



STATE OF MATTER III: Chapter 6

SOLIDS

6

Teaching Periods

14

Assessment

1

Weightage

8

INTRODUCTION

Solid is a condensed state of matter in which particles (atoms, ions or molecules) are closely arranged in fixed position and have very little freedom of movement due to strong inter ionic, inter atomic or inter molecular forces. Unlike liquids and gases, solids cannot flow and cannot take up the shape of container. Solids are identified by their rigid structure and mechanical strength. They tend to resist external pressure applied on them and are nearly incompressible. Solids have very high density as compared to liquids and gases, most of them melt on heating, and however some directly convert into gaseous state. Progress in science and technology leads to advancement in knowledge about solid state, hence we must endeavour to understand the nature and behavior of solids.

6.1 KINETIC MOLECULAR INTERPRETATION OF SOLIDS

Kinetic molecular theory tells us that particles in a solid have very

little space due to strong attractive forces. These particles are tightly packed together about their mean position. Owing to the restricted movement of particles, solids have fixed shape and volume. However when a solid is heated, the vibrational energy of particles increases and when a particular temperature is reached the vibrational energy of solid particles overcome the attractive forces. As a result, particles of solid lose their mean position as well as specific arrangement and change into liquid state.



Students will be able to:

- **Describe** simple properties of solids e.g., diffusion, compression, expansion, motion of molecules, spaces between them, intermolecular forces and kinetic energy based on kinetic molecular theory.
- **Differentiate** between amorphous and crystalline solids.
- **Describe** properties of crystalline solids like geometrical shape, melting point, cleavage planes, crystal growth, anisotropy, symmetry, isomorphism, polymorphism, allotropy and transition temperature.
- **Explain** the significance of the unit cell to the shape of the crystal using NaCl as an example.
- **Name** three types of packing arrangements and draw or construct models of them.
- **Name** three factors that affect the shape of an ionic crystal.
- **Define** lattice energy.
- **Differentiate** between ionic, covalent, molecular and metallic crystalline solids.
- **Explain** the low density and high heat of fusion of ice.
- **Define** and explain molecular and metallic solids.

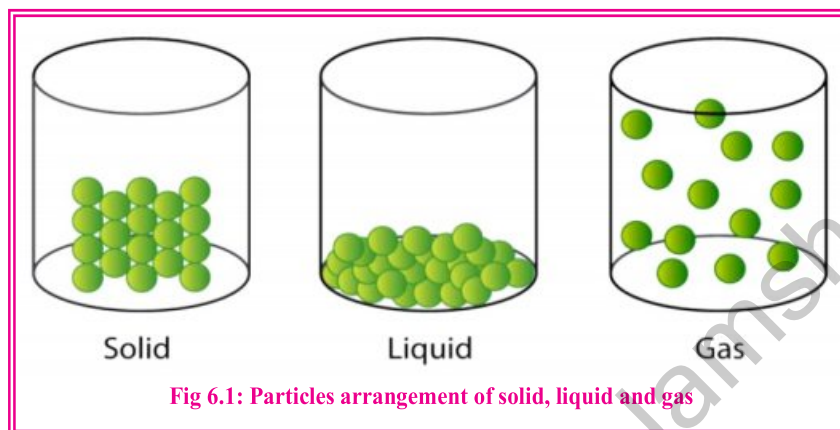


Fig 6.1: Particles arrangement of solid, liquid and gas

6.1.1 Simple Properties of Solids

Before going to deal with the concept of solid in broader aspect in the next sections, you need to understand some simple properties of solids related to their inter particles associations based on some limitations in the freedom of particles movement.

Kinetic energy and Molecular motion: Particles of solid can only vibrate about their mean position. They do not bear translational and rotational kinetic energy as liquid particles do.

Intermolecular forces: Particles in solid held together tightly in a fixed position due to some strong intermolecular forces.

Compression: Solids are nearly incompressible. In term of kinetic theory, particles are tightly bonded together due to strong attractive forces therefore only a very small empty space is left among them. It makes the solid denser, rigid and hard and can withstand considerable external pressure.

Diffusion: Solids diffuses very slowly as compared to liquids and gases. This is due to the close packing of particles and restriction against their free movement.

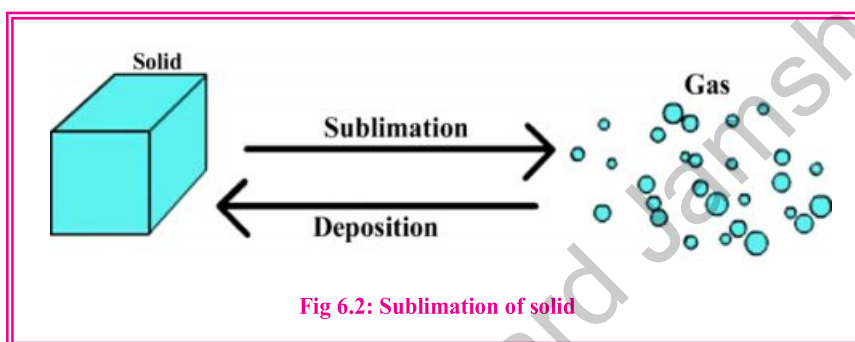
Expansion: Solids expand on heating but this ability is very little as compared to liquids and gases. Since particles of solids are arranged orderly in a fixed position, an increase in temperature weakens their attractive forces giving an increase in the volume.

Melting: Solids melt on heating at a particular temperature. In term of kinetic theory, vibrational energy of particles increases on heating until at melting temperature the vibrational energy of the solid particles overcome the energy of existing bonds among them thus solid melt and change into liquid state.



