Chapter 5

States of Matter

INTERMOLECULAR FORCES AND THERMAL ENERGY

Intermolecular Forces:

These are the forces of attraction and repulsion between interacting particles. (The term does not include electrostatic forces or forces between covalent bonds).

Attractive intermolecular forces are called van der Waals forces. The different types of van der Waals forces are discussed below:

(i) Dispersion forces or London forces: The forces of attraction between induced momentary dipoles are called London forces. These forces arise when the electron cloud of the molecule is distorted momentarily, thus generating a momentary dipole which in turn induces dipole in the neighbouring molecules. These are then attracted to each other. They are important only at short distances and their magnitude depends on the polarisability of the particle.

(ii) Dipole-Dipole forces : These forces act between molecules possessing permanent dipole. The positive pole of one molecule is attracted towards the negative pole of the other molecule.

The magnitude of these forces depends on the polarity of molecules which, in turn, depends on the electronegativities of the atoms present in the molecule. The attractive forces decreases with increase of distance between dipoles.

(iii) Dipole-Induced dipole forces : They operate between molecules having permanent dipole and molecules lacking permanent dipole. Permanent dipole of the polar molecule induces dipole on electrically neutral molecule by deforming its electronic cloud.

(iv) Hydrogen bond : It is a special case of dipole - dipole interactions. It arises in molecules in which highly polar N-H, O-H or H-F bonds are present.

Strength of the H-bond depends on the coulombic interaction between lone pair of electrons of electronegative atom of one molecule and H-atom of the other molecule.

Thermal Energy

It is the energy of a body arising from motion of its atoms or molecules. It is directly proportional to temperature of substance. It is a measure of average KE of particles.

Intermolecular Forces Vs Thermal Energy

Intermolecular forces tend to keep molecules together while thermal energy tends to keep them apart. The three states of matter are the result of balance between intermolecular forces and thermal energy of molecules. The predominance of thermal energy and molecular interaction energy of a substance in the three states is depicted as follows:

$$\text{Gas} \quad \text{Liquid} \quad \text{Solid}$$
$$\xrightarrow{\text{Intermolecular interaction increases}}$$

$$\xrightarrow{\text{Thermal energy decreases}}$$

GASEOUS STATE

The gaseous state is characterized by the following physical properties:

- Gases are highly compressible.
- They exert pressure equally in all the directions.
- Gases have much lower density than solids and liquids.
- The volume and shape of gases are not fixed. They assume volume and shape of the container.
- Gases mix evenly and completely in all proportions.

Gas Laws

Boyle's law: According to this law, at constant temperature, the pressure of a fixed amount of gas varies inversely with its volume.

Mathematically.

$$P \propto \frac{1}{V} \text{ (at constant T and n)}$$

$$\Rightarrow P = \frac{k}{V} \text{ (k} \rightarrow \text{constant of proportionality)}$$

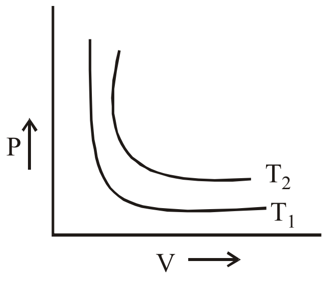
$$\Rightarrow PV = k$$

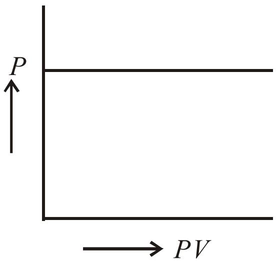
If a fixed amount of gas at constant temperature T occupying volume V_1 at pressure P_1 undergoes expansion, so that volume becomes V_2 and pressure becomes P_2, then according to Boyle's law :

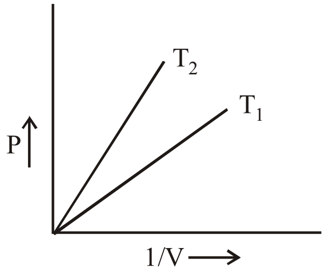
$$P_1V_1 = P_2V_2 = \text{constant}$$

$$\Rightarrow \frac{P_1}{P_2} = \frac{V_2}{V_1}$$

Graphically, Boyle's law can be represented as:







Charle's law : According to this law, pressure remaining constant, the volume of a fixed mass of a gas is directly proportional to its absolute temperature, i.,e.

$$V \propto T \text{ or } V = kT$$

Other way of representing it is following:

For each degree change of temperature, the volume of sample of a gas changes by the fraction of 1/273.15 of its volume at 0ºC.

$$V_t = V_0 + \frac{t}{273.15} V_0$$

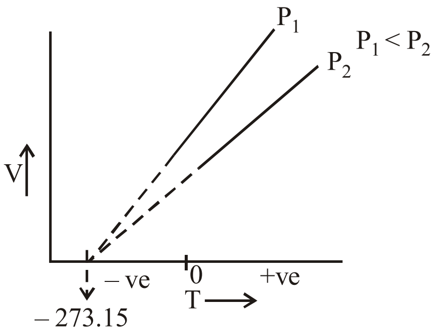
$$\Rightarrow V_t = V_0\left(1 + \frac{t}{273.15}\right) = V_0\left(\frac{273.15 + t}{273.15}\right)$$

$$\Rightarrow V_t = V_0\left(\frac{T_t}{T_0}\right) \Rightarrow \frac{V_t}{V_0} = \frac{T_t}{T_0}$$

Where T_0 = 273.15 and is called Kelvin temperature or Absolute temperature

$$\therefore \boxed{0°C = 273.15K}$$

At – 273.15°C, volume of a gas will be zero. This means that the gas will not exist. This temperature at which gases are supposed to occupy zero volume is called Absolute zero. Graphically, it is represented as:



Gay lussac's law : It states that at constant volume, pressure of a fixed amount of a gas varies directly with the temperature, i.e.

$$P \propto T$$

$$\text{or,} \quad \frac{P}{T} = \text{constant} = k$$

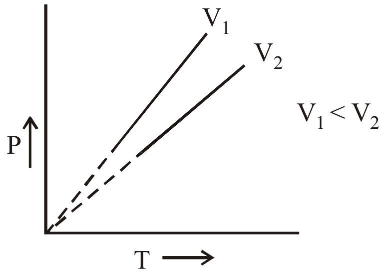
Hence, if the pressure of a gas P_1 at temperature T_1 changes to P_2 at T_2, volume remaining constant, we have

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = \text{constant}$$

$$\text{or,} \quad \log P - \log T = \text{constant}$$

$$P_t = P_0\left(1 + \frac{t}{273.15}\right)$$

Graphically,



Avogadro law : It states that equal volumes of all gases under the same conditions of temperature and pressure contain equal number of molecules.

i.e. $V \propto n$, where $n \rightarrow$ Number of molecules of gas

$V = kn$

Thus, one mole of each gas at standard temperature and pressure will have same volume. Standard temperature and pressure means 273.5 K (0°C) temperature and 1 bar (10^5 Pa) pressure.

As $n = \frac{m}{M}$ where, $m \rightarrow$ given mass, $M \rightarrow$ molar mass

$$\therefore V = k\frac{m}{M} \Rightarrow M = k\frac{m}{V} = k\,d$$

$\Rightarrow V \propto d$ where, $d \rightarrow$ density of gas

Ideal gas equation : A gas that follows Boyle's law, Charle's law and Avogadro law strictly is called an ideal gas. Combining the three laws, we can get the ideal gas equation as discussed below:

Boyle's law : $V \propto \frac{1}{P}$ at constant T and n

Charle's law : $V \propto T$ at constant P and n

Avogadro law : $V \propto n$ at constant P and T

$$\therefore \quad V \propto \frac{nT}{P}$$

$$\Rightarrow V = \frac{RnT}{P}$$

or, PV = nRT Ideal Gas equation or Equation of State.

R=Universal gas constant

$$R = \frac{PV}{nT} = \frac{\left(10^5\,\text{Pa}\right)\left(22.71\times10^{-3}\,\text{m}^3\right)}{(1\,\text{mol})(273.15\,\text{K})}$$

$= 8.314\ \text{Pa m}^3\ \text{K}^{-1}\ \text{mol}^{-1}$.

$= 8.314 \times 10^{-2}\ \text{bar L K}^{-1}\ \text{mol}^{-1}$.

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

If T, P and V of a fixed amount of gas vary from T_1, V_1 and P_1 to T_2, V_2 and P_2, then

$$\frac{P_1 V_1}{T_1} = nR \quad \text{and} \quad \frac{P_2 V_2}{T_2} = nR$$

$$\text{or} \quad \boxed{\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}} \quad \text{combined gas Law}$$

Density and Molar Mass of Gaseous Substance from Ideal Gas Equation,

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

$$\frac{m}{MV} = \frac{P}{RT} \qquad \left(\because n = \frac{m}{M}\right)$$

$$\frac{d}{M} = \frac{P}{RT}$$

$$\boxed{M = \frac{dRT}{P}}$$

Dalton's Law of Partial Pressures : According to this law, the total pressure exerted by a mixture of non-reactive gases is equal to the sum of partial pressures of individual gases, i.e.

$P_{\text{Total}} = P_1 + P_2 + P_3 +$ ------------- (at constant T and V)

Pressure exerted by saturated water vapour is called aqueous tension.

$\therefore \quad P_{\text{dry gas}} = P_{\text{Total}} -$ Aq. tension

Partial pressure in terms of mole fraction

$P_1 = x_1\, P_{\text{Total}}$.

$P_2 = x_2\, P_{\text{Total}}$.

In general, $P = x\, P_{\text{Total}}$.

where x → mole fraction; P → partial pressure

Graham's Law of Diffusion or Effusion : According to this law, at constant temperature and pressure, the rate of diffusion or effusion of a gas is inversely proportional to the square root of its density and is directly proportional to its pressure.

$$\text{Rate of diffusion } (r) \propto \frac{P}{\sqrt{d}}$$

$$\frac{r_1}{r_2} = \frac{p_1}{p_2}\sqrt{\frac{d_2}{d_1}}$$

As pressure is constant

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

Where r_1 & r_2 are rates of diffusion of two gases and d_1 & d_2 are densities.

$\therefore$ 2 × vapour density = Molecular mass

$$\therefore \quad \frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

Where M_1 & M_2 are the molecular masses of two gases.

$$\text{Rate of diffusion} = \frac{\text{Volume of gas diffused}}{\text{Time taken for diffusion}}$$

KINETIC MOLECULAR THEORY OF GASES

This theory attempts to elucidate the behaviour of gases. The assumptions or postulates of this theory are:

(i) Gases consist of large number of identical particles which are very small and far apart so that the actual volume of molecules is negligible in comparison to empty space between them. This explains the compressibility of gases.

(ii) There is no force of attraction between the particles of a gas at ordinary T and P. This is why gases can expand and occupy all the space available to them.

(iii) Particles of a gas are always in constant and random motion. If the particles were at rest and occupied fixed position, a gas would have had a fixed shape, which is not so.

(iv) Particles of a gas move in all possible directions in straight lines. During their random motion, they collide with each other and with the walls of the container. Pressure is exerted by the gas as a result of collision of the particles with the walls of the container.

(v) Collisions of gas molecules are perfectly elastic. This means that total energy of molecules before and after collision remains the same. There may be exchange of energy between colliding molecules, their individual energies may change, but the sum of their energies remains constant.

(vi) At any particular time, the different particles of the gas have different speeds and hence different kinetic energies.

(vii) The average KE of gas molecules is directly proportional to the absolute temperature.

MAXWELL'S DISTRIBUTION OF MOLECULAR SPEEDS/ENERGIES

Maxwell and Boltzmann, however, showed that as a result of collisions, though some molecules are speeded up, some others are slowed down and hence the fractions of molecules possessing particular speed remains constant at constant temperature. This is called Maxwell-Boltzmann distributions.

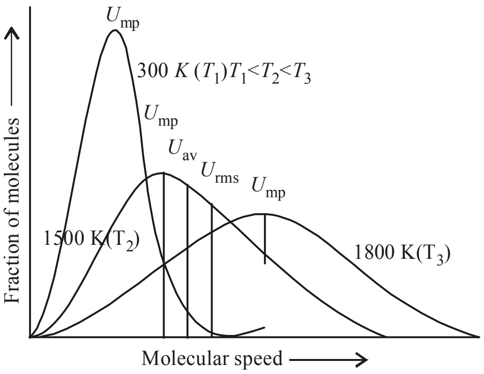
Maxwell gave distribution curves of molecular speeds for CO_2 at different temperatures.

