Chapter#6

Solid State of Matter

QI. Why the solids have definite shape.

Ans. In the solid state a substance has definite shape. Due to maximum inter- molecular forces existing between the molecules, it is little affected by changes in temperature and pressure.

Q2. Define super cooled liquid and crystals.

Ans: Super cooled liquid:

Glasses and amorphous materials where there is no orderly arrangement of atoms. Such solids are called supercooled liquids.

Crystals:

The materials which have complete regularity in their atomic and molecular structures are called crystals.

Q3. Define inter-ionic inter-molecular and inter-atomic forces.

The forces exist between the ions, atoms or molecules which keep them together in a crystalline solid. This gives a definite shape, rigidity and mechanical strength to the solids. Such forces are called inter-ionic inter-molecular and inter- atomic forces. These forces are of different types in different solids.

Q4. Give the postulates of kinetic molecular theory of solids.

Ans: Kinetic Molecular Interpretation of Solids:

Kinetically the crystalline solids can be interpreted as follows:

i. Attractive Forces:

The attractive forces among the molecules are maximum due to closest packing of the molecules.

ii. Rigidity:

The molecules in solids are closely packed. Therefore, their movement 1s restricted (limited).As a result, they are rigid in nature. The molecules cannot move due to maximum attractive forces between them. However, molecules vibrate about their mean position.

iii. High density:

The molecules of a crystalline solid are closely packed. As a result, molecules of solid occupy minimum volume. As density is inversely proportional volume, therefore high density will be observed due to the minimum volume existing between the molecules.

iv. Collision:

As there is no translational movement of particles in a solid, therefore, there are no collisions among the molecules.

vi. Kinetic Energy:

There is negligible translational and rotational Kinetic Energy in solid molecules. However, they can vibrate about their mean positions. So, molecules of solid possess only vibrational K.E.

vii. Geometric Shape:

the crystalline solids have definite distinctive geometrical shape. It is due to the definite and orderly arrangement of atoms ions or molecules in three-dimensional shape.

Q5. Give the general properties of Solids.

Ans: a. Diffusion b. Compression (effect of pressure)

a. Diffusion:

The diffusion depends upon velocity of molecules. As the movement of the molecules is very slow in solids, therefore, the diffusion will be minimum.

b. Compression (Effect of Pressure):

There is practically no effect of pressure on solids as the molecules are very closely packed together.

Compressibility factor:

The effect of pressure on solids is expressed in terms of compressibility. This is defined as, "The decrease in volume per unit volume when the pressure is increased by one atmosphere."

Q6. Define melting and how solid converts into liquid?

Ans: "The temperature at which a solid, changes into the liquid form is called Melting Point of the solid."

When a solid is heated, its geometric shape changes until at a certain temperature, it changes into the liquid form.

Q7. Explain the motion of molecules in solids in terms of kinetic molecular theory.

Ans: Motion of Molecules:

There is no translational and rotational motion due to presence of strong intermolecular forces in the crystalline solid, as the molecules are already closely packed together. However, the molecules. can vibrate about their mean position.

Q8. Why the molecules of solids are closely packed?

Ans: Inter molecular Forces:

In solids, the intermolecular forces are maximum between the particles. These are held together in fixed positions by strong attractive force. They can vibrate only about their fixed positions. Due to intermolecular forces the molecules of solids are closely packed.

Q9. Define the following with the help of examples.

i. Geometrical Shapes of solids.

ii. Melting Points of solids.

Ans: i. Geometrical shapes of solids.

Almost all the crystalline solids have a definite, distinctive geometrical shape because the molecules have fixed positions. Therefore, they cannot move appreciably. Moreover, the solids have orderly arrangement of atoms, ions or molecules in three-dimensional space e.g. NaCl is cubic in nature.

ii. Melting Points of solid:

Pure crystalline solids have sharp melting point. When a solid Is heated, the atoms, ions or molecules present in a solid start vibrating at higher frequency and transfer their kinetic energy throughout the solid. At the fretting point. their vibrational energies become so · much that they leave their fixed positions simultaneously and become a liquid.

