DAY FIVE

States of Matter

(Gaseous and Liquid State)

Learning & Revision for the Day

- Gaseous State
- Gas Laws
- Deviation from Ideal Behaviour
- Liquefaction of Gases and Critical Temperature

Matter is anything that has mass, occupies space and can be felt by our sense organs. Matter is classified into three states; **solid**, **liquid** and **gas** on the basis of their physical and chemical properties.

(i) **Solids** They have definite volume, a definite shape and are rigid.

(ii) **Liquids** They have definite volume, but not definite shape and are non-rigid.

(iii) **Gases** They have neither definite shape, nor definite volume and are non-rigid. It is the simplest state and shows great uniformity in behaviour.

These states are decided by two factors; Thermal energy and forces of attraction.

- In a solid, the forces of attraction predominate the effect of thermal energy. Consequently, the particles are held together in rigid, highly oriented and close-packed structure.
- In liquid, the forces of attraction are greater than thermal energy but are not strong enough to cease the motion of molecules.
- In a gas, the thermal energy dominates the effect of cohesive forces, thus the gas molecules acquire the unrestricted and independent mobility of the vapour state.

NOTE (i) Besides the three states of matter, two more states of matter have been found to exist. These are plasma and Bose-Einstein condensate (predicted by Albert Einstein and Indian physicist Satyendra Nath Bose).

(ii) If plasma are super-hot and super-excited atoms (a mixture of electrons and positively charged ions formed by superheating, e.g. in the sun), the Bose-Einstein condensate are total opposite, i.e. super-cold and super-unexcited atoms formed by super-cooling to such an extent that the atoms lose their individual identity and condensate to form a single super atom.

Types of Bonding

- In case of **ionic compounds**, the constituent particles are positively and negatively charged ions. Hence, the forces of attraction between the oppositely charged ions, being electrostatic in nature, are the strongest.
- In case of **covalent bonding**, the forces of attraction among the molecules are weak van der Waals' forces.
- In case of metals, the forces of attraction between the constituent atom are quite strong called **metallic bonds.**

Intermolecular Interactions

These interactions are arises due to the force of attraction existing among the molecules of substance (liquid or gas). These are of following types :

(i) **London or Dispersive Interactions** These interactions exist between the non-polar molecules as in them, electronic charge cloud is distributed symmetrically and hence, have no dipole moment.

(ii) **Dipole-Dipole Interactions** These interactions exist between the molecules having permanent dipoles (like HCl, NH_3 etc.) due to the interaction between oppositely charged ends.

(iii) **Dipole Induced Dipole Forces** These interactions exist between the polar molecules having permanent dipole and non-polar molecules lacking dipole.

(iv) **Hydrogen Bond** It is formed when a hydrogen is bonded to more electronegative atom (like N, O and F).

(v) **Ion-Dipole Interactions** These forces of attractions exist between an ion and a dipole.

(vi) **Repulsive Interactions** These interactions exist between the electron clouds or the nuclei of two molecules when they are in contact with each other.

Melting and Boiling Points

- The temperature at which the vapour pressure of a liquid becomes equal to one atmospheric pressure is known as its **boiling point.**
- The temperature at which the solid starts melting into the liquid is called its **melting point.**
- The melting and boiling point of a substance depends upon the magnitude of forces existing among its constituent particles.
- The greater is the magnitude of these forces, higher is the melting or boiling point.

Gaseous State

It is the most disordered state of matter. In this state, matter neither have fixed volume nor fixed shape. It takes the shape and volume of the container in which it is placed.

Characteristic Properties of Gases

Gases exhibit following characteristic properties:

- Gases expand indefinitely and fill any vessel, no matter how large in which these are placed.
- Gases are readily compressible.
- Gases intermix freely with one another or move from one place to other without any difficulty.
- Pure gases or their mixtures are all homogeneous in composition.
- Gases possess very low density. The density of gas when compared to that of hydrogen is termed as **relative density.**
- Due to collision of molecules on the walls of the container, gases exert certain amount of pressure, which obviously increases due to increase in temperature.
- Gaseous molecules move very rapidly in all directions in a random manner, i.e. gases have highest kinetic energy.

Measurable Properties of Gases

The measurable properties of gases are described fully in terms of four parameters, i.e. pressure (p), volume (V), temperature (T) and mass or mole, which are termed as measurable properties.

(i) **Mass** It is expressed in gram or kg and is equal to the difference in masses of empty vessel and vessel containing gas.

(ii) **Volume** It is equal to the volume of the container and is expressed in terms of litre (L), millilitre (mL), cubic centimetre (cm^3), cubic metre (m^3) or cubic decimetre (dm^3).

$$1\ \text{L} = 1000\ \text{mL} = 1000\ \text{cm}^3 = 1\ \text{dm}^3$$

$$1\ \text{m}^3 = 10^3\text{dm}^3 = 10^6\text{cm}^3 = 10^6\text{mL} = 10^3\text{L}$$

(iii) **Pressure** It is defined as force divided by the area to which the force is applied.

$$\text{Pressure} = \frac{\text{force}}{\text{area}}$$

- The greater the force acting on a given area,the greater would be the pressure.
- The units of pressure are atm, mm Hg, torr, etc.

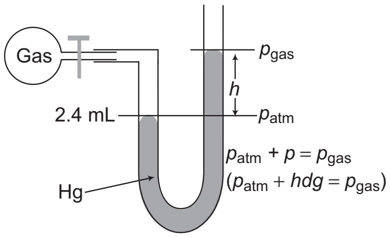
$$1\ \text{atm} = 76\ \text{cm of Hg} = 760\ \text{mm of Hg} = 760\ \text{torr}$$

$$1\ \text{atm} = 101.325\ \text{kPa} = 101325\ \text{Pa} = 101.325\ \text{Nm}^{-2}$$

$$= 1.01325\ \text{bar}$$

$$1\ \text{bar} = 10^5\ \text{Pa} = 0.987\ \text{atm.}$$

- Atmospheric pressure, $p = hdg$. where, h is the height of the mercury column supported by the barometer, d is the density of mercury and g acceleration due to gravity. (The pressure is obtained in pascal when h, d and g are expressed in SI unit.)
- Pressure is measured by using a **manometer** which is a simple device with a horizontal arm and a U-tube carrying mercury or any other suitable liquid.



However, atmospheric pressure is measured by **barometer.** There are two types of manometers: **Closed end manometer** is normally used to measure pressure below atmospheric pressure whereas, **open end manometer** is used to measure pressure above atmospheric pressure.

(iv) **Temperature** It is measured in terms of hotness or coldness. The measurement is based on the expansion of certain material (mostly it is mercury) with increasing temperature. It is measured in celsius scale or absolute scale (Kelvin scale). Celsius scale was earlier known as the **centigrade scale.**

- Standard temperature and pressure (STP or NTP) mean 273.15 K (0°C) temperature and 1 bar (i.e. exactly 10^5 pascal) pressure. At STP, molar volume of an ideal gas is 22.71098 L mol^{-1}.
- The standard temperature for gas measurements (0°C or 273.15 K) is not the same as that usually assumed for thermodynamic measurements (25°C or 298 K is said to be SATP condition or Standard Ambient Temperature and Pressure).

