

INTRAMOLECULAR FORCES: The forces of attraction between atoms of the same molecule are called INTRAMOLECULAR FORCES. For example in H-Cl there is a covalent bond present between Hydrogen and Chlorine. The outermost shell of both atoms is completed as a result of covalent bond formation. Thus two atoms are strongly held together.

Intramolecular forces are also called bonds. For example (i) Covalent bond (ii) Ionic bond (iii) Co-ordinate Covalent bond.

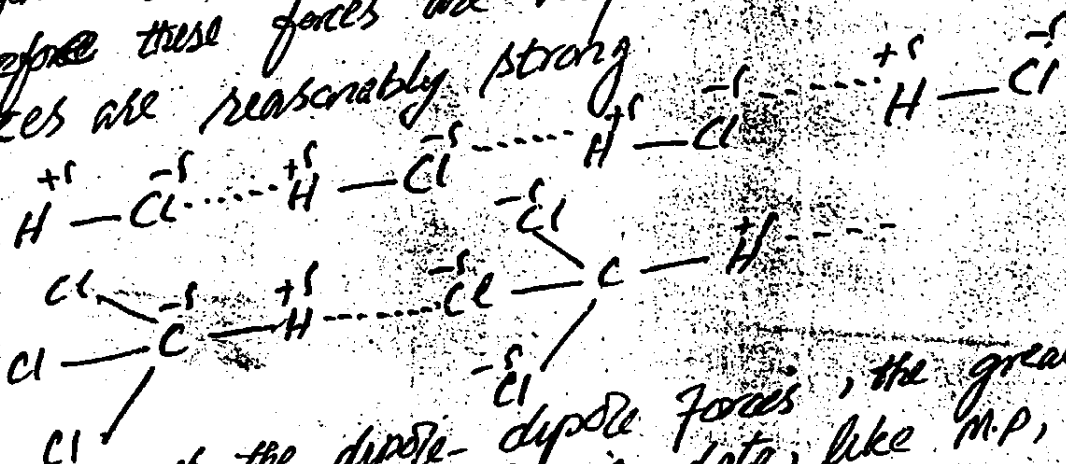
INTERMOLECULAR FORCES The forces of attraction between atoms of two different molecules are called Intermolecular forces. These forces are present in all kinds of molecules when they are very close to each other. These are also called VAN DER WAALS FORCES. These forces are not concerned with valence electrons. Thus these are weaker forces as compared to INTRAMOLECULAR FORCES. The physical properties of different substances depend upon strength of intermolecular forces.

TYPES OF INTERMOLECULAR FORCES :- There are four types of intermolecular forces these are (i) Dipole - dipole forces (ii) Ion - dipole forces (iii) Dipole - induced - dipole forces (iv) INSTANTANEOUS DIPOLE - INDUCED - DIPOLE FORCES OR LONDON DISPERSION FORCES.

Let us consider details of these forces one by one

## DIPOLE - DIPOLE FORCES

These are intermolecular forces in polar substances only. For example, Chlorine is more E.N. than hydrogen. Thus a partial negative charge and hydrogen acquires partial positive charge. Thus a dipole is created. Thus when molecules come close to each other, the positive end of one molecule attracts negative end of other molecule. The molecules tend to line up. But due to thermal energy molecules don't have a perfect alignment. The strength of dipole-dipole forces is almost 1/10 of strength of covalent bond. However the strength of these forces depend upon the difference of E.N. between the atoms. The greater the difference of E.N. the stronger are the dipole-dipole forces. These forces also depend upon the distance between molecules. In gases, the molecules are far apart from each other therefore these forces are very weak. In liquids these forces are reasonably strong.

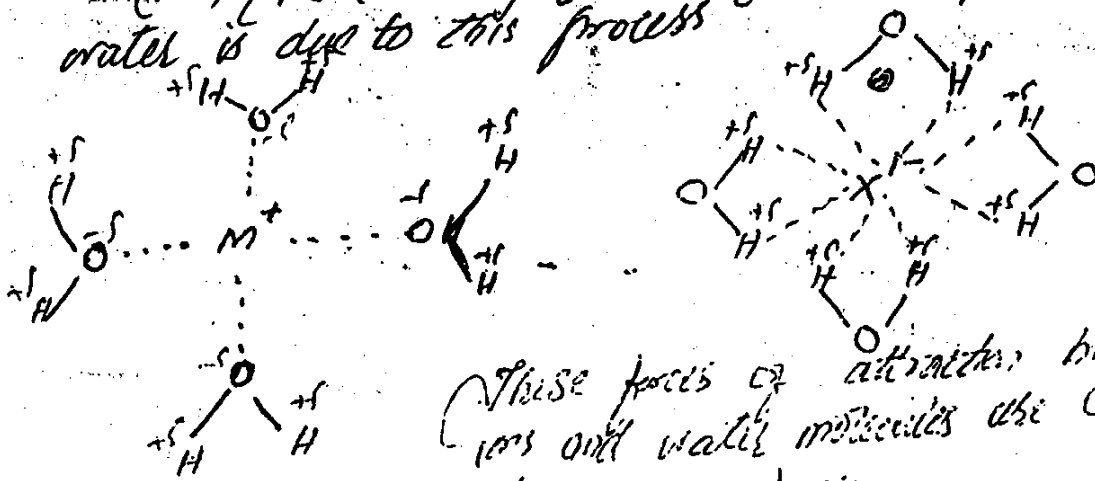


The stronger the dipole-dipole forces, the greater are the values of thermodynamic data, like M.P, B.F, heat of vaporization, heat of sublimation etc.

## 2. ION DIPOLE FORCES:

ions and water molecules (or any other polar molecule) are called ion-dipole forces. For example when an ionic compound like NaCl is dissolved in water, the crystal lattice breaks and ions are set free. These ions are surrounded by water molecules. The negative ends

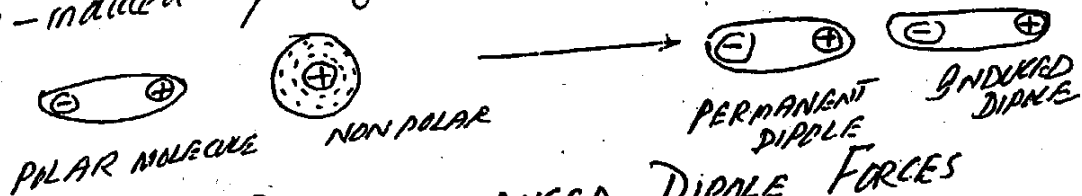
dipoles of water are attracted towards positive ion ( $M^+$ ) and positive ends are attracted towards negative ion ( $X^-$ ). The solubility of most of ionic compounds in water is due to this process.



These forces of attraction between ions and water molecules are called ION-DIPOLE FORCES.

### 3 DIPOLE-INDUCED DIPOLE FORCES

In a mixture containing polar and non polar molecules, the positive end of polar molecule attracts mobile electrons of nearby non polar molecule. A polarity is produced in non polar molecule. The positive end of polar molecule attracts -ve end of induced dipole. These are called DIPOLE-INDUCED DIPOLE FORCES or Deby Forces.



