Chapter

1

Nature of Matter

Remember

Before beginning this chapter, you should be able to:

- understand basic concepts of kinetic molecular theory.
- comprehend classification of matter and different states of matter.

Key Ideas

After completing this chapter, you should be able to:

- understand the comparison between different states of matter in correlation with kinetic molecular theory.
- study the interconversion of different states of matter and correlate it to day-to-day activities and natural phenomena.
- know about the characteristics of elements, compounds, homogeneous and heterogeneous mixtures.
- illustrate the different separation methods for separation of different types of mixtures.

INTRODUCTION

The subject of chemistry basically deals with the study of matter in different perceptions. One of the important aspects 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: 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 a change in physical behaviour of the substances in their respective states. The various characteristics of matter which determine the physical behaviour are envisaged in the 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 following table provides a comparison of the three states of matter:

TABLE 1.1 Different states of matter and their properties

Properties	Solids	Liquids	Gases
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)	Diffuse spontaneously and rapidly

A comparative study of molecular arrangements in solids, liquids and gases, based on the kinetic molecular theory, is provided in the following table:

Parameters	Solids	Liquids	Gases
Packing of molecules	Closely packed	Loosely packed	Very loosely packed
Intermolecular space	Very low	More than those in solids	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	Highest kinetic energy

EXAMPLE

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

SOLUTION

In solids, molecules do not possess translatory motion. Therefore, they occupy fixed positions. As a result, they have any number of free surfaces. In gases, molecules possess translatory motion in all directions randomly. Therefore, they do not have fixed positions and do not possess definite shape. Hence, they do not have free surfaces. In liquids, molecules possess translatory motion which is not random like gaseous molecules and the upper surface is free. Hence, they have only one free surface.

EXAMPLE

Arrange different states of matter in the increasing order of their densities with appropriate reason.

SOLUTION

In solids, the molecules are tightly packed. Hence, the number of molecules per unit volume is more and density is the highest. In gases, the molecules are very loosely packed and the density is the least. Molecules of liquids are loosely packed, but intermolecular space is much less than that in gas. Hence, their denisities are generally less than solids, but more than gases.

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, therefore, matter can be converted from one state to another under suitable conditions. This is also termed as phase transition.

Interconversion Between Solid and Liquid States

The process of conversion of a solid state to a liquid state is called melting or fusion and the opposite process from the liquid to the solid states 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 the solid state is subjected to heating, the molecules absorb heat energy which increases the kinetic energy of molecules. This results in an increase of the kinetic energy of the molecules which in turn leads to increase in temperature; however, further supply of heat energy does not increase the kinetic energy of molecules. Instead, the heat energy is stored in the form of potential energy. With increase in the potential energy, the intermolecular forces of attraction decrease which results in increase in intermolecular spaces. The molecular arrangement of the solid changes to that of the liquid. The temperature at which the solid gets converted to the liquid state at the atmospheric pressure is called melting point of that solid.

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

Factors Affecting the Melting Point

1. **Effect of pressure:** The effect of pressure on the melting point of the solids depends upon the nature of the 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, etc.

   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, etc.

   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.

2. **Effect of addition of impurities:** Addition of impurities to a solid decreases the melting point of the solid thereby allowing the substance to melt at a lower temperature.

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

   Melting point of Rose's metal $\rightarrow$ 94.5°C

   Melting point of Pb $\rightarrow$ 327°C

   Melting point of Sn $\rightarrow$ 231.9°C

   Melting point of Bi $\rightarrow$ 271°C

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

When a substance in the 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 decrease in kinetic energy. Decrease in potential energy leads to increase in intermolecular forces of attraction, and hence, decrease in intermolecular spaces. Hence, the molecular arrangement of the liquid changes to that of solid. The temperature at which the liquid converts into the solid at the atmospheric pressure is called freezing point of the liquid. The 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, addition of impurities to the solids decreases the melting point of the 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 three parts of ice and one 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 the Liquid and Gaseous States

Vaporisation: The process of conversion of the liquid state to the gaseous state is called vaporisation. 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 the kinetic energy of molecules. The heat energy supplied increases the potential energy of the molecules. As a result, the intermolecular forces of attraction decrease. The molecules move apart and the substance passes from liquid to gaseous state. This process is called **boiling** and the temperature at which the conversion of the liquid to the vapour states takes place at normal atmospheric pressure is called **boiling point**.

