NH_3 \rightarrow NH_3Cl$
35. Heating of ore in absence and in presence of air respectively.
39. (i) Preparation
    (ii) Colour
    (iii) Structure/shape
    (iv) Melting, boiling points
    (v) Density
40. (i) Principle
    (ii) Process
    (iii) Reaction
42. Colour of product (precipitate)
44. $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$

Essay type questions

46. (i) Set-up
    (ii) Raw materials
    (iii) Layers
    (iv) Procedure
    (v) Reactions in various layers.
    (vi) Temperature in various layers
    (vii) Collection of metal
47. (ii) Process
    (iii) Purification
48. (i) Arrangement of carbon atoms
    (ii) Bonds
49. (i) State
    (ii) Colour
    (iii) Odour
    (iv) Melting, boiling points
    (v) Physiological nature
    (vi) Atomicity
    (vii) Structure
50. (i) Composition
    (ii) Preparation

KEY

Concept Application Level—1

True or false

1. True
2. True
3. False
4. True
5. True
6. True
7. True

Fill in the blanks

8. calcium carbonate
9. smelting
10. flux
11. ferrosilicon and/or ferromanganese
12. metallic sulphides
13. release
14. carbon content

Match the following

15. A : d

    B : c

    C : a

    D : e

    E : b

Multiple choice questions

16. Choice (1)
17. Choice (1)
18. Choice (4)
19. Choice (3)
20. Choice (1)
21. Choice (1)
22. Choice (1)
23. Choice (4)
24. Choice (2)
25. Choice (1)
26. Choice (3)
27. Choice (2)
28. Choice (4)
29. Choice (1)
30. Choice (2)
31. (i) Dressing of ore
    (ii) Concentration of ore
    (iii) Conversion of ore to oxide
    (iv) Extraction of metal
    (v) Refining

    Choice (2)
32. (i) $C + O_2 + 97$ kcal
    (ii) $CO_2 + C \rightarrow 2CO - 39$ kcal
    (iii) $CaCO_3 \rightarrow CaO + CO_2 + 43$ kcal
    (iv) $CaO + SiO_2 \rightarrow CaSiO_3$
    (v) FeO / $Fe2O_3 + CO \rightarrow Fe + CO_2$

    Choice (1)
33. (i) Preparation of water gas
    (ii) Removal of CO
    (iii) Removal of CO_2
    (iv) Removal of water vapour
    (v) Removal of unoxidized CO

    Choice (3)
34. (i) Conversion of nitrates to plant protein.
    (ii) Conversion of plant protein to animal protein.
    (iii) Conversion of animal protein to excretory product.
    (iv) Conversion of excretory product to ammonia.
    (v) Conversion of ammonia to nitrites.
    (vi) Conversion of nitrites to nitrates.

    Choice (4)

35. Epsom salt is $MgSO_4 .7H_2O$

Choice (1)

36. Combustion of carbon takes place in lower region of blast furnace.

$C + O_2 \rightarrow CO_2 + 97$ kcal

Choice (2)

37. $\underset{\text{(excess)}}{NH_3} + 3Cl_2 \rightarrow NCl_3 + 3HCl$

Choice (4)

38. Water gas is a mixture of $CO + H_2$

Choice (1)

39. Wood charcoal is used in the manufacture of deodorant.

Choice (4)

40. NH_3 is used as the raw material for the production of many fertilizers.

Choice (1)

41. Phosphorus is widely used in the match industry.

Choice (3)

42. Limonite, $Fe_2O_3.H_2O$ cannot be concentrated by froth flotation process.

Choice (4)

43. During calcination, the thermal decomposition of an ore takes place, mass becomes porous and moisture is removed.

Choice (4)

44. In diamond each carbon atom is bonded to four other carbon atoms and forming rigid three dimensional structure. Hence it is a good conductor of heat.

Choice (1)

45. Wrought iron is the purest from of iron and its carbon content is the least. Hence it is highly malleable.

Choice (1)

Concept Application Level—2

Key points

1. (i) Change of movement of metal kernels with the increase in temperature.

(ii) Cause for flow of current through metals.

(iii) Changes in energy of metal kernels with temperature.

(iv) Effect of movement of metal kernels in flow of electricity.

(v) Relation between flow of electricity and conductivity.

2. (i) Reactions taking place in blast furnace.

(ii) Quality of iron obtained from blast furnace.

(iii) Composition of iron obtained.

(iv) Effect of components on properties of iron.

3. (i) Reactivity of nitric acid

(ii) Reaction of nitric acid with iron.

(iii) Changes in iron.

(iv) Reactivity of iron.

4. (i) Changes involved on solidification.

(ii) Arrangement of carbon atoms in diamond.

(iii) Conditions required for the preparation of diamond.

(iv) Comparison of volume changes during solidification of iron and copper.

5. (i) Composition and conditions in coal mines.

(ii) Conditions necessary for the formation of diamonds.

(iii) Comparison of conditions in coal mines and conditions necessary for diamond formation.

6. (i) Reaction of H_3PO_4 with mineral phosphate and ammonia.

(ii) Composition of phosphate rock.

(iii) Solubility of the major component of the phosphate rock.

(iv) Reaction between H_3PO_4 and the above component.

(v) Solubility of the product formed.

(v) Reaction between H_3PO_4 and ammonia.

(vi) Soluble nature of the product formed.

7. (i) Electropositivity
(ii) Ions formed during electrolysis of aqueous salt solution.
(iii) Fate of ions after formation.
(iv) Discharge of ions at the respective electrodes.

8. (i) Comparison of products obtained in different conditions.
(ii) Identification of the products formed in A and B.
(iii) Comparison of the amount of chlorine reacted with ammonia in A and in B.
(iv) Balanced chemical equations of the above two reactions.
(v) Calculation of molar ratio of the reactants in the above reactions.

9. (i) Comparison of structure of white phosphorous and red phosphorous.
(ii) Comparison of ignition temperature of white phosphorous and red phosphorous.
(iii) Relating ignition temperature to usage as match sticks.

10. (i) Composition of turpentine.
(ii) Reaction of chlorine with one of the components of turpentine oil.
(iii) Product formed in the above reaction.
(iv) Identification of the constituent of turpentine oil which is responsible for the black sooty flame.

11. (i) Identification of X, Y and salt Z .
(ii) Effect of heat on Z.
(iii) Nature of the products formed.
(iv) Reaction of the gaseous product with X and Y.
(v) Change in pressure and heat content due to above reactions.

12. (i) Layered structure of graphite.
(ii) Factors that make graphite act as a lubricant.
(iii) Conditions in space.
(iv) Relate conditions in space to factors that help graphite to act as a lubricant.

13. (i) Identification of X and Y.
(ii) Identification of oxide of X.
(iii) Comparison of process of bleaching by Y and that by oxide of X
(iv) Comparison of nature of products.
(v) Effect of atmospheric oxygen on the products.

14. (i) Reactions associated with energy changes.
(ii) Change in energy that is involved in the reactions taking place in fusion zone.
(iii) Effect of this change in energy on the temperature of this zone.

15. (i) Bonds formed in the alloy.
(ii) Reactivity of phosphorous with metals.
(iii) Nature of products formed.
(iv) Effect of these products on the physical properties of the alloy.

16. When iron is exposed to moist air for a long time rust formation takes place, that is iron gets converted to $Fe_2O_3.XH_2O$ and hence iron does not liberate hydrogen gas from dil acids like HCl, H_2SO_4.

17. Wrought iron is the purest form of iron. Its carbon content is least. Hence it is highly malleable. While cast iron has relatively more carbon content along with other impurities. Hence it is less malleable.

18. Charcoal has good adsorbing properties. When charcoal is added, it adsorbs the impurities, and when filtered, the impurities are separated from charcoal.

19. Charcoal is porous in nature and air is present in the pores of charcoal. So in the first case it floats on the water. In the second case, on boiling air escapes from its pores and hence its density becomes more thus, it sinks in the water.

20. The oxide of nitrogen which is a mixed anhydride of its oxy acids is NO_2. The oxy acids are HNO_2 and HNO_3. NO_2 can be obtained from the stable hydride NH_3 by it's reaction with oxygen.

$$4NH_3 + 5O_2 \xrightarrow[900°C]{Pt} 4NO + 6H_2O$$

$$2NO + O_2 \rightarrow 2NO_2$$

21. **(a)** P_2O_5 is a solid and is a good desiccant since it can absorb moisture from other substances. However, on absorbing moisture, P_2O_5 forms H_3PO_4 which forms a layer on the surface. As a result of this, its desiccating ability decreases and hence, its use for drying is limited.

(b) P_2O_5 is a strong dehydrating agent and hence removes water molecules from inorganic compounds. H_2SO_4 and HNO_3 are converted into their corresponding anhydrides.

$$2H_2SO_4 + P_4O_{10} \rightarrow 2SO3 + 4HPO3$$

22. Air plays a very important role in keeping the temperature of the earth within a certain range. This happens as a result of a phenomenon known as the green house effect. The CO_2 and water vapour of air are transparent to the visible radiation of the sun that warms the earth's surface during day time. The radiated IR radiation by earth is trapped by water vapour and CO_2 which maintains the temperature even during night time. The heat is trapped which keeps the earth warm even during the night. Had there been no CO_2 in the air, the night would have been abnormally cold and life would not have existed on earth.

23. Anhydrides of sulphurous acid and carbonic acid are SO_2 and CO_2 respectively. They produce milkiness on passing through a solution of $Ca(OH)_2$. When Cl_2 gas is made to react with $Ca(OH)_2$, $CaOCl_2$ (bleaching powder) is formed. Bleaching power on dissociation in water gives $Ca(OH)_2$, HCl and HOCl. Hypochlorous acid being unstable decomposes to HCl and nascent oxygen which is responsible for bleaching action.

$$CaOCl_2 + H_2O \rightarrow Ca(OH)_2 + HCl + HOCl.$$

$$HOCl \rightarrow HCl + [O]$$

24. **(a)** Carbon dioxide comes out with great force through a small nozzle from soda acid fire extinguisher. Sudden expansion of CO_2 takes place which leads to reduction in temperature of the carbon dioxide to a great extent and moisture present in air condenses on the carbon dioxide molecules and appears like fog.

(b) Na, Mg and K metals continue to burn in atmosphere of CO_2. It is due to fact that these active metals get oxidized by CO_2 to form respective oxides.

25. Nonmetal with 7 electrons in its valence shell (M shell) is chlorine. The salt which gives oxygen on thermal decomposition should be an alkali metal chlorate. Nonmetal with 5 electrons in its valence shell (L shell) should be nitrogen and the salt which can give oxygen on decomposition should be nitrate. Alkali metal chlorate gives only pure oxygen gas whereas bivalent that is lead metal nitrate gives a mixture of oxygen and NO_2. Since it is difficult to separate O_2 from this mixture, the first one is a preferred method to get pure O_2 gas.

Concept Application Level—3

Key points

1. (i) Structure.
   (ii) Comparison between type of bonding in metal and diamond.
   (iii) Influence of metallic bond on lustre of metals.
   (iv) Optical phenomenon which helps in shine of diamond.
   (v) Influence of arrangement of carbon atoms in diamond.

2. (i) Compare composition of wrought iron and cast iron.
   (ii) Bonding involved in wrought iron and cast iron.
   (iii) Comparing the directionality of bonds.
   (iv) Effect of bonding on physical properties.

3. (i) Comparison of ignition temperatures.
   (ii) Surface of metals to be soldered.
   (iii) Reactivity of phosphoric acid with rust, impurities.
   (iv) Products formed and nature of products.

4. (i) Identification of the oxy acid of solid non-metal which can exhibit the given oxidation state.
   (ii) Identification of salt formed.
   (iii) Solubility of the salt formed.
   (iv) Products obtained when the salt reacts with H_3PO_4 and H_2SO_4 separately.
   (v) Solubility of the products formed.
   (vi) Comparison of the extent of acidity imparted to the soil by both the products.

5. (i) Composition of coal.
   (ii) Origin of coal.
   (iii) Reactivity of various components of coal when burnt.
   (iv) Product formed by these components.
   (v) Reactivity of these components with water (rain).

6. The reason behind the lustre of metals is the presence of free electrons which undergo excitation and deexcitation in the visible region of spectrum. Iodine being larger atom, electrons can undergo excitation and deexcitation in the visible region, since they experience less nuclear forces of attraction. Graphite in the layer lattice structure has free electrons which can show the same trend. Due to these reasons, these two nonmetals exhibit lustre like metals.

7. In soda water, CO_2 dissolves in water to form carbonic acid which creates an acidic medium in the digestive system and helps in digestion of excess food.

8. Metals like platinum, palladium adsorb hydrogen on their surfaces. When the metal is heated after adsorption, hydrogen gas is expelled. Since other impurities do not get adsorbed, pure hydrogen can be obtained through this process.