Sublimation: Some solids directly change into vapours on heating without passing through liquid phase, which is known as sublimation. For example naphthalene, iodine, camphor and solid CO_2 are sublime.

In term of kinetic theory, the attractive forces in these solids are quite weaker compared with ordinary solids, thus on heating high energy surface particles of these solids directly pass into vapours.



6.2 TYPES OF SOLIDS

Most of the substances around us are solids rather than liquid or gases. Solids like sugar, salts, metals etc are hard and crystalline while some others such as rubber, plastic, etc are soft and amorphous. There are two main classes of solids named as crystalline solids and amorphous solids.

6.2.1 Crystalline Solids

Solids which comprise particles (atoms, molecules or ions) arranged in a well-defined three-dimensional order are known as crystalline solids. In these solids, the structural unit is an arranged in three dimensions. This regular pattern throughout the crystal is called crystal lattice and the smallest fundamental portion of crystal which repeats in all three dimensions to give the crystal structure is called unit cell. Crystalline solids are characterized by definite geometrical shape and sharp melting points. They are also known as true solids. Most of the solids in nature occur as crystalline solids. Some common example of crystalline solids are Sodium chloride, Diamond, Graphite, Sucrose, Ferrous sulphate, Magnesium chloride, Sodium carbonate etc.

6.2.2 Amorphous Solids

Solids which do not have a three dimensional regular arrangement of particles (atoms, molecules or ions) are known as amorphous solids. These solids do not have long range order of particles and assumed them closer to liquid. Thus, on continuous heating they gradually soften and finally convert into a flowing liquid. Glass for example is often called as super cooled liquid.



Do You Know?

Amorphous silica is one of the best material for converting sunlight into electricity (Photovoltaic cell).



These solids do not have sharp melting point which means that they melt over a wide range of temperatures. Some common example of amorphous solids include rubber, glass, charcoal, plastics etc.

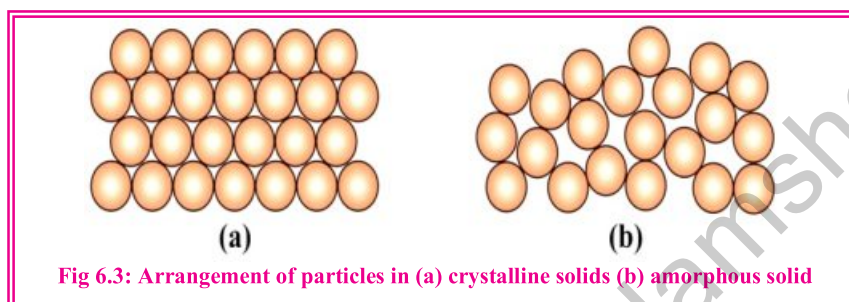


Fig 6.3: Arrangement of particles in (a) crystalline solids (b) amorphous solid

Table 6.1 Comparative Study of Crystalline and Amorphous Solids

Crystalline	Amorphous
They exist in definite geometrical shape	They don't have definite shape
They have sharp melting points	They melt over a wide range of temperatures
They show anisotropic behavior that is properties like mechanical strength, refractive index and electrical conductivity depend upon direction	They are isotropic in nature
They can be cut down at fixed cleavage plane	When they are cut or hammered cause in irregular fracture

6.3 PROPERTIES OF CRYSTALLINE SOLIDS

So far we have learnt that particles of crystalline solids vibrate about their allocated position in a well defined structure. Now we need to know about their fundamental properties on the basis of which a crystalline solid is distinguished from amorphous solid.

6.3.1 Symmetry

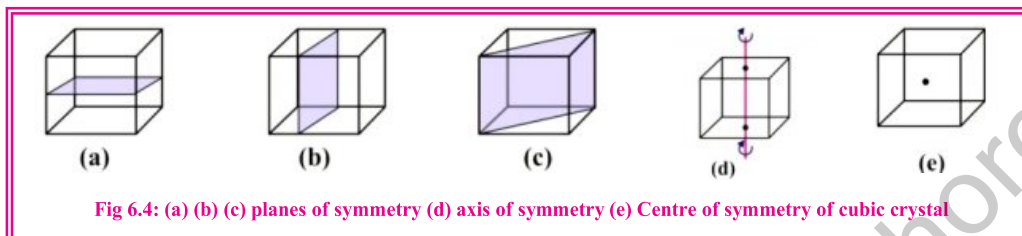
When a crystal is rotated to a certain angle, a regular repetition of edges and faces is observed, this is known as symmetry.

The symmetry of an individual crystal is determined by three elements known as plane of symmetry, axis of symmetry and centre of symmetry.

Plane of symmetry: It is an imaginary plane which divides the crystal into two equal parts in such a way that one is the image of other.

Axis of symmetry: It is an imaginary line on which the crystal can be rotated through 360° .

Centre of symmetry: It is a point in the crystal from which we can draw a line. This line intersects the surface of the crystal at equal distance on either side.



6.3.2 Geometrical Shape of Crystals

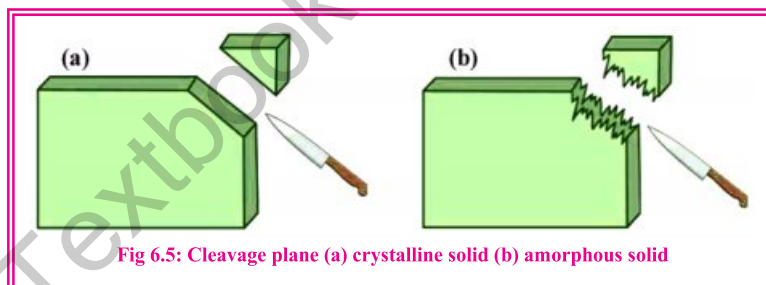
Since the particles in crystalline solids are orderly organized in a repeating pattern in three dimensions, they possess definite geometrical shape. For example the shape of unit cell of diamond is cubic and graphite is hexagonal.