Factors Affecting the Boiling Point

Although every liquid is characterised by a specific value for the boiling point, it depends on some factors as discussed hereunder.

1. **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 a pressure cooker.

   In the 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 rises beyond 100°C. The temperature of cooking medium being greater than the normal boiling point, therefore, food gets cooked at a faster rate, and thus, saving time and fuel.

2. **Effect of impurities:** When solid substances are dissolved in a liquid, the boiling point of the liquid increases 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 to gaseous states can also be brought about even without supplying heat energy to the liquid. In the 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 a vapour state. This process of conversion of the liquid into the vapour takes place at a temperature below the boiling point and 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. Vaporisation is a common term applicable for both evaporation and boiling.

Factors Affecting Evaporation

1. **Surface area:** Increase in surface area increases the rate of evaporation.
2. **Temperature:** Increase in temperature increases the rate of evaporation.
3. **Humidity:** The amount of water vapour which the atmospheric air holds is called humidity. Higher humidity decreases the rate of evaporation.
4. **Wind speed:** Increase in wind speed increases the rate of evaporation.

Condensation: The conversion of a gaseous substance into a 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 the liquid state.

The conversion of the gaseous to the 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 the liquid state. That means, above that minimum temperature, application of any amount of pressure cannot bring about the transformation from the gaseous to the 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.

TABLE 1.2 Critical temperatures of common gases

Gases	Critical temperatures
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

1. **Effects of condensation on climate:** The formation of dew, fog and clouds is the application of condensation.

   When the temperature is high, water in water bodies evaporates and during day time, 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 the atmosphere, the condensed water droplets appear as clouds.

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

   Examples: Camphor, naphthalene, ammonium chloride, iodine, etc.

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 a liquid at atmospheric pressure at its melting point is known as the latent heat of fusion. For ice, it is equal to 80 cal/g/°C.

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 is called latent heat of vaporisation. For steam, this equals 540 cal/g/°C.

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 a vapour state. Since surroundings lose energy, they becomes cold. This principle is made use of in various daily life activities as listed hereunder:

1. Cool sensation produced when alcohol is poured on palm,
2. Cotton clothes producing cooling effect during summer,
3. Formation of water droplets on the outer surface of glass containing ice cold water and
4. Cooling of water in earthen pots during summer.

EXAMPLE

(i) Pressure cooker reduces the cooking time. Explain the principle involved.

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

(iii) When a glass of ice cold water is kept open at room temperature, what observation is found? Give reason.

SOLUTION

(i) In a pressure cooker, water is subjected to heating in a closed vessel in a 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 rises beyond 100°C. The temperature of cooking medium being greater than the normal boiling point, therefore, food gets cooked at a faster rate, and thus, saving time and fuel.

(ii) Addition of common salt to ice reduces the freezing point of ice to below 0°C. A mixture of three 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.

(iii) When a glass of water is kept at room temperature, water droplets are observed on the outer walls of glass. This is because the water vapour present in air when comes in contact with glass containing ice cold water loses the heat energy, and thus, the water vapour present in air gets condensed.

EXAMPLE

When two pieces of ice are pressed together, they form a single lump. Explain

SOLUTION

When two pieces of ice are pressed together, they form a single lump, it is due to regelation. When two ice cubes are pressed together, the ice at the interface melts due to the application of pressure and when the pressure is released, it solidifies again thereby joining the two ice cubes.

EXAMPLE

Why does temperature remain constant as heated liquid gets converted to its gaseous state at its boiling point?

SOLUTION

When the heated liquid is converted to its gaseous state at its boiling point, the temperature remains constant because the change in state of matter is associated with increase in potential energy, and the kinetic energy remains constant.

EXAMPLE

The critical temperature of gases A, B, C and D are –118°C, –240°C, 132°C and 20°C, respectively. Arrange them in the decreasing order of intermolecular force of attraction.

SOLUTION

The higher the critical temperature the more is the intermolecular force of attraction and they can be liquefied easily. Decreasing order of intermolecular force of attraction is C > D > A > B.

EXAMPLE

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

SOLUTION

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.

EXAMPLE

Why are cotton clothes preferred in summer?

