CHAPTER # 6
STATES OF MATTER III
SOLIDS

Q1. 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 super-cooled 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 is 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 to 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.

v. 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.

vi. 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 (β):

The effect of pressure on solids is expressed in terms of compressibility (β). 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: Intermolecular 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 melting 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: i. 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.

ii. 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: i. 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 $NiSO_4$ 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) $CaCO_3$ and $NaNO_3$ 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. $CaCO_3$ is trigonal when present as calcite and orthorhombic when present as aragonite.

3. HgI_2 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-allos (other), tropia (turning) : (forms):

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

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

(ii) C (as graphite) ________ in hexagonal form.

ii. Transition Temperature:

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 polymorph or allotrope can exist.

No	Substance	Crystalline form	Transition temperature
1	Tin (grey) Tin (white)	Orthorhombic Tetragonal	18 °C
2	Sulphur	Monoclinic Ortho rhombic	95.6 °C
3	KNO_3	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-Ozone) are considered to be the two forms of oxygen obtained by the absorption of certain amount of heat from atmosphere.

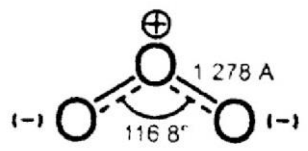
$$3O_2 \rightarrow 2O_3, \quad \Delta H = 142 \text{ kg mole}^{-1} \text{ of } O_3$$

Explanation to form Allotropes:

Certain amount 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). Since the conversion is spontaneous and one directional, therefore, it 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 allotropic forms which are irreversible.

Structures:

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



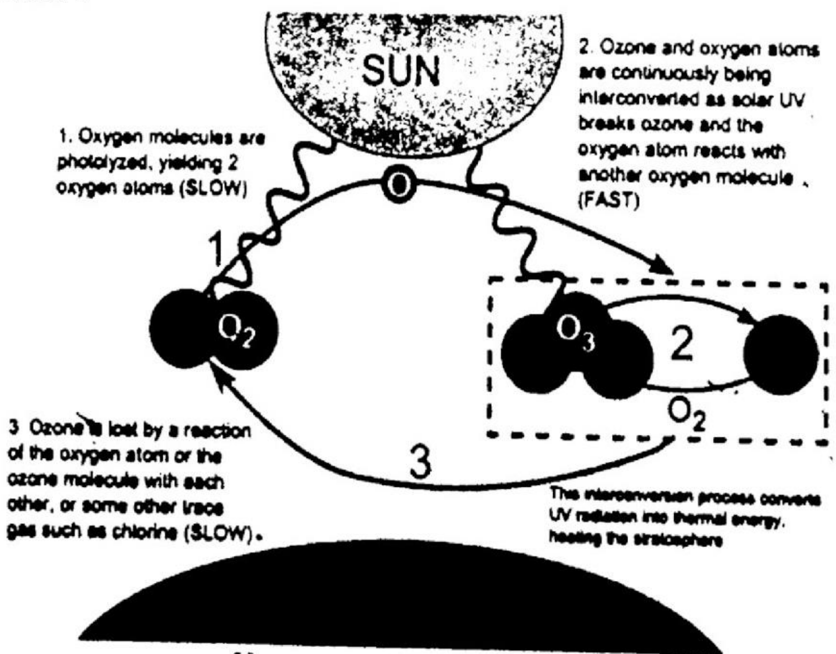
The ozone layer in the stratosphere (one of the layer of atmosphere) is shown below.

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.



How ozone protects earth

Q15. 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 colour 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 (δ-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 colour.

$$2H_2S_{(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)} + 2S_{(s)} \text{ (amorphous solid)}$$

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 crystallisation. 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.

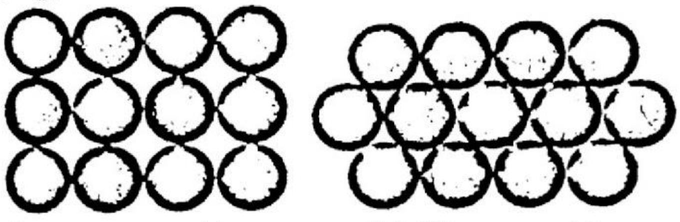
A lattice is of three types:

- 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 neighbouring spheres (in green) as shown in (Fig).

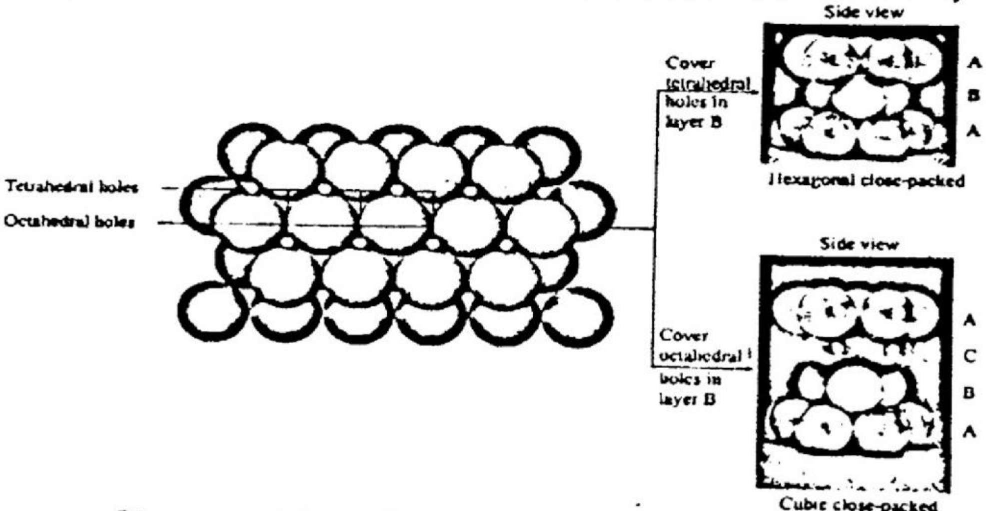


(a) An open packing (b) Close packing

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 B) 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.



Close-packing of spheres in three dimension

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

(b) Hexagonal close-packing:

If tetrahedral holes are covered, the third layer is identical to the bottom layer. This arrangement is called hexagonal close-packing (hcp) arrangement. This pattern of arrangement is usually written as ABAB or 1212.

(c) 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 or 123123.

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^{+1} ions.

$$\underset{(2,8,1)}{Na} - 1e^{-1} \rightarrow \underset{(2,8)}{Na^{+1}} \quad \text{(A cation is fomed)}$$

$$\underset{(2,8,7)}{Cl} + 1e^{-1} \rightarrow \underset{(2,8,8)}{Cl^{-1}} \quad \text{(A anion is fomed)}$$

These ions combine together due to strong electrostatic force.

$$Na^{+1} + Cl^{-1} \rightarrow NaCl \qquad \Delta H = -787 \text{ kg Mole}^{-1}$$

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 6Na^{+1} ions. As a 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.

