CHEMISTRY

11

CH#4

Liquids And Solids

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Chapter 4
LIQUIDS AND SOLIDS

Intermolecular forces :- The forces which hold the molecules together are called intermolecular forces.
OR The forces which bring the molecules close together and give them specific physical properties are called Inter-molecular forces. They are also called Vander Waal's forces. These forces are much weaker than covalent bond or ionic bond. For example HCl molecules in the neighbourhood (قریب) attract each other.
There are four types of intermolecular forces.

(i) Dipole – dipole forces
(ii) Ion - dipole forces
(iii) Dipole - induced dipole forces
(iv) London Dispersion forces

"Dipole – Dipole forces"

When the polar (قطبی) molecules come close then positive end of one molecule attracts (کشش) negative end of other molecule. It is called dipole-dipole force. It is one percent (1%) strong as effective as a covalent bond.

(vi) Amorphous solid like glass has random structure and indefinite arrangement of particles just like a liquid. When molten glass is cooled, then it does not form crystal lattice. It is not in equilibrium with its solid. It becomes less and less mobile and finally becomes rigid. It is the reason that glass is called super cooled liquid

(vii) Some physical properties of crystals can vary (i.e.) from direction to direction. It is called anisotropy. Cleavage is the breakage of crystal along definite planes. Because cleavage of crystal takes place only in particular direction. It is the reason that cleavage of the crystals is an anisotropic behaviour.

(viii) The process in which two different substances exist in same crystalline form is called isomorphism. It is mostly possible when atomic ratios in two compounds are same for example
NaF and MgO both have atomic ratio of 1:1
$NaNO_3$ and $CaCO_3$ both have atomic ratio of 1:1:3

(ix) The temperature at which two crystalline forms of a substance can co-exist in equilibrium is called transition temperature. The transition temperature is for those elements which show allotropy and for those compounds which show polymorphism.
e.g S_8 (rhombic) $\underset{}{\overset{95.5^\circ C}{\rightleftharpoons}}$ S_8 (monoclinic)

KNO_3 (rhombohedral) $\underset{}{\overset{128.5^\circ C}{\rightleftharpoons}}$ KNO_3 (orthorhombic)

(X) In a hexagonal system, two axes have equal length and third has different length. Two angles are of 90° and third angle is of 120°.
$a = b \neq c$, $\alpha = \beta = 90^\circ$ and $\gamma = 120^\circ$ e.g Graphite.

Q.8. (a) Give different theories of a metallic bond. How does electron sea theory justify the electrical conductivity, thermal conductivity and physical properties of metals?

(b) Explain with the help of a diagram

(i) Cubic close packing in the structure of metals.

(ii) Hexagonal close packing in the structure of metals.

Ans: See page No 163, 164, 165, 167

Q.9. Crystals of salts fracture easily but metals are deformed under stress without fracturing. Explain the difference.

Ans: See page No 171

Q.10. (a) What is the coordination number of an ion? What is the coordination number of the cation in (a) NaCl structure and (b) CsCl structure? Explain the reason for this difference?

Ans: See page No 169

Q11. Give examples of ionic solids, molecular solids and covalent or macromolecular solids. What are the factors which determine whether each of these types of solid will dissolve in water or not?

Ans: See page No 171, 172

Q12 Explain the following with reasons:

(i) Sodium is softer than copper but both are very good electrical conductors.

(ii) Diamond is hard and an electrical insulator.

(iii) Sodium chloride and caesium chloride have different structures.

(iv) Iodine dissolves readily in teterachloromethane.

(v) The vapour pressures of solids are far less than those of liquids.

(vi) Amorphous solid like glass is also called super cooled liquid.

(vii) Cleavage of the crystals is itself anisotropic behaviour.

(viii) The crystals showing isomorphism mostly have the same atomic ratios.

(ix) The transition temperature is shown by elements having allotropic forms and by compounds showing polymorphism.

(x) One of the unit cell angles of hexagonal crystal is 120°.

(xi) The electrical conductivity of the metals decrease by increasing temperature.

(xii) In the closest packing of atoms of metals, only 74% space is occupied.

(xiii) Ionic crystals don't conduct electricity in the solid state.

(xiv) Ionic crystals are highly brittle.

(xv) The type of the unit cell surrounding the negative ion in the ionic crystal lattice depends upon the sizes of the two ions.

(viii) see page No 144

(ix) In Sublimation a substance directly changes into vapours. It is the only process (solid → vapours) On other hand vaporization is two step process. It is the reason that heat of sublimation of a substance is greater than that of heat of vaporization.

(X) Iodine has greater atomic size than other halogens (F_2, Cl_2, Br_2). So it can be easily polarizable. Due to high polarizability Iodine has greater London dispersion forces. It is the reason that [illegible] is very high.

(QUESTIONS OF SOLIDS)

Q.1 Multiple choice questions.

(i) Ionic solids are characterized by

(a) low melting points (b) good conductivity in solid state.
(c) high vapour pressures (d) solubility in polar solvents

(ii) Amorphous solids

(a) have sharp melting points.
(b) undergo clean cleavage when cut with knife.
(c) have perfect arrangement of atoms
(d) can possesses small regions of orderly arrangement of atoms

(iii) The molecules of CO_2 in dry ice form the

(a) ionic crystals (b) covalent crystals
(c) molecular crystals (d) any type of crystal

(iv) Which of the following is a pseudo solid?

(a) CaF (b) Glass (c) NaCl (d) All

(v) Diamond is a bad conductor because

(a) it has a tight structure (b) it has a high density
(c) there are no free electron present in the crystal of diamond to conduct electricity (d) is transparent to light

Ans:- (i) d (ii) d [illegible]

Q.2. Fill in the blanks.

(i) In a crystal lattice, the number of nearest neighbours to each atom is called the_____.

(ii) There are _____ Bravis lattices and _____ crystal systems.

(iii) A pseudo solid is regarded as _____ liquid.

[illegible] insulated vessel [illegible] of liquid causes cooling. But [illegible] into liquid from surrounding [illegible]. It is the reason that the temperature [illegible] falls below that of surrounding.

Q12. [illegible] the following [illegible]ated prope[illegible]

(i) [illegible]

(ii) [illegible] hydrogen bonding in proteins

(iii) [illegible] of ice and its lesser density than liquid water

(iv) Solubilities of [illegible]

Answer: [illegible] 131, 134, 135

Q13. What [illegible] their uses in daily life.

Answer: [illegible]

Q14. [illegible]

(i) [illegible]

(ii) [illegible] temperatures.

(iii) [illegible] heat

(iv) [illegible]

(v) [illegible] the fan after bath.

(vi) [illegible] during evaporation of a liquid [illegible] constant temperature

(vii) The [illegible] at Murree hills and at Mount [illegible]

(viii) [illegible] avoid decomposition of a [illegible]

(ix) [illegible] is greater than that of heat of [illegible]

(x) [illegible] is very high as compared to other [illegible]

Answer: (i) [illegible]

(i) [illegible] process. It takes place at [illegible] when high energy molecules [illegible] the surface of liquid, they escape out [illegible] increasing temperature, [illegible] increases. Hence rate

...sponsible for keeping the particles
...elements and compounds and their effect
...ss making use of the data below:

	Molar Mass (in m.u)	M.P (°C)
	20	-248
	40	-189
H_2O	18	0
	12	993
	12	3350

...a noble gas. It has very ... thus it has the least ... °C

... a noble gas. It has very ... dispersion forces. But it has high ... than that of neon. So its melting ... (-189°C) than neon (-248°C)

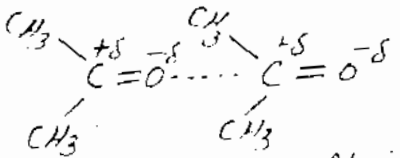
... hydrogen bonding. Due to strong ... melting point of ice (water)

Sodium fluoride :- Sodium fluoride has ionic bond ... and negative) ions are strongly ... forces. It is the reason that ... point of NaF is very high

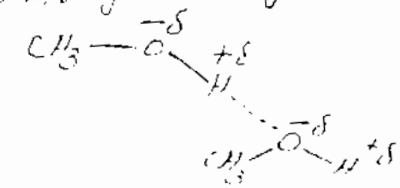
Diamond :- In diamond there is sp^3 hybridization. ... carbon is bonded with four other carbon ... network structure is formed. From ... one single unit can not be ... the reason diamond has very high ... (3550°C)

2.9. The boiling points and molar masses of hydrides of some first row ... are given below:

(iv) Propanone (acetone, CH_3COCH_3) has dipole-dipole interactions.



(v) Methanol (CH_3OH) has hydrogen bonding. It is due to high E.N of oxygen



(b) The increasing order of boiling points is

Butane < Propanone < Propanol

The Propanol ($CH_3-CH_2-CH_2-OH$) has hydrogen bonding. So it has maximum boiling point. Propanone has dipole-dipole interaction while butane has no such forces.

Q.5. Explain the following with reasons.

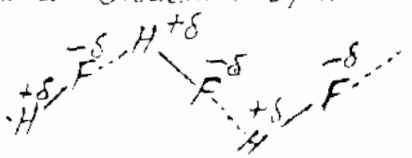
(i) In the hydrogen bonded structure of HF, which is the stronger bond: the shorter covalent bond or the longer hydrogen bond between different molecules.

(ii) In a very cold winter the fish in garden ponds owe their lives to hydrogen bonding?

(iii) Water and ethanol can mix easily and in all proportions.

(iv) The origin of the intermolecular forces in water.

Answer:- (i) The Hydrogen bonded structure of HF is shown in figure. The fluorine has maximum electronegativity. The shorter covalent bond H—F is stronger than longer hydrogen bond H----F



(ii) When winter comes then temperature falls down. The water at 4°C has maximum density. So it goes to the bottom of pond. The surface water freezes into ice. During ice formation the water molecules get

(viii) A layer of ice on the surface of water __the water underneath for further heat loss.

(ix) Evaporation is a _____ process.

(x) Liquid crystals are used in the display of_____ devices.

Ans:- (i) increases (ii) H-bonding (iii) acidic strength (iv) result / goal (v) greater (vi) 5 (vii) increases (viii) insulates or prevents (ix) cooling (x) electrical

Q.3 Indicate true or false as the case may be.

(i) Dipole-dipole forces are weaker than dipole-induced dipole forces.

(ii) The ion dipole interactions are responsible for the dissolution of an ionic substance in water.

(iii) The high polarizability of iodine is responsible for its existence in solid form and its difference from other halogens.

(iv) The strong hydrogen bonding in H_2S makes it different from water.

(v) Hydrocarbons are soluble in water because they are polar compounds

(vi) The viscosities of liquids partially depend upon the extent of hydrogen bonding.

(vii) The state of equilibrium between liquid state and vapours is dynamic in nature.

(viii) Heat of vaporization of liquids depend upon the intermolecular forces of attraction present between their molecules.

(ix) Ice does not show any vapour pressure on its surface at -1 °C.

(x) Boiling point of a liquid is independent of external pressure.

Ans: (i) false (ii) true (iii) true (iv) false (v) false (vi) true (vii) true (viii) true (ix) false (x) false

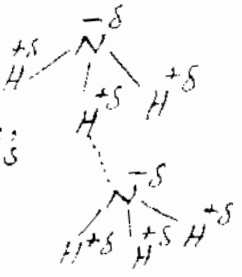
Q.4. (a) What type of intermolecular forces will dominate in the following liquids.

(i) Ammonia, NH_3 (ii) Octane, C_8H_{18} (iii) Argon, Ar (iv) Propanone, CH_3COCH_3 (v) Methanol, CH_3OH

(b) Propanone (CH_3CCCH_3), propanol ($C_3CH_7CH_2OH$) and butane have very similar relative molecular masses. List them in the expected order of increasing boiling points. Explain your answer.

Answer:-

(i) In ammonia (NH_3) hydrogen bonding will dominate. It is due to high E.N of nitrogen



(ii) Octane (C_8H_8) has weak Vander Waal's forces but no hydrogen bonding

(iii) Argon has weak London dispersion forces.

EXAMPLE: The density of LiF is 2.65 g cm^{-3}. It is made up of cubic array of alternate Li^+ and F^- ions and the distance between these ions is 2.01×10^{-8} cm. Calculate the Avogadro number.

Solution:-

Atomic mass of LiF = 6.939 + 18.99 = 25.93 g

Density of LiF = 2.65 g Cm^{-3}

Volume of 1 gram atom of LiF = $\frac{25.93}{2.65}$

= 9.78 Cm^3

Edge length of Cube = $\sqrt[3]{9.78}$

= 2.139 Cm

Distance between two ions = 2.01×10^{-8} Cm

Number of ions in one edge length = $\frac{2.139}{2.01 \times 10^{-8}}$

= 1.064×10^8 ions

Total number of ions in the Cube = $(1.064 \times 10^8)^3$

= 1.204×10^{24}

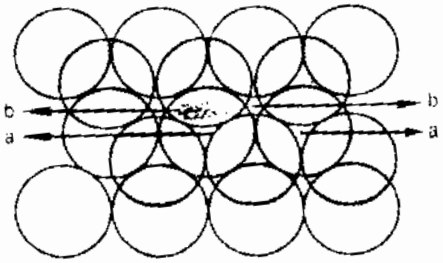
The Cube of LiF contains 1 Avogadro Number of ions. Therefore

Avogadro number = $\frac{1.204 \times 10^{24}}{2}$

= 6.02×10^{23}

The depressions (empty spaces) created by the close packing of atoms are called interstices or crevices or voids.

(d) In fourth case we pack eleven balls in first layer. The balls of the second layer can fit into the interstices created by the first layer. The balls of second layer do not occupy the interstices of first layer completely. Now there are two types of interstices. The interstices of the first layer which remain un-occupied by the second layer. Through these we can see the ground but not balls of first layer. These interstices are marked "b". The new interstices created by the second layer through which we can not see the ground but balls of first layer. These interstices are marked "a".

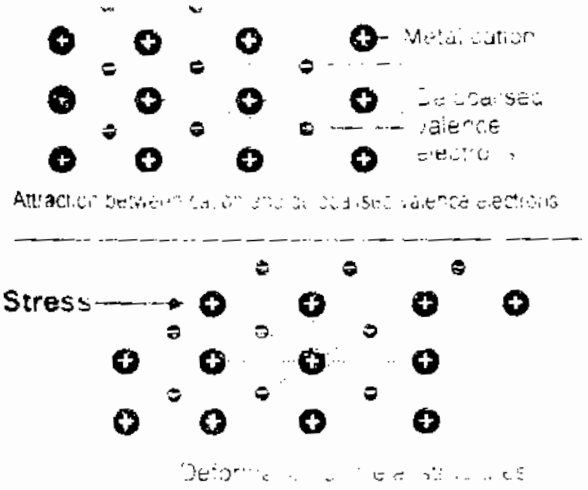


Cubic close packing:- When atoms of third layer fit into the interstices marked "b" then they do not lie directly above the atoms of first layer. This arrangement is called ABCABC------ or 123123------. It gives face centred cubic arrangement. Here atoms of 1st, 4th, 7th and 10th layer will be in front of eachother.

iii) **Shining Surface:-** When a metal piece is cut then its surface becomes shining. It is called metallic luster. When light falls on the surface then mobile electrons are excited. When these excited electrons come back to original position they emit energy in the form of light. This light reflects from surface of metal. Thus metal surface looks shining.

iv) **Malleability and ductility:-**

When stress is applied, then layers of metals slip over eachother. So structure of metals change without fracturing. Thus metals are malleable and ductile. It is the reason that metals can be drawn into sheets and wires. This deformation of metal structure is shown below.