SOLUTION

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

EXAMPLE

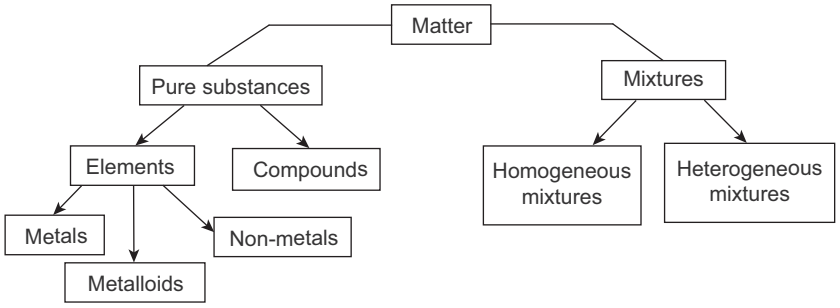
Discuss the change in energy and arrangement of molecules on increasing the temperature of ice from –5°C to 10°C at 1 atm pressure.

SOLUTION

When ice is heated at −5°C, its temperature increases upto 0°C , i.e., the kinetic energy of the molecules increases. At 0°C, the ice starts melting. During this process, the energy supplied is utilised to increase the potential energy of the molecules keeping kinetic energy constant, and the arrangement of molecules changes. Once the process ends, the heat supplied is again used to increase the temperature of water by increasing the kinetic energy. However, from 0°C to 4°C, the molecules of water come closer and above 4°C, the molecules move farther away.

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 a 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



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 is called compounds. A molecule of carbon dioxide is made up of one carbon atom and two oxygen atoms.

A mixture is such a substance which contains two or more kinds of molecules. For example, common salt solution contains molecules of NaCl and molecules of water. A mixture may include constituents as elements, an element and a compound, or only compounds.

Depending on the distribution of the different kinds of molecules within the mixture, the mixture is classified into two types: homogeneous and heterogeneous. A homogeneous mixture has uniform distribution of the different types of molecules in the mixture. A heterogeneous mixture has non-uniform distribution of the different types of molecules. For example, aqueous solution of glucose is a homogeneous mixture, whereas muddy water is a heterogeneous mixture.

Characteristics of Elements

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

   Examples: Na, Mg, Al, Cu, etc., are metals.
   H_2, O_2, He, S, etc., are non-metals.
   As, Sb, Se, Te, Ge are metalloids.

2. 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.

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

   Examples: Ag, Al, Au
   He, Ne
   B, C

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

   Examples: H_2, O_2, N_2

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

   Examples: O_3, P_4, S_8

Characteristics of Compounds

1. The constituent 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)

2. The elements do not retain their properties.

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

3. The constituent elements can be separated only by chemical methods.

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

4. All compounds are invariably homogeneous.

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

Characteristics of a Mixture

1. The constituents may be present in any proportion.

2. The constituents retain their individual properties.

   Example: Aqueous solution of sugar.

3. Separation of constituents is carried out by physical methods.

4. A mixture can be either heterogeneous or homogeneous.

5. Formation of a mixture does not involve significant energy change.

Classification of a Mixture

TABLE 1.3 Classification of mixtures

Types of mixture	Homogeneous	Heterogeneous
Solid–solid	Stainless steel, brass and bronze	Iron and sulphur
Solid–liquid	NaCl in water and iodine in CCl_4	Sulphur in water
Liquid–liquid	Alcohol and water, and benzene and toluene	Oil and water
Liquid–gas	Liquor ammonia and soda water	–
Gas–gas	Air	–
Solid–gas	–	Hydrogen gas adsorbed on Pd

EXAMPLE

"All pure substances are homogeneous. But, all homogeneous substances are not pure". Justify

SOLUTION

A pure substance is the one which is made up of same kind of molecules. So, it is homogeneous in nature. A mixture which has uniform distribution of different kinds of molecules is also homogeneous but it is not pure as it contain two or more kind of molecules.

EXAMPLE

Water is a compound. Explain.

SOLUTION

Water is made up of hydrogen and oxygen which are present in fixed proportion and the properties of water are entirely different form its constituents, hence, it is a compound.