Q10. Define the following with the help of examples.

i. Cleavage Planes:

ii. Habit of a Crystal:

Ans: Cleavage Planes:

The breaking up of larger crystals into smaller one with identical size and shape is called Cleavage.
The plane which contains the direction of cleavage is called cleavage plane.
A crystalline solid contains atoms, ions or molecules closely packed to each other. When some external pressure is applied to it, it changes into small crystals of the same size and shape as that of the original one.

Example:

i. $NiSO_4.6H_2O$ crystal can be cleaved easily provided cleavage is parallel to the surfaces.

ii. The cleavage of $NaNO_3$ and $(CH_3COO)_2Ca$ is easy. It is parallel to the surface.

iii. Mica can be cut easily parallel to the layers.

2. Habit of a Crystal:

The shape of a crystal in which it usually grows is called habit of a crystal.

Example:

Cubic crystals of sodium chloride are obtained from its aqueous solution. If the conditions are changed, the shape of crystal also changes. If 10% urea is present in aqueous solution of sodium chloride, octahedral crystals of sodium chloride are obtained.

Q11. Define the following with the help of examples.

i. Crystal Growth:

ii. Anisotropy:

Ans: Crystal Growth:

The crystal growth takes place when the heated solution of a substance is allowed to cool in a slow manner. The outer appearance or shape of the crystals depends on how it is prepared and under what condition.

Example:

A crystal with cubic structure may develop into a cube, a flat plate or a long needle like structure, under different conditions. The size of a crystal is controlled by its rate of growth. A slowly growing crystal has large size.

ii. Anisotropy:

A substance which shows different intensity of properties in different directions is called **anisotropic** and this property as anisotropy.

Explanation:

A crystalline substance is a built up of small units all having the same geometrical form. But although a crystal is homogeneous, it possesses different

properties in different directions. It is because crystal has different arrangements in different directions.

Examples:

i. Graphite exists in the form of layers, so it is conductor in one direction, parallel to layers but insulator across the layers.

ii. Refractive index, co-efficient of thermal expansion, electrical and thermal conductivities give different intensity of properties in different directions.

iii. Mica can be cut parallel to the layers but difficult to cut in some other plane.

Q12. Differentiate between isomorphism and polymorphism explain them with the help of example.

Ans: Isomorphism:

There are certain substances which are similar in shape. Different crystalline substances having the same crystalline shapes are called isomorphs, and this phenomenon is called Isomorphism.

Examples:

(i)$ZnSO_4$ and Nismo4 are isomorphism because both have the same crystalline shape, i.e. orthorhombic. isomorphs have same atomic ratio.

(ii) Ag_2SO_4 and Na_2SO_4 are hexagonal. (Atomic ratio=2:1:4)

(iii) $CaCO_3$an, $NaNO_3$ are Rhombohedral. (Atomic ratio=1:1:3)

Polymorphism:

The substance existing in more than one crystalline form is called Polymorphous substance and the phenomena as Polymorphism.

Examples:

1. NaCl is found in cubic and octahedral forms.

2. Cacao3 is trigonal when present as calcite and orthorhombic when present as aragonite.

3. Half is orthorhombic (yellow form) and tetragonal in red form.

Q13. Define the following with the help of examples.

i. Allotropy

ii. Transition Temperature

Ans: i. Allotropy (allotrope - Greek-allows (other), tropia (turning):(forms):

An element may exist in different crystalline forms. These forms are called allotropes and this phenomenon are called allotropy.

e.g. (i) C (as diamond) _________ in cubic form

(ii) C (as graphite)_____________ in hexagonal form

ii. Transition Temperature:

in cubic form. in hexagonal form.