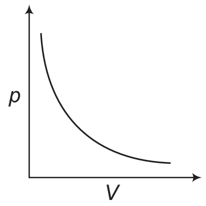
Gas Laws

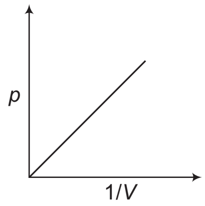
Gases exhibit dependency on temperature, pressure, volume and mass. The inter-relationship of these factors can be analysed through gas laws, which are given below:

1. Boyle's Law (1662)

At constant temperature $(T), p \propto \frac{1}{V}$

pV = constant (for given moles and T) or $p_1V_1 = p_2V_2$

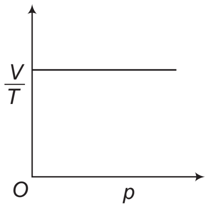


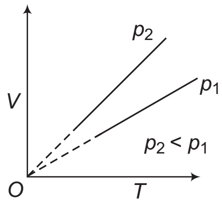


2. Charles' Law (1787)

At constant pressure (p), $V \propto T$

$$\frac{V}{T} = \text{constant (for given } n \text{ and } p) \text{ or } \frac{V_1}{T_1} = \frac{V_2}{T_2}$$





Charles' obtained experimentally that for 1°C change in temperature of a gas, the volume get changed by a fraction of $\frac{1}{273}$.

Hence, if V_0 be the volume of a gas at 0°C and it is recorded to be V at t°C then

$$V = V_0 + \frac{1}{273.15} t\, V_0 = V_0 \left(1 + \frac{1}{273.15} t\right) = \frac{V_0}{273.15} T$$

If temperature is lowered, the volume decreases at constant pressure and become zero at – 273.15°C. Further lowering is not possible thus, it is called the lowest possible temperature or absolute zero of temperature.

Scale of temperature based on choice of zero is called **absolute scale of temperature** or thermodynamic scale of temperature.

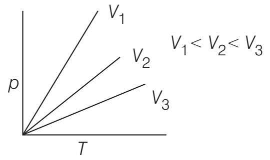
$$T(\text{K}) = t\,(°\text{C}) + 273.15$$

3. Gay-Lussac's Law

At constant volume (V), $p \propto T$

$$\frac{p}{T} = \text{constant} \qquad \text{(for given } n \text{ and } V)$$

$$\text{or} \quad \frac{p_1}{T_1} = \frac{p_2}{T_2}$$



NOTE On combining Boyle's and Charles' law, we get

$$\frac{pV}{T} = \text{constant} \quad \text{or} \quad \frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

This equation is also known as combined gas law.

4. Avogadro's Law

It states that equal volumes of all gases at same pressure and temperature contain equal number of molecules.

$$V \propto n \quad \text{(at given } T \text{ and } p) \quad \text{or} \quad \frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Role of Gas Laws of Elucidating the Concept of the Molecules

Various rules of gas laws are as follows :

The molecular explanation of Boyle's law state that, if a sample of gas is compressed to half of its volume, then the number of molecules striking the walls get doubled. As a result, the average force exerted on the walls is doubled. The molecular explanation of Charle's law lies is the fact that, raising the temperature of a gas, increases the average speed of its molecules. i.e. $V \propto T$ (at n, p) e.g. hot air gas balloon.

5. Ideal Behaviour of Gases

A gas that follows Boyle's law, Charles law and Avogadro's law strictly called an **ideal gas**. These three laws can be combined together in a single equation, which is known as **ideal gas equation,** it is a relation among four variables and it describes the state of any gas and thus also called equation of state.

At constant T and n, $V \propto \frac{1}{p} \Rightarrow$ Boyle's Law

At constant p and n, $V \propto T \Rightarrow$ Charle's Law

At constant p and T, $V \propto n \Rightarrow$ Avogadro's Law

Thus, $V \propto \frac{nT}{p} \Rightarrow V = \frac{RnT}{p}$

$$\boxed{pV = nRT} \quad \text{or} \quad pV = \frac{w}{M}RT \quad \text{or} \quad \boxed{pM = dRT}$$

where, w = mass of gas, M = molecular weight of gas
d = density of gas, p = pressure of gas
T = temperature, V = volume
R = gas constant.

Values of $R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$

$$= 8.314 \text{ J K}^{-1} \text{ mol}^{-1} = 1.987 \text{ cal K}^{-1} \text{ mol}^{-1}$$

$$= 8.314 \text{ kPa dm}^3 \text{ K}^{-1} \text{ mol}^{-1}$$

$$= 0.083 \text{ bar dm}^3 \text{ K}^{-1} \text{ mol}^{-1}$$

6. Dalton's Law of Partial Pressures

It states that total pressure of a mixture of a number of non-reacting gases is equal to the sum of the pressures exerted by individual gases.

$$p_{\text{Total}} = p_1 + p_2 + p_3 + p_4 + \dots$$

- Partial pressure of a gas = its mole fraction × total pressure exerted by the mixture
- Percentage of a gas in the mixture

$$= \frac{\text{its partial pressure}}{\text{total pressure}} \times 100$$

$$= \text{mole fraction of that gas} \times 100$$

- When a gas is collected over the water, the pressure of the gas

$$p_{\text{total}} = \text{pressure of dry gas} + \text{aqueous tension or water VP}$$

- Relative humidity (R_H) is given by R_H = partial pressure of water in air/vapour pressure of water.

7. Graham's Law of Diffusion

It states that under similar conditions of temperature and pressure, the rate of diffusion of different gases are inversely proportional to the square root of their densities or molar masses.

$$\text{i.e., Rate of diffusion/effusion} \propto \sqrt{\frac{1}{d}} \propto \sqrt{\frac{1}{M}}$$

If two gases having their densities d_1 and d_2 and rates of diffusion r_1 and r_2 respectively, be compared. Then Graham's law can be expressed as

$$\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{M_2}{M_1}}$$

This law may be modified for simplicity as show below

- Comparison of time taken for the diffusion of same volume of two gases :

$$\frac{r_1}{r_2} = \frac{\frac{V_1}{t_1}}{\frac{V_2}{t_2}} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{M_2}{M_1}}$$

when, we compare for same volume i.e,... $V_1 = V_2 = V$

$$\frac{r_1}{r_2} = \frac{V}{t_1} \times \frac{t_2}{V} = \frac{t_2}{t_1} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{M_2}{M_1}}$$

- Comparison of the volume of two gases that diffuse in the same time:

In this case, $t_1 = t_2 = t$

$$\text{so,} \quad \frac{r_1}{r_2} = \frac{V_1}{t} \times \frac{t}{V_2} = \frac{V_1}{V_2} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{M_2}{M_1}}$$

Kinetic Molecular Theory of Gases

The molecular details regarding gases can be visualised with the help of kinetic molecular theory of gases which is based on the following assumptions.

- A gas consists of extremely small discrete molecules. These molecules are so small and so far apart that actual volume of the molecules is negligible as compared to the total volume of the gas.
- Gaseous molecules are in random motion with high velocities and change directions on collision with other molecules or wall of the container.
- The intermolecular forces are negligible and the force of gravity on them is also negligible.
- The collisions are perfectly elastic, therefore, there is no loss of kinetic energy during collision.
- The pressure of a gas is caused by bombardment of moving molecules against the wall of the container.
- In a gas, different molecules have different kinetic energies but the average kinetic energy of molecules is proportional to absolute temperature of the gas. This is known as Maxwell's generalisation.