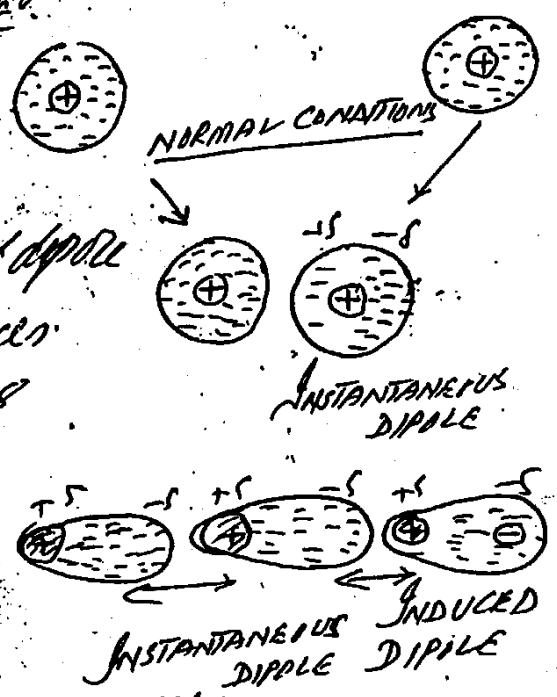
### 4 INSTANTANEOUS DIPOLE-INDUCED DIPOLE FORCES OR LONDON FORCES

These are very weak intermolecular forces created in non polar molecules and noble gases. Due to these forces noble gases like He, Ne, Ar etc can change into liquid at very low temp and high pressure.

A German physicist Fritz London explained these forces in non polar molecules. Under normal conditions of temp and pressure electron cloud is symmetrically distributed around nucleus. But at high pressure and low temp. When atoms come close to each other, the electrons of one atom repel electrons of other.

atom thus a temporary dipole is created. The atom has a partial negative charge on one side and partial positive charge on other side. This is called INSTANTANEOUS DIPOLE. This instantaneous dipole disturbs electronic cloud of nearby atom. Thus a dipole is produced on nearby atom. It is called INDUCED DIPOLE.

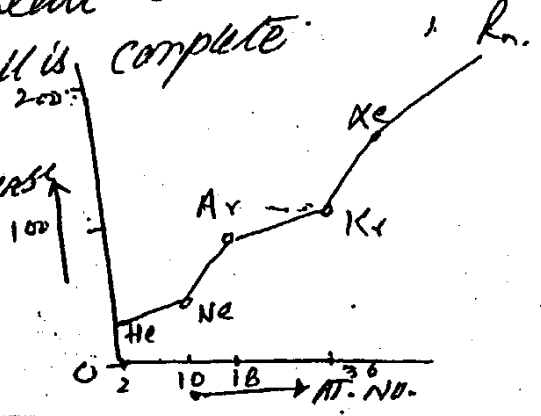
Thus a momentary force of attraction is created between momentary dipole and induced dipole. This is called Instantaneous dipole - induced dipole forces of attraction or London forces. These are very short lived forces of attraction. These dipoles vanish quickly due to movement of electrons. However these forces will appear a moment later in different direction and different orientation.



LONDON FORCES are present in all types of molecules (polar and non polar). But these forces are quite significant in nonpolar molecules like  $Cl_2$ ,  $Br_2$ ,  $H_2$ ,  $He$  etc.

FACTORS AFFECTING LONDON FORCES

SIZE OF ELECTRONIC CLOUD The strength of electronic cloud of an atom or molecule. with increasing size of atom or molecule, the dispersion becomes easy and London forces become more prominent. For example elements of zero group are noble gases. They cannot form covalent bond with other atoms because their outermost shell is complete. Their B.P. increase down the group (from  $He$  —  $Rn$ ) due to increase in size and atomic No.



# POLARIZABILITY

The polarizability is quantitative P-5 in 1; i.e. extent to which electronic cloud could be polarized or distorted. As atomic number increases down the group, the outermost electrons move away from nucleus & the distortion of electrons becomes more and more prominent. Thus strength of London forces increases down the group and B.P. also increase down the group. Similarly all halogens are diatomic non polar molecules. But they differ in physical states.  $F_2$  and  $Cl_2$  are gases,  $Br_2$  is a liquid and  $I_2$  is solid at room Temp. This is due to increase in polarizability down the group.

## NUMBER OF ATOMS IN NON POLAR MOLECULE

Strength of London forces depends upon number of atoms in the non polar molecule. Greater the number of atoms in a non polar molecule the greater is the polarizability. For example in hydrocarbons the B.P. increase with increase in length of carbon chain. For example  $C_2H_6$  has B.P. =  $-88.6^\circ C$  while  $C_4H_{10}$  has B.P.  $68.7^\circ C$ . In longer molecules these are more spaces where they can be attracted to other molecules. Thus hydrocarbons with low molecular masses are gases ( $C_1 - C_4$ ), with higher molecular masses are liquids. Very long chain hydrocarbons are solids.

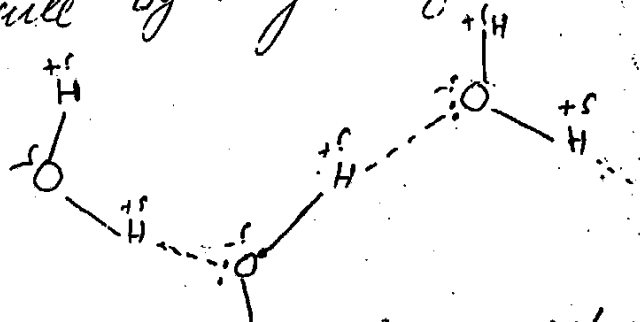
GROUP VII A	B.P. $^\circ C$	GROUP VIII A	B.P. $^\circ C$	Molecular formula	B.P. $^\circ C$	Physical State
$F_2$	-188.1	He	-268.6	$CH_4$	-161.5	Gas
$Cl_2$	-34.6	Ne	-245.9	$C_2H_6$	-88.6	Gas
$Br_2$	58.8	Ar	-185.7	$C_3H_8$	-42.1	Gas
$I_2$	184.4	Kr	-152.3	$C_4H_{10}$	-0.5	Liq
		Xe	-107.1	$C_5H_{12}$	36.1	Liq
		Rn	-61.8	$C_6H_{14}$	68.7	Liq
				$C_{10}H_{22}$	174.1	Solid

# HYDROGEN BONDING

The electrostatic force of attraction between an electronegative atom and partial positively charged hydrogen atom is called hydrogen bonding. Let us consider details of hydrogen bonding.

In water hydrogen is bonded to a more E.N atom oxygen. Thus hydrogen acquires a partial positive charge and oxygen acquires partial negative charge. The two hydrogen atoms of water molecule create a strong electrical field due to their small size. The oxygen atom has two lone pairs of electrons.

The oxygen of one water molecule links by co-ordinate covalent bond with hydrogen of other molecule by using one of its lone pairs of electrons.

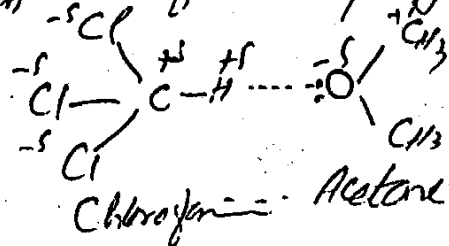


Thus hydrogen bond is a bridge between two more electronegative atoms. It is a special type of dipole-dipole interaction but much stronger than simple dipole-dipole interaction. Hydrogen bond is almost 20 times less stronger than normal covalent bond.

Generally more E.N atoms are F, O, N and rarely chlorine. However in chloroform, the three chlorine atoms create so much positive charge on carbon that hydrogen attached to it is sufficiently positive.