The temperature at which more than one forms of a given substance can exist in equilibrium is called transition temperature. Above and below this temperature only one can exist

No	Substance	Crystal e form	Transition temperature
1	Tin (grey) Tin (white)	Orthorhombic Tetragonal	18°C
2	Sulphur	Monoclinic Ortho rhombic	95.6 °C
3	**KNO**	Orthorhombic Rhombohedral	128.5 °C

Q14. Explain and elaborate the allotropes of oxygen also draw the diagram how ozone protects earth from ultraviolet radiations.

Ans: Allotropy:

It is the ability of an element to exist in more than one form in the same crystalline state.

Allotropes of Oxygen:

Dioxygen (O_2) and Trioxygen (O_3 or. Zone) are considered to be the two forms of oxygen obtained by the absorption of certain amount of heat from atmosphere.

$$3O_2 \longrightarrow 2O_3 \quad \Delta H = 142 \text{ kg mole}^{-1} \text{ of } O_3$$

Explanation to form Allotropes:

Certain am9unt of heat is absorbed by dioxygen to form trioxygen. I.e. ozone, the ultraviolet (U.V) light in the form of energy brings about photo-chemical reactions. These reactions can convert oxygen (O_2) to ozone (O_3). See the conversion is spontaneous and one directional, therefore, 1t is called monotropic (moving in one direction). It has been found that the maximum concentration of ozone is (about 10 ppm) (parts per million), occurs 24-30 Km from the surface of the earth. Thus, oxygen has two apotropaic forms which are irreversible.

Structures:

Oxygen molecule O = O has a sigma (o) bond and a Pi-bond (7t) between the two atoms. In ozone molecule, there is an angle of 117° between the bonds as indicated.

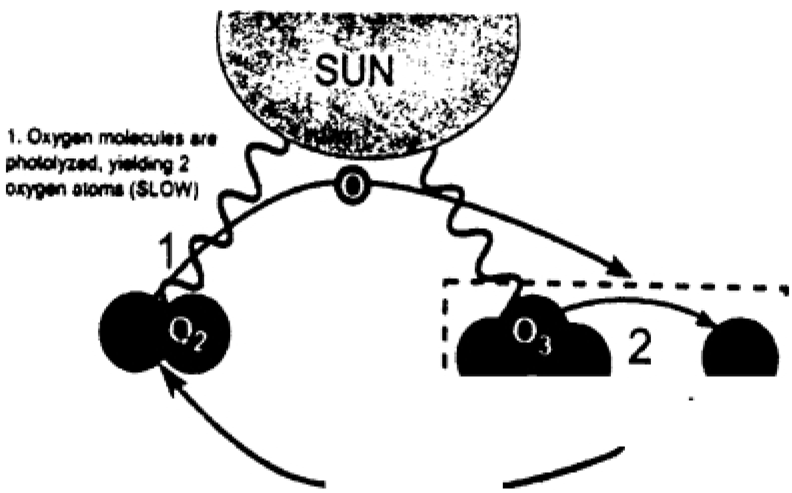
The ozone layer in the stratosphere (one ot the toyers ot atmosphere) is shown below.

The allotropes of oxygen are of two types:

i. Oxygen (O_2)

ii. Ozone (O_3)

Ozone has a characteristic smell, in concentration above 1000 ppm, it is damaging the health.



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QI5. Explain and elaborate the allotropes of Sulphur.

Ans: Allotropes of Sulphur:

Allotropes of sulphur are of four types:

- Rhombic sulphur
- Monoclinic sulphur
- Amorphous sulphur
- Plastic Sulphur

Sulphur exists in four allotropic forms which are:

i. Rhombic Sulphur(α-Sulphur}:

It is bright yellow in color and stable below 96°C. It is crystalline in nature and made up of S_8 molecules.

ii. Monoclinic Sulphur (β-Sulphur):

It is a crystalline solid and stable between 96°C and 119°C. It is converted to Rhombic Sulphur at room temperature.

iii. Amorphous Sulphur (γ-Sulphur):