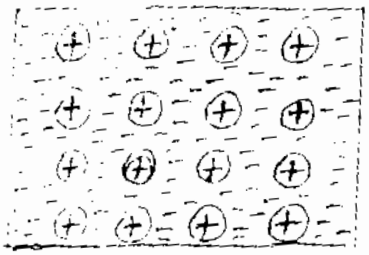


Deformation of metallic crystal

Metallic Solids:- The crystals in which atoms are held together by metallic bond are called metallic solids. e.g Cu, Fe, Ag, Au etc. The metallic bond is explained by following theories. (i) **Electron gas theory**

(Metallic bonding 1st theory was proposed by Drude and extended by Lorentz (1923). It is also called electron pool theory. According to this theory, metals lose all of their valence electrons. These valence electrons form a pool or a gas. The metal positive ions are held together by electron pool or gas.

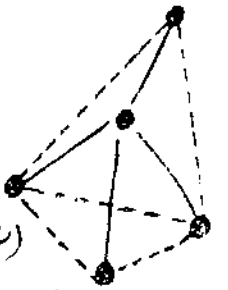
This force which binds a metal cation to a number of electrons is called metallic bond. It is shown in figure.



(ii) **Valence bond theory:-** L. Pauling tried to explain metallic bond by valence bond theory. According to this theory, the metallic bond is essentially a covalent bond. This covalent bond is not localized but it is highly delocalized (resonated among many positions)

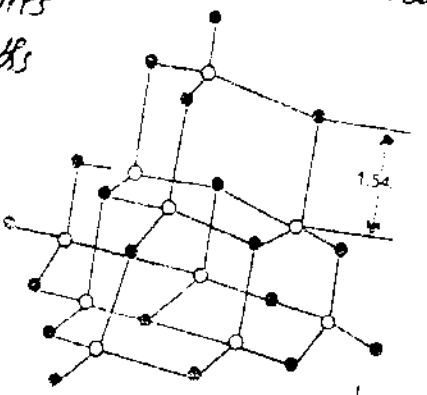
(iii) **Molecular Orbital theory:-** According to this theory electrons in completely filled orbitals are localized and atomic orbitals containing valence electrons overlap to form a set of delocalized orbitals. These delocalized orbitals are called molecular orbitals. A very large number of these molecular orbitals form closely

Structure of Diamond:- There is sp^3-hybridization in diamond. The four atomic orbitals ($2s, 2p_x, 2p_y, 2p_z$) intermix and give four sp^3 hybridized orbitals. These four sp^3-hybrid orbitals are directed along the four corners of tetrahedron. It is the unit cell of diamond. A very large number of such unit cells join and form huge structure.



(a)

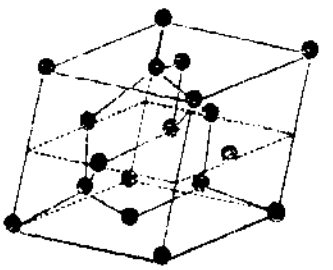
Each carbon atom is bonded with four other carbon atoms. All the bond angles are 109.5° and bond lengths are 154 pm. We may say that a diamond crystal is a huge or giant three dimensional molecule of carbon. This is also called macro-molecule. It is shown in figure (b).



(b)

Structure of diamond

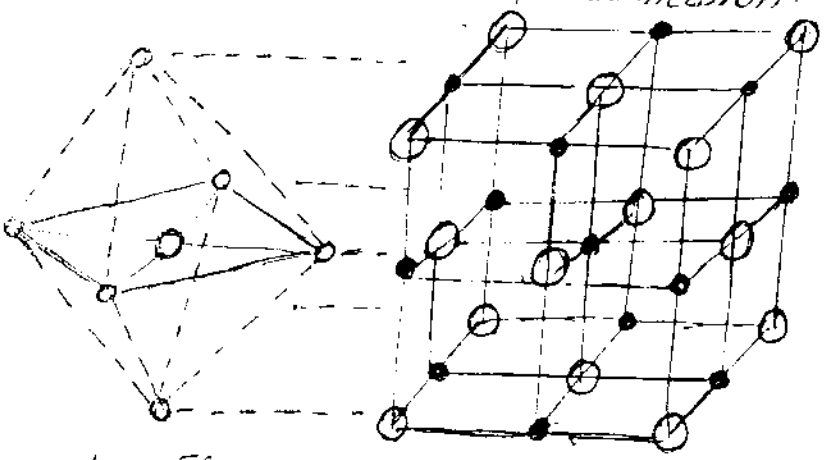
The overall structure of diamond is face centred cubic. It is shown in figure (c)



(c)

Structure of Sodium Chloride

The structure of sodium chloride is face centered cubic (FCC). Each Na^+ or $\bar{C}l$ ion is surrounded by six oppsite ions. So coordination number of Na^+ or $\bar{C}l$ ion is six. The Na^+ ions are placed at six corners of regular octahedron and $\bar{C}l$ ion is placed at the centre of octahedron.



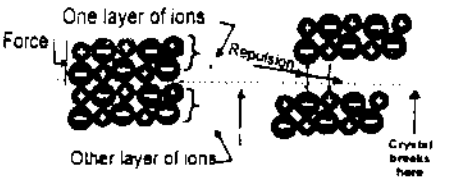
The Na^+ and $\bar{C}l$ ions are not connected to one another by pairs because all chloride ions are at same distance from one Na^+ ion. In NaCl lattice no independent molecules exist. However independent NaCl molecules of NaCl do exist in the vapour phase.

The structure of NaCl tells that eight $\bar{C}l$ ions are present at the corners of cube. Each $\bar{C}l$ ion is shared by eight cubes. Similarly there are six $\bar{C}l$ ions at the face centres and each is shared by two unit cells. Thus number of $\bar{C}l$

Properties of Ionic Solids

(i) Ionic crystals are very stable compounds
(ii) They are very hard with high M.P and B.P
(iii) They never exist in the form of liquids or gases.
(iv) They have low volatility and very high density.
(v) They do not exist in the form of molecules. It is the reason that they have formula mass but no molecular mass.
(vi) They can show isomorphism and polymorphism.
(vii) They give very fast ionic reactions in polar solvents.
(viii) The structure of ionic crystals depend upon the radius ratio of cations and anions. For example NaCl and CsF have same cubic geometry because both have same radius ratio.
(ix) In solid state ionic crystals do not conduct electricity. The reason is that in solid state their ions occupy fixed position and are tightly held due to strong electrostatic attractions.
(x) In solution or in molten state ionic crystals conduct electricity. It is due to free movements of their ions
(xi) Ionic crystals are highly brittle.

The ionic crystals consist of parallel layers of opposite ions. These opposite ions lie over each other. When external force is applied then one layer slides a bit over the other. So like ions come in front of each other. Thus like ions show repulsion. This repulsion of ions causes brittleness.

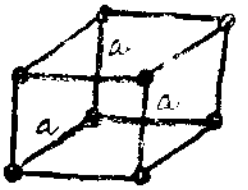


Lattice Energy:- The amount of energy released when one mole of ionic crystal is formed from its

(i) Cubic system:- In this system all three axes are of equal length and all three angles are of 90°.

$a = b = c$, $\alpha = \beta = \gamma = 90°$

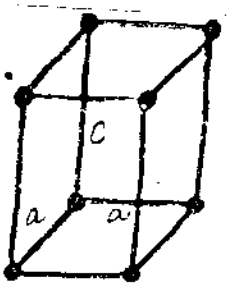
Examples are NaCl, NaBr, Fe, Cu, Ag, Au and diamond.



(ii) Tetragonal system:- In this system two axes are of equal length and third axis may be shorter or larger than the other two. All angles are of 90°.

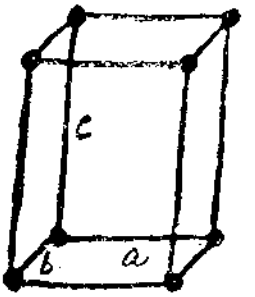
$a = b \neq c$, $\alpha = \beta = \gamma = 90°$

Examples are Sn, SnO_2, MnO_2 and NH_4Br



(iii) Orthorhombic (Rhombic) system:- In this system all three axes are unequal and all three angles are of 90°. ($a \neq b \neq c$, $\alpha = \beta = \gamma = 90°$)

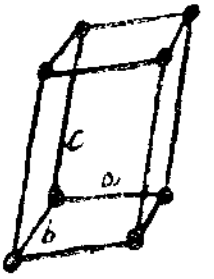
Examples are $BaSO_4$, K_2SO_4, Iodine and rhombic Sulphur etc.



(iv) Monoclinic System:- In this system all three axes are unequal. Two angles are of 90° and third angle is greater than 90°.

$a \neq b \neq c$, $\alpha = \gamma = 90°$, $\beta > 90°$

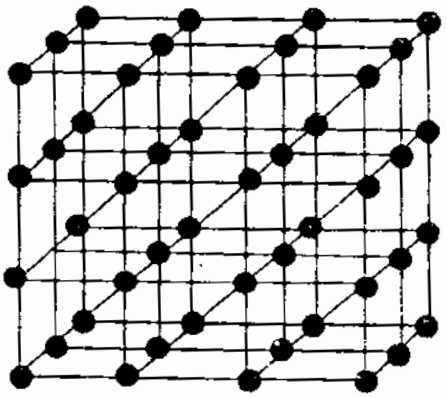
Examples are sugar, monoclinic sulphur, Borax and $Na_2SO_4 \cdot 10H_2O$



(v) Hexagonal.- Two axes are of equal length and third is of different length. Two angles are of 90° and third angle is of 120°.

Crystal Lattice

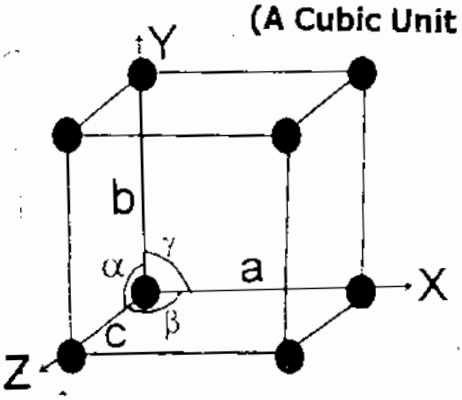
An array of points which represent atoms, ions or molecules of a crystal arranged at different sites in three dimensional space is called crystal lattice It is also called space lattice. A crystal lattice with cubic structure is shown below.



Cubic crystal lattice

Unit Cell:- The smallest part of a crystal lattice which shows all the characteristic features of the entire crystal is called unit cell. OR The smallest block which is repeated again and again to build up the entire crystal is called unit cell.

(A Cubic Unit Cell)



(i) NaF and MgO are cubic (1:1) (ii) Zn and Cd are hexagonal (1:1)
(iii) $NaNO_3$ and KNO_3 are rhombohedral (1:1:3)
(iv) K_2SO_4 and K_2CrO_4 are orthorhombic (2:1:4)
(v) $ZnSO_4$ and $NiSO_4$ are orthorhombic (1:1:4)
(vi) Cu and Ag are cubic (1:1)
The isomorphs have different physical and chemical properties. They can crystallize together in all proportions and give homogeneous mixtures. Moreover isomorphs have same atomic ratios.

(viii) **Polymorphism:-** The process in which a compound exists in more than one crystalline forms is called Polymorphism and substance itself is called Polymorphic. The different crystalline forms of a substance are called polymorphs of eachother. The polymorphs have same chemical properties but different physical properties. For example (i) $CaCO_3$ exists in Trigonal and Orthorhombic forms. (ii) $AgNO_3$ gives rhombohedral and orthorhombic forms. (ix) **Allotropy** (ایلوٹروپی)
The process in which an element exists in more than one crystalline forms is called allotropy and different forms are called allotropes or allotropic forms.

Crystallites:- The crystalline parts of otherwise amorphous solids are called crystallites. It means that amorphous solids have no long range regularity. But it may have small regions of orderly arrangement

The amorphous solids have no sharp melting points. Moreover they have no definite heat of fusion.

Properties of Crystalline Solids

(i) **Geometric Shape:-** The crystalline solids have definite geometrical shapes. Their interfacial angles and interfacial distances are constant due to the arrangement of atoms in three dimensions

(ii) **Melting point:-** The crystalline solids have sharp melting points

(iii) **Cleavage Planes:-** The crystalline solids are broken along definite planes. These planes are called cleavage planes.

(iv) **Anisotropy:-** The physical properties of crystals can vary (i.e.) from direction to direction. It is called anisotropy and crystals are called anisotropic. The refractive index, Cleavage, thermal expansion and electrical conductivity are anisotropic properties For example graphite can conduct electricity parallel to the plane of layers but not

Uses of Liquid Crystals :-

by ΔH_f. The pressure is kept one atmosphere during the change. e.g ΔH_f of ice is 6 Kj mole^{-1}

(iii) **Molar Heat of Vaporization:-** Amount of heat absorbed when one mole of a liquid is changed into vapours at its boiling point is called molar heat of vaporization. It is denoted by ΔH_v. e.g ΔH_v of water is 40.6 Kj mole^{-1}

(iv) **Molar Heat of Sublimation:-** Amount of heat absorbed when one mole of solid sublimes (directly changes into vapours) at particular temperature and one atmospheric pressure is called molar heat of sublimation. It is denoted by ΔH_s e.g ΔH_s of Iodine is 62.2 Kj mole^{-1}

Energy Changes and Intermolecular Attractions

During melting, atoms, ions or molecules show small changes in intermolecular distances and potential energy. But during evaporation larger changes in intermolecular distances and potential energy take place. Hence ΔH_v is larger than ΔH_f. The solids have strong forces of attraction than liquids. So ΔH_s is larger than ΔH_v

By ΔH_v and ΔH_s we can compare intermolecular forces in different compounds. In halogens, iodine has the biggest size and greater polarizability. So it has strong London dispersion forces. It is the reason that iodine has highest ΔH_v among its family members. Similarly Hexane (C_6H_{14}) has large size than methane, Ethane and Propane. So it has strong London forces. Thus it has greater ΔH_v value.

Molar Heat of Vaporization:-

Amount of heat required to vaporize one mole of liquid at its boiling point is called molar heat of vaporization. e.g molar heat of vaporization of water is 40.6 KJ $mole^{-1}$. The ΔH_{vap} of methane is 8.6 KJ $mole^{-1}$. The molar heat of vaporization depends upon intermolecular forces.

"Boiling Point and External Pressure"

The external pressure has direct effect on boiling point. When external pressure is high, the boiling point of liquid increases. For example in Pressure Cooker external pressure increases. The vapours can not escape (go out) from cooker. So they exert more pressure in the cooker. Thus boiling point of water increases and it absorbs (stores) more heat. Hence food cooks more quickly in Pressure Cooker. Similarly when external pressure is low, the boiling point of liquid decreases. For example at Murree Hills external pressure is 700 torr. So water boils at 98°C instead of 100°C.