Separation of a Mixture

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

TABLE 1.4 Types of separation methods of a solid–solid mixture

Methods	Properties exploited	Description with examples
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

Methods	Properties exploited	Description with examples
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

TABLE 1.5 Types of separation method af a solid–liquid mixture

Methods	Properties exploited	Description with examples
Sedimentation and decantation	High density of an 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 an 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 a solid to remain undecomposed when a 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 the 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

TABLE 1.6 Types of separation method of a liquid–liquid mixture

Methods	Properties exploited	Description with examples
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 vaporises. On passing through fractionating column, the vapours condense to give alcohol in a receiver. Water is left behind in the distillation flask

TABLE 1.7 Types of separation method af a gas–gas mixture

Methods	Properties exploited	Description with examples
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, and 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 in liquefaction of component gases under pressure	A mixture of NH_3 and H_2. Ammonia gets liquefied 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, whereas O_2 has a higher boiling point and remains behind

TABLE 1.8 Types of separation method of a liquid–gas mixture

Methods	Properties exploited	Description with examples
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 a gas in the liquid at different pressures	When a 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 types of a mixture, 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 a coloured constituent in a mixture of ink by paper chromatography.

Process: A filter paper is taken which generally absorbs water. It acts as a 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 a moving phase, it moves rapidly on the filter paper. Therefore, depending on the relative affinities of the various constituents with the stationary and moving phases, spots or lines appear on the filter paper at different positions.

Example: Separation of coloured constituents in a mixture of ink.

EXAMPLE

How is oxygen prepared from air?

SOLUTION

When air is liquefied, the major components of air, nitrogen and oxygen can be separated by subjecting the liquids to fractional evaporation. Nitrogen has a lower boiling point, and hence boils off and oxygen has a higher boiling point, and hence remains behind.

EXAMPLE

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

SOLUTION

Mixture of NaCl and NH_4Cl can be separated by sublimation.

PROCESS

Ammonium chloride and sodium chloride mixture is taken in a porcelain dish.

It is covered by an inverted funnel. The opening of the stem of the funnel is closed by means of a cotton plug. The outside of the funnel is kept cool by wrapping with wet blotting paper.

On heating the porcelain dish, ammonium chloride changes into vapour state, which on coming in contact with the inner wall of the cooled funnel condenses into the original solid and gets collected there.

EXAMPLE

Mention the separation method and property exploited in the separation of the following solid-solid mixtures.

(a) S + sand **(b)** I_2 + sand **(c)** KNO_3 + NaCl

SOLUTION

(a)	S + sand	Solvent extraction	Solubility of one component in a given solvent
(b)	I_2 + sand	Sublimation	Ability of one component to sublime.
(c)	KNO_3 + NaCl	Fractional crystallisation	Difference in solubility of the components in the same solvent.

EXAMPLE

How will you separate sulphur dioxide gas from the gaseous mixture of SO_2 and O_2?

SOLUTION

SO_2 gas from O_2 can be separated by preferential liquefaction. SO_2 gas liquefied under high pressure and O_2 is left behind. Since SO_2 is acidic in nature, it can also be separated by passing the gaseous mixture through KOH solution.

EXAMPLE

When soda water bottle is kept open for sometime, it loses the tangy taste. Give reason.

SOLUTION

At high pressure, more amount of CO_2 is dissolved in water. When the bottle is opened, excess amount of CO_2 comes out as solubility of gas decreases with decrease in pressure, and hence, the soda water loses its tangy taste.

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

1. **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 reacts to give sodium hydroxide and hydrogen, and hence, sodium catches fire. Due to this reason, only sodium is stored in kerosene.

2. **Heat**: Generally, chemical reaction involves 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 and their ΔH is positive.

   Examples: $KNO_3 \xrightarrow{\Delta} KNO_2 + O_2 \ \Delta H = 244.7 \text{ kJ}$

   $CaCO_3 \xrightarrow{\Delta} CaO + CO_2 \ \Delta H = 178 \text{ kJ}$

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

   Example: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \ \Delta H = -890.4 \text{ kJ}$

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

   Example: $H_2 + Cl_2 \xrightarrow{\text{light}} 2HCl$

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

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

   Example: $Mg + O \rightarrow 2MgO + \text{Light}$

4. **Pressure**: There are some chemical reactions which require high pressure conditions for the reaction to take place at a reasonable rate:

   Example: $2SO + O_2 \xrightarrow{V_2O_5} 2SO_2$ (manufacture of H_2SO_4 by contact process)

   $Pb + S \rightarrow PbS$

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

Example: $N_2 + 3H_2 \xrightarrow[450°C\ 200\ atm]{Fe} 2NH_3$

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 numbers of chemical reactions, the study of these reactions becomes easier and convenient by classifying them into various types.