  On the basis of these assumptions, the following mathematical expression is derived.

$$pV = \frac{1}{3} mNu^2 \quad \text{or} \quad pV = \frac{1}{3} Mu^2$$

$$(\because M = m \times N, \text{ for one mole } m = 1)$$

where, u = rms velocity.

Kinetic Energy and Molecular Speeds

$$\text{As,} \quad pV = \frac{1}{3} mu^2$$

$$\text{or} \quad pV = \frac{2}{3} \cdot \frac{1}{2} mu^2 \qquad \left(\text{where, } \frac{1}{2} mu^2 = \text{KE per mole}\right)$$

$$\text{K.E. per mole} = \frac{3}{2} pV = \frac{3}{RT}$$

Also, average KE per molecule is given by

$$\overline{\text{KE}} = \frac{3}{2} \frac{R}{N} T$$

$$\boxed{\overline{\text{KE}} = \frac{3}{2} kT} \quad \left(k = \frac{R}{N} \text{ is called Boltzmann constant}\right)$$

thus, $\overline{\text{KE}} \propto T$

At absolute zero (0K), the kinetic energy of gas molecules becomes zero.

Molecular Speeds

There are three types of speeds of gaseous molecules which are :

(i) **Root Mean Square Velocity** (U_{rms})

$$U_{\text{rms}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3p}{d}}$$

(ii) **Average Velocity (U_{av})**

$$U_{av} = \sqrt{\frac{8RT}{\pi M}}$$

(iii) **Most Probable Velocity** (V_{mp})

$$V_{mp} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2pV}{M}} = \sqrt{\frac{2p}{d}}$$

$$V_{mp} : U_{av} : U_{rms} :: \sqrt{2} : \sqrt{\frac{8}{\pi}} : \sqrt{3} \;= 1 : 1.128 : 1.224$$

$$U_{av} = U_{rms} \times 0.9213$$

- For the same gas at two different temperatures, the ratio of RMS velocities will be

$$\frac{U_1}{U_2} = \sqrt{\frac{T_1}{T_2}}$$

- For two different gases, the ratio of the RMS velocities will be

$$\frac{U_1}{U_2} = \sqrt{\frac{M_2}{M_1}}$$

Deviation from Ideal Behaviour

Real gases follow the laws of ideal gas only at high temperature and low pressure.

At very low temperature and high pressure, these gases show deviation from the ideal gas behaviour. The causes of deviation are :

- at low temperature and high pressure, volume of a real gas is materially larger than that predicted for an ideal gas, as the molecules of gas have their own volume, and
- at low temperature and high pressure inter molecular forces are not negligible.

$$\text{Compressibility factor } (Z) = \frac{pV}{RT} = 1 \qquad \text{(for ideal gas)}$$

- For real gas, $Z < 1$ or $Z > 1$
- $Z < 1$ (as for CH_4, CO_2) can be attributed to predominance of attractive forces among the molecules of these gases at the temperature of experimentation.
- $Z > 1$ can be attributed to the dominance of strong repulsive forces among the molecules.
- For H_2 and He, Z is always greater than 1 due to negligible intermolecular forces of attraction.

van der Waals' Equation

To rectify the errors caused by ignoring the intermolecular forces of attraction and the volume occupied by molecules, **Johannes van der Waals'** proposed following equation, which is valid for real gases upto a large range of temperature and pressure.

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

where, n = number of moles,

a = constant (related to force of attraction between the gas molecules)

b = constant (due to occupied volume of gaseous molecules = co-volume).

NOTE Greater the value of 'a' easier the liquefaction of gas.

Merits of van der Waals' Equation

- This equation explains behaviour of real gases upto moderately high pressure.
- This equation represents the trend of the isotherms representing the variation of pV with p for various gases.
- With the help of this equation, values of Boyle's temperature, critical constants and inversion temperatures may be calculated in terms of 'a' and 'b'.
- This equation is also helpful in obtaining a 'reduced equation of state' which being a general equation of state has the advantage that a single curve can be obtained for all gases when the equation is graphically represented by plotting the variables.

Limitations of van der Waals' Equation

- Although van der Waals' equation is much more accurate than the ideal gas equation, appreciable deviation at too low temperatures and pressures have been observed.
- he values of van der Waals' constant 'a' and 'b' do not remain constant over the entire ranges of temperature and pressure. Hence, van der Waals' equation is valid only over specific range of temperature and pressure.

Liquefaction of Gases and Critical Temperature

The phenomenon of converting a gas into liquid is known as **liquefaction** at particular temperature, pressure and volume. When a gas changes into liquid, these conditions are known as critical conditions, e.g. T_c, V_c, p_c, etc.

(i) **Critical temperature** of a gas may be defined as that temperature above which it can not be liquefied howsoever high pressure may be applied on the gas

$$\boxed{(T_c) = \frac{8a}{27\,Rb}}$$

(ii) **Critical pressure** is the pressure which is required to liquefy the gas at critical temperature.

$$\boxed{(p_c) = \frac{a}{27b^2}}$$

(iii) **Critical volume** is the volume occupied by one mole of the gas at critical temperature and critical pressure.

$$\boxed{(V_c) = 3b}$$

NOTE (i) Relation between critical p, V and T

$$p_cV_c = \frac{3}{8} RT_c \text{ or } \frac{p_cV_c}{RT_c} = \frac{3}{8}, Z < 1 \text{ at critical point.}$$

(ii) At critical point, there is no distinction between gaseous state and liquid state as densities of a substance in gaseous and liquid states are same.

Liquid State

- It is the state of matter in which the molecules are held close to each other and execute random motion through intervening spaces.
- Most of the physical properties of liquids are controlled by the strength of intermolecular attractive forces.
- **Vapour Pressure** Inside a closed vessel, the liquid and its vapours are in dynamic equilibrium. The pressure exerted by the vapours is then known as equilibrium vapour pressure or vapour pressure.
- Since, the vapour pressure is a kinetic phenomenon, it is independent of the amount of a liquid. It only depends on the temperature.
- **Trouton's Rule** (For liquids which are non-associated and which do not have too high boiling points). The ratio of the heat of vaporisation to the boiling point is approximately 88 JK^{-1},

  i.e. $$\frac{\Delta_{\text{vap}}H}{T_b} \approx 88\text{JK}^{-1}$$
- **Guldberg's Rule** The boiling point of a liquid is nearly two third of its critical temperature when both are expressed on absolute scale,

  i.e. $$T_b = \frac{2}{3} T_c$$
- **Viscosity** The ease with which a fluid can flow is determined by its property, called viscosity. Viscosity arises due to the internal friction between layers of fluids.
- Force is proportional to area of contact and velocity gradient.

  $$F \propto A \text{ (area)} \propto \frac{dv}{dX} \qquad \text{(velocity gradient)}$$

  $$\therefore \qquad F = \eta A \frac{dv}{dX}$$

  'η' is called the coefficient of viscosity and it has the unit poise; g/cm-s.
- Viscosity of liquid decreases with increase in temperature because rise in temperature increases the kinetic energy of molecules, this results in decrease in inter-layer friction.
- The reciprocal of η of a liquid is called its fluidity,

  i.e. $$\phi = \frac{1}{\eta}$$

Surface Tension

- The force acting along the surface of a liquid at right angle to any line per unit length, is called surface tension. The unit of surface tension is Nm^{-1}.
- Surface tension decreases with rise in temperature.
- It is different for different liquids due to different intermolecular forces.
- Due to surface tension, the small drops of liquids are spherical as the liquid tends to have a minimum surface area.
- Due to surface tension, liquids rise or fall in capillary tube.