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

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

No	Shape of ionic solid	Limiting Radius Radio r^{+1}/r^{-1}
1	Body centred 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 = 0.40 – 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:

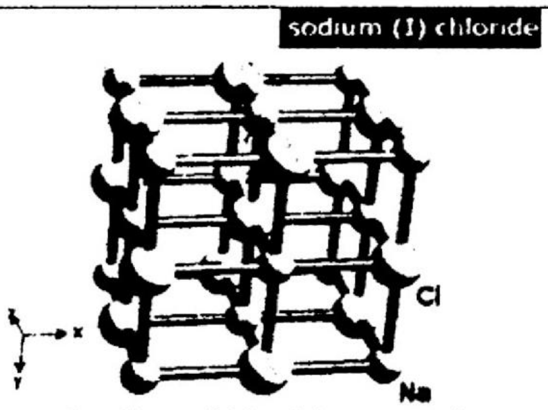
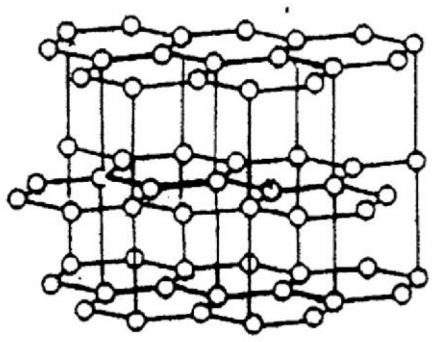
NaCl, the crystal lattice is broken and the ionic solid changes into cation and anion. This is because the crystal lattice is broken due to high dielectric constant of water. In other words the shape of the crystal is ruptured.

$$NaCl_{(s)} \xrightarrow{water} Na^{+1}_{(aq)} + Cl^{-1}_{(aq)}$$

Thus the ions are solvated.

Q19. Differentiate between ionic and covalent crystals.

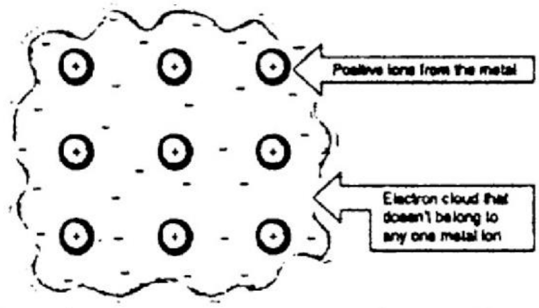
Ans: Comparison of Ionic and Covalent Crystals:

Difference Between	
Ionic Crystals (Solid)	**Covalent Crystals**
1. An ionic crystal is formed due to the transference of electrons to the other e.g. NaCl formation. The cations and anions formed are held together through strong electrostatic forces of attractions.	**1.** 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.
2. Formation of NaCl $\underset{(2,8,1)}{Na} - e^{-1} \rightarrow \underset{(2,8)}{Na^{+1}}$ (cation) $\underset{(2,8,7)}{Cl} + e^{-1} \rightarrow \underset{(2,8,8)}{Cl^{-1}}$ (anion) $Na^{+1} + Cl^{-1} \rightarrow NaCl$	**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 a network structure.
5. They are non-directional in nature.	**5.** They have open structures due to the valences of atoms directed in definite directions.
6. They do not exist in the form of molecules due to their ionic nature.	**6.** They may be called as molecules due to their covalent nature. e.g. S_8, P_4, 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. I_2, S_8, P_4 etc.	**2.** In metallic crystals, electron gas theory is involved.  An electron sea surrounding cations
3. They are bad conductors of electricity because they have not free electrons.	**3.** They are good conductors of electricity due to presence of free electrons.
4. They are not malleable and ductile.	**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 $CaCl_2$ and $MgCl_2$ it has deliquescens 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.

EXERCISE

MULTIPLE CHOICE QUESTIONS

1. Choose the correct answer (MCQS).

i. The temperature at which two or more than two types of crystals exist in equilibrium is called.

(a) Melting Point (b) Transition temperature
(c) Eutectic temperature (d) Boiling point.

ii. The solids in which atoms, ions or molecules have random non-repetitive three dimensional arrangements are termed as:

(a) Crystals (b) Glasses (c) Alloys (d) Amalgams

iii. The nature of bond in diamond is

(a) Ionic (b) Covalent (c) Molecular (d) Metallic

iv. Crystal Lattice is an arrangement of particles in

(a) One dimension (b) Two dimensions
(c) Three dimensions (d) Four dimensions

v. Lattice energy is also called

(a) Crystal energy (b) Ionization energy
(c) Energy of affinity (d) Bond Energy

vi. When gaseous ions are allowed to form a crystal, energy

(a) is evolved
(b) is absorbed
(c) is sometimes absorbed and sometimes released
(d) has no effect

vii. NaF and MgO have both atomic ratio 1:1 in their crystals such property is

(a) Polymorphism (b) Isomorphism
(c) Isotropy (d) Allotropy

viii. Electric current can pass through graphite in one direction but not through other direction of crystal such a property is called

(a) Allotropy (b) Anisotropy
(c) Isomorphism (d) Polymorphism

ix. Iron acts as an electrical conductor due to

(a) Electron cloud (b) Free protons
(c) Free neutrons (d) Free ions

x. A crystal of the purple compound Potassium Permanganate placed at the bottom of a beaker of water and the beaker left until there is no further change. What will be observed?

(a) A uniformly purple solution
(b) A colourless liquid with the purple crystal unchanged.

(c) A purple layer below a colourless layer
(d) A colourless layer below a purple layer.
(e) A deep purple layer below a pale purple layer.

xi. Which of the following method is most suitable for obtaining a pure, dry sample of NaCl from a mixture of NaCl and sand?
(a) Shake the mixture with water. Filter and dry the substances on the filter paper.
(b) Shake the mixture with water. Filter and evaporate the filtrate.
(c) Shake the mixture with water and distil off the sand.
(d) Heat the mixture gently and collect the substances which boil off.

xii. What method could be used to obtain copper from mixture of pondered copper and sodium chloride?
(a) Heating the mixture.
(b) Fractional distillation of the mixture.
(c) Passing an electric current through the mixture.
(d) Adding excess water to the mixture and filtering

xiii. A bottle of copper oxide has been contaminated with some sodium chloride. How can the NaCl be removed from the copper oxide?
(a) Place the mixture in a separating funnel.
(b) Heat the mixture and allow it to cool.
(c) Add water to the mixture and filter.
(d) Add aqueous Ag NO_3 to the mixture.

xiv. Lead and zinc can be separated by distillation because they have different.
(a) Boiling point (b) Densities
(c) Mass numbers (d) Reactivities.

