UNIT – VI – GASEOUS STATE

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

UNIT – 6 – GASEOUS STATE

II. WRITE BRIEF ANSWER TO THE FOLLOWING QUESTIONS.

26. State Boyle's law.

At a given temperature the volume occupied by a fixed mass of a gas is inversely proportional to its pressure. Mathematically, Boyle's law can be written as $V \propto \frac{1}{P}$ ………….(1)

(T and n are fixed, T-temperature, n-number of moles) $V = k \times \frac{1}{P}$ ………..…(2)

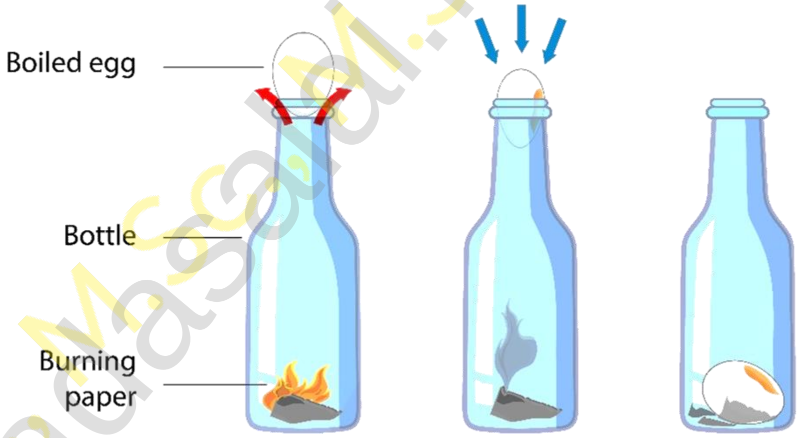
k – proportionality constant PV = k (at constant temperature and mass)

27. Name two items that can serve as a model for Gay Lussac's law and explain.

(i) $P \propto T$ at constant volume (or) $= \frac{P_1}{T_1} = \frac{P_2}{T_2}$

(iii) **Example – 1:** You fill the car type completely full of air on the hottest day of summer. The type cannot change it shape and volume. But when winter comes, the pressure inside the lyre is reduced and the shape is also reduced. This confirms that pressure and temperature are direct related to each other.

(iii) **Example – 2:** The egg in the bottle experiment. A glass bottle is taken, inside the bottle put some pieces of cotton with fire. Then place a boiled egg (shell removed) at the top of the bottle. The temperature inside the bottle increases from the fire, rising (he pressure. By scaling the bottle with egg, the fire goes on, dropping the temperature and pressure.



This causes the egg to be sucked into the bottle (after cooling). $P \propto T$ is proved (or) $= \frac{P_1}{T_1} = \frac{P_2}{T_2}$

28. Give the mathematical expression that relates gas volume and moles.

The mathematical expression that relates gas volume and moles is Avogadro's hypothesis. It may be expressed as $V \propto n$, $\frac{v_1}{n_1} = \frac{v_2}{n_2}$ = constant

where V_1 and n_1 are the volume and number of moles of a gas and V_2 and n_2 are a different set of values of volume and number of moles of the same gas at the same temperature and pressure.

29. What are ideal gases? In what way real gases differ from ideal gases. [MAR-19]

An ideal gas is defined as one in which all collisions between atoms or molecules are perfectly elastic and in which there are no intermolecular attractive forces. An ideal gas is a gas that obeys the ideal gas law, PV = nRT, where n is the number of moles of the gas, R is the ideal gas constant, pressure P, volume V, and temperature T.

	Ideal Gas	Real Gas
1	Ideal gases obey all gas laws under all conditions of temperature and pressure	Real obey gas law only at low pressures and high temperature
2	The volume occupied by the molecules is negligible as compared to the total volume occupied by the gas	The volume occupied by the molecules is not negligible as compared to the total volume of the gas

3	The force of attraction among the molecules is negligible	The force of attraction is not negligible at all temperatures and pressures.

30. Can a Van der Waals gas with a = 0 be liquefied? Explain.

- If the van der Waals constant (a) = 0 for gas, then it behaves ideally, (i.e.,) there is no intermolecular forces of attraction. So it cannot be liquefied.
- If a = 0, there is a very less inter action between the molecules of the gas.
- a is the measure of strength of vander waals force of attraction between the molecules of the gas.
- If a is equal to zero, the vander waals force of attraction is very less and the gas cannot be liquefied.