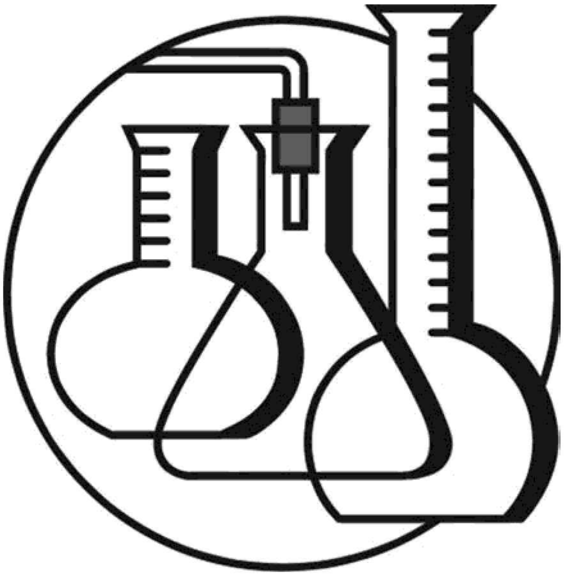
9. White paint has lead sulphate in it. As the polluted atmosphere has H_2S, it reduces the lead sulphate to lead sulphide which is black in colour. When these walls are washed with hydrogen peroxide, it acts as an oxidizing agent and converts black lead sulphide to white lead sulphate.

$$\underset{\text{White}}{PbSO_4} + H_2S \rightarrow \underset{\text{Black}}{PbS} + H_2SO_4$$

$$\underset{\text{Black}}{PbS} + 4H_2O_2 \rightarrow \underset{\text{White}}{PbSO_4} + 4H_2O$$

10. Thermal conductivity and electrical conductivity of metals are attributed to close packing in metals and the presence of free electrons in the metal lattice respectively. Though diamond and graphite are allotropes of carbon, diamond

is a good thermal conductor due to its rigid three dimensional structure, in which carbon atoms are closely and regularly arranged. Diamond is a not good electrical conductor as there are no free electrons in the structure. Graphite on the other hand has free electrons in the layer lattice structure which makes it a good electrical conductor. Graphite is a bad thermal conductor.



9

Organic Chemistry

INTRODUCTION

Organic chemistry is the branch of science which touches almost every aspect of material civilization today. The age old classification of chemical compounds into two broad categories as organic and inorganic compounds originated on the basis of the conception that they basically differ in their source of origin. Inorganic compounds were supposed to take their origin from mineral kingdom whereas organic compounds were believed to have their origin from plant and animal kingdom. This concept leads to the assumption of vital force theory according to which the synthesis of organic compounds could be carried out only in the presence of a mysterious vital force available in living systems. The name 'organic' originated from this concept.

The accidental synthesis of urea from an organic compound, ammonium cyanate was a major breakthrough in the field of organic chemistry. A German scientist Fredrich Wohler prepared urea, a component of human urine, by heating ammonium sulphate and potassium cyanate. Since then, the development of organic chemistry has proceeded at a tremendous pace. With the advent of synthesis of a large number of organic compounds, the definition of organic chemistry lost its significance.

The modified definition of organic chemistry was stated as the chemistry of carbon compounds. This definition stemmed from the basic fact that all the compounds in living systems bearing water invariably contain carbon. However, this definition was considered ambiguous because many inorganic compounds like CO_2, $CaCO_3$, etc. containing carbon are available. Later on, the principal characteristic of carbon compounds in living systems is that carbon is essentially associated with hydrogen. This idea paved the way for the precise definition of organic chemistry as the chemistry of hydrocarbons and their derivatives.

Though the name 'organic' is slightly misleading in the context of the present status of chemistry, the sharp line of distinction between inorganic and organic compounds continues to remain as such till today. Nevertheless, in the present scenario, the special status of organic chemistry owes not to the source of origin but to the remarkable properties exhibited by the compounds of carbon which clearly distinguish them from compounds of the rest of the hundred odd elements in the periodic table.

Unique properties of carbon compounds

Organic compounds differ from inorganic compounds in most of the general properties.

(i) **Number of compounds**

The number of organic compounds is much more than that of inorganic compounds. In fact, the organic compounds comprise about 90% of all known compounds.

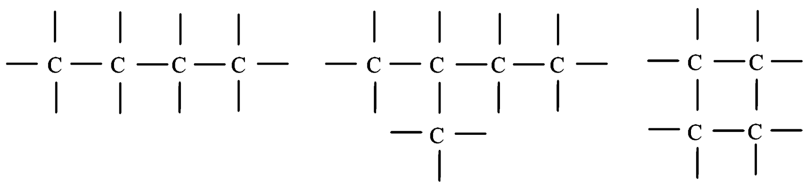
(ii) **Composition of compounds**

Composition of organic compounds is confined to very few elements of the periodic table like carbon, oxygen, hydrogen, nitrogen, halogens and sulphur. In contrast to these, inorganic compounds are composed of almost all the elements in the periodic table.

All these properties distinguish organic compounds from the inorganic compounds. In view of these characteristics, the study of carbon compounds as a separate branch of organic chemistry is justifiable. These properties of organic compounds are due to some special features possessed by carbon.

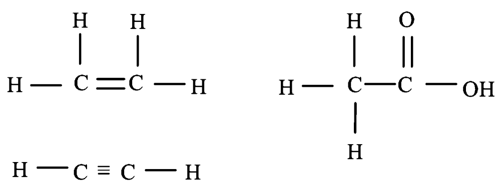
(i) **Tetravalency:** Carbon atom has electronic arrangement of 2, 4 which represents the presence of 4 electrons in the valence shell. It requires 4 more electrons to complete its octet. Therefore, carbon exhibits tetravalency.

(ii) **Catenation:** Carbon has a remarkable property of forming covalent bonds with other carbon atoms, thus, forming long chains. This ability of forming long chains with atoms of the same element is called catenation. Among all the elements, carbon shows maximum catenation capacity due to the maximum strength of carbon–carbon bonds. This catenation property of carbon accounts for the formation of innumerable number of compounds.



(iii) **Formation of multiple bonds:** Due to its small size, carbon can easily form multiple bonds with carbon, oxygen, nitrogen, etc. This bond multiplicity is also responsible for the formation of a wide variety of carbon compounds.

☛ *Example*



(iv) **Isomerism:** The molecules of all organic compounds can be represented by two types of formulae. They are

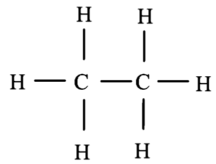
(a) Molecular formula: It indicates the actual number of atoms of various elements present in one molecule of an organic compound. However, it does not give us any idea regarding the type of bonds in the molecule.

☛ *Example* C_2H_6

In one molecule of ethane, there are two carbon atoms and six hydrogen atoms.

(b) Structural Formula: It gives the exact arrangement of the atoms of different elements present in the molecule.

☛ *Example*


Ethane

In case of organic compounds, it is quite probable that two or more organic molecules may possess the same molecular formulae but different structural formulae. That means the molecules may differ in the structural arrangement of atoms. This phenomenon is called **isomerism**.

Classification of hydrocarbons

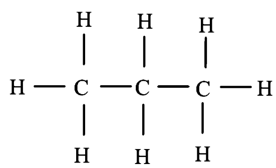
Hydrocarbons are a major class of organic compounds which contain only carbon and hydrogen as the constituent elements.

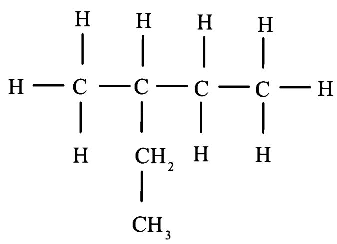
Hydrocarbons are broadly classified into two categories on the basis of the skeleton of carbon chain.

(i) **Aliphatic hydrocarbons or Open chain hydrocarbons**

The hydrocarbons which contain straight chain or branched chain of carbons are called **aliphatic hydrocarbons**.

☛ *Example*

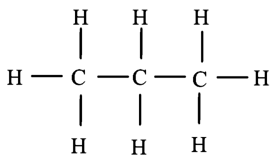

Straight chain hydrocarbon


Branched chain hydrocarbon

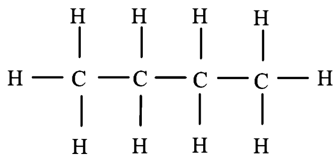
Aliphatic hydrocarbons are further classified as saturated and unsaturated hydrocarbons based on the nature of carbon-carbon bonds present in the hydrocarbon molecules.

(a) Saturated hydrocarbons: In the molecules of saturated hydrocarbons, all the valencies of the carbon atoms are satisfied by single bonds. These are called alkanes. General formula of this class of compounds is C_nH_{2n+2}.

☛ *Example*



Propane

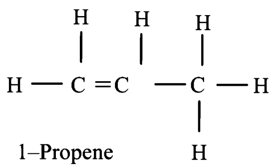


Butane

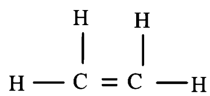
(b) Unsaturated hydrocarbons: The molecules of these hydrocarbons contain one or more carbon-carbon multiple bonds. These are called unsaturated hydrocarbons. Based on the type of multiple bond, unsaturated hydrocarbons are further classified into two categories.

Alkenes: The unsaturated hydrocarbons which contain a carbon-carbon double bond in their molecules are called alkenes. General formula of alkenes is C_nH_{2n} (assuming that one double bond is present in the molecule)

☛ *Example*

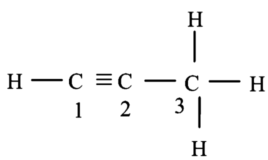


1–Propene

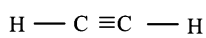


Ethene

Alkynes: These are unsaturated hydrocarbons which contain a carbon-carbon triple bond in their molecules. General formula of alkynes is C_nH_{2n-2} (assuming that one triple bond is present in the molecule)



1–Propyne



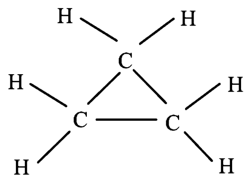
Ethyne

☛ *Example*

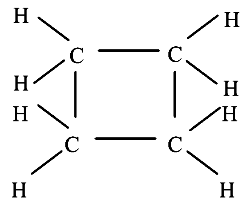
(ii) **Closed chain hydrocarbons**

The class of hydrocarbons which posses closed chains of carbon skeleton are called closed chain hydrocarbons. On the basis of chemical behaviour, they are further classified into two types alicyclic and aromatic hydrocarbons.

(a) Alicyclic hydrocarbons: These compounds resemble aliphatic hydrocarbons in their chemical characteristics. They contain rings of three or more carbon atoms.

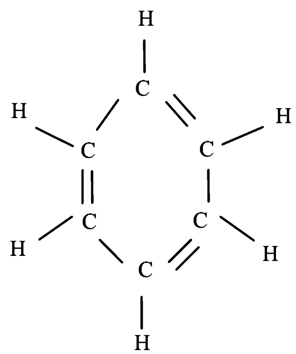


Cyclopropane



Cyclobutane

(b) Aromatic hydrocarbons: This class of compounds also contain rings of carbon atoms but differ widely from aliphatic hydrocarbon analogs in their chemical behaviour. They show certain characteristic features which are not shown by aliphatic hydrocarbons. Benzene is the simplest aromatic hydrocarbon. As a matter of fact, benzene is considered the parent hydrocarbon for the entire class aromatic compounds since all of them essentially possess one or more benzene rings in their structures.



Benzene

Nomenclature of hydrocarbons

Nomenclature implies assigning proper names to the various compounds on the basis of certain criteria. In case of organic compounds, two systems of nomenclature are in use.

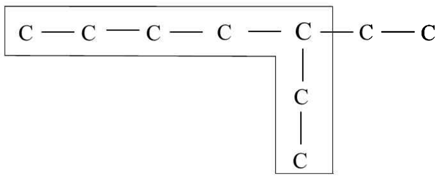
(i) **Trivial system:** In the earlier period when vital force theory was in effect, the names of organic compounds were given on the basis of the source of origin of the compounds. But, with the advancement of synthetic organic chemistry and discovery of enormous number of organic compounds, this system of nomenclature lost its significance.

(ii) **IUPAC system:** The need for a more systematic method of naming the organic compounds resulted in framing certain rules for nomenclature of organic compounds by IUPAC.

(a) Longest chain rule: In the given structural formula, the longest possible carbon chain is selected. This carbon chain is called parent carbon chain. Based on the number of carbon atoms in the longest chain, a root word is assigned. The root word for the first four members take their origin from trivial names. For the other members, Greek numerals are used for giving root word.

[redacted]	
1	Meth
2	Eth
3	Prop
4	But
5	Pent
6	Hex
7	Hept
8	Oct
9	Non
10	Dec

☛ *Example*



Longest chain with 7 carbon atoms.

Root word corresponding to seven carbons–hept.

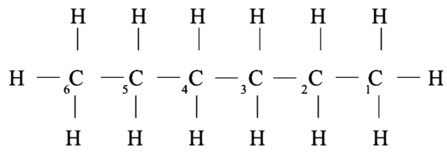
(b) Rule of primary suffix: The extent of saturation or unsaturation in the carbon chain is indicated by **primary suffix** which is added to the root word.

[redacted]	
Saturated (all C — C bonds)	— ane
Doubled bonded Unsaturated (one C = C bond)	— ene
Triple bonded Unsaturated (one C ≡ C bond)	— yne

In case of unsaturated hydrocarbon, the parent carbon chain selected should include multiple bond.

It is also essential to mention the position of multiple bond in the carbon chain. This is done by numbering the carbon chain from one end to the other. The chain is numbered in that direction in which the multiple bonded carbon gets the least number. The position of multiple bonded carbon is mentioned before the root word.

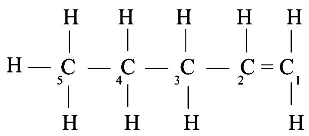
☛ *Examples*



Root word for 6 carbon chain–hex

Primary suffix–ane

Name–Hexane

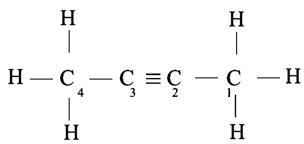


Root word for five carbon Chain –pent

Primary suffix –ene.