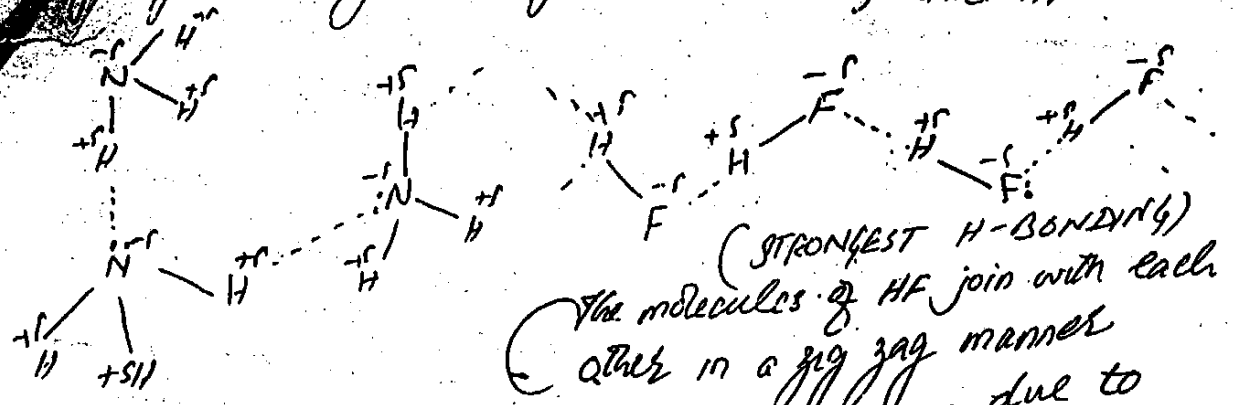
This hydrogen attached to carbon can form hydrogen bond with oxygen of

Acetone as shown below



Chloroform - Acetone

Hydrogen bonding is also present in  $\text{NH}_3$  and  $\text{HF}$  P-7



(STRONGEST H-BONDING)  
The molecules of HF join with each other in a zig zag manner

HF is THE WEAKEST HALOGEN ACID due to strongest hydrogen bonding. Hydrogen is entrapped between two more E.N atoms.

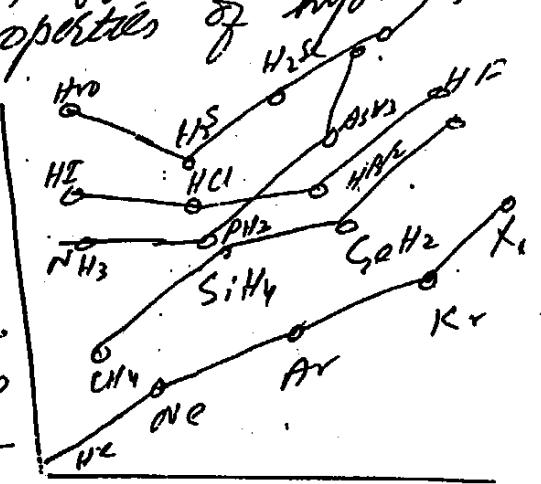
PROPERTIES OF COMPOUNDS CONTAINING HYDROGEN BONDING

Hydrogen bonding is a type of intermolecular forces. It has a greatly effects physical properties of compounds

1. THERMODYNAMIC PROPERTIES OF COVALENT HYDRIDES

M.P. and B.P of substances are greatly effected by hydrogen bonding. Let us compare physical properties of hydrides of IV-A to VII A group.

IV group hydrides ( $\text{CH}_4, \text{SiH}_4$  etc) have minimum M.P, B.P due to their lowest E.N. out of IV to VII group. Carbon atom is very small and its polarizability is quite low.



$\text{NH}_3, \text{HF}$  and  $\text{H}_2\text{O}$  have maximum B.P. in respective series due to highest E.N.  $\text{H}_2\text{O}$  is a liquid but  $\text{H}_2\text{S}$  and  $\text{H}_2\text{Se}$  are gases

Fluorine is the most E.N atom and it should have high B.P. However it is lower than that of  $\text{H}_2\text{O}$ . It is due to the fact that in  $\text{HF}$ , fluorine has one lone pair which can form hydrogen bond with  $\text{H}^{\delta+}$  of neighbouring molecule.

but water can form two hydrogen bonds per molecule. It has two lone pairs on oxygen and two hydrogen atoms per molecule.

Ammonia can form only one hydrogen bond per molecule because nitrogen has one lone pair only.

Boiling point of HCl is slightly higher than that of HBr. It is due to relatively higher E.N of chlorine. Some times it is considered that it forms hydrogen bond and sometimes it is considered that it has strong dipole-dipole interaction. In reality it is border line case.

## 2. SOLUBILITY OF HYDROGEN BONDED MOLECULE

Compounds which are able to form hydrogen bonds with water are soluble in water. For example ethyl alcohol is soluble in water. Similarly small size carboxylic acids are soluble in water. Hydrocarbons are non polar compounds. They cannot form hydrogen bonds with water. Thus hydrocarbons are insoluble in water.

CLEANSING ACTION Soaps and detergents have surfactant molecules. These molecules have polar end on one side which can form hydrogen bond with water. The other end is non polar and it remains outside the water.

## APPLICATION OF HYDROGEN BONDING IN BIOLOGICAL SYSTEM.

Hydrogen bonding exists in molecules of living organisms. PROTEINS | Proteins are long chain of amino acids. They play a very important role in living organism. Fibres like hair, silk and muscles consist of long chain of amino acids. These chains of amino acids are called in the form of a helix. Helix may be right handed or left handed. In right handed helix N-H and  $C=O$  are vertically adjacent. They are linked by hydrogen bonds which link one spiral with other. At an average these are



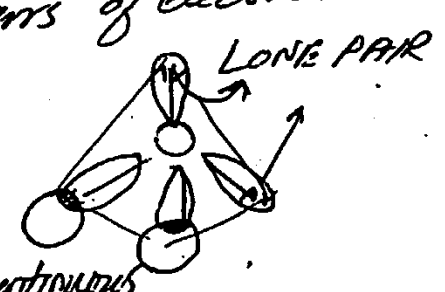
21- Amino acids in each turn of helix  
STRUCTURE OF D.N.A | D.N.A has a double helical structure. The diameter is 18-20A. The two strands are held together by hydrogen bonds.

HYDROGEN BONDING IN PAINTS & DYES | The adhesive action of paints and dyes is due to hydrogen bonding. Similarly glue and honey are sticky substances due to hydrogen bonding.

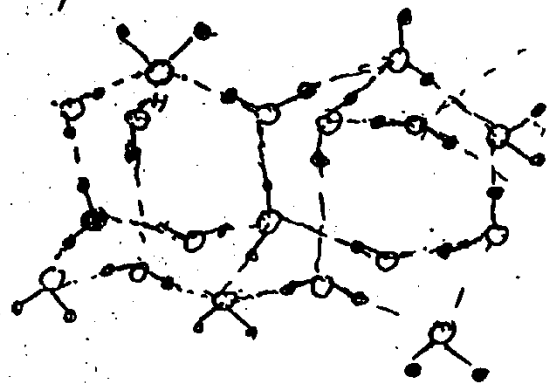
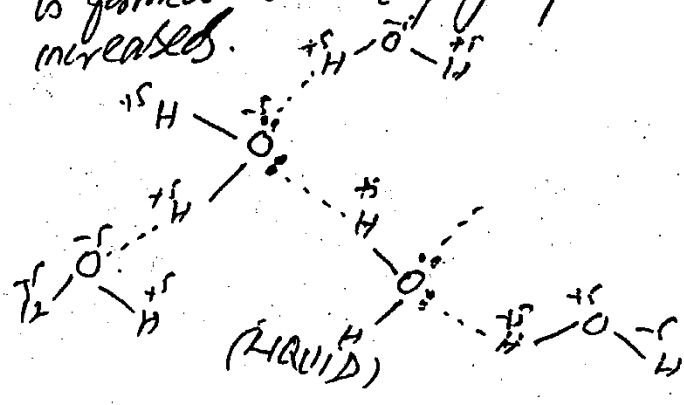
CLOTHING | Hydrogen bonding plays a very important role in thread making materials like Cotton, silk and synthetic fibres. The rigidity and tensile strength is due to hydrogen bonding.