DAY PRACTICE SESSION 1

FOUNDATION QUESTIONS EXERCISE

1 Which one of the following statements is wrong for gases?

(a) Gases do not have a definite shape and volume
(b) Volume of the gas is equal to volume of container confining the gas
(c) Confined gas exerts uniform pressure on the walls of its container in all directions
(d) Mass of gas cannot be determined by weighing a container in which it is enclosed

2 A person living in Shimla observed that cooking food without using pressure cooker takes more time. The reason for this observation is that at high altitude

(a) pressure increases (b) temperature decreases
(c) pressure decreases (d) temperature increases

3 At 25°C and 730 mm pressure, 380 mL of dry oxygen was collected. If the temperature is constant, what volumes will be the oxygen occupy at 760 mm pressure?

(a) 2 mL (b) 10 mL
(c) 20 mL (d) 365 mL

4. A 20 L container at 400 K contains $CO_2(g)$ at pressure 0.4 atm and an excess of SrO (neglect the volume of solid SrO). The volume of the container is now decreased by moving the movable piston fitted in the container. The maximum volume of the container, when pressure of CO_2 attains its maximum value, will be **→ NEET 2017**

(Given that : $SrCO_3(s) \rightleftharpoons SrO(s) + CO_2(g)$, $K_p = 1.6$ atm)

(a) 5 L (b) 10 L
(c) 4 L (d) 2 L

5 A balloon has maximum capacity of 20 L. At one atmospheric pressure, 10 L of air is filled in the balloon. It will burst when pressure is (assuming isothermal condition)

(a) 0.5 atm (b) 0.4 atm (c) 0.7 atm (d) 0.8 atm

6 A cylinder of 5 L capacity, filled with air at NTP is connected with another evacuated cylinder of 30 L of capacity. The resultant air pressure in both the cylinders will be

(a) 10.8 cm of Hg (b) 14.9 cm of Hg
(c) 21.8 cm of Hg (d) 38.8 cm of Hg

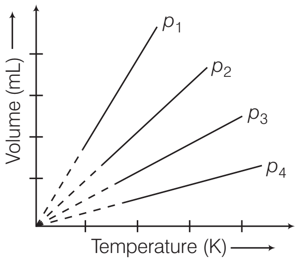
7 500 mL of nitrogen at 27°C is cooled to –5°C at the same pressure. The new volume becomes

(a) 326.32 mL (b) 446.66 mL
(c) 546.32 mL (d) 771.56 mL

8 Pressure remaining the same, the volume of a given mass of an ideal gas increases for every degree centigrade rise in temperature by definite fraction of its volume at

(a) 0°C (b) absolute zero
(c) its critical temperature (d) its Boyle's temperature

9 A plot of volume (V) *versus* temperature (T) for a gas at constant pressure is a straight line passing through the origin. The plots at different values of pressure are shown in the figure. Which of the following order of pressure is correct for this gas?



(a) $p_1 > p_2 > p_3 > p_4$ (b) $p_1 = p_2 = p_3 = p_4$
(c) $p_1 < p_2 < p_3 < p_4$ (d) $p_1 < p_2 = p_3 < p_4$

10 When the volume of a gas is plotted *versus* the celsius temperature with pressure and number of moles held constant, the x-intercept is at what temperature?

(a) 0°C
(b) –273°C
(c) The boiling point of the gas
(d) The melting point of the gas

11 By Avogadro's law, $V = Kn$

If volume occupied by 1 mole of a gas at STP is 22.4 L then K is ...., if we take 0.5 mole of gas under same condition of temperature and pressure.

(a) 22.4 L mol^{-1}
(b) 11.2 L mol^{-1}
(c) 0.5 L mol^{-1}
(d) 1.0 L mol^{-1}

12 Avogadro's hypothesis states that

(a) the ideal gas consists of a large number of small particles called molecules
(b) under the same conditions of temperature and pressure equal volumes of gases contain the same number of molecules
(c) volume of a definite quantity of gas at constant pressure is directly proportional to absolute temperature
(d) a given mass of gas at constant pressure is directly proportional to absolute temperature

13 A gas that follows Boyle's law, Charles' law and Avogadro's law is called an ideal gas. Under what conditions a real gas would behave ideally?

(a) High pressure and low temperature
(b) Low pressure and high temperature
(c) High pressure and high temperature
(d) Low pressure and low temperature

14 Under what conditions will a pure sample of an ideal gas not only exhibit a pressure of 1 atm but also a concentration of 1 mol L^{-1}? ($R = 0.082$ L atm mol^{-1} deg^{-1})

(a) At STP
(b) When $V = 22.4$ L
(c) When $T = 12$ K
(d) Impossible under any conditions

15 Select the correct statement. In the gas equation $pV = nRT$

(a) n is the number of molecules of a gas
(b) V denotes volume of one mole of the gas
(c) n moles of the gas have a volume V
(d) p is the pressure of the gas when only one mole of the gas is present

16 A gaseous mixture was prepared by taking equal moles of CO and N_2. If the total pressure of the mixture was found to be 1 atm, the partial pressure of the nitrogen (N_2) in the mixture is **→ CBSE-AIPMT 2011**

(a) 0.8 atm (b) 0.9 atm
(c) 1 atm (d) 0.5 atm

17 What will be the partial pressure of He and O_2 respectively, if 200 mL of He at 0.66 atm and 400 mL of O_2 at 0.52 atm pressure are mixed in 400 mL vessel at 20°C?

(a) 0.33 and 0.56
(b) 0.33 and 0.52
(c) 0.38 and 0.52
(d) 0.25 and 0.45

18 Equal moles of hydrogen and oxygen gases are placed in container with a pin-hole through which both can escape. What fraction of the oxygen escapes in the time required for one-half of the hydrogen to escape? **→ NEET 2016, Phase I**

(a) 1/4 (b) 3/8
(c) 1/2 (d) 1/8

19 50 mL of each gas A and of gas B takes 150 and 200 s respectively for effusing through a pin hole under the similar conditions. If molecular mass of gas B is 36, the molecular mass of gas A will be **→ CBSE-AIPMT 2012**

(a) 96 (b) 128 (c) 32 (d) 20

20 Rate of effusion of LPG (a mixture of n-butane and propane) is 1.25 times that of SO_3. Hence, mass fraction of n-butane in LPG is

(a) 0.75 (b) 0.25
(c) 0.50 (d) 0.67

21 Consider the following pairs of gases A and B.

	A	B
I.	CO_2	N_2O
II.	CO	N_2
III.	O_2	O_3
IV.	H_2O	D_2O
V.	$^{235}UF_6$	$^{238}UF_6$

Relative rates of effusion of gases A and B is in the order

(a) I = II < V < IV < III (b) I = II < III < IV < V
(c) I = II < IV < III < V (d) I < II < III < IV < V

22 Which of the following expressions correctly represents the relationship between the average molar kinetic energy, $\overline{KE}$ of CO and N_2 molecules at the same temperature?