Position of double bond–1

Name: 1–Pentene



Root word for four carbon chain–But

Primary suffix–yne

Position of triple bond–2

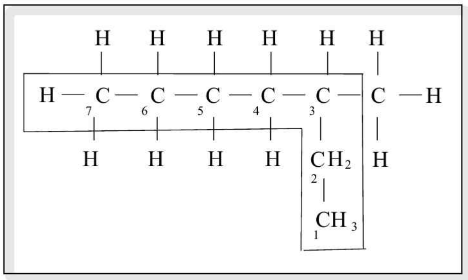
Name: 2–Butyne

(c) Rules of substituents: A univalent group formed after the removal of one hydrogen atom from alkane remains attached to the parent carbon chain. This univalent group is called alkyl group.

[redacted]		
CH_4 (methane)	$-CH_3$	methyl
C_2H_6 (ethane)	$-C_2H_5$	ethyl
C_3H_8 (propane)	$-C_3H_7$	propyl
C_4H_{10} (butane)	$-C_4H_9$	butyl

In case of branched chain hydrocarbon,these alkyl groups which are linked to the parent carbon chain are considered substituents. The prefix corresponding to the alkyl group is added before the root word by mentioning the position number of the carbon in the main chain which it is attached to. The carbon chain is numbered in that direction in which the carbon linked to the substituent gets the least number.

☛ *Examples*



Root word–hept

Prefix–methyl

Position of the substituent–3

Name–3–methyl heptane

Isomerism

When two or more substances have the same molecular formulae but differ in the structural arrangement of atoms within the molecule, they are called isomers and the phenomenon is called isomerism.

Since the isomers differ in the structural arrangement of atoms, the phenomenon is called structural isomerism. Depending on the type of variation in carbon chain, the structural isomerism is of different types.

Chain isomerism in alkanes

Long chain alkanes differ in the arrangement of carbon atoms in the chain. Two or more molecules may possess the same molecular formula, but they may differ in the arrangement of carbon atoms in the chain. This type of isomerism exhibited by hydrocarbons is known as chain isomerism and the molecules are called chain isomers. The straight chain isomer is called n-Isomer. The isomer with a single branch at a carbon atom is called Iso isomer. The isomer with two branches on the same carbon atom is called Neo isomer.

☛ *Examples*

(i) **Butane**

Molecular Formula: C_4H_{10}

Chain isomers of butane

(a) $H_3C - H_2C - CH_2 - CH_3$

n – butane

(b)

$$\begin{array}{c} CH_3 \\ | \\ H_3C - CH - CH_3 \end{array}$$

Isobutane

(ii) **Pentane**

Molecular formula: C_5H_{12}

Chain isomers of pentane

(a) $H_3C - CH_2 - CH_2 - CH_2 - CH3$

n – pentane

(b)

$$\begin{array}{ccccccc} & & & & CH_3 & & \\ & & & & | & & \\ H_3C & - & CH_2 & - & CH & - & CH_3 \end{array}$$

Isopentane

(c)

$$\begin{array}{ccc} & & CH_3 \\ & & | \\ CH_3 - & C & - CH_3 \\ & | & \\ & CH_3 & \end{array}$$

Neopentane

Position isomerism: These isomers have same carbon chain with same number of branches but differ in the position of multiple bond or substituent on the carbon chain.

Example

Pentene Molecular formula – C_5H_{10}

$CH_3 - CH_2 - CH_2 - CH = CH_2$ $CH_3 - CH = CH - CH_2 - CH_3$

1–Pentene 2–Pentene

$$\begin{array}{c} H_3C - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_2 - CH_2 - CH_3 \end{array} \qquad \begin{array}{c} H_3C - CH_2 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_2 - CH_3 \end{array}$$

2–Methyl pentane 3–Methyl pentane

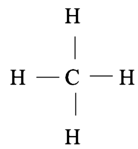
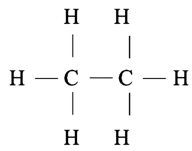
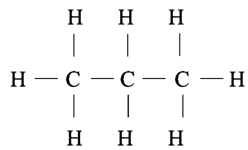
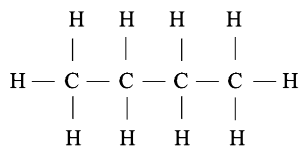
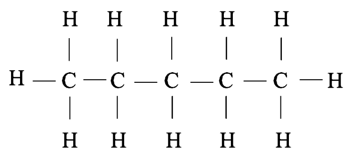
Thus on rearranging the carbon atoms different isomers are obtained. These isomers differ largely in physical properties and to some extent in chemical properties. However, the compounds with same constituent elements may possess different molecular formulae but have similar type of bonding and hence show similar chemical properties. These compounds can be arranged into series which gives rise to an idea of homologous series.

Homologous series

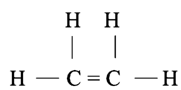
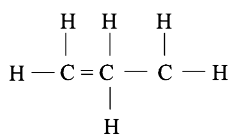
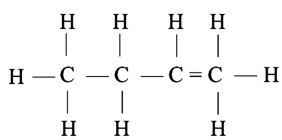
A series of organic compounds in which each member differs from the next by a constant amount when arranged in an increasing order of their molecular weights is called a homologous series.

The adjacent members of this series differ by 14 in their molecular weights or $–CH_2$ group, and hence have a general formula. The members show a regular gradation in physical properties and similar chemical properties. Thus, these can be prepared by similar methods.

Homologous series of alkanes (General formula C_nH_{2n+2})

[redacted]		
Methane	CH_4	
Ethane	C_2H_6	
Propane	C_3H_8	
Butane	C_4H_{10}	
Pentane	C_5H_{12}	

Homologous series of alkenes (General formula C_nH_{2n})

[redacted]		
Ethene	C_2H_4	
1 – Propene	C_3H_6	
1 – Butene	C_4H_8	

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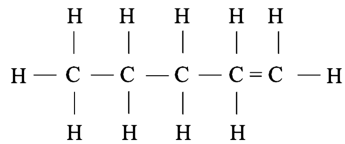
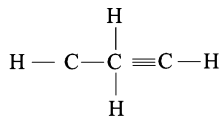
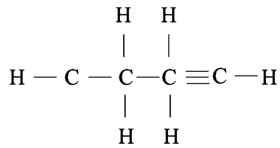
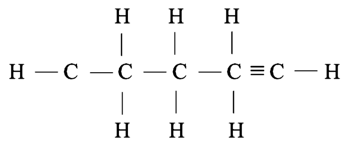
[redacted]		
1 – Pentene	C_5H_{10}	

Homologous series of alkynes (General formula C_nH_{2n-2})

[redacted]		
Ethyne	C_2H_2	$H—C\equiv C—H$
1 – Propyne	C_3H_4	
1 – Butyne	C_4H_6	
1 – Pentyne	C_5H_8	

Alkanes

Alkanes are aliphatic saturated hydrocarbons represented by a general formula C_nH_{2n+2}, where 'n' is the number of carbon atoms. The simplest hydrocarbon is an alkane with one carbon attached to four hydrogens.

Methane

Methane is the simplest hydrocarbon of the homologous series of alkanes. Trivial names for methane are marsh gas and fire damp.

Occurrence

It is available in earth's crust in the form of natural gas as it is the most volatile of all alkanes. Biogas or gobar gas also contain methane a the chief constituent.

Laboratory preparation of methane

Principle: In general, all alkanes can be prepared by the decarboxylation of sodium or potassium salts of corresponding carboxylic acids. Carboxylic acids are a class of organic compounds containing –COOH group where the hydrogen is acidic in nature and can be replaced by sodium or potassium. The reagent used for decarboxylation is soda lime (NaOH + CaO).

$$RCOONa + NaOH \xrightarrow{CaO} \underset{\text{(alkane)}}{R\_H} + Na_2CO_3$$

Methane can be prepared from the sodium salt of the carboxylic acid containing two carbon atoms. The carboxylic acid containing two carbon atoms is ethanoic acid or acetic acid (CH_3COOH), and its sodium salt is (CH_3COONa), i.e., sodium acetate. This on treatment with sodalime (NaOH + CaO) gives methane.

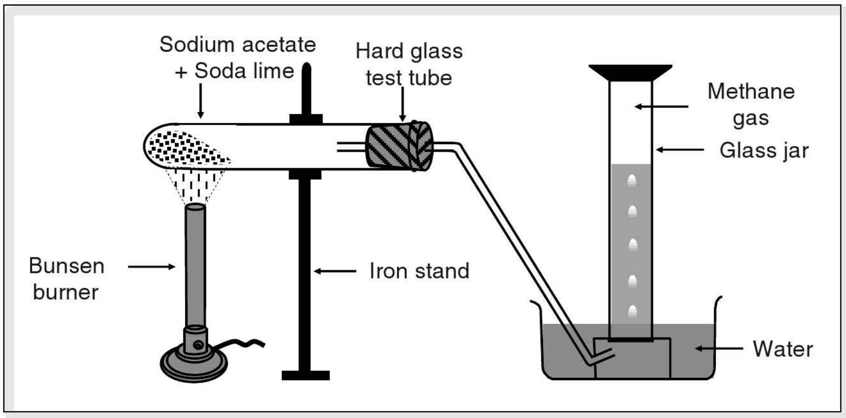


Figure 9.1 Preparation of methane gas

$$CH_3COOH + NaOH + \rightarrow CH_3COONa + H_2O$$

$$CH_3COONa + NaOH + \xrightarrow{CaO} \underset{\text{(methane)}}{CH_4} + Na_2CO_3$$

Process

The mixture of sodium acetate and soda lime is heated in a hard glass test tube. Methane gas is evolved and is collected by downward displacement of water.

Physical Properties

Colour	Colourless
Odour	No characteristic smell
Taste	Tasteless
Solubility	Insoluble in water and soluble in organic solvents like CCl_4, alcohol
Vapour density	8 (lighter than air)

Chemical Properties

(i) Combustibility: Methane burns in excess of oxygen to give carbon dioxide and water. This reaction is called combustion and it is an exothermic reaction. It burns with a pale blue flame.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

In an inadequate supply of oxygen, methane undergoes incomplete combustion to give carbon monoxide and water.

$$2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$$

(ii) Pyrolysis: On heating methane strongly in the absence of air above 1000°C, methane undergoes decomposition forming carbon and hydrogen.

$$CH_4 \xrightarrow{>1000°C} C + 2H_2\uparrow$$

(iii) With steam: In the presence of Al_2O_3, methane reacts with steam liberating hydrogen and carbon monoxide.

$$CH_4 + H_2O \xrightarrow[750°C]{Al_2O_3} CO + 3H_2$$

(iv) **Substitution reactions:** Since alkanes are unreactive due to the presence of all C – C single bonds, the characteristic reactions of alkanes are substitution reactions.

Example: Halogenation of methane

Methane undergoes substitution reaction with chlorine in presence of sunlight. In this reaction, one or more hydrogens are replaced by chlorine to form corresponding methylhalides.

$CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl$ (Methyl chloride)

$CH_3Cl + Cl_2 \longrightarrow CH_2Cl_2 + HCl$ (Methylene dichloride)

$CH_2Cl_2 + Cl_2 \longrightarrow CHCl_3 + HCl$ (Chloroform)

$CH\,Cl_3 + Cl_2 \longrightarrow CCl_4 + HCl$ (Carbon tetrachloride)

Structure: Methane molecule has four carbon hydrogen bonds which are arranged tetrahedrally. The shape of the molecule is tetrahedral with a bond angle of 109.5°.

Alkenes and alkynes

Comparative study of alkenes and alkynes

General Formula	C_nH_{2n}	C_nH_{2n-2}
Type of carbon-carbon bond	Double bond (C = C)	Triple bond (C ≡ C)
Common name	Olefins	Acetylenes
Simplest compound	Ethene (Ehtylene)	Ethyne (Acetylene)

Ethene and Ethyne

Molecular formula	C_2H_4	C_2H_2
Structural formula	$\begin{array}{c} \;\;\;\;\;\mathrm{H}\;\;\;\mathrm{H} \\ \;\;\;\;\;\vert\;\;\;\;\vert \\ \mathrm{H-C=C-H} \end{array}$	$\mathrm{H-C\equiv C-H}$
Trivial name	Ethylene	Acetylene

Preparation method of ethene

Ethene can be prepared by cracking kerosene.

Cracking

Cracking is the process of breaking up long chain hydrocarbons into smaller chain hydrocarbons by heating at high temperature in the absence of oxygen. Basically, cracking is an important method of preparing simpler alkanes and alkanes from higher alkanes. Cracking is of two types:

(i) **Thermal Cracking:** The process involves heating the compound to a high temperature in the absence of catalyst.

(ii) **Catalytic cracking:** The process involves heating the compound in the presence of catalyst.

☛ *Example* Long chain alkane with six carbon atoms, i.e. hexane when subjected to cracking gives butane and ethene.

$$\underset{\text{(Hexane)}}{CH_3-CH_2-CH_2-CH_2-CH_2-CH_3} \xrightarrow{\text{Heat}} \underset{\text{(Butane)}}{H_3C-CH_2-CH_2-CH_3} + \underset{\text{(Ethene)}}{CH_2=CH_2}$$

Laboratory Preparation of ethene

In laboratory ethene can be prepared by heating ethyl alcohol with excess of concentrated sulphuric acid at 180°C. Apart from ethene, carbon dioxide and sulphur dioxide gases are evolved. These gases are removed by passing the gases over caustic soda. Finally, ethene gas is collected over water by the down ward displacement of water.

