CHAPTER # 5
STATE OF MATTER II
LIQUIDS

Q1. Define liquid, gas, solid and cohesive forces.

Ans: Liquid:

A simple definition of a liquid is that "it is a material that assumes the shape of a container without filling it completely"

Gas:

A gas on the other hand takes the shape of the vessel and has the characteristics to fill it completely.

Solid:

A solid neither takes the shape of the vessel nor fills the container completely

Note: The definition of a liquid is satisfactory on the whole with the exception of glasses, polymers (e.g. PVC etc); they appear in the solid but at higher temperatures they behave like liquid even before they melt.

Cohesive forces:

The cohesive force is the force of attraction between molecules of substance. It is stronger in liquid than those in a gas even at high pressure.

Q2. How many types of liquid? Explain their properties and also give their examples.

Ans: Liquids may be of three types. The types of liquids, their physical properties with examples are shown below

Sr. #.	Types of liquids	Properties	Examples
01	Ionic Liquid	High Boiling Point	Molten Salt e.g. $AlCl_3$
02	Molecular Liquid	Low Boiling Point	H_2O, C_2H_5OH
03	Metallic Liquid	Moderate to High BP	Molten metals e.g. Hg

Q3. Give the Postulates of Kinetic Molecular Theory of Liquids.

Ans: Kinetic Molecular Theory of Liquids:

The kinetic molecular theory also applies to liquids. Postulates of kinetic molecular theory of liquids are given below:

(i) A liquid is made up of molecules which touch one another

(ii) The molecules within the liquid are in constant motion but the movement of molecules is restricted due to their close packing together

(iii) Attractive forces among liquid molecules are greater than those among gas molecules. However these attractive forces are not sufficient to hold molecules in fixed position. The liquid molecules can slide each other

(iv) The average Kinetic Energy of liquid molecules is directly proportional to the Absolute Temperature.

(v) At constant temperature, the average K.E of the molecules is equal to the K.E of the vapours of liquids.

Q4. Describe the Diffusion of liquids on the basis of kinetic molecular theory.

Ans: Diffusion of liquids:

The diffusion in liquids takes place because the molecules move from one place to another due to K.E. The restricted movement of the molecule reduces the rate of diffusion

Example:

A drop of ink when added to water diffuses slowly due to relatively small empty spaces between the molecules. The diffusion between closely packed molecules of liquids is slow due to less collision between them.

Q5. Describe the Compression or effect of pressure on liquids on the basis of Kinetic molecular theory.

Ans: Compression of liquid (effect of pressure):

A liquid cannot be compressed significantly by increasing the pressure because the molecules are already in close contact with one another

Example:

An increase of pressure from one to two atmospheres reduces the volume of water to 0.0045 percent which is negligible. However the same pressure reduces the volume of a gas up to 50 percent.

Q6. Describe the Expansion of liquid on the basis of Kinetic Molecular Theory.

Ans: Expansion of liquid (effect of temperature):

The liquids expand on heating because the intermolecular forces between them decrease. Moreover the increase of temperature increases the effective collisions between the molecules. If the temperature is decreased, contraction of molecules takes place. This property is useful for making thermometers,

Example:

Mercury thermometer is a good example to explain expansion of liquid. In it, if the temperature rises, the mercury expands in the capillary tube. As the volume of capillary is much less than the volume of the bulb containing mercury, a small expansion gives a large movement of mercury thread.

Q7. Describe the motion of molecules of liquid on the basis of Kinetic Molecular Theory.

Ans: Motion of molecules of liquid:

The molecules move with lesser speed due to larger forces of attraction among them, As a result they have lesser kinetic energy. However the Kinetic Energy increases with the increase of Temperature.

Q8. Describe the Spaces between molecules of liquid on the basis of Kinetic Molecular Theory.

Ans: Spaces between molecules of liquid:

The molecules forming the liquid states are fairly close to each other. There is very little space between them. As a result the numbers of collisions among the molecules are moderate. Therefore, the average Kinetic Energy is also moderate.

Q9. Describe the Intermolecular forces of liquid on the basis of Kinetic Molecular Theory.

Ans: Intermolecular forces of liquid:

The attractive forces existing between the individual particles of a substance are called intermolecular forces.

Dependence of physical properties of liquids:

The physical properties of liquids such as boiling point, vapour pressure, surface tension, viscosity and heat of vaporization depend upon the strength of intermolecular attractive forces.

Q10. Describe the Kinetic Energy of liquid based on Kinetic Molecular Theory.

Ans: Kinetic Energy based on Kinetic Molecular Theory:

According to the Kinetic Molecular Theory, the molecules due to strong inter-molecular attractions have minimum movements and minimum collisions.

Example:

Let us consider the example of water, as the molecules are closer to each other and have strong forces of attractions due to hydrogen bonding so have low kinetic energy.

Q11. Define the Intermolecular forces.

Ans: Intermolecular Forces:

The forces of attractions among the molecules of a substance are called inter-molecular forces.

Example:

Water exists as a liquid due to inter-molecular attractions called Hydrogen bonds.

Q12. Define Van Der-Waal's forces.

Ans: Van Der-Waal's forces:

The forces of attraction existing between the molecules of a non-polar substance are also known as Van Der-Waal's forces.

Q13. List the different types of Intermolecular forces.

Ans: Types of intermolecular forces:

The intermolecular forces are of five types:

- **i.** Dipole-Dipole forces
- **ii.** Ion-Dipole forces
- **iii.** Dipole-induced dipole forces
- **iv.** London Dispersion forces
- **v.** Hydrogen bonding

Q14. Briefly explain Dipole – Dipole Forces.

Ans: Dipole – Dipole Forces:

The attractive forces between the positive ends of one molecule with the negative end of other molecule are called dipole – dipole forces. This means dipole - dipole interactions are electrostatic interactions between permanent dipoles in molecules.

Examples:

Examples of polar molecules include hydrogen chloride (HCl) chloroform ($CHCl_3$), Acetone $(CH_3)_2CO$ etc.

Note: Stronger these dipole-dipole forces, greater would be the value of thermodynamic parameters like melting point, boiling point, heat of vaporization, heat of subliminal etc.

Q15. Briefly explain London Dispersion Forces.

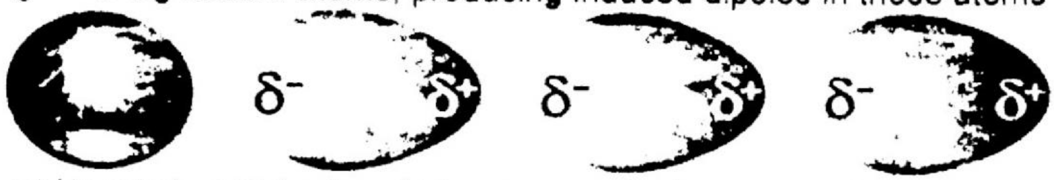
Ans: London Dispersion Forces:

The forces of attractions between non-polar molecules which become polar for an instant are called London dispersion forces.

Explanation:

Substances like hydrogen, helium, neon, argon, chlorine, fluorine, methane etc are non-polar in nature. These gases can be liquefied and solidified under appropriate conditions. Some forces must be holding these molecules in contact with one another in the liquid and solid states.

In *He* gas, on the average, the electron charge density is evenly distributed in a spherical region about the nucleus. However, at any given instant, the actual location of two electrons relative to the nucleus can produce an instantaneous dipole. This temporary dipole, in turn, can influence the distribution of electrons in neighbouring helium atoms, producing induced dipoles in those atoms.



(a) Un-polarized Molecule (b) Instantaneous dipole (c) Induced dipole

London dispersion forces Instantaneous dipole

London Dispersion force:

The forces of attraction between an instantaneous dipole and an induced dipole are known as a dispersion force. It is also called as London dispersion force, named for Fritz London who offered a theoretical explanation for these forces in 1928.

Q16. Explain the factors affecting the London Dispersion Forces.

Ans: Applications of London Dispersion Forces:

Factors affecting the London dispersion force are.

- **i.** Atomic or molecular size
- **ii.** Polarizability
- **iii.** Number of atoms in a molecules

(I) Atomic or Molecular Size:

The strength of London dispersion forces depends upon the size of the electronic cloud of the atom or molecule. With the increase in size of atom or molecule, the dispersion becomes easy and these forces become prominent.

Inert gases are all monotonic gases. They do not make covalent bonds with other atoms because their valence shells are complete. Their boiling point increase down the group from *He* to *Rn*. This is because of increase in molecular size.

Table Boiling points of noble gasses

Noble Gas	He	Ne	Ar	Kr	Xe	Rn
Boiling Points (°C)	-268.6	-245.9	-185.7	-152.3	-107.1	-61.8

(II) Polarizability:

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

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

Examples:

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

(iii) Number of atoms in a molecule:

Elongated molecules make contact with neighbouring molecules over a greater surface than do small molecules. Greater the number of atoms in a molecule, greater is the polarizability of the molecule.

Table: Boiling points and physical states of some hydrocarbons.

Molecular formula	B .P (°C at 1 atm)	Physical State at STP
CH_4	-161.5	Gas
C_2H_6	-88.6	Gas
C_3H_8	-42.1	Gas
C_4H_{10}	-0.5	Gas
C_5H_{12}	36.1	Liquid
C_6H_{14}	68.7	Liquid
$C_{10}H_{22}$	174.1	Liquid

Examples:

C_2H_6 and C_6H_{14} have the boiling points as -88.6°C and 67.7°C respectively. This shows that the molecule with a large chain length experiences stronger attractive forces.

Q17. Explain hydrogen bonding? Why the boiling point and heat of vaporization of water are higher than those of H_2S?

Ans: Hydrogen Bonding:

A hydrogen bond is the attraction between the lone pair of an electronegative atom and a hydrogen atom that is bonded to either N, O or F. This limits hydrogen bonding mainly to the participation of nitrogen, oxygen and fluorine atoms.

Strength of bonds:

Hydrogen bonds are weaker than covalent bonds but stronger than dipole-dipole interactions, which are stronger than London dispersion forces.

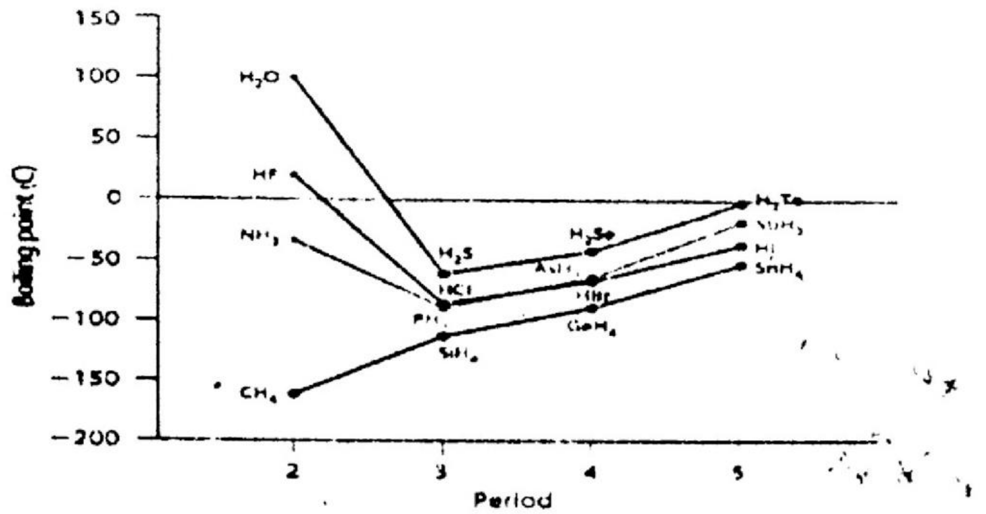
Reason:

The boiling point and heat of vaporization of water are higher than those of H_2S because H_2O molecules attract each other through **H-bonding** whereas H_2S molecules attract each other by **dipole-dipole interactions.**

Q18. Graphically explain Hydrogen Bonding in terms of thermodynamic properties.

Ans: Thermodynamic properties:

The boiling points of hydrides of group IVA, VA, VIA and VIIA plotted against period number of the periodic table is shown in figure.



A graph between period number and the boiling points of hydrides.

Explanation:

The boiling point of hydrides:

Note that hydrides of group IVA have lower boiling points. The reason is that these hydrides are non-polar and have only **London dispersion forces** among their molecules. Hydrides of group VA, VIA and VII-A have **polar molecules**.

NH_3, H_2O and HF show maximum boiling points in their respective series. This is due to hydrogen bonding in their molecules.

Q19. Why the boiling point of H_2O is greater than that of HF?

Ans: The boiling point of H_2O seems to be more affected than that of HF. As F is more electronegative than O. One should expect H-bonding to be stronger in HF than H_2O. But boiling point of H_2O is higher than that of HF.