They exert pressure on Hg level. So Hg level falls in L.H.S of the manometer. The Δh is difference of two Hg levels of manometer. The V.P of liquid is given by following equation

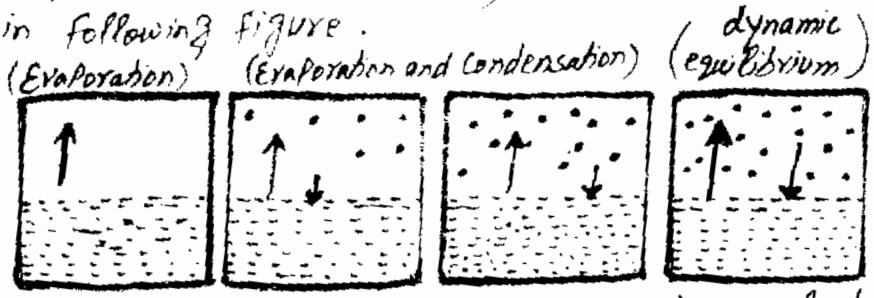
$$P = P_a + \Delta h$$

where P is V.P of liquid
P_a is atmospheric pressure
Δh is difference of two Hg levels

Boiling Point:-

The temperature at which vapour pressure of liquid is equal to external or atmospheric pressure is called boiling point. e.g boiling point of water is 100°C boiling point of ethyl alcohol is 78.3°C when we heat a liquid, then vapours in the interior of liquid have greater internal pressure than atmospheric pressure. Thus these vapours come out of the liquid in the form of bubbles These bubbles of vapours burst (उबलना) on the surface of liquid and we observe boiling. It is in the form of constant stream of bubbles coming out.

Let us suppose a liquid in a closed vessel. The vapours can not go out but they gather above the surface. These vapours can collide back with liquid surface and rejoin it. This process is called condensation. So in a closed vessel two processes (evaporation and condensation) continue. It is shown in following figure.



After some time rate of evaporation is equal to rate of condensation. It is called state of dynamic equilibrium

$$\text{Liquid} \rightleftharpoons \text{Vapours}$$

At equilibrium state, the pressure exerted by the vapours is called vapour pressure.

The vapour pressure depends upon (i) nature of liquid (ii) Temperature and (iii) Intermolecular forces.

At high temperature, the K.E of molecules is high so intermolecular forces break down and molecules easily leave the surface. Thus V.P increases with rise of temperature. For example when temperature of water increases from 0°C to 10°C, then V.P increases from 4.579 torr to 9.209 torr. Similarly when temperature of water increases from 90°C to 100°C, then V.P increases from 527.8 torr to 760 torr.

Evaporation:- The spontaneous change of liquid molecules into vapours is called evaporation. for example drying of wet cloth is due to evaporation. The molecules of a liquid are always in motion. The molecules with low kinetic energy move slowly and molecules with high K.E move fastly. When a high energy molecule reaches the surface, it breaks attractions of neighbouring molecules. So it leaves the liquid.

Factors affecting Evaporation:-

Following factors affect evaporation

(i) Surface area (ii) Temperature

(iii) Intermolecular forces

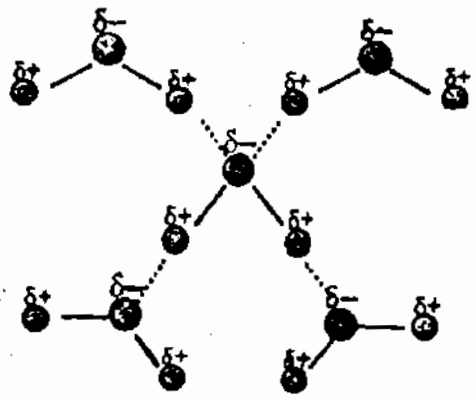
i, Surface area:- If surface area of liquid is increased then more and more molecules will be escaped (evaporated) Thus liquid evaporates more quickly.

(ii) Temperature:- At high temperature the molecules have high K.E and velocity. So they break intermolecular forces. Hence rate of evaporation increases by increase of temperature.

(iii) Intermolecular forces:- When intermolecular forces are weak then rate of evaporation is faster and vice versa (ویسے ہی).

(ix) Structure of liquid water

The structure of water is tetrahedral. The two corners of a tetrahedron are occupied by two H–atoms and other two corners are occupied by two lone pairs of electrons of oxygen. Due to two lone pairs of electrons, each oxygen of water molecule can form two H–bonds with hydrogen atoms of two neighbouring water molecules. In liquid state water molecules are mobile. So H-bonds are broken and reformed again and again. The structure of liquid water is shown below.



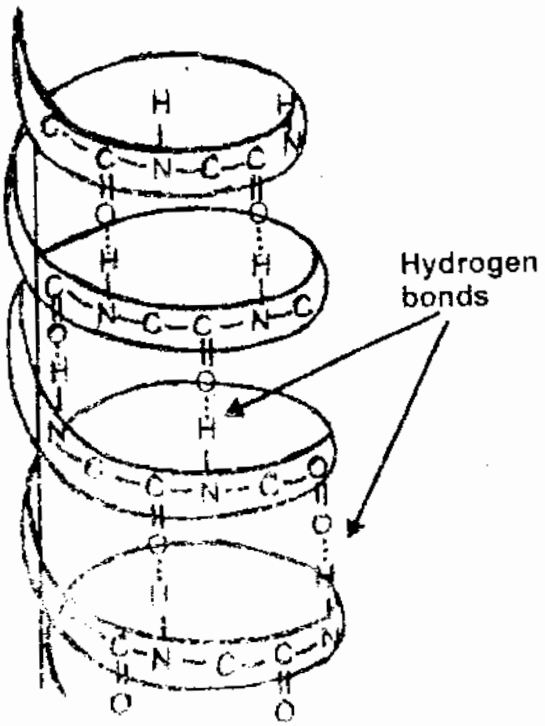
(Structure of liquid water)

(x) Structure of Ice :-

During ice formation the water molecules become more and more regular.

(viii) Biological Compounds

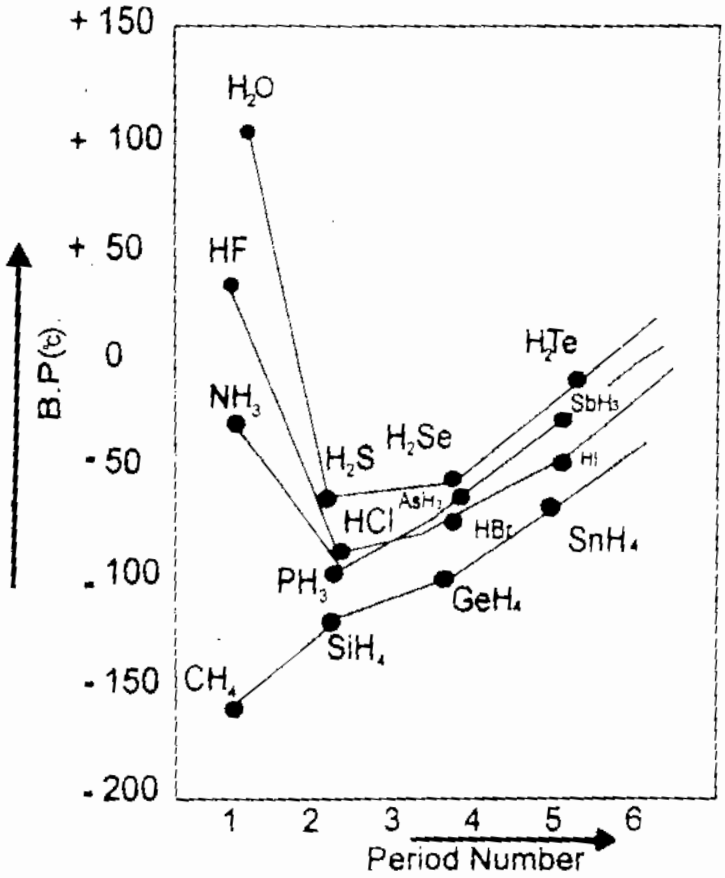
Proteins, amino acids, DNA and carbohydrates are biological compounds. The Protein fibres consist of long chains of amino acids. These long chains of amino acids coil (لپیٹنا) and give spiral like structure. This spiral is called helix. This helix may be right-handed or left-handed. In a right-handed helix the groups $>NH$ and $>C=O$ are vertically linked together by H-bonds. Thus one spiral is linked to another spiral by H-bonds. The H-bonding in Proteins is shown in following figure.



The H-bonding increases their sticky and adhesive properties.

(VIII) Thermodynamic Properties of Covalent Hydrides

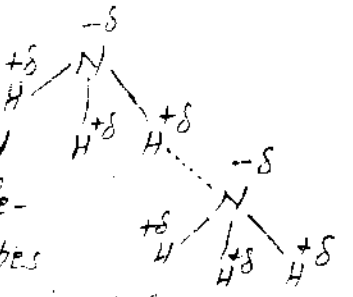
H-bonding affects thermodynamic properties (M.P, B.P) of covalent hydrides. Here we discuss the physical properties of hydrides of the group IV-A, V-A, VI-A and VII-A. We plot graphs between period number and boiling points. They are shown below.



From the graph it is clear that hydrides of group IV-A (CH_4, SiH_4, GeH_4 and SnH_4) have low boiling points the reason is that elements of group IV-A are the least electronegative. In this group CH_4 has the lowest

The hydrogen bonding are in H_2O, NH_3, HF and

The hydrogen bonding in NH_3 is shown in figure. We should know that H-bond is stronger than simple dipole-dipole force. Some properties and applications of H-bond are given below.



Properties (applications) of Hydrogen Bonding

(i) **Acid Strength**:- HF is weaker acid than HCl, HBr and HI. The reason is that molecules of HF are joined with each other by H-bonding. Each H-atom is sandwiched between two highly electronegative atoms. So hydrofluoric acid cannot donate (دینا) H^+ ions easily. Thus HF has low acid strength than HCl, HBr and HI.

(ii) **Solubility**:- Water, Ethyl alcohol (C_2H_5OH) and Carboxylic acids are H bonded molecules. They can form hydrogen bonds with each other. This is the reason that ethyl alcohol and Carboxylic acid (CH_3COOH) are soluble in water. On other hand the

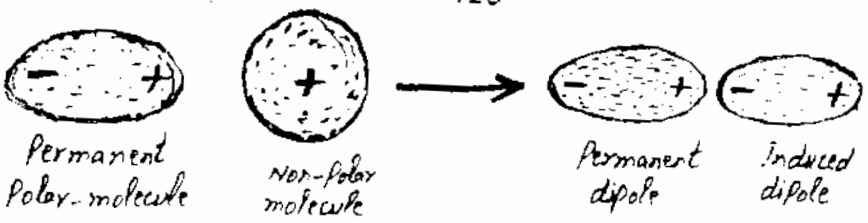
For example in VIIA group of halogens, the fluorine has less polarizability and Iodine has more polarizability. It is the reason that fluorine is a gas with low boiling point and Iodine is a solid at room temperature with high boiling point. The boiling points of halogens are given in the table

Group VIIA (Halogens)
9 F -188.1°C
17 Cl -34.6°C
35 Br 58.8°C
53 I 184.4°C
85 At 337.1°C

(iv) Number of atoms in a molecule

Greater the number of atoms in a non-polar molecule, greater will be the polarizability in the molecule. Thus stronger will be the London forces among the molecules. For example boiling points of saturated hydrocarbons increase with the number of atoms. Ethane (C_2H_6) is a gas with low boiling point and Hexane (C_6H_{14}) is a liquid with high boiling point. The reason is that a long chain molecule has more places where it can be attached to other molecules. The physical state of saturated hydrocarbons change from gaseous to solid and from liquid to solid with increase of molecular mass. The physical state and boiling points of some hydrocarbons are given below:

Methane	Ethane	Propane	Butane	Pentane	Hexane	Decane	Iso-decane
Gas	Gas	Gas	Gas	liquid	Liquid	Liquid	Solid
-161.5°C	-88.6°C	-42°C	0.5°C	36.1°C	68.7°C	174.1°C	327°C



Instantaneous dipole-Induced dipole forces OR London Dispersion forces

The momentary force of attraction created between instantaneous dipole and induced dipole is called dipole-induced dipole force. A German Physicist Fritz London in 1930 explained these forces. It is the reason that they are also called London forces. These forces may be present in polar and non-polar molecules. But they are significant for non-polar molecules (H_2, Cl_2, CH_4, Helium, Neon, Argon etc). Now we see that how these forces are generated. Consider two atoms of helium. When these atoms come close, then the electrons of one atom repel the electrons of other atom. In this way a temporary dipole is produced in the atom. This temporary or instantaneous dipole disturbs electronic cloud of other nearby atom. So a dipole is induced in the second atom. It is called induced dipole. The result is that instantaneous dipole and induced dipole attract eachother by a force. It is called London Force. Because electrons always keep moving, So London forces are short lived forces.

(London Forces between Helium molecules)

Chapter 4
LIQUIDS AND SOLIDS

Intermolecular forces :- The forces which hold the molecules together are called intermolecular forces.

OR The forces which bring the molecules close together and give them specific physical properties are called Inter-molecular forces. They are also called Vander Waal's forces. These forces are much weaker than covalent bond or ionic bond. For example HCl molecules in the neighbourhood (قریب) attract each other. There are four types of intermolecular forces.

(i) Dipole – dipole forces
(ii) Ion - dipole forces
(iii) Dipole - induced dipole forces
(iv) London Dispersion forces

"Dipole – Dipole forces"

When the polar (قطبی) molecules come close then positive end of one molecule attracts (کشش) negative end of other molecule. It is called dipole-dipole force. It is one percent (1%) strong as effective as a covalent bond.

(ii) 6.02×10^{23} molecules of O_2 at S.T.P = 32 g

1 " " " $= \frac{32}{6.02 \times 10^{23}}$ g

10^{20} " " " $= \frac{32 \times 10^{20}}{6.02 \times 10^{23}}$

$= 5.31 \times 10^{-3}$ g

(iii) 6.02×10^{23} molecules of CO_2 at S.T.P = 44 g

1 " " " " $= \frac{44}{6.02 \times 10^{23}}$

10^{20} " " " " $= \frac{44 \times 10^{20}}{6.02 \times 10^{23}}$

$= 7.30 \times 10^{-3}$ g

The mass of these gases does not change when temperature and pressure are changed.

Q24. Two moles of NH_3 are enclosed in a 5 dm^3 flask at 27 °C. Calculate the pressure exerted by the gas assuming that

(i) it behaves like an ideal gas

(ii) it behaves like a real gas

a=4.17 atm dm^6 mol^{-2}

b= 0.0371 dm^3 mol^{-1}

(b) Also calculate the amount of pressure lessened due to forces of attractions at these conditions of volume and temperature.

(c) Do you expect the same decrease in the pressure of two moles of NH_3 having a volume of 40 dm^3 and at temperature of 27 °C.

Solution:- (a) $V = 5 dm^3$, $T = 27^\circ C = 27+273 = 300K$

$n = 2$ moles, $P = ?$

$PV = nRT$ or $P = \frac{nRT}{V} = \frac{2 \times 0.0821 \times 300}{5}$

or $P = 9.85$ atm

(ii) When gas behaves like a real gas.