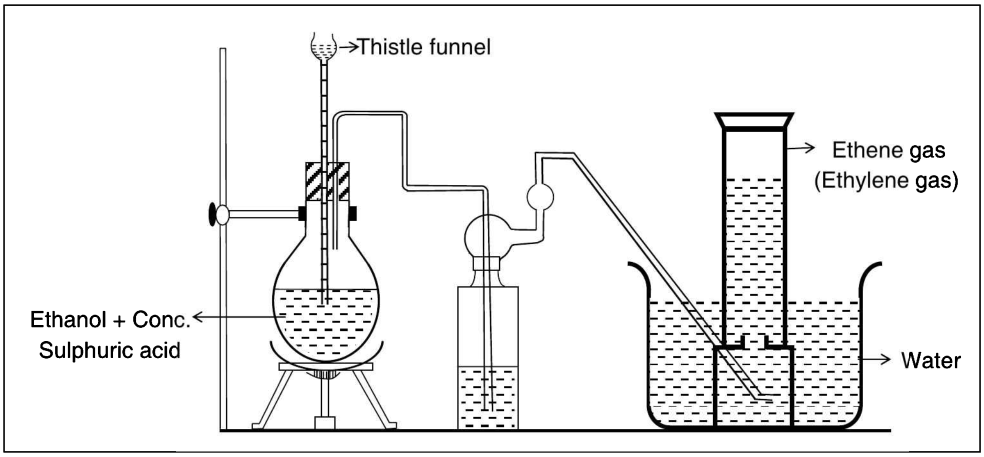


Figure 9.2

$$C_2H_5OH \xrightarrow[180°C]{\text{Con.}H_2SO_4} C_2H_4 + H_2O$$

Laboratory preparation of ethyne

Ethyne can be prepared in the laboratory by taking a little amount of calcium carbide in a conical flask to which a few drops of water are added. Ethyne gas is evolved and it is collected by downward displacement of water.

$$CaC_2 + 2H_2O \rightarrow \underset{\text{Ethyne}}{HC \equiv CH} + Ca(OH)_2$$

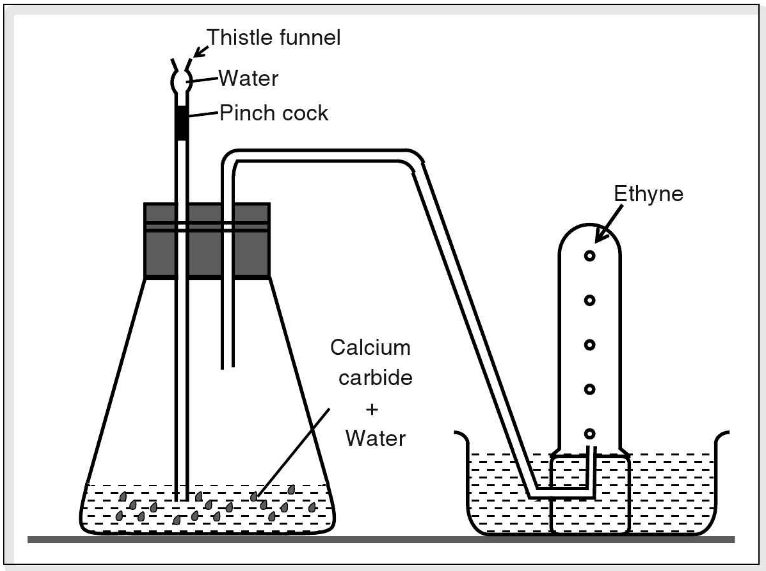


Figure 9.3

Comparative study of ethene and ethyne

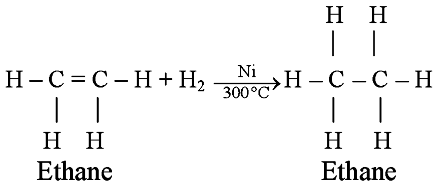
[redacted]	
Colourless, tasteless gas	Colourless, tasteless gas
Peculiar odour	Characteristic garlic odour
Insoluble in water	Insoluble in water
Soluble in non–polar solvents	Soluble in non–polar solvents
Vapour density 14	Vapour density 13
Slightly lighter than air	Slightly lighter than air
[redacted]	
(i) Combustion	
Burns with pale blue, sooty flame in excess of air.	Burns in excess of air with evolution of large amounts of CO_2
$C_2H_4 + 3O_2 \xrightarrow[\text{air}]{} 2CO_2 + 2H_2O$	$2C_2H_2 = 5O_2 \xrightarrow[\text{Air}]{\text{Excess}} 4CO_2 + 2H_2O$

(Continued on following page)

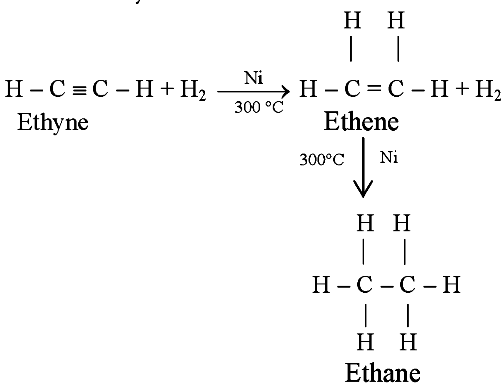
[redacted]

(ii) Hydrogenation

When equal volumes of ethane gas and hydrogen is passed over heated nickel or platinum at 300°C, one molecule of hydrogen is added.

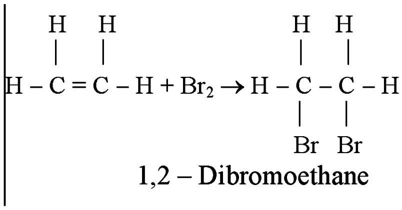


When a mixture of ethyne and hydrogen in 1 : 2 ratio is passed over heated nickel at 300°C, two molecules of hydrogen get added. Product may be ethene or ethane.

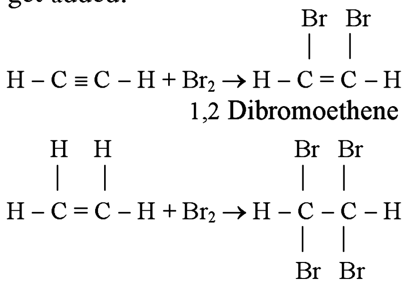


(iii) Addition of bromine

Decolourization of bromine water takes place when ethene gas is passed through bromine water and one molecule of bromine is added.



Decolourization of bromine water takes place when ethyne gas is passed through bromine water as two molecules of bromine get added.



1,1,2,2 – Tetabromoethane

(iv) Polymerization

A number of ethene molecules add to each other at high temperature forming long chains called polythene.

$nH_2C = CH_2 \rightarrow \;(CH_2 - CH_2)_n$

Three molecules of ethyne add to each other forming benzene.

$3HC \equiv CH \xrightarrow[\text{Red hot Cu tube}]{300°C} C_6H_6$

Applications of chemical properties

(i) **Hydrogenation of unsaturated hydrocarbons:** This reaction is made use of in the hydrogenation of vegetable oils. Some vegetable oils containing unsaturation, when subjected to hydrogenation in the presence of nickel catalyst at 473K and 5 atm pressure, get solidified and produce vanaspati ghee.

$$\text{Vegetable oils} + H_2 \xrightarrow[473\ K,\ 5\ atm]{Ni} \text{vanaspati ghee.}$$

☛ *Example* Groundnut oil, Mustard Oil, Cotton Seed Oil.

(ii) Decolourization of bromine water: This reaction is used for testing the unsaturation in organic compounds.

Uses of hydrocarbons

Methane	Natural gas	Automobile fuel, fertilizer synthesis
	Bio gas	Domestic fuel
	Derivatives	Synthesis of useful industrial products
Ethene	Polythene	Manufacture of plastics.
	Ethene gas	Artificial ripening of fruits, preparation of thiokol and glycol.
Ethyne	Oxy acetylene	Welding metals
	Acetylene	Illumination, ripening of fruits.

Hydrocarbons, thus, in most cases are useful for the generation of energy. Some of them are available naturally. There are also other natural resources of energy which are widely used.

Natural sources of energy

Energy is the primary requirement for the existence of life on earth. Solar energy, hydel energy and wind energy are some sources of energy which are inexhaustible. This is because they can be generated continuously and can replace the used up energy from time to time. They are, therefore, called **renewable sources** of energy. On the other hand, there are some energy sources which get exhausted over a period of time as they can not be replenished from time to time so easily. Coal and Petroleum are two major **non-renewable sources** of energy. These are organic matter and are formed by the degradation of dead plants and animals.

Formation

Millions of years ago, the dead plants and animals were buried beneath the surface of earth. Owing to the high temperature and pressure existing in the bottom most strata of earth's crust, the organic matter in the remains of plants got converted to coal while small marine animals and plants got converted into petroleum. Hence, these are called **fossil fuels**. As this is very slow process and takes millions of years coal and petroleum are known as non-renewable sources of energy.

Coal as well as petroleum are complex mixtures of hydrocarbons. Hydrocarbons being combustible, coal and petroleum also undergo combustion producing large amounts of energy. Therefore, they act as sources of energy. These two are not only the major reservoirs of energy which meet 90% of the energy requirements of the world, but also the main sources for the synthesis of many useful organic chemicals.

Coal

Composition of coal: Coal is mainly composed of carbon and also some hydrocarbons. In addition to these, coal contains some inorganic compounds of nitrogen, oxygen and sulphur.

Different varieties of coal which differ in the percentage of carbon are available.

Anthracite	90%
Bituminous	70%
Lignite	40%
Peat	10–15%

Extraction of Coal: The technique used for the extraction of coal from mines depends upon the mode of occurrence of coal in the earth's crust. Coal, when present in the upper layers, is extracted by open cast mining technology. Coal available in the deeper layers of earth's crust can be extracted by using underground mining technology.

Destructive distillation of coal: When coal is subjected to heating at high temperatures up to 1300–1700 K in the absence of air, a number of volatile products are obtained along with a non-volatile residue called coke. The process of heating of coal in the absence of air is called **destructive distillation** or **carbonization**: The volatile products are mainly composed of three components, namely, coal gas, ammonia and coal tar.

Isolation of products: The volatile products are first passed through water. Ammonia gets dissolved in water and is removed. Coal tar being insoluble in water, settles down as oily liquid. Coal gas which is also insoluble in water escapes out. It consists mainly of methane, carbonmonoxide and hydrogen.

Fractional distillation of coal tar

Coal tar, a black viscous liquid, when subjected to fractional distillation gives different products. These products on further distillation give various aromatic compounds like benzene. These compounds are the parent compounds used in the preparation of various industrially useful products such as dyes, drugs, polymers, pesticides, etc.

Light oil	80°C–170°C	Benzene
Middle oil	170°C–230°C	Phenol, naphthalene
Heavy oil	230°C–270°C	Phenol, naphthalene, anthracene
Green oil	270°C–400°C	Anthracene
Residue	Above 400°C	Pitch

Petroleum

It is a dark viscous oily liquid generally known as rock oil or crude oil. The word petroleum originated from Greek words petra- meaning rock and oleum- meaning oil.

Composition of petroleum: The precise composition of petroleum cannot be specified since it depends on the place of origin. Nevertheless, petroleum can be considered a complex mixture of hydrocarbons, composed predominantly of alkanes and cycloalkanes. Some petroleum deposits also contain reasonable amounts of aromatic hydrocarbons and alkenes. Trace amounts of oxygen, nitrogen and sulphur are also present since it is obtained from the remains of dead plants and animals.

Extraction of petroleum: Under earth's surface, petroleum deposits are found to be associated with a layer of natural gas. These can be drawn out by drilling deep wells through the various layers of earth till the oil bearing strata are reached. Due to the process of drilling, pressure is developed in those layers. Consequently, the gases are fizzed out of the solution and the crude oil is gushed out.

As the oil drawn out by this method is only 20 per cent, water or compressed air is pumped through the outer pipe and oil is drawn out through the inner pipe. By this way, it is possible to draw greater proportion of petroleum.

Processing of petroleum: Since the crude oil is drilled out from earth's crust, it obviously consists of lots of impurities. In addition to this, petroleum being a complex mixture of various hydrocarbons, it is necessary to separate the components. The process of removal of undesirable impurities followed by the separation into different useful fractions is called **refining of petroleum**.

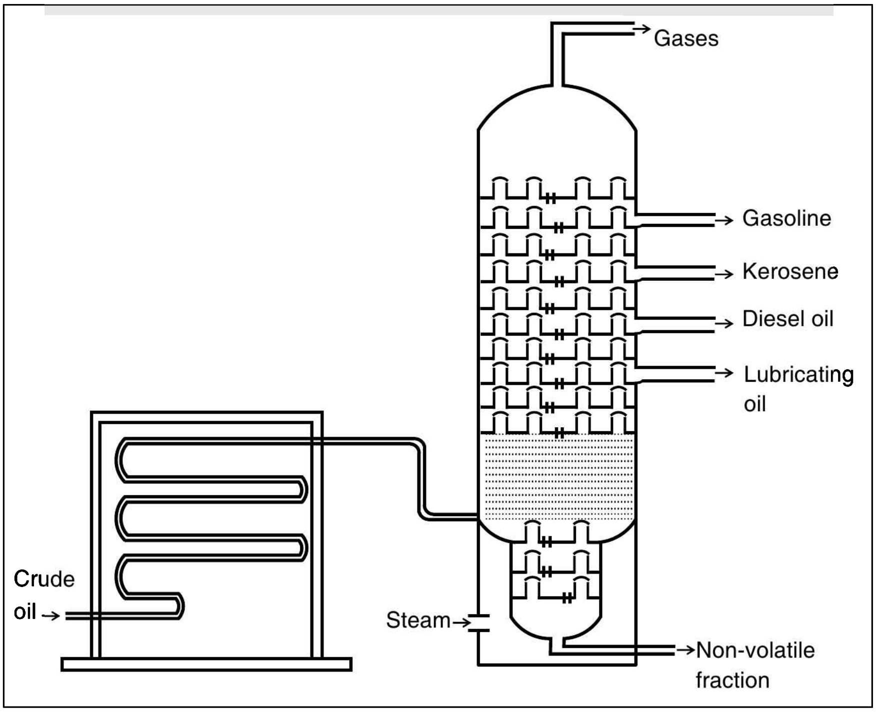


Figure 9.4

Refining of petroleum: The basic principle involved in refining petroleum is fractional distillation of the crude oil over a specific range of temperature as the different hydrocarbons have different boiling points. The refining is carried out in a fractionating tower. The fractionating tower is a tall cylindrical tower made up of a number of horizontal stainless steel troughs.