Reason:

The reason is that fluorine can make only one hydrogen bond with hydrogen of the neighbouring molecule. On the other hand oxygen atom can form two hydrogen bonds with the neighbouring molecules.

NH_3 can also form only one hydrogen bond per molecule as it has only one lone pair.

Q20. Why the compounds that have hydrogen bonds are soluble in each other?

Ans: Solubility of Hydrogen Bonded Molecules:

The compounds that have hydrogen bonds are soluble in each other

Reason:

Ethyl alcohol can dissolve in water because both can form hydrogen bonds with each other. Similarly carboxylic acids are also soluble in water, if their molecular sizes are small. This is all because of hydrogen bonding.

Q21. Write different uses of hydrogen bonding?

Ans: (i) Cleansing Action:

Soaps and detergents perform the cleaning action. Their molecules contain both polar and non-polar ends. Their polar parts are water soluble due to hydrogen bonding and non-polar part dissolve oil or grease. Attraction between water and polar end of soap molecule carries the oil or grease droplet into the water.

(ii) Hydrogen Bonding in Paints and Dyes:

Paints and dyes have adhesive action due to hydrogen bonding. Similarly hydrogen bonding also makes glue and honey stickle substances.

(iii) Clothing:

We use cotton, silk or synthetic fibres for clothing. Hydrogen bonding is of great importance in thread making materials. This hydrogen bonding is responsible in their rigidity and tensile strength.

(iv) Food Materials:

Food materials like carbohydrates consist of glucose, fructose, sucrose, each of them contains –OH groups which is responsible for H-bonding in them.

(v) Hydrogen Bonding in Biological Molecules:

The structure of proteins, substances essential to life, is determined partly by hydrogen bonding. The action of enzymes, the protein molecules that catalyze the reactions that sustain life, depends in part on the forming and breaking of hydrogen bonds. The hereditary information passed from one generation to the next is carried in nucleic acid molecules joined by hydrogen bonds into an elegant structure.

Q22. What are the physical properties of liquid explain them with the help of example.

Ans: Physical Properties of Liquids:

In a liquid the molecules are very close to each other due to the presence of intermolecular forces. As a result their independent motion is greatly hindered and the flow of liquid and the rate of diffusion are much less than in the case of gases.

The existence of powerful forces of cohesion (forces between similar types of molecules e.g. H_2O) is responsible for the main properties of liquids.

The properties of liquid molecules are as under:

i. **Additive properties:**
Such properties depend upon the number and kind of atoms present in the molecule e.g. molecular weight

ii. **Constitutive properties:**
Such properties depend upon the arrangement of atoms in the molecules and not their number e.g. optical activity.

iii. **Colligative properties:**
Such properties depend on the number of ions and molecules present but do not depend upon the structure of molecules. e.g. Osmotic pressure, molar volume etc.

Q23. Define boiling point and also explain it in terms of vapour pressure.

Ans: Vapour pressure and boiling point:

When a liquid is heated, its V.P. increases due to the decrease of intermolecular forces with rise in temperature. As a result more and more vapours escape in the air. A stage reaches at which the liquid begins to boil.

So the temperature at which the vapour pressure of the liquid equals to atmospheric pressure or some external pressure is called boiling point of that liquid.

Example:

Boiling Point of water at 760mm = 100 °C
Boiling Point of water at 23.7mm = 25 °C

Q24. Explain the factors affecting the boiling point of a Liquid.

Ans: Effect of Pressure on boiling point of a Liquid:

There are two practical applications regarding the effect of pressure.

i. Effect of Increase of Pressure:

Food can be cooked **easily** in pressure cookers, which is a closed container. The vapours are not allowed to escape out and, therefore, develop more pressure. This **increases** the B.P of water

Example:

Pressure cookers help us in cooking the food quickly even at high attitude **e.g.** B.P of water at 2026mm Hg is 130°C

ii. Effect of decrease of pressure:

The liquids which decompose at their B.P can be obtained in the pure form under reduced pressure by Vacuum distillation

Example:

Glycerine has a B.P of 290°C at 760mm but it decomposes at its B.P. Now in order to get it in the pure form, the **V.P is decreased** to 50mm by Vacuum pump.

The B.P decreases to 120°C without decomposition. In this way the liquids can be purified

Q25. Define evaporation and the factor affecting the rate of evaporation.

Ans: Evaporation:

Evaporation is the process in which liquid molecules escape from the surface and enter the gas phase

Explanation:

It can be explained in terms of the energy possessed by the molecules on the liquid's surface. Surface molecules whose kinetic energies are higher than average kinetic energies, overcome the intermolecular forces that bind them to the liquid and enter the gas phase. After their escape, the average kinetic energy of the remaining molecules decreases. Therefore temperature of the liquid decreases, thus evaporation is a cooling process.

Factor affecting the rate of evaporation:

The factors which can affect the rate of evaporation are as follow:

i. Surface Area:

The rate of evaporation **increases** with increasing surface area. This is because large surface area allows more molecules to evaporate.

ii. Intermolecular Forces:

The escaping tendency of molecules depends upon attractive forces between the molecules. The liquids with **strong intermolecular forces** have **less evaporation**.

Example:

Thus water has less evaporation rate than petrol.

Reason:

This is because water has stronger intermolecular forces (H-bonding) than petrol which has weak dispersion forces between the molecules.

Volatile:

A liquid which can rapidly change into vapours is called volatile e.g. petrol is more volatile than water

iii. Temperature:

Evaporation takes place at all temperature. Rate of evaporation however is affected by the change in temperature. **Increase in temperature increases** the number of molecules having kinetic energy sufficient to overcome intermolecular forces and escape more readily from the surface of the liquid. Thus the rate of **evaporation increases** with increasing temperature. This is why cloths dry more readily in summer.

Q26. Explain vapour pressure and the factors affecting the rate of vapour pressure.

Ans: Vapour Pressure (V.P):

"The pressure exerted by vapours in equilibrium with its liquid state is called the liquid's vapour pressure at the given temperature"

Condensation:

In closed containers, the vapours cannot escape. Therefore, as the vapour concentration increases, some of the vapour molecules lose energy and return to the liquid state. **This process is called condensation.**

Explanation:

Evaporation involves molecules leaving the liquid and condensation occurs when a vapour changes back to a liquid. While the liquid is placed in a closed container, it begins to evaporate at a constant rate, very little condensation takes place. But as the concentration of the vapour increases above the liquid, the rate of condensation increases.

After some time the rate of condensation equals the rate of evaporation. At this stage, the number of molecules entering the gas phase equals the number returning to the liquid phase, the system is said to be in a dynamic equilibrium.

Intensive property:

Vapour pressure is independent of the amount of liquid, so this is called an intensive property of the liquid.

Factors affecting Vapour Pressure:

Vapour pressure is measured in the **same units** used for gas pressure. Two factors affect liquid's vapour pressure

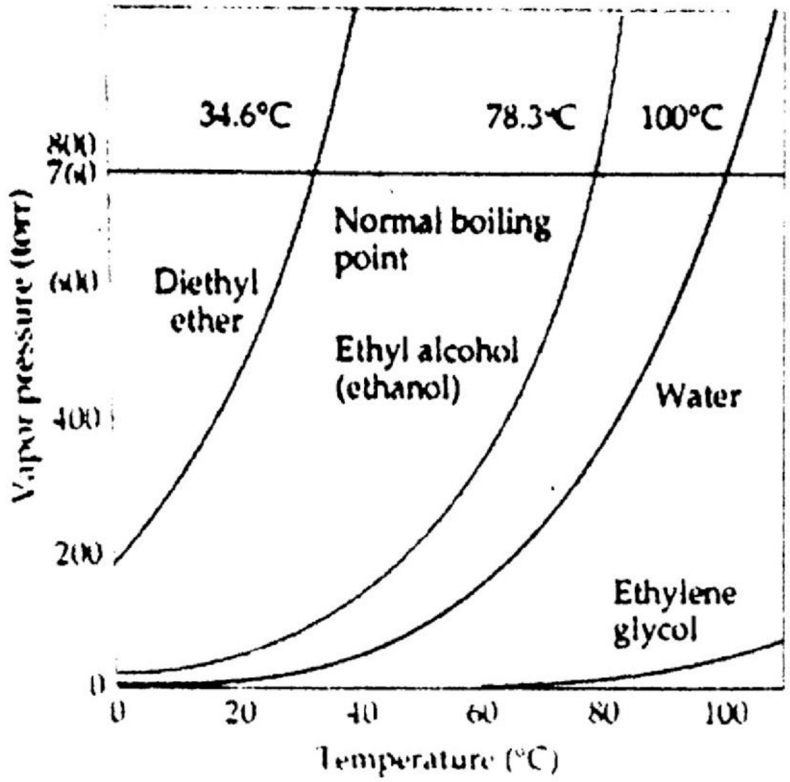
- **Intermolecular forces**
- **Temperature**

Intermolecular forces:

The vapour pressure of a liquid depends upon the strength of intermolecular forces. Liquids having **stronger intermolecular forces possess low vapour pressure** and vice versa.

Example:

Water having hydrogen bonding possesses low vapour pressure. On the other hand ether, petrol etc have high vapour pressure due to weak dispersion forces.



Temperature:

As the **temperature increases, the vapour pressure increases.** This is because increase in temperature increases the average kinetic energies of the molecules which in turn decreases the intermolecular forces.

Examples:

Vapour pressure of water at 0 °C is 4.6 mm of Hg but at 100 °C it is 760mm of Hg. The relationship of vapour pressure and temperature is shown by the graph.

Notice that the vapour pressure of diethyl ether (185mm Hg) at 0° C is much greater than that of ethanol (12mm Hg) or water (4.6mm Hg). Ether is non-polar in nature.

Therefore, its high vapour pressure is due to its weak intermolecular forces (dispersion forces). Thus at the surface ether molecules require less energy to break free and change into vapour.

Similarly, external intermolecular forces (H-bonding) are not as strong as those of water. Consequently vapour pressure of ethanol is greater than that of water at all temperatures.

It is observed that each of the three vapour pressure curves cross the line corresponding to one atmosphere at different temperatures. Therefore they boil at different temperatures.

Ether boils at 35 °C, ethanol at 78 °C and water at 100°C.

Q27. Define Viscosity? What is its SI unit and the relationship between its different units?

Ans: Viscosity:

A liquid's resistance to flow is called its viscosity. The larger the viscosity, the more slowly the liquid flows. **Viscosity measures, how easily molecules slide by one another.**

Explanation:

To understand viscosity, consider a liquid flowing in a tube is made up of a series of concentric circular layers. The resistance to flow is due to the internal friction between the layers of the molecules. The layers adjacent to the walls have the lowest velocity. Each layer exerts a drag on one another and thus causes resistance to flow.

Units:

SI units of viscosity are kilogram per meter per second ($Kgm^{-1}s^{-1}$) or Nm^{-2}.

Non-SI unit of viscosity is poise.

1 poise = 0.1 $Kgm^{-1}s^{-1}$ or $g\,m^{-1}s^{-1}$

Q28. Describe the factors on which viscosity depends.

Ans: Factors Affecting Viscosity:

Viscosity depends on the following factors:

- **Molecular shape and size**
- **Intermolecular forces**
- **Temperature**

Molecular shape and size:

Molecular size and shape strongly influence viscosity

Liquids such as water, acetone, benzene and methanol, whose molecules are small and compact, have **low viscosity.**

Whereas liquids having large and **irregular shaped** molecules like honey, glycerine tends to get tangled up with each other. This inhibits the flow of molecules and leads to **high viscosity.**

Intermolecular forces:

Stronger the intermolecular force among the molecules higher is the viscosity. Liquids whose molecules form hydrogen bonds are more viscous than other without hydrogen bonding.

Example:

Water is more viscous than methanol mainly due to extensive hydrogen bonding.

Temperature:

Molecules move faster as temperature increases.

This is because an increase in temperature decreases the intermolecular forces. This dependence is quite noticeable for highly viscous liquids such as honey and syrup. It is easier to pour these liquids when hot than when cold.

Q29. Define surface tension. Give its SI units.

Ans: Surface Tension:

"The force in dynes acting at right angle on a unit length of surface of a liquid is called surface tension".

Surface tension is the property of the surface of the liquids to act as if there is a membrane stretched across it.

Explanation:

All molecules below the surface of the liquid are surrounded in all directions by other molecules. Thus the force exhibited by such molecules is balanced in all directions whereas a molecule at a liquid surface has molecules beside it and beneath it but no one above it. This results in an unbalanced force pulling the surface molecules inward.