(a) $\overline{KE}_{CO} < \overline{KE}_{N_2}$
(b) $\overline{KE}_{CO} > \overline{KE}_{N_2}$
(c) $\overline{KE}_{CO} = \overline{KE}_{N_2}$
(d) Cannot be predicted unless volumes of the gases are given

23 The temperature of the gas is raised from 27°C to 927°C the root mean square velocity is

(a) $\sqrt{\frac{927}{27}}$ times of the earlier value
(b) same as before
(c) halved
(d) doubled

24 Two gases A and B having the same volume diffuse through a porous partition in 20 and 10s respectively. The molecular mass of A is 49 u. Molecular mass of B will be **→ CBSE-AIPMT 2011**

(a) 12.25 u (b) 6.50 u
(c) 25.00 u (d) 50.00 u

25 Maximum deviation from ideal gas is expected from **→ NEET 2013**

(a) $H_2(g)$ (b) $N_2(g)$
(c) $CH_4(g)$ (d) $NH_3(g)$

26 At which one of the following temperature and pressure conditions, the deviation of a gas from ideal behaviour is expected to be minimum?

(a) 350 K and 3 atm (b) 550 K and 1 atm
(c) 250 K and 4 atm (d) 450 K and 2 atm

27 A gas obeys the equation of state $p(V - b) = RT$, where b is a constant. The slope for an isochore will be

(a) negative (b) zero
(c) $\frac{R}{(V-b)}$ (d) $\frac{R}{p}$

28 The compressibility factor of a gas is less than unity at STP, therefore

(a) V_m (molar volume) > 22.4 L (b) $V_m < 22.4$ L
(c) $V_m = 22.4$ L (d) $V_m = 44.8$ L

29 *a* and *b* are van der Waals' constants for gases. Chlorine is more easily liquefied than ethane because

(a) *a* and *b* for Cl_2 > a and *b* for C_2H_6
(b) *a* and *b* for Cl_2 < *a* and *b* for C_2H_6
(c) *a* for Cl_2 > *a* for C_2H_6 but *b* for Cl_2 > *b* for C_2H_6
(d) *a* for Cl_2 > *a* for C_2H_6 but *b* for Cl_2 < *b* for C_2H_6

30 The correction factor '*a*' to the ideal gas equation corresponds to **→ NEET 2018**

(a) electric field present between the gas molecules
(b) volume of the gas molecules
(c) density of the gas molecules
(d) forces of attraction between the gas molecules

31 Given van der Waals' constant (a) of NH_3, H_2, O_2 and CO_2 are respectively 4.17, 0.244, 1.36 and 3.59, which one of the following gases is most easily liquefied? **→ NEET 2018**

(a) O_2 (b) H_2
(c) NH_3 (d) CO_2

32 Gases possess characteristic critical temperature which depends upon the magnitude of intermolecular forces between the particles. Following are the critical temperatures of some gases.

Gases	H_2	He	O_2	N_2
Critical temperature (in Kelvin)	33.2	5.3	154.3	126

From the above data what would be the order of liquefaction of these gases?

Start writing the order from the gas liquefying first

(a) H_2, He, O_2, N_2 (b) He, O_2, H_2, N_2
(c) N_2, O_2, He, H_2 (d) O_2, N_2, H_2, He

33 Vapour pressure increases with increase in

(a) concentration of solution containing non-volatile solute
(b) temperature up to boiling point
(c) temperature up to triple point
(d) altitude of the concerned place of boiling

34 The surface tension of which of the following liquid is maximum?

(a) H_2O (b) C_6H_6 (c) CH_3OH (d) C_2H_5OH

35 The magnitude of surface tension of liquid depends on the attractive forces between the molecules. Arrange the following in increasing order of surface tension water, alcohol (C_2H_5OH) and hexane [$CH_3(CH_2)_4CH_3$]

(a) water < alcohol < hexane (b) hexane < alcohol < water
(c) alcohol < water < hexane (d) hexane < water < alcohol

DAY PRACTICE SESSION 2

PROGRESSIVE QUESTIONS EXERCISE

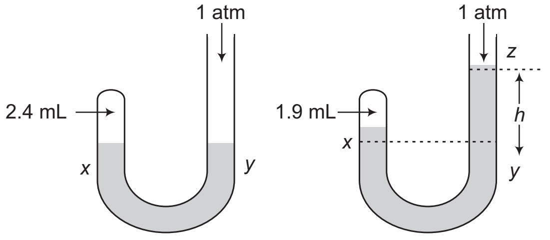
1 A closed flask contains water in all its three states solid, liquid and vapour at 0°C. In this situation, the average kinetic energy of water molecules will be

(a) the greatest in all the three states
(b) the greatest in vapour state
(c) the greatest in liquid state
(d) the greatest in solid state

2 A gas in an open container is heated from 27°C to 127°C. The fraction of the original amount of the gas remaining in the container will be

(a) $\frac{3}{4}$ (b) $\frac{1}{2}$ (c) $\frac{1}{4}$ (d) $\frac{1}{8}$

3 Given J-tube has 2.4 mL of air at a pressure of 1 atm. On adding mercury, volume of air is reduced to 1.9 mL as shown. Difference in the level of mercury in two columns is



(a) 700 mm (b) 200 mm (c) 900 mm (d) 760 mm

4 Containers *A* and *B* have same gases. Pressure, volume and temperature of *A* are all twice that of *B*, then the ratio of number of molecules of *A* and *B* are

(a) 1 : 2 (b) 2 : 1 (c) 1 : 4 (d) 4 : 1

5 600 cc of a gas at a pressure of 750 mm is compressed to 500 cc. Taking the temperature to remain constant,the increase in pressure is

(a) 150 mm (b) 250 mm (c) 350 mm (d) 450 mm

6 Cyclopropane and oxygen at partial pressures of 170 torr and 570 torr respectively are mixed in a gas cylinder. What is the ratio of the number of moles of cyclopropane to the number of moles of oxygen?

(a) $\frac{170 \times 42}{570 \times 32} = 0.39$ (b) $\frac{170}{42}\left(\frac{170}{42}+\frac{570}{32}\right) \simeq 0.19$
(c) $\frac{170}{740} = 0.23$ (d) $\frac{170}{570} = 0.30$

7 A quantity of gas is collected in a graduated tube over the mercury. The volume of gas at 18°C is 50.0 mL and the level of mercury in the tube is 100 mm above the outside mercury level. The barometer reads 750 torr. Hence, volume at STP is approximately

(a) 22 mL (b) 40 mL
(c) 20 mL (d) 44 mL

8 A mixture of nitrogen and oxygen has a density of 1.00 g and the average molecular weight of 31.2 g mol^{-1} at 27°C and 600 mm Hg pressure. The mole fraction of nitrogen, assuming ideal gas behaviour, is

(a) 0.78 (b) 0.60 (c) 0.40 (d) 0.22

9 In van der Waals' equation of state for a non-ideal gas, the term that accounts for intermolecular forces is

(a) $(V - b)$

(b) $(RT)^{-1}$

(c) $\left(p + \frac{a}{V^2}\right)$

(d) RT

10 At what temperature, will the total kinetic energy of 0.30 mol of He be the same as the total kinetic energy of 0.40 mole of Ar at 400 K?