The crude oil which is free from impurities is fed at the base of the fractionating tower at 675K. At this temperature, all the volatile components vapourize and pass through the fractionating tower. As the vapour is passed through this column, they get condensed at different heights of the tower. The components which have higher boiling points get condensed first and the components having lower boiling points are carried to the top. Thus, the various fractions formed by condensation are collected in different trays separately. The non-volatile part of the crude oil remains in the tower in the form of solid residue called asphalt.

Before subjecting crude oil to fractional distillation, it should be freed from inorganic impurities. This is done by passing the raw crude oil between highly charged electrodes which remove all water from the sample. It is, then, treated with copper oxide to remove the sulphur compounds.

Petroleum gas	Below 30°C	C_1 to C_4	Fuel, for making carbon black
Crude naphtha	30°C–150°C	i) Petroleum ether (below 90°C) (C_5–C_7) ii) Gasoline or Petrol (90°C–120 °C) (C_7–C_9) iii) Benzene (120°C–150°C) (C_9–C_{10})	Solvent Motor Fuel Dry cleaning
Kerosene Oil	150°C–300°C	C_{10}–C_{16}	Cooking fuel illuminant oil gas
Fuel oil	300°C–350°C	C_{16}–C_{20} i) Gas oil ii) Diesel oil iii) Furnace oil	Motor fuel, cracking stock for gasoline.
Lubricating oil	350°C–400°C	C_{20}–C_{24}	Paint oil, lubricants
Paraffin wax	Above 400 °C	C_{24} and above	Candles, matches, paints, water proofing, ointments, protective paints.

Important fuels obtained from petroleum

The various components obtained by the process of fractional distillation of petroleum contains mixtures of hydrocarbons having different lengths of carbon chains. These fractions are used as fuels for different purposes after further purification. Purification makes the fuels devoid of corrosive constituents and unpleasant odours.

(i) Natural gas: Since all petroleum deposits are associated with natural gas, extraction of petroleum inevitably involves the collection of natural gas. Natural gas is composed of highly volatile alkanes, predominantly methane. Consequently, it undergoes rapid combustion releasing large amounts of heat.

Natural gas has a wide range of applications in domestic and industrial activities.

(a) Compressed natural gas can be used as an automobile fuel, i.e., as a substitute for petrol and diesel. It shows greater fuel efficiency and is available at a lower cost.

(b) Natural gas can also be used as domestic fuel.

(c) Natural gas can be used as a raw material for the manufacture of carbon black and hydrogen. The hydrogen so obtained can be used in the synthesis of ammonia which is the most important component of nitrogenous fertilizers.

$$CH_4 + H_2O \xrightarrow{1100\ K} CO + 3H_2 + 11.7KJ$$

$$N_2 + 3H_2 \xrightarrow[\text{Fe + Mo}]{\text{high temperature and pressure}} 2NH_3$$

(ii) Petroleum gas: This is the most important by–product of petroleum processing. The major proportion of petroleum gas is n-butane, the minor components being ethane and propane. Petroleum gas, when subjected to high pressure, can easily pass into liquid state. This easy liquefaction of petroleum gas renders it a very useful domestic fuel in the form of LPG (Liquefied Petroleum Gas).

LPG: It has a high calorific value and burns in air with a blue non-luminous flame. It is associated with very low ignition temperature and can be lighted easily. This, being a colourless and odourless gas, is mixed with small amounts of ethyl mercaptan which imparts a characteristic unpleasant odour to LPG, thus, rendering easy detection of leakages.

(iii) Petrol or Gasoline: The most important product of petroleum processing is petrol or gasoline which is used as fuel for automobiles. In addition to this, it is also used for dry cleaning of clothes.

Coal and petroleum have wide range of applications both in industry and day to day life. All the applications are based on the same principle of combustibility of hydrocarbons. Combustion being a highly exothermic process, the heat energy can be either directly used or can be trapped and converted to another form of energy and used.. The domestic fuels like LPG, kerosene and biogas are important products of petroleum industry. Coal forms the most important fuel for the generation of electricity in thermal power plants.

Some important applications of organic chemistry

Chemistry has a very important role to play in our daily life and it is more so with organic chemistry. The food we consume, the cosmetics we use, the drugs we use for treating various diseases etc., are all made up of organic compounds. Therefore, it is not an exaggeration to claim that organic chemistry intrudes into each and every aspect of our day to day life.

Use of organic compounds as ingredients of food

It is a well known fact that the food is made up of complex organic compounds such as carbohydrates, proteins, oils, fats, vitamins, etc. These are all quite essential for growth and maintenance of our body. In addition to these, there are other ingredients of food which are consumed in relatively lesser proportions. They include food preservatives and food colours. Food preservatives: These are chemical substances added to packed food items for the purpose of preventing spoilage of food material over a long period of usage.

Name	**Structure**
Acetic acid (vinegar)	$CH_3\ COOH$
Sodium benzoate	C_6H_5COONa

Flavouring agents: These are chemical substances added in minor proportions which enhance the flavour and taste of the food materials.

☛ *Examples*

Name	**Structure**
Monosodium glutamate (MSG)	$H_2N-(CH_2)_2\,C\begin{array}{l}\diagup COONa\\ \diagdown COOH\end{array}$
Esters of carboxylic acids	$RCOOR^1$
Citric acid or sodium citrate (soft drinks)	$\begin{array}{l}CH_2-COOH\\ \vert\\ CH-COOH\\ \vert\\ CH_2-COOH\end{array}$

Colouring agents

Certain chemical substances can be added to food items which impart colour to them.

☛ *Examples*

Name	**Colour**
Tartrazine	Yellow
Erithrocine	Red
Indigo	Carmine (blue)

Apart from all these, certain ingredients like caffein (alkaloid) are added to chocolates and soft drinks which act as stimulants to central nervous system.

Other ingredients

Caffeine (alkaloid): It is generally added to soft drinks and chocolates. It acts as a stimulant to central nervous system.

Citric acid or sodium citrate: Used as flavouring agent in soft drinks.

All these ingredients do not constitute essential part of our food. Since these substance have little or no nutritional value and their intake causes more harm to the body, the consumption of these substances should be either avoided or minimised.

Just like in food materials, the role of chemical in cleaning is also inevitable. Soaps and detergents are the most common commodities used for the purpose of cleaning.

Soap and detergents

Soap is the sodium or potassium salt of higher fatty acids. Fatty acids are a class of organic compounds, which show characteristic acidic properties. Since fatty acids are the major constituents of vegetable oils, soaps are prepared by the hydrolysis of these oils in presence of an alkali like NaOH or KOH. The most commonly used oils are coconut oil, palm oil, cotton seed oil, ground nut oil, etc.

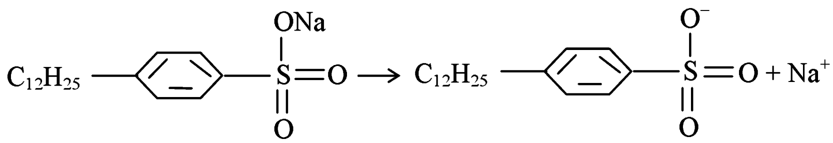
Detergents are also used for the same purpose and possess similar structure except that detergents are sodium or potassium salts of benzene sulphonic acids. These acids are generally available or made from petroleum products.

Structure and composition of soaps and detergents

Soap molecule is made up of a long chain of hydrocarbons attached to carboxylate group which constitutes anionic part of the molecule and positive part of Na^+ and K^+.

$$C_{17}H_{35}COONa \rightarrow C_{17}H_{35}COO^-Na^+$$

Similarly a detergent molecule is composed of a long chain of hydrocarbons containing benzene ring attached to sulphonate group which constitutes anionic part.

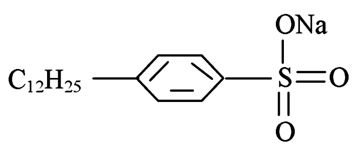


Example

Soap ⇒ Sodium or potassium salt of Stearic acid

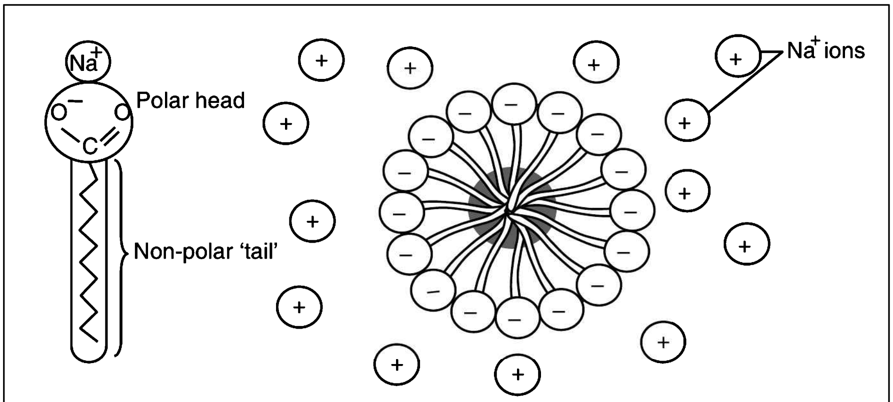
$C_{17}H_{35}COONa$

Detergent ⇒ Sodium laurate



Cleansing action of soaps and detergents

Generally, dirt is found to stick to the surface by means of oily substance. Since oil and water are not miscible with each other, water cannot remove the dirt. When soap is dissolved in water, firstly it reduces the surface tension of water, thereby increasing the area of contact between water and dirt. Secondly, soap gets ionized into an anionic radical such as stearate radical and Na^+ or K^+ as cationic radical. The anionic radical consists of a hydrocarbon chain which is hydrophobic and a hydrophilic carboxylic acid as head. The hydrophilic end dissolves in water and the hydrophobic end mixes with the oil. Thus, soap forms a link between oil and water thereby separating the dirt which forms an emulsion with water and is removed off.



(a) A soap molecule **(b) Cross section of a soap micelle in water**

Figure 9.5

The detergents are also similar in structure and action as soaps. The basic difference between soap and detergent is that soap forms insoluble calcium and magnesium stearates on dissolution in hard water. On the other hand, detergents produce soluble calcium and magnesium sulphonates on dissolution in hard water. Therefore, detergents are more efficient with hard water when compared to soaps. However, detergent have a disadvantage of causing environmental pollution over soaps.

Types of soaps

In addition to the sodium stearate which is the main ingredient, different types of soaps contain different additional ingredients which impart required quality to soaps.

Washing soap	Washing soda in place of caustic soda
Toilet soap	Caustic soda (for harder soaps)
	Caustic potash (for soft soaps)
	Mixture of oils and fats
Baby soap	Olive oil as additional ingredient
Transparent soap	Glycerine and castor oil

With the tremendous industrial and technological development of society, hydrocarbons and their derivatives continue to have more and more significant applications. Petroleum is the most important raw material for the manufacture of hydrocarbons. Therefore, it is a high time to realise that the rational and judicious use of exhaustible natural resources can go a long way in achieving sustainable development coupled with conservation of environment.

test your concepts

Very short-answer type questions

1. Why was organic chemistry considered chemistry of carbon compounds?

2. Name the first organic compound synthesized and mention how it was synthesized.

3. State the modern definition of organic chemistry and justify.

4. Unsaturated hydrocarbons give their characteristic ________ reactions.

5. Define catenation. What is its special significance with respect to organic chemistry?

6. Give general formulae for alkanes, alkenes and alkynes.

7. What are aliphatic hydrocarbons? How are they classified?

8. The structure of isobutane is _______.

9. What is primary suffix in the name of an organic compound?

10. Why are coal and petroleum called fossil fuels?

11. What are the techniques available for the extraction of coal from coal mines?

12. What is the principle involved in the refining of crude oil?

13. Calcium carbide, on hydrolysis, gives _______.

14. What are natural gas and petroleum gas?

15. What is meant by destructive distillation? What are the products of destructive distillation of coal?

16. What is meant by decarboxylation? How can methane be prepared by using this reaction?

17. Why is natural gas composed of major proportion of methane?

18. Cyclohexane is an example for ________ hydrocarbon.

19. On what basis is coal classified into different varieties?

20. How is ammonia manufactured from natural gas?

21. Give IUPAC names for the following hydrocarbons.

(a) $H_3C - CH_2 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_3$ (b) $H_3C - \overset{\displaystyle CH_3}{\overset{|}{CH_2}} - CH = CH - CH_3$

22. Mention some uses of methane.

23. Detergents are sodium salts of ________.

24. Write position isomer for butyne.

25. How is acetylene prepared from calcium carbide. Give equation.

26. What is the chemical reaction associated with the hydrogenation of oils?

27. What are soaps? How are detergents different from soaps in chemical composition?

28. __________ is the additive added to soap to make it transparent.