31. Suppose there ¡s a tiny sticky area on the wan of a container of gas. Molecules hitting this area stick there permanently. Is the pressure greater or less than on the ordinary area of walls?

If the gas molecules stick to the walls of the container, then the number of molecules striking the walls of the container decreases. A decrease in the number of gas molecules in the same volume container decreases pressure.

32. Explain the following observations? (a) Aerated water bottles are kept under water during summer [FMT-18] (b) Liquid ammonia bottle is cooled before opening the seal [QY-18] (c) The type of an automobile is inflated to slightly lesser pressure in summer than in winter [FMT-18] (d) The size of a weather balloon becomes larger and larger as it ascends up into larger altitude

(a) Aerated water bottles contains excess dissolved oxygen and minerals which dissolved under certain pressure and if this pressure suddenly decrease due to change in atmospheric pressure, the bottle will certainly burst with decrease the amount of dissolved oxygen in water, this tends to change the aerated water into normal water.

(b) The vapour pressure of ammonia at room temperature is very high and hence the ammonia will evaporate unless the vapour pressure is decreased. On cooling the vapour pressure decreases so that the liquid remains in the same state. Hence, the bottle is cooled' before opening.

(c) In Summer due to hot weather conditions, the air inside the tyre expands to large volumes due to heat as compared to winter, therefore, inflated to lesser pressure in summer.

(d) As we move to higher altitude, the atmospheric pressure decreases, therefore the balloon can easily expand to large volume.

33. Give suitable explanation for the following facts about gases. (a) Gases don't settle at the bottom of a container (b) Gases diffuse through all the space available to them

(a) Gases by definition are the least dense state of matter. They have negligible intermolecular forces of attraction. So they are all free to roam separately. So the least dense gas particles will not sink at the bottom of a container.

(b) When a sample of a gas introduced to one part of a closed container, its molecules very quickly disperse throughout the container, this process by which molecules disperse in space in response to differences in concentration is called diffusion.

For e.g., you can smell perfume in a room, because it diffuses into the air totally inside the room.

UNIT – VI – GASEOUS STATE

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

34. Suggest why there is no hydrogen (H2) in our atmosphere. Why does the moon have no atmosphere?

Hydrogen is the third most abundant element in the earth's surface. However, hydrogen gas is very rare in the earth's atmosphere due to its light weight, which enable it to escape from earth's gravity easily than heavier gas.

Moon has very low gravity and so have escape velocity. The atmospheric gases on the surface of the moon have thermal velocities greater than escape velocity. That is the reason why molecules of gases escape and there is no atmosphere in the moon.

35. Explain whether a gas approaches ideal behaviour or deviates from ideal behaviour if (a) it is compressed to a smaller volume at constant temperature (b) the temperature is raised while keeping the volume constant (c) more gas is introduced into the same volume and at the same temperature

(a) it a gas is compressed to a smaller volume at constant temperature, pressure is increased. At high pressure with a smaller volume, the gas deviates from ideal behaviour.

(b) If a gas temperature is raised keeping the volume constant, the pressure of the gas will increase. At high pressure, the gas deviates from ideal behaviour.

(c) if more gas is introduced into the same volume and at the same temperature, the number of moles are increasing. if the volume remains same, the increased number of moles collide with each other and kinetic energy increases and pressure decreases. At increased pressure, the gas deviates from ideal behaviour.

36. Which of the following gases would you expect to deviate from ideal behaviour under conditions of low-temperature F_2, Cl_2, or Br_2? Explain.

Bromine has a greater tendency to deviate from ideal behaviour at high pressure and low temperatures. As both conditions increases the intermolecular force of attraction, greater deviation from the ideal behaviour will occur. F_2, Cl_2 and Br_2 are all non polar molecules but the heaviest molecule will have stronger dispersion force. Dispersion force increases with molar mass. So, the compressibility factor tends to deviate from unity for bromine.

37. Distinguish between diffusion and effusion. [GMQ-18, CRT,AUG-22]

	Diffusion	Effusion
1	During diffusion one gas mixes with another usually by thermal random motion resulting in the collision between each other while releasing molecular energy.	Effusion is said to occur when gas molecules escape through a pinhole into a vacuum.
2	Diffusion is the ability of gases to mix with each other usually in the absence of a barrier.	Effusion in simple terms is the ability of gas to travel through a small opening.
3	Diffusion happens when there are no holes or if holes in the barrier are larger than the mean free path.	Effusion occurs when the size or aperture of the hole is smaller than the mean free path of the molecules.
4	Diffusion occurs due to difference in concentrations.	Effusion occurs or is facilitated by a difference of pressures.

