Written as per the revised syllabus prescribed by the Maharashtra State Board of Secondary and Higher Secondary Education, Pune.

Precise
Chemistry – I
STD. XII Sci.

Salient Features

- Concise coverage of syllabus in Question Answer Format.
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'Chapters 8 to 16 are a part of Std. XII: Precise Chemistry - II'

Note: All the Textual questions are represented by * mark.
All the Intext questions are represented by # mark.

01 Solid State

Subtopics

1.1 Introduction

Q.1. Define a solid.

Ans: *A **solid** is defined as that form of matter which possesses rigidity and hence possesses a definite shape and a definite volume.*

***Q.2. Give characteristics of solid state.**

Ans: The solid state is characterized by the following properties:

i. Solids have definite mass, volume, shape and density. Usually, the density of solid state is greater than the density of liquid and gaseous state. Water and mercury are exceptions. The density of ice (solid state of water) is lower than the density of liquid state of water. The density of mercury (which exists in liquid state) is very high (13.6 g mL^{-1}).

ii. Solids are usually hard, incompressible and rigid. Some solids like sodium, potassium and phosphorous are exceptions; they are soft. Solids cannot be compressed because the intermolecular distance of separation between neighbouring molecules is very small.

iii. In a solid state, intermolecular forces of attraction between the constituent particles are stronger than those present in liquid and gaseous states.

iv. All pure solids have characteristic melting points which depend on the extent of intermolecular forces present in the solid state. Stronger the intermolecular forces of attraction, higher is the melting point of the solid. Weaker the intermolecular forces of attraction, lower is its melting point. Hence, depending on the intermolecular forces of attraction, melting points of the different solids range from almost absolute zero (helium) to a few thousand Kelvin (diamond).

v. The intermolecular forces of attraction hold the constituent particles of the solids tightly. Hence the particles cannot change their positions and remain stationary at one position. Therefore, solids cannot flow like liquids.

1.2 Classification of solids

***Q.3. Give the classification of solids.**

Ans: Solids are classified as crystalline and amorphous on the basis of the presence or absence of orderly arrangement of their constituent particles (atoms, ions or molecules).

i. Crystalline solids: *A **crystalline solid** is a homogeneous solid in which the constituent particles (atoms, ions or molecules) are arranged in a definite repeating pattern.*

Crystalline solids are further classified as:

a. Isomorphous form:

1. *Two or more substances having the same crystal structure are said to be **isomorphous** (iso-same, morphous-form) and the phenomenon is called **isomorphism**.*

2. The constituent atoms of isomorphous substances are in the same atomic ratio. The molecular formula and chemical properties of the isomorphous substances are similar.
3. Following are some examples of pairs of isomorphous substances and their atomic ratios:

Sr. no.	Isomorphous substances	Atomic ratios
i.	NaF and MgO	1:1
ii.	$NaNO_3$ and $CaCO_3$	1:1:3

Sr. no.	Isomorphous substances	Atomic ratios
iii.	K_2SO_4 and K_2SeO_4	2:1:4
iv.	Cr_2O_3 and Fe_2O_3	2:3

4. Some substances are not isomorphous even though they have same atomic ratio, similar molecular formula and similar chemical properties. This is because they have different crystal structures.
   eg. Sodium chloride (NaCl) and potassium chloride (KCl)

b. Polymorphous / Allotropic form:

1. *A single substance that crystallises in two or more forms under different conditions is called **polymorphous** (poly-many, morphous-form) and the phenomenon is called **polymorphism**.*
2. The polymorphic forms are also called allotropic forms.
   eg. i. Diamond, graphite and fullerene are three polymorphic forms of carbon.
   ii. Rhombic sulphur and monoclinic sulphur are two allotropes of sulphur.
   iii. Silicon dioxide and calcium carbonate also have allotropes.

ii. Amorphous solids / Pseudo solids / Super cooled liquids: *The substances that appear like solids but do not have well developed perfectly ordered crystalline structure are called **amorphous** (no form) **solids**.*
eg. Tar, glass, plastic, rubber, butter, etc.

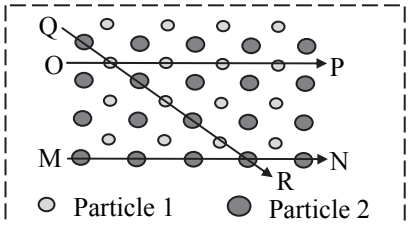
Q.4. Define the term 'anisotropy'. [Mar 17]

Ans: Anisotropy: *The ability of crystalline solids to change values of physical properties when measured in different directions is called **anisotropy**.* *[Definition – **1 Mark**]*

#Q.5. Explain the terms anisotropy and unit cell.