FOOD MATERIALS | Glucose, fructose and sucrose are carbohydrates. They have a number of -OH groups. These -OH are responsible for hydrogen bonding.

STRUCTURE OF ICE | In water oxygen has tetrahedral electronic arrangement of electron pairs. Two corners of tetrahedron are occupied by lone pairs of electrons. In liquid state water molecules are extensively hydrogen bonding bonded with each other. However this hydrogen bonding goes on breaking and reforming due to continuous movement of water molecules.



When temperature is decreased and ice is formed an open network like regular structure is formed. Some empty spaces are produced and volume increases.



Thus volume of ice is 9% more greater than that <sup>10</sup> of water. The density of ice is less than water. That is why ice floats on surface of water. The structure of ice is similar to structure of diamond. In ice each oxygen is present in the centre of a tetrahedron just like carbon present in centre of tetrahedron in diamond.

### IMPORTANCE OF LOW DENSITY OF ICE --

The low density of ice is very important for life of aquatic organisms. As the temperature of surroundings falls in winter, less dense water (below  $4^{\circ}\text{C}$ ) stays at the top and water at  $4^{\circ}\text{C}$  sinks down. As water begins to freeze, a layer of ice is formed at the surface of water. This layer of ice acts as an insulator of heat and it prevents further loss of heat from water. Thus aquatic plants and animals live under blanket of ice during winter season.

EVAPORATION :- The spontaneous change of liquid into vapours is called Evaporation.

EXPLANATION :- Liquid molecules have some kinetic energy due to constant motion. All liquid molecules do not have equal kinetic energy. Some have low kinetic energy and others have high kinetic energy. When a fast moving liquid molecule with high kinetic energy comes to the surface of liquid it breaks intermolecular forces and goes into vapour state. This is called EVAPORATION. It is a continuous process and it takes place at all temperatures.

FACTORS AFFECTING EVAPORATION | It depends upon following factors.

SURFACE AREA

Evaporation takes place from surface of liquid. If surface area is increased more molecules are able to escape from surface of liquid. Hence rate of evaporation increases.

2) TEMPERATURE

Rate of evaporation increases on increasing temperature. When temperature is increased average K.E. is increased. More and more molecules possess sufficient energy, that they can break intermolecular forces and go into vapour state. Hence rate of evaporation is increased.

3) INTERMOLECULAR FORCES

The stronger the intermolecular forces, the lesser is the rate of evaporation. For example gasoline is a non polar liquid having weak London forces. Hence it has higher evaporation rate than water.

WHAT IS ENTHALPY CHANGE? GIVE ITS THREE TYPES?

DEFINITION

:- During a physical or chemical change there is a change in energy. This change in energy is in the form of heat. The heat change during a physical or chemical process at constant pressure is called ENTHALPY CHANGE. This is denoted by  $\Delta H$ . The enthalpy changes are generally expressed kJ/mole. The enthalpy changes are of following

MOLAR HEAT OF FUSION /  $H_f$

Types  
It is amount of absorbed heat when 1 mole of solid melts into liquid at M.P. The pressure must be kept 1 atm during this change.

MOLAR HEAT OF VAPORIZATION /  $H_v$

The amount of heat absorbed when 1 mole of liquid changes into vapours at B.P. The pressure must be kept 1 atm. It is denoted by  $\Delta H_v$ .

MOLAR HEAT OF SUBLIMATION /  $H_s$

The amount of heat absorbed when 1 mole of solid sublimes into 1 mole of vapours at its a particular Temp. and constant pressure. It is denoted by  $\Delta H_s$ .

All these changes are positive because reactions are endothermic.

## VAPOUR PRESSURE (AN EXAMPLE OF DYNAMIC) (EQUILIBRIUM)

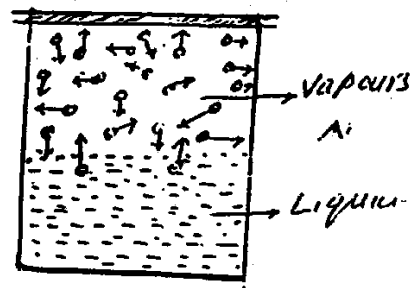
**WHAT IS VAPOUR PRESSURE? DISCUSS FACTORS AFFECTING VAPOUR PRESSURE. DISCUSS ITS MEASUREMENT.**

The pressure exerted by vapours when they are in equilibrium with liquid is called VAPOUR PRESSURE at that temperature.

**EXPLANATION:-** When a liquid is taken in a closed ~~at~~ (closed) container, liquid molecules which are converted into vapours, are collected above liquid surface. These vapours collide with walls of container and with liquid surface. Some of these vapours are recaptured by liquid surface.

In the beginning more liquid molecules are converted into vapours than number of molecules going from vapour to liquid. It can be written as  $\text{Liquid} \rightleftharpoons \text{vapours}$ .

After some time space above liquid gets saturated with vapours. At this state number of molecules going from liquid to vapours become equal to number of molecules (vapours) going back from vapour to liquid state. This state is called equilibrium state.



At this state number of vapours above liquid become constant.

The pressure exerted by vapours when they are in equilibrium with liquid at a given temperature is called VAPOUR PRESSURE. It is an example of dynamic equilibrium. It means rate of evaporation and rate of condensation reaction become exactly equal, and it "SEEMS" as the evaporation process has stopped. But actually it becomes equal to rate of condensation.

### FACTORS AFFECTING VAPOUR PRESSURE.

The vapour pressure depend upon following factors:

1. **INTERMOLECULAR FORCES:-** Intermolecular forces greatly affect vapour pressure. Liquids having strong intermolecular forces have low vapour pressure and vice versa.

For example water has quite low vapour pressure as compared to ether. It is due to strong hydrogen bonding in water which is not there in ether. For example vapour pressure of water at  $0^{\circ}\text{C}$  is  $5\text{ mm(Hg)}$  while that of ether is  $185\text{ mm(Hg)}$  at same temperature.

2. **NATURE OF LIQUIDS** :- Different liquids have different vapour pressures at same temperature. It is due to different strength of intermolecular forces in different liquids. For example  $\uparrow$  vapour pressure of ether is quite high as compared to water. Liquids with high B.P has low vapour pressure at a given temperature.

3. **TEMPERATURE** :- The vapour pressure increases with increase in temperature and decreases with decrease in temperature. It is due to the fact that by increasing temperature average K.E. of molecules increases. More and more molecules possess sufficient energy that they can break intermolecular forces and go into vapour state.

Further vapours being gas molecules collide with walls of container more powerfully and pressure increases. For example vapour pressure of water is  $5\text{ mm(Hg)}$  at  $0^{\circ}\text{C}$  and  $760\text{ mm(Hg)}$  at  $100^{\circ}\text{C}$ .

The temperature at which vapour pressure becomes equal to external pressure is called boiling point.

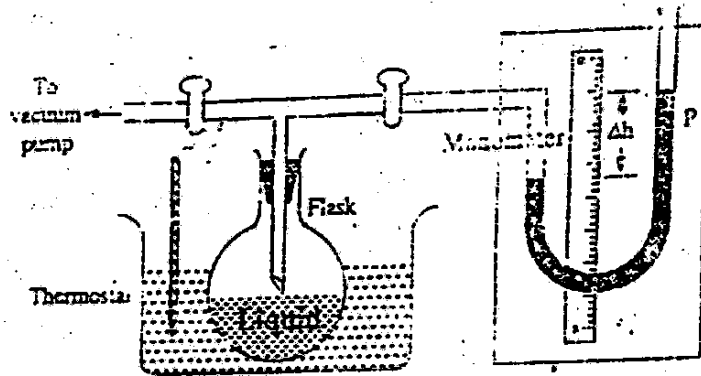
4. **AMOUNT OF LIQUID** :- The vapour pressure is independent of amount of liquid. It is a constitutive property.