Special features of the curve are :

(i) Fraction of molecules with too high or too low speeds is very small.

(ii) No molecules has zero velocity.

(iii) Initially the fraction of molecules increases with velocity till the peak of the curve which pertains to most probable velocity and thereafter it falls with increase in velocity.



Speed Related to Gaseous State

(a) Root mean square speed (RMS speed) -

$$u = \frac{\sqrt{u_1^2 + u_2^2 + u_3^2 + ...u_n^2}}{n}$$

$$C = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3P}{d}}$$

(b) Average speed (AVS) :

$$\text{Average speed} = \sqrt{\frac{8RT}{\pi m}}$$

Average speed = .9213 × RMS speed

RMS speed = 1.085 × Average speed

(c) Most probable speed (MPS) :

$$\text{Most probable speed} = \sqrt{\frac{2RT}{M}}$$

MPS = .816 × RMS ; RMS = 1.224 MPS

Relation between the three types of velocities

$$\alpha : v : u$$

$$\sqrt{\frac{2RT}{M}} : \sqrt{\frac{8RT}{\pi M}} : \sqrt{\frac{3RT}{M}}$$

$$\sqrt{2} : \sqrt{\frac{8}{\pi}} : \sqrt{3}$$

1.414 : 1.595 : 1.732

1 : 1.128 : 1.234 i.e., $\alpha < v < u$.

DEVIATION FROM IDEAL GAS BEHAVIOUR : REAL GASES

A gas that follows Boyle's law, Charle's law and Avogadro law strictly is called an ideal gas. Such a gas is hypothetical. Real gases follow these laws only under certain specific conditions when forces of interaction are practically negligible. This is discussed as follows:

Two questions arise :

(i) Why do gases deviate from ideality?

(ii) Under what conditions gases deviate from ideality?

Gases deviate from ideality because two assumptions of kinetic theory do not hold good:

(i) There is no force of attraction between molecules of a gas.

(ii) Volume of molecules of a gas is negligible compared to volume of the gas.

Equation of State for Real Gases (Van der Waals Equation)

Correction for pressure : Real gases show deviations from ideal gas law because molecules interact with each other. At high pressures, molecules of gas are very close to each other. Molecular interactions start operating. As a result, pressure exerted by the gas is lower than the pressure exerted by the ideal gas.

Hence, corrected pressure :

$$P_{ideal} = P_{real} + \frac{an^2}{V^2} \qquad a \rightarrow \text{constant}$$

Volume correction : The volume occupied by the molecules also becomes significant at high pressure when the molecules are quite close together because instead of moving in volume V, these are now restricted to volume (V – nb) where nb is approximately the volume occupied by molecules themselves.

i.e., corrected volume = (V – nb)

Thus, taking into account the corrections for P and V, we have

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

van der Waals equation a, b → van der Waals constants

units of 'a' → atm. litre^2 mole^{-2}

units of 'b' → litres mole^{-1}

Value of 'a' is a measure of magnitude of intermolecular attractive forces within the gas and is independent of temperature and pressure.

Also, at very low temperature, intermolecular forces become significant. Thus, real gases show ideal behaviour when conditions of temperature and pressure are such that the intermolecular forces are practically negligible.

As *b* is the effective volume of the gas molecules, the constant value of *b* for any gas over a wide range of temperature and pressure indicates that the gas molecules are incompressible.

Study of Deviation

The deviation from ideal behaviour can be measured in terms of compressibility factor Z which is given by

$$Z = \frac{PV}{nRT}$$

For ideal gas, Z = 1 at all temperatures and pressures.

At very low pressure, all gases have Z = 1 and behave ideally. At high pressure, all gases have Z > 1. They are difficult to compress. At intermediate pressure, most gases have Z < 1.

The temperature at which a real gas obeys ideal gas law over an appreciable range of pressure is called Boyle temperature or Boyle point. At low pressure and high temperature, gases show ideal behaviour.

The temperature at which a real gas obeys ideal gas laws over an appreciable range of pressure is called **Boyle temperature or Boyle point T_B**. T_B and two van der Waal's constants are related as below

$$T_B = \frac{a}{bR}$$

Liquifaction of Gases

Critical temperature (T_c) of a gas is the highest temperature at which liquifaction of the gas first occurs.

Liquifaction of gas requires cooling as well as considerable compression. Compression brings the molecules in close vicinity and cooling slows down the movement of molecules. Therefore, intermolecular interactions may hold the closely and slowly moving molecules together and the gas liquifies.

Critical Constants

(i) **Critical temperature (T_c) :** The temperature above which gas cannot be liquefied whatever pressure is applied is called critical temperature $T_c = \frac{8a}{27bR}$

(ii) **Critical pressure (P_c) :** The minimum pressure required to liquefy a gas at its critical temperature is called critical pressure. $P_c = \frac{a}{27b^2}$

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

$$V_c = 3b$$

There is continuity between gaseous and liquid state. The term fluid is used for either a liquid or a gas to recognise this continuity. A liquid can be viewed as a very dense gas. Liquid and gas can be distinguished only when the fluid is below its critical temperature, since in that case liquid and gas are in equilibrium and a surface separating the two phases is visible. At critical temperature, liquid passes into gaseous state imperceptibly and continuously, the surface separating two phases disappears. A gas below T_c can be liquified by applying pressure, and is called vapour of the substance.

LIQUID STATE

Molecules in liquids are so close that there is very little empty space between them and under normal conditions, liquids are denser than gases. Their molecules are held together by attractive intermolecular forces. They have definite volume and the molecules can move past one another freely and thus liquids can flow, can be poured and can assume the shape of the container.

Some physical properties of liquids are:

(i) Vapour Pressure

It is the pressure exerted by the vapours in equilibrium with the liquid. The temperature at which vapour pressure of liquid is equal to external pressure is called boiling point of the liquid.

At 1 atm, it is the normal boiling point and at 1 bar, it is standard boiling point. At high altitudes, atmospheric pressure is low. Therefore, liquids at high altitudes boil at lower temperatures in comparison to that at sea level. Since water boils at lower temperature on hills, pressure cooker is used for cooking food.

(ii) Surface Tension

A molecule in the bulk of the liquid experiences equal intermolecular forces from all sides but the molecule on the surface experiences a net attractive force towards the interior of the liquid. This phenomena is called surface tension.

It is defined as the force acting at right angles to the surface along 1 cm length of the surface. Thus, the units of surface tension are dynes per cm (or Nm^{-1} in SI system).

Due to net downward force at the surface, liquids tend to have minimum number of molecules at their surface. If surface of liquid is increased by pulling a molecule from the bulk, attractive forces will have to be overcome. The energy required to increase the surface area of the liquid by one unit is called surface energy.

Magnitude of surface tension of a liquid depends on attractive forces between molecules. As temperature increases, attractive forces decreases and thus, surface tension also decreases.

Since a sphere has minimum surface area and lowest energy state of a liquid is when surface area is minimum, therefore, mercury drops are spherical in shape. Liquid tends to rise (or fall) in capillary because of surface tension.

(iii) Viscosity

It is a measure of resistance to flow which arises due to internal friction between layers of fluid as they slip past one another while liquid flows.

A force is required to maintain the flow of layers. It is given by: $F = \eta A \frac{du}{dz}$ where A → area of contact $\frac{du}{dz}$ → velocity gradient η → coefficient of viscosity.

SI unit of η is 1 N sm^{-2} and its cgs unit is poise

Viscosity of liquids decreases as temperature increases because at high temperature, molecules have high KE and can overcome intermolecular forces to slip past one another between the layers.

Greater viscosity, more slowly the liquid flows. H-bonding and van der Waals forces are strong enough to cause high viscosity. Glass is an extremely viscous liquid. It is so viscous that many of its properties resemble solids.

CONCEPT MAP

STATES OF MATTER

Intermolecular Interactions Dispersion or London Forces: (act between induced momentary dipoles)
Dipole-Dipole Force:
(act between molecules possessing permanent dipoles)
Dipole-Induced Dipole Forces:
(act between molecules having permanent dipole and molecules lacking it)
Hydrogen Bonding:
(It is a special case of dipole-dipole interactions)

Kinetic Theory of Gases.
All the gases are made up of molecules moving randomly in all the directions.

$$\text{K.E} = \frac{3}{2}\text{RT},\ c = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3P}{d}}$$

$$\text{Average speed} = \sqrt{\frac{8RT}{\pi m}} = 0.9213 \times \text{rms speed}$$

$$\text{Most probable speed} = \sqrt{\frac{2RT}{M}}$$

$\text{MPs} = 816 \times \text{RMS}$

Behaviour of Real Gases
Two faulty assumptions of kinetic theory lead van der Waal to modify ideal gas equation as,

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

Compressibility factor $Z = \frac{PV}{nRT}$

For ideal gas = Z = 1; For real gas $Z \neq 1$

$Z > 1$ the gas shows + ve deviation

$Z < 1$ the gas shows –ve deviation

Gas Laws

Boyle's Law : $V \propto 1/P$

$P_1V_1 = P_2V_2,\ P \propto d$

Charle's Law: $V \propto T$

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

Gay Lussac's Law: $P \propto T$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Avogadro's Law: $V = Kn$

$M = Kd$

Grahm's Law: $\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$

Liquifaction of Gases

$T_C = \frac{8a}{27bR}$ (temperature above which gas can not be liquified)

$P_C = \frac{a}{27b^2}$ (minimum pressure required to liquify a gas at its critical temperature)

$V_C = 3b$ (Volume occupied by one mole of gas at T_C and P_C

Ideal Gas Equation : $PV = nRT$

Value of $R = 8.314\ JK^{-1}mol^{-1}$, 0.0822 atm $K^{-1}\ mol^{-1}$, 8.314 Pa $m^3\ K^{-1}\ mol^{-1}$ and 8.314×10^{-2} bar $LK^{-1}\ mol^{-1}$

Equation of state :

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Dalton's Law $P_{Total} = P_1 + P_2 + P_3 + \ldots$ (at const. T, V)

Liquid State: Intermolecular forces are stronger than gaseous state and have definite volume.
Vapour pressure: Pressure exerted by the vapour in equilibrium with the liquid at that temperature. It increases with increase in temperature.
Surface Tension: Force acting at right angles to the surface along 1 cm length of the surface. Unit dynes per cm or Nm^{-1} SI System. It decreases with increase in temperature.
Viscosity: It is a measure of resistance to flow which arises due to internal friction between layers of fluid as they slip past one another as the liquid flows.

EXERCISE - 1

Conceptual Questions

1. Correct gas equation is :

(a) $\frac{V_1T_2}{P_1}=\frac{V_2T_1}{P_2}$ (b) $\frac{P_1V_1}{P_2V_2}=\frac{T_1}{T_2}$

(c) $\frac{P_1T_2}{V_1}=\frac{P_2V_2}{T_2}$ (d) $\frac{V_1V_2}{T_1T_2}=P_1P_2$

2. A gas of volume of 15 ml at 300 K and 740 mm of Hg. Find the temperature if volume becomes 10 ml at 760 mm pressure of Hg.

(a) 209 K (b) 200 K (c) 205 K (d) 275 K

3. The K.E. for 14 g of nitrogen gas at 127°C is nearly (molecular mass of nitrogen is 28 g/mole) and gas constant is 8.31 J/mol K)

(a) 8.3 kJ (b) 4.15 kJ (c) 2.5 kJ (d) 3.3 kJ

4. At constant temperature, for a given mass of an ideal gas

(a) the ratio of pressure and volume always remains constant.

(b) volume always remains constant.

(c) pressure always remains constant.

(d) the product of pressure and volume always remains constant.

5. The molecular weight of two gases are 100 and 81 respectively. Their rates of diffusions are in the ratio:

(a) 81 : 100 (b) 100 : 81

(c) 10 : 9 (d) 9 : 10

6. Which is not true in case of an ideal gas ?

(a) It cannot be converted into a liquid

(b) There is no interaction between the molecules

(c) All molecules of the gas move with same speed

(d) At a given temperature, PV is proportional to the amount of the gas

7. The correct value of the gas constant 'R' is close to :

(a) 0.082 litre-atmosphere K

(b) 0.082 litre-atmosphere K^{-1} mol^{-1}

(c) 0.082 litre – atmosphere^{-1} K mol^{-1}

(d) 0.082 litre^{-1} atmosphere^{-1} K mol

8. In two separate bulbs containing ideal gases A and B respectively, the density of gas A is twice of that of gas B, while mol wt. of gas A is half of that of gas B at the same temperature, pressure. P_A/P_B will be:

(a) 1 (b) 4

(c) 1/4 (d) 1/2

9. Under what conditions will a pure sample of ideal gas not only exhibit a pressure of 1 atm, but also a concentration of 2 moles per litre?