xv. An insoluble solid was dropped into a measuring cylinder containing 50 cm^3 of water. What will be the effect on volume of water?
(a) 15 cm^3 (b) 17 cm^3 (c) 50 cm^3 (d) 65 cm^3

xvi. The results of the accurate weighing of some crystals are as follows:
Mass of weighing bottle empty = 25.652 gm
Mass of weighing bottle + crystals = 26.541 gm
What is the mass of the crystals?
(a) 0.111 gm (b) 0.889 gm (c) 1.111 gm (d) 1.889 gm

xvii. The spontaneous mixing of particles is called:
(a) Evaporation (b) Sublimation
(c) Diffusion (d) Boiling

Answers

i. b	ii. b	iii. b	iv. c	v. a	vi. a	vii. b
viii. b	ix. a	x. a	xi. b	xii. d	xiii. c	xiv. a
xv. d	xvi. b	xvii. c				

2. **Write brief and short answers to the following:**

i. **Indicate the effect of pressure and temperature on solids.**

Ans. Compression (Effect of Pressure):

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

Effect of temperature:

The solids expand when heated i.e. their volume increases. This is because the increase of temperature decreases the intermolecular attractive forces. As a result, the volume increases.

ii. **Differentiate between amorphous solids and crystalline solids.**

Ans: Differences between Amorphous and Crystalline Solids:

Crystalline Solids	Amorphous Solids
i. In the crystalline state, the crystals possess definite geometrical structure e.g. NaCl is cubic in nature.	**i.** In the amorphous state the solids do not have definite geometrical structure e.g. glass.
ii. There is a complete regularity of arrangement of atoms, ions or molecules in a crystalline solid	**ii.** The atoms, ions or molecules are not arranged in a regular manner in amorphous solids.
iii. The crystalline substance has a sharp Melting Point.	**iii.** Amorphous solid do not have sharp Melting Point and gradually soften on heating. They may be called as super-cooled liquids e.g. glass, plastic etc.
iv. In a crystalline substance, water molecules are a part of crystal e.g. $FeSO_4.7H_2O$, $CuSO_4.5H_2O$ etc.	**iv.** The amorphous substances have no such water of crystallization.
v. The crystalline substances do not soften on heating.	**v.** The amorphous solid is a solid which soften on heating ultimately they become mobile over a wide range of temperatures.
vi. Three dimensional arrangement of particles.	**vi.** No three dimensional arrangement of particles.
vii. They have definite heat of fusion.	**vii.** They do not have definite heat of fusion.
viii. Examples: NaCl, Sugar, Ice, Diamond etc.	**viii. Examples:** Rubber. Plastic. Glue, Glass, Paper etc.

iii. **Write a note on Anisotropy.**

Ans. 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.

iv. What is symmetry, symmetry operations, planes of symmetry and symmetry elements?

Ans. Symmetry:

The repetition of angles faces and edges when a crystal is rotated about 360° angle along its axis is called symmetry.

Symmetry elements:

The rotational operation which brings the crystals into its original appearance is called symmetry of element.

Example:

If a regular cube is rotated about its axis at an angle of 90°, the identical face is obtained.

Symmetry operation:

On rotating to 180°, a second identical face and at 360°, four identical faces are observed. An axis containing four identical faces is called four-fold axis of rotation. The process through which the crystal was brought back to its identical position is called symmetry operation.

Plane of symmetry:

An imaginary plane passing through a crystal that divides a crystal into two identical halves is called plane of symmetry.

The symmetry elements that occur in a crystal are plane of symmetry, centre of symmetry, axis of symmetry and angle of symmetry.

v. Write a note on transition temperature?

Ans. Transition Temperature:

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 polymorph or allotrope can exist.

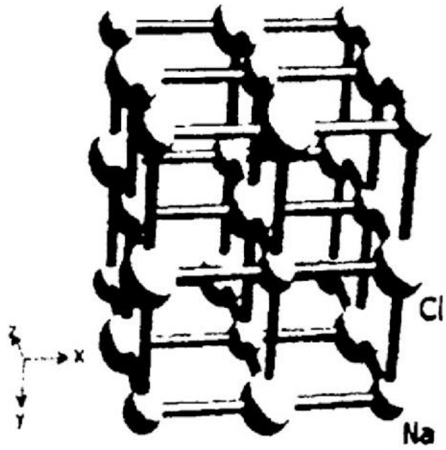
No	Substance	Crystalline form	Transition temperature
1	Tin (grey) Tin (white)	Orthorhombic Tetragonal	18 °C
2	Sulphur	Monoclinic Ortho rhombic	95.6 °C
3	KNO_3	Orthorhombic Rhombohedral	128.5 °C

vi. What do you know by a Unit Cell?

Ans. The smallest unit of volume of a crystal, which shows all the properties of its pattern, is called a unit cell.

We can explain significance of unit cell to the shape of crystal using NaCl as an example.

sodium (I) chloride



This is a basic structural unit of a crystal. The systematic arrangement of atoms in a crystal is called lattice. It represents the structure of any substance. Primarily a crystal depends upon,

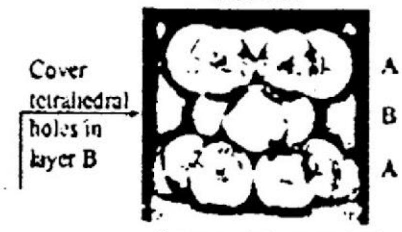
- **Shape of the unit cell.**
- **Contents of the unit cell.**

  The atoms, molecules or ions in a crystal are repeated in a systematic manner.

vii. What do you know about Hexagonal Closest Packing?

Ans. If tetrahedral holes are covered, the third layer is identical to the bottom layer. This arrangement is called hexagonal close-packing (hcp) arrangement. This pattern of arrangement is usually written as ABAB or 1212.

Side view



Hexagonal close-packed

viii. What do you know about Lattice Energy?

Ans. Lattice Energy:

1. The amount of heat or energy released when gaseous ions of opposite charges combine to give one mole of a crystalline ionic compound is called **lattice energy**

Example:

$$Na^{+1}_{(g)} + Cl^{-1}_{(g)} \rightarrow NaCl_{(s)} \Delta H = -787 \text{ kg mole}^{-1}$$

2. The amount of energy required to break one mole crystal lattice into its gaseous ions is called **lattice energy**.

e.g. $NaCl_{(s)} \rightarrow Na^{+}_{(g)} + Cl^{-}_{(g)} \quad \Delta H = +787 \text{ kg mole}^{-1}$

Dependence:

The lattice energy of the ions depends upon their size and charge of the ions. Lattice energy decreases with the increase in the size of the ions, (whether cations or anions) the packing of oppositely charged ions become less and less tight. Lattice energy increases with increasing ionic charge

ix. Write a note on Dispersion Effect.

Ans. Dispersion Effect:

The dispersion effect of electronic cloud can be explained in terms polarizability.