**MEASUREMENT OF VAPOUR PRESSURE** :- Vapour pressure is a measurable quantity. There are several methods of its measurement. The most common methods are given below.

- (i) BAROMETRIC METHOD.
- (ii) MANOMETRIC METHOD.

## MANOMETRIC METHOD (ACCURATE DETERMINATION).

For accurate determination vapour pressure of liquid is determined under vacuum. The apparatus used for this purpose is shown below.



The liquid whose vapour pressure is to be determined is taken in a round bottom flask. The liquid is frozen and space above liquid is evacuated by a vacuum pump. The frozen liquid is melted to release entrapped air. The liquid is frozen again and space above frozen liquid is evacuated again. The process is repeated several times, till all air above liquid surface is removed.

The flask is now placed in a thermostat at a temperature at which vapour pressure is to be determined. The vapours push mercury level of its side and mercury level in two limbs is no more equal. The difference in height of mercury in two limbs is determined. Let this difference is " $\Delta h$ ". Then vapour pressure is equal to

$$\text{Vapour Pressure} = P_{\text{atm}} + \Delta h$$

The vapour pressure can be determined at any desired temperature.

## WHAT IS BOILING POINT? DISCUSS AFFECT OF EXTERNAL PRESSURE ON BOILING POINT.

ANS:-

The temperature at which vapour pressure of a liquid becomes equal to atmospheric pressure or any other external pressure to which liquid is subjected is called BOILING POINT.

EXPLANATION:- When a liquid is heated its vapour pressure increases with increase in temperature. At some temperature it becomes equal to atmospheric pressure or external pressure. At this temperature liquid begins to boil. This temperature is called BOILING POINT.

### AFFECT OF EXTERNAL PRESSURE:-

The boiling point increases with increase in external pressure and decreases with decrease in external pressure.

When external pressure is increased, more heat and higher temperature will be required to bring its vapour pressure of liquid equal to increased external pressure. For example water boils at  $100^{\circ}\text{C}$  when external pressure is  $760\text{ mm(Hg)}$  while it boils at  $120^{\circ}\text{C}$  when external pressure is  $1489\text{ mm(Hg)}$ .

### USE OF PRESSURE COOKERS:-

In a pressure cooker boiling point of water is increased by increasing external pressure. The vapours are not allowed to escape, thus they develop more pressure on liquid. This boiling point of water increases. In a pressure cooker (increased pressure) water <sup>temp.</sup> could be increased above  $100^{\circ}\text{C}$ . This helps in cooking meat and vegetables quickly even at high altitudes.

The boiling point is decreased by decreasing external pressure. It is due to the fact that vapour pressure becomes equal to reduced external pressure at lower temperature.

### WATER BOILS AT DIFFERENT TEMP. AT HIGH ALTITUDES:-

The vapour <sup>pressure</sup> of water becomes  $760\text{ mm(Hg)}$  at  $100^{\circ}\text{C}$ . At sea level ~~at~~ atmospheric pressure is  $760\text{ mm(Hg)}$ . Thus water boils at  $100^{\circ}\text{C}$  at sea level. At high altitudes atmospheric pressure is decreased and water boils at lower temperature. For example water boils at  $98^{\circ}\text{C}$  at <sup>Manee</sup> ~~Manee~~.

hills because atmospheric pressure at Murree hills is 0.921 atm. The vapour pressure of water becomes 0.921 atm at  $98^{\circ}\text{C}$ . Thus temperature of water cannot be increased above  $98^{\circ}\text{C}$  in open container at Murree hills. It increases cooking time at high altitude.

### TEMPERATURE REMAINS CONSTANT AT BOILING POINT. EXPLAIN ON MOLECULAR LEVEL.

When a liquid is heated, it increases average kinetic energy of molecules. Hence temperature of liquid increases. The vapour pressure of liquid also increases. At boiling point average kinetic energy of molecules becomes maximum hence temperature becomes maximum. Whatever heat is supplied to liquid at boiling point, it is used to convert liquid molecules to vapours by breaking intermolecular forces. The amount of heat required to convert 1 mole of liquid into its vapours at boiling point is called LATENT HEAT OF VAPORIZATION. The heat supplied at boiling point is used in converting liquid into vapours and temperature remains constant.

### STEAM PRODUCES MORE SEVERE BURNS THAN BOILING WATER. EXPLAIN WHY?

It is due to latent heat of vaporization. It is defined as amount of heat required to convert 1 gram of water into its vapours at its boiling point. For example latent heat of vaporization of water is  $2.26 \text{ kJ/gram}$ . This much heat is stored in steam when boiling water is converted into steam at its boiling point. Thus steam is more rich in heat contents than boiling water. That is why it produces more severe burns than boiling water.

### WHAT IS VACUUM DISTILLATION? DISCUSS ITS APPLICATION.

**DISTILLATION:-**  
The process in which a liquid is converted into vapours by boiling and vapours are condensed back to liquid is called DISTILLATION.



(V)

VACUUM DISTILLATION :- The distillation under reduced pressure is called Vacuum Distillation.

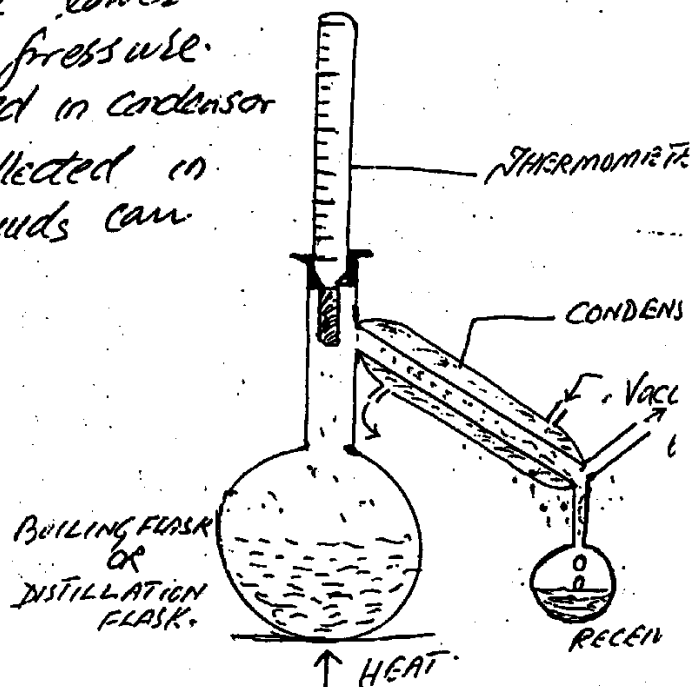
PRINCIPLE OF VACUUM DISTILLATION :- The boiling point of a liquid is decreased by decreasing external pressure. The boiling point is decreased by distilling it under vacuum.

VALIDITY OF VACUUM DISTILLATION :- Some liquids have very high boiling points. When these liquids are heated to their boiling points to distill them, they begin to decompose. These liquids are distilled under reduced pressure. For example boiling point of glycerine is  $290^{\circ}\text{C}$  at 1 atm. pressure. But when external pressure is reduced to 50 mm(Hg) its boiling point is reduced to  $210^{\circ}\text{C}$  and it can be distilled without decomposition.

APPARATUS :- Following apparatus is used in vacuum distillation. It consists of following parts:

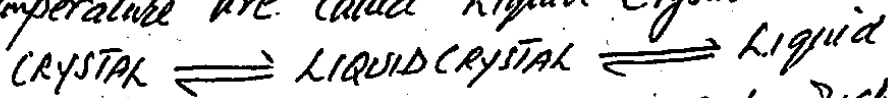
- (i) Distillation head
- (ii) Distillation flask
- (iii) Condenser
- (iv) Thermometer
- (v) Receiver
- (vi) Vacuum pump.