$V = 5 dm^3$, $T = 27+273 = 300K$, $n = 2$ moles

$a = 4.17$ atm $dm^6 mol^{-2}$, $b = 0.0371 dm^3 mol^{-1}$

Vander Waal's equation is

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

Solution:- Density of gas A = 1.00

(a) Density of gas B = 1.5

Volume of gas A = 150 dm^3

volume of gas B = ?

$$\frac{r_A}{r_B} = \sqrt{\frac{d_B}{d_A}} \quad \text{or} \quad \frac{150}{r_B} = \sqrt{\frac{1.5}{1}}$$

$$\text{or} \quad \left(\frac{150}{r_B}\right)^2 = 1.5 \quad \text{OR} \quad r_B^2 = \frac{(150)^2}{1.5}$$

$$\text{or} \quad r_B^2 = \frac{22500}{1.5} = 15000$$

$$\text{or} \quad r_B = \sqrt{15000} \quad \text{or} \quad r_B = \boxed{122.47\ dm^3}$$

(b) $r_{H_2} = 500\ cm^3/min \quad M_{H_2} = 2$

$r_{O_2} = ? \quad M_{O_2} = 32$

$$\frac{r_{O_2}}{r_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}} \quad \text{or} \quad \frac{r_{O_2}}{500} = \sqrt{\frac{2}{32}}$$

$$\frac{r_{O_2}}{500} = \sqrt{1/16} \quad \text{or} \quad r_{O_2} = 500 \times \frac{1}{4}$$

$$\boxed{r_{O_2} = 125\ cm^3/min}$$

(C) $r_{H_2} = 1, \quad r_A = 0.279$

$M_{H_2} = 2, \quad M_A = ?$

$$r_{H_2}/r_A = \sqrt{M_A/M_{H_2}} \quad \text{or} \quad \frac{1}{0.279} = \sqrt{\frac{M_A}{2}}$$

Squaring both sides $\left(1/0.279\right)^2 = M_A/2$

$$\text{or} \quad \frac{1}{0.0778} = \frac{M_A}{2} \quad \text{or} \quad M_A = \frac{2}{0.0778}$$

$$\text{or} \quad M_A = 25.7\ g\,mol^{-1}$$

Q22. Calculate the number of molecules and the number of atoms in the given amounts of each gas

a. 20 cm^3 of CH_4 at 0 °C and pressure of 700 mm of mercury

b. 1 cm^3 of NH_3 at 100 °C and pressure of 1.5 atm.

(ii) Density of oxygen = ?

$P = 101325\ N m^{-2}$, $T = 273$, $R = 8.31\ J K^{-1} mol^{-1}$

$M = 32\ g\ mol^{-1} = 32 \times 10^{-3}\ kg\ mol^{-1}$

$$d = \frac{PM}{RT} = \frac{101325 \times 32 \times 10^{-3}}{8.31 \times 273}$$

$$d = \boxed{1.428\ kg\ m^{-3}}$$

(iii) Density of Hydrogen = ?

$P = 101325\ N m^{-2}$, $T = 273\ K$

$M = 2\ g\ mol^{-1} = 2 \times 10^{-3}\ kg\ mol^{-1}$

$$d = \frac{PM}{RT} = \frac{101325 \times 2 \times 10^{-3}}{8.31 \times 273}$$

$$d = \boxed{0.089\ kg\ m^{-3}}$$

Q18. A sample of krypton with a volume of 6.25 dm^3, a pressure of 765 torr and a temperature of 20 °C is expanded to a volume of 9.55 dm^3 and a pressure of 375 torr. What will be its final temperature (in °C)?

Solution:- $V_1 = 6.25\ dm^3$, $P_1 = 765$ torr

$T_1 = 20°C + 273 = 293\ K$

$V_2 = 9.55\ dm^3$, $P_2 = 375$ torr

$T_2 = ?$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad \text{or} \quad \frac{765 \times 6.25}{293} = \frac{375 \times 9.55}{T_2}$$

$$\text{or } T_2 = \frac{375 \times 9.55 \times 293}{765 \times 6.25} = 219.5\ K$$

$$\text{or } T_2 = 219.5 - 273 = \boxed{-53.5°C}$$

Q19. Working at a vacuum line, a chemist isolated a gas in a weighing bulb with a volume of 255 cm^3, at a temperature of 25°C and under a pressure in the bulb of 10.0 torr. The gas weighed 12.1 mg. What is the molar

(iii) NH_3 is a polar gas. Its molecules are attracted by [illegible] due to attraction of molecules, it [illegible] ideal behaviour. So molecules moving towards the walls of container are attracted by the neighbouring molecules. It is the reason that actual pressure of NH_3 gas is less than that of calculated one.

(iv) The temperature 273K or 0°C is the freezing point of water at this low temperature the water molecules [illegible]. So their inter-molecular force [illegible]. Thus water vapours show deviation from ideal behaviour. It is the reason that [illegible] water vapours donot behave ideally.

(v) The temperature 273K (0°C) is low. At low temperature the SO_2 has strong inter-molecular forces. It is the reason that at 273K SO_2 behaves non-ideal. On other hand 327°C (600K) is high. At high temperature SO_2 has weak inter-molecular forces. It is the reason that at [illegible] SO_2 behaves ideal.

(d) How do you differentiate between diffusion and effusion? Explain Graham's law of diffusion.

Answer:- see page No. 82 · 83, 84

Q11 (a) What is critical temperature of a gas? What is its importance for liquefaction of gases? Discuss Lind's method of liquefaction of gases.

(b) What is Joule-Thomson effect? Explain its importance in Lind's method of liquefaction of gases.

Answer: (a) see page No. 96, 97 (b) see page No. 97

Q12. (a) What is kinetic molecular theory of gases? Give its postulates.

(b) How does kinetic molecular theory of gases explain the following gas laws:

(i) Boyle's law (ii) Charles's law

(iii) Avogadro's law (iv) Graham's law of diffusion

Answer:- (a) see page No 89 (b) see page No. 92, 93

Q13. (a) Gases show non ideal behaviour at low temperature and high pressure. Explain this with the help of a graph.

(b) Do you think that some of the postulates of kinetic molecular theory of gases are faulty? Point out these postulates.

(c) Hydrogen and helium are ideal at room temperature, but SO_2 and Cl_2 are non-ideal. How will you explain this?

Answer:- (a) see page No 98, 99 (b) see page No 100

(C) ... H_2 and He have small size and low Polarizability. Moreover their boiling points are very low than room temperature. Thus they have no force of attraction. It means H_2 and He are ideal at room temperature. On other hand SO_2 and Cl_2 have greater size, high Polarizability and boiling points close to room temperature. So they have strong intermolecular forces. It is the reason SO_2 and Cl_2 are non-ideal at room temperature.

before reaching $-273.16^{\circ}C$. The lowest possible temperature at which volume of gas should decrease to zero is called absolute zero. It is also called zero of Kelvin scale. Its value is $-273.16^{\circ}C$.

Q6:- What is Kelvin scale of temperature? Plot a graph for one mole of an a real gas to prove that a gas becomes liquid, earlier than -273.16 °C.

(b) Throw some light on the factor 1/273 in Charles's law.

Answer:- (a) see page No 74, 75 (b) see page No 73

Q7. (a) What is the general gas equation? Derive it in various forms.

(b) Can we determine the molecular mass of an unknown gas if we know the pressure, temperature and volume along with the mass of that gas.

(c) How do you justify from general gas equation that increase in temperature or decrease of pressure decreases the density of the gas?

(d) Why do we feel comfortable in expressing the densities of gases in the units of g dm^{-3} rather than g cm^{3} a unit which is used to express the densities of liquids and solids.

Answer:- (a) see page No. 76, 77

(b) yes, by general gas equation we can determine the molecular mass of an unknown gas. The formula used is $PV = \frac{W}{M}RT$

(C):- The density of gas is determined by formula $d = PM/RT$. According to this formula density of gas is directly proportional to pressure and inversly proportional to temperature. So density of gas decreases by decrease of pressure or by increase of temperature.

(d):- The density of a gas is very low as compared

c. At high pressure, the volume of the gas becomes insignificant.

d. At high pressure, the intermolecular attractions become significant

(x) The deviation of a gas from ideal behaviour is maximum at:

a. -10°Cand5.0atm b. -10°Cand2.0atm

c. 100°Cand2.0atm d. 0°Cand2.0atm

(xi) A real gas obeying van der Waal's equation will resemble ideal gas if

a. both 'a' and 'b' are large b. both 'a' and 'b' are small

c. 'a' is small and 'b' is large d. 'a' is large and 'b' is small

Ans:- (i) c (ii) d (iii) a (iv) b (v) a (vi) b (vii) b (viii) a (ix) d (x) a

Q2. Fill in the blanks.

(i) The product PV has the S.I. unit of _____.

(ii) Eight grams each of O_2 and H_2 at 27°C will have total K.E in the ratio of ____ ____.

(iii) Smell of the cooking gas during leakage from a gas cylinder is due to the property of _____ of gases.

(iv) Equal ____ ____ of ideal gases at the same temperature and pressure contain ____ ____ number of molecules.

(v) The temperature above which a substance exists only as a gas is called _____.

Ans (i) Newton. Meter (ii) 1:16 (iii) diffusion (iv) Volume, equal (v) critical temperature

Q3. Label the following sentences as true or false.

(i) Kinetic energy of molecules of a gas is zero at 0°C.

(ii) A gas in a closed container will exert much higher pressure at the bottom due to gravity than at the top.

(iii) Real gases show ideal gas behaviour at low pressure and high temperature.

(iv) Liquefaction of gases involves decrease in inter molecular spaces.

(v) An ideal gas on expansion will show Joule-Thomson effect.

Ans:- (i) false (ii) false (iii) true (iv) false (v) false

Q4. (a) What is Boyle's law of gases? Give its experimental verification.

(b) What are isotherms? What happens to the positions of isotherms when they are plotted at high temperature for a particular gas.

(c) Why do we get a straight line when pressures exerted on a gas are plotted against inverse of volumes? This straight line changes its position in the graph by varying the temperature. Justify it.

(d) How will you explain that the value of the constant k in the equation PV = k depends upon

(i) the temperature of a gas (ii) the quantity of a gas

EXAMPLE(8):- One mole of methane gas is maintained at 300 K. Its volume is 250cm^3. Calculate the pressure exerted by the gas under the following conditions (i) When the gas is ideal (ii) When gas is non ideal.
a= 2.253 atm dm^6 mol^{-2} ; b=0.0428 dm^3 mol^{-1}

Solution:-

(i) $n = 1 \text{ mole}$, $T = 300K$

$V = 250 cm^3 = \frac{250}{1000} = 0.25 dm^3$

$R = 0.0821 \text{ dm}^3 \text{ atm } K^{-1} \text{ mol}^{-1}$

$P = ?$

$PV = nRT$ or $P = \frac{nRT}{V}$

$P = \frac{1 \times 0.0821 \times 300}{0.25}$

$P = \boxed{98.52 \text{ atm}}$

(ii) $n = 1 \text{ mole}$, $T = 300K$

$V = 0.25 dm^3$, $P = ?$

$a = 2.253 \text{ atm dm}^6 \text{ mol}^{-2}$

$b = 0.0428 \text{ dm}^3 \text{ mol}^{-1}$

When gas is non ideal we apply vander Waal's equation.

$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$

$P + \frac{n^2 a}{V^2} = \frac{nRT}{V - nb}$

$P = \frac{nRT}{V - nb} - \frac{n^2 a}{V^2}$

$= \frac{1(0.0821)300}{0.25 - 1(0.0428)} - \frac{(1)^2(2.253)}{(0.25)^2}$

$= \frac{24.63}{0.2072} - \frac{2.253}{0.0625}$

$= 118.8 - 36 = \boxed{82.8 \text{ atm}}$

Types of Plasma :- There are two types of Plasma. They are natural and artificial Plasma. An artificial Plasma can be produced by passing electric current through a gas. It is low temperature Plasma and reacts rapidly with any incoming molecule. The natural Plasma is very hot and its temperature is over 20000°C. It vaporizes any material which touches it.

Characteristics of Plasma :-

(i) Plasma is conductor of electricity.
(ii) Plasma Produces electromagnetic field.
(iii) Plasma as a whole is neutral.
(iv) Plasma has equal number of electrons and ions.
(v) Plasma is a unique, fascinating and complex state of matter.

Where Plasma is found ? Plasma is found everywhere in our universe. It is the most abundant form of matter. It is found in every thing from sun to quark (the smallest particle in universe) All shining stars are made of Plasma. The sun is a 1.5 million Kilometer ball of Plasma. It is heated by nuclear fusion. On our earth Plasma is found in a few places like flames, lightning bolts (بجلی کا کڑکا), fluorescent light and auroras.

are two types of molecules in the gas. A type molecules are striking the walls and B type molecules are pulling them inward. Let C_A and C_B are molar concentrations of A type and B type molecules.

$$P' \propto C_A \cdot C_B$$

or $$P' \propto n/V \cdot n/V$$

or $$P' \propto n^2/V^2$$

or $$P' = a\, n^2/V^2$$

If $n = 1$, then

$$P' = a/V^2$$

Units of a :- we have

$$P' = a\, n^2/V^2$$

or $$a = P' V^2/n^2$$

$$a = \frac{atm\,(dm^3)^2}{(mol)^2} = atm\, dm^6\, mol^{-2}$$

In S.I system

$$a = \frac{N m^{-2} \cdot (m^3)^2}{(mol)^2}$$

$$a = N m^4 \cdot mol^{-2}$$

Units of b :- The b is effective volume of gas. It is also called excluded or incompressible volume Its unit is volume/mole So unit of b is $dm^3 mol^{-1}$ or $m^3 mol^{-1}$

Vander Waal's Equation

A modified (alternative) kinetic equation used to calculate Pressure or Volume of a real gas under non-ideal conditions is called Vander Waal's equation. It is desived as.

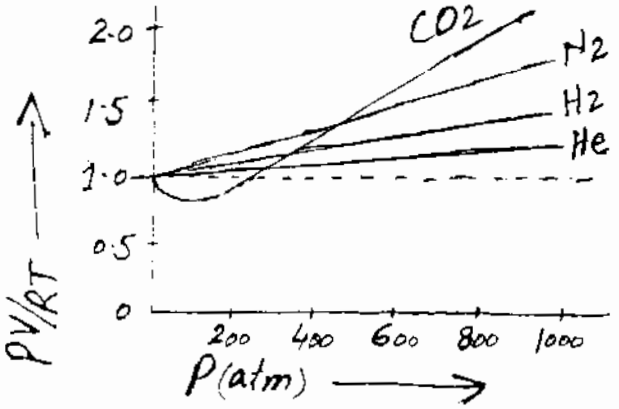
Volume Correction:- Let us suppose a gas in a vessel. Its volume is V. If b is the effective volume of the gas, then

$$V_{free} = V - b \quad \text{——— (1)}$$

where V_{free} is that volume which is available to the gas and b is effective volume of gas. The volume occupied by one mole of a gas in highly compressed state is called effective volume of a gas. It is also called excluded volume of a gas. It is four times of the actual volume. $b = 4V_m$ where V_m is actual volume of one mole of gas. The effective volume "b" is characteristic constant which depends upon size of the gas molecules.

Pressure Correction:- Let us suppose a gas in a vessel. A molecule in the interior of a gas is attracted by other molecules from all sides. A molecule near the walls of vessel can

But at high Pressure all four gases show positive deviation.



The other graph is plotted at 100°C. It tells that at low pressure only CO_2 shows negative deviation and other three gases (H_2, He, N_2) show positive deviation. At high Pressure all four gases show positive deviations. The above discussion gives following results.