(a) 533 K (b) 400 K
(c) 346 K (d) 300 K

11 The average molecular speed is greatest in which of the following gas samples?

(a) 1.0 mole of O_2 at 560 K
(b) 0.50 mole of Ne at 500 K
(c) 0.20 mole of CO_2 at 440 K
(d) 2.0 mole of He at 140 K

12 Nitrogen gas and water vapours are filled in a vessel and the total pressure of vessel is 1 atm. The partial pressure of water vapour is 0.3 atm. When the contents of this vessel are transferred to another vessel having one third of the capacity of original vessel, completely at the same temperature, the total pressure of the system in the new vessel is

(a) 2.4 atm (b) 1 atm
(c) 3.33 atm (d) 3.0 atm

13 An LPG cylinder, containing 15 kg butane at 27°C and 10 atm pressure, is leaking. After one day, its pressure decreased to 8 atm. The quantity of gas leaked is

(a) 12 kg (b) 3 kg
(c) 1 kg (d) 4 kg

14 Four gases P, Q, R and S have almost same values of 'b' but their 'a' values (a and b are van der Waals' constants) are in the order of $Q > R > S > P$. At a particular temperature, among the from gases, the most easily liquefiable is

(a) P (b) S
(c) R (d) Q

15 When a capillary tube of diameter 0.8 mm is dipped in a liquid having density 800 kg m^{-3} then the height of liquid in the capillary tube rises to 4 cm. The surface tension of liquid is ($g = 9.8$ m/s^2)

(a) 4.3×10^{-2} Nm^{-1} (b) 5.6×10^{-2} Nm^{-1}
(c) 6.3×10^{-2} Nm^{-1} (d) 7.3×10^{-2} Nm^{-1}

16 Which of the following is not a property of liquid state?

(a) Intermolecular force of attraction in a liquid is quite large.
(b) All liquids accompanied by cooling on evaporation
(c) Lower the boiling point of a liquid, greater is its vapour pressure at room temperature.
(d) A liquid boils at high temperature at the top of a mountain that at the sea level.

ANSWERS

SESSION 1	**1** (d)	**2** (c)	**3** (d)	**4** (a)	**5** (a)	**6.** (a)	**7** (b)	**8** (a)	**9** (c)	**10** (b)
	11 (a)	**12** (b)	**13** (b)	**14** (c)	**15** (c)	**16** (d)	**17** (b)	**18** (d)	**19** (d)	**20** (c)
	21 (a)	**22** (c)	**23** (d)	**24** (a)	**25** (d)	**26** (b)	**27** (c)	**28** (b)	**29** (d)	**30** (d)
	31 (c)	**32** (d)	**33** (b)	**34** (a)	**35** (b)					
SESSION 2	**1** (b)	**2** (a)	**3** (b)	**4** (b)	**5** (a)	**6** (d)	**7** (b)	**8** (d)	**9** (c)	**10** (a)
	11 (d)	**12** (d)	**13** (a)	**14** (d)	**15** (c)	**16** (d)				

Hints and Explanations

SESSION 1

1 Mass of gas can be determined by weighing a container in which it is enclosed as follows:

Mass of the gas = mass of the cylinder including gas – mass of empty cylinder

So, it is a wrong statement.

2 Food takes more time to cook that means its vapour pressure becomes equal to atmospheric pressure at a lower temperature. That is at high altitude pressure is lower or pressure decreases (as $p \propto T$ at constant V and n).

3 As the temperature is constant, Boyle's law is applicable

$$p_1V_1 = p_2V_2$$

$$V_1 = 380 \text{ mL}, p_1 = 730 \text{ mm}, V_2 = ?$$

$$p_2 = 760 \text{ mm}$$

$$730 \times 380 = 760 \times V_2$$

$$V_2 = \frac{730 \times 380}{760} = 365 \text{ mL}$$

4 For the reaction,

$$SrCO_3(s) \rightleftharpoons SrO(s) + CO_2(g),$$

$K_p = 1.6$ atm $= p_{CO_2} =$ maximum pressure of CO_2

Given, $p_1 = 0.4$ atm, $V_1 = 20$ L, $T_1 = 400$ K

$$p_2 = 1.6 \text{ atm}, V_2 = ?, T_2 = 400 \text{ K}$$

According to Boyle's law,

At constant temperature, $p_1V_1 = p_2V_2$

$$0.4 \times 20 = 1.6 \times V_2$$

$$V_2 = \frac{0.4 \times 20}{1.6} = 5 \text{ L}$$

5 The balloon would burst when $V > 20$ L

$$p_1V_1 = p_2V_2,$$

$$\Rightarrow \quad 1 \times 10 = p_2 \times 20$$

$$p_2 = 0.5 \text{ atm (no bursting)}$$

Thus, a pressure below 0.5 atm, it would burst.

6 Boyle's law $p_1V_1 = p_2V_2$,

$$p_1 = 76 \text{ cm of Hg},$$

$$p_2 = ?$$

$$V_1 = 5 \text{ L}, V_2 = 30 + 5 = 35 \text{ L}$$

$$\therefore \quad p_2 = \frac{76 \times 5}{35} = 10.8 \text{ cm of Hg}$$

7 Initial volume, $V_1 = 500$ mL

Initial temperature,

$$T_1 = 27°C = 27 + 273 = 300 \text{ K}$$

Final temperature,

$$T_2 = -5 + 273 = 268 \text{ K}, V_2 = ?$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$V_2 = \frac{V_1T_2}{T_1} = \frac{500 \times 268}{300}$$

$$= 446.66 \text{ mL}$$

8 According to Charle's law "the volume of a fixed mass of a gas increases or decreases by $\frac{1}{273.15}$ of its volume at 0°C for each degree rise or fall of temperature, if pressure is kept constant".

9 According to the Boyle's law'

At a particular temperature, $pV =$ constant.

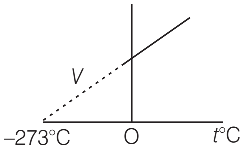
or, we can write it as,

$$p_1V_1 = p_2V_2 = p_3V_3 = p_4V_4$$

As, $V_1 > V_2 > V_3 > V_4$

$\therefore \quad p_1 < p_2 < p_3 < p_4$

10



$$p_1n = \text{constant}$$

Volume $V = K(t + 273)$

at –273° C (0 K) , volume = 0 L (i.e. x-intercept)

11 $K = \frac{V}{n} = \frac{22.4}{1}$ L mol^{-1}

when $n = 0.5$ mol, $V = 11.2$ L, Hence $K = 22.4$ mol^{-1} L (again constant).

12 According to Avogadro's hypothesis, 'under the same conditions of temperature and pressure equal volumes of gases contain the same number of molecules'.

13 At low pressure and high temperature, a real gas would behave ideally.

14 According to ideal gas equation,

$$pV = nRT$$

$$p = \frac{n}{V}RT$$

$$1 \text{ atm} = 1 \text{ mol L}^{-1} \times 0.0821 \times T$$

$$T = \frac{1}{0.0821} = 12 \text{ K}$$

15 The ideal gas equation is $pV = nRT$

where, V is the volume of n moles of a gas.