The simple vacuum distillation apparatus is shown below. It consists of a boiling flask connected to a receiver through a condenser. The tube near receiver flask is connected to a vacuum pump to reduce pressure. The apparatus is completely air tight. The apparatus is evacuated, and on heating liquid boils at lower temperature at reduced pressure. The vapours are condensed in condenser and distilled liquid is collected in receiver. In this way liquids can be purified.



## WHAT ARE LIQUID CRYSTALS? WRITE THEIR PROPERTIES?

The turbid liquids which exist between melting temperature and clearing temperature are called liquid crystals.



EXPLANATION There are many crystalline solids which melt to a turbid liquid phase before finally melting to a clear liquid. These turbid liquid phases are called liquid crystals because they can flow like liquids. They possess some other properties of liquids like viscosity, surface tension. However these liquids have some degree of order like crystalline solids. They possess optical properties like crystals. They are also isotropic. Thus the liquid crystals have properties intermediate between those of crystals and isotropic liquids. They have fluidity of liquids and optical properties of the crystals.

USES OF LIQUID CRYSTALS Due to remarkable optical and electrical properties liquid crystals have wide range of practical applications.

1) TEMPERATURE SENSORS : Liquid crystals can diffract light. When one of the wavelengths of light is reflected by liquid crystal it appears coloured. With increase or decrease in temperature, the distance between layers of liquid crystals changes. Thus a different wavelength of light is reflected by crystal and a different colour is produced. Thus liquid crystals can be used as temperature sensors.

2) POTENTIAL FAILURE | Liquid crystals are used to find the point of potential failure in electrical circuits.

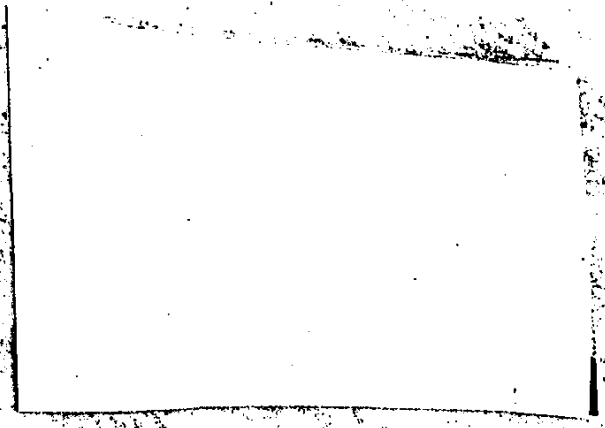
3) ROOM THERMOMETERS | Room thermometers also contain liquid crystals with suitable temperature range. The figures show up with different colours as temp. changes.

MEDICAL NCE / Liquid crystals are used to locate veins, arteries, infections, and tumors. These parts of body are warmer than surrounding tissues. Specialists can use skin thermography to detect blockages in veins and arteries. When layer of liquid crystal is painted on surface of a breast, a tumor shows up as hot area which colored blue. This technique is useful to detect early breast-cancer.

ELECTRICAL DEVICES / Liquid crystals are used in display of electrical devices such as digital watches, calculators and computers. These molecules of liquid crystals are greatly affected by temp, pressure, and electromagnetic fields.

CHROMATOGRAPHY / Liquid crystals are used as solvents in chromatographic separations.

T.V. DISPLAYS / Oscillographic and T.V. displays make use of liquid crystals screen.



The physical state in which atoms or molecules have very strong intermolecular forces is called solid state. Atoms or molecules are closely packed and there are no intermolecular spaces. There are two types of solids (i) Crystalline Solids (ii) Amorphous Solids

**CRYSTALLINE SOLIDS** :- A crystal is a solid having definite geometric shape. In a crystal there is a characteristic, regular and repetitive arrangement of atoms ions or molecules. A crystal has definite shape bounded by definite number of sides intersecting at fixed angles. Crystalline solids are also called true solids.

**CHARACTERISTICS OF A CRYSTAL** :- Several characteristics of crystals distinguish them from liquids and gases. These characteristics are given below

**DEFINITE SHAPE AND VOLUME** :- Crystals retain their shapes under small shear stresses of gravity. On the other hand gases fill any available volume and liquids acquire shape of a container.

**ANISOTROPY** :- Due to internal structure, certain physical properties of crystals vary with direction. It is called ANISOTROPY. For example electrical conductivity or refractive index may be greater in one direction than the other. Thus crystals are ANISOTROPIC. The physical properties of gases and liquids are independent of direction. They are called ISOTROPIC.

**HARDNESS AND ELASTICITY** :- Crystals are hard and elastic in different extents. Hardness means the ability to retain its shape under effect of deforming force. Elasticity means ability to regain its shape when deforming force is removed.

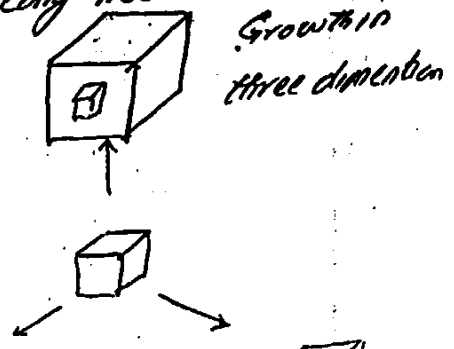
**SHARP MELTING POINTS** :- Crystalline solids have sharp M.P. As a crystal is heated all particles are released from their fixed position at same temperature. In other words temperature remains constant at M.P.

**CLEAVAGE PLANE** :- The surfaces formed when a crystal breaks or splits are planes called cleavage planes. The angles between adjacent cleavage planes is always the same and characteristic of crystal. It is easier to cleave a crystal along its cleavage plane

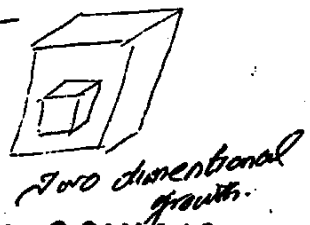
rather than other direction. This cleavage is also a part of Anisotropy.

**PREPARATION OF CRYSTAL:** Crystals are usually prepared by slow cooling of molten substances or cooling of saturated solution. The outer appearance of a crystal depends upon how it is prepared and under what conditions. For example a substance with cubic crystal structure may develop into a cube, a flat plate or long needle like structure.

**HABIT OF CRYSTAL** The shape in which a crystal usually grows is called its habit. For example sodium chloride has cubic habit because it always grows in cubic form if grown under identical conditions.



**CHANGE IN HABIT** The appearance of new faces in crystal due to some impurity is called change in habit of crystal.



**WRITE NOTE ON ISOMORPHISM.**

Two different substances which exhibit same crystalline form are called isomorphous, and this property is called isomorphism. For example NaF and MgO are cubic,  $K_2SO_4$  and  $K_2SeO_4$  are orthorhombic,  $NaN_3$  and  $CaCO_3$  are rhombohedral.

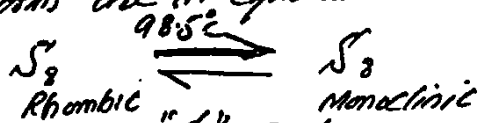
It is clear from above examples that isomorphous substances have same ratio of atoms in one formula unit. For example NaF and MgO have atomic ratio 1:1. Similarly  $K_2SO_4$  and  $K_2SeO_4$  have atomic ratio 2:1:4.

Some isomorphous substances can crystallize out together to form mixed crystals. The physical and chemical properties of isomorphous substances are quite different from one another.