(i) Gases are ideal at low Pressure
(ii) Gases are non ideal at high Pressure
(iii) Gases are ideal at high temperature
(iv) Gases are non ideal at low temperature

Compressibility Factor:- The factor $\frac{PV}{RT}$ is called Compressibility factor. Its value is one for an ideal gas. Its value is less or more than 1 for a non ideal gas.

Solution:- (a) $V = 20\,cm^3 = 0.02\,dm^3$

$T = 0^\circ C + 273 = 273K$, $P = \frac{700}{760} = 0.92\,atm$

$PV = nRT$ or $n = PV/RT$

$n = \frac{0.92 \times 0.02}{0.0821 \times 273} = 0.00082$

Number of molecules $= 0.00082 \times 6.02 \times 10^{23}$

$= \boxed{4.9 \times 10^{20}}$

Number of atoms in $CH_4 = 5 \times 4.9 \times 10^{20}$

$= \boxed{2.45 \times 10^{21}}$

(b) $V = 1\,cm^3 = 0.001\,dm^3$

$T = 100^\circ C + 273 = 373K$

$P = 1.5\,atm$, $R = 0.0821\,dm^3\,atm\,K^{-1}$

$PV = nRT$ or $n = PV/RT$

$n = \frac{1.5 \times 0.001}{0.0821 \times 373} = 0.000049$

number of molecules of NH_3 = moles $\times N_A$

$= 0.000049 \times 6.02 \times 10^{23}$

$= 2.9 \times 10^{19}$ molecules

number of atoms $= 4 \times 2.9 \times 10^{19}$

$= 1.16 \times 10^{20}$ atoms

Q23. Calculate the masses of 10^{20} molecules of each of H_2O_2 and CO_2 at STP. What will happen to the masses of these gases, when the temperature of these gases are increased by 100 °C and the pressure is decreased by 100 mm of Hg.

Solution:- 6.02×10^{23} molecules of H_2 at S.T.P $= 2$ g

1 " " " $= 2/6.02 \times 10^{23}$

10^{20} " " " $= \frac{2}{6.02 \times 10^{23}} \times 10^{20}$

$= 0.33 \times 10^{-3}$ g

$= \boxed{3.3 \times 10^{-4}\,g}$

$$\left(P+\frac{n^2a}{V^2}\right)(V-nb)=nRT$$

$$\text{or } \left(P+\frac{2^2(4.17)}{5^2}\right)(5-2(0.037))=2(0.0821)(300)$$

$$\text{or } \left(P+\frac{16.68}{25}\right)(5-0.074)=49.26$$

$$\text{or } (P+0.67)(4.926)=49.26$$

$$\text{or } 4.926P+3.28=49.26 \text{ or } 4.926P=49.26-3.28$$

$$\text{or } 4.926P=45.98 \text{ or } P=\frac{45.98}{4.926}=\boxed{9.33\ atm}$$

(b) Decrease in pressure = ideal pressure − observed pressure

Decrease in pressure = $9.85-9.33=0.52$ atm

(C):-(i) $V=40dm^3$, $T=27+273=300K$, $n=2$

$$PV=nRT \text{ or } P=\frac{nRT}{V}=\frac{2\times0.0821\times300}{40}$$

$$P=1.23115\ atm$$

(ii) When gas behaves real (non-ideal) gas

$$\left(P+\frac{n^2a}{V^2}\right)(V-nb)=nRT$$

$$\left(P+\frac{2^2(4.17)}{40^2}\right)(40-2(0.037))=2(0.0821)(300)$$

$$\left(P+\frac{16.68}{1600}\right)(40-0.074)=49.26$$

$$(P+0.010425)(39.926)=49.26$$

$$39.926P+0.41623=49.26$$

$$39.926P=49.26-0.41623$$

$$39.926P=48.844 \text{ or } P=\frac{48.844}{39.926}$$

$$\text{or } P=1.22335\ atm$$

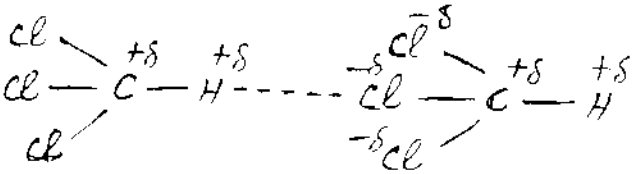
Decrease in pressure $=1.23115-1.22335=0.00780$ atm

So decrease in pressure in both cases is not same

In gases dipole - dipole forces are very weak but in liquids these forces are strong. The molecules of HCl and $CHCl_3$ (Chloroform) have dipole - dipole forces.

(i) $H^{+\delta}—Cl^{-\delta}\cdots\cdots H^{+\delta}—Cl^{-\delta}\cdots\cdots H^{+\delta}—Cl^{-\delta}$

(ii)



These forces affect thermodynamic properties (M.P, B.P, ΔH_{vap}, ΔH_{sub}) of the compounds.

"Dipole - Induced dipole forces"

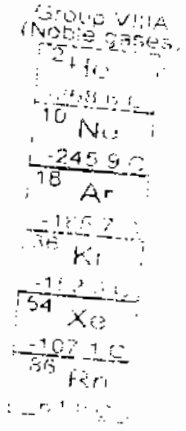
Forces of attraction between permanent polar molecules and non polar molecules are called Dipole-induced dipole forces. When polar and non-polar molecules come close then positive end of polar molecule attracts nearby electrons of non-polar molecule. Thus polarity is induced in non-polar molecule therefore both molecules become dipoles. These forces are called dipole-induced dipole forces or Debye forces. They are shown in figure.

Factors Affecting the London forces

London forces are weaker than dipole-dipole forces. There are many factors which affect London forces. They are given below.

(i) Size of atom or molecule :-

When size of an atom or molecule is large then dispersion (i.e. shift) of electrons is easy. So London forces become stronger. Thus boiling points of noble gases increase down the group from Helium to Radon. It is given in the table



(ii) Atomic number :-

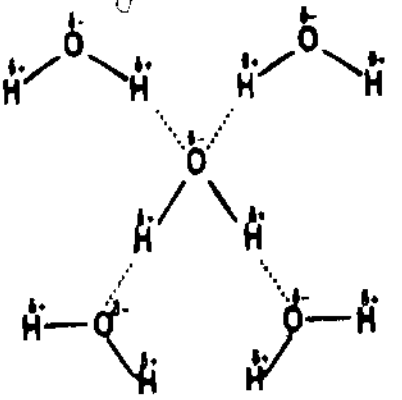
When atomic number increases down a group then outermost electrons move away from the nucleus. So electronic cloud shows ... Therefore London forces become stronger. It is the reason that boiling points of noble gases increase down the group.

(iii) Polarizability :-

The extent to which the electronic cloud of an atom can be distorted is called polarizability. Higher the polarizability of atoms, stronger will be the London forces produced. The polarizability increases with atomic number and size of atoms.

Hydrogen Bonding

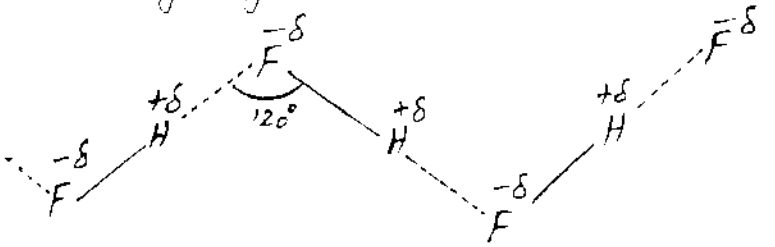
An electrostatic attraction between partial positive hydrogen atom and highly electronegative atom is called hydrogen bonding. It is a weak bond and is denoted by dotted line. For example H-bonding in water is shown in figure



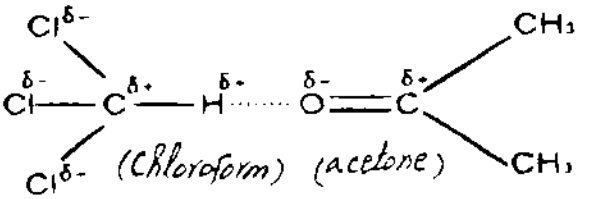
The H-bonding is present in those molecules which have H-atom and highly electronegative atom like F, O and N. The energy required to break H-bonding is 25–33 Kj/mole

The strength of H-bond is twenty times less than that of a covalent bond

The HF molecules are bonded by H-bonding in a zig-zag manner. It is shown below.



The H-bond between chloroform and acetone is shown below



Hydrocarbons are non polar molecules. They can not form H-bonds with water molecules. It is the reason that hydrocarbons are insoluble in water.

(iii) **Cleansing Action:-** The cleansing action of soap and detergent (surf) is due to H-bonding. The soap and detergent have two parts (Polar, non-Polar) The polar part is water soluble due to H-bonding and non-polar part remains outside the water.

(iv) **Clothing:-** Hydrogen bonding is present in thread like (fibres) materials. It increases rigidity (سختی) and tensile strength of thread. It is the reason that we use cotton, silk or synthetic fibres for clothing.

(v) **Food Materials:-**

The food materials like glucose, Fructose and sucrose have —OH groups. This is the reason that they have H-bonding.

(vi) **Paints and dyes:-** The paints, dyes (رنگ) and glue have H-bonding

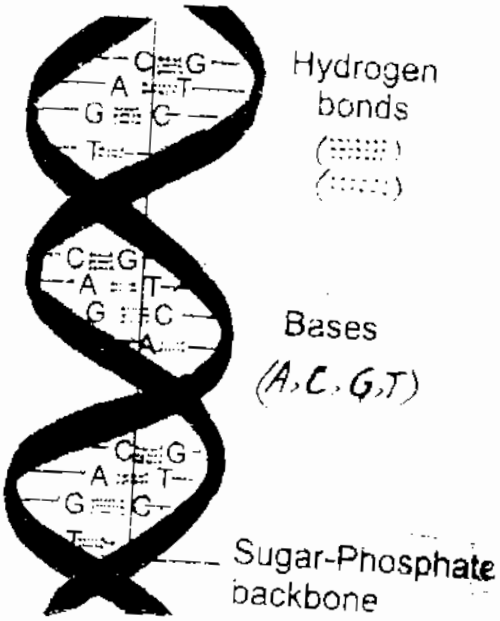
boiling point because of
the least Polarizability. The
are NH_3, PH_3, AsH_3 and
has maximum electronegativity
and other hydrides do not
the reason that boiling point of
that of PH_3, AsH_3 and
VI-A are H_2O, H_2S, H_2Se and
group VII-A are HF, HCl,
hydrides oxygen and
electronegativity. Thus
boiling points in their respective
water is liquid at room
H_2Se are gases.

Boiling Points of H_2O and
Fluorine is more
H-bonding in HF should be
in water. Thus boiling point of
higher than that of water. But
than that of water. The reason is
make only one H-bond and
two H-bonds per molecule due to
of electrons

Boiling Points of HCl and
Chlorine is more E.N than Bromine. It means
that Chlorine can form H-bond. Moreover HCl
has strong dipole-dipole forces. But due to
border line case the boiling
higher than that of HCl.

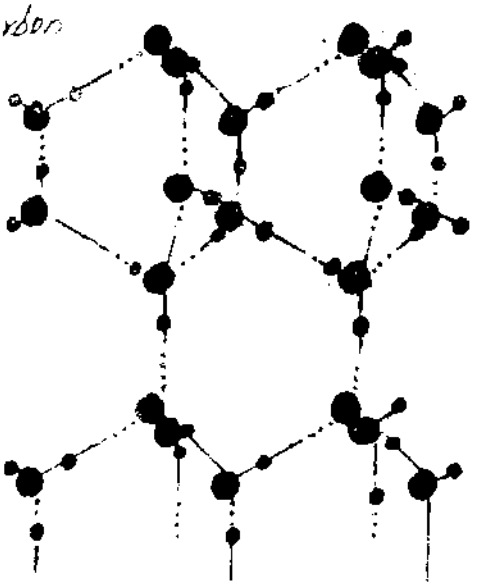
By x-ray analysis it becomes clear that there are average 27 units of amino acids for each turn of the helix.

Deoxyribonucleic acid or DNA is present in living cells. It has two spiral chains. These two spiral chains are coiled about each other on a common axis. In this way double helix structure is formed. Its diameter is 18-20Å. The two spiral chains are linked together by H-bonding. It is shown in following figure.



A DNA molecule contains the bases Adenine, thyamine, Cytocine and guanine. The bases adenine (A) and thyamine (T) form double H-bonds. The bases guanine (G) and cytocine (C) form triple H-bonds

This regularity is present throughout the structure. In this regular structure of ice empty spaces are created. Thus ice occupies 9% more space than the liquid water. So ice has less density and it floats on water. The structure of ice is just like that of diamond. In diamond each carbon atom is in the centre of tetrahedron and in ice each oxygen atom is in the centre of tetrahedron. The structure of ice is shown in figure. During winter, the temperature falls down. At 4°C water has maximum density.



(Structure of ice)

This water goes to the bottom of pond or lake But temperature of surface water falls more and more and it freezes into ice. This ice floats on the surface. Because ice is an insulator of heat, so it prevents underneath water from freezing. Therefore fish, plants and other aquatic animals survive under the blanket of ice.

For example gasoline (پٹرول) evaporates much faster than water. The reason is that gasoline has weak London forces and water has strong intermolecular forces.

Evaporation Causes Cooling:-

Evaporation Causes Cooling. یعنی بخارات ٹھنڈک پیدا کرتے ہیں۔

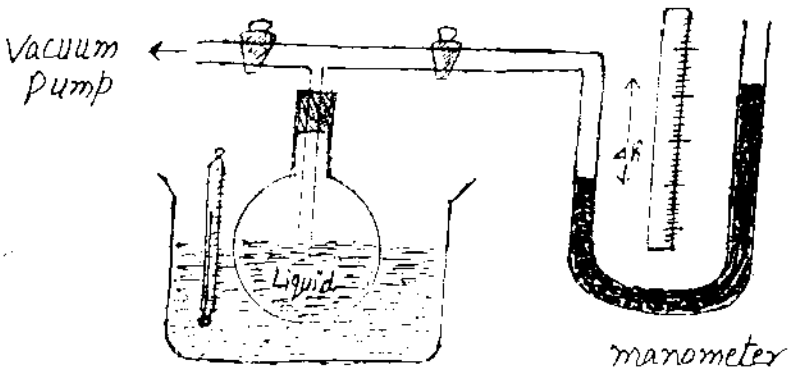
The reason is that during evaporation first of all high energy molecules leave the liquid and low energy molecules are left behind. So temperature of the liquid falls and cooling is produced. To continue the evaporation heat moves from surrounding to the liquid. Thus temperature of surrounding also falls. For example when we put spirit on our hands then spirit evaporates and hand feels cooling.

Vapour Pressure

The Pressure exerted by (of) the vapours in equilibrium with its liquid at given temperature is called Vapour Pressure of liquid. e.g vapour pressure of water is 24 torr at 25°C. The V.P does not depend upon amounts of liquid. It also does not depend on surface area of liquid.

Measurement of Vapour Pressure

There are many methods for measurement of vapour pressure. Here we explain the manometric method. The liquid is taken in flask. The flask is placed in thermostat to keep the temperature constant. The flask is connected to manometer and vacuum pump. It is shown in figure.