6.3.3 Sharp Melting Point

Crystalline solids have sharp melting point because attractive forces between the particles are long ranged and uniform.

6.3.4 Cleavage Plane

A big crystal can be cut or split into smaller crystals of identical shape, this process is called as cleavage and the line or point which have direction of cleavage is known as cleavage plane.



6.3.5 Crystal growth

When a hot saturated solution of salt or a molten solid is allowed to cool slowly, crystals are grown in various directions it is called crystal growth. For example a slow cooling of hot saturated solution of table salt gives cubic crystals.

6.3.6 Anisotropy

A very unique behavior of crystalline solid is the variation in certain physical properties (Refractive index, Coefficient of thermal expansion, Electrical and Thermal conductivity) along different directions in the crystal lattice. This phenomenon is known as anisotropy. The reason of anisotropic attitude is attributed to the fact that arrangement of particles is different in the different directions.



For example graphite conduct electricity parallel to the layer because of electron movement is not allowed on perpendicular of the layer.

6.3.7 Isomorphism

The phenomenon in which different solid substances exist in the same crystalline structure is called isomorphism (iso; same and morphous; shape) and the substances which exhibit this behaviour are referred as isomorphous.

The constituent atoms of isomorphous substance are in the same atomic ratio but they have different physical and chemical properties.

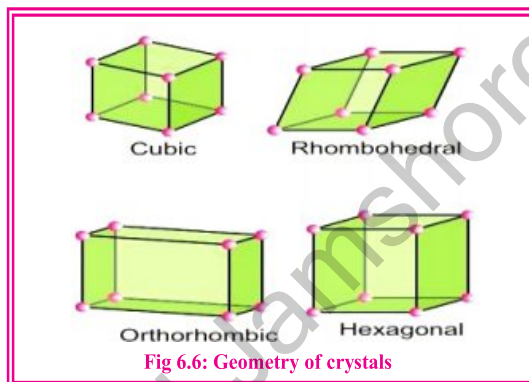


Table 6.2 Isomorphism in different crystalline solids		
Isomorphous Substance	Atomic Ratio	Geometry of Unit cell
NaCl and MgO	1 : 1	Cubic
NaNO ₃ and CaCO ₃	1 : 1 : 3	Rhombohedral
ZnSO ₄ and NiSO ₄	1 : 1 : 4	Orthorhombic
Ag ₂ SO ₄ and Na ₂ SO ₄	2 : 1 : 4	Hexagonal

6.3.8 Polymorphism

In the studies of crystallography, a unique feature of crystalline solid is the phenomena of exhibiting polymorphism. It refers to the existence of one chemical compound into two or more feasible geometry of unit cell. **“The phenomenon in which a substance under different conditions can exist in more than one crystalline structure is known as polymorphism”**. It is important to note that chemical nature of polymorphous substances remains the same but their physical properties like solubility, melting point, refractive index, hardness, thermal stability etc are different.

For example Lime (CaCO₃) exists in the following two crystalline form.

- (i) Calcite (CaCO₃) which posses trigonal crystal structure
- (ii) Aragonite (CaCO₃) which posses orthorhombic crystal structure

Both calcite and Aragonite have same chemical composition but different physical properties.



Self Assessment

- (i) Crystalline substances are anisotropic in behavior, what does this statement means.
- (ii) NaCl and MgO are isomeric substances how can you explain it?



6.3.9 Allotropic Modification and Transition Temperature

Allotropy is limited to pure elements only. It defines as “**The existence of the same elements in two or more different crystal structures having the same chemical nature but different physical properties**”.

Carbon exists in two crystalline allotropic forms one is called Diamond which has a cubic geometry while other is Graphite in which the geometry of crystal is hexagonal.

The two important crystalline allotropic form of sulphur are:

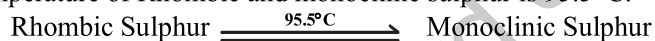
* Rhombic sulphur (α - sulphur)

* Monoclinic sulphur (β - sulphur)

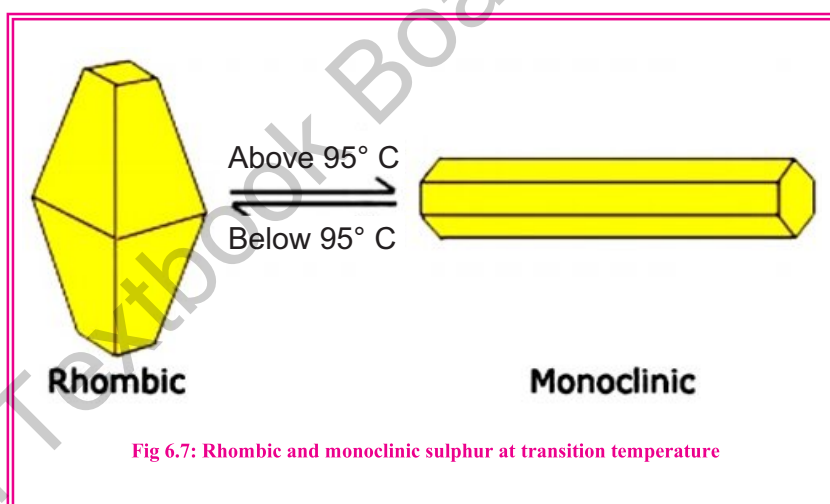
Rhombic sulphur is a yellow octahedral crystalline form. It is stable at ordinary temperature but when heated gently above 95.5°C , it change into monoclinic sulphur

Transition temperature: The temperature at which two allotropic forms of the same element co exist in equilibrium with each other is known as transition temperature.