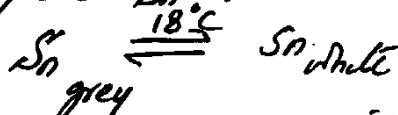
**POLYMORPHISM:** If a single substance exhibit more than one crystalline forms under different conditions it is said to be polymorphous and this property is called polymorphism. For example sodium sulphate exist in Rhombic and Monoclinic form.  $Na_2SO_4 \xrightleftharpoons{32.5} Na_2SO_4$   
 (R) (M)  
 CARBON (diamond and graphite)  
 SULPHUR RHOMBIC and monoclinic

ALLOTROPY: If an element exists in more than one crystalline form it is said to possess allotropy. These forms are called Allotropic forms. In other words polymeric forms of element are called Allotropic forms. For example "S" exists as Rhombic crystal and monoclinic crystalline form.

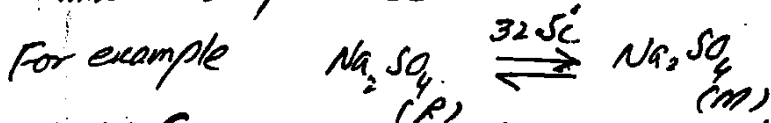
TRANSITION TEMPERATURE The temperature at which two crystalline forms of a substance can co-exist in equilibrium is called Transition temperature. For example transition temperature of Sulphur is  $95.5^{\circ}\text{C}$  at which Rhombic and monoclinic forms are in equilibrium



Similarly Sn grey and Sn white are in equilibrium at  $18^{\circ}\text{C}$



Transition temperature is also exhibited by compound



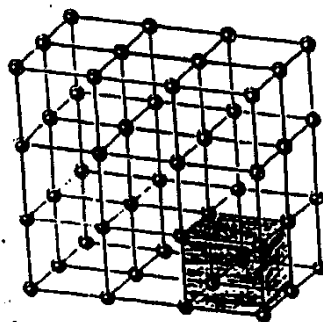
UNIT CELL: The smallest unit of volume of a crystal showing all characteristics of a crystal is called Unit Cell.

All crystals consist of regularly repeating arrangement of atoms. To describe such a repeating pattern we must know two things :-

- (i) The size and shape of repeating unit
- (ii) The contents of a unit.

In a crystal the repeating unit is three dimensional and its contents are atoms ions or molecule. This smallest unit by volume of a crystal is called Unit Cell.

The unit cell is described by lengths of its edges and "a" "b" and "c" and angles  $\alpha$ ,  $\beta$  and  $\gamma$  between edges. A cubic unit cell is shown in fig

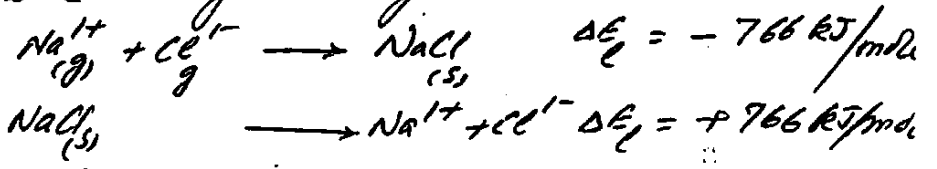


(CUBIC LATTICE)

repeat unit of crystal is represented by a point placed at the same place in the unit cell. All such points would have same environment and indistinguishable from each other.

1) CRYSTAL LATTICE The resulting three dimensional array of points is called crystal lattice or space lattice.

LATTICE ENERGY OF IONIC CRYSTALS The amount of energy required to separate atoms, ions or molecule in a crystal to infinite distance is called lattice energy. OR The amount of energy released when gaseous ions of opposite charges combine to give one mole of crystalline compound is called lattice energy. The lattice energy in this case is given negative value.



The amount of lattice energy is a measure of stability of an ionic compound.

CRYSTAL SYSTEMS The individual crystals are identified by lengths of unit cells and corresponding angles between them. Seven crystal systems have been identified on the basis of seven types of unit cells.

(SEVEN TYPES OF CRYSTAL SYSTEMS)

NAME OF SYSTEM	SIDES LENGTH	ANGLES	EXAMPLES
CUBIC	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	NaCl, Diamond.
TETRAGONAL	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	$\text{SnO}_2, \text{BaSO}_4, 4\text{H}_2\text{O}$
ORTHORHOMBIC	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$
TRIGONAL	$a = b = c$	$\alpha = \beta = \gamma > 90$	$\text{NaNO}_3$
HEXAGONAL	$a = b \neq c$	$\alpha = \beta = 90^\circ < 120$ $\gamma = 120$	GRAPHITE
MONOCLINIC	$a \neq b \neq c$	$\alpha = \gamma = 90$ $\beta = 120$	$\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$
TRICLINIC	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90$	$\text{CuSO}_4$

CUBIC SYSTEM / In cubic system all three axes are of equal length and are at  $90^\circ$  to each other

$$a = b = c \quad \alpha = \beta = \gamma = 90^\circ$$

EXAMPLE = NaCl

TETAGONAL SYSTEM / Two axes are equal and at  $90^\circ$  from each other

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

Examples: -  $\text{SnO}_2$

ORTHORHOMBIC SYSTEM

All three axes are unequal and at right angle to each other

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

Examples: -  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$

TRIGONAL SYSTEM / All three axes are equal but intersect at angle greater than  $90^\circ$  but less than  $120^\circ$ .

$$a = b = c \quad \alpha = \beta = \gamma > 90^\circ < 120^\circ$$

Example  $\text{NaNO}_3$

HEXAGONAL SYSTEM / Two out of three axes are equal length. Two angles are  $90^\circ$  while third angle is  $120^\circ$ .

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

Example Graphite

MONOCLINIC / Two All three axes are unequal. Two angles are  $90^\circ$  but third is greater than  $90^\circ$ .

$$\alpha = \gamma = 90^\circ \quad \beta > 90^\circ$$

$$a \neq b \neq c$$

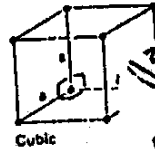
Example:  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$

TRICLINIC SYSTEM

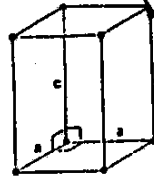
$$a \neq b \neq c$$

$$\alpha \neq \beta \neq \gamma \neq 90^\circ$$

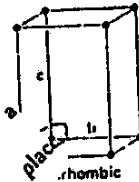
Example  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$



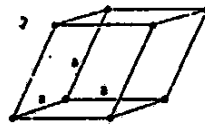
Cubic



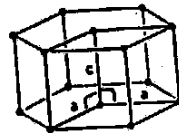
Tetragonal



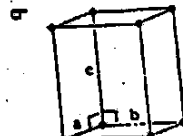
Rhombic



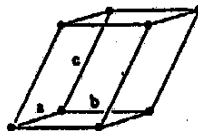
Rhombohedral



Hexagonal



Monoclinic



Triclinic



# CLASSIFICATION OF SOLIDS:

25

crystalline solids depending upon types of bonds present in them.

- 1) IONIC SOLIDS
- 2) COVALENT SOLIDS
- 3) METALLIC SOLIDS
- 4) MOLECULAR SOLIDS

**IONIC SOLIDS:-** Crystalline solids which are formed due to ionic bonds present between oppositely charged ions, are called ionic solids. The oppositely charged ions are held together due to electrostatic forces of attraction between oppositely charged ions. Examples of such crystals are NaCl, KBr, etc.

## PROPERTIES:-

**SOLID STATE:-** These solids exist in solid state at room temperature, they never exist in liquid or gaseous state.

HIGH M.P., B.P

Ionic crystals are very stable compounds. Very high energy is required to separate positive and negative ions. Ionic crystals are very hard, they have low volatility, high M.P. and B.P.

## NON DIRECTIONAL

The forces of attraction present between oppositely charged ions are non directional. The close packing of ions enable them to occupy minimum space. Thus ionic crystals never exist as individual neutral independent molecules.