(a) At STP

(b) When volume is 22.41litre

(c) At 6.1 K

(d) When R has no unit

10. Select one 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 gas is present.

11. 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

12. 600 c.c. of a gas at a pressure of 750 mm of Hg is compressed to 500 c.c. Taking the temperature to remain constant, the increase in pressure, is

(a) 150 mm of Hg (b) 250 mm of Hg

(c) 350 mm of Hg (d) 450 mm of Hg

13. From a heated mixture of nitrogen, oxygen and carbon, two compounds (out of the many obtained) are isolated. The rates of diffusion of the two isolated compounds are almost identical. The two compounds are

(a) N_2O and CO_2 (b) CO and NO

(c) CO_2 and NO_2 (d) N_2O and CO

14. The ratio of the rate of diffusion of helium and methane under identical condition of pressure and temperature will be

(a) 4 (b) 2 (c) 1 (d) 0.5

15. Gas equation $PV = nRT$ is obeyed by

(a) Only isothermal process (b) Only adiabatic process

(c) Both (a) and (b) (d) None of these

16. Densities of two gases are in the ratio 1:2 and their temperatures are in the ratio 2:1 then the ratio of their respective pressures is

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

17. 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

(a) 10.8 cm of Hg (b) 14.9 cm of Hg

(c) 21.8 cm of Hg (d) 38.8 cm of Hg

18. Volume occupied by a gas at one atmospheric pressure and 0°C is V mL. Its volume at 273 K will be

(a) V ml (b) V/2 ml

(c) 2V (d) None of these

19. Van der Waal's equation

$\left[P+\frac{a}{V^2}\right](V-b)=nRT$ is applicable for :

(a) Ideal gas (b) Non-ideal gas

(c) Both (a) and (b) (d) None of these

20. Which one of the following indicates the value of the gas constant R?

(a) 1.987 cal K^{-1} mol^{-1} (b) 8.3 cal K^{-1} mol^{-1}
(c) 0.0821lit K^{-1} mol^{-1} (d) 1.987 Joules K^{-1} mol^{-1}

21. 16 g of oxygen and 3 g of hydrogen are mixed and kept at 760 mm of Hg pressure and 0° C. The total volume occupied by the mixture will be nearly

(a) 22.4 litres (b) 33.6 litres (c) 448 litres (d) 44800 ml

22. If P is pressure and ρ is density of a gas, then P and ρ are related as

(a) $P \propto \rho$ (b) $P \propto (1/\rho)$
(c) $P \propto \rho^2$ (d) $P \propto (1/\rho^2)$

23. Pure hydrogen sulphide is stored in a tank of 100 litre capacity at 20° C and 2 atm pressure. The mass of the gas will be

(a) 34 g (b) 340 g (c) 282.68 g (d) 28.24 g

24. If three unreactive gases having partial pressures P_A, P_B and P_C and their moles are 1, 2 and 3 respectively then their total pressure will be

(a) $P = P_A + P_B + P_C$ (b) $P = \frac{P_A + P_B + P_C}{6}$

(c) $P = \frac{\sqrt{P_A + P_B + P_C}}{3}$ (d) None of these

25. When a substance is dissolved in a solvent, the vapour pressure of solvent decreases. It brings:

(a) a decrease in boiling point of solution
(b) an increase in boiling point of the solution
(c) a decrease in freezing point of the solution
(d) an increase in freezing point of the solution

26. Dalton's law of partial pressure will not apply to which of the following mixture of gases

(a) H_2 and SO_2 (b) H_2 and Cl_2
(c) H_2 and CO_2 (d) CO_2 and Cl_2

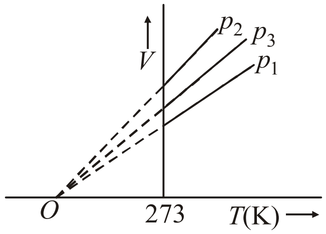
27. A gas diffuse1/5 times as fast as hydrogen. Its molecular weight is

(a) 50 (b) 25 (c) $25\sqrt{2}$ (d) $50\sqrt{2}$

28. Dominance of strong repulsive forces among the molecules of the gas (Z = compressibility factor):

(a) Depends on Z and indicated by $Z = 1$
(b) Depends on Z and indicated by $Z > 1$
(c) Depends on Z and indicated by $Z < 1$
(d) Is independent of Z.

29. The volume-temperature graphs of a given mass of an ideal gas at constant pressure are shown below.



What is the correct order of pressures ?

(a) $p_1 > p_3 > p_2$ (b) $p_1 > p_2 > p_3$
(c) $p_2 > p_3 > p_1$ (d) $p_2 > p_1 > p_3$

30. Equal weights of methane and hydrogen are mixed in an empty container at 25ºC. The fraction of the total pressure exerted by hydrogen is :

(a) $\frac{1}{2}$ (b) $\frac{8}{9}$ (c) $\frac{1}{9}$ (d) $\frac{16}{17}$

31. The rate of diffusion of methane at a given temperature is twice that of a gas X. The molecular weight of X is

(a) 64.0 (b) 32.0 (c) 4.0 (d) 8.0

32. X mL of H_2 gas effuses through a hole in a container in 5 seconds. The time taken for the effusion of the same volume of the gas specified below under identical conditions is :

(a) 10 seconds : He (b) 20 seconds : O_2
(c) 25 seconds : CO (d) 55 seconds : CO_2

33. The inversion temperature T_i (K) of hydrogen is (given van der Waal's constants a and b are 0.244 atm L^2 mol^{-2} and 0.027 L mol^{-1} respectively)

(a) 440 (b) 220 (c) 110 (d) 330

34. The ratio between most probable velocity, mean velocity and r.m.s velocity is :

(a) $\sqrt{2} : \sqrt{8/\pi} : \sqrt{3}$ (b) $\sqrt{2} : \sqrt{3} : \sqrt{8/\pi}$

(c) $1 : 2 : 3$ (d) $1 : \sqrt{2} : \sqrt{3}$

35. Root mean square velocity of a gas molecule is proportional to

(a) $m^{1/2}$ (b) m^0 (c) $m^{-1/2}$ (d) m

36. 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 than at the sea level

37. In a closed flask of 5 litres, 1.0 g of H_2 is heated from 300 to 600 K. Which statement is not correct?

(a) Pressure of the gas increases
(b) The rate of collision increases
(c) The number of moles of gas increases
(d) The energy of gaseous molecules increases

38. Internal energy and pressure of a gas per unit volume are related as :

(a) $P = \frac{2}{3}E$ (b) $P = \frac{3}{2}E$ (c) $P = \frac{1}{2}E$ (d) $P = 2E$

39. Which of the following gases will have highest rate of diffusion?

(a) CO_2 (b) NH_3
(c) O_2 (d) N_2

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

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

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

(a) $\overline{\mathrm{KE}}_{\mathrm{CO}} < \overline{\mathrm{KE}}_{\mathrm{N_2}}$

(b) $\overline{\mathrm{KE}}_{\mathrm{CO}} > \overline{\mathrm{KE}}_{\mathrm{N_2}}$

(c) $\overline{\mathrm{KE}}_{\mathrm{CO}} = \overline{\mathrm{KE}}_{\mathrm{N_2}}$

(d) cannot be predicted unless volumes of the gases are given

42. The inversion temperature for van der Waal's gas is :

(a) $T_i = \dfrac{a}{(Rb)}$ (b) $T_i = \left(\dfrac{2a}{Rb}\right)$

(c) $T_i = 0.5\,T$ (d) $T_i = \dfrac{a}{2(R/b)}$

43. Root mean square velocity of a molecule is 1000 m/s. The average velocity of the molecule is :

(a) 455.55 m/s (b) 675.55 m/s

(c) 921.58 m/s (d) 1221.58 m/s

44. According to the kinetic theory of gases, in an ideal gas, between two successive collisions a gas molecule travels

(a) in a wavy path

(b) in a straight line path

(c) with an accelerated velocity

(d) in a circular path

45. As the temperature is raised from 20ºC to 40ºC, the average kinetic energy of neon atoms changes by a factor of which of the following ?

(a) $^{313}\!/_{293}$ (b) $\sqrt{(313/293)}$

(c) $^{1}\!/_{2}$ (d) 2

46. When universal gas constant (R) is divided by Avogadro no. (N_0), then the value of R / N_0 is equivalent to

(a) Rydberg's constant

(b) Boltzmann's constant

(c) Planck's constant

(d) Van der waal's constant

47. The ratio of root mean square velocity to average velocity of a gas molecule at a particular temperature is

(a) 1.086 : 1 (b) 1 : 1.086 (c) 2 : 1.086 (d) 1.086 : 2

48. The rms speed at NTP of a gas can be calculated from the expression :

(a) $\sqrt{3P/d}$ (b) $\sqrt{3PV/M}$

(c) $\sqrt{3RT/M}$ (d) All of these

49. Ratio of molecular weights of A and B is $\dfrac{4}{25}$ then ratio of rates of diffusion will be :

(a) 5 : 1 (b) 5 : 2

(c) 25 : 3 (d) 25 : 4

50. When the temperature of an ideal gas is increased from 27ºC to 927ºC, the kinetic energy will be :

(a) same (b) eight times

(c) four times (d) twice

51. The ratio between the root mean square speed of H_2 at 50 K and that of O_2 at 800 K is,

(a) 4 (b) 2

(c) 1 (d) 1/4

52. The root mean square velocity of an ideal gas at constant pressure varies with density (d) as

(a) d^2 (b) d (c) $\sqrt{d}$ (d) $1/\sqrt{d}$

53. The root mean square velocity of one mole of a monoatomic gas having molar mass M is $u_{\text{r.m.s.}}$. The relation between the average kinetic energy (E) of the gas and $u_{\text{r.m.s.}}$ is

(a) $u_{r.m.s.} = \sqrt{\dfrac{3E}{2M}}$ (b) $u_{r.m.s.} = \sqrt{\dfrac{2E}{3M}}$

(c) $u_{r.m.s.} = \sqrt{\dfrac{2E}{M}}$ (d) $u_{r.m.s.} = \sqrt{\dfrac{E}{3M}}$

54. The total pressure of a mixture of two gases is :

(a) The sum of the partial pressures

(b) The difference between the partial pressures

(c) The product of the partial pressures

(d) The ratio of the partial pressures.

55. An ideal gas can't be liquefied because

(a) its critical temperature is always above 0°C

(b) Its molecules are relatively smaller in size

(c) it solidifies before becoming a liquid

(d) forces between its molecules are negligible

56. When is deviation more in the behaviour of a gas from the ideal gas equation $PV = nRT$?

(a) At high temperature and low pressure

(b) At low temperature and high pressure

(c) At high temperature and high pressure

(d) At low temperature and low pressure

57. Some moles of O_2 diffuse through a small opening in 18 s. Same number of moles of an unknown gas diffuse through the same opening in 45 s. molecular weight of the unknown gas is :

(a) $32 \times \dfrac{45^2}{18^2}$ (b) $32 \times \dfrac{18^2}{45^2}$

(c) $32 \times \dfrac{45}{18}$ (d) $32^2 \times \dfrac{18}{45}$

58. At which one of the following temperature-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.

59. In van der Waal's equation of state of the gas law, the constant 'b' is a measure of

(a) volume occupied by the molecules

(b) intermolecular attraction

(c) intermolecular repulsions

(d) intermolecular collisions per unit volume

60. At what centigrade temperature will the volume of gas becomes 2x, if the volume of this gas is ‘x’ at 0° C at constant pressure?