TABLE 1.9 Chemical reactions and their examples

Types of chemical reactions	Explanation	Examples
Chemical combination	Combination of two or more substances	$N_2 + O_2 \rightarrow 2NO$ (synthesis) and $2CO + O_2 \rightarrow 2CO_2$ (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)
		$2HgO \xrightarrow{\Delta} 2Hg + O_2$
		$2HOC \xrightarrow{light} 2HCl + O_2$ (photolytic decomposition)
		$2H_2O \xrightarrow{electric} 2H_2 + O_2$ (electrolyte decomposition)
Double decomposition	The radicals of the reactants are interchanged. A double decomposition reaction between an acid and a base is called neutralisation reaction	$Na_2SO_4 + Zn(NO_3)_2 \rightarrow 2NaNO_3 + ZnSO_4$
		$2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$
	Precipitation reactions also are double decomposition reactions	$CaBr_2 + K_2SO_4 \downarrow CaSO_4 + 2KBr$
Displacement	A less reactive element is displaced by a more reactive element	$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$
		$2KCl + F_2 \rightarrow 2KF + C1_2$

Since the displacement reaction depends upon the relative reactivities of various metals, they are arranged in a 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	Reactivity decreases
Zinc	Zn	
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:

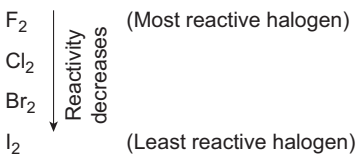
Example: $Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$

(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



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 and boiling points 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 and adhesive forces?
5. Cotton clothes producing cooling effect during summer is an application of _____.
6. Why do wet clothes dry faster on a windy day?
7. Is it possible to liquefy CO_2 gas at 50°C? Give a 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. Distinguish between filtration and centrifugation.
12. Silver is a substance which expands on melting, so, its melting point _____ when pressure is raised.
13. Give an example each for solid–liquid and solid–solid types of a homogeneous mixture.
14. The atomicity of the element phosphorus is _____.
15. _____ is the method of separating heavier fat particles of milk from lighter water.
16. 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?
17. Solubility of a gas in a liquid _____ with rise of temperature.
18. Give an example for a liquid–liquid heterogeneous mixture. Suggest a method of separation for it.
19. The forces of attraction existing between similar molecules are _____.
20. How do you separate a mixture of

    (a) CO_2 and O_2 and (b) H_2 and O_2?
21. The formation of phosphorus pentachloride from phosphorus trichloride and chlorine gas is a _____ type of combination reaction.
22. The addition of MnO_2 to $KClO_3$ decreases the temperature at which $KClO_3$ decomposes because MnO_2 added acts as a _____ catalyst.
23. What is paper chromatography?
24. A mixture of NH_3 and H_2 can be separated by applying pressure, because of their high difference in _____.
25. Why is sodium stored in kerosene?
26. A compound is always _____.
27. A reaction of decomposition of a compound AB is accompanied by absorption of some heat energy.

    What is the sign of ΔH?
28. The temperature above which no amount of pressure can cause a gas to liquefy is _____.
29. What is sublimation? Give some examples.

Short Answer Type Questions

30. When two ice cubes are pressed, they join together. Explain the principle involved.
31. Why are cotton clothes preferable in summer?
32. How is liquefaction different from condensation?
33. Distinguish between evaporation and boiling.
34. When a glass of ice cold water is taken in a glass, water drops are formed on the outer surface of the glass. Give a reason.
35. What is a double decomposition reaction? Give an example each for neutralisation and precipitation reactions.
36. Why is it not possible to displace fluorine from metallic fluorides by any other halogens?
37. Explain the process of condensation with respect to kinetic molecular theory.

PRACTICE QUESTIONS

38. What is critical temperature? How does it affect the liquefaction of gas?
39. Why does steam cause more burns than boiling water?
40. List out the differences between physical and chemical changes.
41. What are the different types of combination reactions? Give an example of each.