UNIT – VI – GASEOUS STATE

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

38. Aerosol cans carry clear warning of heating of the can. Why?

Aerosol cans carry clear warning of heating of the can. As the temperature rises, pressure in the can will increase and ambient temperatures about 120°F may lead to explosions. So aerosol cans should always be stored in dry areas where they will not be exposed to excessive temperatures. You should never throw an aerosol can onto a fire or leave it in the direct sunlight. Even it is empty. This is because the pressure will build up so much that the can will burst. It is due to 2 reasons.

- The gas pressure increases.
- More of the liquefied propellant turns into a gas.

39. Would it be easier to drink water with a straw on the top of Mount Everest? [FMT-18]

It is difficult to drink water with a straw on the top of Mount Everest. This is because the reduced atmospheric pressure is less effective in pushing water into the straw at the top of the mountain because gravity falls off gradually with height. The air pressure falls off, there isn't enough atmospheric pressure to push the water up in the straw all the way to the mouth.

40. Write the Van der Waals equation for a real gas. Explain the correction term for pressure and volume. [GMQ-18, MAR-24]

Van der Waals equation of state for real gases is $\left(P + \frac{an^2}{V^2}\right)(V-nb) = nRT$

Correction term for pressure:

$\frac{an^2}{V^2}$ is the pressure correction. It represents the intermolecular interaction that causes the non ideal behaviour.

Correction term for Volume:

V – nb is the volume correction. it is the effective volume occupied by real gas.

41. Derive the values of critical constants from the VanderWaals constants. [FMT18, MAR24]

The van der Waals equation for n moles is

$$\left(P + \frac{a\,n^2}{V^2}\right)(V - nb) = nRT \text{ ---------- } (6.22)$$

For 1 mole

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT \text{ ---------- } (6.23)$$

From the equation we can derive the values of critical constants P_c, V_c and T_c in terms of a and b, the van der Waals constants, On expanding the above equation

$$PV + \frac{a}{V} - Pb - \frac{ab}{V^2} - RT = 0 \text{ ------- } (6.24)$$

Multiply equation (6.24) by V^2 / P

$$\frac{V^2}{P}\left(PV + \frac{a}{V} - Pb - \frac{ab}{V^2} - RT\right) = 0$$

$$V^3 + \frac{aV}{P} + -bV^2 - \frac{ab}{P} - \frac{RTV^2}{P} = 0 \text{ --- } (6.25)$$

When the above equation is rearranged in powers of V

$$V^3 - \left[\frac{RT}{P} + b\right]V^2 + \left[\frac{a}{P}\right]V - \left[\frac{ab}{P}\right] = 0 \text{ --- } (6.26)$$

UNIT – VI – GASEOUS STATE

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

The equation (6.26) is a cubic equation in V. On solving this equation, we will get three solutions. At the critical point all these three solutions of V are equal to the critical volume VC. The pressure and temperature becomes Pc and Tc respectively

i.e., $V = V_C$ $\qquad (V - V_C)^3 = 0$

$V - V_C = 0$ $\qquad V^3 - 3V_CV^2 + 3V_C^2V - V_C^3 = 0$ ---- (6.27)

As equation (6.26) is identical with equation (6.27), we can equate the coefficients of V2, V and constant terms in (6.26) and (6.27).

$$-3V_CV^2 = -\left[\frac{RT_C}{P_C} + b\right]V^2 \qquad 3V_C = \frac{RT_C}{P_C} + b \quad \text{---- (6.28)}$$

$$3V_C^2 = \frac{a}{P_C} \quad \text{---- (6.29)}$$

$$V_C^3 = \frac{ab}{P_C} \quad \text{---- (6.30)}$$

Divide equation (6.30) by equation (6.29)

$$\frac{V_C^3}{3V_C^2} = \frac{ab/P_C}{a/P_C}$$

$$\frac{V_C}{3} = b \qquad \text{i.e. } V_C = 3b \quad \text{------- (6.31)}$$

when equation (6.31) is substituted in (6.29)