(a) 0°C (b) 237°C
(c) 273°C (d) 546°C

61. Value of universal gas constant (R) depends upon

(a) Number of moles of gas
(b) Volume of gas
(c) Temperature of gas
(d) None of these

62. The temperature at which a real gas obeys the ideal gas laws over a wide range of pressure is

(a) critical temperature (b) Boyle temperature
(c) inversion temperature (d) reduced temperature

63. In van der Waal’s equation of state for a non-ideal gas, the term that accounts for intermolecular forces is

(a) $(V-b)$ (b) RT
(c) $\left(P+\frac{a}{V^2}\right)$ (d) $(RT)^{-1}$

64. The compressibility factor for an ideal gas is

(a) 1.5 (b) 1.0 (c) 2.0 (d) ∞

65. Graph between P and V at constant temperature is

(a) straight
(b) curved increasing
(c) straight line with slope
(d) none of these

66. A gas described by van der Waal’s equation

(i) behaves similar to an ideal gas in the limit of large molar volume
(ii) behaves similar to an ideal gas in the limit of large pressure
(iii) is characterised by van der Waal's coefficients that are dependent on the identity of the gas but are independent of the temperature
(iv) has the pressure that is lower than the pressure exerted by the same gas behaving ideally

(a) (i) and (ii) (b) (i) and (iii)
(c) (i), (ii) and (iii) (d) (ii) and (iv)

67. Rate of diffusion of NH_3 is twice that of X. What is the molecular mass of X?

(a) 68 (b) 48
(c) 12 (d) 8

68. Gas deviates from ideal gas nature because molecules

(a) are colouress
(b) attaract each other
(c) contain covalent bond
(d) show Brownian movement.

69. The van der Waal’s constant ‘a’ for four gases P, Q, R and S are 4.17, 3.59, 6.71 and 3.8 atm L^2 mol^{-2} respectively. Therefore, the ascending order of their liquefaction is

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

70. At low pressure the van der Waal’s equation is reduced to

(a) $Z=\frac{pV_m}{RT}=1-\frac{ap}{RT}$ (b) $Z=\frac{pV_m}{RT}=1+\frac{b}{RT}p$
(c) $pV_m=RT$ (d) $Z=\frac{pV_m}{RT}=1-\frac{a}{RT}$

71. Same mass of CH_4 and H_2 is taken in container, The partial pressure caused by H_2 is

(a) $\frac{8}{9}$ (b) $\frac{1}{9}$
(c) $\frac{1}{2}$ (d) 1

72. In which molecule the van der Waal’s force is likely to be the most important in determining the m.pt. and b.pt.?

(a) H_2S (b) Br_2
(c) HCl (d) CO

73. Soap helps in cleaning clothes, because

(a) chemical of soap change
(b) it increases the surface tension of the solution
(c) it absorbs the dirt
(d) it lowers the surface tension of the solution

74. The r.m.s Velocity of hydrogen is $\sqrt{7}$ times the r.m.s velocity of nitrogen. If T is the temperature of the gas , than

(a) $T(H_2) = T(N_2)$ (b) $T(H_2) > T(N_2)$
(c) $T(H_2) < T(N_2)$ (d) $T(H_2) = \sqrt{7}T(N_2)$

75. If temperature increases, the surface tension of a liquid

(a) increases
(b) decreases
(c) remains the same
(d) increases then decreases

EXERCISE - 2
Applied Questions

1. The molecular velocities of two gases at the same temperature are u_1 and u_2. Their masses are m_1 and m_2 respectively . Which of the following expression is correct.

(a) $m_1/u_1^2 = m_2/u_2^2$ (b) $m_1u_1 = m_2u_2$
(c) $m_1/u_1 = m_2/u_2$ (d) $m_1u_1^2 = m_2u_2^2$

2. Reducing the pressure from 1.0 atm to 0.5 atm would change the number of molecules in one mole of ammonia to

(a) 25% of its initial value (b) 50% of its initial value
(c) 75% of its initial value (d) None of the above

3. 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 mole litre^{-1} ? ($R = 0.082$ litre atm mol^{-1}deg^{-1})

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

4. The average kinetic energy of 28 g CO at, 300 K is E kcal. The average kinetic energy of 2 g H_2 at the same temperature would be..... k cal.
(a) E (b) 14E
(c) 1/14E (c) 28E

5. Cyclopropane and oxygen at partial pressures 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 (nC_3H_6/nO_2)?
(a) $\frac{170\times42}{570\times32} = 0.39$ (b) $\frac{170}{42}\Big/\left(\frac{170}{42}+\frac{570}{32}\right) \approx 0.19$
(c) $\frac{170}{740} = 0.23$ (d) $\frac{170}{570} = 0.30$

6. 14 g of N_2 and 36 g of ozone are at the same pressure and temperature . Their volumes will be related as
(a) $2V_{N_2} = 3V_{O_3}$ (b) $3V_{N_2} = 2V_{O_3}$
(c) $3V_{N_2} = 4V_{O_3}$ (d) $4V_{N_2} = 3V_{O_3}$

7. If 500 ml of gas A at 400 torr and 666.6 ml of B at 600 torr are placed in a 3 litre flask, the pressure of the system will be
(a) 200 torr (b) 100 torr (c) 550 torr (d) 366 torr

8. The beans are cooked earlier in pressure cooker, because
(a) boiling point increases with increasing pressure
(b) boiling point decreases with increasing pressure
(c) internal energy is not lost while cooking in pressure cooker
(d) extra pressure of pressure cooker, softens the beans

9. When an ideal gas undergoes unrestrained expansion, no cooling occurs because the molecules
(a) are above the inversion temperature
(b) exert no attractive forces on each other
(c) do work equal to loss in kinetic energy
(d) collide without loss of energy

10. The reciprocal of compressibility factor of a real gas in the critical state is
(a) $\frac{3}{8}$ (b) $\frac{3}{4}$ (c) $\frac{8}{3}$ (d) $\frac{1}{3}$

11. Use of hot air balloons in sports and meteorological observations is an application of
(a) Boyle's law (b) Charle's law
(c) Kelvin's law (d) Gay-Lussac's law

12. Air at sea level is dense. This is a practical application of
(a) Boyle's law (b) Charle's law
(c) Kelvin's law (d) Brown's law

13. Consider a real gas placed in a container. If the intermolecular attractions are supposed to disappear suddenly which of the following would happen?
(a) The pressure decreases
(b) The pressure increases
(c) The pressure remains unchanged
(d) The gas collapses

14. Calculate the total pressure in a 10.0 L cylinder which contains 0.4g helium, 1.6 g oxygen and 1.4 g nitrogen at 27°C.
(a) 0.492 atm (b) 49.2 atm
(c) 4.52 atm (d) 0.0492 atm

15. When helium is allowed to expand into vacuum, heating effect is observed. Its reason is that
(a) helium is an ideal gas
(b) helium is an inert gas
(c) the inversion temperature of helium is very low
(d) the boiling point of helium is the lowest amongst the elements

16. Diffusion of helium gas is four times faster than
(a) CO_2 (b) SO_2 (c) NO_2 (d) O_2

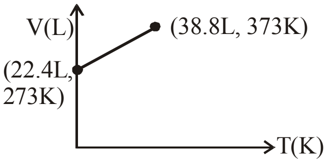
17. A bottle of dry ammonia and a bottle of dry hydrogen chloride connected through a long tube are opened simultaneously at both ends the white ammonium chloride ring first formed will be
(a) at the centre of the tube.
(b) near the hydrogen chloride bottle.
(c) near the ammonia bottle.
(d) throughout the length of the tube.

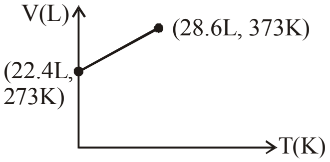
18. The ratio $\frac{a}{b}$ (a and b being the van der Waal's constants of real gases) has the dimensions of
(a) atm mol^{-1} (b) L mol^{-1}
(c) atm L mol^{-1} (d) atm L mol^{-2}

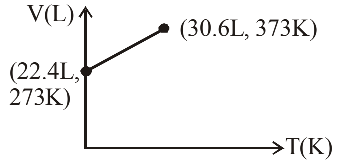
19. At 100°C and 1 atm, if the density of liquid water is 1.0 g cm^{-3} and that of water vapour is 0.0006 g cm^{-3}, then the volume occupied by water molecules in 1 litre of steam at that temperature is
(a) 6 cm^3 (b) 60 cm^3 (c) 0.6 cm^3 (d) 0.06 cm^3

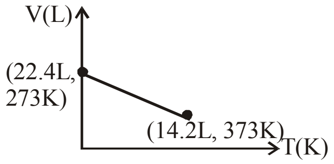
20. It V is the volume of one molecule of gas under given conditions, the van der Waal's constant b is
(a) $4V$ (b) $\frac{4V}{N_0}$
(c) $\frac{N_0}{4V}$ (d) $4VN_0$

21. Which of the following volume (V) - temperature (T) plots represents the behaviour of one mole of an ideal gas at one atmospheric pressure ?

(a) 

(b) 

(c) 

(d) 

22. If for two gases of molecular masses M_A and M_B at temperatures T_A and T_B, $T_A M_B = T_B M_A$, then which of the following properties has the same magnitude for both the gases

(a) Pressure (b) Density
(c) Molar K.E. (d) rms velocity

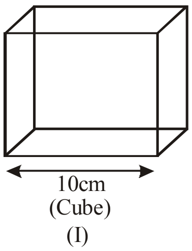
23. Positive deviation from ideal behaviour takes place because of

(a) molecular interaction between atoms and $PV/nRT > 1$
(b) molecular interaction between atoms and $PV/nRT < 1$
(c) finite size of atoms and $PV/nRT > 1$
(d) finite size of atoms and $PV/nRT < 1$

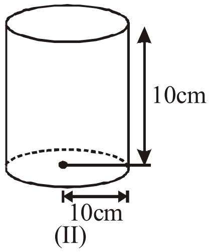
24. At what temperature the average speed of helium molecule will be the same as that of oxygen molecule at 527°C

(a) 100 K (b) 200 K (c) 273 K (d) 400 K

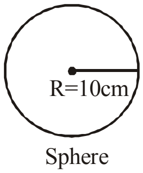
25. There are three closed containers in which equal amount of the gas are filled.



(Cube)
(I)



(II)



Sphere
(hollow)
(III)

If all the containers are placed at the same temperatures, then find the incorrect options –

(a) Pressure of the gas is minimum in (III) container
(b) Pressure of the gas is equal in I and II container
(c) Pressure of the gas is maximum in (I)
(d) The ratio of pressure in II and III container is 4 : 3

26. The compressibility factor $Z = \dfrac{PV}{RT}$ for 1 mol of a real gas is greater than unity at a pressure of 1 atm and 273 .15 K. The molar volume of the gas at STP will be

(a) less than 22.4 L (b) greater than 22.4 L
(c) equal to 22.4 L (d) none of these

27. The van der Waals's constants for gases *A, B* and *C* are as follows

Gas	***a*** **(L^2 atm mol^{-2})**	***b*** **(L mol^{-1})**
A	0.024	0.027
B	4.17	0.037
C	3.59	0.043

Based upon the above data, which of the following statements is correct?

(i) The gas ***B*** has the highest critical temperature
(ii) The gas ***A*** has minimum departure from the ideal behavior
(iii) The gas ***C*** has largest molecular volume

(a) (i) (b) (i) and (ii)
(c) (ii) and (iii) (d) all the three

28. The pressure of 11gm of a gas which is placed in a 4 litres container at 127°C is 2 atm, then the gas would be
(Take : R = 0.08 litre atm K^{-1} mol^{-1})

(a) N_2O (b) CO_2
(c) NO_2 (d) Both (a) and (b) possible

29. A mixture of two gases A and B in the mole ratio 2 : 3 is kept in a 2 litre vessel. A second 3L vessel has the same two gases in the mole ratio 3 : 5. Both gas mixtures have the same temperature and same total pressure. They are allowed to intermix and the final temperature and the total pressure are the same as the initial values, the final volume being 5 litres. Given that the molar masses are M_A and M_B. What is the mean molar mass of the final mixture?

(a) $\dfrac{5M_A + 8M_B}{13}$ (b) $\dfrac{77M_A + 123M_B}{200}$

(c) $\dfrac{123M_A + 77M_B}{250}$ (d) $\dfrac{123M_A + 77M_B}{150}$

30. Two flasks *A* and *B* of equal volumes maintained at temperatures 300K and 600K contain equal mass of H_2 and CH_4 respectively. The ratio of total translational kinetic energy of gas in flask *A* to that in flask *B* is

(a) unity (b) 2 (c) 4 (c) 0.25

31. By what factor does the average velocity of a gaseous molecule increase when the temperature (in Kelvin) is doubled ?