The molecules at the surface therefore feel a net attraction inwards, which creates surface tension. For a molecule to come to the surface it must overcome the attraction directed downward. This means work be done to pull it to the surface. Therefore, increase in surface areas of a liquid requires an input energy.

Surface tension can also be defined as the amount of energy required to expand the surface of a liquid by a unit area.

Small drops of a liquid tend to be spherical:

Molecules at the surface of a liquid are less stable than those inside it, so a liquid is stable when the fewest molecules are at its surface. This occurs when the liquid has minimum surface area. Spheres have less area per unit volume than any other. Therefore small drops of a liquid tend to be spherical.

Units:

SI unit of surface tension is joule per square meter, Jm^{-2} or Newton per meter, Nm^{-1}

Q30. What are the different factors affecting surface tension?

Ans: Factors Affecting Surface Tension:

Surface tension of a liquid depends upon the following factors.

(i) Intermolecular forces:

Surface tension of a liquid **depends directly** on the strength of intermolecular forces.

Stronger the intermolecular forces among the molecules of liquid, greater is the surface tension and vice versa.

Examples:

The surface tension of water is higher than many liquids such as alcohols, ethers benzene etc. this is due to **strong hydrogen bonding** between water molecules.

(ii) Temperature:

Surface tension of a liquid **decreases with the increase of temperature.** This is because increased kinetic energy of the molecules decreases strength of intermolecular forces.

(iii) Nature:

It is different for different liquids due to the presence of different types of intermolecular forces.

Q31. Why water behave anomalously at 3.98°C ? How aquatic life survive under freezing water?

Ans: Anomalous Behaviour of Water:

i. In ice hydrogen bonds hold water molecules in a rigid but open **hexagonal structure.**

ii. As ice melts, some of the **hydrogen bonds are overcome**, and water molecules move into the holes that were present in ice structure.

iii. As a result, the H_2O molecules **are closer together** in liquid **water than in ice.**

iv. When ice melts there is about **9% decrease** in **volume** and a corresponding **increase** in density.

v. So, water is most unusual in this regard, because the **liquid state is less dense** than the solid for most substances.

vi. If we continue to **heat water** just above the melting point, more hydrogen bonds are overcome.

vii. The molecules become still more closely packed and the density of liquid increases to a maximum density at **3.98°C**. **Above 3.98°C the density of water decreases with temperature, as we expect for a liquid.**

viii. These density phenomena explain why a freshwater lake **freezes from the top down in winter.**

Survival of aquatic life:

When temperature falls below 4°C, the more dense water sinks to the bottom of the lake.

The colder surface water freezes first. Since ice is less dense than water, the water that freezes remain at the top to cover the lake with a layer of ice. This layer of ice insulates the water underneath.

Thus under this thick blanket of ice, fish and plants survive for months.

Q32. How hydrogen bonding help us to explain the different properties of water?

Ans: i. High surface tension:

A stretched membrane is formed on the surface of water. The force on the surface acting downwards is due to strong hydrogen bond in water. Therefore a high surface tension is observed. This has been proved by the following data.

Solvent	Surface tension (γ) (Nm^{-1})
Water	7.275
Methanol	2.26
Ethanol	2.28
Benzene	2.888
Hexane	1.84
CCl_4	2.70

ii. **High specific heat:**

Specific heat is the quantity of heat required to raise the temperature of 1g of the substance by 1°C (or by 1K).

Examples:

Specific heat of water is 4.180J/g/°C. It is much higher than those of metals. It takes almost ten times as much heat to raise the temperature of 1g of water 1°C as to raise the temperature of 1g of iron by 1°C.

Conversely, much heat is given off by water even a small drop in temperature. The vast amounts of water on the surface of Earth thus act as a giant heat reservoir to moderate daily temperature variations.

That is why the climate near large bodies of water such as lakes, pounds, oceans etc, is more moderate than interior of the land.

iii. **High heat of Vaporization:**

Water has a high heat of vaporization due to extensive hydrogen bonding. A large amount of heat is required to evaporate a small amount of water. This is of enormous importance to us because large amounts of body heat can be **dissipated by the evaporation** of small amounts of water (perspiration) from the skin. This **effect also** accounts for the climate-modifying property of lakes and oceans.

iv. **High boiling points:**

Water has a high B.P. due to strong H-bonding.

It is practically observed that the B.P. of water is 100°C at one atmospheric pressure (760mm) at sea level, however, the organic solvents like benzene (B.P50°C), ether (45°C) etc have lower B.P. due to poor interactions between the molecules

Q33. Define enthalpy change and also express its unit.

Ans: Enthalpy change:

Physical and chemical changes are accompanied by energy change in the form of heat. A physical change in energy is the quantitative measurement of the strength of intermolecular forces.

Energy change at constant pressure is known as enthalpy change denoted by ΔH.

When a substance undergoes a phase change (change of state), its temperature remains constant, even though heat is being added.

Unit:

It is expressed in kg mole^{-1}

Q34. Explain molar heat of fusion, molar heat of vaporization and molar heat of sublimation with the help of examples.

Ans: Molar Heat of Fusion, Molar Heat of Vaporization and Molar Heat of Sublimation:

Molar heat of fusion (ΔH_f):

Molar heat of fusion (ΔH_f) is the amount of heat required to convert one mole of a solid into its liquid state at its melting point is called molar heat of fusion (ΔH_f).

Example:

Molar heat of fusion for ice is +6.02 KJ mole^{-1}

$H_2O_{(s)} \longrightarrow H_2O_{(l)}$, $\Delta H_f = +6.02$ KJ mole^{-1}

Molar heat of vaporization (ΔH_v) :

The amount of heat required to convert one mole of a liquid into its vapours at its boiling point is called molar heat of vaporization.

Example:

$H_2O_{(l)} \longrightarrow H_2O_{(g)}$ $\Delta H_v = +40.7$ KJ mole^{-1}

Molar heat of Sublimation (ΔH_s) :

The amount of heat absorbed when one mole of a solid sublimes to give vapour at a particular temperature at one atmospheric pressure is called molar heat of sublimation.

Example:

$I_{2(s)} \longrightarrow I_{2(g)}$ $\Delta H_s = +41.80$ KJ mole^{-1}

Q35. Why heat of vaporization is greater than heat of fusion? Give its particular examples.

Ans: Heat of vaporization is greater than heat of fusion:

As a result of melting of a solid, a small change in intermolecular distance and potential energy takes place in atoms, molecules or ions.

On the other hand on evaporation of a liquid atoms. molecules or ions undergo large changes in their intermolecular distance and potential energy Therefore, heat of vaporisation is much greater than that heat of fusion.

Particular examples:

i. ΔHv (heat of vaporization) for H_2O (40.6 KJ mole^{-1} at 373.15K, for NH_3 (23.35 KJ mole^{-1} at 239K) and CO_2 (25.23 KJ mole^{-1} at 194.5K) are high due to their polar nature and strong intermolecular forces ΔH_f (Heat of fusion) will be as under:

H_2O = 6.02 KJ mole^{-1} at 273.15K
NH_3 = 6.652 KJ mole^{-1} at 195.4K
CO_2 = 8.33 KJ mole^{-1} at 217.0K

ii. I_2, a volatile solid has the highest value of Heat of sublimation i.e 41.80 KJ mole^{-1} at 458.4K. The values for other halogens are

ΔH_v, Br_2	=	29.4	KJ mole^{-1} at	332.4K
Cl_2	=	20.21	KJ mole^{-1} at	239.1K
F_2	=	3.16	kJ mole^{-1} at	85.0K

This shows that ΔH_v (heat of vapourization)of I_2 is the highest because of strong intermolecular forces than the other halogens.

Q36. How can you explain dynamic equilibrium between two physical states.

Ans: Dynamic Equilibrium between two Physical States:

Dynamic equilibrium is a situation when two opposite changes occur i.e. from solid to liquid when a change of state occurs (solid to liquid or liquid to gas) and vice versa The system moves towards the condition of dynamic equilibrium.

Example:

At 0 °C. ice exists in dynamic equilibrium with liquid water.

$$Ice_{solid} \rightleftharpoons Water_{liq}$$

Q37. Define liquid crystals and give its daily life uses.

Ans: Liquid Crystals and Their use in Daily Life:

Definition:

(i) The substance which can flow like a liquid and also have some of the properties of liquids within a certain temperature range are called liquid crystals.

(ii) The intermediate phase lying between the solid phase and the normal liquid phase is called liquid crystal.

Uses in daily life:

i. Liquid crystals are used as temperature sensors. This is because the liquid crystals change their colour with change in temperature.

ii. They are used to monitor temperature changes where conventional methods are not feasible, e.g. they are used in thermometer for measuring skin temperature of infants.

iii. Some of the modern room thermometers contain liquid crystals with a suitable temperature range. As temperature changes, the liquid crystal show up the figure in different colours.

iv. They are used to find the point of potential failure in micro-electronic circuits.

v. They are used to locate the veins, arteries and tumours, e.g. when a layer of liquid crystal is painted on the surface of the breast, a tumour shows up as a hot area which is coloured blue. Thus this technique helps in early diagnosis of breast tumours

vi. Liquid crystals are used in the display of numbers and letters of electrical devices such as digital watches. calculators and computers etc.

vii. Liquid crystals are used in LCD screens of oscillographs and TV

Q38. How will you differentiate between liquid crystals and pure liquid?

Ans: Differentiate Liquid Crystals from Pure Liquids:

i. A liquid crystal is a state of matter which is in between pure liquid (transparent) and crystalline solid.
i.e. crystalline solid = liquid crystals = pure liquid

ii. A liquid crystal resembles the crystalline solid in certain respects, e.g. optical properties. However pure liquids remain as such.

iii. A crystalline solid may be isotropic (A substance showing same properties in all directions) and an anisotropic (A substance showing different properties in different direction) but liquid crystals are always isotropic. Pure liquids remain as such

iv. Liquid crystal is intermediate in between pure liquid and crystalline phase.

EXERCISE

MULTIPLE CHOICE QUESTIONS

1. Choose the correct answer (MCQs).

i. Van Der Waal's forces are effective.
(a) At long distance
(b) Both at long as well as short distance
(c) Only at short distance
(d) Independent of distance

ii. Which one of the following forces are also called London forces.
(a) Ion-dipole forces (b) Dipole-induced dipole forces
(c) Dipole-dipole forces (d) Dispersion forces

iii. Which of the following two halogens are gases at room temperature.
(a) Fluorine and Iodine (b) Chlorine and Bromine
(c) Fluorine and Chlorine (d) Iodine and Bromine

iv. The intermolecular forces are of.
(a) Two types (b) Three types
(c) Four types (d) Five types

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(a) Two types (b) Three types
(c) Four types (d) Five types

v. **Thermostat is an instrument which**

(a) Increases the temperature (b) Decreases the temperature

(c) Maintains the temperature (d) Fluctuate the temperature

vi. **The scientist who discussed the phenomenon of viscosity are**

(a) Poisentillie (b) Newton

(c) Fritz (d) Vander Wall

vii. **The distillation under reduced pressure is called**

(a) Fractional distillation (b) Vacuum distillation

(c) Steam distillation (d) Pressure distillation

viii. **The unit of surface tension is**

(a) Newton per metre (b) Newton per metre square

(c) 760mm of Hg (d) Newton square per metre

ix. **The flow of the liquid where the velocity of layers is not too large is called**

(a) Streamline flow (b) Newtonian (or Laminar flow)

(c) Turbulent flow (d) None of these

x. **The intermediate phase lying between the solid phase and the normal liquid phase is called**

(a) Crystalline solid (b) liquid crystals

(c) Mesogens (d) Crystal lattice

xi. **In which of the following are the particles the most disordered?**

(a) Water at 100 °C (b) Steam at 100 °C

(c) Impure water at 102 °C . (d) Water at 10 °C

xii. **Which of these statement best supports the idea that matter is made up of particles?**

(a) Liquids always fill the space available to them

(b) Liquids are easily compressible

(c) 1 cm^3 of water produces nearly 1700 cm^3 of steam

(d) If a bottle of perfume is opened. the smell spread quickly

xiii. **Which of these processes involve a weakening of the attraction between particles?**

(a) Condensation (b) Freezing

(c) Crystallization (d) Evaporation

xiv. **A liquid is thought to be pure ethanoic acid (acetic acid), which of the following is the best way to test its purity?**

(a) Measure its B P (b) React it with ethanol

(c) Burn it completely in oxygen

(d) Dehydrate it with concentrated H_2SO_4

xv. **A flask contains the liquid chloroform and water. They are separated using a separating funnel, which conclusion can be from this observation alone.**

(a) Chloroform and water have different relative molecular masses

(b) Chloroform and water have different, boiling points

(c) Chloroform has a higher density than water

(d) Chloroform and water do not mix

xvi. Which of the following is the best method of obtaining water from ink?