## RADIUS RATIO

The structure of ionic crystals depends upon their radius ratio of cation and anion. For example NaCl and CsF has same radius ratio, their geometry is also the same (both are cubic).

## CONDUCTIVITY

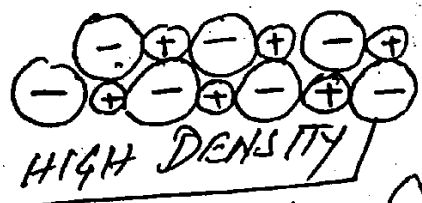
Ionic crystals do not conduct electricity in solid state. However in aqueous solution or in molten state positive and negative ions are set free and they begin to conduct electricity.

## FORMULA MASS

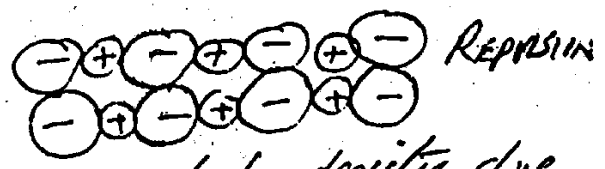
The ionic crystals are generally expressed in terms of their formula mass. They do not exist as molecules, thus their molecules wt cannot be expressed.

BRITTLENESS

Ionic crystals are highly brittle. They are composed of parallel layers which contain +ve and -ve ions in alternate positions. When some force is applied one layer slides over other layer. Thus, same charges come in front of each other. They begin to repel causing brittleness.



FORCE →



Ionic solids have very high density due to close packing of ions. They are soluble in polar solvents. Their reactions are very fast.

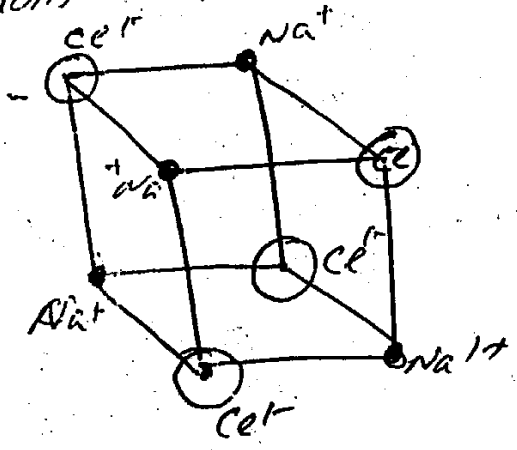
The properties of isomorphism and polymorphism are associated with ionic crystals.

STRUCTURE OF SODIUM CHLORIDE

The structure of ionic crystal depend upon the structure and size of their ions. In NaCl each sodium ion is surrounded by six chloride ions and each chloride ion is surrounded by six Na<sup>+</sup> ions. The size of Cl<sup>-</sup> ion is larger than Na<sup>+</sup> ion.

The distance between two chloride ions is 5.63 Å while distance between a positive and negative ion is  $\frac{5.63}{2} = 2.815 \text{ Å}$ .

Sodium chloride has cubic crystalline structure. It has co-ordination number 6. Each unit cell contains four Na<sup>+</sup> ions and four chloride ions as shown below.



## COVALENT SOLIDS. (ATOMIC SOLIDS) 27 21

These are also called atomic solids because they are composed of atoms of <sup>one</sup> two or more different elements. These atoms are held together by covalent bond.

COVALENT SOLIDS ARE OF TWO TYPES.

- which consist of giant molecules like diamond
- when atoms join to form covalent bonds. Separate layers of atoms are produced due to these covalent bonds. For example graphite, Cadmium iodide, Boron nitride.

### PROPERTIES:-

OPEN STRUCTURE:- Covalent bonds are directional. These bonds are formed in a specific direction and an open net work like structure is produced.

HIGH M.P. These crystals are hard and large amount of energy is required to break them. They have high M.P. and their volatility is quite low.

CONDUCTIVITY Due to absence of free electrons and ions they are bad conductors of electricity. Graphite has layered structure. The electrons are available between these layers. Thus graphite is a good conductor of electricity.

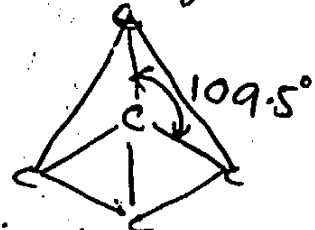
SOLUBILITY These are insoluble in polar solvents but they are soluble in non polar solvents like Benzene,  $CCl_4$  etc. Covalent crystals like diamond are giant molecules which are insoluble in all solvents. Due to big size they ~~are~~ do not interact with solvent molecules.

REACTIONS:- The chemical reactions of such covalent crystals are very slow.

STRUCTURE OF DIAMOND:- Diamond is an allotropic form of carbon. Carbon has four electrons in outermost shell. Each carbon is  $sp^3$  hybridized. Four hybrid orbitals

are produced. These four hybrid orbitals are located at an angle of  $109.5^\circ$ . A tetrahedral structure is produced.

Each unit cell is ~~four~~ formed by five carbon atoms. Each



c-c bond is formed by overlap of  $sp^3-sp^3$  orbitals. Each bond length is  $1.54 \text{ \AA}$ .

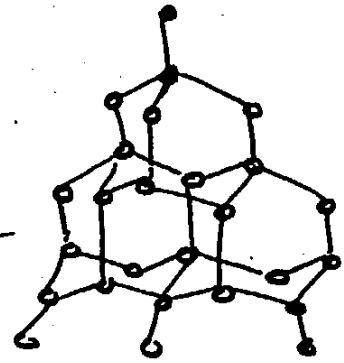
This type of structure runs throughout the crystal.

The entire structure behaves like a huge molecule.

This is called MACROMOLECULE or giant molecule. The overall structure is face centered cubic.

### MOLECULAR SOLIDS

These are solids whose crystals are formed by polar or nonpolar atoms or molecules. Two type of intermolecular forces hold them together.



- 1- DIPOLE - DIPOLE FORCES
- 2- VANDER - WAALS FORCES.

These forces are much weaker than covalent and ionic bond.

For example noble gases can be solidified due to London forces. They consist of nonpolar atoms. Iodine, Phosphorus,  $CO_2$  form molecular crystals containing nonpolar molecules. These molecular crystals have low M.P and B.P. Ice and glucose are molecular crystals which consist of polar molecules. They have relatively high M.P. B.P.

### PROPERTIES OF MOLECULAR CRYSTAL.

- 1) These are soft and easily compressible.
- 2) They are mostly volatile and have low M.P. B.P.
- 3) They have low densities and poor conductor of electricity.
- 4) They may be transparent to light.

- Polar molecular crystals are mostly soluble in polar solvents like water. The molecular crystals which consist of non polar molecules are soluble in non polar solvents.

**STRUCTURE OF IODINE MOLECULE.**

In solid state iodine molecule form layer lattice structure. I—I bond distance is 271.5 pm which is larger than gaseous iodine (266.6 pm). Iodine is a poor conductor of electricity.

**METALLIC SOLIDS:-** In order to explain characteristics of metals different theories have been proposed.

**1. METALLIC BOND THEORY OR ELECTRON GAS THEORY**

It was proposed by Drude and extended by Loren. According to this theory each metal atom loses all of its valence electrons. These valence electrons form a pool or an electron gas. The positively charged ions remain at their fixed positions. The electrons are free to move from one part of crystal to other. These electrons belong to the crystal as a whole and not attached to any atom or ion. The force which binds metal cation to a number of electrons is called metallic bond.

**VALENCE BOND THEORY**

According to this theory metallic bond is a covalent bond. These covalent bonds are not localized but ~~separate~~ they are highly delocalized in metal structure.