Ans: i. Anisotropy:

a. *The ability of crystalline solids to change values of physical properties when measured in different directions is called **anisotropy**.*
b. For crystalline solids, the physical properties like refractive index, electrical conductance, dielectric constant, etc., are different in different directions. As the direction changes (MN, OP, QR, etc.), the composition of the medium changes. This results in anisotropy.



Anisotropy in crystalline solid

ii. Unit cell:

a. Crystalline solids are aggregates of many small, tiny crystals. These tiny crystals are called unit cells.
b. *A **unit cell** is a basic repeating structural unit of a crystalline solid.*

Q.6. *Distinguish between crystalline solids and amorphous solids. Give examples. OR
Distinguish between crystalline solids and amorphous solids. [Mar 13, 14, 17]

Ans:

	Property	Crystalline solids	Amorphous solids
i.	Definition	*A **crystalline solid** is a homogeneous solid in which the constituent particles (atoms, ions or molecules) are arranged in a definite repeating pattern.*	*The substances that appear like solids but do not have well developed perfectly ordered crystalline structure are called **amorphous** (no form) **solids**.*
ii.	Shape	They have definite characteristic geometrical shape due to the orderly regular long range arrangement of constituent particles.	They have irregular shape and lack characteristic geometrical shape due to the short range orderly arrangement of constituent particles.
iii.	Melting point	They have sharp and characteristic melting point.	They do not have sharp melting point. They gradually soften over a range of temperature.

iv.	Cleavage property	When cut with a sharp edged tool, they split into two pieces and the newly generated surfaces are plain and smooth.	When cut with a sharp edged tool, they cut into two pieces with irregular surfaces.
v.	Heat of fusion	They have a definite and characteristic heat of fusion.	They do not have definite heat of fusion.
vi.	Anisotropy	They are anisotropic, i.e., have different physical properties in different direction.	They are isotropic, i.e., have same physical properties in all directions.
vii.	Nature	They are true solids.	They are pseudo solids or super cooled liquids.
viii.	Order in arrangement of constituent particles	They have long range order.	They have only short range order.
eg.		Crystalline quartz, Copper, silver, iron, zinc sulphide, common salt, potassium nitrate, etc.	Glass, rubber, plastics, etc.

[Any four distinguishing points – ½ ***Mark each****]*

Note: The structure of the amorphous solids resembles that of liquids, due to which they exhibit the property of liquids such as fluidity. Thus, these amorphous solids tend to float very slowly under gravity. Thus, amorphous solid is considered as a pseudo solid or super cooled liquid.

***Q.7. Explain crystalline solids and amorphous solids.**

Ans: *Refer Q.6.*

***Q.8. What is a glass?**

Ans: i. Silicon dioxide is fused with sodium oxide and boron oxide to form an optically transparent material known as glass. The colour of glass is due to addition of a trace amount of transition metal oxide.

ii. Different types of glass are manufactured by changing its composition. Almost eight hundred different types of glasses are manufactured.

iii. Quartz glass is obtained from only silicon dioxide.

iv. Pyrex glass is obtained by fusing together 60 to 80% SiO_2, 10 to 25% B_2O_3 and remaining amount of Al_2O_3.

1.3 Classification of crystalline solids

Q.9. Name the different types of crystalline solids on the basis of different forces present in them.

Ans: Depending upon the nature of intermolecular forces present in the constituent particles, crystalline solids are classified into the following four classes:

i. Molecular solids ii. Ionic solids iii. Metallic solids iv. Covalent solids

Q.10. Explain the following terms:

***i. Molecular solids** **ii. Polar molecular solids**

iii. Non-polar molecular solids ***iv. Hydrogen bonded molecular solids**

***v. Ionic solids** ***vi. Metallic solids**

***vii. Covalent solids**

Ans: i. Molecular solids:

a. ***Molecular solids*** *are crystalline solids in which the constituent particles are molecules of the same compound.*

b. These are further subdivided into the following three categories:

1. Polar molecular solids
2. Non-polar molecular solids
3. Hydrogen bonded molecular solids

ii. Polar molecular solids:

a. In these crystalline solids, the constituent particles are covalently bonded polar molecules.

b. Polar molecules possess permanent dipole moment and in solid state they are held together by strong dipole-dipole interaction.

c. There is a separation of positive and negative charges because of the polar nature of molecule. Hence, the polar molecules arrange themselves in such a way that opposite charges of the neighbouring molecules are brought closer.

Characteristics:

a. They are soft.

b. They do not conduct electricity.

c. The melting points of the solids are relatively low, as the bonding is relatively weak.

eg. Solid SO_2, solid NH_3 and solid HCl.

iii. Non-polar molecular solids:

a. These crystalline solids comprise of either atoms or molecules formed by non-polar covalent bonds.

b. In these solids, the atoms or molecules are held by weak dispersion forces or London forces.