(a) Distillation (b) Filtration

(c) Freezing (d) Chromatography

xvii. To help diagnose illness, doctors often need to know which amino acids are present in blood or urine. Which method is common by used to separate and identify amino acids?

(a) Chromatography (b) Distillation

(c) Re-crystallization (d) Filtration

(e) Sublimation

Answers

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

2: Write brief answer to the following.

i. Give the general properties of liquids as to

(a) Diffusion (b) Compression

Ans. (a) Diffusion of liquids:

The diffusion in liquids takes place because the molecules move from one place to another due to K.E. The restricted movement of the molecule reduces the rate of diffusion

Example:

A drop of ink when added to water diffuses slowly due to relatively small empty spaces between the molecules. The diffusion between closely packed molecules of liquids ~~is~~ slow due to less collision between them.

(b) Compression of liquid (effect of pressure):

A liquid cannot be compressed significantly by increasing the pressure because the molecules are already in close contact with one another

Example:

An increase of pressure from one to two atmospheres reduces the volume of water to 0.0045 percent which is negligible. However the same pressure reduces the volume of a gas up to 50 percent.

ii. What are intermolecular forces?

Ans. Intermolecular forces:

The forces of attractions among the molecules of a substance are called inter-molecular forces.

Example:

Water exists as a liquid due to inter-molecular attractions called Hydrogen bonds. The forces of attraction existing between the molecules of a non-polar substance are also known as Van Der-Waal's forces.

iii. What are the types of intermolecular forces, give examples?

Ans. Intermolecular Forces (Van Der-Waal's forces):

The forces of attractions among the molecules of a substance are called inter-molecular forces.

Types:

The intermolecular forces are of five types:

- **Dipole-Dipole forces:**

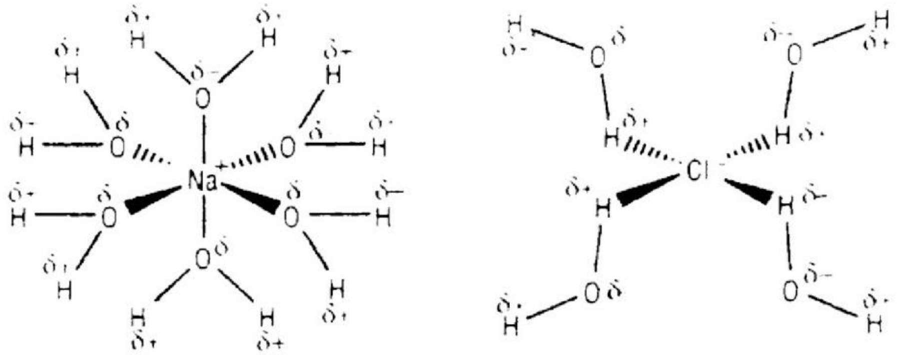
Examples:

Hydrogen chloride (HCl) chloroform ($CHCl_3$), Acetone $(CH_3)_2CO$ etc.

- **Ion-Dipole forces:**

Examples:

Forces between ions and water molecules.



- **Dipole-induced dipole forces:**

Examples:

Forces between HCl (polar) and He (non-polar)

- **London Dispersion forces:**

Examples:

Substances like hydrogen, helium, neon, argon, chlorine, fluorine, methane etc.

- **Hydrogen bonding:**

Examples: NH_3, H_2O and HF

iv. **What is hydrogen bonding, give particular examples?**

Ans. **Hydrogen Bonding**

A hydrogen bond is the attraction between the lone pair of an electronegative atom and a hydrogen atom that is bonded to either N, O or F.

This limits hydrogen bonding mainly to the participation of nitrogen, oxygen and fluorine atoms. Hydrogen bonds are weaker than covalent bonds but stronger than dipole-dipole interactions, which are stronger than London dispersion forces.

Examples: H_2O, HF and NH_3 have hydrogen bonding.

v. **What are the applications of H-bonding?**

Ans. **Applications of Hydrogen Bonding:**

(i) **Thermodynamic properties:**

The boiling points of hydrides of group IVA, VA, VIA and VIIA plotted against period number of the periodic table is shown in figure.

The boiling point of hydrides:

i. Note that hydrides of group IVA have lower boiling points

ii. The reason is that these hydrides are non-polar and have only London dispersion forces among their molecules.

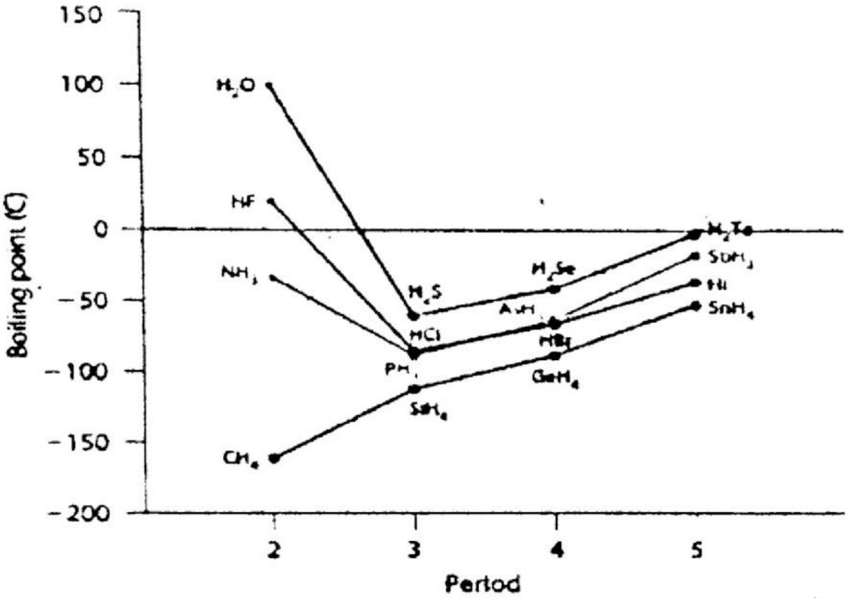
iii. Hydrides of group VA, VIA and VII-A have polar molecules.

iv. NH_3, H_2O and HF show maximum boiling points in their respective series. This is due to hydrogen bonding in their molecules.

v. One should expect H-bonding to be stronger in HF than H_2O. But boiling point of H_2O is higher than that of HF. The reason is that fluorine can make only one hydrogen bond with hydrogen of the neighbouring molecule.

vi. On the other hand oxygen atom can form two hydrogen bonds with the neighbonring molecules

vii. NH_3 can also form only one hydrogen bond per molecule as it has only one lone pair.



A graph between period number and the boiling points of hydrides.

(ii) Solubility of Hydrogen Bonded Molecules:

The compounds that have hydrogen bonds are soluble in each other. Ethyl alcohol can dissolve in water because both can form hydrogen bonds with each other. Similarly carboxylic acids are also soluble in water, if their molecular sizes are small.

(iii) Cleansing Action:

Soaps and detergents perform the cleaning action. Their molecules contain both polar and non-polar ends. Their polar parts are water soluble due to hydrogen bonding and non-polar part dissolve oil or grease. Attraction between water and polar end of soap molecule carries the oil or grease droplet into the water.

(iv) Hydrogen Bonding in Paints and Dyes:

Paints and dyes have adhesive action due to hydrogen bonding. Similarly hydrogen bonding also makes glue and honey stickle substances.

(v) Clothing:

We use cotton, silk or synthetic fibres for clothing. Hydrogen bonding is of great importance in thread making materials. This hydrogen bonding is responsible in their rigidity and tensile strength.

(vi) Food Materials:

Food materials like carbohydrates consist of glucose, fructose, sucrose each of them contains –OH groups which is responsible for H-bonding in them.

(vii) Hydrogen Bonding in Biological Molecules:

The structure of proteins, substances essential to life, is determined partly by hydrogen bonding. The action of enzymes, the protein molecules that catalyze the reactions that sustain life, depends in part on the forming and breaking of hydrogen bonds. The hereditary information passed from one generation to the next is carried in nucleic acid molecules joined by hydrogen bonds into an elegant structure.

vi. What are the different types of physical properties of liquids?

Ans. Physical Properties of Liquids:

Following are the physical properties of liquids

i. Additive properties:

Such properties depend upon the number and kind of atoms present in the molecule.

Example:

Molecular weight.

ii. Constitutive properties:

Such properties depend upon the arrangement of atoms in the molecules and not their number.

Example:

Optical activity.

iii. Colligative properties:

Such properties depend on the number of ions and molecules present but do not depend upon the structure of molecules.

Example: **Osmotic pressure, molar volume etc.**

vii. Define vapour pressure. What are the factors affecting the V.P?

Ans. Vapour Pressure (V.P):

"The pressure exerted by vapours in equilibrium with its liquid state is called the liquid's vapour pressure at the given temperature"

Factors affecting Vapour Pressure:

Vapour pressure is measured in the **same units** used for gas pressure. Two factors affect liquid's vapour pressure:

- **Intermolecular forces**
- **Temperature**

viii. What is (a) Viscosity. (b) Surface tension.

Ans. (a) Viscosity:

A liquid's resistance to flow is called its viscosity. The larger the viscosity, the more slowly the liquid flows. **Viscosity measures, how easily molecules slide by one another.**

Examples:

Liquids such as water, acetone, benzene and methanol, whose molecules are small and compact, have **low viscosity.**

Whereas liquids having large and **irregular shaped** molecules like honey, glycerine tends to get tangled up with each other. This inhibits the flow of molecules and leads to **high viscosity.**

(b) Surface tension:

"The force in dynes acting at right angle on a unit length of surface of a liquid is called surface tension".

Surface tension can also be defined as the amount of energy required to expand the surface of a liquid by a unit area.

ix. Define molar heat of fusion and molar heat of vaporization.

Ans. Molar Heat of Fusion, Molar Heat of Vaporization and Molar Heat of Sublimation:

Molar heat of fusion (ΔH_f) is the amount of heat required to convert one mole of a solid into its liquid state at its melting point is called molar heat of fusion (ΔH_f)

e.g. Molar heat of fusion for ice is +6.02 KJ mole^{-1}

$H_2O_{(s)} \longrightarrow H_2O_{(l)}$, $\Delta H_f = +6.02$ KJ mole^{-1}

Molar heat of vaporization (ΔH_v):

The amount of heat required to convert one mole of a liquid into its vapours at its boiling point is called molar heat of vaporization.

e.g. $H_2O_{(l)} \longrightarrow H_2O_{(g)}$ $\Delta H_v = +40.7$ KJ mole^{-1}

x. How will you differentiate liquid crystals from pure liquids?

Ans. Differentiate Liquid Crystals from Pure Liquids and Crystalline Solids:

A liquid crystal is a state of matter which is in between pure liquid (transparent) and crystalline solid

i.e. crystalline solid ⇌ liquid crystals ⇌ pure liquid

A liquid crystal resembles the crystalline solid in certain respects, e.g. optical properties. However pure liquids remain as such

A crystalline solid may be isotropic (A substance showing same properties in all directions) and an anisotropic (A substance showing different properties in different direction) but liquid crystals are always isotropic. Pure liquids remain as such

Liquid crystal is intermediate in between pure liquid and crystalline phase

xi. Why distillation under reduced pressure is often used in the purification of chemicals?

Ans. Distillation is a process in which liquid are separated from each other on the basis of their boiling points. In this process liquids are heated under reduced pressure condition. This process is known as vacuum distillation.

Explanation:

The liquids which decompose at their B.P can be obtained in the pure form under reduced pressure by Vacuum distillation

Example:

Glycerine has a B.P of 290°C at 760mm but it decomposes at its B.P. Now in order to get it in the pure form, the **V.P is decreased** to 50mm by Vacuum pump.

The B.P decreases to 120°C without decomposition. In this way the liquids can be purified.

xii. You wish to have a "five minute" boiled egg for breakfast. For each of the following location or situations, would you cook your egg less than or more than five minutes to produce your "five minute" boiled egg. Explain your answers of the following.

(a) You are at the top of Whittler Mountain in British Columbia.

(b) You have breakfast just before you start work 2000 meter underground in a gold mine in Timmons, Ontario.

(c) You have breakfast on a very clear and bright sunny day at sea level.

Ans. As we know that boiling point is directly proportional to external pressure

Boiling point $\propto$ External pressure

a. At the top of the Whittler Mountain in British Columbia the external pressure is less than the normal pressure. Due to which the boiling point of the water decreases and water boils below 100 °C and that is why cooking of egg will require **more than five minutes.**

b. In underground gold mine the external pressure is greater than the normal pressure. Due to which the boiling point of the water increases and water boils above 100 °C. So the cooking of egg will require **less than five minutes.**

c. At sea level external pressure is equal to the normal pressure. Therefore cooking of food requires 5 minutes because at normal conditions the water boils at 100 °C.

xiii. Explain:

(a) What happens to the particles of a solid at its melting point?