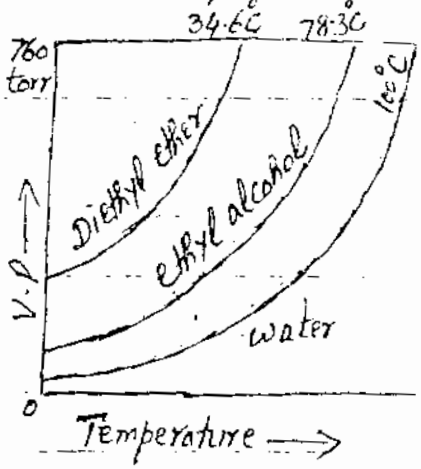
The air in the flask is removed by vacuum pump. But there is some dissolved air in the liquid. The liquid in flask is frozen and melted to release the air. The freezing and melting of liquid is done for many times to release out the air. In this way flask is evacuated Now the liquid is heated at required temperature. The vapours go to manometer

At boiling point Temperature remains Constant

When a liquid is heated, the K.E of its molecules increases. So the temperature of liquid also increases. But at boiling point the heat is only used to break the intermolecular forces. Thus more and more vapours are formed and there is no increase in K.E of molecules at boiling point. When there is no increase in K.E, the temperature does not increase. Hence at boiling point temperature remains constant.

"Variation of V.P with Temperature"

When we increase the temperature, the V.P of liquid increases. As soon as the V.P of liquid becomes equal to atmospheric pressure (760 torr), then liquid starts boiling. e.g diethyl ether, ethyl alcohol and water boil at 34.6°C, 78.3°C and 100°C. At these Temp their V.P become equal to 760 torr



"Change of State and dynamic Equilibrium

When a change of state occurs بجب then system moves towards dynamic equilibrium A situation (حالت) when two opposite changes are occuring at equal rates is called dynamic equilibrium. All the reversible changes attain the dynamic equilibrium. e.g At 0°C ice and liquid water are in dynamic equilibrium.

ice $\underset{}{\overset{0^\circ C}{\rightleftharpoons}}$ Water

Liquid Crystals:- The turbid liquids with some degree of order are called liquid crystals. The liquid like crystals which exist between melting temperature and clearing temperature are called liquid crystals.

Crystal $\rightleftharpoons$ Liquid crystal $\rightleftharpoons$ Liquid

First of all liquid crystals were discovered in 1888 by Frederick Reinitzer an Austrain botanist. He was studying an organic compound Cholesteryl benzoate. This compound turns milky liquid at 145°C and becomes a clear liquid at 179°C By cooling, the reverse process occurs and liquid crystals are formed. The liquid crystals are composed of long rod like molecules. They have some degree of order. On the basis of ordering, the liquid crystals are of three types.

Crystal is painted on them, they produce blue coloured spots. Thus indication(نشانی) of any problem is easy.

SOLIDS (ٹھوس)

A rigid and hard substance with definite shape and volume is called solid.
e.g NaCl, sugar, glass etc

Types of Solids

There are two types of solids

(i) **Crystalline Solids:-** The solids in which atoms, ions or molecules have definite three dimensional arrangement are called crystalline solids
e.g NaCl, KNO_3, $CuSO_4 \cdot 5H_2O$

(ii) **Amorphous Solids:-** The solids in which atoms, ions or molecules have indefinite non repeated arrangement are called amorphous solids. e.g Rubber, Plastics glass and glue etc. When a crystalline solid is melted and the molten mass is rapidly cooled then amorphous solid is produced. In this way particles do not find time to rearrange themselves.

perpendicular to the layer. The reason is that in graphite electrons are mobile parallel to the layers.

(V) Symmetry: The repetition of faces, angles or edges when a crystal is rotated by 360° along its axis is called symmetry. The centre of symmetry, plane of symmetry and axis of symmetry are called symmetry elements.

(Vi) Habit of crystal:-

The shape in which a crystal usually grows is called habit of crystal. For example, habit of Sodium Chloride is cubic and that of graphite is hexagonal. The crystals are prepared as follows

(i) Slow cooling of liquid substance

(ii) Cooling of saturated solution

Sometimes new faces appear on crystals. It is called change of habit. It is due to change of conditions. For example NaCl gives needle like crystals when 10% urea is present as impurity.

(Vii) Isomorphism:- The process in which two different substances exist (are) in same crystalline form is called isomorphism and substances are called isomorphs of eachother. Some isomorphs and their atomic ratios are given below.

Carbon, Sulphur, Phosphorous and Tin show allotropy Sulphur has two allotropes (rhombic and monoclinic) Carbon has two allotropes (diamond which is cubic and graphite which is hexagonal). Tin, Sn has two allotropes (Grey tin which is cubic and white tin which is tetragonal.

(X) Transition temperature:-

The temperature at which two or more crystalline forms of the same substance can co-exist in equilibrium with eachother is called transition temperature. At this temperature one crystalline form of a substance changes into another. Above or below the transition temperature only one form exists we should know that transition temperature is always less than the melting point of an element. Examples are given as

$$\text{Sulphur, } S_8 \text{ (rhombic)} \xrightleftharpoons{95.5^\circ C} S_8 \text{ (monoclinic)}$$

$$\text{Grey tin (cubic)} \xrightleftharpoons{13.2^\circ C} \text{White tin (tetragonal)}$$

$$KNO_3 \text{ (orthorhombic)} \xrightleftharpoons{128^\circ C} KNO_3 \text{ (rhombohedral)}$$

$$Na_2SO_4 \cdot 10H_2O \xrightleftharpoons{32.38^\circ C} Na_2SO_4 + 10H_2O$$

(Hydrated form) (anhydrous form)

$$Na_2CO_3 \cdot 10H_2O \xrightleftharpoons{32.02^\circ C} Na_2CO_3 \cdot 7H_2O + 3H_2O$$

A unit cell gives a complete information about crystal structure. There are three unit cell lengths (a, b, c) and three unit cell angles (α, β, γ). These six parameters of the unit cell are called unit cell dimensions or crystallographic elements. The lengths a, b, c are taken along x, y and z-axis respectively. The angle 'α' is between lengths 'b' and 'c'. The angle 'β' is between lengths 'a' and 'c'. The angle 'γ' is between lengths 'a' and 'b'.
The quantitative aspects of a crystal lattice can be deduced from size and shape of the unit cell.

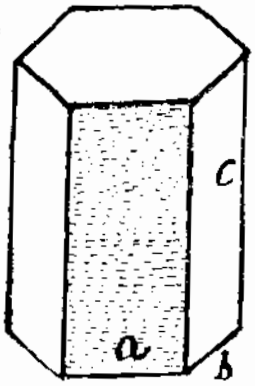
Crystals and their Classification (Crystal Systems)

A group of crystals which have one kind of unit cells is called crystal system. There are totally seven crystal systems. Each crystal system is identified by its unit cell dimensions (a, b, c and α, β, γ). The seven crystal systems are given below.
(i) Cubic system (ii) Tetragonal system
(iii) Orthorhombic system (iv) Monoclinic system
(v) Hexagonal system (vi) Rhombohedral system
(vii) Triclinic system. The description of seven crystal systems is given below.

$a = b \neq c$, $\alpha = \beta = 90^\circ$, $\gamma = 120^\circ$

Examples of hexagonal system are given below

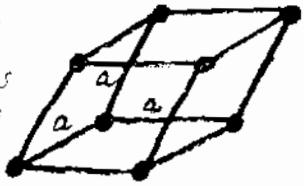
Graphite, Ice, Zn, Cd, CdS and ZnO



(vi) Rhombohedral (Trigonal) System

In this system all three axes are of equal length. All angles are unequal. They are more than 90° and less than 120°

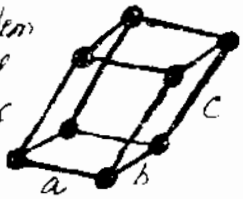
$a = b = c$, $\alpha \neq \beta \neq \gamma > 90^\circ$ and $< 120^\circ$



Examples are KNO_3, $NaNO_3$, Al_2O_3 and Bi

(vii) Triclinic System: - In this system all three axes are unequal and all three angles are unequal and none of them is of 90°.

$a \neq b \neq c$, $\alpha \neq \beta \neq \gamma \neq 90^\circ$



Examples are H_3BO_3, $K_2Cr_2O_7$, $CuSO_4 \cdot 5H_2O$

Classification of Solids: - There are four types of crystalline solids on the basis of bonds (Cohesive forces) They are ionic solids, covalent solids, molecular solids and metallic solids (i) **Ionic Solids**

The crystalline solids formed by ionic bonds between positive and negative ions are called ionic solids. In these solids opposite ions are held together by electrostatic forces of attractions e.g NaCl. KCl

gaseous ions is called lattice energy OR the amount of energy required to break one mole of ionic solid into isolated gaseous ions is called lattice energy. It is expressed in $KJ\,mole^{-1}$. e.g $NaCl_{(s)} \longrightarrow Na^{+}_{(g)} + Cl^{-}_{(g)}$, $\Delta H = -787\,KJ\,mole^{-1}$

$Na^{+}_{(g)} + Cl^{-}_{(g)} \longrightarrow NaCl_{(s)}$, $\Delta H = +787\,KJ\,mole^{-1}$

The lattice energy decreases when size of cation increases and its value increases when size of anion decreases. The reason is that when size of either ion increases, then packing of opposite ions become less and less tight. For example

$NaCl = 787\,KJ\,mole^{-1}$, $NaF = 895\,KJ\,mole^{-1}$, $KCl = 690\,KJ\,mole^{-1}$

Coordination Number of ion

In crystal lattice, the number of nearest neighbours of ions is called coordination number of cation.

e.g Coordination number of Na^{+} ion in NaCl is six because each Na^{+} ion is surrounded by six Cl^{-} ions. The structure of NaCl is face centred cubic (FCC)

The coordination number of Cs^{+} ion in CsCl is eight. The structure of CsCl is body centred cubic (BCC)

The coordination number defends upon radius ratio. Radius ratio = $\frac{\text{radius of cation}}{\text{radius of anion}}$. Higher the radius ratio of cation, higher is the coordination number of cation. In CsCl, radius ratio is higher (0.93) than that in NaCl (0.53). It is the reason that coordination number of Cs^{+} ion is 8 and Na^{+} ion is 6.

ions per unit cell is $\frac{8}{8} + \frac{6}{2} = 1 + 3 = 4$.

Similarly the number of Na^+ ions per unit cell = 4

Therefore there are 4 NaCl units per unit cell. It is necessary to note that the distance between two nearest ions of same kind is 5.63 Å. So distance between two adjacent ions of different kinds is $\frac{5.63}{2} = 2.815$ Å

Covalent Solids:- The solids in which atoms are held together by covalent bonds are called Covalent Solids. e.g diamond, graphite, Silicon-Carbide (SiC) and Aluminium nitride (AlN)

There are two types of covalent solids

(i) The crystals in which atoms join by covalent bonds and give giant molecules. e.g SiC

(ii) The crystals in which atoms join by covalent bonds and give separate layers. e.g graphite, BN and CdI_2

Properties of Covalent Solids:-

(i) Covalent crystals are hard with high melting points.

(ii) They are insoluble in polar solvents like H_2O

(iii) They are soluble in non-polar solvents (CCl_4, benzene)

(iv) Their reactions are very slow.

(v) The Covalent crystals have open structure. The reason is that in Covalent crystals three dimensional bonding gives a network of atoms. So atoms are directed in definite directions. Thus a looser packing of atoms takes place. Hence structure becomes open.

(vi) Covalent crystals are bad conductors of electricity. It is due to absence of free electrons.

(vii) The Covalent crystals with giant molecules (diamond, SiC) are insoluble in all solvents. The reason is that big size molecules do not interact with solvent molecules

Molecular Solids:- The solids in which atoms or molecules are held together by dipole – dipole forces or Vander Waal's forces are called molecular solids. e.g Ice, Sugar, I_2, S, P, C.

Molecular Solids contain two types of molecules

(i) Molecular crystals such as ice and sugar contain Polar molecules

(ii) Molecular crystals such as I_2, O_2, CO_2 and noble gases contain non-Polar molecules.

Properties of molecular solids:-

(i) Molecular solids are soft and easily compressible.

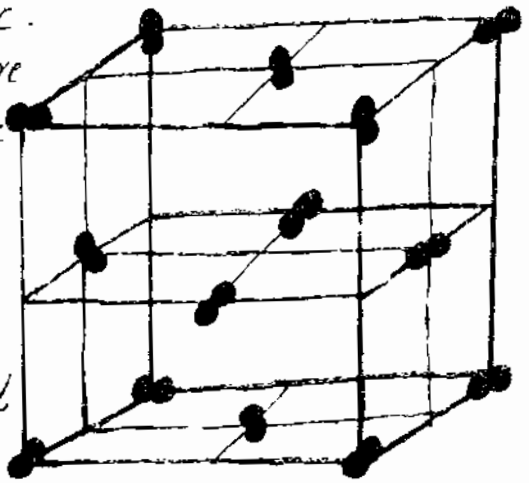
(ii) They have low melting and boiling points.

(iii) They are bad conductors of electricity.

(iv) They are transparent to light.

(v) Polar molecular crystals are soluble in Polar solvents and non-Polar molecular crystals are soluble in non-Polar solvents.

Structure of I_2 crystals:- Iodine is the best example of molecular solids. The structure of Iodine crystal is face centred cubic. The lattice Points are occupied by diatomic I_2 molecules. These molecules further align in form of layer lattice. The I–I bond distance is 271.5 Pm in solid form and 266.6 Pm in gaseous form.

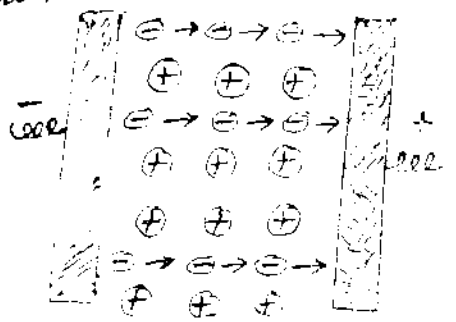


spaced states. These states of energy are called bands of energy. It is the reason that molecular orbital theory is also called band theory.

Properties of metallic crystals:-

(i) **Thermal Conductivity:-** When a piece of metal is heated at one end, then mobile electrons absorb heat energy and move rapidly towards cooler end. Thus they collide with adjacent electrons and transfer their heat to them.

(ii) **Electrical Conductivity:-** Metals are good conductors of electricity. When we apply electric field, then mobile electrons of metals move towards positive plate. Now the new electrons from negative plate take their empty spaces. It is shown below.



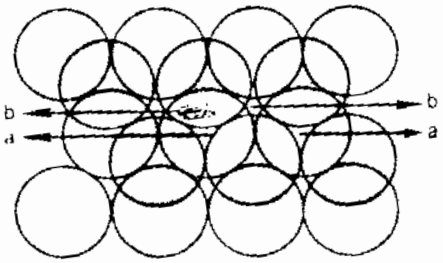
Sometimes electrical conductivity of metals decreases with increase in temperature. The reason is that with increase of temperature metal positive ions begin to oscillate. Thus they hinder free movement of mobile electrons. Therefore electrical conductivity of metals decreases with increase of temperature.