Polarizability:

The polarizability of an atom or molecule is a measure of the ease with which electron charge density is distorted. Large atoms have more electrons and larger electron cloud than small atoms.

In large atoms, the outer electrons are more loosely bound, they can shift towards another atom more readily than the more tightly bounded electrons in small atoms. This means polarizability increases with increased atomic and molecular size.

Examples:

For example among halogens, the first member, F_2 is a gas at room temperature. The second member, Cl_2 is also a gas but it is more easily liquefied than F_2. Bromine is a liquid and iodine is solid at room temperature. Because large molecules are easily polarisable, the intermolecular forces between them are strong enough to form liquids or solids.

x. There are some changes in matter.

(i) Solids → Liquid
(ii) Liquid → Gas
(iii) Gas → Liquid
(iv) Liquid → Solid

Which of the changes require us to provide energy and which gives out energy?

Ans. Lighter ⟶ Denser

Energy is given out.

$$\Delta H = \text{Negative}$$

Denser ⟶ Lighter

Energy is taken in

$$\Delta H = \text{Positive}$$

(i) Solids → Liquid

Energy is required to convert a solid into liquid. **ΔH is** Positive in this case. This energy is called heat of fusion.

(ii) Liquid → Gas

Energy is required to convert a liquid into gas. **ΔH is** Positive in this case. This energy is called heat of vaporization.

(iii) Gas → Liquid

Energy is released when a gas is converted into a liquid. **ΔH is** negative in this case. This process is called condensation process.

(iv) Liquid → Solid

Energy is released when a liquid converts into solid. **ΔH is** negative in this case. This process is called freezing process.

xi. Explain each of the statements below,

(a) You can smell a fish from across the road.

(b) Sugar dissolves faster in hot water than in cold water.

(c) Condensation occurs on the inside of your windows in winter.

Ans. (a) Due to diffusion we can smell of fish from across the road.

Explanation:

According to the kinetic molecular theory of gases, the molecules of the gases are in random motion. They collide with each other and change their directions. That is why you can smell a fish from across the road due to diffusion.

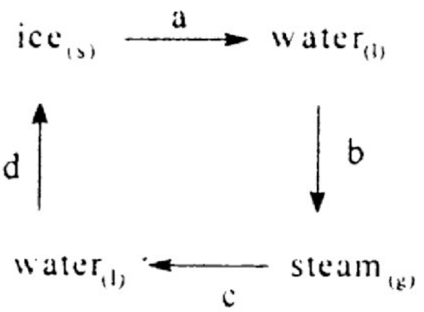
(b) Solubility increase with the increase in temperature

Explanation:

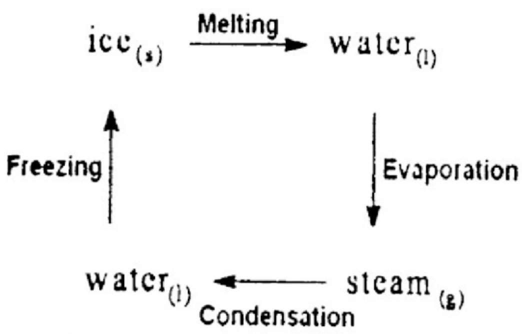
When temperature increases the intermolecular forces among the sugar molecules decreases and therefore the sugar dissolves faster in hot water than in cold water

(c) Condensation is the process in which vapours are converted into liquid. Condensation occurs on the inside of our windows in winter because the temperature of outside environment is lower than inside. It makes the window cold. Therefore when the water vapours strike the cold window they condense into liquid.

xii. Use the following words to label the changes "a" to "d" condensation, evaporation, freezing, melting.



Ans: a = melting
b = evaporation
c = condensation
d = freezing



xiii. Look at the densities in the table below:

No	Element	Density (g/Cm^3)
1	Oxygen	0.00133 at room temperature and pressure
2	Sulphur	8.92
3	Potassium	7.14
4	Nitrogen	0.00117 at room temperature and pressure

a. What is the physical state of each element in the above table at 25°C?

b. Give the reason for big differences in the densities of elements shown above?

c. Why is the temperature and pressure important when giving the density of oxygen and nitrogen?

Ans. a. Oxygen and nitrogen are gases at room temperature (25°C) because their densities a quite low

While Sulphur and potassium are solids at room temperature because their densities are quite high as shown in the table.

b. At room temperature oxygen and nitrogen are gases because they have low densities and have high volume

At room temperature sulphur and potassium are solids because they have high densities and have small volume.

c. Temperature and pressure important while giving the density of oxygen and nitrogen

As we know that d = PM/RT

From the equation it is concluded that density is directly proportional to pressure and inversely proportional to temperature.

i.e. $d \propto p$ and $d \propto \frac{1}{T}$

Therefore pressure and temperature should be mentioned along with the densities.

xiv. Explain why the particles in solid ice stick together and those of steam do not (even when they get very close (collision)?

Ans. Particles in solid ice:

As we know that solids have strong intermolecular forces due to which they have only vibrational motion That is why the particles in solid ice stick together.

Particles in steam:

As we know that gases have weak intermolecular forces due to which they posses high kinetic energy That is why the particles of steam do not stick together even when they get very close (collision).

xv. When long bridges are constructed, the roadbed is made in sections with spaces between the sections. Why must be done so?

Ans. When long bridges are constructed, the roadbed is made in sections with spaces between the sections. It is because solid expand on heating.

In summers the bridges expands due to the increase in temperature That is why the space is provided between the sections to avoid the damage due to expansion.

xvi. Explain each of the following situations in terms of energy produced or used.

(a) You feel cold immediately after getting out of a swimming pool, but you feel comfortably warm when you have dried yourself.

(b) Skin exposed for just a short time to steam can suffer severe burns whereas; skin exposed to hot water for the same length of time suffers only a mild burn or none at all.

Ans. (a) Evaporation is a cooling process:

When we come out from swimming pool water molecules are present on our body these water molecules evaporates by taking the heat from the surrounding Thus due to evaporation of water molecules from our body we feel cold immediately after getting out of a swimming pool as we know that evaporation is a cooling process

But when we dried our body evaporation does not occur and therefore the temperature of our body becomes equal to the temperature of surrounding. That is why we feel comfortably warm when we dried our self.

(b) Gases have high energy:

As we know that gas molecules have high kinetic energy. Thus steam have high kinetic energy than hot water that is why when skin expose for just a short time period can suffer severe burn.

xvii. Write notes on (i) Amorphous solids (ii) Crystalline solids.

Ans: i. Amorphous Solids:

The solids which have no definite geometric shape are called amorphous solids e.g. glass, rubber, dust etc.

ii. Crystalline Solids:

The solid, which have a definite regular and three-dimensional geometric shape are called crystalline solids. Some crystalline solids have certain molecules of water of crystallization e.g. $CuSO_4.5H_2O$, $Na_2SO_4.10H_2O$.