(b) What happens during evaporation in a liquid?

(c) Why a given gas occupies all the available space?

(d) The latent heat of fusion?

Ans.

(a) When a solid is heated the particles gain energy and start to vibrate faster and faster. Initially the structure becomes weakened due to the expansion the solid. Further heating provides more energy and the solid begin to melt. At melting point the solid particles acquire more kinetic energy, vibrate more violently and the high frequency of vibration overcomes the Intermolecular forces in the solid due to which their structure collapse.

(b) Evaporation is the process in which liquid molecules escape from the surface and enter the gas phase.

Explanation:

Surface molecules whose kinetic energies are higher than average kinetic energies, overcome the intermolecular forces that bind them to the liquid and enter the gas phase. After their escape, the average kinetic energy of the remaining molecules decreases. Therefore temperature of the liquid decreases, thus **evaporation is a cooling process.**

(c) Gas molecules have large empty spaces between them due to weak intermolecular forces and they posses high kinetic energy.

That is why the gases occupies all the available space.

(d) Latent heat of fusion:

The amount of heat require to convert a unit mass of a solid at its melting point into a liquid without an increase in temperature is called latent of heat of fusion.

Example:

For example, the latent heat of fusion for water (ice) is about 334 kJ/mol

xiv. Explain:

(a) How liquids mix?

(b) Why temperature of a boiling liquid does not raise at its boiling point?

Ans. (a) Liquids mixes in one another because of the process of diffusion.

Explanation:

The diffusion in liquids takes place because the molecules move from one place to another due to K.E. The restricted movement of the molecule reduces the rate of diffusion

Example:

A drop of ink when added to water diffuses slowly due to relatively small empty spaces between the molecules. The diffusion between closely packed molecules of liquids is slow due to less collision between them.

(b) The increase in temperature increase the kinetic energy of the liquid molecules due to which the intermolecular forces decreases. Heat supplied at boiling point is used in breaking intermolecular forces and to convert the liquid into its vapours. That is why the temperature of a boiling liquid does not raise at its boiling point.

3. (a) Define a liquid and give a particular example.

(b) Give the simple properties of liquids with special reference to the following:

- **Diffusion**
- **Compression**
- **Expansion**
- **Inter molecular forces**
- **Kinetic energy**

(c) Explain on the basis of Kinetic Molecular Theory. Why the B.P of a liquid remains constant although heat is continuously supplied to the liquid?

Ans. (a) Define a liquid and give a particular example.

Liquid:

A simple definition of a liquid is that "it is a material that assumes the shape of a container without filling it completely"

Examples:

Liquids may be of three types. The types of liquids, their physical properties with examples are shown below

Sr. #.	Types of liquids	Properties	Examples
01	Ionic Liquid	High Boiling Point	Molten Salt e.g. $AlCl_3$
02	Molecular Liquid	Low Boiling Point	H_2O. C_2H_5OH
03	Metallic Liquid	Moderate to High BP	Molten metals e.g. Hg

(b) Give the simple properties of liquids with special reference to the following:

- **Diffusion**
- **Compression**

- **Expansion**
- **Inter molecular forces**
- **Kinetic energy**

i. Diffusion:

The diffusion in liquids takes place because the molecules move from one place to another due to K.E. The restricted movement of the molecule reduces the rate of diffusion e.g. a drop of ink when added to water diffuses slowly due to relatively small empty spaces between the molecules. The diffusion between closely packed molecules of liquids is slow due to less collision between them.

ii. Compression (effect of pressure):

A liquid cannot be compressed significantly by increasing the pressure because the molecules are already in close contact with one another e.g. an increase of pressure from one to two atmospheres reduces the volume of water to 0.0045 percent which is negligible. However the same pressure reduces the volume of a gas up to 50 percent.

iii. Expansion (effect of temperature):

The liquids expand on heating because the intermolecular forces between them decrease. Moreover the increase of temperature increases the effective collisions between the molecules. If the temperature is decreased, contraction of molecules takes place. This property is useful for making thermometers, e.g. mercury thermometer. In it, if the temperature rises, the mercury expands in the capillary tube. As the volume of capillary is much less than the volume of the bulb containing mercury, a small expansion gives a large movement of mercury thread.

iv. Motion of molecules:

The molecules move with lesser speed due to larger forces of attraction among them. As a result they have lesser kinetic energy. However the Kinetic Energy increases with the increase of Temperature.

v. Spaces between them:

The molecules forming the liquid states are fairly close to each other. There is very little space between them. As a result the numbers of collisions among the molecules are moderate. Therefore, the average Kinetic Energy is also moderate.

vi. Intermolecular forces:

The attractive forces existing between the individual particles of a substance are called intermolecular forces. The physical properties of liquids such as boiling point, vapour pressure, surface tension, viscosity and heat of vaporization depend upon the strength of intermolecular attractive forces.

vii. Kinetic Energy based on Kinetic Molecular Theory:

According to the Kinetic Molecular Theory, the molecules due to strong inter-molecular attractions have minimum movements and minimum collisions. Let us consider the example of water, as the molecules are closer to each other and have strong forces of attractions due to hydrogen bonding so have low kinetic energy.

(c) Explain on the basis of Kinetic Molecular Theory. Why the B.P of a liquid remains constant although heat is continuously supplied to the liquid?

When a liquid is heated its temperature increases until its boiling point is achieved. The increase in temperature increase the kinetic energy of the liquid molecules due to which the intermolecular forces decreases. Heat supplied at boiling point is used in breaking intermolecular forces and to convert the liquid into its vapours. That is why the temperature of a boiling liquid does not raise at its boiling point.

4. (a) What are the main types of Intermolecular Forces?

(b) Explain the applications of dipole-dipole forces, Hydrogen bonding and London forces.

Ans. (a) Intermolecular Forces (Van Der-Waal's forces):

The forces of attractions among the molecules of a substance are called inter-molecular forces.

Types:

The intermolecular forces are of five types:

- Dipole-Dipole forces
- Ion-Dipole forces
- Dipole-induced dipole forces
- London Dispersion forces
- Hydrogen bonding

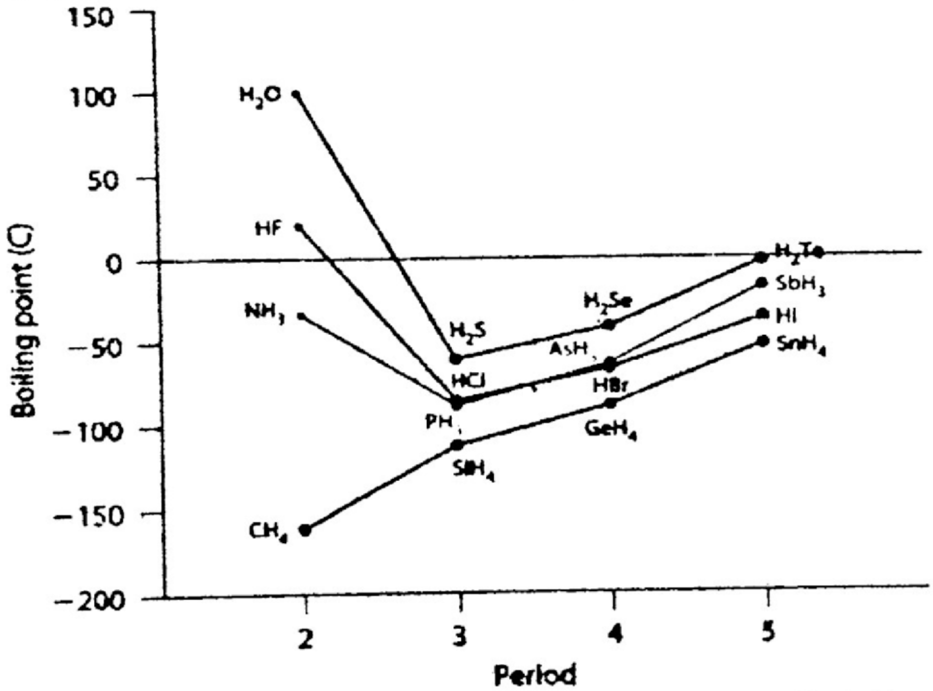
(b) Applications of dipole-dipole forces:

Stronger these dipole-dipole forces, greater would be the value of thermodynamic parameters like melting point, boiling point, heat of vaporization, heat of subliminal etc.

Applications of hydrogen bonding:

(i) Thermodynamic properties

The boiling points of hydrides of group IVA, VA, VIA and VIIA plotted against period number of the periodic table is shown in figure.



A graph between period number and the boiling points of hydrides.

Explanation:

The boiling point of hydrides:

Note that hydrides of group IVA have lower boiling points. The reason is that these hydrides are non-polar and have only London dispersion forces among their molecules. Hydrides of group VA, VIA and VII-A have polar molecules. NH_3, H_2O and HF show maximum boiling points in their respective series. This is due to hydrogen bonding in their molecules.

The boiling point of H_2O seems to be more affected than that of HF. As F is more electronegative than O. One should expect H-bonding to be stronger in HF than H_2O. But boiling point of H_2O is higher than that of HF. The reason is that fluorine can make only one hydrogen bond with hydrogen of the neighbouring molecule. On the other hand oxygen atom can form two hydrogen bonds with the neighbouring molecules. NH_3 can also form only one hydrogen bond per molecule as it has only one lone pair.

Solubility of Hydrogen Bonded Molecules:

The compounds that have hydrogen bonds are soluble in each other. Ethyl alcohol can dissolve in water because both can form hydrogen bonds with each other. Similarly carboxylic acids are also soluble in water, if their molecular sizes are small. This is all because of hydrogen bonding.

(i) Cleansing Action:

Soaps and detergents perform the cleaning action. Their molecules contain both polar and non-polar ends. Their polar parts are water soluble due to hydrogen bonding and non-polar part dissolve oil or grease. Attraction between water and polar end of soap molecule carries the oil or grease droplet into the water.

(ii) Hydrogen Bonding in Paints and Dyes:

Paints and dyes have adhesive action due to hydrogen bonding. Similarly hydrogen bonding also makes glue and honey stickle substances.

(iii) Clothing:

We use cotton, silk or synthetic fibres for clothing. Hydrogen bonding is of great importance in thread making materials. This hydrogen bonding is responsible in their rigidity and tensile strength.

(iv) Food Materials:

Food materials like carbohydrates consist of glucose, fructose, sucrose, each of them contains –OH groups which is responsible for H-bonding in them.

(v) Hydrogen Bonding in Biological Molecules:

The structure of proteins, substances essential to life, is determined partly by hydrogen bonding. The action of enzymes, the protein molecules that catalyze the reactions that sustain life, depends in part on the forming and breaking of hydrogen bonds. The hereditary information passed from one generation to the next is carried in nucleic acid molecules joined by hydrogen bonds into an elegant structure.

Applications of London Dispersion Forces:

Factors affecting the London dispersion force are:

i. Atomic or molecular size

ii. Polarizability

iii. Number of atoms in a molecules

(i) Atomic or Molecular Size:

The strength of London dispersion forces depends upon the size of the electronic cloud of the atom or molecule. With the increase in size of atom or molecule, the dispersion becomes easy and these forces become prominent.

Inert gases are all monotonic gases. They do not make covalent bonds with other atoms because their valence shells are complete. Their boiling point increase down the group from *He* to *Rn*. This is because of increase in molecular size.

Table Boiling points of noble gasses

Noble Gas	He	Ne	Ar	Kr	Xe	Rn
Boiling Points (°C)	-268.6	-245.9	-185.7	-152.3	-107.1	-61.8

(ii) Polarizability:

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

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

Examples:

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

(iii) Number of atoms in a molecule:

Elongated molecules make contact with neighbouring molecules over a greater surface than do small molecules. **Greater the number of atoms in a molecule, greater is the polarizability of the molecule.**

Table: Boiling points and physical states of some hydrocarbons.

Molecular formula	B.P (°C at 1 atm)	Physical State at STP
CH_4	-161.5	Gas
C_2H_6	-88.6	Gas
C_3H_8	-42.1	Gas
C_4H_{10}	-0.5	Gas
C_5H_{12}	36.1	Liquid
C_6H_{14}	68.7	Liquid
$C_{10}H_{22}$	174.1	Liquid

Examples:

C_2H_6 and C_6H_{14} have the boiling points as -88.6°C and 67.7°C respectively. This shows that the molecule with a large chain length experiences stronger attractive forces.

5. (a) Define and explain evaporation.

(b) What are the factors affecting evaporation?