The transition temperature of Rhombic and monoclinic sulphur is 95.5°C .



This means that just above and below of this specific temperature only one allotropic form can exist.

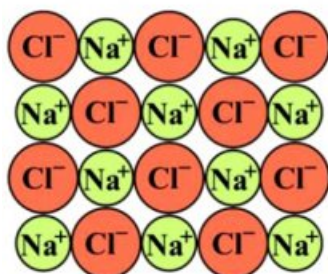


6.4 TYPES OF CRYSTALLINE SOLIDS

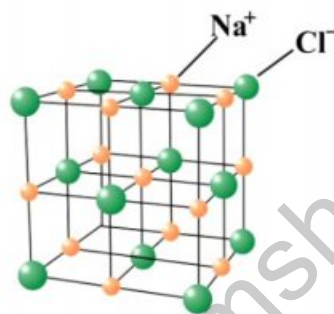
Crystalline solids are classified into following four main categories based on the nature of attractive forces.

6.4.1 Ionic Solids

These solids consist of positive and negative charged ions. The arrangement of these ions in three dimension network takes place in such a way that each ion is surrounded by fixed number of oppositely charged ions so that the strong and long range electrostatic attractions have developed among the ions in all directions.



(a)



(b)

Fig 6.7: (a) Arrangement of ions in sodium chloride crystal (b) crystal lattice of sodium chloride

Some characteristics properties of ionic crystals are described here.

- (i) They are hard at room temperature due to the presence of strong electrostatic forces of attraction.
- (ii) They are brittle and can be shatter easily by hammering.
- (iii) They possess high melting point.
- (iv) They are soluble in water and similar polar solvent.
- (v) They are unable to conduct electricity and heat in solid state because of restricted vibration of ions about their allocated position. In molten or aqueous state they conduct electricity since the ions move freely.

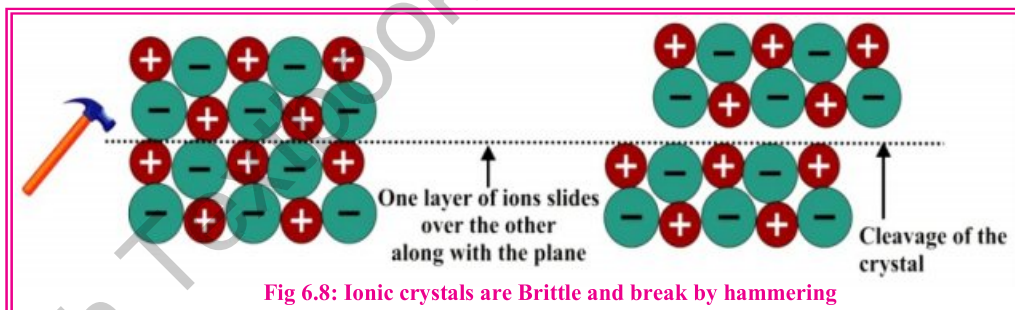


Fig 6.8: Ionic crystals are Brittle and break by hammering

Factors affecting the shape of an Ionic Crystal

Following factors affect the shape of ionic crystal.

i) Ionic Association:

Since the holding force in ionic solids is electrostatic type, the oppositely charge ions are closely packed in specific order to form a particular



Do You Know?

CaCl_2 an ionic solid has the ability to absorb moisture from air due to its hygroscopic and deliquescent nature.

Its rate of moisture absorption is different from day to day depending upon air temperature and humidity.

Therefore it serves as better dehumidifier than silica gel.



shape. For example in the crystal of common salt, each Na^+ ion is covered up with six Cl^- ions. Similarly each Cl^- ion is surrounding by six Na^+ ion this arrangement give a cubic shape.

ii) Radius Ratio:

It is the ratio of radius of cation to that of radius of anion (r^+ / r^-) in the given ionic solid. It helps in predicting the shape of ionic solid.

$$\text{Radius ratio} = \frac{\text{radius of cation}}{\text{radius of anion}}$$

Limiting Radius ratio (r^+ / r^-)	Coordination No.	Geometry	Examples
0.15 to 0.22	3	Triangular planar	B_2O_3
0.225 to 0.414	4	Tetrahedral	ZnS , CuCl
0.414 to 0.732	6	Octahedral/Face Centered Cubic	NaCl , MgO
0.732 to 1.00	8	Body Centered Cubic	CsCl

iii) Poor Conductivity

Ionic compound are good conductor of electricity either in fused state or in aqueous solution due to the free movement of ions towards respective electrode when a potential difference is applied.

However, ionic compound exhibit poor conductivity in the solid state which indicates that ions are not free to move, rather they stay in a fixed position ensuring that the ionic crystal has a fixed shape.



Self Assessment

If the radius of Zn^{+2} ion is 0.74 \AA and S^{-2} ion is 1.84 \AA , determine the radius ratio and predict the geometry of ZnS .