3. (a) How will you define a crystalline solid?

(b) Explain the kinetic molecular interpretation of a solid, keeping in view the following properties:

(i) Rigidity (ii) Collision

(iii) Geometric shape (iv) Attractive forces

Ans. (a) Crystalline Solids:

The solid, which have a definite regular and three-dimensional geometric shape are called crystalline solids. Some crystalline solids have certain molecules of water of crystallization e.g. $CuSO_4.5H_2O$, $Na_2SO_4.10H_2O$.

(b) (i) Rigidity (ii) Collision

(iii) Geometric shape (iv) Attractive forces

Ans.

i. Rigidity:

The molecules in solids are closely packed. Therefore their movement is 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.

ii. Collision:

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

iii. 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.

iv. Attractive Forces:

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

4. Define and explain compressibility (β)?

Ans. Compression (Effect of Pressure):

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

Compressibility factor (β):

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

5. Define the co-efficient of expansion (α)?

Ans. Expansion:

The solids expand when heated i.e. their volume increases. This is because the increase of temperature decreases the intermolecular attractive forces. As a result, the volume increases.

Co-efficient of expansion:

The co-efficient of expansion (α) is defined as "the increase in volume per unit volume when the temperature is increased by 1 $^\circ$C."

6. Describe the following properties of crystalline solids:

(i) Cleavage plane **(ii) Melting point**
(iii) Isomorphism **(iv) Polymorphism**
(v) Allotropy **(vi) Transition temperature**

Ans. Properties of crystalline solids:

Some important properties of crystalline solids are described here:

(i) Cleavage plane:

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.

(ii) Melting point:

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 melting point, their vibrational energies become so much that they leave their fixed positions simultaneously and become a liquid.

(iii) 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 $NiSO_4$ 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) $CaCO_3$ and $NaNO_3$ are Rhombohedral. (Atomic ratio= 1:1:3)

(iv) 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. $CaCO_3$ is trigonal when present as calcite and orthorhombic when present as aragonite.
3. HgI_2 is orthorhombic (yellow form) and tetragonal in red form.

(v) Allotropy (allotrope – Greek-allos (other), tropia (turning) : (forms):

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

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

(ii) C (as graphite) ________ in hexagonal form.

(vi) Transition temperature:

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 polymorph or allotrope can exist.

No	Substance	Crystalline form	Transition temperature
1	Tin (grey) Tin (white)	Crthorhombic Tetragonal	18 °C
2	Sulphur	Monoclinic Ortho rhombic	95.6 °C
3	KNO_3	Orthorhombic Rhombohedral	128.5 °C

7. Differentiate between the following pairs:

(a) Crystalline solids and amorphous solids.

(b) Lattice and crystal lattice.

(c) Polymorphism and isomorphism.

(d) Hexagonal closest packing and cubic closest packing.

Ans: (a) Crystalline Solids And Amorphous Solids.

Differences between Amorphous and Crystalline Solids:

Crystalline Solids	Amorphous Solids
i. In the crystalline state, the crystals possess definite geometrical structure e.g. NaCl is cubic in nature.	**i.** In the amorphous state the solids do not have definite geometrical structure e.g. glass.

ii. There is a complete regularity of arrangement of atoms, ions or molecules in a crystalline solid	**ii.** The atoms, ions or molecules are not arranged in a regular manner in amorphous solids
iii. The crystalline substance has a sharp Melting Point.	**iii.** Amorphous solid do not have sharp Melting Point and gradually soften on heating. They may be called as super-cooled liquids e.g. glass, plastic etc.
iv. In a crystalline substance, water molecules are a part of crystal e.g. $FeSO_4.7H_2O$, $CuSO_4.5H_2O$ etc.	**iv.** The amorphous substances have no such water of crystallization.
v. The crystalline substances do not soften on heating.	**v.** The amorphous solid is a solid which soften on heating ultimately they become mobile over a wide range of temperatures.
vi. Three dimensional arrangement of particles.	**vi.** No three dimensional arrangement of particles.
vii. They have definite heat of fusion.	**vii.** They do not have definite heat of fusion.
viii. Examples: NaCl, Sugar, Ice, Diamond etc	**viii. Examples:** Rubber. Plastic. Glue, Glass, Paper etc.

(b) Lattice and crystal lattice.

Crystal Lattice:

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

Lattice:

The position of the particles **(atoms, ions or molecules)** in a crystalline solid is called Lattice.

(c) Polymorphism and isomorphism.

Polymorphism	**Isomorphism**
The substance existing in more than one crystalline form is called Polymorphous substance and the phenomena as Polymorphism.	Different crystalline substances having the same crystalline shapes are called Isomorphs, and this phenomenon is called Isomorphism
This is compound phenomenon.	They may be elements or compounds.
They can be convert able from one form to another.	They cannot be inter-converted.
They have same chemical but different physical properties.	They have different physical and chemical property.
Examples: **i.** NaCl is found in cubic and octahedral forms. **ii.** $CaCO_3$ is trigonal when present as calcite and orthorhombic when present as aragonite.	**Examples:** **(i)** $ZnSO_4$ and $NiSO_4$ are isomorphism because both have the same crystalline shape, i.e. orthorhombic. Isomorphs have same atomic ratio.

iii. HgI₂ is orthorhombic (yellow form) and tetragonal in red form	**(ii)** Ag_2SO_4 and Na_2SO_4 are hexagonal (Atomic ratio= 2:1:4) **(iii)** $CaCO_3$ and $NaNO_3$ are Rhombohedral. (Atomic ratio= 1:1:3)

(d) Hexagonal closest packing and cubic closest packing.

Hexagonal close-packing:

If tetrahedral holes are covered, the third layer is identical to the bottom layer. This arrangement is called hexagonal close-packing (hcp) arrangement. This pattern of arrangement is usually written as ABAB or 1212.

Cubic closed packing:

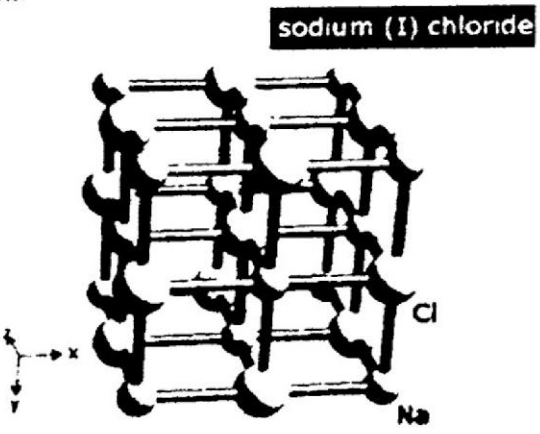
In contrast, if we cover the octahedral holes, the third layer is not identical with the bottom layer. This is called the cubic closed packing (ccp) arrangement. It is usually written as ABCABC or 123123.