(c) Different liquids have different rates of evaporation. Explain with reference to ether and alcohol?

Ans. (a) Evaporation:

Evaporation is the process in which liquid molecules escape from the surface and enter the gas phase.

Explanation:

It can be explained in terms of the energy possessed by the molecules on the liquid's surface. Surface molecules whose kinetic energies are higher than average kinetic energies, overcome the intermolecular forces that bind them to the liquid and enter the gas phase. After their escape, the average kinetic energy of the remaining molecules decreases. Therefore temperature of the liquid decreases, thus evaporation is a cooling process

(b) Factors affecting evaporation:

i. Surface Area:

The rate of evaporation increases with increasing surface area. This is because large surface area allows more molecules to evaporate

ii. Intermolecular Forces:

The escaping tendency of molecules depends upon attractive forces between the molecules. The liquids with strong intermolecular forces have less evaporation. Thus water has less evaporation rate than petrol. This is because water has stronger intermolecular forces (H-bonding) than petrol which has weak dispersion forces between the molecules. A liquid which can rapidly change into vapours is called volatile e.g. petrol is more volatile than water.

iii. Temperature:

Evaporation takes place at all temperature. Rate of evaporation however is affected by the change in temperature. Increase in temperature increases the number of molecules having kinetic energy sufficient to overcome intermolecular forces and escape more readily from the surface of the liquid. Thus the rate of evaporation increases with increasing temperature. This is why cloths dry more readily in summer.

(c) The rate of the evaporation depends upon the strength of intermolecular forces.

Stronger the intermolecular forces slower will be the rate of evaporation and vice versa.

Example:

Ether and alcohol have London dispersion forces which are weak intermolecular forces that are why they have high rate of evaporation.

6. (a) Define and explain vapour pressure. How equilibrium is established between evaporation and condensation?

(b) What are the factors affecting V.P of a liquid?

(c) Kinetically how will you explain the effect of temperature on vapour pressure?

Ans. (a) Vapour Pressure (V.P):

Vapour Pressure (V.P):

"The pressure exerted by vapours in equilibrium with its liquid state is called the liquid's vapour pressure at the given temperature"

Condensation:

In closed containers, the vapours cannot escape. Therefore, as the vapour concentration increases, some of the vapour molecules lose energy and return to the liquid state. **This process is called condensation.**

Explanation:

Evaporation involves molecules leaving the liquid and condensation occurs when a vapour changes back to a liquid. While the liquid is placed in a closed container, it begins to evaporate at a constant rate very little condensation takes place. But as the concentration of the vapour increases above the liquid, the rate of condensation increases.

After som time the rate of condensation equals the rate of evaporation. At this stage the number of molecules entering the gas phase equals the number returning to the liquid phase the system is said to be in a dynamic equilibrium.

Intensive property:

Vapour pressure is independent of the amount of liquid, so this is called an intensive property of the liquid.

Factors affecting Vapour Pressure:

Vapour pressure is measured in the **same units** used for gas pressure. Two factors affect liquid s vapour pressure

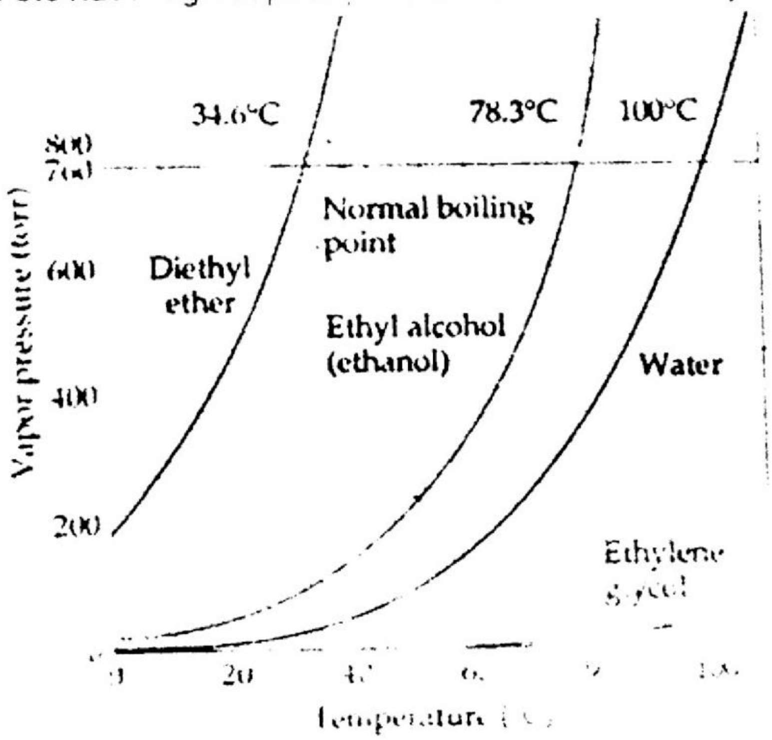
- **Intermolecular forces**
- **Temperature**

Intermolecular forces:

The vapour pressure of a liquid depends upon the strength of intermolecular forces Liquids having **stronger intermolecula. forces possess low vapour pressure** and vice versa

Example:

Water having hydrogen bonding possesses low vapour pressure On the other hand ether petrol etc have high vapour pressure due to weak dispersion forces



Temperature:

As the **temperature increases, the vapour pressure increases.** This is because increase in temperature increases the average kinetic energies of the molecules which in turn decreases the intermolecular forces.

Examples:

Vapour pressure of water at 0 °C is 4.6 mm of Hg but at 100 °C it is 760mm of Hg. The relationship of vapour pressure and temperature is shown by the graph.

Notice that the vapour pressure of diethyl ether (185mm Hg) at 0° C is much greater than that of ethanol (12mm Hg) or water (4.6mm Hg). Ether is non-polar in nature.

Therefore, its high vapour pressure is due to its weak intermolecular forces (dispersion forces). Thus at the surface ether molecules require less energy to break free and change into vapour.

Similarly, external intermolecular forces (H-bonding) are not as strong as those of water. Consequently vapour pressure of ethanol is greater than that of water at all temperatures.

It is observed that each of the three vapour pressure curves cross the line corresponding to one atmosphere at different temperatures. Therefore they boil at different temperatures.

Ether boils at 35 °C, ethanol at 78 °C and water at 100°C.

7. (a) Define and explain boiling point of a liquid?

(b) How will you explain the effect of pressure on the B.P of a liquid?

(c) Practically how will you explain the

(i) Effect of increase of pressure on boiling point.

(ii) Effect of decrease of pressure on boiling point.

Ans. The temperature at which the vapour pressure of the liquid equals to atmospheric pressure or some external pressure is called boiling point of that liquid.

Explanation:

When a liquid is heated, its V.P increases due to the decrease of intermolecular forces with rise in temperature. As a result more and more vapours escape in the air. A stage reaches at which the liquid begins to boil. So the temperature at which the vapour pressure of the liquid equals to atmospheric pressure or some external pressure is called boiling point of that liquid.

Example: Boiling Point of water at 760mm = 100 °C
Boiling Point of water at 23.7mm = 25 °C

(b) Effect of Pressure on boiling point of a Liquid:

There are two practical applications regarding the effect of pressure.

i. Effect of Increase of Pressure:

Food can be cooked easily in pressure cookers, which is a closed container. The vapours are not allowed to escape out and, therefore, develop more pressure. This increases the B.P of water. Pressure cookers help us in cooking the food quickly even at high attitude e.g. B.P of water at 2026mm Hg is 130°C

ii. Effect of decrease of pressure:

The liquids which decompose at their B.P can be obtained in the pure form under reduced pressure by Vacuum distillation e.g. Glycerine has a B.P of 290°C at 760mm but it decomposes at its B.P. Now in order to get it in the pure form, the V.P is decreased to 50mm by Vacuum pump. The B.P decreases to 120°C without decomposition. In this way the liquids can be purified.

(c) i. Effect of Increase of Pressure:

Food can be cooked easily in pressure cookers, which is a closed container. The vapours are not allowed to escape out and, therefore, develop more pressure. This increases the B.P of water. Pressure cookers help us in cooking the food quickly even at high attitude e.g. B.P of water at 2026mm Hg is 130°C

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8. (a) Define and explain the term viscosity of a liquid? How the resistance to the layers causes viscosity?

(b) What are the factors affecting the viscosity of a liquid?

Ans. (a) Viscosity:

A liquid's resistance to flow is called its viscosity. The larger the viscosity, the more slowly the liquid flows. Viscosity measures, how easily molecules slide by one another.

Explanation:

It is common observation that water can be poured very quickly from one container to another as compared to honey and glycerine. To understand viscosity, consider a liquid flowing in a tube is made up of a series of concentric circular layers. The resistance to flow is due to the internal friction between the layers of the molecules. The layers adjacent to the walls have the lowest velocity. Each layer exerts a drag on one another and thus causes resistance to flow.

(b) Factors Affecting Viscosity:

Viscosity depends on the following factors:

- **Molecular shape and size**
- **Intermolecular forces**
- **Temperature**

Molecular size:

Molecular size and shape strongly influence viscosity. Liquids such as water, acetone, benzene and methanol. whose molecules are small and compact have low viscosity. Whereas liquids having large and irregular shaped molecules like honey, glycerine tends to get tangled up with each other. This inhibits the flow of molecules and leads to high viscosity.

Intermolecular force:

Stronger the intermolecular force among the molecules higher is the viscosity. Liquids whose molecules form hydrogen bonds are more viscous than other without hydrogen bonding. For example water is more viscous than methanol mainly due to extensive hydrogen bonding.

Temperature:

Molecules move faster as temperature increases. This is because; an increase in temperature decreases the intermolecular forces. This dependence is quite noticeable for highly viscous liquids such as honey and syrup. It is easier to pour these liquids when hot than when cold.

9. (a) **What are the S.I unit of viscosity and surface tension?**
(b) **Use the concept of hydrogen bonding to explain the following properties of water?**
(i) **High surface tension**
(ii) **High heat of vaporization**
(iii) **High B.P**

Ans. (a) Units of viscosity:

SI units of viscosity are kilogram per meter per second ($Kgm^{-1}s^{-1}$) or Nm^{-2}. Non-SI unit of viscosity is poise.

1 poise= $0.1\ Kgm^{-1}s^{-1}$ or $g\ m^{-1}s^{-1}$

Units surface tension:

SI unit of surface tension is joule per square meter, Jm^{-2} or Newton per meter, Nm^{-1}.

(b) (i) **High surface tension**
(ii) **High heat of vaporization**
(iii) **High B.P**

i. High surface tension:

A stretched membrane is formed on the surface of water. The force on the surface acting downwards is due to strong hydrogen bond in water. Therefore a high surface tension is observed. This has been proved by the following data.

Solvent	Surface tension (γ) (Nm^{-1})
Water	7.275
Methanol	2.26
Ethanol	2.28
Benzene	2.888
Hexane	1.84
CCl_4	2.70

ii. High heat of Vaporization:

Water has a high heat of vaporization due to extensive hydrogen bonding. A large amount of heat is required to evaporate a small amount of water. This is of enormous importance to us because large amounts of body heat can be dissipated by the evaporation of small amounts of water (perspiration) from the skin. This effect also accounts for the climate-modifying property of lakes and oceans.

iii. High boiling points:

Water has a high B.P due to strong H-bonding.

It is practically observed that the B.P. of water is 100°C at one atmospheric pressure (760mm) at sea level, however, the organic solvents like benzene (B.P50°C), ether (45°C) etc have lower B.P due to poor interactions between the molecules.

10. (a) **Define and explain the phenomena of surface tension?**
(b) **What are the factors affecting surface tension?**
(c) **Define dynamic equilibrium between two physical states?**
(d) **Define?**
(i) **Molar Heat of fusion**
(ii) **Molar Heat of vapourization.**

Ans. (a) Surface Tension:

"The force in dynes acting at right angle on a unit length of surface of a liquid is called surface tension"

Explanation:

Surface tension is the property of the surface of the liquids to act as if there is a membrane stretched across it. We can understand that the level of liquids exhibit surface tensions. All molecules below the surface of the liquid are surrounded in all directions by other molecules. Thus the force exhibited by such molecules is balanced in all directions whereas a molecule at a liquid surface has molecules beside it and beneath it but no one above it. This results in an unbalanced force pulling the surface molecules inward.

The molecules at the surface therefore, feel a net attraction inwards, which creates surface tension. For a molecule to come to the surface, it must overcome the attraction directed downward. This means work be done to pull it to the surface. Therefore, increase in surface areas of a liquid requires an input energy.

Surface tension can also be defined as the amount of energy required to expand the surface of a liquid by a unit area.