6.4.2 Covalent Solids

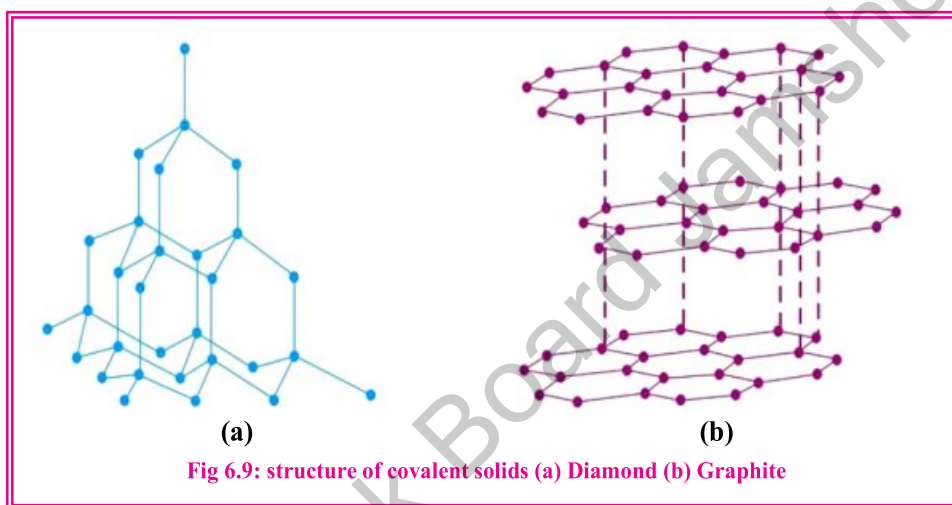
Covalent or atomic solids consist of atoms of the same or different elements which are bonded to each other by strong covalent bonds. A perfect single crystal of a covalent solid is considered as a single giant molecule as seen in diamond and silicon carbide etc.

Carbon exists in two common crystalline form known as diamond and graphite. Both are covalent solids but have different physical properties due to difference in the particles arrangement.



In diamond each carbon atom is covalently bonded with four other carbon atoms at an angle of 109.5° to form basic tetrahedral unit. This trend of covalent bond formation run continuously in the entire crystal three dimensionally and develop a network of covalent bonding which give rise to a giant structure.

Due to the close packing of atoms and large number of covalent bonds, diamond is hardest substance known having a very high melting point.



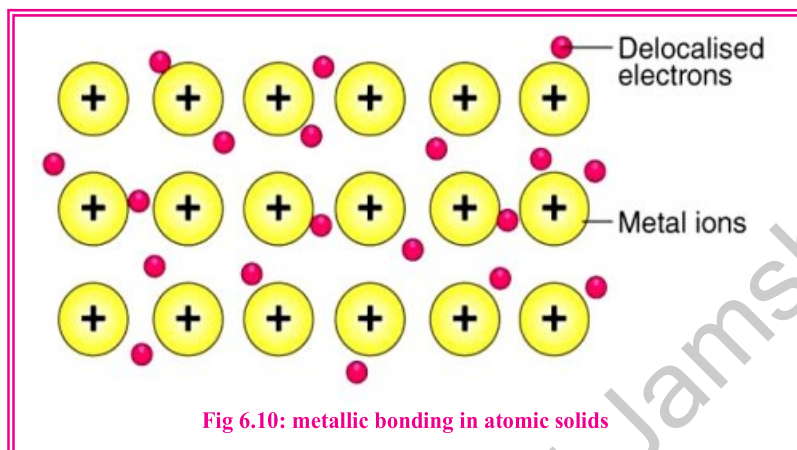
In graphite each carbon is bonded to three other carbon atoms at 120° forming layers of hexagons. These layers are held together by weak Vander Waal forces and are 3.35\AA apart from each other. The greasy nature of graphite is due to inter layer space which allows one layer to glide over the other.

Some characteristics properties of covalent crystals are described below.

- (i) Metallic solids are hard, high melting point and high density due to strong bonding among atoms.
- (ii) They are bad conductor of electricity.
- (iii) They are insoluble in water.
- (iv) Graphite however, conducts electricity parallel to the layers due to the availability of delocalized electrons.

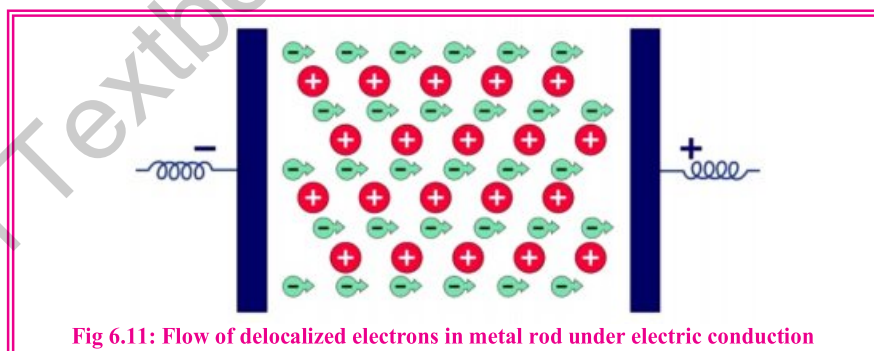
6.4.3 Metallic Solids

Particles of metallic crystals are metal atoms. According to electron sea theory, metal atoms lose their all valence electrons into the vacant spaces and become positively charged metal ions. These positive charged metal ions arranged themselves in a three dimensional crystal lattice and bonded with sea of electrons. This unique force of attraction between metal cations and sea of delocalized electrons is known as metallic bond.



Some characteristics properties of ionic crystals are described below.

- (i) Metallic solids are identified by their malleability and ductility.
- (ii) Metallic solids are looks like dull but when freshly cut, the inner layer appear shiny. This property is known as metallic luster.
- (iii) The electrical conductivity of metallic solids is due to the free movement of delocalized electron in electric field.
- (iv) Metals are good conductor of heat. Thus when a rod of metal is heated from one of its terminal, the free electrons of metal absorb heat and hence their kinetic energy increases. These free electrons then tends move towards the other end of the rod which is relatively cooler.