It has irregular crystalline shape which may be called as Amorphous. It is not found in the free state. It may be prepared by passing H_2S gas through water 'for a long time. The saturated solution of H_2S so obtained is exposed to air. Amorphous Sulphur so produced has 'almost white color.

$$2H_2O + O_2 \quad \geq 2H_2O \quad + 2S \quad \text{(amorphous solid)}$$

iv. **Plastic Sulphur:**

It is a super cooled form of Sulphur. If yellow Sulphur is heated to boiling and poured into liquid water. it will roll up and produce yellow ribbons resembling plastic like material. It is not considered to be a true allotrope of Sulphur because it is soft and elastic in nature and insoluble in H_2S.

Q16. Define and explain the crystal lattice.

Ans: Crystal Lattice:

An array of points representing the arrangement of particles (atoms, ions or molecules) in three dimensional spaces is called crystal lattice.

Explanation:

The regular arrangement of the particles of a crystalline solid at the microscopic level produces characteristic shapes of crystals. The position of the particles in a crystalline solid is represented by a Lattice.

Dependence:

The external shape of a crystal depends upon the conditions of crystallization. It may be different in · one form or the other e.g. NaCl is cubic at ordinary conditions but octahedral in the presence of urea as impurity. But the internal structure is the same with basic structural unit. This unit describes the pattern by which the particles are arranged in a crystal.

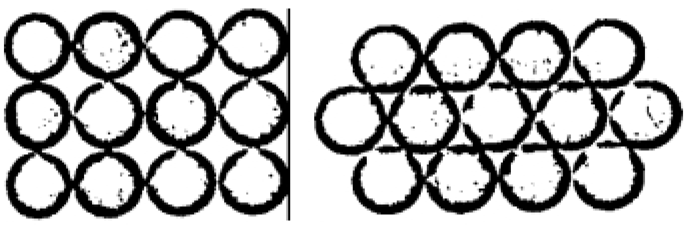
A lattice is of three types:

- Three-dimensional lattice.
- Two-dimensional lattice.
- One dimensional lattice.

Q17. How many types of packing arrangements are present in **solids? Also differentiate between hexagonal close-packing and cubic closed packing.**

Ans: Types of Packing Arrangements:

The structure of metals can be explained when the atoms are packed together. The atoms in metals are considered as spheres of identical size. The closest packing is the most efficient arrangement of spheres of identical size and to fill available spaces. In which each sphere



touches six neighboring spheres (in green) as shown in (Fig).

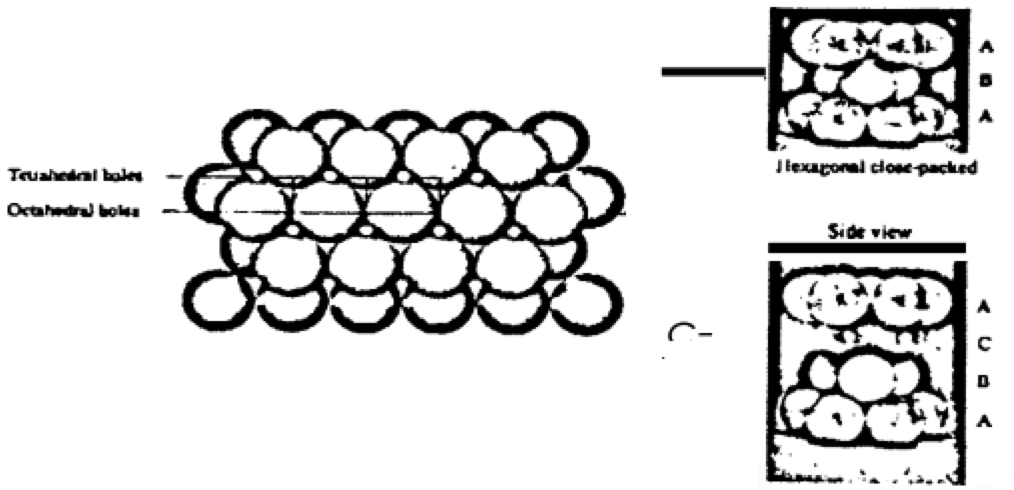
(a) An open packing **(b) Close packing**

Packing spheres in two dimensions

(a) Close Packing:

This layer is shown in figure as the bottom layer (layer A). When we place spheres in the second layer (layer 8) each added sphere will rest in the hollow above a void or hole in the bottom layer. The spheres of the second layer will produce two types of voids. (i) a tetrahedral hole which falls above a sphere in the bottom layer. (ii) an octahedral hole, it falls above **a** void in the bottom layer.