$$3V_C^2 = \frac{a}{P_C}$$

$$P_C = \frac{a}{3V_C^2} = \frac{a}{3(3b^2)} = \frac{a}{3\times 9b^2} = \frac{a}{27\,b^2} \qquad P_C = \frac{a}{27b^2} \quad \text{------ (6.32)}$$

substituting the values of Vc and Pc in equation (6.28),

$$3V_C = b + \frac{R\,T_C}{P}$$

$$3(3\,b) = b + \frac{R\,T_C}{\left(a/27\,b^2\right)}$$

$$9\,b - b = \left(\frac{R\,T_C}{a}\right)27\,b^2$$

$$8\,b = \frac{T_C\,R\,27b^2}{a}$$

$$\therefore\ T_C = \frac{8\,a\,b}{27\,R\,b^2} = \frac{8\,a}{27\,R\,b}$$

$$T_C = \frac{8\,a}{27\,R\,b} \quad \text{------ (6.33)}$$

The critical constants can be calculated using the values of van der waals constant of a gas and vice versa.

$$a = 3\,V_C^2\,P_C \quad \text{and} \quad b = \frac{V_C}{3}$$

42. Why do astronauts have to wear protective suits when they are on the surface of moon?

Astronauts must wear spacesuits whenever they leave a spacecraft and are exposed to the environment of the moon.

On the moon, there is no air to breathe and no air pressure. Moon is extremely cold and filled with dangerous radiation.

Without protection, an astronaut would quickly die in space. Spacesuits are specially designed to protect astronauts from the cold, radiation, and low pressure in space. They also provide air to breathe. Wearing a spacesuit allows an astronaut to survive and work on the moon.

UNIT – VI – GASEOUS STATE

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

43. When ammonia combines with HCl, NH_4Cl is formed as white dense fumes. Why do more fumes appear near HCl?

NH_3 having lower molar mass will diffuse faster and hence travel a greater length of the tube hence more fumes appear near HCl.

44. A sample of gas at 15°C at 1 atm has a volume of 2.58 dm³. When the temperature is raised to 38°C at 1 atm does the volume of the gas increase? If so, calculate the final volume. [FMT-18]

$T_1 = 15°C + 273$ $T_2 = 38°C + 273$

$T_1 = 288\ K$ $T_2 = 311\ K$

$V_1 = 2.58\ dm^3$ $V_2 = ?$

(P = 1 atom constant)

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

$$V_2 = \left(\frac{V_1}{T_1}\right) \times T_2$$

$$= \frac{2.58\ dm^3}{288\ K} \times 311\ K$$

V_2 = 2.78 dm³ i.e. volume increased from 2.58 dm³ to 2.78 dm³.

45. A sample of gas has a volume of 8.5 dm³ at an unknown temperature. When the sample is submerged in ice water at 0°C, its volume gets reduced to 6.37 dm³. What is its initial temperature?

$V_1 = 8.5\ dm^3$ $V_2 = 6.37\ dm^3$

$T_1 = ?$ $T_2 = 0°C = 273\ K$

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

$$V_1 \times \left(\frac{T_2}{V_2}\right) = T_1$$

$$T_1 = 8.5\ dm^3 \times \frac{273\ K}{6.37\ dm^3}$$

T_1 = 364.28 K

46. Of two samples of nitrogen gas, sample A contains 1.5 moles of nitrogen in a vessel of volume of 37.6 dm³ at 298K, and the sample B is in a vessel of volume 16.5 dm³ at 298 K. Calculate the number of moles in sample B. [CRT-22]

$n_A = 1.5$ mol $n_B = ?$ $V_A = 37.6\ dm^3$ $V_B = 16.5\ dm^3$ (T = 298 K constant)

$$\frac{V_A}{n_A} = \frac{V_B}{n_B}$$

$$n_A = \left(\frac{n_A}{V_A}\right) V_B$$

$$= \frac{1.5\ mol}{37.6\ dm^3} \times 16.5\ dm^3$$

= 0.66 mol.

47. Sulphur hexafluoride is a colourless, odourless gas; calculate the pressure exerted by 1.82 moles of the gas in a steel vessel of volume 5.43 dm³ at 69.5°C, assuming ideal gas behaviour.

n = 1.82 mole V = 5.43 dm3 T = 69.5 + 273 = 342.5 P = ?

PV = nRT Rearrange to get, $P = \frac{nRT}{V}$

UNIT – VI – GASEOUS STATE

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

$$P = \frac{1.82\ mol \times 0.821\ dm^3\ atm\ mol^{-1}K^{-1} \times 342.5\ K}{5.43\ dm^3}$$

P = 94.25 atm.