Self Assessment

- (i) How do metallic and ionic substance differ in conducting electricity.
- (ii) How graphite conduct electricity?



6.4.4 Molecular Solids

In these solids, constituent particles are molecules of the same substance.

The bonding in a particular molecular solid may be one of the following types.

- (i) Dipole – dipole interaction
- (ii) Hydrogen bonding
- (iii) London forces

Since these intermolecular forces are much weaker than attractive forces found in ionic or covalent solids, that is why molecular crystals melt under relatively low temperature compared with ionic or covalent crystals. Molecular solid have low density, low melting point and serves as bad conductor of electricity.

Reason of low density and high heat of fusion of ice

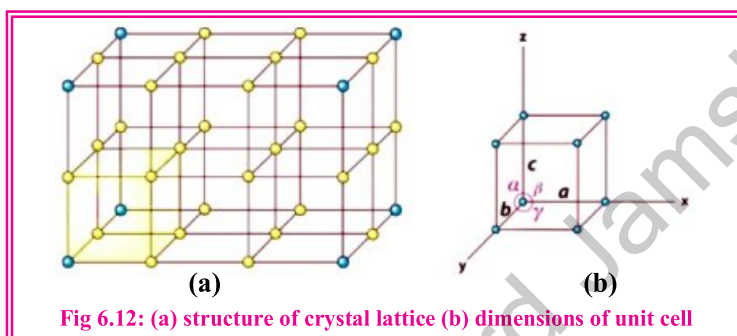
Low density of ice is attributed to the tetrahedral arrangement of H₂O molecules through hydrogen bonding which create empty spaces and causes the structure of ice to expand. The expansion in the volume of ice decreases its density that is why ice float on liquid water. The high latent heat of fusion of ice (97.7 cal/g) is also related to the hydrogen bonding.

Name of Crystalline Solid	Particles Type	Nature of Bond	General Properties	Examples
Ionic Crystals	Cat ion and an ions	Ionic bond	Hard, high m.p Conductor of electricity in molten and aqueous state	NaCl, KBr, CaCl ₂
Covalent Crystals	Atoms	Network of covalent bond	Hard, high m.p Mostly bad conductor of electricity	Silicon carbide, Diamond
Metallic Crystals	Metal cat ion and electron sea	Metallic bond	Hard, high m.p malleable, ductile conductor of electricity	Na, Al, Fe, Cu etc
Molecular Crystals	Molecules	London forces Hydrogen bond Dipole dipole interaction	Soft, low m.p bad conductor of electricity	Ice, Iodine, Dry ice



6.5 CRYSTAL LATTICE

Atoms, ions or molecules in all solids are orderly placed on fixed positions or points in a most adequate manner. A crystal lattice or space lattice is a set of these infinite points representing the particles of crystals in three dimensional space. It is referred as “an array of points representing atoms, ion, or molecules of a crystal placed at three dimensional space.



6.5.1 Unit Cell

The smallest structural part of a crystal lattice is known as unit cell. It shows the 3D pattern of a specific crystal lattice in a least volume and provide us a detailed structural information of a crystalline solid. **“The smallest repeating pattern from which the lattice is built is known as unit cell”**. The unit cells are repeated again and again to make the whole crystal lattice.

The shape of a unit cell is associated with three axial distance named as (a, b and c) and three axial angles named as (α , β and γ). The axial distance (a, b, c) are the distances along three edges (x, y, z). The angle between **b** and **c** is α , the angle between **a** and **c** is β and the angle between **a** and **b** is γ .

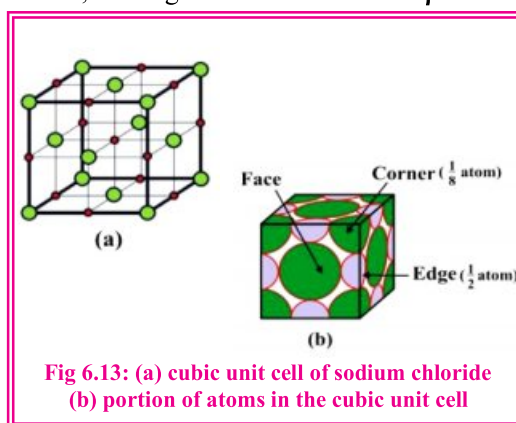
6.5.2 Unit Cell of NaCl Crystal

The structure of sodium chloride crystal is built up by repeating face centered cubic unit cells. In crystallographic view point, each Na^+ ion is covered up with six Cl^- ions; similarly each Cl^- ion is surrounded by six Na^+ ions. This ionic arrangement suggests that the coordination number of sodium chloride crystal is 12.

Do You Know?

There are seven crystal system based on axis (a, b, c) and angle (α , β , γ)

- * Cubic $\rightarrow a = b = c$ and $\alpha = \beta = \gamma = 90^\circ$
- * Tetragonal $\rightarrow a = b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$
- * Orthorhombic $\rightarrow a \neq b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$
- * Rhombohedral $\rightarrow a = b = c$ and $\alpha = \beta = \gamma \neq 90^\circ$
- * Hexagonal $\rightarrow a = b \neq c$ and $\alpha = \beta = 90^\circ$ but $\gamma = 120^\circ$
- * Monoclinic $\rightarrow a \neq b \neq c$ and $\alpha = \gamma = 90^\circ$ but $\beta \neq 90^\circ$
- * Triclinic $\rightarrow a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma \neq 90^\circ$





Chloride (Cl^-) ion determination

Fig 6.10 reveals that eight (8) chloride ions are located at the eight corners of cube while six (6) chloride ions (Cl^-) at the centre of its six faces. On the basis of this information, one can determine the number of Cl^- ions in each unit cell of sodium chloride crystal.