Sidelock



Close packing of spheres in three dimensions

In adding a third layer of spheres (layer C), there are two possibilities.

Hexagonal close packing:

If tetrahedral holes are covered, the third layer is identical to the bottom layer.

This are argument is called hexagonal close-packing (hep) arrangement. This pattern of arrangement is usually written as ABAB or 1212.

Cubic closed packing:

In contrast, if we cover the octahedral holes, the third layer is not identical with the bottom layer. This is called the cubic closed packing (ccp) arrangement. It is usually written as ABCABC or123123.

Q18. Explain the three factors that affect the shape of an ionic solid.

Ans: The Factors that Affect the Shape of an Ionic Solid:

There are three factors which affect the shape of an ionic crystal.

1. Electrostatic Forces of Attractions:

The ionic solids are composed of cations and anions. They are held together through strong electrostatic forces of attraction forming a well-defined geometric shape e.g. formation of NaCl.

Sodium loses one electron to be converted to $Na^{\cdot 1}$ ions.

$Na - 1e^{-1} \rightarrow Na^{+1}$ (A cation is formed)

$Cl + 1e^{-1} \rightarrow Cl^{-1}$ (A anion is formed)

These ions combine together due to strong electrostatic force.

$Na^{+1} + Cl^{-1} \rightarrow NaCl$ L\H=-787kgMole^{-1}

It is an exothermic reaction. To form a crystal lattice of NaCl, each Na^{+1} ion is surrounded by 6 Cl^{-1} ions and each Cl^{-1} ion is surrounded by 6 Na^{+1} result a cubic structure of ionic solid of NaCl is formed.

2. Radius Ratio:

The structure and shape of an ionic solid depends upon the radius ratio of cations and anions.

e.g. NaCl and CsF have the different geometry because the radius ratio is different in both the cases.

Radius Ratio= $\frac{\textit{Radius of cation}}{\text{Radius of anion}}$

The structure and limiting Radius Ratio of certain crystalline substances are given below

No	Shape of ionic solid	Limiting Radius Radio $r^{\bullet 1} / r^{\cdot 1}$
1	Body centered cubic	0.732 and above
2	Octahedral	0.414 to 0.732
3	Tetrahedral	0.22 to 0.414
4	Triangular	0.15 to 0.22

Thus, knowledge of Radius Ratio consisting of cations and anions can give a good idea of the shape of crystal.

Cubic structure:

And ionic compound with Radius Ratio greater than 0.732 will have cubic structure e.g. NaCl.

Octahedral structure:

The radius ratio of an ionic compound with octahedral structure should be in between 0.414 and 0.732.

Tetrahedral structure:

A tetrahedral structure is formed if the radius ratio is in between 0.22 to 0.414.

The Radius Ratio of the following ionic crystals are:

1. NaCl = 0.522 - Octahedral arrangement or cubic structure.

2. CsCl = 0.93 - Body centred cubic arrangement.

3. ZnS=0.4 Tetrahedral arrangement.

3. Poor Conductivity:

The ionic crystals do not conduct electricity in the solid state. The shape of the crystals remains as such. However, when a solvent (H_2O) is added to the ionic solid.

Example:

NaCl, the crystal lattice is broken and the ionic solid changes into cation and anion. This is because the crystal lattice is broken due to high dielectric constant of water in other words the shape of the crystal 1s ruptured.