(a) 2.0 (b) 2.8 (c) 4.0 (d) 1.4

32. A bubble of air is underwater at temperature 15°C and the pressure 1.5 bar. If the bubble rises to the surface where the temperature is 25°C and the pressure is 1.0 bar, what will happen to the volume of the bubble ?

(a) Volume will become greater by a factor of 1.6.
(b) Volume will become greater by a factor of 1.1.
(c) Volume will become smaller by a factor of 0.70.
(d) Volume will become greater by a factor of 2.5.

33. 50 mL of each gas A and of gas B takes 150 and 200 seconds respectively for effusing through a pin hole under the similar condition. If molecular mass of gas B is 36, the molecular mass of gas A will be :

(a) 96 (b) 128 (c) 20.25 (d) 64

34. When *r*, *P* and *M* represent rate of diffusion, pressure and molecular mass, respectively, then the ratio of the rates of diffusion (r_A/r_B) of two gases *A* and *B*, is given as :

(a) $(P_A/P_B)(M_B/M_A)^{1/2}$ (b) $(P_A/P_B)^{1/2}(M_B/M_A)$

(c) $(P_A/P_B)(M_A/M_B)^{1/2}$ (d) $(P_A/P_B)^{1/2}(M_A/M_B)$

35. The compressibility factor for a real gas at high pressure is :

(a) $1 + \dfrac{RT}{pb}$ (b) 1

(c) $1 + \dfrac{pb}{RT}$ (d) $1 - \dfrac{pb}{RT}$

36. At constant volume and temperature conditions, the rate of diffusion D_A and D_B of gases A and B having densities ρ_A and ρ_B are related by the expression.

(a) $D_A = \left[D_B \dfrac{\rho_A}{\rho_B}\right]^{1/2}$ (b) $D_A = \left[D_B \dfrac{\rho_B}{\rho_A}\right]^{1/2}$

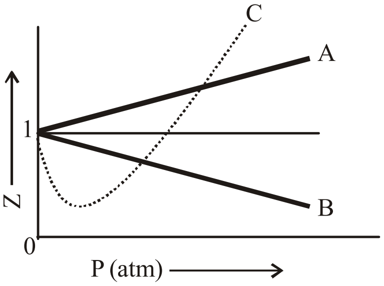
(c) $D_A = D_B\left(\dfrac{\rho_A}{\rho_B}\right)^{1/2}$ (d) $D_A = D_B\left(\dfrac{\rho_B}{\rho_A}\right)^{1/2}$

37. The compression factor (compressibility factor) for 1 mole of a van der Waal's gas at 0°C and 100 atm pressure if found to be 0.5. Assuming that the volume of gas molecules is negligible, calculate the van der Waal's constant 'a'.

(a) 0.253 $L^2mol^{-2}atm$ (b) 0.53 $L^2mol^{-2}atm$

(c) 1.853 $L^2mol^{-2}atm$ (d) 1.253 $L^2mol^{-2}atm$

38. The given graph represents the variation of Z (compressibility factor $= \dfrac{PV}{nRT}$) versus P, for three real gases A, B and C. Identify the only incorrect statement



(a) For the gas A, a = 0 and its dependence on P is linear at all pressure.

(b) For the gas B, b = 0 and its dependence on P is linear at all pressure

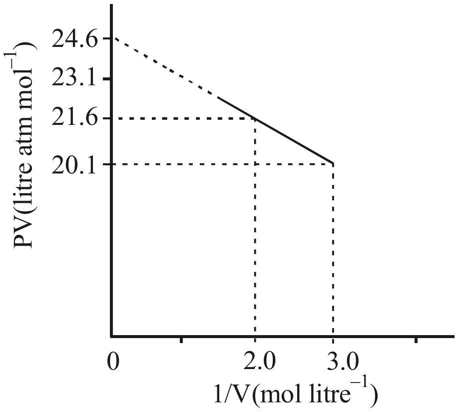
(c) For the gas C, which is typical real gas for which neither a nor b = 0. By knowing the minima and the point of intersection, with Z = 1, a and b can be calculated

(d) At high pressure, the slope is positive for all real gases

39. The term that corrects for the attractive forces present in a real gas in the van der Waals equation is

(a) nb (b) $\dfrac{an^2}{V^2}$ (c) $-\dfrac{an^2}{V^2}$ (d) $-nb$

40. For one mole of a van der Waals gas when $b = 0$ and T = 300 K, the PV vs, 1/V plot is shown below. The value of the van der Waals constant a (atm. liter^2 mol^{-2}) is :



(a) 1.0 (b) 4.5 (c) 1.5 (d) 3.0

41. For gaseous state, if most probable speed is denoted by C*, average speed by $\overline{C}$ and mean square speed by C, then for a large number of molecules the ratios of these speeds are :

(a) $C^* : \overline{C} : C = 1.225 : 1.128 : 1$

(b) $C^* : \overline{C} : C = 1.128 : 1.225 : 1$

(c) $C^* : \overline{C} : C = 1 : 1.128 : 1.225$

(d) $C^* : \overline{C} : C = 1 : 1.225 : 1.128$

42. Small droplets of a liquid are usually more spherical in shape than larger drops of the same liquid because

(a) force of surface tension is equal and opposite to the force of gravity

(b) force of surface tension predominates the force of gravity

(c) force of gravity predominates the force of surface tension

(d) force of gravity and force of surface tension act in the same direction and are equal

43. A weather ballon filled with hydrogen at 1 atm and 27°C has volume equal to 12000 litres. On ascending it reaches a place where the temperature is –23°C and pressure is 0.5 atm. The volume of the balloon is

(a) 24000 litres (b) 20000 litres

(c) 10000 litres (d) 12000 litres

44. The pressure exerted by 6.0g of methane gas in a 0.03 m^3 vessel at 129°C is (Atomic masses : C = 12.01, H = 1.01 and R = 8.314 Kpa dm^3K^{-1} mol^{-1})

(a) 31684 Pa (b) 215216 Pa

(c) 13409 Pa (d) 41777 Pa

45. Two gases A and B having the same volume diffuse through a porous partition in 20 and 10 seconds respectively. The molecular mass of A is 49 u. Molecular mass of B will be :

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

46. A gaseous mixture was prepared by taking equal mole of CO and N_2. If the total pressure of the mixture was found 1 atmosphere, the partial pressure of the nitrogen (N_2) in the mixture is :

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

47. Which one of the following statements is NOT true about the effect of an increase in temperature on the distribution of molecular speeds in a gas?

(a) The area under the distribution curve remains the same as under the lower temperature

(b) The distribution becomes broader

(c) The fraction of the molecules with the most probable speed increases

(d) The most probable speed increases

DIRECTIONS for Qs. 48 to 50 : These are Assertion-Reason type questions. Each of these question contains two statements: Statement-1 (Assertion) and Statement-2 (Reason). Answer these questions from the following four options.

(a) Statement-1 is true, Statement-2 is true, Statement-2 is a correct explanation for Statement -1

(b) Statement-1 is True, Statement-2 is True ; Statement-2 is NOT a correct explanation for Statement-1

(c) Statement-1 is True, Statement-2 is False

(d) Statement-1 is False, Statement-2 is True

48. **Statement-1 :** Jet aeroplane flying at high altitude need pressurization of the cabin.

Statement-2 : Oxygen is not present at higher altitude.

49. **Statement-1 :** 1 mol of H_2 and O_2 each occupy 22.4 L of volume at 0°C and 1 bar pressure.

Statement-2 : Molar volume for all gases at the same temperature and pressure has the same volume.

50. **Statement-1 :** Greater the value of van der Waal's constant '*a*' greater is the liquefaction of gas.

Statement-2 : '*a*' indirectly measures the magnitude of attractive forces between the molecules.

EXERCISE - 3

Exemplar & Past Years NEET/AIPMT Questions

Exemplar Questions

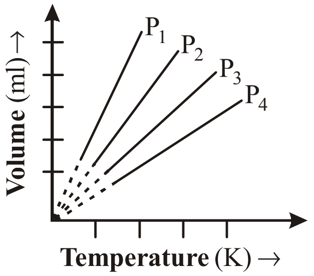
1. A person living in shimla observed that cooking food without using pressure cooker takes more time. The reason for this observation is that at high altitude

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

2. Which of the following property of water can be used to explain the spherical shape of rain droplets?

(a) Viscosity
(b) Surface tension
(c) Critical phenomena
(d) Pressure

3. 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 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) $P_1 < P_2 = P_3 < P_4$

4. The interaction energy of London force is inversely proportional to sixth power of the distance between two interacting particles but their magnitude depends upon

(a) charge of interacting particles
(b) mass of interacting particles
(c) polarisability of interacting particles
(d) strength of permanent dipoles in the particles

5. Dipole-dipole forces act between the molecules possessing permanent dipole. Ends of dipoles possess 'partial charges'. The partial charge is

(a) more than unit electronic charge
(b) equal to unit electronic charge
(c) less than unit electronic charge
(d) double the unit electronic charge

6. The pressure of a 1 : 4 mixture of dihydrogen and dioxygen enclosed in a vessel is one atmosphere. What would be the partial pressure of dioxygen?

(a) 0.8×10^5 atm
(b) $0.008\ Nm^{-2}$
(c) $8 \times 10^4\ Nm^{-2}$
(d) 0.25 atm

7. As the temperature increases average kinetic energy of molecules increases. What would be the effect of increase of temperature on pressure provided the volume is constant?

(a) Increases
(b) Decreases
(c) Remains same
(d) Becomes half

8. 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

9. What is SI unit of viscosity coefficient (η)?

(a) Pascal
(b) Nsm^{-2}
(c) $km^{-2}s$
(d) Nm^{-2}

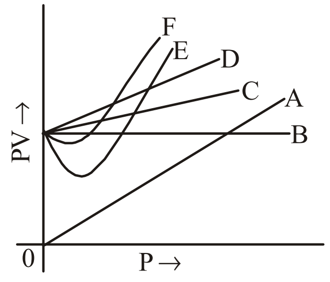
10. Atmospheric pressures recorded in different cities are as follows

Cities	Shimla	Bengaluru	Delhi	Mumbai
p in N/m^2	1.01×10^5	1.2×10^5	1.02×10^5	1.21×10^5

Consider the above data and mark the place at which liquid will boil first.

(a) Shimla
(b) Bengaluru
(c) Delhi
(d) Mumbai

11. Which curve in figure represents the curve of ideal gas?



(a) Only B
(b) C and D
(c) E and F
(d) A and B

12. Increase in kinetic energy can overcome intermolecular forces of attraction. How will the viscosity of liquid be affected by the increase in temperature?

(a) Increase
(b) No effect
(c) Decrease
(d) No regular pattern will be followed

13. How does the surface tension of a liquid vary with increase in temperature?

(a) Remains same
(b) Decreases
(c) Increases
(d) No regular pattern is followed

NEET/AIPMT (2013-2017) Questions

14. Maximum deviation from ideal gas is expected from : ***[2013]***

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

15. Dipole-induced dipole interactions are present in which of the following pairs : ***[2013]***

(a) Cl_2 and CCl_4
(b) HCl and He atoms
(c) SiF_4 and He atoms
(d) H_2O and alcohol

16. What is the density of N_2 gas at 227°C and 5.00 atm pressure? ($R = 0.0821$ atm K^{-1} mol^{-1}) ***[NEET Kar. 2013]***

(a) 0.29 g/ml (b) 1.40 g/ml
(c) 2.81 g/ml (d) 3.41 g/ml

17. Equal masses of H_2,O_2 and methane have been taken in a container of volume V at temperature 27°C in identical conditions. The ratio of the volumes of gases $H_2 : O_2$: methane would be : ***[2014]***

(a) 8 : 16 : 1 (b) 16 : 8 : 1
(c) 16 : 1 : 2 (d) 8 : 1 : 2

18. A gas such as carbon monoxide would be most likely to obey the ideal gas law at : ***[2015 RS]***

(a) high temperatures and low pressures.
(b) low temperatures and high pressures.
(c) high temperatures and low pressures.
(d) low temperatures and low pressures.