29. ________end of soap dissolves in soft water

30. What are food preservatives? Give two examples.

Short-answer type questions

31. What is meant by homologous series? What are its characteristics?

32. List out the characteristic properties of carbon compounds.

33. Define cracking. Explain the types of cracking.

34. Why are coal and petroleum considered non–renewable sources of energy?

35. Explain the process of refining crude oil.

36. Explain the composition of petroleum.

37. What is the composition of petroleum gas? Why is it used as domestic fuel?

38. By giving equations, explain the decolourization of bromine water by unsaturated hydrocarbons.

39. Explain hydrogenation of ethene and ethyne.

40. Give the structural formulae of the first four members of homologous series of alkanes, alkenes and alkynes.

41. Explain isomerism in alkanes.

42. Explain the laboratory preparation of ethylene.

43. How can CNG be a better alternative to petrol?

44. Explain the advantages of detergents over soaps.

45. Explain the various ingredients added to food items by giving examples.

Essay type questions

46. Explain the unique features of carbon.

47. Discuss in detail the important products of petroleum processing. Give an account of their uses.

48. Explain the extraction and processing of coal.

49. Give the chemical properties of methane, ethane and ethyne. Give equations.

50. Explain in detail the cleansing action of soaps and detergents.

CONCEPT APPLICATION

Concept Application Level—1

Direction for questions 1 to 7: State whether the following statements are true or false.

1. Each homologous series is characterized by a general formula.
2. Pentane has three chain isomers.
3. All saturated hydrocarbons are aliphatic hydrocarbons.
4. Methane can be prepared by the decarboxylation of sodium methanoate.
5. Hydrogenation reaction can be used to detect unsaturation in an organic compound.
6. Ethyne on polymerisation gives benzene.
7. Hexyne can decolourise bromine water.

Direction for questions 8 to 14: Fill in the blanks.

8. Closed chain hydrocarbons which do not resemble aliphatic hydrocarbons in their chemical behaviour are called _________.
9. IUPAC name of saturated straight chain hydrocarbon with 10 carbon atoms is _______.
10. 1-butene and 2-butene are _________isomers.
11. Ethane can be prepared by decarboxylation of _______.
12. The method involved in refining of petroleum is _________.
13. Hexane, on cracking, gives ______ and ______.
14. The best quality coal with respect to percentage of carbon is ________.

Direction for question 15: Match the entries in column A with the appropriate ones in column B.

15.

	Column A			Column B
A.	Natural gas	( )	a.	Polymerization of ethene
B.	Coke	( )	b.	Benzene
C.	C_nH_{2n}	( )	c.	Methane
D.	Kerosene	( )	d.	Destructive distillation of coal
E.	C_6H_6	( )	e.	Refining of petroleum
F.	Polythene	( )	f.	Alkene

Direction for questions 16 to 30: For each of the questions given below, four choices have been provided. Select the correct alternative.

16. Identify the compound which does not belong to the same homologous series.

(1) Propane (2) Butyne (3) Ethyne (4) Hexyne

17. The IUPAC name of

$$\begin{array}{ccccccccc} CH_3 & - & CH & - & CH & - & CH & - & CH_3 \\ & & | & & | & & | & & \\ & & C_3H_7 & & C_2H_5 & & C_2H_5 & & \end{array}$$

(1) 3, 4–dimethyl–4–ethyl Octane (2) 4–ethyl–3, 5–dimethyl Octane

(3) 2, 3–dimethyl–4–Propyl pentane (4) 3, 4–dimethyl–2–Propyl pentane

18. The products of incomplete combustion of methane are

(1) carbon and hydrogen. (2) carbon monoxide and water.

(3) carbon dioxide and water. (4) carbon monoxide and hydrogen.

19. Which among the following pairs belong to the same homologous series?

(1) C_3H_4, C_5H_{10} (2) C_2H_6, C_4H_{10} (3) C_2H_4, C_4H_8 (4) C_4H_8, C_5H_{10}

20. Which among the following isomers of hexane has the highest boiling point?

(1) $CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH_3$

(2)
$$\begin{array}{ccccccccc} CH_3 & - & CH & - & CH_2 & - & CH_2 & - & CH_3 \\ & & | & & & & & & \\ & & CH_3 & & & & & & \end{array}$$

(3)
$$\begin{array}{ccccccc} & & & & CH_3 & & \\ & & & & | & & \\ H_3C & - & CH_2 & - & C & - & CH_3 \\ & & & & | & & \\ & & & & CH_3 & & \end{array}$$

(4)
$$\begin{array}{ccccccc} CH_3 & - & CH & - & CH & - & CH_3 \\ & & | & & | & & \\ & & CH_3 & & CH_3 & & \end{array}$$

21. The straight chain isomer of C_4H_{10} is the major component in __________.

(1) biogas (2) petroleum gas (3) natural gas (4) coal gas

22. The IUPAC name of the following compound is __________.

$$\begin{array}{ccccccccccccc} & & & & & & & & CH_3 & & & & \\ & & & & & & & & | & & & & \\ H_3C & - & H_2C & - & C & \equiv & C & - & CH & - & CH_2 & - & CH_3 \end{array}$$

(1) 2–ethyl–3–hexyne (2) 3–methyl–4–heptyne

(3) 5–methyl–3–heptyne (4) 5–ethyl–3–hexyne

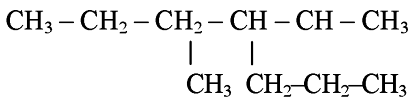
23. The hydrocarbon obtained on heating calcium oxide with coke in an electric furnace which is followed by hydrolysis is

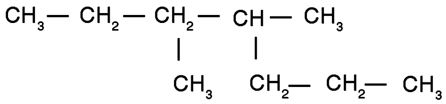
(1) C_2H_4 (2) C_2H_6 (3) CH_4 (4) C_2H_2

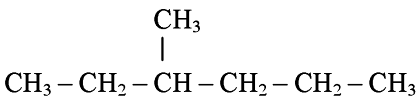
24. Which of the following can be the best substitute for petrol as an automobile fuel?

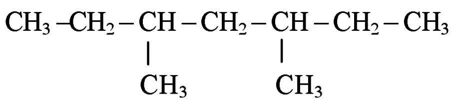
(1) Gasoline (2) Biogas (3) Kerosene (4) CNG

25. Structural formula of 3, 4-dimethyl heptane is

(1) 

(2) 

(3) 

(4) 

26. The primary suffix for a compound with general formula $C_n H_{2n-2}$ is

(1) –ane (2) –yne (3) –ene (4) –enol

27. A compound on hydrogenation yields ethane by consuming 2 molecules of hydrogen. The same compound on being treated with excess of bromine water gives

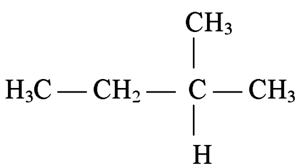
(1) CH_2Br_2 (2) $C_2H_4Br_2$ (3) $C_2H_2Br_4$ (4) C_2H_5Br

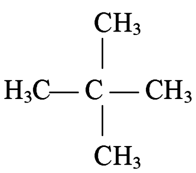
28. The reagent used for decarboxylation reaction is

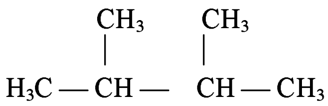
(1) NaOH + $Ca(OH)_2$ (2) only NaOH

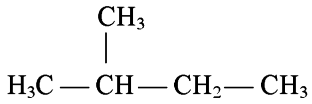
(3) NaOH + CaO (4) NaOH + $CaCO_3$

29. Which of following structures does not correspond to the chain isomer of pentane?

(1) 

(2) 

(3) 

(4) 

30. Which of the following is not an alkene?

(1) C_4H_8 (2) C_4H_6 (3) C_3H_6 (4) C_5H_{10}

31. IUPAC name of a hydrocarbon is given as 3, 5 – Dimethyl-2-hexene. Identify the correct sequence of steps to draw its structural formula.

(a) Numbering of carbon chain

(b) Locating the position of double bond

(c) Writing long chain corresponding to hexane

(d) Locating the methyl groups (prefixes) at the respective positions

(e) Placing hydrogens to satisfy tetravalency of carbon

(1) acbed (2) cbade (3) acbde (4) cabde

32. Identify the correct sequence of fractions obtained when petroleum is subjected to fractional distillation.

(a) Lubricating oil (b) Gasoline (c) Petroleum ether (d) Diesel oil

(1) bcda (2) cbda (3) cbad (4) bdca

33. 1 mole of ethyne on complete combustion gives

(1) 2 moles of carbon monoxide and half mole of water

(2) 4 moles of carbon dioxide and 1 mole of water

(3) 2 moles of carbon dioxide and 1 mole of water

(4) 2 moles of carbon dioxide and 2 moles of water

34. Which among the following molecular formulae represents a saturated hydrocarbon?

(1) C_4H_8 (2) C_4H_6 (3) C_3H_4 (4) C_5H_{12}

35. Which among the following pairs belong to the same homologous series?

(1) C_3H_4, C_5H_{10} (2) C_2H_6, C_4H_8 (3) C_2H_4, C_4H_6 (4) C_4H_8, C_5H_{10}

36. The number of bromine molecules required for the decolourization of 1 mole of ethene and ethyne are respectively

(1) one and three (2) two and three (3) one and two (4) two and four

37. Polymerisation of ethyne at 300°C gives

(1) Polyethene

(2) Polyethyne

(3) Benzene

(4) Polyvinyl chloride

38. The bromination of acetylene gives _____ as the final product.

(1) dibromoethane
(2) tetrabromoethane
(3) tetrabromoethene
(4) dibromoethene.

39. Which of the following is an identification test for unsaturation in an organic compound?

(1) Addition of hydrogen
(2) Addition of ozone
(3) Addition of bromine
(4) Addition of oxygen

40. The hydrocarbon used for welding purpose is

(1) ethane (2) ethyne (3) ethene (4) benzene

41. Coal gas mainly consists of

(1) methane, CO, H_2
(2) propane, CO_2, H_2
(3) methane, CO, H_2O
(4) methane, CO_2, H_2

42. The reagent NaOH + CaO is used for

(1) carboxylation
(2) dehydrogenation
(3) hydrogenation
(4) decarboxylation

43. Degradation of organic wastes in the absence of air gives

(1) methane
(2) methane, hydrogen, nitrogen and CO_2
(3) methane, carbon monoxide and hydrogen
(4) methane, SO_2 and hydrogen

44. Sulphur compounds in crude oil can be removed by using

(1) copper oxide
(2) alumina
(3) iron oxide
(4) magnesium oxide

45. Petroleum fraction of which of the following compositions can be used as a lubricating oil?

(1) $C_5 - C_7$
(2) $C_{10} - C_{16}$
(3) $C_{20} - C_{24}$
(4) $C_{30} - C_{40}$

Concept Application Level—2

1. Write all possible chain isomers for pentene and hexyne.
2. Give IUPAC names for the following.

(a) $$H_3C - \underset{\underset{\displaystyle CH_3}{|}}{CH} - CH_2 - CH = CH_2$$

(b) $$\overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{HC}} - CH_2 - CH_3$$

(c) $$HC \equiv C - \overset{\overset{\displaystyle C_2H_5}{|}}{\underset{\underset{\displaystyle H}{|}}{C}} - CH_3$$

(d) $$H_3C - CH = CH - \overset{\overset{\displaystyle CH_3}{|}}{CH} - CH_3$$

3. A hydrocarbon "X" can have only three chain isomers and one of the isomers consists of same alkyl groups attached to central carbon atom with single bonds. Identify the preceding and succeeding homologue of 'X'.
4. Methane is considered as a more environment friendly fuel than petrol. Justify.
5. Explain the role of natural gas in the preparation of ammonium fertilizers?
6. A straight chain saturated hydrocarbon with vapour density 43 on heating in absence of air gives X and Y. Y on treatment with bromine water gives Z. Identify X, Y and Z.
7. The percentage composition of a hydrocarbon 'X' is 90% carbon and 10% hydrogen respectively. Write the structural formulae of two successive and preceding homologues of X.
8. Why are some coal deposits associated with large amounts of sulphur?
9. Give the structural formulae of four compounds of the homologous series succeeding the one having molecular formula C_3H_4. Also give their molecular weights.
10. Compound X can be prepared by passing a gas Y through a metal tube which is at very high temperature. Y on treatment with 2 g of hydrogen gas in presence of nickel gives a compound Z. Z can also be prepared by treating ethyl alcohol with "ic" acid of sulphur at 170°C. Y can also be prepared by hydrolysis of 'A'. Identify X, Y, Z and A and write all the balanced chemical equations.
11. Two containers A and B are filled with the same amount of chlorine gas. Limited amount of methane is passed into container 'A' and excess of methane into container 'B'. Identify the products formed in A and B. Give reason in support of your answer.
12. The vapour density of an unsaturated aliphatic hydrocarbon 'X' is 34. Write the structural formula of X and its succeeding homologue Y. Also write the position isomers of X and Y.

13. How does the burning of coal lead to air pollution as well as water pollution?

14. At the end of the process of preparation of soap, common salt is added. Explain the role of common salt in that process.

15. A compound X on hydrolysis produces a gas Y which on hydrogenation produces a gas Z which can decolourize bromine water forming a compound with molecular weight 188 a.m.u. Identify X, Y and Z.

16. Two students Rishi and Kushi were preparing for International Chemistry Olympiad. They had come across a question. In that, table of boiling points of members of homologous series of alkanes was given and similar trend is followed in other classes of compounds also, predict the trend. What reason can be attributed to the above trend?

17. In an organic chemistry laboratory, a scientist subjected a hydrocarbon to combustion. The products occupied a volume ratio of 4 : 3 under the same conditions of temperature and pressure. The scientist drew the possible structures of the hydrocarbon. She then subjected the compound to ozonolysis to identify the exact structure. Predict the products formed when the compound is treated with bromine water.