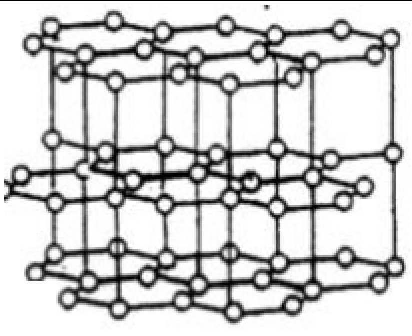
$NaCl \xrightarrow{water} Na^{-1} + Cl^{-1}$

Thus, the ions are solvated.

Q19. Differentiate between ionic and covalent crystals.

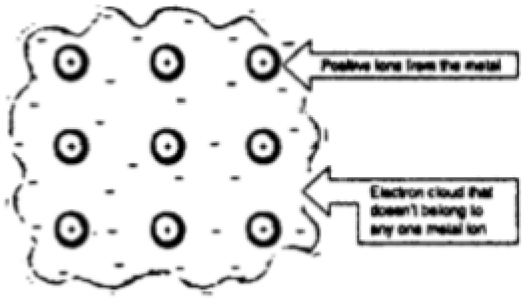
<u>Ans; Comparison of Ionic and Coeval,</u>

Difference Between	
Ionic Crystals Solid	**Covalent Crystals**
An ionic crystal is formed due to the transference of electron to the other e.g NaCl formation. The cations and anions	The crystalline solids in which atoms of similar or dissimilar elements are held together in a network of single bond are known as covalent crystals e.g. diamond etc.

formed are held together through strong electrostatic forces of attractions.	
2. Formation of NaCl Na - e^{-1} → Na^{-1} (cation) Cl + e^{-1} → Cl^{-1} (anion) Na^{-1} + Cl^{-1} → NaCl	2. Covalent crystals are of two types: (i) When covalent bonds give giant molecules e.g. diamond, SiC (Silicon carbide). (ii)When atoms Join together by sharing of electrons. As a result, separate layers are formed e.g. graphite.
 Sodium Chloride crystal	 Graphite crystal
3. they are non-conductors of electricity in the solid state. However, they conduct electricity in the molten or solution form.	3. they are bad conductors of electricity with the exception of graphite.
4. they have definite geometric shape.	4. they have definite shape and oriented in three directions with network structure.
5. they are non-dimensional in nature.	5. they have open structures due to valences of atoms directed in definite directions.
6. they do not exist in the form of molecules due to their ionic nature	They may be called as molecules due to their covalent nature. S8. P4, ice

Q20. Deference between molecular crystals and metallic solids.

Ans: Comparison of molecular crystals and metallic solids:

Molecular Crystals	Metallic Solids
1. Those solid substances In which the particles forming the solids are polar or non-polar molecules are called molecular crystals e.g. ice etc.	**1.** The crystalline solid in which metal atoms are held together by metallic bonds are known as metallic solids e.g. Na, Cu etc.
2. Two types of intermolecular forces hold them together. (i) Dipole-Dipole interactions (Polar) e.g. Ice, Sugar. (ii) Van der Waal's forces (Non-Polar) e.g.12 ,Sa.Retc.	**2.** In metallic crystals, electron gas theory is involved. An electron sea surrounding cations 
3. They are bad conductors ofelectricity because they have not freed electrons.	**3.** They are good conductors of electricity due to presence of free electrons.
4. They are not malleable andductile.	**7.** They may be malleable and ductile.

ACTIVITY FOR STUDENTS

Students have to perform the experiments by themselves to get pure NaCl crystals from a saturated solution of impure NaCl solution.

Solution: Sea water contains 2.7 to 2.9% by mass of the salt. Sodium Chloride is obtained by evaporation of sea water but due to the presence of impurities like CaCl2 and MgCl2 it has deliquescent nature. It is purified by passing HCl gas through the impure saturated solution of NaCl and due to common ion effect, pure NaCl gets precipitated. 28% NaCl solution is called brine.