Characteristics:

a. They are soft.

b. They do not conduct electricity.

c. They have very low melting points (lower than polar molecular solids) and are usually in liquid or gaseous state at room temperature and pressure. Iodine (I_2) exists in solid state even at room temperature.

eg. Non-polar molecules like CO_2, H_2, Cl_2, CH_4 and weakly polar molecules like CO and other hydrocarbons form non-polar molecular solids at relatively lower temperatures.

iv. Hydrogen bonded molecular solids:

a. These crystalline solids consist of hydrogen atom covalently bonded to strongly electronegative atom like oxygen, nitrogen or fluorine.

b. In these molecules, the hydrogen atoms acquire additional positive charge and form additional bond with strongly electronegative atoms in the vicinity. This additional bond is called **hydrogen bond.**

Characteristics:

a. They do not conduct electricity.

b. These solids exist as liquids or gases at room temperature and pressure.

c. On cooling, the liquids solidify.

eg. H_2O, NH_3.

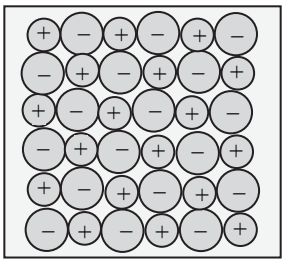
v. Ionic Solids:

a. ***Ionic solids*** *are crystalline salts formed by the three dimensional arrangement of cations and anions bound by electrostatic forces.*

b. Two types of electrostatic forces are present. One is the force of attraction between the ions carrying opposite charges. The other is the force of repulsion between the ions carrying same charges.

c. The arrangement of ions depends on following factors:

1. Sizes of the cation and anion
2. The charges on the ions
3. The ease of polarisability of the anion



Ionic solid

Characteristics:

a. Ionic solids are hard and brittle in nature. They have high melting and boiling points.

b. In ionic solids, constituent ions are held together by strong electrostatic forces of attraction and they are present in fixed position in crystal lattice. Therefore, they cannot move when an electric field is applied.

c. However, in the molten or fused state or when dissolved in water, the ions become free to move about and thereby conduct electricity.

d. When shearing force is applied, ionic crystals distort and the crystal structure is fractured.

eg. NaCl, ZnS, CuCl, etc.

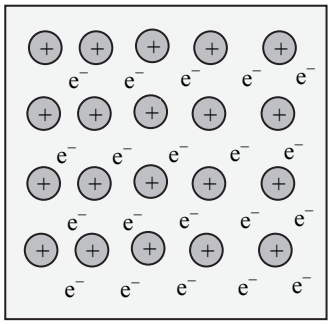
vi. Metallic solids:

a. ***Metallic solids*** *are the crystalline solids formed by atoms of the same metallic element.*

b. Metals are orderly collection of positive ions (called kernels) in the sea of delocalised electrons.

c. These electrons are mobile and are evenly spread throughout the crystal. Each metal atom contributes one or more electrons towards the sea of mobile electrons.

d. The force of attraction between positively charged metallic ion and negatively charged sea of delocalised electrons is called metallic bond. Metallic bonds are stronger than ionic and covalent bonds.



Metallic solid

Characteristics:

a. Metallic solids are good conductors of heat and electricity due to the presence of mobile electrons.

b. Metallic solids are tougher than other solids due to presence of strong metallic bonds.

c. The metallic solid contains several layers of the metallic ions arranged over one another. These layers can slide on other layers. Hence, the metallic solids are malleable and ductile.

d. Alloys can be formed by fusing the mixture of metals. Alloys show all properties of metals.

e. Metallic solids possess metallic lustre due to which the surface appears grey or silvery.

eg. The surface of gold appears yellow whereas the surface of copper appears reddish.

vii. Covalent or network solids:

a. ***Covalent solids*** *are those in which the constituent particles are non-metal atoms linked to the adjacent atoms by covalent bonds throughout the crystal.*

b. A network of covalent bonds is formed and the covalent solids are also called **giant solids**.

Characteristics:

a. Depending on the type of covalent bonding present between the atoms, covalent solids are either hard or brittle.

b. They have extremely high melting points.

c. Covalent solids are good conductors of electricity if mobile electrons are available, otherwise they are insulators.

eg. Three allotropic forms of carbon i.e. diamond, graphite and fullerene.