Essay Type Questions

42. Suggest the possible methods of separation of liquid–gas mixtures. Explain each method with an example.
43. Explain the factors affecting
    (a) melting point
    (b) boiling point
    (c) evaporation
44. Give the postulates of kinetic molecular theory of matter. Explain the process of melting on the basis of this theory.
45. Explain the process of separation of different constituents in coloured ink.
46. Explain the following methods of separation with an example each.
    (a) Fractional crystallisation
    (b) Sedimentation and decantation
    (c) Preferential liquefaction
    (d) Fractional distillation

CONCEPT APPLICATION

Level 1

Direction for questions from 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 from 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 and z are heated, the number of free surfaces of substances x and 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 is/are _____.

PRACTICE QUESTIONS

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

15.

Column A	Column B
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 from 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
(a) starts falling
(b) starts rising
(c) remains at the same level
(d) initially falls and then rises

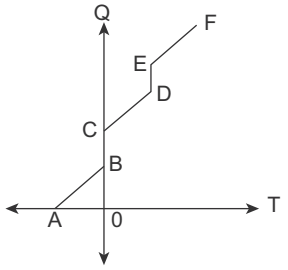
17. The high diffusibility of gases is due to
(a) high intermolecular forces of attraction
(b) high KE of molecules
(c) restricted translatory motion in upward direction
(d) all the above

18. Water kept in an earthen pitcher, during summer days becomes very cold due to
(a) condensation (b) evaporation
(c) freezing (d) fusion

19. The electric bulb on long use forms a black coating on its inner surface. The process associated with this is
(a) melting of tungsten
(b) sublimation of tungsten
(c) oxidation of tungsten
(d) reduction of tungsten

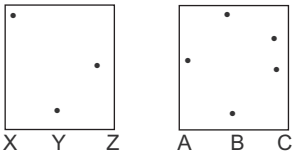
20. Identify a physical change among the following:
(a) respiration
(b) digestion of food
(c) burning of wax
(d) glowing of an electric bulb

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.



(a) AB, BC
(b) BC, DE
(c) CD, EF
(d) all the regions in the given graph

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



(a) A (b) B
(c) C (d) A and C

23. Maximum intermolecular forces of attraction exists in
(a) bromine (b) air
(c) oxygen (d) 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,

PRACTICE QUESTIONS

B liquefies leaving behind C. Identify the set of gases.

(a) SO_3, NO_2, O_2 (b) Cl_2, SO_2, H_2

(c) CO_2, CO, N_2 (d) NH_3, N_2, H_2

25. Identify the element from the following:

(a) air (b) iodine vapour

(c) water (d) amalgam

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

(a) pressure cooker at sea level

(b) pressure cooker at higher altitude

(c) open vessel at sea level

(d) open vessel at higher altitude

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

(a) reaction of iodine with white phosphorus

(b) reaction of iron with sulphur

(c) addition of water to lime

(d) 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.

(a) Z < X < Y (b) Y < X < Z

(c) X < Z < Y (d) X < Y < Z

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

(a) chromatography

(b) solvent extraction

(c) sublimation

(d) dissolution in suitable solvents

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

(a) reaction between baking powder and H_2SO_4

(b) reaction between $BaCl_2$ and Na_2SO_4

(c) reaction between $AgNO_3$ and HCl

(d) 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)

(1) potential energy increases and kinetic energy remains constant

(2) potential energy decreases and kinetic energy remains constant

(3) potential energy increases and kinetic energy increases

(4) potential energy decreases and kinetic energy decreases

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

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

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.

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

(2) Paper chromatography is used for the separation.

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

(4) 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.

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

(a) 2 4 3 5 1 (b) 2 5 3 1 4

(c) 2 3 4 5 1 (d) 1 4 5 3 2

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

(a) bromine (b) iodine

(c) ammonia (d) silicon dioxide

34. In Darjeeling, distilled water boils at a temperature

(a) above 373 K (b) above 473 K

(c) below 373 K (d) at 373 K

35. At melting point,

(a) kinetic energy remains constant and potential energy increases

(b) kinetic energy increases and potential energy remains constant

(c) both potential energy and kinetic energy increase

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

36. Which among the following statements is true?

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

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

(c) In both the areas the rate of evaporation is the same.
(d) None of the above

37. Which among the following is not a homogeneous mixture?
(a) solder
(b) aqueous solution of NaCl
(c) sulphur in carbon disulphide
(d) sulphur in water

38. Gunpowder is a _____
(a) solid–liquid homogeneous mixture
(b) solid–liquid heterogeneous mixture
(c) solid–solid homogeneous mixture
(d) solid–solid heterogeneous mixture