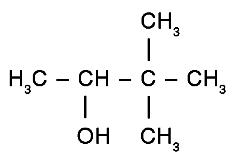
18. A research scholar, during his experiment came across an aliphatic hydrocarbon 'X'. In the process of identification of 'X' he passed 'X' through alkaline KMnO4. The solution became colourless. He found out the vapour density of the compound to be 34. Identify X and its succeeding homologue 'Y' and also position isomers of straight chain isomers.

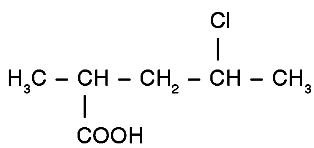
19. The molar ratio of carbon dioxide and water produced by the combustion of one mole of an aliphatic hydrocarbon 'X' is 5 : 4. Write the possible structures of X. What happens when 'X' is passed through bromine water?

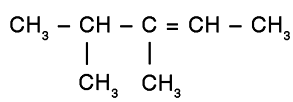
20. The government had a proposal for establishing a thermal power plant where coal would be the source of power. A panel has been sent to the site to examine the feasibility of the proposal. The farmers in that area became panicky that their soils may become less fertile and may even become unfit for cultivation. However, the panel members convinced them by giving an assurance that the best quality coal will be used in the plant to minimise the effect. Can you explain the reason why burning of coal makes the soil lose fertility and how quality of coal has a bearing on the above? What other effects does burning of coal have on the environment?

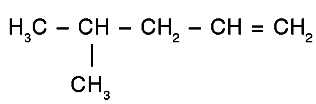
21. CNG is a better automobile fuel when compared to petrol and diesel. Give reasons.

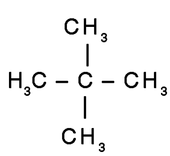
22. Write IUPAC names for the following structures

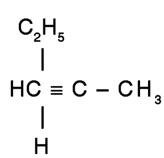
(a) 

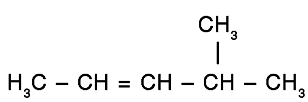
(b) 

(c) 

(d) 

(e) 

(f) 

(g) 

23. 'X' is an alicylic hydrocarbon with molecular formula C4H8.Y is the corresponding aliphatic compound. Give all the possible isomers ofY and their IUPAC names. Identify the products of bromination.WhenY is treated with hydrogen what are the products formed? How are these products separated from the mixture?

24. Coke is obtained by the destructive distillation of coal. But, coke is considered to be the purer form of carbon than coal. Give reason.

25. Give reasons for the following.

(a) Petroleum deposits are always associated with a layer of natural gas

(b) The volatile products obtained by distillation of coal are passed through water .

(c) A mixture of acetylene and oxygen is used for welding metals.

(d) Anthracite coal is of better quality than bituminous coal.

(e) It is possible to prepare an alkane with one carbon atom from a carboxylic acid with two carbon atoms.

Concept Application Level—3

1. Chloromethane has a certain value of dipole moment even though the dipole moment value of methane is zero. Justify.
2. "Carbon is not the only element showing catenation. However, carbon is the only element forming millions of compounds". Comment on the statement.
3. Coal has a major role to play in the production of steel. Explain the role of coal.
4. Petrol used in automobiles obtained by fractional distillation is less preferred over the petrol obtained by cracking. Justify.
5. Why do detergents cause pollution? How do newly developed biodegradable detergents differ from them?
6. Fluorination of methane is explosive. How do you account for this? How can fluorination of methane be carried out?
7. Can kerosene be used as a substitute for gasoline in automobiles? Give reasons in support of your answer.
8. Iodination of methane is carried out in the presence of oxidizing agents like iodic acid or HNO_3. How do you account for this?
9. Why are shaving creams and shampoos softer than soap?
10. "The same coal deposit is found to contain variable composition of coal". Justify.

key points for selected questions

Very short-answer type questions

1. Origin from plants and animals
2. Urea, heating ammonium sulphate and potassium cyanate
3. Chemistry of hydrocarbon and their derivatives.
4. Carbon content
5. Ability of forming long chains with atoms of the same element; formation of innumerable number of compounds
6. C_nH_{2n+2}; C_nH_{2n}, C_nH_{2n-2}
7. The hydrocarbons which contain straight chain or branched chains of carbons; saturated and unsaturated hydrocarbons.
8. Gangue
9. Extent of saturation or unsaturation in the carbon chain
10. Obtained from remains of plants and from small marine animals in a span of millions of years
11. Open cast mining and underground mining
12. Fractional distillation.
13. Flux
14. Composed of highly volatile alkanes, predominantly methane; petroleum gas → n–butane, minor components being ethane and propane.
15. Heating of coal at high temperature in the absence of air, nonvolatile coke, volatile coalgas, ammonia and coal tar
16. Removing of CO_2 from sodium or potassium salts of carboxylic acids.
17. Lighter nature of methane
19. Carbon content
20. Natural gas provides source of hydrogen with which ammonia is prepared by Harbers process

$$N_2 + 3H_2 \xrightarrow[\text{Pressure}]{\text{High temperature}} 2NH_3$$

21. (a) 2-methyl butane (b) 4-methyl 2-pentene
22. Automobile and domestic fuel, fertilizer synthesis, synthesis of industrial products
23. Phospho bronze
24. 1-butyne, 2-buyne
25. $CaC_2 + H_2O \rightarrow \underset{\text{Ethyne}}{HC \equiv CH} + Ca(OH)_2$
26. Vegetable oils + H_2 → Vanaspati ghee
27. Soap is the sodium or potassium salt of higher fatty acids. Detergents composed a long chain of hydro carbons containing benzene ring attached to sulphonate group
28. Calcium chloro hypocholrite
30. Chemical substances added to packed food items for the purpose of preventing spoilage of food material over a long period of usage. E.g.: Acetic acid, sodium benzoate.

Short-answer type questions

31. (i) Differ by–'CH_2' group
    (ii) General formulae and chemical properties
    (iii) Physical properties
33. (i) Thermal cracking
    (ii) Catalytic cracking
34. (i) Formation of coal and petroleum
    (ii) Conditions during formation.
    (iii) Source of energy which is exhaustible and non-replenishable
35. (i) Principle
    (ii) Tower
    (iii) Process
36. (i) Mixture of hydrocarbons
    (ii) Fractional distillation
37. (i) Composition of LPG
    (ii) Characteristics of LPG
38. (i) Addition of Br_2 on multiple bond
    (ii) Products formed
    (iii) Test for unstauration/multiple bond

key points for selected questions

39. (i) Addition of hydrogen in presence of catalyst
    (ii) Reaction conditions
    (iii) Products formed
42. (i) Principle with reaction (dehydration of ethyl alcohol)
    (ii) Set-up
    (iii) Procedure
43. (i) Composition
    (ii) Effect on atmosphere
    (iii) Calorific value
    (iv) Residue on combustion
44. (i) Composition of soap and detergents
    (ii) Reaction of soap and detergents in hard and soft water.
    (iii) Products formed

Essay type questions

46. (i) Catenation
    (ii) Isomerism
    (iii) Formation of multiple bonds.
47. (i) Principle
    (ii) Refining of petroleum
    (iii) Various fractions obtained
    (iv) Uses of each fraction
48. (i) Mining
    (ii) Destructive distillation
    (iii) Isolation of products
50. (i) Composition of soap and detergent
    (ii) Hydrophilic and hydrophobic parts of soap and detergent
    (iii) Formation of emulsion

KEY

Concept Application Level—1

True or false

1. True
2. True
3. True
4. False
5. True
6. True
7. True

Fill in the blanks

8. aromatic hydrocarbons
9. Decane
10. position
11. sodium propanoate
12. fractional distillation.
13. ethene, butane
14. anthracite

Match the following

15. A : c
    B : d
    C : f
    D : e
    E : b
    F : a

Multiple choice questions

16. Choice (1)
17. Choice (2)
18. Choice (2)
19. Choice (4)
20. Choice (1)
21. Choice (2)

22. Choice (3)

23. Choice (4)

24. Choice (4)

25. Choice (2)

26. Choice (2)

27. Choice (3)

28. Choice (3)

29. Choice (3)

30. Choice (2)

31. (i) Locating the long chains corresponding to hexane
(ii) Numbering of carbon chain
(iii) Locating the position of double bond
(iv) Locating the methyl groups (prefixes) at the respective position
(v) Locating hydrogens to satisfy tetravalency of carbon

Choice (4)

32. (i) Petroleum ether
(ii) Gasoline
(iii) Diesel oil
(iv) Lubricating oil

Choice (2)

33. $C_2H_2 + 5O_2 \rightarrow 2CO_2 + H_2O$

When one mole of ethyne is subjected to complete combustion, 2 moles of CO_2 and 1 mole of water are formed

Choice (3)

34. Saturated hydrocarbons have the general formula $C_nH_{2n}+2$ and C_5H_{12} corresponds to that formula.

Choice (4)

35. C_4H_8 and C_5H_{10} belong to same homologous series of alkenes as they possess same general formula (C_nH_{2n})

Choice (4)

36. $H_2C = CH_2 + Br_2 \rightarrow BrH_2C - CH_2Br$

$$HC \equiv CH + 2Br_2 \rightarrow \begin{array}{c} \quad\ \ Br\ \ \ Br \\ \quad\ \ |\ \ \ \ \ | \\ H - C - C - H \\ \quad\ \ |\ \ \ \ \ | \\ \quad\ \ Br\ \ \ Br \end{array}$$

One mole of ethene requires one mole of bromine and one mole of ethyne requires two mole of bromine for decolourization

Choice (3)

37. Polymerization of ethyne at 300°C gives benzene

Choice (3)

38. The bromination of acetylene gives terabromoethane.

Choice (2)

39. Addition of bromine is used as an identification test for detection of unsaturation in an organic compound as bromine is reddish brown liquid and loses colour due to the addition reaction.

Choice (3)

40. The hydrocarbon used for welding purposes is acetylene (ethyne) since oxyacetylene flame produces a high temperature of 3800°C

Choice (2)

41. The constituents of coal gas are methane carbon monoxide and hydrogen

Choice (1)

42. The reagent NaOH + CaO is called soda lime and is used for decarboxylation

Choice (4)

43. When organic wastes undergo degradation in the absence of air, methane is formed

Choice (1)

44. Sulphur compounds in crude oil can be removed by using copper oxide

Choice (1)

45. The composition of lubricating oil is hydrocarbons in the range $C_{20} - C_{24}$ due to high boiling point.

Choice (3)

Concept Application Level—2

Key points

1. Structures of the compounds.
2. Rules for IUPAC nomenclature.
3. (i) Identification of hydrocarbon 'X'
(ii) Valency of carbon atom.
(iii) Relation between valency of carbon atom and the number of single bonds it can form.

(iv) Identification of hydrocarbon on basis of number of chain isomer.
(v) Prediction of molecular formula from the structure of hydrocarbon.
(vi) Identification of preceding and succeeding homologues of hydrocarbon.

4. (i) Composition of methane and petrol.
(ii) Comparison of products obtained on combustion of methane and petrol.
(iii) Effect of the products on the environment.

5. (i) Raw materials for preparation ammonia.
(ii) Reaction of chief constituent of natural gas to give the raw material required.
(iii) Haber's process.
(iv) Role of product of Haber's process in manufacturing ammonium fertilizers.

6. (i) Calculation of molecular weight of hydrocarbon.
(ii) Identification of molecular formula of hydrocarbon based on given data.
(iii) Identification of products namely X and Y of hydrocarbon upon cracking.
(iv) Identification of Z from bromination of X.

7. (i) Identification of atomic ratio
(ii) Calculation of simple atomic ratio from atomic ratio.
(iii) Calculation of integral ratio and molecular formula from simple atomic ratio.
(iv) Prediction of succeeding and preceding homologues of above hydrocarbon.

8. (i) Composition of submerged plants.
(ii) Process of decay of submerged plants.
(iii) Changes that take place in submerged plants.

9. Characteristics of homologous series.

10. (i) Identification of Z
(ii) Identification of Y from Z.
(iii) Identification of X from given reaction of Y.
(iv) Identification of A from Y.

11. The Van der Waal's forces which hold the non polar alkane molecules are weak and have a very short range. The larger the molecule, the stronger are the intermolecular forces. Since boiling point depends upon the intermolecular forces, the boiling points of alkanes increase with increase in chain length. Also as the molecular weight increases, the velocity of the molecule decreases at a particular temperature. Thus alkanes tend to be in a liquid or a solid state.

12. General combustion equation is

$$C_xH_y + \left(x + \frac{y}{4}\right) O_2 \rightarrow X.CO_2 + \frac{y}{2} H_2C$$

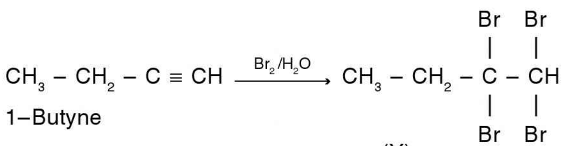
As the molar ratio of CO_2 and H_2O is 4 : 3,

$x = 4$ and $\frac{y}{2} = 3 \Rightarrow y = 6$

$\therefore\ x \equiv C_4H_6$

Since x reacts with bromine water and its formula indicates that X is butyne

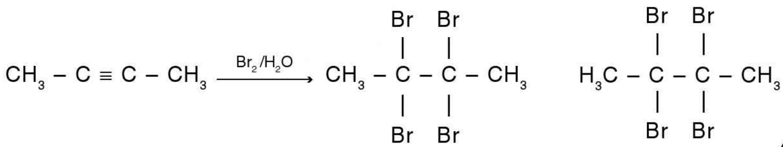
$\therefore$ x may be 1-Butyne or 2-Butyne



1–Butyne

(Y)

1, 1, 2, 2-tetrabromo ethane



(Y)

2–Butyne

2, 2, 3, 3-tetrabromo ethane

13. Molecular mass of X is 68. It may be alkene or alkyne.

Alkene	Alkyne
$\therefore C_nH_{2n}$	$C_nH_{2n} - 2$
$12n + 2n = 68$	$12n + 2n - 2 = 68$
$14n = 68$	$\Rightarrow n = 5$
$n = \frac{68}{14}$	$\therefore$ X is C_5H_8

But it is impossible

Succeeding homogolue "Y' is C_6H_8 (Hexyne)

Position isomers of X are 1–Pentyne, 2–Pentyne.