19. Equal moles of hydrogen and oxygen gases are placed in a 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 ? ***[2016]***

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

Hints & Solutions

EXERCISE - 1

1. (b) $\frac{PV}{T}$ = constant or $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$$\Rightarrow \frac{P_1V_1}{P_2V_2} = \frac{T_1}{T_2}$$

2. (c) Given: $P_1 = 740$ mm of Hg; $V_1 = 15$ mL; $T_1 = 300$ K and $P_2 = 760$ mm of Hg; $V_2 = 10$ mL; $T_2 = ?$
Using gas equation,

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\Rightarrow \frac{740 \times 15}{300} = \frac{760 \times 10}{T_2}$$

$$\Rightarrow T_2 = \frac{760 \times 10 \times 300}{740 \times 15} = 205.405 \approx 205\text{ K}$$

3. (c) K. E of n moles of N_2 gas $= \frac{3}{2}nRT$

Here $n = \frac{14}{28} = \frac{1}{2}$ moles

R = 8.31 J/mol/K
T = 127°C = 400K

$$\therefore \text{K E} = \frac{3}{2} \times \frac{1}{2} \times 8.31 \times 400\text{J}$$

$$= 2493.0\text{ J} = 2.493\text{ kJ} \approx 2.5\text{ kJ}$$

4. (d) According to Boyle's law at constant temperature,

$V \propto \frac{1}{P}$ or PV = constant

5. (d) According to Graham's law of diffusion,

$$r \propto \sqrt{\frac{1}{M}}$$

where r is rate of diffusion of gas and M is its molcular weight

So, $\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}} \Rightarrow \frac{r_1}{r_2} = \sqrt{\frac{81}{100}} = \frac{9}{10}$

$\Rightarrow r_1 : r_2 = 9 : 10$

6. (c) Molecules in an ideal gas move with different speeds.

7. (b) $R = 0.082$ litre atm K^{-1} $mole^{-1}$.

8. (b) For an ideal gas, PV = nRT

$$\Rightarrow P = \frac{n}{V}RT = \frac{mRT}{MV} = \frac{dRT}{M} \left(\frac{m}{V} = \text{density(say d)}\right)$$

$$\text{So, } \frac{P_A}{P_B} = \frac{d_A M_B}{d_B M_A} = \frac{(2d_B) \times M_B}{d_B(M_B/2)} = 4$$

9. (c) Given P = 1atm, n = 2 mole, V = 1L
Let at T K the given sample will exhibit pressure of 1 atm and a concentration of 2M.
For an ideal gas, PV = nRT
$\Rightarrow$ (1 atm) (1 L)
= (2 mol) (0.0821 mol^{-1} L atm K^{-1})T

$$\Rightarrow T = \frac{1}{2(0.0821)}\text{K} = 6.0901\text{ K} \approx 6.1\text{ K}$$

So, T = 6.1 K is the required condition.

10. (c) In the equation $PV = nRT$, n moles of the gas have volume V.

11. (b) Given initial volume (V_1) = 500 ml ; Initial temperature (T_1) = 27ºC = 300 K and final temperature (T_2) = –5ºC = 268 K.

From Charle's law : $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ or $\frac{500}{300} = \frac{V_2}{268}$

Where V_2 = New volume of gas

$$V_2 = \frac{500}{300} \times 268 = 446.66\text{ml.}$$

12. (a) Given initial volume (V_1) = 600 c.c.; Initial pressure (P_1) = 750 mm of Hg and final volume (V_2) = 500 c.c. according to Boyle's law,
$P_1V_1 = P_2V_2$

or $750 \times 600 = P_2 \times 500$

or $P_2 = \frac{750 \times 600}{500} = 900$ mm of Hg
Therefore increase of pressure = (900 – 750) = 150 mm of Hg

13. (a) Rate of diffusion depend upon molecular weight

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}} \Rightarrow r_1 = r_2 \text{ if } M_1 = M_2$$

Hence, compounds are N_2O and CO_2 as both have same molar mass.

14. (b) Use Grahams' law of diffusion

$$\frac{r_{He}}{r_{CH_4}} = \sqrt{\frac{M_{CH_4}}{M_{He}}} = \sqrt{\frac{16}{4}} = 2$$

15. (c) PV = nRT is for an ideal gas which follows both isothermal and adiabatic processes.

16. (a) $P \propto d$ and T, $\frac{P_1}{P_2} = \frac{d_1T_1}{d_2T_2} = \frac{1}{2} \times \frac{2}{1} \Rightarrow P_1 : P_2 = 1:1$

17. (a) The gas inside the cylinder of 5L capacity has pressure 76 cm of Hg (NTP)
The new volume for the gas = (30 + 5)L = 35 L.
According to Boyle's law: $P_1V_1 = P_2V_2$
$76 \times 5 = P_2 \times 35$

$$\therefore P_2 = \frac{76 \times 5}{35} = 10.85 \approx 10.8\text{cm of Hg}$$

18. (a) 0°C is equivalent to 273° K i.e., conditions are same so volume will be V ml.

19. (b) Vandar Waal's equation is applicable for real (non-ideal) gases.

20. (a) $8.31\ \text{J.K}^{-1}\text{mol}^{-1}$

1 cal = 4.2 J.

$$\therefore \frac{8.31}{4.2}\text{cal.K}^{-1}\text{mol}^{-1} = 1.987\text{calK}^{-1}\text{mol}^{-1}$$

21. (d) n of $O_2 = \frac{16}{32} = \frac{1}{2}$

n of $H_2 = \frac{3}{2}$

Total no. of moles $= \frac{3}{2} + \frac{1}{2} = 2$

$$V = \frac{nRT}{P} = \frac{2 \times .082 \times 273}{1} = 44.8 lit = 44800 \text{ ml}$$

22. (a) $\text{P} \propto \frac{1}{\text{V}}$ and $\frac{\text{m}}{\text{V}} = \rho$; $\frac{1}{\text{V}} = \frac{\rho}{\text{m}}$

So, $\text{P} \propto \frac{\rho}{\text{m}}$ i.e. Pressure $\propto \rho$

23. (c) $n = \frac{PV}{RT} = \frac{m}{M}$

$$m = \frac{MPV}{RT} = \frac{34 \times 2 \times 100}{0.082 \times 293} = 282.68\text{gm}$$

24. (a)

25. (a) When vapour pressure decreases, boiling point increases correspondingly.

26. (b) Because H_2 & Cl_2 gases may react with each other to produce HCl gas hence Dalton's law is not applicable.

27. (a) $r_g = \frac{1}{5}.r_{H_2}$

$$\frac{M_g}{M_{H_2}} = \left[\frac{r_{H_2}}{r_g}\right]^2 = (5)^2 = 25; M_g = 2 \times 25 = 50$$

28. (b) Repulsive force will decrease the compressibility factor i.e. so, value of Z > 1as

$$\text{Z} = \frac{\text{PV}}{\text{RT}}$$

Due to repulsion value of PV will be greater than RT so Z > 1.

29. (a) From the graph we can see the correct order of pressures $p_1 > p_3 > p_2$

30. (b) Pressure exerted by hydrogen will be proportional to its mole fraction.

$$\text{Mole fraction of } H_2 = \frac{\frac{w}{2}}{\frac{w}{16} + \frac{w}{2}} = \frac{8}{9}$$

31. (a) $\frac{r_{CH_4}}{r_x} = 2 = \sqrt{\frac{M_x}{M_{CH_4}}} = \sqrt{\frac{M_x}{16}}$, or $M_x = 64$

32. (b) Under identical conditions, $\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$

As rate of diffusion is also inversely proportional to time, we will have, $\frac{t_2}{t_1} = \sqrt{\frac{M_2}{M_1}}$

(a) Thus, For He, $t_2 = \sqrt{\frac{4}{2}}(5s) = 5\sqrt{2}s \neq 10s$;

(b) For O_2, $t_2 = \sqrt{\frac{32}{2}}(5s) = 20s$

(c) For CO, $t_2 = \sqrt{\frac{28}{2}}(5s) \neq 25s$;

(d) For CO_2, $t_2 = \sqrt{\frac{44}{2}}(5s) \neq 55s$

33. (b) Gases become cooler during Joule Thomson's expansion only if they are below a certain temperature known as inversion temperature (T_i). The inversion temperature is characteristic of each gas and is given by

$T_i = \frac{2a}{bR}$, where R is gas constant

Given $a = 0.244$ atm $\text{L}^2\ \text{mol}^{-2}$

$b = 0.027\ \text{L mol}^{-1}$

$R = 0.0821$ L atm $\text{deg}^{-1}\ \text{mol}^{-1}$

$$\therefore T_i = \frac{2 \times 0.244}{0.027 \times 0.0821} = 220 \text{ K}$$

34. (a) Most probable velocity $= \sqrt{\frac{2RT}{M}}$

Average velocity $= \sqrt{\frac{8RT}{\pi M}}$

Root mean square velocity $= \sqrt{\frac{3RT}{M}}$

∴ Most probable velocity : Average velocity : Root mean square velocity

$$= \sqrt{\frac{2RT}{M}} : \sqrt{\frac{8RT}{\pi M}} : \sqrt{\frac{3RT}{M}} = \sqrt{2} : \sqrt{\frac{8}{\pi}} : \sqrt{3}$$

35. (c) According to kinetic gas equation

$PV = \frac{1}{3}mNu^2$, u = root mean square velocity

$$\Rightarrow u^2 = \frac{3PV}{mN} \text{ or } u \propto \frac{1}{\sqrt{m}} \text{ i.e } u \propto m^{-\frac{1}{2}}$$

36. (d) A liquid boils at lower temperature at the top of a mountain.

37. (c) Here volume is constant. Again the mass of H_2 is fixed so the number of moles of the gas do not change. As temperature increases the pressure also increases. The rate of collision among the gas molecules and their energy also increases.

38. (a) $PV = \frac{1}{3}mnu^2 = \frac{1}{3}Mu^2$

$$= \frac{2}{3}.\frac{1}{2}Mu^2 = \frac{2}{3}E \text{ or } P = \frac{2}{3}E \text{ per unit vol.}$$

39. (b) Rate of diffusion

$$\propto \frac{1}{\sqrt{\text{density}}} \propto \frac{1}{\sqrt{\text{molality}}}.$$

NH_3 has the highest rate of diffusion as it is the lightest molecule.

40. (d) $u\,\alpha\sqrt{T}$ or $u_1/u_2=\sqrt{T_1/T_2}$

$$=\sqrt{\frac{27+273}{927+273}}=\sqrt{\frac{300}{1200}}=\frac{1}{2}$$

$u_2=2u_1$

41. (c) Average molar kinetic energy $=\frac{3}{2}kT$

As temeprature is same hence average kinetic energy of CO and N_2 is same.

42. (b) The inversion temp is the temp below which the gas warms up on expansion

for, Vander Waal's gas, $T_i=\left(\frac{2a}{Rb}\right)$.

43. (c) R.M.S. velocity $=\sqrt{\frac{3RT}{M}}$

Average velocity

$$=\sqrt{\frac{8RT}{\pi M}}=\sqrt{\frac{8}{3\pi}}\times\sqrt{\frac{3RT}{M}}$$

$$=\sqrt{\frac{8}{3\pi}}\times\text{R.M.S. velocity}$$

$=0.921\times1000=921\,\text{m/sec}$

44. (b) According to kinetic theory the gas molecules are in a state of constant rapid motion in all possible directions colloiding in a random manner with one another and with the walls of the container and between two successive collisions molecules travel in a straight line path but show haphazard motion due to collisions.

45. (a) $$\frac{\text{K.E of neon at }40°\text{C}}{\text{K.E of neon at }20°\text{C}}=\frac{\frac{3}{2}K\times313}{\frac{3}{2}K\times293}=\frac{313}{293}$$

46. (b) $\frac{R}{No}$ is also known as Boltz mann's constant.

47. (a) $u_{rms}:u_{av}=\sqrt{\frac{3RT}{M}}:\sqrt{\frac{8RT}{\pi M}}$ or $\sqrt{3}:\sqrt{\frac{8}{\pi}}=1.086:1$

48. (d) $u_{rms}=\sqrt{\frac{3RT}{M}}$ (As $PV=RT$) ....(i)

By putting this value in eq. (i) we get

$$=\sqrt{\frac{3PV}{M}}$$

Now, $\frac{PVM}{M}=RT=PM=dRT=T=\frac{PM}{dR}$

By substituting T in eq. (i) we get

$$=\sqrt{\frac{3RPM}{dRM}}=\sqrt{\frac{3P}{d}}$$

49. (b) Rate of diffusion $\propto\frac{1}{\sqrt{\text{molecular weight}}}$

So, ratio of rate of diffusion $=\sqrt{\frac{25}{4}}=\frac{5}{2}$

50. (c) K.E. $\propto$ T [K.E. of one molecule of monoatomic gas $=\frac{3}{2}RT$]

As temperature increases to

$$\frac{927+273}{27+273}=\frac{1200}{300}=4\text{ times}$$

therefore, Kinetic engergy will be increased to 4 times.