48. Argon is an inert gas used in light bulbs to retard the vapourlzation of the tungsten filament. A certain light bulb containing argon at 1.2 atm and 18°C is heated to 85°C at constant volume. Calculate its final pressure in atm.

P_1 = 1.2 atm T_1 = 18°C + 273 = 291 K T_2 = 85°C + 273 = 358 K P_2 = ?

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad P_2 = \frac{P_1}{T_1} \times T_2 \qquad = \frac{1.2\ atm}{291\ K} \times 358\ K$$

= 148 atm.

49. A small bubble rises from the bottom of a lake, where the temperature and pressure are 6°C and 4 atm. to the water surface, where the temperature is 25°C and pressure is 1 atm. Calculate the final volume in (ml) of the bubble, if its initial volume is 1.5 ml.

T_1 = 6°C + 273 = 279 K P_1 = 4 atm V_1 = 1.5m T_2 = 25°C + 273 = 298 K

P_2 = 1 atm V_2 = ?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2} \qquad = \frac{4\ atm \times 1.5\ ml \times 298\ K}{279\ K \times 1\ atm}$$

V_2 = 6.41 mol.

50. Hydrochloric acid is treated with a metal to produce hydrogen gas. Suppose a student carries out this reaction and collects a volume of 154.4 x 10^{-3} dm^3 of a gas at a pressure of 742 mm of Hg at a temperature of 298 K. What mass of hydrogen gas (in mg) did the student collect?

V = 154.4 x $10^{-3}dm^3$; P = 742 mm of Hg; T = 298 K; m = ?

$$n = \frac{PV}{RT} = \frac{742\ mm\ Hg \times 154.4 \times 10^{-3}\ L}{62\ mm\ Hg\ L\ K^{-1}\ mol^{-1} \times 298\ K} = 0.006\ mol$$

$$n = \frac{Mass}{Molar\ Mass}$$

Mass = n x Molar mass = 0.006 x 2.016 = 0.0121 g = **12.1 mg**.

51. It takes 192 sec for an unknown gas to diffuse through a porous wall and 84 sec for N_2 gas to effuse at the same temperature and pressure. What is the molar mass of the unknown gas? [QY-19]

$$\frac{\gamma_{unknown}}{\gamma_{N_2}} = \frac{t_{N_2}}{t_{unknown}} = \sqrt{\frac{m_{N_2}}{m_{unknown}}} \qquad \frac{84 sec}{192 sec} = \sqrt{\frac{14g\ mol^{-1}}{m_{unknown}}} = \frac{14g\ mol^{-1}}{m_{unknown}}$$

$$m_{unknown} = 14g\ mol^{-1} \times \left(\frac{192\ sec}{84\ sec}\right)^2 = \mathbf{73.14g\ mol^{-1}}$$

52. A tank contains a mixture of 52.5 g of oxygen and 65.1 g of CO_2 at 300 K the total pressure in the tank is 9.21 atm. Calculate the partial pressure (in atm.) of each gas in the mixture.

m_{O2} = 52.5 g; P_{O2} = ? ; m_{CO2} = 65.1 g; P_{CO2} = ? ; T = 300 K; P = 9.21 atm

P_{O2} = X_{O2} x total pressure

$$X_{O_2} = \frac{n_{O_2}}{n_{O_2} + n_{CO_2}} \qquad n_{O_2} = \frac{Mass\ of\ O_2}{Molar\ mass\ of\ O_2} = \frac{52.5\ g}{32\ g\ mol^{-1}} = 1.64\ mol$$

$$n_{CO_2} = \frac{Mass\ of\ CO_2}{Molar\ mass\ of\ CO_2} = \frac{65.1\ g}{44\ g\ mol^{-1}} = 1.48\ mol$$

UNIT – VI – GASEOUS STATE

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

$$X_{O_2} = \frac{n_{O_2}}{n_{O_2} + n_{CO_2}} = \frac{1.64}{3.12} = 0.53 \qquad X_{CO_2} = \frac{n_{CO_2}}{n_{O_2} + n_{CO_2}} = \frac{1.48}{3.12} = 0.47$$

$P_{O2} = X_{O2}$ x Total pressure = 0.53 x 9.21 atm = **4.88 atm**

$P_{CO2} = X_{CO2}$ x Total pressure = 0.47 x 9.21 atm = **4.33 atm**

53. A combustible gas Is stored in a metal tank at a pressure of 2.98 atm at 25°C. The tank can withstand a maximum pressure of 12 atm after which it will explode. The building in which the tank has been stored catches fire. Now predict whether the tank will blow up first or start melting? (Melting point of the metal = 1100 K).