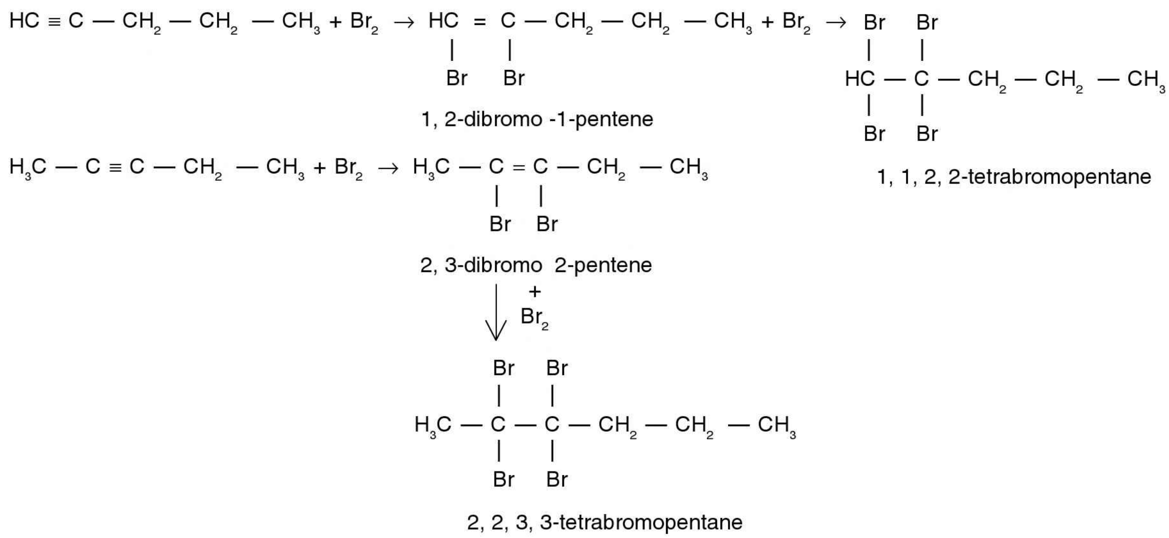
Position isomers of Y are 1–Hexyne, 2–Hexyne and 3–Hexyne.

14. The molecular formula of hydrocarbon giving CO_2 and H_2O in 5 : 4 ratio can be C_5H_8

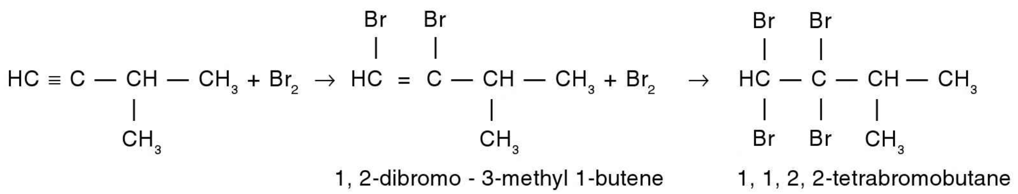
$$(C_xH_y + (x + \frac{y}{4})\ O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O)$$

(I)

(II)



(III)



15. Coal is formed from various organic compounds. In coal along with carbon, nitrogen and sulphur are also present in varying amounts. When the coal is burnt the N and S form corresponding oxides which escape into the atmosphere. These oxides combine with water forming their corresponding acids namely HNO3 and H2SO4. These acids reach earth as acid rain. As a result the acidity of soil increases. Anthracite coal is the best type of coal as it contains least percentage of 'S' and 'N' and minimises the effect of acidity of soil to the maximum extent.

16. In CNG the major component is methane. Since the calorific value is more and the products formed as a result of combustion are less polluting agents when compared with petrol and diesel, it is preferred. Petrol and diesel are mixtures of hydrocarbons where incomplete combustion takes place forming carbon monoxide which cases air pollution. More over in petrol and diesel sulphur and nitrogen are present which forms corresponding oxides. These oxides cause air pollution. And also CNG undergo rapid combustion due to it's low ignition temperature.

17. (a) 3, 3 – Dimethyl – 2 – butanol

(b) 4 – Chloro – 2 – methyl pentanoic acid

(c) 3, 4 – Dimethyl – 2 – pentene

(d) 4-Methyl-1-pentene

(e) 2, 2-Dimethyl propane

(f) 3-Methyl-1-pentyne

(g) 4-Methyl-2-pentene

18. X is cyclobutane

Y is butene

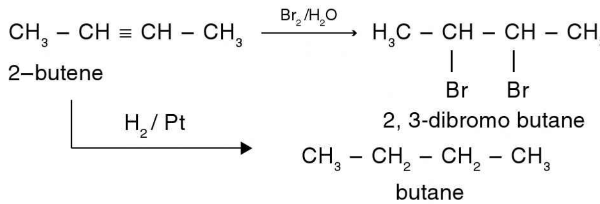
Isomers of Y are

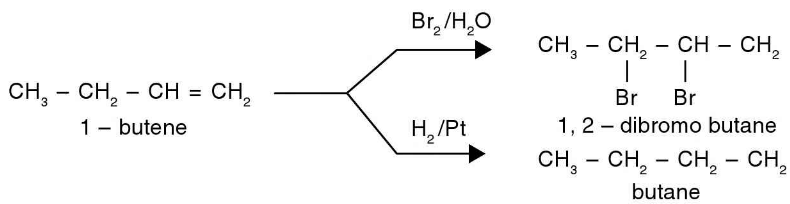
(a) $CH_3 - CH = CH - CH_3$,
2-Butene

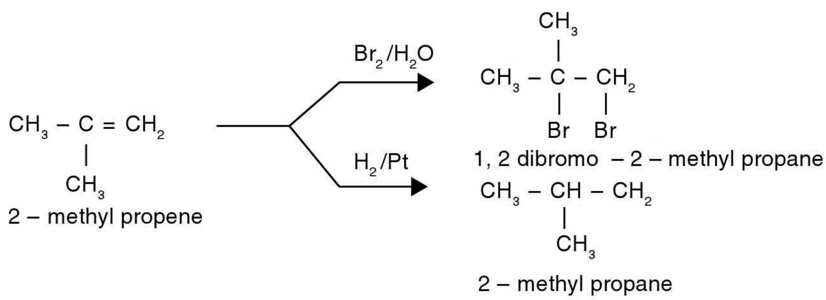
(b) $CH_3 - CH_2 = CH = CH_2$
1-Butene

(c) $\begin{array}{l} {}^3CH_3 - {}^2\underset{\displaystyle CH_3}{\underset{|}{C}} = {}^1CH_2 \end{array}$
2–Methyl– 1–propene

(a), (b) are position isomers. (a), (c); (b), (c) are chain isomers.

(a) 

(b) 

(c) 

∴ The hydrogenated products are n–butane C in case (a), (b) and isobutene in case if (c). Among these two n–butane is having high boiling point than isobutane. The boiling point is proportional to surface area of the molecule, more is the surface area more are the intermolecular forces of attraction between the molecules. So it's boiling point increases. Between n–butane and isobutene n–butane is having high surface area so boiling point is more when compared to isobutene. Hence, these two can be separated by fractional distillation.

19. Coal contains appreciable proportion of sulphur and nitrogen as it is formed by the degradation of dead organic matter. During destructive distillation of coal, sulphur and nitrogen are removed and coke is obtained which is a purer form of carbon.

20. (a) The most volatile hydrocarbons under the earth's crust vapourise under high temperature and pressure conditions and form a layer of natural gas.

(b) The volatile products obtained by distillation of coal may contain some water soluble gases such as NH_3 as impurities. Therefore, they are passed through water to remove the volatile impurities.

(c) Acetylene undergoes combustion to produce large amount of heat. A mixture of acetylene and oxygen produces a temperature of 3800°C which is higher than the melting points of metals. Therefore, it is used for welding purpose.

(d) Anthracite coal contains 90% carbon and 10% of other components such as sulphur or nitrogen. Bituminous coal contains 70% carbon and 30% of other components such as sulphur and nitrogen. As sulphur and nitrogen contribute much to the air and water pollution, anthracite coal is considered as better type of coal.

(e) Decarboxylation involves removal of CO_2 and resultant reduction in number of carbon atoms from the parent carboxylic acid. Hence, alkane with one carbon atom is prepared from carboxylic acid with two carbon atoms.

21. (i) Effect of amount of methane on product formation.
(ii) The initial product formed in container A.
(iii) Comparison of amounts of methane and product present is container A with time.
(iv) Comparison of reactivity of methane and product with chlorine.
(v) Final products formed incontainer A.
(vi) Product formed in container B based on availability of reactants.

22. (i) Calculation of molecular weight of X.
(ii) Calculation of molecular formula of hydrocarbon from molecular weight.
(iii) Identification of type of hydrocarbon based on formula.
(iv) Identification of possible ways the atoms can be arranged.
(v) Identification of succeeding homologue of the above hydrocarbon.
(vi) Number of position isomers of succeeding homologue based on number of carbon atoms.

23. (i) Impurities in coal.
(ii) Different reactions of coal on burning.
(iii) Effect of products of burning of coal on environmental pollution.

24. (i) Application of Le Chatelier principle.
(ii) Composition of soap.
(iii) Types of reactions involved in the preparation of soap.
(iv) Effect of common salt on the final step of the reaction.

25. (i) Identification of Z.
(ii) Nature of 'Z'.
(iii) Identification of 'y', based on its hydrogenation reaction.

Concept Application Level—3

Key points

1. (i) The nature of bonds in CH_3CI and CH_4.
(ii) Nature of the constituent atoms present in the respective molecules.
(iii) Reason for dipole moment of a molecule.

3. (i) Composition of steel
(ii) Compound formed with major constituent of coal and that of major constituent of steel.
(iii) Effect of formation of this compound on steel.

4. (i) Comparison of the components present in petrol obtained by fractional distillation and by cracking.

(ii) Comparison of products obtained on fractional distillation and cracking of petrol.

(iii) Effect of the products on the characteristic reaction involved in the usage of petrol as fuel.

(iv) Comparison of type and nature of products produced by the two types of petrol.

(v) Comparison of effect of these products on the environment.

(vi) Comparison of effect of products obtained on knocking property of engines.

5. (i) Structure of non-polar hydrocarbon part of detergent molecule.

(ii) Effect of structure on degradation.

(iii) Structure of bio-degradable detergents.

(iv) Comparison of structures of biodegradable and non-bio-degradable detergents.

6. .Attack of fluorine on methane is highly exothermic reaction with very less activation energy. The high amounts of energy released in this step make the fluorine molecules to dissociate in greater number leading to a greater increase in the rate of reaction, which ultimately makes the reaction explosive. Hence the mixture of CH_4 and F_2 when diluted with inert gas like. He or Ne or N_2, the rate of the reaction can be decreased. And also when the reaction is carried in copper vessel copper being good conductor of heat, absorbs excess heat and thus makes the reaction to be moderate.

7. No, kerosene cannot be used as a substitute for gasoline as an automobile fuel. Gasoline has lower ignition temperature and the hydrocarbons have carbon chain length ranging from $C_5 - C_{10}$. Kerosene has higher ignition temperature and the hydrocarbons have carbon chain length ranging from $C_{10} - C_{18}$. Due to higher ignition temperature, kerosene cannot be ignited by spark plug. Because of longer carbon chain, it produces very high knocking which makes it unsuitable for use as an automobile fuel.

8. Chlorination of methane gives methyl chloride and hydrochloric acid, which are stable where as iodination of methane gives methyl iodide and hydrogen iodide which is strong reducing agent and hence reduces $CH_3 - I$ to CH_4.
So iodination is reversible.

$$CH_4 + I_2 \rightleftarrows CH_3I + HI$$

As a result iodination is carried out in the presence oxidising agent like HIO_3 which oxidises HI to I_2 and thus prevents the reversibility of the reaction.

$$5HI + HIO_3 \rightarrow I_2 + H_2O$$

$$CH_4 + I_2 \xrightarrow{HIO_3} CH_3I + I_2 + H_2O$$

9. Soaps are prepared by subjecting oils or fats to hydrolysis with sodium hydroxide. That means, soaps are sodium salts of higher fatty acids. Shampoos and shaving creams are prepared by subjecting oils or fats to hydrolysis with potassium hydroxide. That means, they are potassium salts of higher fatty acids. Potassium salts are more soluble than sodium salts. Hence shampoos and shaving creams softer than soaps.

10. Coal is formed when wood and plant remains decompose in the absence of air. They contain carbon, hydrogen and oxygen. The process of gradual decomposition results in the increase of carbon content by the removal of hydrogen and oxygen in the form of water. As they become richer in carbon, the quality of coal goes on increasing from the stage of peat to the stage of anthracite. This is the reason why the same coal deposit may contain coal of different compositions.