39. Which of the following gases can be separated completely from a mixture by using water as a solvent?
(a) CO_2 and O_2 (b) N_2 and NH_3
(c) CO_2 and NH_3 (d) H_2 and N_2

40. Identify the mixture which can be separated by magnetic separation method.
(a) chalk powder + sand (b) iron + sand
(c) common salt + sand (d) sulphur + sand

41. Which among the following is true?
(a) Air is a bad conductor of heat and thermal expansion of solids is more than that of gases.
(b) Air is a good conductor of heat and thermal expansion of solids is less than that of gases.
(c) Air is a bad conductor of heat and thermal expansion of solids is less than that of gases.
(d) 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?
(a) formation of water drops on the surface of cold drink bottle
(b) formation of crystals of ice on the inner surface of the lid of an ice cream box in freezer
(c) white foggy appearance on the surface of large ice blocks
(d) stretching out of tongues by dogs during summer

43. Which among the following is the false statement?
(a) Water boils below 100°C on mountain peaks.
(b) Ice undergoes sublimation on surface of moon.
(c) Ice melts above 0°C on mountain peaks.
(d) 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?
(a) P (b) Q
(c) R (d) S

45. Identify the methods by which the individual components of mixture containing water, potassium nitrate, sodium chloride, alcohol and carbon tetrachloride can be separated.
(a) separating funnel, fractional distillation, fractional crystallisation, distillation
(b) fractional distillation, distillation, fractional crystallisation
(c) separating funnel, fractional distillation, filtration, distillation
(d) separating funnel, fractional distillation, sedimentation and decantation

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?

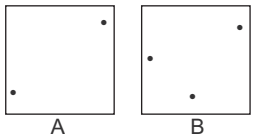
4. A tarnished silver rod when kept in water containing magnesium bars regains its lustre. Justify.

5. In summer, 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.

PRACTICE QUESTIONS

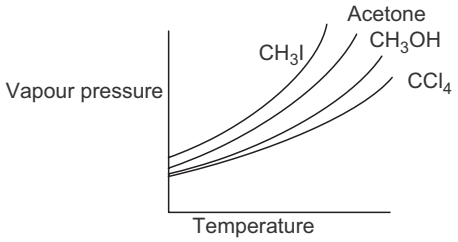
7. A mixture of X and Y on subjecting to paper chromatography gave the chromatogram 'A.' When the same mixture is subjected to heating, chromatogram B was obtained. What do you infer from the chromatograms?



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 gunpowder. What types of reactions are involved in the explosion of gunpowder?

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 from 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 a freezer for too long, crystals of ice are formed inside the box. Give reasons.

18. Why are cotton clothes preferred in summer?

19. 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.

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

21. The critical temperatures of CO_2 gas and N_2 gas are 31°C and –147°C, respectively. Which gas is liquefied easily and why?

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

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 a 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. When 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 from 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 non-sublimable 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?

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. a
17. b
18. b
19. b
20. d
21. b
22. c
23. d
24. d
25. b
26. d
27. d
28. c
29. b
30. d

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

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 inks are separated on the paper by adsorption technique.

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

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

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

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.

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

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

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

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

HINTS AND EXPLANATION

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 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 KE of molecules increases, and therefore, the volume increases.

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

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.

44. Rate of sublimation is directly proportional to vapour pressure. Hence, 'S' undergo sublimation more easily at room temperature.

45. Both KNO_3 and 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. Hence, CCl_4 is separated by separating funnel. Alcohol is separated by fractional distillation. As KNO_3 is more soluble than NaCl in water, therefore, it is separated by fractional crystallisation. NaCl from water is separated by distillation.

Level 2

1. (i) conditions required for burning.
(ii) utilisation 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 gunpowder
(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. 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 vaporisation from the body and gets evaporated, thus, keeping the body cool.

19. Steel is an alloy, i.e., 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.

20. 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, therefore, they can be separated by diffusion, where H_2 will come out first.

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

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

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 a car during summer and winter
(iii) effect addition of ethylene glycol to water of a 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, i.e., a high vapour pressure, distils. 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 reduces the melting point of the 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 meniscus as it has higher cohesive forces than adhesive forces with glass. Water, on the other hand, shows a concave meniscus as the adhesive forces between water and glass are higher than the cohesive forces between water molecules.