Since each chloride ion (Cl^-) at the corner is shared between eight other unit cells thus, its share to each unit cell should be $\frac{1}{8}$ therefore,

No. of chloride (Cl^-) ions at the corner of one unit cell = $\frac{1}{8} \times 8 = 1$.

On the other hand six faces possess six chloride ions at their centre but each face share with two unit cells therefore.

No. of chloride (Cl^-) ions at face centre = $\frac{1}{2} \times 6 = 3$

Total No. of chloride ions in each unit cell = $1 + 3 = 4$.

Sodium (Na^+) ion determination:

There are 12 edges of cube, each contains one sodium ion (Na^+). Also each Na^+ ion on the edge of cube is shared by four (4) unit cells therefore.

No. of Na^+ ions on each edge = $\frac{1}{4} \times 12 = 3$.

No. of Na^+ ion on the centre of unit cell = 1.

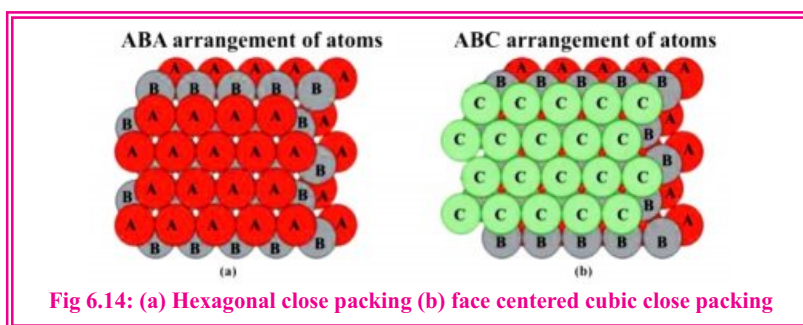
Total Na^+ ion in each unit cell = $3 + 1 = 4$.

Close Packing in Metallic Solids

It is believed that metal atoms are arranged most likely in a tightly packed balls structure which minimize the empty space between them and justifying their high density. There are three types of close packing found in metals.

(i) Hexagonal Close Packing

In this type of packing the empty spaces create due to three neighboring sphere of the first layer is filled by the alignment of spheres of second layer. The spheres of third layer are directly parallel on the sphere of first layer so that an ABA type arrangement is developed which covers the 74% of empty space.





(ii) Face Centered Cubic Close Packing

In this type of packing the void spaces among the spheres of first layer is filled by spheres of second layer; however the spheres of third layer are displaced horizontally from first layer. This gives an ABCA arrangement which covers 74% of empty space.

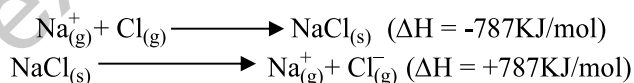
(iii) Body Centered Cubic

This type of packing has relatively big void space. The arrangement of layer is ABAC type which covers up only 68% of empty space.

Type of close packing	Layer arrangement	Coordination number	Space Used
Hexagonal close packing	ABA	12	74
Face centered cubic close packing	ABCA	12	74
Body centered cubic	ABAC	8	68

6.5.3 Lattice Energy

In the formation of ionic solids, oppositely charged gaseous ions brought closer to each other and arranged three dimensionally in certain pattern. During this process a high amount of energy is released known as lattice energy. It is the energy associated with electrostatic interaction between the ions in a crystal and may be defined as **“the quantity of energy released when one mole of the Ionic crystal is formed from the gaseous Ions”**. It is also defined as the energy required to break one mole of crystalline solid into isolated ions in the gas phase. It is expressed in KJ mole⁻¹.



The lattice energy decreases with the increase in the size of cation or anions. The reason in both cases is the same. The smaller the size of cat ion or an ion the closer the packing of oppositely charged ions and thus require high energy to break the lattice and convert the solid into isolated ions. For example lattice energy of NaF (923 KJ/mol) is higher than KF (821 KJ/mol) because of smaller ionic radii of Na⁺ than K⁺ ion. The smaller ionic size of Na⁺ ion makes the packing more closely and thus need relatively high lattice energy for the separation of ions.

Lattice energy also affected by the charge of ion. The greater the charge of ion the higher is the lattice energy. For example lattice energy of BeF₂ (3505 KJ/mol) is much higher than LiF (1036) because Lithium possess +1 charge in LiF where as the charge of Beryllium is +2 in BeF₂.



Table 6.6 Lattice energy values of some ionic solid in KJ/mole

Ionic Solids	Lattice energy KJ/mole	Ionic Solids	Lattice energy KJ/mole
LiF	1036	BeF ₂	3505
NaF	923	BeCl ₂	3020
KF	821	MgCl ₂	2524
LiCl	853	MgBr ₂	440
NaCl	787	CaCl ₂	2258
LiBr	807	CaBr ₂	2176
NaBr	747	AlCl ₃	5492

Lattice energy values are important in predicting the solubility of ionic solids in water. Ionic compounds with smaller Lattice energy and greater hydration energy are more soluble in water. Lattice energy is indirectly determined by the use of Born-Haber cycle. The procedure is based on Hess's Law (see section 11.4).



Society, Technology and Science

Specific use of crystalline and amorphous solid

Many crystalline and amorphous solids have diverse application in current technology and science. For example

- Sodium chloride is used in the manufacturing of various industrial chemicals such as Caustic Soda, Soda Ash, Sodium metal etc. It maintains the electrolyte balance in fluid of our body and also serves as food preservative.
- Graphite due to its slippery nature use as lubricant and in making pencils.
- Polystyrene is foam like amorphous solid. It is used in packaging of food, laboratory wares and sensitive electronic items.