8. (a) Define a unit cell. List the factors on which a unit cell depends?

(b) Explain the structure of NaCl, keeping in view the unit cell?

Ans. (a) Unit cell:

The smallest unit of volume of a crystal, which shows all the properties of its pattern, is called a unit cell.



Structure of NaCl Crystal

This is a basic structural unit of a crystal. The systematic arrangement of atoms in a crystal is called lattice. It represents the structure of any substance. Primarily a crystal depends upon,

- Shape of the unit cell.
- Contents of the unit cell.

The atoms, molecules or ions in a crystal are repeated in a systematic manner.

We can explain significance of unit cell to the shape of crystal using NaCl as an example.

The unit cell is primarily concerned with the shape of the crystalline substance. Keeping in view the shape of the crystal, its structure can be identified. Let us take the example of NaCl.

(b) Unit Cell and Shape of NaCl:

We can explain significance of unit cell to the shape of crystal using NaCl as an example.

The unit cell is primarily concerned with the shape of the crystalline substance. Keeping in view the shape of the crystal, its structure can be identified. Let us take the example of NaCl.

Location of ions:

In NaCl, each Na^{+1} ion is surrounded by 6 Cl^{-1} ions and vice versa. The size of Cl^{-1} ion is bigger than Na^{+1} ion because Cl^{-1} ion has 18 electrons and Na^{+1} ion has 10 electrons.

i. Co-ordinate Number:

The number of negative ions which contact a unit positive ion is called it's co-ordinate number. In NaCl each Na^{+1} ion contacts with 6 Cl^{-1} ions at the corner of a regular octahedron. So the co-ordination number of Na^{+1} ion is 6. Similarly co-ordination number of Cl^{-1} ion is also 6. The distance between all Na^{+1} ions and Cl^{-1} ion is the same.

ii. No. of NaCl in Each Unit Cell:

In NaCl there are 8 Cl^{-1} ions at each corner of the cube. Each Cl^{-1} ion is shared among eight unit cells. Each face shares with two unit cells. So the number of Cl^{-1} ion in each unit cell can be calculated.

Calculation of Na^{+} ions and Cl^{-} ions:

(a) Calculation of Cl^{-1} ions:

(i) No of unit cells = 8

No of Cl^{-1} ions = 8

Number of Cl^{-1} ions in one unit cell = $\frac{8}{8}$ = 1

(ii) Total number of Cl^{-1} ions at the corner of a regular octahedron = 6

No of unit cells containing each face = 2

No of Cl^{-1} ion in each unit cell = $\frac{6}{2}$ = 3

Total number of Cl^{-1} ion in each unit cell = 1 + 3 = 4 Cl^{-1}

(b) Calculation of Na^{+1} ions:

Na^{+1} ions are present at the edges.

No of edges present in the cube = 12

Number of unit cells of Na^{+1} ions = 4

No of Na^{+1} ion present in each edge = $\frac{12}{4}$ = 3 Na^{+1}

Na^{+1} ion present in the centre = 1 Na^{+1}

Total number of Na^{+1} ions = 3 + 1 = 4 Na^{+1} ions

So each unit cell consists of 4 Na^{+1} ions and 4 Cl^{-1} ions.

Hence 4 Na^{+1} + 4 Cl^{-1} = 4 NaCl can be written.

9. Explain the three factors that affect the shape of an ionic crystal?

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

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^{+1} ions.

$$\underset{(2,8,1)}{Na} - 1e \rightarrow \underset{(2,8)}{Na^{+1}} \quad \text{(A cation is fomed)}$$

$$\underset{(2,8,7)}{Cl} + 1e^{-1} \rightarrow \underset{(2,8,8)}{Cl^{-1}} \quad \text{(A anion is fomed)}$$

These ions combine together due to strong electrostatic force.

$$Na^{+1} + Cl^{-1} \rightarrow NaCl \quad \Delta H = -787 \text{ kg Mole}^{-1}$$

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 $6Na^{+1}$ ions. As a 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.

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

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

No	Shape of ionic solid	Limiting Radius Radio r^{+1}/r^{-1}
1	Body centred 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:

4. NaCl = 0.522 – Octahedral arrangement or cubic structure.

5. CsCl = 0.93 – Body centred cubic arrangement.

6. ZnS = 0.40 – 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 is ruptured

$$NaCl_{(s)} \xrightarrow{water} Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

Thus the ions are solvated

10. (a) Define lattice energy and give a particular example?

(b) Explain the low density and high heat of fusion of ice?

Ans. (a) Lattice Energy:

1. The amount of heat or energy released when gaseous ions of opposite charges combine to give one mole of a crystalline ionic compound is called **lattice energy**.

Example:

$$Na^{+1}_{(g)} + Cl^{-1}_{(g)} \rightarrow NaCl_{(s)} \Delta H = -787 \text{ kg mole}^{-1}$$

2. The amount of energy required to break one mole crystal lattice into its gaseous ions is called **lattice energy**

Example:

$$NaCl_{(s)} \rightarrow Na^{+}_{(g)} + Cl^{-}_{(g)} \qquad \Delta H = +787 \text{ kg mole}^{-1}$$

Dependence:

The lattice energy of the ions depends upon their size and charge of the ions. Lattice energy decreases with the increase in the size of the ions, (whether cations or anions), the packing of oppositely charged ions become less and less tight. Lattice energy increases with increasing ionic charge.

(b) Low Density and high Heat of Fusion of Ice:

i. Low density of ice:

When the temperature is decreased the molecules come close to each other. As a result the intermolecular attractive forces increase. However some empty spaces are developed in the ice. As a result about 9% more space than liquid water is produced. As $d = \frac{m}{v}$ that is density is inversely proportional to volume, the increase in volume decreases the density. That is why ice floats over water.

Application of Low Density in Real Life:

In cold countries when temperature is decreased to 0°C, water in ponds and lakes **freezes.** The ice formed stays on the **top**. This layer of ice acts as **insulator** for further heat loss. A thick layer of ice is formed at the top. Fish and plants can survive in the water for months under the thick blanket of ice.

Keeping in view the above discussion, we are forced to believe that the pattern of life for plants and animals would have been totally different in the absence of Hydrogen bonding in water.

ii. High Heat of Fusion of Ice:

The quantity of heat required to convert one mole of a solid into liquid is called **molar heat of fusion.**

e.g. Ice → liquid water $\quad \Delta H_f = 6.02 \text{ KJ mole}^{-1}$

Applications in Real Life:

Ice absorbs 333 joules of energy for every gram of ice to melt. It means, if 33.3 K. Joules of energy from the surrounding is absorbed by each of the drink, the temperature of the drink without ice would rise from 0°C to 20°C. The drink containing the ice would remain at 0°C but 100 grams of ice would melt.