Drops of a liquid tend to be spherical:

Molecules at the surface of a liquid are less stable than those inside it, so a liquid is stable when the fewest molecules are at its surface. This occurs when the liquid has minimum surface area. Spheres have less area per unit volume than any other. **Therefore small drops of a liquid tend to be spherical.**

(b) Factors Affecting Surface Tension:

Surface tension of a liquid depends upon the following factors.

i. Intermolecular forces:

Surface tension of a liquid depends directly on the strength of intermolecular forces. Stronger the intermolecular forces among the molecules of liquid, greater is the surface tension and vice versa. For example the surface tension of water is higher than many liquids such as alcohols, ethers benzene etc. this is due to strong hydrogen bonding between water molecules.

ii. Temperature:

Surface tension of a liquid decreases with the increase of temperature. This is because increased kinetic energy of the molecules decreases strength of intermolecular forces.

iii. Nature:

It is different for different liquids due to the presence of different types of intermolecular forces.

(c) Dynamic Equilibrium between two Physical States:

Dynamic equilibrium is a situation when two opposite changes occur i.e. from solid to liquid when a change of state occurs (solid to liquid or liquid to gas) and vice versa. The system moves towards the condition of dynamic equilibrium.

e.g. At 0 °C, ice exists in dynamic equilibrium with liquid water.

$$\text{Ice}_{\text{solid}} \rightleftharpoons \text{Water}_{\text{liq.}}$$

(d) Molar Heat of Fusion, Molar Heat of Vaporization and Molar Heat of Sublimation:

(i) Molar heat of fusion (ΔH_f):

Molar heat of fusion (ΔH_f) is the amount of heat required to convert one mole of a solid into its liquid state at its melting point is called molar heat of fusion (ΔH_f) e.g. Molar heat of fusion for ice is +6.02 KJ mole

$$H_2O \longrightarrow H_2O \qquad \Delta H_f = +6.02\ KJ\ mole^{-1}$$

(ii) Molar Heat of vapourization.

Ans. Molar heat of vaporization (ΔH_v)

The amount of heat required to convert one mole of a liquid into its vapours at its boiling point is called molar heat of vaporization.

e.g. $H_2O_{(l)} \longrightarrow H_2O_{(g)}$ $\Delta H_v = +40.7\ KJ\ mole^{-1}$

12. (a) How will you relate energy changes with changes in intermolecular forces?

(b) How will you explain dynamic equilibrium between two physical states?

Ans. (a) Energy Changes and Intermolecular Forces:

As a result of melting of a solid, a small change in intermolecular distance and potential energy takes place in atoms, molecules or ions. On the other hand on evaporation of a liquid atoms, molecules or ions undergo large changes in their intermolecular distance and potential energy. Therefore, heat of vaporisation is much greater than that heat of fusion.

Particular examples:

i. ΔHv (heat of vapourization) for H_2O (40.6 KJ mole^{-1} at 373.15K, for NH_3 (23.35 KJ mole^{-1} at 239K) and CO_2 (25.23 KJ mole^{-1} at 194.5K) are high due to their polar nature and strong intermolecular forces ΔH_f (Heat of fusion) will be as under:

H_2O = 6.02 KJ mole^{-1} at 273.15K

NH_3 = 6.652 KJ mole^{-1} at 195.4K

CO_2 = 8.33 KJ mole^{-1} at 217.0K

ii. I_2, a volatile solid has the highest value of Heat of sublimation i.e 41.80 KJ mole^{-1} at 458.4K. The values for other halogens are

ΔH_v, Br_2	=	29.4	KJ mole^{-1} at	332.4K
Cl_2	=	20.21	KJ mole^{-1} at	239.1K
F_2	=	3.16	kJ mole^{-1} at	85.0K

This shows that ΔH_v (heat of vapourization)of I_2 is the highest because of strong intermolecular forces than the other halogens.

(b) Dynamic Equilibrium between two Physical States:

Dynamic equilibrium is a situation when two opposite changes occur i.e. from solid to liquid when a change of state occurs (solid to liquid or liquid to gas) and vice versa. The system moves towards the condition of dynamic equilibrium.

e.g. At 0 °C, ice exists in dynamic equilibrium with liquid water.

$$Ice_{solid} \rightleftharpoons Water_{liq.}$$

13. (a) Define a liquid crystal?

(b) What are the uses of liquid crystals in daily life?

(c) How will you differentiate liquid crystals from pure liquids and crystalline solids?

Ans. (a) Liquid Crystal:

The substance which can flow like a liquid and also have some of the properties of liquids within a certain temperature range are called liquid crystals.

OR

The intermediate phase lying between the solid phase and the normal liquid phase is called liquid crystal.

(b) Uses in daily life:

i. Liquid crystals are used as temperature sensors. This is because the liquid crystals change their colour with change in temperature

ii. They are used to monitor temperature changes where conventional methods are not feasible, e.g. they are used in thermometer for measuring skin temperature of infants.

iii. Some of the modern room thermometers contain liquid crystals with a suitable temperature range. As temperature changes, the liquid crystal show up the figure in different colours.

iv. They are used to find the point of potential failure in micro-electronic circuits.

v. They are used to locate the veins, arteries and tumours. e.g. when a layer of liquid crystal is painted on the surface of the breast, a tumour shows up as a hot area which is coloured blue. Thus this technique helps in early diagnosis of breast tumours

vi. Liquid crystals are used in the display of numbers and letters of electrical devices such as digital watches, calculators and computers etc.

vii. Liquid crystals are used in LCD screens of oscillographs and TV.

(c) How to Differentiate Liquid Crystals from Pure Liquids and Crystalline Solids:

A liquid crystal is a state of matter which is in between pure liquid (transparent) and crystalline solid.

i.e. crystalline solid = liquid crystals = pure liquid

A liquid crystal resembles the crystalline solid in certain respects, e.g. optical properties. However pure liquids remain as such.

A crystalline solid may be isotropic (A substance showing same properties in all directions) and an anisotropic (A substance showing different properties in different direction) but liquid crystals are always isotropic. Pure liquids remain as such.

Liquid crystal is intermediate in between pure liquid and crystalline phase.

14. Define the following?

a. Evaporation b. Vapour pressure c. Boiling Point
d. Viscosity e. Surface tension

Ans. a. Evaporation:

Evaporation is the process in which liquid molecules escape from the surface and enter the gas phase.

Explanation:

It can be explained in terms of the energy possessed by the molecules on the liquid's surface. Surface molecules whose kinetic energies are higher than average kinetic energies, overcome the intermolecular forces that bind them to the liquid and enter the gas phase. After their escape, the average kinetic energy of the remaining molecules decreases. Therefore temperature of the liquid decreases, thus evaporation is a cooling process.

b. Vapour pressure:

The pressure exerted by the vapours of a liquid in equilibrium with its liquid state, at a given temperature is called vapour pressure of a liquid.

c. Boiling Point:

The temperature at which the vapour pressure of the liquid equals to atmospheric pressure or some external pressure is called boiling point of that liquid.

d. Viscosity:

A liquid's resistance to flow is called its viscosity. The larger the viscosity, the more slowly the liquid flows. Viscosity measures, how easily molecules slide by one another.

Vapour Pressure (V.P):

"The pressure exerted by vapours in equilibrium with its liquid state is called the liquid's vapour pressure at the given temperature"

Condensation:

In closed containers, the vapours cannot escape. Therefore, as the vapour concentration increases, some of the vapour molecules lose energy and return to the liquid state. **This process is called condensation.**

Explanation:

Evaporation involves molecules leaving the liquid and condensation occurs when a vapour changes back to a liquid. While the liquid is placed in a closed container, it begins to evaporate at a constant rate, very little condensation takes place. But as the concentration of the vapour increases above the liquid, the rate of condensation increases.

After some time the rate of condensation equals the rate of evaporation. At this stage, the number of molecules entering the gas phase equals the number returning to the liquid phase, the system is said to be in a dynamic equilibrium.

Intensive property:

Vapour pressure is independent of the amount of liquid, so this is called an intensive property of the liquid.

Factors affecting Vapour Pressure:

Vapour pressure is measured in the **same units** used for gas pressure. Two factors affect liquid's vapour pressure:

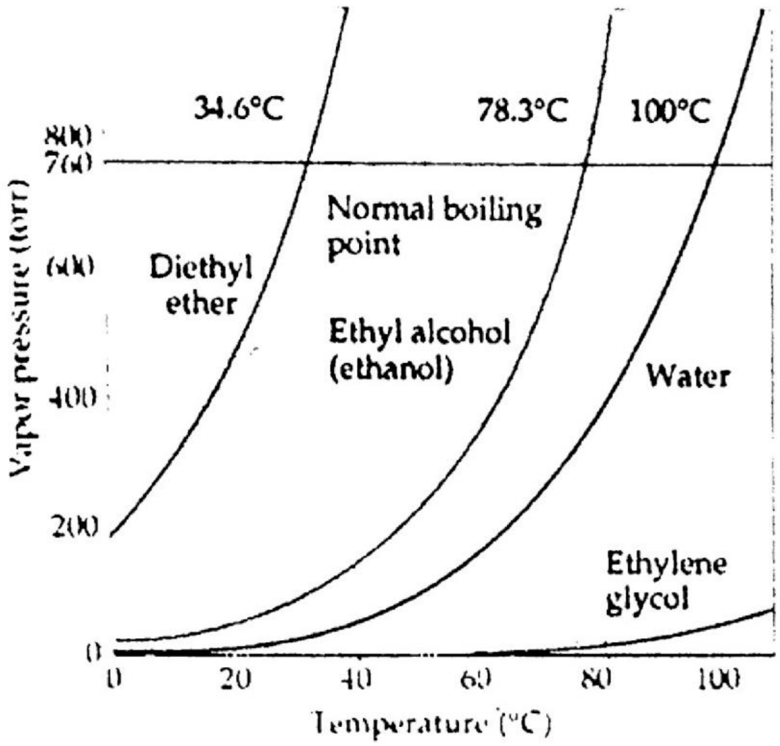
- **Intermolecular forces**
- **Temperature**

Intermolecular forces:

The vapour pressure of a liquid depends upon the strength of intermolecular forces. Liquids having **stronger intermolecular forces possess low vapour pressure** and vice versa.

Example:

Water having hydrogen bonding possesses low vapour pressure. On the other hand ether, petrol etc have high vapour pressure due to weak dispersion forces.



Temperature:

As the **temperature increases, the vapour pressure increases.** This is because increase in temperature increases the average kinetic energies of the molecules which in turn decreases the intermolecular forces.

Examples:

Vapour pressure of water at 0 ^{0}C is 4.6 mm of Hg but at 100 ^{0}C it is 760mm of Hg. The relationship of vapour pressure and temperature is shown by the graph.

Notice that the vapour pressure of diethyl ether (185mm Hg) at 0° C is much greater than that of ethanol (12mm Hg) or water (4.6mm Hg). Ether is non-polar in nature.

Therefore, its high vapour pressure is due to its weak intermolecular forces (dispersion forces). Thus at the surface ether molecules require less energy to break free and change into vapour.

Similarly, external intermolecular forces (H-bonding) are not as strong as those of water. Consequently vapour pressure of ethanol is greater than that of water at all temperatures.

It is observed that each of the three vapour pressure curves cross the line corresponding to one atmosphere at different temperatures. Therefore they boil at different temperatures.

Ether boils at 35 ^{0}C, ethanol at 78 ^{0}C and water at 100^{0}C.

e. Surface tension:

"The force in dynes acting at right angle on a unit length of surface of a liquid is called surface tension".

Surface tension can also be defined as the amount of energy required to expand the surface of a liquid by a unit area.

15. (a) Define and explain the intermolecular forces existing between the liquid molecules?

(b) Explain the applications of dipole-dipole forces hydrogen bonding and London forces?

Ans. (a) Intermolecular Forces:

The forces of attractions among the molecules of a Substance are called inter-molecular forces.

Example:

Water exists as a liquid due to inter-molecular attractions called Hydrogen bonds.

Dipole – Dipole Forces:

The attractive forces between the positive ends of one molecule with the negative end of other molecule are called dipole – dipole forces. This means dipole – dipole interactions are electrostatic interactions between permanent dipoles in molecules.

Examples:

Examples of polar molecules include hydrogen chloride (HCl) chloroform ($CHCl_3$), Acetone ($(CH_3)_2CO$) etc.

Note: Stronger these dipole-dipole forces, greater would be the value of thermodynamic parameters like melting point, boiling point, heat of vaporization, heat of subliminal etc.

London Dispersion Forces:

The forces of attractions between non-polar molecules which become polar for an instant are called London dispersion forces.

Explanation:

Substances like hydrogen, helium, neon, argon, chlorine, fluorine, methane etc are non-polar in nature. These gases can be liquefied and solidified under appropriate conditions. Some forces must be holding these molecules in contact with one another in the liquid and solid states.