Activity

This activity will let you verify that graphite conducts electricity.

Take a pencil and sharp it from both the sides. Take a metallic wire (of copper for instance) and then connect the two ends of pencil through wire with a battery or cell having a bulb in between as a part of circuit. What will you observe?

You will observe that the bulb will glow as soon as you have closed circuit, it means that the pencil is conducting charges since it contains lead and graphite. The former is a metal while the latter is a non-metal but it still conducts electricity due to the presence of a spare electron in its crystal lattice.



SUMMARY with Key Terms

- ◆ **Solid** is a condensed state of matter in which particles are tightly bonded together due to strong attractive forces.
- ◆ **Crystalline Solids** consist of numerous small building blocks called as crystals. They are identified by sharp melting point, anisotropic behavior and cleavage plane.
- ◆ **Crystal** of each solid has definite geometrical shapes, sharp edges and flat faces.
- ◆ **Amorphous Solids** are those in which particles are not organized in definite lattice pattern but are randomly arranged.
- ◆ **Sublimation** is the phenomenon of direct conversion of solid into gases. This happens due to weak interparticle bonding in sublimable solids.
- ◆ **Anisotropy** describes the behavior of crystalline solids in the variation of certain physical properties like electric conduction and refractive index.
- ◆ **Isomorphism** is the phenomenon in which different solid substances exist in the same crystalline structure.
- ◆ **Polymorphism** is the phenomenon in which a solid substance under different conditions can exist in more than one crystalline shape.
- ◆ **Allotropy** is the phenomenon in which the same element exists in two or more crystal structures.
- ◆ **Transition temperature** is the temperature at which both allotropic forms of the same element co-exist in equilibrium.
- ◆ **Ionic crystals** are hard and brittle because oppositely charged ions are held up through strong attractive forces. Thus on applying external pressure similar ions come in front of each and create repulsive forces.
- ◆ **Diamond** is the hardest substance known because of close packing of atoms and large number of covalent bonds.
- ◆ **Graphite** is a conductor of electricity parallel to the layer because in this direction flow of delocalized electrons is possible.
- ◆ **Metallic solids** are characterized by their malleability, ductility, electrical and thermal conduction.
- ◆ **Crystal Lattice of sodium chloride** is made up of a face-centered cubic cell in which eight Cl^- ions are located at eight corners and one Cl^- ion is located at the centre of each face. On the other hand 12 Na^+ ions are located at the edge and one Na^+ ion on the centre. However total number of Na^+ and Cl^- ions in each unit cell are ($\text{Na}^+ = 4$ and $\text{Cl}^- = 4$)
- ◆ **Lattice energy** is the energy released when one mole of ionic crystal is formed from isolated gaseous ions.



EXERCISE

Multiple Choice Questions

1. Choose the correct answer

- (i) Quantity of energy released when 1 mole of the ionic crystal is formed from the gaseous ions is called:
- (a) Bond energy (b) Potential energy
(c) Ionization energy (d) Lattice energy
- (ii) Graphite can conduct electricity in one direction only. With this behavior, it is said to be:
- (a) Amorphous (b) Symmetrical
(c) Anisotropic (d) Polymorphous
- (iii) NaCl and MgO are isomorphous solids because these have same:
- (a) Melting point (b) Boiling point
(c) Geometrical shapes (d) Chemical Properties
- (iv) The temperature at which two allotropic forms co-exist in equilibrium is called as:
- (a) Melting temperature (b) Fusion temperature
(c) Transition temperature (d) Critical temperature
- (v) Diamond is the example of:
- (a) Ionic solid (b) Covalent solid
(c) Metallic solid (d) Molecular solid
- (vi) Ice is a molecular solid, the intermolecular force of attraction among its molecules are:
- (a) Ionic bond (b) Covalent bond
(c) Metallic bond (d) Hydrogen bond
- (vii) If all three axes in unit cell are of different length but all angles are of 90° then it is identified as:
- (a) Orthorhombic system (b) Cubic system
(c) Tetragonal system (d) Hexagonal system
- (viii) In NaCl, each Na^+ ion is surrounded by Cl^- ions in the numbers:
- (a) Four (b) Three
(c) Six (d) Seven
- (ix) It is an example of crystalline solid:
- (a) Alum (b) Glass
(c) Plastic (d) Rubber
- (x) Each unit cell of sodium chloride consists of:
- (a) Eight Na^+ and Eight Cl^- ions (b) Two Na^+ and Two Cl^- ions
(c) Four Na^+ and Four Cl^- ions (d) Four Na^+ and Six Cl^- ions



Short Questions

1. Define the following terms:
* Allotropy * Sublimation * Melting point * Unit cell
2. Define anisotropy. Which type of solids have this property?
3. What is Transition temperature? Explain with examples.
4. Explain why diamond is non-conductor of electricity and Graphite is a conductor?
5. Define lattice energy. Explain how it is effected by size and the charge of ion.
6. Differentiate between the following:
(i) Crystalline and amorphous solids (ii) Isomorphism and polymorphism
7. Explain the following with scientific reason.
(i) Why the compressibility of solids is nearly zero?
(ii) Why some solids are sublime in nature?

Descriptive Questions

1. Define unit cell. Draw a diagram to show its axial distances and axial angles.
2. Give four properties of ionic solids. How can you determine the number of Na^+ and Cl^- ions in a unit cell of sodium chloride?
3. Give a brief account on metallic solids. Why they conduct heat and electricity?
4. What is meant by polymorphism? How it is related to allotropy. Give your answer with examples.
5. Molecular solids are soft and possess low melting point, how can you justify this statement?