Therefore it can be said that the aquatic life would be totally different in the absence of hydrogen bonding.

11. Write notes on molecular crystals and metallic crystals.

Ans: Molecular Crystal:

Definition:

The solid substances in which the particles forming the solids are polar or non-polar molecules are called molecular crystals.

Examples:

e.g. In solidified gases, these are non-polar atoms. Two types of intermolecular forces hold them together

i. Dipole-Dipole interactions.

ii. Van der Waal's forces

Examples:

i. Crystals with polar molecules e.g. Ice, Sugar

ii. Crystals with non-polar molecules e.g. I_2, S_8, P_4, CO_2 etc.

Properties:

i. X-ray analysis indicates the regular arrangement of atoms. Thus we get the exact positions of all the atoms.

ii. Polar molecular crystals have high M.P. and B.P. as compared to non-polar molecular crystals.

iii. They are soft and easily compressible.

iv. They are volatile in nature.

v. They are bad conductors of electricity.

vi. They have low densities due to weak attractive forces.

vii. They are transparent to light.

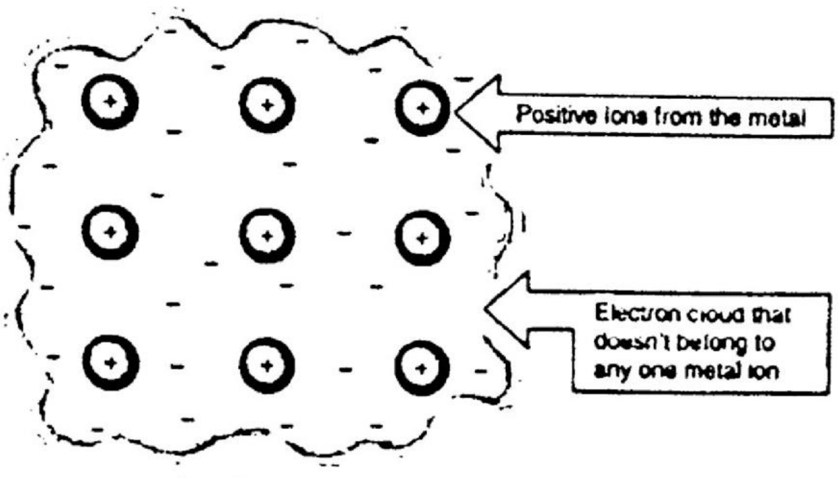
Metallic crystal:

Definition:

The crystalline solids in which metal atoms are held together by metallic bonds are known as metallic solid e.g. Na, Cu etc.

Explanation (Electron Sea or Electron Gas Theory:

Metals are good conductors because the valence electrons are loosely bound. Therefore they can move from one atom to the other. Due to this mobility of electrons, they are considered to conduct electricity. The positively charged portion of the metallic atom is surrounded by electrons in such a way that these electrons serve as an atmosphere of distributed charges. The positively charged particles are immersed in it. Such an atmosphere is called an electron gas or sea. This is shown below



An electron sea surrounding cations

There are two forces responsible for the metallic bond

i. Force of attraction between the electron gas and the positive ions.

ii. Force of repulsion between positively charged ions. These forces are equal and opposite. Therefore, they counterbalance each other. Thus the metallic atom is neutral as a whole

Properties:

i. They are best conductors of heat and electricity

ii. They have lustrous surfaces.

iii. They are malleable and ductile.

iv. They have high melting points.

12. Explain the conductivity of a metallic crystal using "electron sea theory".

Ans. Metallic Solids:

Definition:

The crystalline solids in which metal atoms are held together by metallic bonds are known as metallic solid e.g. Na, Cu etc

Explanation (Electron Sea or Electron Gas Theory:

Metals are good conductors because the valence electrons are loosely bound. Therefore they can move from one atom to the other. Due to this mobility of electrons, they are considered **to conduct electricity**

The positively charged portion of the metallic atom is surrounded by electrons in such a way that these electrons serve as an atmosphere of distributed charges. The positively charged particles are immersed in it. Such an atmosphere is called an electron gas or sea

Properties:

i. They are best conductors of heat and electricity

ii. They have lustrous surfaces

iii. They are malleable and ductile

iv. They have high melting points.

13. Write a detail note on ionic solids.

Ans. Ionic Solids:

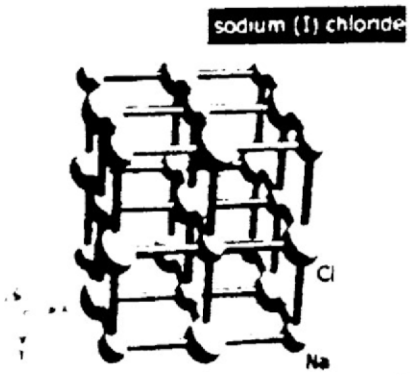
An ionic solid is formed due to the transference of electrons to the other e.g. NaCl formation. The cations and anions formed are held together through strong electrostatic forces of attractions.

Formation of NaCl:

$$\underset{(2,8,1)}{Na} - e^{-1} \rightarrow \underset{(2,8)}{Na^{+1}} \quad (\text{cation})$$

$$\underset{(2,8,7)}{Cl} + e^{-1} \rightarrow \underset{(2,8,8)}{Cl^{-1}} \quad (\text{anion})$$

$$Na^{+1} + Cl^{-1} \rightarrow NaCl$$



Sodium Chloride crystal

i. They are non-conductors of electricity in the solid state. However they conduct electricity in the molten or solution form.

ii. They have definite geometric shape.

iii. They are non-directional in nature.

iv. They do not exist in the form of molecules due to their ionic nature.

14. (a) Define covalent crystals and give their properties?

(b) How will you explain the covalent solids?

i. When the atoms are jointly held together like diamond.

ii. When the atoms have separate layers like graphite.

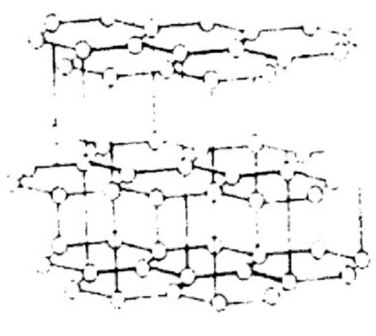
Ans. (a) Covalent crystals (Solid):

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.

Properties:

(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.



Graphite crystal

(iii) They are bad conductors of electricity with the exception of graphite.

(iv) They have definite shape and oriented in three directions with a network structure.

(v) They have open structures due to the valences of atoms directed in definite directions.

(vi) They may be called as molecules due to their covalent nature e.g. S_8, P_4, ice.

(b) i. When the atoms are jointly held together like diamond.

When the atoms are jointly held together like diamond then covalent bonds give giant molecules. It is non-conductors of electricity due to complete sharing of electrons.