In *He* gas, on the average, the electron charge density is evenly distributed in a spherical region about the nucleus. However, at any given instant, the actual location of two electrons relative to the nucleus can produce an instantaneous dipole. This temporary dipole, in turn, can influence the distribution of electrons in neighbouring helium atoms, producing induced dipoles in those atoms.

(a) Un-polarized Molecule (b) Instantaneous dipole (c) Induced dipole

London dispersion forces Instantaneous dipole

London Dispersion force:

The forces of attraction between an instantaneous dipole and an induced dipole are known as a dispersion force. It is also called as London dispersion force, named for Fritz London who offered a theoretical explanation for these forces in 1928.

Hydrogen bonding:

A hydrogen bond is the attraction between the lone pair of an electronegative atom and a hydrogen atom that is bonded to either N, O or F. This limits hydrogen bonding mainly to the participation of nitrogen, oxygen and fluorine atoms

Strength of bonds:

Hydrogen bonds are weaker than covalent bonds but stronger than dipole-dipole interactions which are stronger than London dispersion forces.

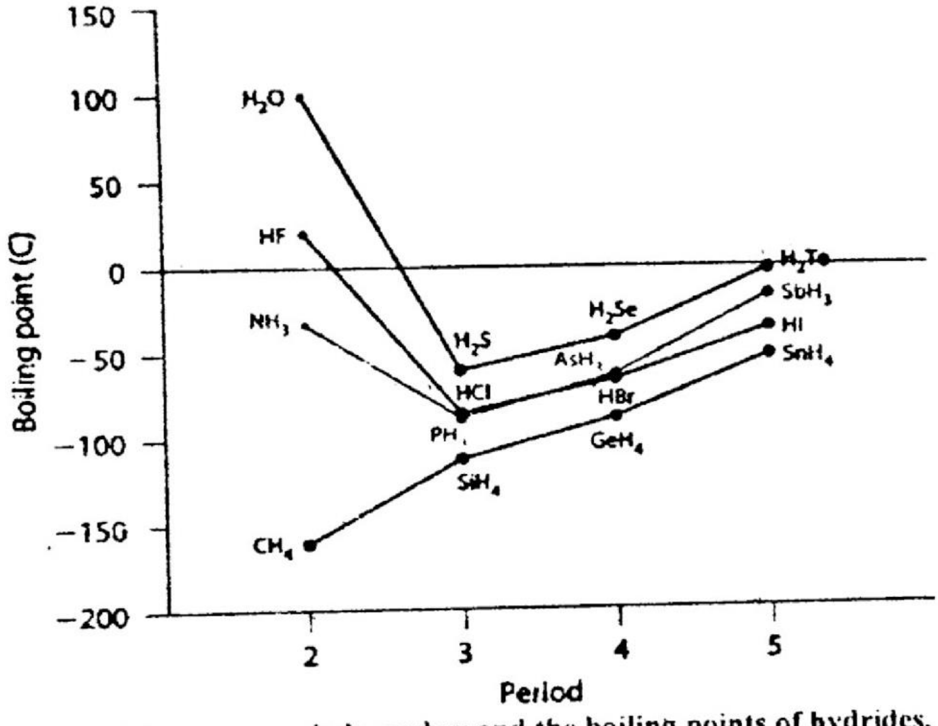
(b) Applications of dipole-dipole forces:

Stronger these dipole-dipole forces, greater would be the value of thermodynamic parameters like melting point, boiling point, heat of vaporization, heat of subliminal etc.

Applications of hydrogen bonding:

(i) Thermodynamic properties:

The boiling points of hydrides of group IVA, VA, VIA and VIIA plotted against period number of the periodic table is shown in figure.



A graph between period number and the boiling points of hydrides.

Explanation:

The boiling point of hydrides:

Note that hydrides of group IVA have lower boiling points. The reason is that these hydrides are non-polar and have only London dispersion forces among their molecules. Hydrides of group VA, VIA and VII-A have polar molecules. NH_3, H_2O and HF show maximum boiling points in their respective series. This is due to hydrogen bonding in their molecules.

Solubility of Hydrogen Bonded Molecules:

The compounds that have hydrogen bonds are soluble in each other. Ethyl alcohol can dissolve in water because both can form hydrogen bonds with each other. Similarly carboxylic acids are also soluble in water, if their molecular sizes are small. This is all because of hydrogen bonding.

(i) Cleansing Action:

Soaps and detergents perform the cleaning action. Their molecules contain both polar and non-polar ends. Their polar parts are water soluble due to hydrogen bonding and non-polar part dissolve oil or grease. Attraction between water and polar end of soap molecule carries the oil or grease droplet into the water

(ii) Hydrogen Bonding in Paints and Dyes:

Paints and dyes have adhesive action due to hydrogen bonding. Similarly hydrogen bonding also makes glue and honey stickle substances.

(iii) Clothing:

We use cotton, silk or synthetic fibres for clothing. Hydrogen bonding is of great importance in thread making materials. This hydrogen bonding is responsible in their rigidity and tensile strength.

(iv) Food Materials:

Food materials like carbohydrates consist of glucose, fructose, sucrose, each of them contains –OH groups which is responsible for H-bonding in them.

(v) Hydrogen Bonding in Biological Molecules:

The structure of proteins, substances essential to life, is determined partly by hydrogen bonding. The action of enzymes, the protein molecules that catalyze the reactions that sustain life, depends in part on the forming and breaking of hydrogen bonds. The hereditary information passed from one generation to the next is carried in nucleic acid molecules joined by hydrogen bonds into an elegant structure.

Applications of London Dispersion Forces:

i. Atomic or molecular size

ii. Polarizability

iii. Number of atoms in a molecules

(i) Atomic or Molecular Size:

The strength of London dispersion forces depends upon the size of the electronic cloud of the atom or molecule. With the increase in size of atom or molecule, the dispersion becomes easy and these forces become prominent.

Inert gases are all monotonic gases. They do not make covalent bonds with other atoms because their valence shells are complete. Their boiling point increase down the group from He to Rn. This is because of increase in molecular size.

(ii) Polarizability:

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

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

Examples:

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

(iii) Number of atoms in a molecule:

Elongated molecules make contact with neighbouring molecules over a greater surface than do small molecules **Greater the number of atoms in a molecule, greater is the polarizability of the molecule**

Examples:

C_2H_6 and C_6H_{14} have the boiling points as -88 6°C and 67 7°C respectively This shows that the molecule with a large chain length experiences stronger attractive forces.

16. What are the energetics of phase changes?

Ans. Energetic Of Phase Changes:

i. Physical and chemical changes are accompanied by energy change in the form of heat

ii. A physical change in energy is the quantitative measurement of the strength of intermolecular forces.

iii. Energy change at constant pressure is known as enthalpy change denoted by ΔH

iv. It is expressed in kg mole

v. When a substance undergoes a phase change (change of state), its temperature remains constant even though heat is being added

17. (a) Describe the Kinetic Molecular Interpretation of liquids?

(b) Relate energy changes with changes in intermolecular forces?

Ans: (a) Kinetic Molecular Interpretation of liquids:

The kinetic molecular theory also applies to liquids. Postulates of kinetic molecular theory of liquids are given below

i. A liquid is made up of molecules which touch one another

ii. The molecules within the liquid are in constant motion but the movement of molecules is restricted due to their close packing together

iii. Attractive forces among liquid molecules are greater than those among gas molecules However these attractive forces are not sufficient to hold molecules in fixed position The liquid molecules can slide each other

iv. The average Kinetic Energy of liquid molecules is directly proportional to the Absolute Temperature

v. At constant temperature, the average K E of the molecules is equal to the K E of the vapours of liquids

(b) Energy Changes and Intermolecular Forces:

As a result of melting of a solid, a small change in intermolecular distance and potential energy takes place in atoms, molecules or ions. On the other hand on evaporation of liquid atoms, molecules or ions undergo large changes in their intermolecular distance and potential energy Therefore, heat of vaporisation is much greater than that heat of fusion

Particular examples:

i. ΔH_v (heat of vapcurization) for H_2O (40.6 KJ $mole^{-1}$ at 373.15K, for NH_3 (23.35 KJ $mole^{-1}$ at 239K) and CO_2 (25.23 KJ $mole^{-1}$ at 194.5K) are high due to their polar nature and strong intermolecular forces ΔH_f (Heat of fusion) will be as under

H_2O = 6.02 KJ $mole^{-1}$ at 273.15K

NH_3 = 6.652 KJ $mole^{-1}$ at 195.4K

CO_2 = 8.33 KJ $mole^{-1}$ at 217.0K

ii. I_2, a volatile solid has the highest value of Heat of sublimation i.e. 41.80 KJ $mole^{-1}$ at 458.4K. The values for other halogens are

ΔH_v,	Br_2	=	29.4	KJ $mole^{-1}$ at	332.4K
	Cl_2	=	20.21	KJ $mole^{-1}$ at	239.1K
	F_2	=	3.16	kJ $mole^{-1}$ at	85.0K

This shows that ΔH_v (heat of vapourization)of I_2 is the highest because of strong intermolecular forces than the other halogens

18. (a) Define and explain the Boiling Point of a liquid?
(b) How will you explain the two practical applications regarding the effect of pressure on the Boiling Point of a liquid?

Ans. (a) Boiling Point:

The temperature at which the vapour pressure of the liquid equals to atmospheric pressure or some external pressure is called boiling point of that liquid.

Explanation:

When a liquid is heated, its V.P. increases due to the decrease of intermolecular forces with rise in temperature. As a result more and more vapours escape in the air. A stage reaches at which the liquid begins to boil. So the temperature at which the vapour pressure of the liquid equals to atmospheric pressure or some external pressure is called boiling point of that liquid.

Example:

Boiling Point of water at 760mm = 100 °C
Boiling Point of water at 23.7mm = 25 °C

(b) There are two practical applications regarding the effect of pressure.

i. Effect of Increase of Pressure:

Food can be cooked easily in pressure cookers, which is a closed container. The vapours are not allowed to escape out and, therefore, develop more pressure. This increases the B.P of water.

Example:

Pressure cookers help us in cooking the food quickly even at high attitude e.g. B.P of water at 2026mm Hg is 130°C

ii. Effect of decrease of pressure:

The liquids which decompose at their B.P can be obtained in the pure form under reduced pressure by Vacuum distillation

Example:

Glycerine has a B.P of 290°C at 760mm but it decomposes at its B.P. Now in order to get it in the pure form, the V.P is decreased to 50mm by Vacuum pump. The B.P decreases to 120°C without decomposition. In this way the liquids can be purified.

19. How will you explain the anomalous behaviour of water when its density shows maximum at 4°C?

Ans. Anomalous Behaviour of Water:

Anomalous Behaviour of Water:

i. In ice hydrogen bonds hold water molecules in a rigid but open **hexagonal structure.**

ii. As ice melts, some of the **hydrogen bonds are overcome**, and water molecules move into the holes that were present in ice structure.

iii. As a result, the H_2O molecules are **closer together** in liquid water **than in ice.**

iv. When ice melts, there is about **9% decrease in volume** and a corresponding **increase** in density.

v. So, water is most unusual in this regard, because the **liquid state is less dense** than the solid for most substances.

vi. If we continue to **heat water** just above the melting point, more hydrogen bonds are overcome.

vii. The molecules become still more closely packed and the density of liquid increases to a maximum density at **3.98°C. Above 3.98°C the density of water decreases with temperature, as we expect for a liquid.**

viii. These density phenomena explain why a freshwater lake **freezes from the top down in winter.**

Survival of aquatic life:

When temperature falls below 4°C, the more dense water sinks to the bottom of the lake.

The colder surface water freezes first. Since ice is less dense than water, the water that freezes remain at the top to cover the lake with a layer of ice. This layer of ice insulates the water underneath.

Thus under this thick blanket of ice, fish and plants survive for months.

20. Relate energy changes with changes in intermolecular forces?

Ans. Energy Changes and Intermolecular Forces:

As a result of melting of a solid, a small change in intermolecular distance and potential energy takes place in atoms, molecules or ions. On the other hand on evaporation of a liquid atoms, molecules or ions undergo large changes in their intermolecular distance and potential energy. Therefore, heat of vaporisation is much greater than that heat of fusion.

Particular examples:

i. ΔH_v (heat of vapourization) for H_2O (40.6 KJ mole^{-1} at 373.15K, for NH_3 (23.35 KJ mole^{-1} at 239K) and CO_2 (25.23 KJ mole^{-1}at 194.5K) are high due to their polar nature and strong intermolecular forces ΔH_f (Heat of fusion) will be as under:

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