(b)

(c)

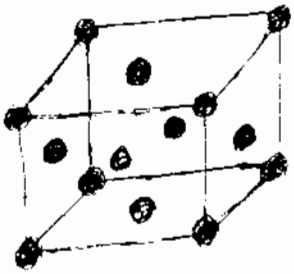
The depressions (empty spaces) created by the close packing of atoms are called interstices or crevices or voids.

(d) In fourth case we pack eleven balls in first layer. The balls of the second layer can fit into the interstices created by the first layer. The balls of second layer do not occupy the interstices of first layer completely. Now there are two types of interstices. The interstices of the first layer which remain un-occupied by the second layer. Through these we can see the ground but not balls of first layer. These interstices are marked "b". The new interstices created by the second layer through which we can not see the ground but balls of first layer. These interstices are marked "a".

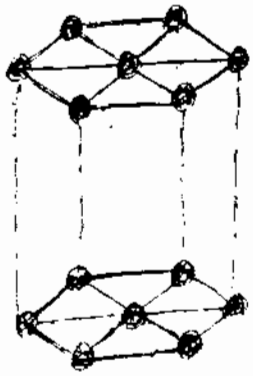


Cubic close packing:- When atoms of third layer fit into the interstices marked "b" then they do not lie directly above the atoms of first layer. This arrangement is called ABCABC------ or 123123------. It gives face centred cubic arrangement. Here atoms of 1st, 4th, 7th and 10th layer will be in front of eachother.

Hexagonal Close Packing:- When the atoms of third layer fit into interstices of type "a", then they directly lie above the atoms of first layer. This arrangement is called ABAB..... or 1212..... It gives hexagonal close packing. Here atoms of first, third, fifth and seventh layers will be in front of each other.



Face centred cubic (FCC)



Hexagonal close Packing

"Determination of Avogadro Number"

We determine Avogadro number by following method. First of all we take a crystalline solid (say NaCl) and find its density (ρ). From density we find volume of one gram atom (mole) of crystal. Then using X-rays we find distance between two atoms of crystal. Let this distance is d. Then by following formula we determine Avogadro number

$N_A = M/2\rho d^3$ where M is molecular mass

EXAMPLE: The density of LiF is 2.65 g cm^{-3}. It is made up of cubic unit cells of Li^+ and F^- ions and the distance between these ions is 2.01×10^{-8} cm. Calculate the Avogadro's number.

Solution:-

Molecular mass of LiF = 6.939 + 18.99 = 25.93 g

Density of LiF = 2.65 g Cm^{-3}

Volume of 1 gram atom of LiF = $\frac{25.93}{2.65}$

= 9.78 Cm^3

Edge length of Cube = $\sqrt[3]{9.78}$

= 2.139 Cm

Distance between two ions = 2.01×10^{-8} Cm

Number of ions in one edge length = $\frac{2.139}{2.01 \times 10^{-8}}$

= 1.064×10^8 ions

Total number of ions in the Cube = $(1.064 \times 10^8)^3$

= 1.204×10^{24}

The Cube of LiF contains Avogadro number of ions. Therefore

Avogadro number = $\frac{1.204 \times 10^{24}}{2}$

= 6.02×10^{23}

EXERCISE

(QUESTIONS OF LIQUIDS)

Q.1. Choose the best answers from the given choices

(i) London dispersion forces are the only forces present among the
a). molecules of water in liquid state
b). atoms of helium in gaseous state at high temperature
c). molecules of solid iodine.
d). molecules of hydrogen chloride gas.

(ii) Acetone and chloroform are soluble in each other due to
(a) intermolecular hydrogen bonding
(b) ion-dipole interaction
(c) instantaneous dipole (d) all of the above

(iii) NH_3 shows a maximum boiling point among the hydrides of group elements due to
(a) very small size of nitrogen
(b) lone pair of electrons present on nitrogen.
(c) enhanced electronegative character of nitrogen
(d) pyramidal structure of NH_3

(iv) When water freezes at 0 °C, its density decreases due to
(a) cubic structure of ice
(b) empty spaces present in the structure of ice
(c) change of bond lengths (d) change of bond angles

(v) In order to mention the boiling point of water at 100 °C the atmospheric pressure should be
(a) between 760 torr and 1200 torr (b) between 200 torr and 760 torr
(c) 765torr (d) any value of pressure

Ans:- i) c (ii) a (iii) c (iv) b (v) a

Q.2 Fill in the blanks with suitable words.

(i) The polarizability of noble gases _____down the group and results in the increase in their boiling points.

(ii) ___ ___ is developed in acetone and chloroform when they are mixed together.

(iii) Exceptionally weak _____of HF is due to strong hydrogen bonding present in it.

(iv) The concept of dynamic equilibrium is the ultimate ___ of reversible systems.

(v) ΔH_v of C_6H_{14} should be _____ than that of C_2H_6

(vi) During the formation of ice from liquid water there is a _____ increase in volume.

(vii) The rate of increase of vapour pressure of water ___ at high temperatures

(viii) A layer of ice on the surface of water __the water underneath for further heat loss.

(ix) Evaporation is a _____ process.

(x) Liquid crystals are used in the display of_____ devices.

Ans:- (i) increases (ii) H-bonding (iii) acidic strength (iv) result / goal (v) greater (vi) δ (vii) increases (viii) insulates or prevents (ix) cooling (x) electrical

Q.3 Indicate true or false as the case may be.

(i) Dipole-dipole forces are weaker than dipole-induced dipole forces.

(ii) The ion dipole interactions are responsible for the dissolution of an ionic substance in water.

(iii) The high polarizability of iodine is responsible for its existence in solid form and its difference from other halogens.

(iv) The strong hydrogen bonding in H_2S makes it different from water

(v) Hydrocarbons are soluble in water because they are polar compounds.

(vi) The viscosities of liquids partially depend upon the extent of hydrogen bonding.

(vii) The state of equilibrium between liquid state and vapours is dynamic in nature.

(viii) Heat of vaporization of liquids depend upon the intermolecular forces of attraction present between their molecules.

(ix) Ice does not show any vapour pressure on its surface at -1 °C.

(x) Boiling point of a liquid is independent of external pressure.

Ans: (i) false (ii) true (iii) true (iv) false (v) false (vi) true (vii) true (viii) true (ix) false (x) false

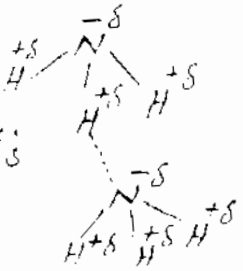
Q.4. (a) What type of intermolecular forces will dominate in the following liquids.

(i) Ammonia, NH_3 (ii) Octane, C_8H_{18} (iii) Argon, Ar (iv) Propanone, CH_3COCH_3 (v) Methanol, CH_3OH

(b) Propanone (CH_3COCH_3), propanol ($C_2CH_5CH_2OH$) and butane have very similar relative molecular masses. List them in the expected order of increasing boiling point. Explain your answer.

Answer:-

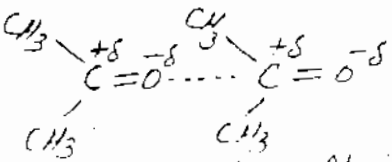
(i) In ammonia (NH_3) hydrogen bonding will dominate. It is due to high E.N of nitrogen



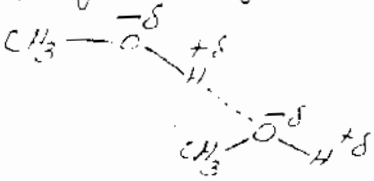
(ii) Octane (C_8H_{18}) has weak vander Waal's forces but no hydrogen bonding

(iii) Argon has weak London dispersion forces.

(iv) Propanone (acetone, CH_3COCH_3) has dipole - dipole interactions.



(v) Methanol (CH_3OH) has hydrogen bonding. It is due to high E.N of oxygen



(b) The increasing order of boiling points is

Butane < Propanone < Propanol

The Propanol ($CH_3-CH_2-CH_2-OH$) has hydrogen bonding. So it has maximum boiling point. Propanone has dipole dipole interaction while butane has no such forces.

Q.5. Explain the following with reasons.

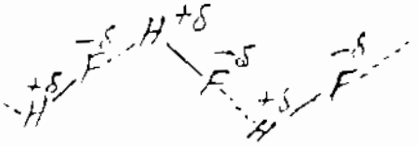
(i) In the hydrogen bonded structure of HF, which is the stronger bond: the shorter covalent bond or the longer hydrogen bond between different molecules.

(ii) In a very cold winter the fish in garden ponds owe their lives to hydrogen bonding?

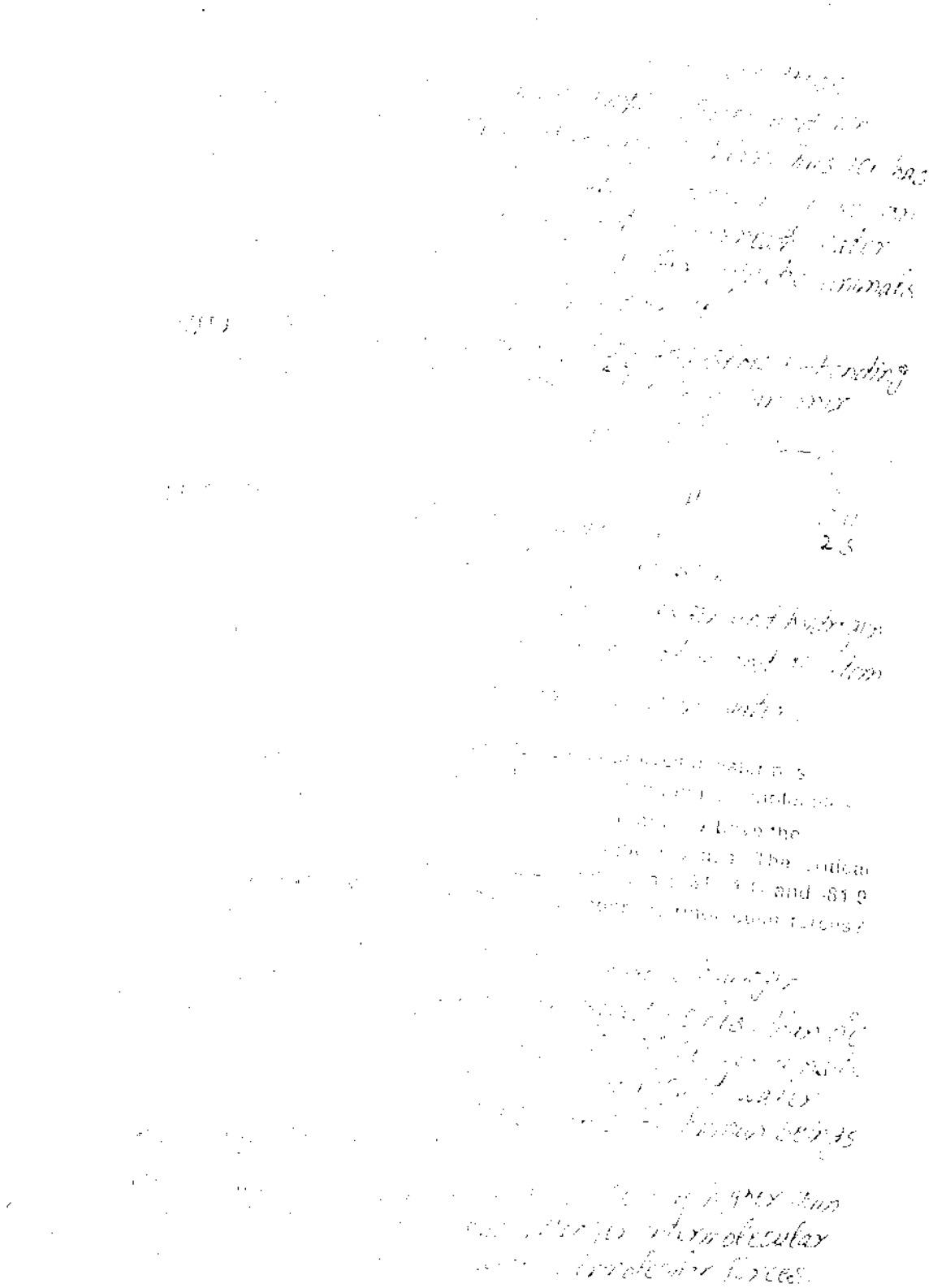
(iii) Water and ethanol can mix easily and in all proportions.

(iv) The origin of the intermolecular forces in water.

Answer:- (i) The Hydrogen bonded structure of HF is shown in figure. The fluorine has maximum electronegativity. The shorter covalent bond H—F is stronger than longer hydrogen bond H·····F



(ii) When winter comes then temperature falls down. The water at 4°C has maximum density. So it goes to the bottom of pond. The surface water freezes into ice. During ice formation the water molecules get



Q.7. Three liquids have the properties mentioned against it in the table.

(i)		Water	Propanone	Pentane
(ii)	Molecular formula	H_2O	C_3H_6O	C_5H_{12}
(iii)	Relative molecular mass (amu)	18	58	72
(iv)	Enthalpy change of vapourization (kJ mol^{-1})	41.1	31.9	27.7
(v)	Boiling Point (°C)	100	56	36

(a) What type of intermolecular force predominates in each liquid?

(i) In water (ii) in propanone (iii) in Pentane

(b) What do you deduce about the relative strength of these forces in the liquids? Justify your conclusions.

(c) If the liquids are shaken together in pairs,

(i) Which pair would be unlikely to mix?

(ii) Explain this immiscibility in terms of the forces between the molecules.

(iii) Choose one of the pairs that mix and say whether the enthalpy change on mixing would be positive or negative.

Answer:- **(a)** Water has hydrogen bonding, Propanone has dipole - dipole interactions and London dispersion forces. Pentane has London dispersion forces.

(b) From boiling points and enthalpies of vaporization of three liquids we deduce that

(i) H-bonding in water is strongest

(ii) Dipole - dipole interactions in Propanone are less.

(iii) London dispersion forces in Pentane are weakest.

(C) (i) :- The pair (water, Pentane) would not mix to mix

(ii) Water is polar molecule and Pentane is non-polar molecule. Or water has H-bonding and Pentane has very weak London dispersion forces. So the pair of liquids is immiscible

(iii) Water and Propanone mix with exothermic because both liquids are polar. So the process of mixing is exothermic process as bonds are formed. So enthalpy change will be negative

...sponsible for keeping the particles
...ments and compounds and their effect
...es making use of the data below:

	Molar Mass (a.m.u)	M.P (°C)
	20	-248
	40	-189
	18	0
	12	993
	12	3350

...is a noble gas. It has very ... forces thus it has the least ... °C

... a noble gas. It has very ... forces. But it has high ... of Neon. So its melting ... (-189°C) than neon (-248°C)

... hydrogen bonding. Due to strong ... boiling point of ice (water)

... Fluoride :- Sodium fluoride has ionic bond ... negative (F^-) ions are strongly ... forces. It is the reason that ... of NaF is very high

Diamond :- In diamond there is sp^3 hybridization ... is bonded with four other carbon ... network structure is formed. From ... a single unit can not be ... the whole diamond has very high ... (3550°C)

Q.5. The boiling points and molar masses of hydrides of some first row ... are given below:

Substance	Boiling Point (K)	Molar Mass (g mol^{-1})
CH_4	109	16
NH_3	240	17
H_2O	373	18

Suggest reasons for the difference in their boiling points in terms of the type of molecules involved and the nature of the forces present between them.