16 $\because \quad n_{CO} = n_{N_2}$

$\therefore \quad p_{CO} = p_{N_2}$

Given, $p_{CO} + p_{N_2} = 1$ atm

or $\quad 2p_{N_2} = 1$ atm

or $\quad p_{N_2} = 0.5$ atm

17 Total pressure,

$$p = \frac{\text{milliequiv. of He + milliequiv. of } O_2}{\text{total volume}}$$

$$= \frac{200 \times 0.66 + 400 \times 0.52}{400}$$

$$= \frac{340}{400} = 0.85$$

Partial pressure of He

$$= \frac{\text{milliequiv. of He}}{\text{total milliequiv.}} \times p$$

$$= \frac{132}{340} \times 0.85$$

$$= 0.33 \text{ atm}$$

Similarly, partial pressure of O_2

$$= \frac{208}{340} \times 0.85 = 0.52 \text{ atm}$$

18 Given, number of moles of hydrogen (n_{H_2}) and that of oxygen (n_{O_2}) are equal.

$\therefore$ We have, the relation between ratio of number of moles escaped and ratio of molecular mass.

$$\frac{n_{O_2}}{n_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}}$$

where, $M =$ Molecular mass of the molecule.

$$\Rightarrow \quad \frac{n_{O_2}}{n_{H_2}} = \sqrt{\frac{2}{32}}$$

$$\Rightarrow \quad \frac{n_{O_2}}{n_{H_2}} = \sqrt{\frac{1}{16}}$$

$$\Rightarrow \quad \frac{n_{O_2}}{0.5} = \frac{1}{4}$$

$$\Rightarrow \quad n_{O_2} = \frac{0.5}{4} = \frac{1}{8}$$

19 Given, $\quad V_A = V_B = 50$ mL

$$T_A = 150 \text{s}$$

$$T_B = 200\,\text{s}$$
$$M_B = 36$$
$$\frac{r_B}{r_A} = \sqrt{\frac{M_A}{M_B}} = \frac{V_B T_A}{T_B V_A}$$
$$\Rightarrow \quad \sqrt{\frac{M_A}{36}} = \frac{V_B \times 150}{200 \times V_A}$$
$$\text{or} \quad \sqrt{\frac{M_A}{36}} = \frac{15}{20} = \frac{3}{4}$$
$$\frac{M_A}{36} = \frac{9}{16}$$
$$M_A = \frac{9 \times 36}{16}$$
$$= \frac{9 \times 9}{4} = \frac{81}{4} = 20.2 \cong 20$$

20 $$\frac{R_{LPG}}{R_{SO_3}} = \sqrt{\frac{M_{(SO_3)}}{M_{(LPG)}}} \cdot \sqrt{\frac{80}{M_{LPG}}} = 1.25$$
$$\frac{80}{M_{LPG}} = (1.25)^2$$
$$M_{LPG} = 51.2$$
$$M = \frac{M_1(\text{butane})\chi_1 + M_2(\text{propane})\chi_2}{\chi_1 + \chi_2}$$
$$51.2 = \frac{58\chi_1 + 44(1 - \chi_1)}{1}, \ \chi_1 \approx 0.50$$

21 $$\frac{r_A}{r_B} = \sqrt{\frac{M_B}{M_A}}$$

I. $\frac{r_A}{r_B} = \sqrt{\frac{44}{44}} = 1$

II. $\frac{r_A}{r_B} = \sqrt{\frac{28}{28}} = 1$

III. $\frac{r_A}{r_B} = \sqrt{\frac{48}{32}} = 1.225$

IV. $\frac{r_A}{r_B} = \sqrt{\frac{20}{18}} = 1.054$

V. $\frac{r_A}{r_B} = \sqrt{\frac{352}{349}} = 1.004$

∴ Relative rates of effusion = I = II < V < IV < III

22 KE $= \frac{3}{2} RT$ (for one mole of a gas)

The temperature is constant and kinetic energy is independent on molecular weights. So,

$$\overline{KE}_{CO} = \overline{KE}_{N_2}$$

23 Root mean square velocity (v) at T_1 temperature,

$$U_1 = \sqrt{\frac{3RT_1}{M}} = \sqrt{\frac{3R(27 + 273)}{M}} \quad \ldots\text{(i)}$$

Root mean square velocity at T_2 temperature,

$$U_2 = \sqrt{\frac{3RT_2}{M}} = \sqrt{\frac{3R(927 + 273)}{M}} \quad \ldots\text{(ii)}$$

Eq. (i) divided by Eq. (ii)

$$\frac{U_1}{U_2} = \sqrt{\frac{27 + 273}{927 + 273}} = \sqrt{\frac{300}{1200}} = \frac{1}{2}$$
$$\Rightarrow \quad U_2 = 2U_1$$

24 According to Graham's law of diffusion,

Rate of diffusion $r \propto \frac{1}{\sqrt{M}}, r \propto \frac{V}{t}$

where, V is the volume of the gas diffused in time t.

$$\frac{r_A}{r_B} = \sqrt{\frac{M_B}{M_A}}$$
$$\text{or} \quad \frac{V_A}{t_A} \times \frac{t_B}{V_B} = \sqrt{\frac{M_B}{M_A}}$$
$$\text{Given,} \quad V_A = V_B$$
$$\therefore \quad \frac{10}{20} = \sqrt{\frac{M_B}{49}}$$
$$\Rightarrow \quad \frac{1}{4} = \frac{M_B}{49}$$
$$M_B = \frac{49}{4} = 12.25\,\text{u}$$

25 The extent to which a real gas deviates from ideal behaviour can be understood by a quantity 'Z' called the **compressibility factor.** Easily liquefiable gases like NH_3, SO_2 etc. exhibit maximum deviation from ideal gas as for them $Z <<< 1$.

CH_4 also exhibits deviation but it is less as compared to NH_3.

26 A real gas behave as an ideal gas at low pressure and high temperature. Among the given option, 550K temperature is the highest and 1atm pressure is the lowest pressure.

27 $p(V - b) = RT \Rightarrow p = \frac{RT}{(V - b)}$

Isochore is a graph between p and T at constant volume.

Thus, slope $= \left(\frac{R}{(V - b)}\right)$

28 $\because \quad Z < 1$ i.e. $\frac{pV}{RT} < 1$

$$\text{Again} \quad \frac{p}{RT} = \frac{1}{0.0821 \times 273} = \frac{1}{22.4}$$
$$\therefore \quad \frac{V_m}{22.4} < 1$$
$$V_m < 22.4\,\text{L}$$

29 van der Waals' constant a is due to force of attraction and 'b' is due to finite size of molecules.

Thus, greater the value of a and smaller the value of 'b', larger the liquefaction.

Thus, $a(Cl_2) > a(C_2H_6)$

and $b(Cl_2) < b(C_2H_6)$

30 According to van der Waals' equation,

$$\left[p + \frac{an^2}{V^2}\right](V - nb) = nRT$$

where, a and b are called van der Waals' constant.

$\frac{an^2}{V^2}$ is called internal pressure of the gas

where, 'a' is a measure of force of attraction between gas molecules.

'b' is also called co-volume or excluded volume.

The constants 'a' and 'b' are expressed in atm L^2 mol^{-2} and L mol^{-1}, respectively.

31 In the van der Waals equation,

$$\left[p + \frac{an^2}{V^2}\right](V - nb) = nRT$$

'a' and 'b' are known as van der Walls' constant.

'a' is a measure of force of attraction between gas molecules. Greater the value of a, easier the liquefaction of the gas.