51. (c) The expression of root mean square speed is

$$u_{rms}=\sqrt{\frac{3RT}{M}}$$

Hence,

$$\frac{u_{rms}(H_2)}{u_{rms}(O_2)}=\left[\frac{3R(50K)/(2\,g\,mol^{-1})}{3R(800K)/(32\,g\,mol^{-1})}\right]^{1/2}=1$$

52. (d) $u_{rms}=\sqrt{\frac{3RT}{M}}$ Using ideal gas equation,

$PV=nRT=\frac{w}{M}RT;\quad \frac{RT}{M}=\frac{PV}{w}=\frac{p}{d}$ where d is the density of the gas

$\therefore\ u_{rms}=\sqrt{\frac{3P}{d}}$ at constant pressure, $u_{rms}\propto\frac{1}{\sqrt{d}}$

53. (c) Average KE $=E=\frac{1}{2}M\,u_{rms}^2$

$$\therefore\ u_{rms}^2=\frac{2E}{M}\ \text{or}\ u_{rms}=\sqrt{\frac{2E}{M}}$$

54. (a) By Dalton's law of partial pressures, the total pressure of a mixture of two gases is the sum of the partial pressures.

55. (d) In the ideal gas, the intermolecular forces of attraction are negligible and hence it cannot be liquefied.

56. (b) At low temperature and high pressure.

57. (a) $r_1=\frac{V}{t_1}=\frac{V}{18},\ r_2=\frac{V}{t_2}=\frac{V}{45}$

$$\frac{r_1}{r_2}=\sqrt{\frac{M_2}{M_1}}\Rightarrow\frac{\frac{V}{18}}{\frac{V}{45}}=\sqrt{\frac{x}{32}}$$

$$\Rightarrow\sqrt{\frac{x}{32}}=\frac{45}{18}\Rightarrow x=32\times\frac{45^2}{18^2}$$

58. (b) At low pressure and high temperature real gas nearly behave like ideal gas. Hence deviation is minimum from ideal behaviour.

59. (a) In van der waals equation '*b*' is for volume correction

60. (c) By ideal gas equation

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Given that,

$$P_1 = P_2\ ,\ V_1 = x,\ V_2 = 2x,$$

$$T_1 = 273\ K\ ,\ T_2 = ?$$

On putting value

$$\frac{P_2 x}{273} = \frac{P_2 2x}{T_2}$$

$$T_2 = 2 \times 273 = 546\ K \text{ or } 273°C$$

Hence, option (d) is correct.

61. (d) Value of gas constant depends only upon units of measurement.

62. (b) The temperature at which a real gas behaves like an ideal gas is called Boyle's temperature or Boyle's point.

63. (c) $\left(P + \frac{a}{V^2}\right)(V - b) = RT$; Here $\left(P + \frac{a}{V^2}\right)$ represents the intermolecular forces.

64. (b) The compressibility factor of a gas is defined as

$$Z = \frac{pV_m}{RT}$$

For an ideal gas, $pV_m = RT$. Hence $Z = 1$

65. (d) $P \propto \frac{1}{V}$ (at constant T)

$\therefore$ PV = constant.

66. (b)

(i) At very large molar volume

$$P + \frac{a}{V_m^2} \approx P \text{ and } V_m - b = V_m$$

(iii) According to van der Waals equation '*a*' and '*b*' are independent of temperature.

67. (a) r_1 = rate of diffusion of $NH_3 = 2R$

r_2 = rate of diffusion of X = R

M_1 = Molecular mass of NH_3

$= 14 + 1 \times 3 = 17$

$M_2 = ?$

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

$$\text{or } \frac{2R}{R} = \sqrt{\frac{M_2}{17}}$$

$$\text{or } 2 = \sqrt{\frac{M_2}{17}}$$

$$\therefore M_2 = 17 \times 4 = 68$$

68. (b) Due to intermolecular interactions appreciable at high P and low T, the ideal gas deviates from ideal behaviour.

69. (c) Easily liquefiable gases have greater intermolecular forces which is represented by high value of '*a*'. The greater the value of '*a*' more will be liquefiability.

So, the order is Q < S < P < R.

70. (a) When pressure is low '*b*' can be neglected, thus

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

$$PV + \frac{a}{V} = RT$$

$$PV = RT - \frac{a}{V}$$

$$\frac{PV}{RT} = \frac{RT}{RT} - \frac{a}{VRT}$$

$$Z = \frac{PV}{RT} = 1 - \frac{a}{VRT}$$

71. (a) Let the mass be x, then moles of CH_4 and H_2 are $\frac{x}{16}$ & $\frac{x}{2}$;

$$\text{Total moles} = \frac{9x}{16}$$

$$pH_2 = \text{mole Fraction} \times P = \frac{x/2}{9x/16}.P = \frac{8}{9}P$$

72. (b)

73. (d) Soap helps to lower the surface tension of solution, thus soap get stick to the dust particles and grease and these are removed by action of water.

74. (c) $\frac{U_{H_2}}{U_{N_2}} = \sqrt{\frac{T_{H_2}\ 28}{T_{N_2} \times 2}} = \sqrt{7} \Rightarrow \frac{T_{H_2}}{T_{N_2}} = \frac{1}{2}$

$$\Rightarrow T_{N_2} = 2T_{H_2}$$

$$\therefore T_{N_2} > T_{H_2}$$

75. (b)

EXERCISE - 2

1. (d) $u_{rms} \alpha \sqrt{\frac{1}{M}} : u_1 \alpha \sqrt{\frac{1}{m_1}}, u_2 \alpha \sqrt{\frac{1}{m_2}} \therefore \frac{u_1^2}{u_2^2} = \frac{m_2}{m_1}$

2. (d) One mole of a substance contains the number of molecules which is independent of pressure.

3. (c) $PV = nRT$ or $P = \frac{n}{V}RT = CRT.$

Hence $1 = 1 \times 0.082 \times T$ is $T = \frac{1}{0.082} = 12K$

4. (a) 28g of CO $= \frac{28}{28} = 1$ mole; 2g $H_2 = \frac{2}{2} = 1$ mole

Since the temperature and moles are the same, the average kinetic energy will also be the same.

5. (d) By Ideal gas equation

$$P_1 V = n_1 RT$$

$$n_1 \propto P_1 \text{ and } n_2 \propto P_2$$

$$\frac{n_1}{n_2} = \frac{P_1}{P_2} \Rightarrow \frac{n_1}{n_2} = \frac{170}{570} = 0.30$$

6. (b) At the same conditions of T and P, $V \alpha n$

$$n_{N_2} = \frac{14}{28} = \frac{1}{2};\ V_{N_2} \alpha \frac{1}{2} \qquad n_{O_3} = \frac{36}{48} = \frac{3}{4};\ V_{O_3} \alpha \frac{3}{4}$$

Hence, $V_{N_2} / V_{O_3} = \frac{2}{3}$, $3V_{N_2} = 2V_{O_3}$

7. (a) Applying Boyle's law $P_1V_1 = P_2V_2$ for both gases

$$\frac{500}{1000} \times 400 = P \times 3 \Rightarrow P = \frac{200}{3}$$

$$600 \times \frac{666.6}{1000} = P' \times 3 \Rightarrow P' = \frac{400}{3}$$

$$\Rightarrow P_T = P + P' = \frac{200}{3} + \frac{400}{3} = \frac{600}{3} = 200 \text{ torr}$$

8. (a) The beans are cooked earlier in pressure cooker because boiling point increases with increasing pressure.

9. (b) No work is required to tear apart the molecules due to the absence of attractive forces in an ideal gas.

10. (c) Critical compressibility factor $Z = \frac{P_c V_c}{RT_c}$

$$P_c = \frac{a}{27}b^2;\ Vc = 3b, Tc = \frac{8a}{Rb}$$

Hence, $Z = \frac{3}{8}$ or $\frac{1}{Z} = \frac{8}{3}$

11. (b) Hot air is lighter due to less density (Charle's law) $\left(d = \frac{MP}{RT}\right)$

12. (a) $d \propto P$, Boyle's law, $\left(d = \frac{MP}{RT}\right)$. At sea level pressure is more, hence density of air is more.

13. (b)

14. (a) Given $T = 27°\text{C} = 27 + 273 = 300$ K

$V = 10.0$ L

Mass of He = 0.4 g

Mass of oxygen = 1.6 g

Mass of nitrogen = 1.4 g

n He = 0.4/4 = 0.1

$n\ O_2 = 1.6/32 = 0.05$

$n\ N_2 = 1.4/28 = 0.05$

n total = n He + $n\ O_2$ + $n\ N_2$ = 0.1 + 0.05 + 0.05 = 0.2

$$P = \frac{nRT}{V} = \frac{0.2 \times 0.082 \times 300}{10} = 0.492 \text{ atm}$$

15. (c) Since the inversion temperature of helium is very low, hence during the expansion into vacuum, heating effect is observed.

16. (b) rate of diffusion $\propto \sqrt{\frac{1}{\text{molecular mass}}}$

Let the molecular mass of the gas X = M_x

Thus $\frac{r_{He}}{r_x} = 4 = \sqrt{\frac{M_x}{M_{He}}}$

or $4 = \sqrt{\frac{M_x}{4}}$ or $16 = \frac{M_x}{4}$

or $M_x = 64$

The molecular masses of given gases are 44, 64, 46 and 32 respectively. Thus (b) is correct option.

17. (b) Rate of diffusion $\propto \sqrt{\frac{1}{\text{Molecular mass}}}$

$\because$ Molecular mass of HCl > Molecular mass of NH_3

$\therefore$ HCl diffuses at slower rate and white ammonium chloride is first formed near HCl bottle.

18. (c) $a = \frac{PV^2}{n^2}$ (atm L^2 mol^{-2}) ; b = L mol^{-1} ;

$$\text{Hence, } \frac{a}{b} = \left(\frac{\text{atm } L^2 \text{ mol}^{-2}}{\text{L mol}^{-1}}\right) = \text{atm L mol}^{-1}$$

19. (c) Mass of 1 L of vapour = volume × density

= 1000 × 0.0006 = 0.6 g

$$V \text{ of liquid water} = \frac{\text{mass}}{\text{density}} = \frac{0.6}{1} = 0.6 \text{ cm}^3$$

20. (d) van der Waals's constant b = 4 times the actual volume of 1 mole molecules = $4\,VN_0$

21. (c) Find the volume by either $V = RT/P$ ($PV = RT$) or $P_1V_1 = P_2V_2$ and and match it with the values given in graph to find correct answer.

Volume of 1 mole of an ideal gas at 273 K and 1 atm pressure is 22.4 L and that at 373 K and 1 atm pressure is calculated as ;

$$V = \frac{RT}{P} = \frac{0.082 \times 373}{1} = 30.58L \simeq 30.6 \text{ L}$$

22. (d)

23. (c) For positive deviation: $PV = nRT + nPb$

$$\Rightarrow \frac{PV}{nRT} = 1 + \frac{Pb}{RT}$$

Thus, the factor nPb is responsible for increasing the PV value, above ideal value. b is actually the effective volume of molecules. So, it is the finite size of molecules that leads to the origin of b and hence positive deviation at high pressure.

24. (a) For equal average speeds of two of gases,

$$\sqrt{\frac{T_1}{M_1}} = \sqrt{\frac{T_2}{M_2}}$$

$$T_1 = ?; M_1 = 4; T_2 = 273 + 527 = 800\text{K}; M_2 = 32$$

25. (b) n, T same hence $P \propto \frac{1}{V}$,

$V_1 = 1000 \text{ cm}^3$

$V_2 = \pi(10)^2 \times 10 = 1000\,\pi\,\text{cm}^3$

$V_3 = \frac{4}{3}\pi(10)^3 = \frac{4}{3}\pi\,1000\,\text{cm}^3$

$\therefore$ Pressure of the gas is minimum in (III) container, pressure of the gas is maximum in (I),

The ratio of pressure in II and III container is 4 : 3

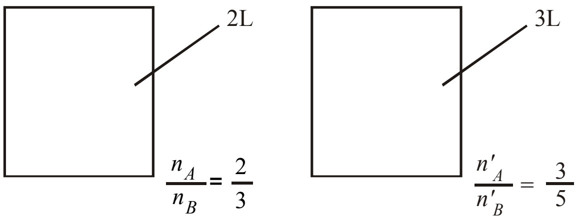
26. (b) The gas is less compressible than ideal gas. Hence, $V_m > 22.4\text{L}$

27. (d) (i) Greater is the van der Waals's constant *a*, higher would be T_c (easier liquefaction of the gas).
   (ii) Smaller the constants *a* and *b*, lesser departure from ideal behaviour.
   (iii) Greater the constant *b*, larger is the molecular volume.