Answer: (i) **CH_4** :- CH_4 is non polar molecule. It has only weak London dispersion forces. It is the reason that CH_4 has very low boiling point (109 K or −164°C)

(ii) **NH_3** :- NH_3 is a polar molecule. It has hydrogen bonding and dipole-dipole interactions. It is the reason that boiling point of NH_3 is high (240 K or −33°C)

(iii) **H_2O** :- H_2O is a polar molecule. It has hydrogen bonding and dipole-dipole interaction. Because oxygen is more electronegative than nitrogen so water has greater hydrogen bonding than ammonia. It is the reason H_2O has higher boiling point (373 K or 100°C)

Q10 Explain the term saturated vapour pressure. Arrange in order of increasing
vapour pressure: 1dm^3 water, 1 dm^3 ethanol, 50cm^3 water, 50 cm^3 ethanol and 50 cm^3 of ether.

Answer: see page No

The order of increasing vapour pressure is

$50cm^3$ ether > $50cm^3$ ethanol = $1dm^3$ ethanol > $1dm^3 H_2O$ = $50cm^3 H_2O$

Q11 While a volatile liquid standing in a breaker evaporates, the temperature of the liquid remains the same as that of its surrounding. If the same liquid is allowed to vapourize into atmosphere in an insulated vessel, its temperature falls below that of its surrounding. Explain the difference in behaviour.

Answer: When a liquid evaporates in a beaker, it causes cooling. Heat flow from surrounding cools the liquid. So it is the reason temperature remains

can ... water ... present in an insulated ... flask ... evaporation of liquid causes cooling. But ... water ... liquid from surrounding due ... insulated wall. It is the reason that the temperature of liquid falls below that of surrounding.

Q12. ... explain the following indicated ...

(i) ... hydrogen bonding in proteins

(ii) ... ice and its lesser density than liquid water

(iv) Solubilities of ...

Answer ... 134, 135

Q13. ... their uses in daily life

Answer ...

Q14. ...

(i) ...

(ii) ... temperatures

(iii) ...

(iv) ...

(v) ... the fan after bath.

(vi) ... abished during evaporation of a liquid ...

(vii) ... at Murree hills and at Mount ...

(viii) ... avoid decomposition of a ...

(ix) ... than that of heat of ...

(x) ... is very high as compared to other ...

Answer ...

(i) ... process. It takes place ... when fast energy molecules ... of liquid, they escape out ... increasing temperature, ... molecules increases. Hence rate

of evaporation increases by increasing the temperature

(iii) When we supply heat to a liquid, K.E. of molecules and rate of evaporation increase. At boiling point the K.E of molecules becomes maximum. Thus heat supplied at boiling point is used to break intermolecular forces. So there is no increase in K.E of molecules. Hence temperature remains constant at boiling point. [illegible] is the reason that boiling point [illegible] heat.

(iv) Earthenware vessels [illegible] them water evaporates from the [illegible]. During evaporation [illegible] from neighbours [illegible] temperature of remaining water [illegible] earthenware pores are [illegible] can not evaporate [illegible].

(V) One feels sense of cooling [illegible] bath. It is due to evaporation process. [illegible] water molecules are present on [illegible]. These molecules get heat from the [illegible] and evaporate. Thus body feels cooling.

(VI) see page No 137

(VII) Atmospheric pressure [illegible] atmospheric pressure [illegible] different at [illegible] places [illegible] pressure is [illegible] reduced and boiling point [illegible]

(viii) See page No 14.

(ix) In sublimation a substance directly changes into vapours. It is the only process (solid → liquid → vapours) On other hand vaporization is a single step process. It is the reason that heat of sublimation of a substance is greater than that of heat of vaporization

(x) Iodine has [illegible] than other halogens (F_2, Cl_2, Br_2). So it has [illegible] solubility. Due to high polarizability Iodine has greater London dispersion forces. It is the reason that [illegible] is very high

(QUESTIONS OF SOLIDS)

Q.1 Multiple choice questions.

(i) Ionic solids are characterized by

(a) low melting points (b) good conductivity in solid state.

(c) high vapour pressures. (d) solubility in polar solvents

(ii) Amorphous solids

(a) have sharp melting points

(b) undergo clean cleavage when cut with knife.

(c) have perfect arrangement of atoms

(d) can possesses small regions of orderly arrangement of atoms.

(iii) The molecules of CO_2 in dry ice form the

(a) ionic crystals (b) covalent crystals

(c) molecular crystals (d) any type of crystal

(iv) Which of the following is a pseudo solid?

(a) CaF (b) Glass (c) NaCl (d) All

(v) Diamond is a bad conductor because

(a) it has a tight structure (b) it has a high density

(c) there are no free electron present in the crystal of diamond to conduct electricity (d) is transparent to light

Ans:- (i) d (ii) d (iii) c (iv) c

Q.2. Fill in the blanks.

(i) In a crystal lattice, the number of nearest neighbours to each atom is called the_____.

(ii) There are _____ Bravais lattices and _____ crystal systems

(iii) A pseudo solid is regarded as _____ liquid

(iv) Glass may begin to crystallize [illegible]

(v) Crystalline solids which [illegible] directions are called_____

(vi) The branch of science which [illegible] crystals is called crystallography.

Ans:- (i) coordination number (ii) 14, (iii) [illegible] (iv) [illegible] (v) properties, isotropic (vi) structure

Q.3. Indicate true / false as the case may be.

(i) There are five parameters in unit cell dimensions of a crystal.

(ii) Ionic crystals are very hard, low volatility, high [illegible] boiling points.

(iii) The value of lattice energy of the ionic substance [illegible] size of ions.

(iv) Molecular orbital theory [illegible]

(v) Ionic solid is good conductor of electricity [illegible]

Ans:- i) false (ii) false (iii) true (iv) true (v) true

Q.4 What are solids? Give general properties of solids, how you differentiate between crystalline solids and [illegible]

Ans: See page No. 148

Q.5 a) Explain the following properties of crystalline solids, give examples in each case.

(i) Anisotropy (vi) Transition temperature

(ii) Cleavage (vii) Symmetry

(iii) Habit of a crystal (viii) Growing of a crystal

(iv) Isomorphism (v) Polymorphism

(b) How polymorphism and allotropy are related to each other? Give examples. [illegible]

Ans: See page No. 150, 151, 152, 153

Q6. (a) Define unit cell. What are unit cell dimensions? How crystal lattice is developed from the concept of unit cell?

b) Explain seven crystal systems and draw their [illegible] cells.

Ans: See page No. 154, 155

Q7. (a) What are ionic solids? Give their properties. Explain the structure of NaCl. Sketch a model to justify that unit cell of NaCl has [illegible]

(b) What are covalent solids? Give their properties. Explain the structure of diamond.

(c) What are molecular crystals? Give their properties. Why molecular crystals are softer than ionic crystals.

Ans: See page No. 156, 160, 162

Q.8. (a) Give different theories of a metallic bond. How does electron sea theory justify the electrical conductivity, thermal conductivity and shiny surfaces of metals?

(b) Explain with the help of a diagram

(i) Cubic close packing in the structure of metals.

(ii) Hexagonal close packing in the structure of metals.

Ans: See page No 163, 164, 165, 167

Q.9. Crystals of salts fracture easily but metals are deformed under stress without fracture. Explain the difference.

Ans: See page No 170

Q.10 What is the coordination number of an ion? What is the coordination number of the cation in (a) NaCl structure and (b) CsCl structure? Explain the reason for this difference?

Ans: See page No 168

Q.11. Give examples of ionic solids, molecular solids and covalent network solids. What are the factors which determine whether each of these types of solid will dissolve in water or not?

Ans: See page No 171, 172, 173

Q.12 Explain the following with reasons:

(i) Sodium is softer than copper, but both are very good electrical conductors.

(ii) Diamond is hard and an electrical insulator.

(iii) Sodium chloride and caesium chloride have different structures.

(iv) Iodine dissolves readily in teterachloromethane.

(v) The vapour pressures of solids are far less than those of liquids.

(vi) Amorphous solid like glass is also called super cooled liquid.

(vii) Cleavage of the crystals is itself anisotropic behaviour.

(viii) The crystals showing isomorphism mostly have the same atomic ratios.

(ix) The transition temperature is shown by elements having allotropic forms and by compounds showing polymorphism.

(x) One of the unit cell angles of hexagonal crystal is 120°.

(xi) The electrical conductivity of the metals decrease by increasing temperature.

(xii) In the closest packing of atoms of metals, only 74% space is occupied.

(xiii) Ionic crystals don't conduct electricity in the solid state.

(xiv) Most crystals are highly brittle.

(xv) The coordination number of the surrounding the negative ion in the ionic crystal lattice depends upon the sizes of the two ions.

ANSWER **(i)** Sodium has one valence electron and Copper has two valence electrons. So more are greater chances for overlapping of orbitals in copper than in sodium. It is the reason that Sodium is softer than copper. Both metals are good conductor of electricity due to movement of free electrons.

(ii) There is sp^3 hybridization in diamond. Each carbon is bonded to four other carbon atoms in tetrahedral way. A very large number of such tetrahedrons join together to form a huge structure. Moreover valence electrons of diamond are tightly held. It is the reason that diamond is hard and electrical insulator.

(iii) The structure of NaCl is face centred cubic. The structure of CsCl is body centred cubic. In NaCl the coordination number of each ion is six. It is due to lower value of radius ratio (0.52). In CsCl the coordination number of each ion is eight. It is due to higher value of radius ratio (0.93).

(iv) We know that "Like dissolves like". Iodine is a non-polar solute and tetrachloromethane (CCl_4) is a non-polar solvent. It is the reason that iodine dissolves readily in tetrachloromethane.

(v) Solids have very strong intermolecular forces and liquids have weak intermolecular forces. Due to strong intermolecular forces, the particles in solids do not move freely. Hence their escaping tendency is far less than liquid particles. It is the reason that vapour pressure of solids is far less than liquids.

(vi) Amorphous solid like glass has random structure i.e. indefinite arrangement of particles just like a liquid. When molten glass is cooled, then it does not form crystal lattice. It is not in equilibrium with its solid. It becomes less and less mobile and finally becomes rigid. It is the reason that glass is called supercooled liquid

(vii) Some Physical properties of crystals can vary (Up) from direction to direction. It is called anisotropy. Cleavage is the breakage of crystal along definite planes. Because cleavage of crystal takes place only in particular direction. It is the reason that cleavage of the crystals is an anisotropic behaviour.

(viii) The process in which two different substances exist in same crystalline form is called isomorphism. It is mostly possible when atomic ratios in two compounds are same for example

NaF and MgO both have atomic ratio of 1:1

$NaNO_3$ and $LaCO_3$ both have atomic ratio of 1:1:3

(ix) The temperature at which two crystalline forms of a substance can co-exist in equilibrium is called transition temperature. The transition temperature is for those elements which show allotropy and for those compounds which show polymorphism.

e.g. S_β (rhombic) $\xrightleftharpoons{95.5^\circ C}$ S_α (Monoclinic)

KNO_3 (rhombohedral) $\xrightleftharpoons{128.5^\circ C}$ KNO_3 (orthorhombic)

(x) In a hexagonal system, two axes have equal length and third has different length. Two angles are of 90° and third angle is of 120°.

$a = b \neq c$, $\alpha = \beta = 90^\circ$ and $\gamma = 120^\circ$ e.g Graphite.

(XII) The electrical conductivity ...
... of conductor ...
... temperature, the metal ...
Thus they ...
The ... electrical conductivity ... decrease with ...
increase of temperature

(XIII) The metal atoms have spherical shape ...
packing is ... the ... are ... and ... of atoms some empty space ... interstices are left ...
... the solid state. The reason is that ... state ... are very ... by ... of ...
... is the reason ...

(XIV) ... is ... Ions ... in front to ... pressure the layers ... ions ... Hence ... the ... of ... ions ...

(XV) ... by a ... called ... when the ... radius ratio = ...
... is six ...

گلدستہ ڈاٹ پی کے کی جانب سے خوش آمدید

السلام علیکم ورحمتہ اللہ وبرکاتہ

مختصر تعارف

کافی عرصہ سے خواہش تھی کہ ایک ایسی ویب سائٹ بناؤں جس پر طالب العلموں کیلئے کچھ تعلیمی مواد جمع کر سکوں۔ اللہ تعالیٰ نے توفیق دی اور میں نے ایک سال کی محنت کے بعد ایک سائٹ "گلدستہ ڈاٹ پی کے" کے نام سے بنائی جو کہ قرآن و حدیث، اصلاحی، دلچسپ، تاریخی قصے واقعات، اُردو انگلش تحریریں، شاعری و اقوال زریں، F.Sc اور B.Sc کے مضامین کے آن لائن نوٹس، اسلامک، تفریحی، معلوماتی وال پیپرز، حمد و نعت، فرقہ واریت سے پاک اسلامی بیانات، پنجابی نظمیں و ترانے اور کمپیوٹر و انٹرنیٹ کی دنیا کے بارے میں ٹپس، آن لائن کمائی کرنے کے مستند طریقہ کار۔ کے ساتھ ساتھ اور بھی بہت سی چیزوں پر مشتمل ہے۔ اور انشاء اللہ میں مزید وقت کے ساتھ ساتھ اضافہ کرتا جاؤں گا۔ آپ کی قیمتی رائے کی ضرورت ہے۔ عرنان شفیق

اہم نوٹ

ذیل میں جو نوٹس مہیا کیے گئے ہیں وہ کئی گھنٹوں کی لگاتار محنت کے مرتب ہوئے ہیں۔ اور آپ کو بالکل مفت مہیا کر رہے کیے جارہے ہیں۔ آپ سے ان کی قیمت صرف اتنی سی متوقع ہے کہ ایک بار **درودّ ابراھیمی** اپنی زبان سے ادا کر دیں۔

درود شریف

بسم اللہ الرحمٰن الرحیم

اَللّٰھُمَّ صَلِّ عَلٰی مُحَمَّدٍ وَّ عَلٰٓی اٰلِ مُحَمَّدٍ کَمَا

اے اللہ! رحمت بھیج حضرت محمد پر اور حضرت محمدؐ کی آل پر

صَلَّیْتَ عَلٰٓی اِبْرَاھِیْمَ وَ عَلٰٓی اٰلِ اِبْرَاھِیْمَ

جس طرح تو نے رحمت بھیجی حضرت ابراھیم پر اور حضرت ابراہیمؑ کی آل پر

اِنَّکَ حَمِیْدٌ مَّجِیْدٌ

بے شک تو تعریف کیا گیا بزرگ ہے۔

اَللّٰھُمَّ بَارِکْ عَلٰی مُحَمَّدٍ وَّ عَلٰٓی اٰلِ مُحَمَّدٍ کَمَا

اے اللہ! برکت دے حضرت محمد کو اور حضرت محمدؐ کی آل کو جس

بَارَکْتَ عَلٰٓی اِبْرَاھِیْمَ وَ عَلٰٓی اٰلِ اِبْرَاھِیْمَ

طرح برکت دی تو نے حضرت ابراھیم کو اور حضرت ابراہیمؑ کی آل کو

اِنَّکَ حَمِیْدٌ مَّجِیْدٌ

بے شک تو تعریف کیا گیا بزرگ ہے۔