***Q.11. Write a note on: i. Diamond ii. Graphite iii. Fullerene**

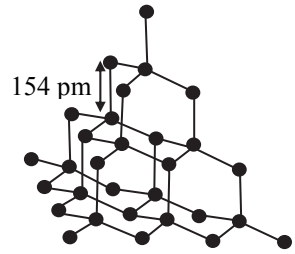
Ans: i. Diamond:

a. Diamond is an allotrope of carbon. It is used in jewellery and is the most precious crystal.

b. Covalent bonds between sp^3 hybridized carbon atoms continue in all directions to form a giant network.

c. Diamond is very strong and hard due to presence of strong covalent bonds.

d. It is the hardest material and has very high melting point (3550 °C).



Network Structure of Diamond

ii. Graphite:

a. Graphite is an allotrope of carbon in which each carbon atom is sp^2 hybridized and forms covalent bonds with three other sp^2 hybridised carbon atoms. This results in formation of interlinked six membered rings.

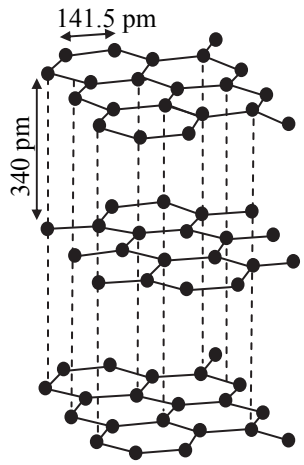
b. π bonds are formed between carbon atoms by utilizing half filled unhybridised $2p_z$ orbital on each carbon atom. Layers of carbon atoms are formed.

c. Electrons present in delocalized molecular orbitals can move freely and conduct electricity. Hence graphite is a good conductor of electricity.

d. Graphite is sufficiently hard due to presence of relatively stronger covalent bonds. The adjacent layers of carbon atoms are held together by weak van der Waal's forces of attraction.

e. The layers of carbon atoms in graphite can slide over other layers. Hence, graphite is used as lubricant for reducing friction.

f. It is used in ribbons used for printing in computers and typewriters. It is also used in lead pencils.



Layer Structure of Graphite

iii. Fullerene:

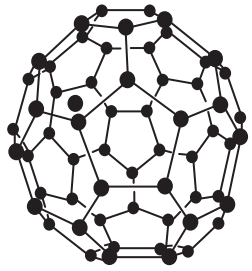
a. Fullerene is an allotrope of carbon. It is also called **Buckball** or **Buckminster fullerene**.

b. When a high power laser was focused on carbon, fullerene was formed. It has formula C_{60} and shape of a soccer ball (hollow sphere).

c. sp^2 hybridized carbon atoms occupy sixty equidistant places on this sphere. They form hexagons and pentagons.

d. Fullerenes are present in carbon soot.

e. Fullerene reacts with potassium to form $K_{35}C_{60}$. This compound is a superconductor of electricity at 18 K. It reacts with transition metal to form a catalyst.


The Structure of C_{60}, Buckminster-Fullerene

f. Tubes made from fullerene and graphite are called nanotubes. These are used as high strength materials, electric conductors, molecular sensors and semiconductors.

Q.12. What is the hybridisation of carbon atom in diamond and graphite? 0.1 mole of Buckminster fullerene contains how many kg of carbon? [Atomic mass of carbon = 12] [Oct 15]

Ans: Hybridisation of carbon atom in diamond is sp^3 and that in graphite is sp^2. ***[1 Mark]***

The chemical formula of Buckminster fullerene is C_{60}.

$\therefore$ 1 mole of C_{60} contains 60 moles of C.

0.1 mole of C_{60} will contain 6.0 moles of C. ***[½ Mark]***

Weight of C-atoms = Number of moles of C × atomic mass of C = 6.0 × 12 = 72.0 g = **0.072 kg**

$\therefore$ 0.1 mole of Buckminster fullerene contains **0.072 kg** of carbon. ***[½ Mark]***

Q.13. Classify the following solids into different types

***i.**	**Plastic**	***ii.**	**P_4 molecule**
***iii.**	**S_8 molecule**	***iv.**	**Iodine molecule**
***v.**	**Tetra phosphorus decoxide (P_4O_{10})**	***vi.**	**Ammonium phosphate $(NH_4)_3PO_4$**
***vii.**	**Brass**	***viii.**	**Rubidium**
***ix.**	**Graphite**	***x.**	**Diamond**
***xi.**	**NaCl**	***xii.**	**Silicon**
xiii.	**SiC**	**xiv.**	**LiBr**

Ans: i. Amorphous solid – Plastic

ii. Molecular solids – P_4 molecule, S_8 molecule, Iodine molecule, Tetra phosphorus decoxide

iii. Ionic solids – Ammonium phosphate, NaCl, LiBr

iv. Metallic solids – Brass, Rubidium

v. Covalent or Network solids – Graphite, Diamond, Silicon, SiC.