28. (d) Calculate molar mass *M*,

$$M = \frac{mRT}{PV} = \frac{11 \times 0.08 \times 400}{2 \times 4} = 44$$

29. (b)



$$\text{Mean molar mass} = \frac{(n_A + n'_A)\,M_A + (n_B + n'_B)\,M_B}{n_A + n'_A + n_B + n'_B}$$

30. (c) $\text{K.E.} = \frac{3}{2}nRT$; $\text{K.E}(\text{H}_2) = \frac{3}{2} \times \frac{w}{2} \times R \times 300$;

$$\text{K.E.}(\text{CH}_4) = \frac{3}{2} \times \frac{w}{16} \times R \times 600;$$

$$\text{Hence}\ \frac{\text{K.E.}(\text{H}_2)}{\text{K.E.}(\text{CH}_4)} = 4$$

31. (d) Average velocity $= \sqrt{\frac{8RT}{\pi M}}$

i.e., $v \propto \sqrt{T}$

$$\therefore \frac{v_2}{v_1} = \sqrt{\frac{2T}{T}} = 1.41$$

32. (a) Given

$P_1 = 1.5\ \text{bar}\ T_1 = 273 + 15 = 288\ \text{K}\ V_1 = V$
$P_2 = 1.0\ \text{bar}\ T_1 = 273 + 25 = 298\text{K}\ V_2 = ?$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{1.5 \times V}{288} = \frac{1 \times V_2}{298}$$

$V_2 = 1.55$ V i.e., volume of bubble will be almost 1.6 time to initial volume of bubble.

33. (c) $\frac{V_A}{t_A} \Big/ \frac{V_B}{t_B} = \sqrt{\frac{M_B}{M_A}}$

$$\Rightarrow \frac{200}{150} = \sqrt{\frac{36}{M_A}} \Rightarrow \frac{4}{3} = \sqrt{\frac{36}{M_A}}$$

$$\Rightarrow \frac{16}{9} = \frac{36}{M_A} \Rightarrow M_A = \frac{81}{4} = 20.25$$

34. (a) $r \propto \frac{p}{\sqrt{m}}$

$$\frac{r_A}{r_B} = \frac{p_A}{P_B}\sqrt{\frac{M_B}{M_A}}$$

35. (c) $\left(P + \frac{a}{V^2}\right)(V - b) = RT$ at high pressure $\frac{a}{V^2}$ can be neglected

$PV - Pb = RT$ and $PV = RT + Pb$

$$\frac{PV}{RT} = 1 + \frac{Pb}{RT}$$

$Z = 1 + \frac{Pb}{RT}$; $Z > 1$ at high pressure

36. (d) $\frac{D_A}{D_B} = \sqrt{\frac{\rho_B}{\rho_A}} = \left[\frac{\rho_B}{\rho_A}\right]^{1/2}$; $\therefore D_A = D_B\left(\frac{\rho_B}{\rho_A}\right)^{1/2}$

37. (d) We know that

$$Z = \frac{PV}{nRT} \Rightarrow 0.5 = \frac{100 \times V}{1 \times 0.0821 \times 273} \Rightarrow V = 0.112\ \text{lit.}$$

According to van der Waals equation

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

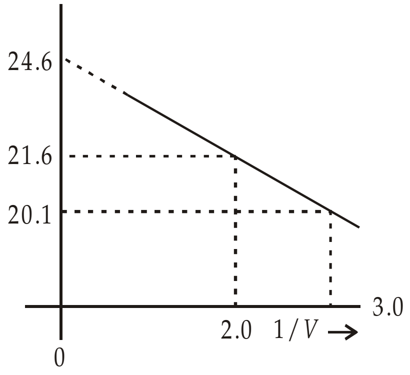
$$\left(100 + \frac{a}{(0.112)^2}\right)(0.112 - 0) = 0.0821 \times 273$$

$a = 1.253\ \text{L}^2\ \text{mol}^{-2}\ \text{atm}$

38. (b)

39. (b) Correction factor for attractive force for *n* moles of real gas is given by the term mentioned in (b).

40. (c)



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

$PV + a/V = RT$

$$PV = RT - \frac{a}{V}$$

$y = RT - a(x)$

$$\text{So, slope} = -a = \frac{21.6-20.1}{2-3} = -a = -1.5$$

$$a = 1.5$$

41. (c) Most probable speed (C*) = $\sqrt{\frac{2RT}{M}}$

Average Speed $(\bar{C}) = \sqrt{\frac{8RT}{\pi M}}$

Root mean square velocity (C) = $\sqrt{\frac{3RT}{M}}$

$$C^*:\bar{C}:C = \sqrt{\frac{2RT}{M}}:\sqrt{\frac{8RT}{\pi M}}:\sqrt{\frac{3RT}{M}}$$

$$= 1:\sqrt{\frac{4}{\pi}}:\sqrt{\frac{3}{2}} = 1:1.128:1.225$$

42. (b)

43. (b) $V_2 = \frac{P_1}{P_2}\frac{T_2}{T_1}.V_1 = \frac{1}{0.5}\times\frac{250}{300}\times 12000\ lit. = 20000$ lit.

44. (d) $P = \frac{nRT}{V} = \frac{6}{16}\frac{\times 8.314\times 402}{0.03\times 10^3} \simeq 41777\,\text{Pa}$

45. (b) $\frac{r_A}{r_B} = \sqrt{\frac{M_B}{M_A}}$

$$\frac{\frac{V}{20}}{\frac{V}{10}} = \sqrt{\frac{M_B}{49}} \Rightarrow \frac{1}{2} = \sqrt{\frac{M_B}{49}}$$

$$M_B = \frac{1}{4}\times 49 = 12.25$$

46. (a) Given $n_{CO} = n_{N_2}$

$P_{CO} + P_{N_2} = 1$ atm

Partial pressure of a gas

= mole fraction of gas × total pressure

$$\therefore\ P_{N_2} = \frac{n_{N_2}}{n_{CO}+n_{N_2}}\times 1 = \frac{n_{N_2}}{2n_{N_2}}\times 1 = \frac{1}{2} = 0.5\ \text{atm.}$$

47. (c) As temperature rises the most probable speed increases and the fraction of molecules possessing most probable speed decreases.

48. (c) The air pressure decreases with increase in altitude. So the partial pressure of oxygen is not sufficient for breathing at higher altitude and thus pressurization is needed to increase the concentration of oxygen.

49. (a) At STP one mole of each gas occupies 22.4 L

50. (a) Considering the attractive forces between gas molecules pressure in ideal gas equation (PV = nRT) is corrected by introducing a factor of $\frac{an^2}{V^2}$ where '*a*' is a van der Waal's constant.

EXERCISE - 3

Exemplar Questions

1. (c) At high altitude pressure is low hence boiling point is low due to which things take more time to cook. However, in a pressure cooker, pressure is increased and hence, boiling point increases. Thus, in a pressure cooker food get cook faster i.e. a less period of time.

2. (b) The property of surface tension explain the spherical shape of rain droplets. Surface tension tries to decrease the surface area of the liquid to the minimum. The rain droplets are spherical because for a given volume, a sphere has minimum surface area.

3. (c) According to Boyle's law at a particular temperature, PV = constant

Thus, $P_1V_1 = P_2V_2 = P_3V_3 = P_4V_4$

As $V_1 > V_2 > V_3 > V_4$

Therefore, $P_1 < P_2 < P_3 < P_4$

4. (c) London dispersion force is a temporary attractive force that results when the electrons in two adjacent atom occupy position that makes the atoms form temporary dipoles. The energy of interaction varies as

$$\frac{1}{(\text{distance between two interacting particles})^6}.$$

Larger or more complex are the molecules, greater is the magnitude of London forces. This is obviously due to the fact that the large electron clouds are easily distorted or polarised. Hence, greater the polarisability of the interacting particles, greater is the magnitude of the interaction energy.

5. (c) Dipole-dipole forces act between the molecules possessing permanent dipole and ends of dipoles possess 'partial charges'. Partial charges present on ends of a dipole are always less than the unit electronic charge.

6. (c) Let the number of moles of dihydrogen and dioxygen be 1 and 4.

Mole fraction of $O_2 = \frac{4}{5}$

Partial pressure of O_2 = Mole fraction of O_2 × total pressure of mixture

$$= \frac{4}{5}\times 1\ \text{atm}$$

$$= 0.8\ \text{atm} = 0.8\times 10^5\ \text{Nm}^{-2} = 8\times 10^4\ \text{Nm}^{-2}$$

7. (a) From Gay-Lussac's law, at constant volume, as the temperature is increased, pressure increases.

8. (d) Higher the critical temperature, more easily is the gas get liquified. Hence, order of liquefaction starting with the gas liquefying first will be : O_2, N_2, H_2, He.

9. (b) The SI unit of viscosity coefficient (η) in Nm^{-2} s or Nsm^{-2}.

As we know that, $f = \eta A\frac{dv}{dx}$

where, f = force

η = viscosity coefficient

$\frac{dv}{dx}$ = velocity gradient

Substitute SI units of f = N, dx = m, A = m^2 and v = ms^{-1} in above equation, we get,

$$\eta = \frac{N \times m}{m^2 \times ms^{-1}} = Nm^{-2}s$$

Hence, the SI unit of η is Nsm^{-2}

10. (a) Among all the four cities Shimla has the lowest atmospheric pressure. Since lower the atmospheric pressure, lower is the boiling point. Thus, at Shimla liquid will boil first.

11. (a) For ideal gas PV = constant at all pressures. Therefore, only B represents ideal gas.

12. (c) Kinetic energy of the molecules of liquid increases with increase of temperature, which can overcome the intermolecular forces. Hence, the liquid starts flowing. In other words the viscosity of a liquid decrease with increase in temperature.

13. (b) The surface tension of liquids generally decreases with increase of temperature and becomes zero at the critical temperature. This is due to the fact that with increase of temperature, the kinetic energy of the molecules increases and therefore, the intermolecular attraction decreases.

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14. (c) Higher the critical temperature more easily will be the gas liquify. Now since most easily liquifiable gas show larger deviation, NH_3 will show maximum deviation from ideal behaviour.

15. (b) This type of attractive force operates between the polar molecules having permanent dipole and the molecules lacking permanent dipole.
HCl is polar ($\mu \neq 0$) and He is non polar ($\mu = 0$), thus gives dipole-induced dipole interaction.

16. (d) Density $= \frac{PM}{RT} = \frac{5 \times 28}{0.0821 \times 500} = 3.41 g/ml$

17. (c) According to Avogadro's law "At same temperature and pressure
Volume ∝ no. of moles"

$$n_{H_2} = \frac{w}{2}; \quad n_{O_2} = \frac{w}{32}; \; n_{CH_4} = \frac{w}{16}$$

$$\because \; V_{H_2} : V_{O_2} : V_{CH_4} = n_{H_2} : n_{O_2} : n_{CH_4}$$

$$= \frac{w}{2} : \frac{w}{32} : \frac{w}{16} = 16 : 1 : 2$$

18. (a) At high temperature and low pressure.

19. (a) Given, $n_{H_2} = n_{O_2}$ and $t_{H_2} = t_{O_2}$
According to Graham's law of diffusion for two different gases.

$$\frac{r_{H_2}}{r_{O_2}} = \frac{v_1 / t_1}{v_2 / t_2} \Rightarrow \sqrt{\frac{M_{O_2}}{M_{H_2}}} = \sqrt{\frac{32}{2}}$$

$$\frac{1/2}{1/x} = \sqrt{16} = 4$$

$$\frac{x}{2} = 4$$

$\therefore$ x = 8

$\therefore$ Fraction of O_2 = 1/8