Thus, among NH_3(4.17), H_2(0.244), O_2 (1.36) and CO_2(3.59), the value of a is greatest in NH_3, hence it is most easily liquefied.

32 A gas with higher critical temperature liquefy first.

Since, $a_{O_2} > a_{N_2} > a_{H_2} > a_{He}$

Hence, T_c will be higher in this order too. Therefore, the correct order is similar to this order.

O_2, N_2, H_2, He

33 Vapour pressure becomes identical as the atmospheric pressure at boiling point. If the liquid is heated beyond that only evaporation continues, vapour pressure does not rise further.

34 Surface tension of H_2O is maximum due to maximum hydrogen bonding in comparison to C_6H_6, CH_3OH, C_2H_5OH.

The order of H-bonding is

$$H_2O > CH_3OH > C_2H_5OH$$

(Benzene does not form H-bond).

35 In hexane, there are only London forces between the molecules. These forces are very weak. H-bonding is stronger in H_2O in comparison to C_2H_5OH. Hence, the increasing order of surface tension is

hexane < alcohol < water

SESSION 2

1
$$pV = nRT$$
$$n \propto \frac{1}{T}$$
$$\frac{n_2}{n_1} = \frac{T_1}{T_2} = \frac{300}{400} = \frac{3}{4}$$

2 Atmospheric pressure = 760 mm Hg

$$\because \quad p_1V_1 = p_2V_2$$
$$\therefore \quad p_2 = \frac{p_1V_1}{V_2} = \frac{760 \times 2.4}{1.9}$$
$$= 960 \text{ mm Hg}$$

$\therefore$ Difference in column

$$= 960 - 760 = 200 \text{ mm}$$

3 For B container gas; $p_B = p$, $V_B = V$, $T_B = T$

For A container gas;

$$p_A = 2p, V_A = 2V, T_A = 2T$$

According to gas laws;

$$\frac{p_AV_A}{n_ART_A} = \frac{p_BV_B}{n_BRT_B}$$
$$\frac{2p \times 2V}{n_A \times R \times 2T} = \frac{p \times V}{n_B \times R \times T}$$
$$\frac{n_A}{n_B} = \frac{2}{1}$$

Number of molecules

= Mole × Avogadro's number

$$= \frac{\text{molecules } A}{\text{molecules } B}$$
$$= \frac{2 \times N_A}{1 \times N_A} = \frac{2}{1}$$

4 Surface tension, $T = \frac{rhdg}{2}$

$$= \frac{(4 \times 10^{-4}) \times (0.04) \times 800 \times 9.8}{2}$$
$$(\because r = 0.4 \text{mm} = 4 \times 10^{-4} \text{m})$$
$$= 6.3 \times 10^{-2} \text{ Nm}^{-1}$$

5 According to Boyle's law,

$$p_1V_1 = p_2V_2$$
$$750 \times 600 = p_2 \times 500$$
$$p_2 = \frac{750 \times 600}{500} = 900 \text{ mm}$$

So, the increase in pressure

$$= 900 - 750 = 150 \text{ mm}$$

6 According to ideal gas equation,

$$p_1V_1 = n_1RT \qquad \ldots\text{(i)}$$
$$p_2V = n_2RT \qquad \ldots\text{(ii)}$$

From equation (i) and (ii),

$$\frac{p_1V}{p_2V} = \frac{n_1RT}{n_2RT}$$
$$\Rightarrow \quad \frac{p_1}{p_2} = \frac{n_1}{n_2}$$
$$\Rightarrow \quad \frac{n_1}{n_2} = \frac{p_1}{p_2} = \frac{170}{570} = 0.30$$

7 Net pressure recorded = 750 − 100

= 650 torr

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$
$$V_2 = \frac{p_1V_1T_2}{p_2T_1} = \frac{650 \times 50 \times 273}{760 \times 291}$$
$$= 40 \text{ mL}$$

8 $p = \frac{nRT}{V} = \frac{w}{MV}RT = \frac{dRT}{M}$

Let N_2 be = w_1 g with χ %

O_2 be = w_2 g with $(100 - \chi)$%

$$\therefore \quad \overline{M} = \frac{m_1\chi + m_2(100 - \chi)}{\chi + (100 - \chi)}$$
$$31.2 = \frac{28\chi + 32(100 - \chi)}{100}$$
$$\therefore \quad \chi = 20$$
$$\therefore N_2 = 20 \text{ g} = \frac{20}{28} \text{ mol} = 0.71 \text{ mol}$$

Thus, $O_2 = 80 = \frac{80}{32}$ mol = 2.50 mol

$\therefore$ Mole fraction of $N_2 = \frac{0.71}{3.21} = 0.22$

9 The van der Waals' equation is

$$\left(p + \frac{a}{V^2}\right)(V - b) = RT$$

The term $\left(p + \frac{a}{V^2}\right)$ is used for pressure correction, it measures the intermolecular forces between the molecules of gas.

10 $\text{KE} = \frac{3}{2}nRT$

$$\frac{3}{2} \times 0.30 \times T = \frac{3}{2} \times 0.4 \times 400$$
$$T = 533 \text{ K}$$

11 Average molecular speed = $\sqrt{\frac{8RT}{\pi M}}$ is dependent on T and M. Thus, greater the value of $\sqrt{\frac{T}{M}}$, greater will be the molecular speed.

Thus, $V_{\text{gas}} = \sqrt{\frac{T}{M}}$

(a) $V_{O_2} = \sqrt{\frac{560}{32}} = 4.18$

(b) $V_{Ne} = \sqrt{\frac{500}{20}} = 5.0$

(c) $V_{O_2} = \sqrt{\frac{440}{44}} = 3.16$

(d) $V_{He} = \sqrt{\frac{140}{4}} = 5.91$

12 $p_{N_2} + p_{H_2O} = 1 \text{ atm} \qquad [\because p_{H_2O} = 0.3 \text{ atm}]$

$\therefore \quad p_{N_2} = 0.7$ atm in I vessel

Now, new pressure of N_2 in another vessel can be calculated by using equation,

$$p_1V_1 = p_2V_2$$
$$\therefore \quad 0.7 \times V_1 = p_2 \times \frac{V_1}{3}$$
$$p_{N_2} = 2.1 \text{ atm}$$

Similarly, new pressure of water vapours is

$$0.3 \times V_1 = p_2 \times \frac{V_1}{3}$$

or $\quad p_{H_2O} = 0.9 \text{ atm}$

$\therefore \quad p_{\text{total}} = 2.1 + 0.9 = 3.0 \text{ atm}$

13 In the three states of matter, the maximum kinetic energy is possessed by the gaseous molecules, so water vapour state has maximum kinetic energy in this situation.

14 According to the question, temperature and volume are constant, hence from ideal gas equation we have

$$\frac{p_1}{p_2} = \frac{n_1}{n_2} \qquad \frac{p_1}{p_2} = \frac{W_1}{W_2}$$
$$[\because M_2 = M_1 \text{ as same gas is leaked}]$$
$$\frac{10}{8} = \frac{15}{W_2} \Rightarrow W_2 = 12 \text{ kg}$$

15 Higher the value of a more will be the tendency to get liquefy. Since, value of a is highest for Q, thus Q is the most liquefiable gas among the given gases.

16 A liquid at mountain top boils at low temperature than at sea level.