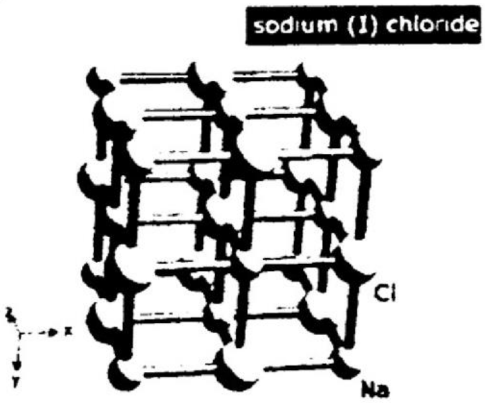
ii. When the atoms have separate layers like graphite.

When atoms join together by sharing of electrons. As a result separate layers are formed e.g. graphite. Graphite is good conductors of electricity due to free electrons.

Note: Network covalent solids vary from insulating to semiconducting in their behavior, depending on the band gap of the material.

15. Explain the significance of a unit cell to tell the shape of a crystal, using NaCl as an example?

Ans. The smallest unit of volume of a crystal, which shows all the properties of its pattern, is called a unit cell.



Structure of NaCl Crystal

This is a basic structural unit of a crystal. The systematic arrangement of atoms in a crystal is called lattice. It represents the structure of any substance. Primarily a crystal depends upon,

- Shape of the unit cell.
- Contents of the unit cell.

The atoms, molecules or ions in a crystal are repeated in a systematic manner.

We can explain significance of unit cell to the shape of crystal using NaCl as an example.

The unit cell is primarily concerned with the shape of the crystalline substance. Keeping in view the shape of the crystal its structure can be identified. Let us take the example of NaCl.

Unit Cell and Shape of NaCl:

We can explain significance of unit cell to the shape of crystal using NaCl as an example.

The unit cell is primarily concerned with the shape of the crystalline substance. Keeping in view the shape of the crystal, its structure can be identified. Let us take the example of NaCl. **Location of ions:**

In NaCl, each Na^{+1} ion is surrounded by 6 Cl^{-1} ions and vice versa. The size of Cl^{-1} ion is bigger than Na^{+1} ion because Cl^{-1} ion has 18 electrons and Na^{+1} ion has 10 electrons.

Co-ordinate Number:

The number of negative ions which contact a unit positive ion is called it's co-ordinate number. In NaCl each Na^{+1} ion contacts with 6 Cl^{-1} ions at the corner of a regular octahedron. So the co-ordination number of Na^{+1} ion is 6. Similarly co-ordination number of Cl^{-1} ion is also 6. The distance between all Na^{+1} ions and Cl^{-1} ion is the same.

No. of NaCl in Each Unit Cell:

In NaCl there are 8 Cl^{-1} ions at each corner of the cube. Each Cl^{-1} ion is shared among eight unit cells. Each face shares with two unit cells. So the number of Cl^{-1} ion in each unit cell can be calculated.

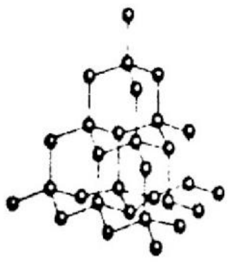
16. How will you explain that diamond is non-conductor while graphite is conductor in nature?

Ans. Diamond is non-conductor:

In diamond free electrons are not present therefore it is non-conductor in nature.

Explanation:

In diamond each carbon atom is covalently bonded with four other carbon atoms and have a network structure as shown in the figure.



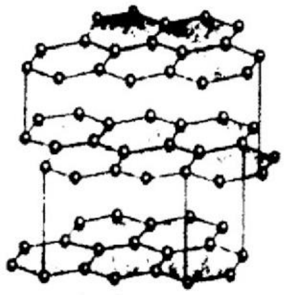
Therefore it has no free electron for the conduction of electricity hence it is non-conductor.

Graphite is a conductor:

In graphite free electrons are present therefore it is a conductor in nature.

Explanation:

In graphite each carbon atom is covalently bonded with three other carbon atoms and has a layered structure as shown in the figure.



Therefore the fourth outermost electron of carbon is free which can be used for the conduction of electricity.

But according to Anisotropy graphite exist in the form of layers so it is conductor in one direction, parallel to layers but insulator across the layers.

17. Explain the kinetic energy of solids, based upon the kinetic molecular theory?

Ans. Kinetic Energy Based Upon Kinetic Molecular Theory:

According to the Kinetic Molecular Theory, the attractive forces between the solid particles are maximum. This is due to minimum distance between them and, therefore, molecules do not possess translation and vibrational kinetic energies. However, they can vibrate about their mean positions. So they possess vibirational kinetic energy.

18. How will you explain the use of oxygen and sulphur to define allotropes?

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 Ozone) are considered to be the two forms of oxygen obtained by the absorption of certain amount of heat from atmosphere.

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

Explanation to form Allotropes

Certain amount 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). Since the conversion is spontaneous and one directional, therefore, it 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 allotropic forms which are irreversible.

Structures

Oxygen molecule O = O has a sigma (σ) bond and a Pi-bond (π) 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 of the layer of 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.

Allotropes of Sulphur

Allotropes of sulphur are of four types:

- Rhombic sulphur
- Monoclinic sulphur.
- orphous sulphur
- Plastic sulphur

xists in four allotropic forms which

Rhombic Sulphur (α -Sulphur):

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

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.

Amorphous Sulphur (δ-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 colour.

$$2H_2S_{(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)} + 2S_{(s)} \text{ (amorphous solid)}$$

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.

19. Explain, why a compound like $CaCl_2$ (calcium chloride) fluctuate in mass from day to day because of humidity?

Ans. Hygroscopic Salts:

Some salts absorb moisture from atmosphere. Such salts are called hygroscopic salts.

Calcium chloride ($CaCl_2$) has the property of absorption of moisture from the atmosphere. Thus it becomes hygroscopic.

The absorption of moisture becomes maximum when there is humidity in air.

The water molecules absorbed will become part of crystal of $CaCl_2$ and may be called as water of crystallization such substances are called Hydrates. $CaCl_2$ can absorb a maximum of $2H_2O$. Therefore $CaCl_2$ becomes $CaCl_2.2H_2O$. The water of crystallization attached will increase the mass of calcium chloride.

That is why a compound like $CaCl_2$ (calcium chloride) fluctuate in mass from day to day because of humidity.

20. How will you purify saline water by repeated freezing method?

Ans. Sodium chloride salt from saline solution:

Saline water (NaCl solution) contains water along with certain impurities. If saline water is allowed to freeze in freezing mixture of water the impurities come up to the surface in the form of ice at 4°C leaving behind NaCl.

Ice and impurities are removed from the surface leaving behind pure NaCl