Pressure of the gas in the tank at its melting point

T_1 = 298 K; P_1 = 2.98 atm; T_2 = 1100K; P_2 = ?

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \quad \text{rearrange to get, } P_2 = \frac{P_1}{T_1} \times T_2 = \frac{2.98 atm}{298K} \times 1100K = \mathbf{11\ atm}$$

At 1100 K, the pressure of the gas inside the tank will become 11 atm. Given that tank can withstand a maximum pressure of 12 atm, the tank will start melting first.

EVALUATE YOURSELF

1. **Freon-12, the compound widely used in the refrigerator system as coolant causes depletion of ozone layer. Now it has been replaced by eco-friendly compounds. Consider 1.5 dm³ sample of gaseous Freon at a pressure of 0.3 atm. If the pressure is changed to 1.2 atm. at a constant temperature, what will be the volume of the gas increased or decreased?**

Volume of freon (V_1) = 1.5 dm^3; Pressure (P_1) = 0.3 atm; 'T' is constant

P_2 = 1.2 atm; V_2 = ? ; $\therefore P_1V_1 = P_2V_2$

$$V_2 = \frac{P_1V_1}{P_2} = \frac{0.3\ \text{atm} \times 1.5\ dm^3}{1.2\ \text{atm}} = \mathbf{0.375\ dm^3}$$

Volume decreased from 1.5 dm^3 to 0.375 dm^3

2. **Inside a certain automobile engine, the volume of air in a cylinder is 0.375 dm³, when the pressure is 1.05 atm. When the gas is compressed to a volume of 0.125 dm³ at the same temperature, what is the pressure of the compressed air?**

V_1 = 0.375dm^3; V_2 = 0.125 dm^3; P_1 = 1.05 atm; P_2 = ? ; T – Constant

$$P_1V_1 = P_2V_2 \quad \therefore P_2 = \frac{P_1 V_1}{V_2} = \frac{10.5 \times 0.375}{0.125} = \mathbf{3.15\ atm.}$$

3. **A sample of gas has a volume of 3.8 dm3 at an unknown temperature. When the sample is submerged in ice water at 0°C, its volume gets reduced to 2.27 dm3. What is its initial temperature?**

V_1 = 3.8 dm^3; T_2 = 0°C = 273K; T_1 = ? ; V_2 = 2.27dm^3

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \quad T_1 = \left(\frac{T_2}{V_2}\right) \times V_1 = \frac{273\ K}{2.27\ dm^3} \times 3.8\ dm^3 \quad \mathbf{T_1 = 457\ K}$$

4. **An athlete in a kinesiology research study has his lung volume of 7.05 dm³ during a deep inhalation. At this volume the lungs contain 0.312 mole of air. During exhalation the volume of his Jung decreases to 2.35 dm³. How many moles of air does the athlete exhale during exhalation? (assume pressure and temperature remain constant)**

V_1 = 7.05 dm^3; V_2 = 2.35 dm^3; n_1 = 0.312 mol; n_1 = ? ; 'P' and 'T' are constant

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \quad n_2 = \left(\frac{n_1}{V_1}\right) \times V_2$$

$$n_2 = \frac{0.312\ mol}{7.05\ dm^3} \times 2.35\ dm^3$$

$n_2 = 0.104$ mol

Number of moles exhaled = 0.312 – 0.104 = **0.208 moles**

5. **A small bubble rises from the bottom of a lake, where the temperature and pressure are 8°C and 6.4 atm. to the water surface, where the temperature is 25°C and pressure is 1 atm. Calculate the final volume in (ml) of the bubble, if its initial volume is 2.1 ml.**

T_1 = 8°C = 8 + 273 = 281K; P_1 = 6.4atm; V_1 = 2.1 mol; T_2 = 25°C = 25 + 273 =298K

P_2 = 1 atm; V_2 = ?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad V_2 = \left(\frac{P_1V_1}{T_1}\right) \times \frac{T_2}{P_2} = \frac{6.4\ atm \times 2.1\ mol}{281\ K} \times \frac{298\ K}{1\ atm}$$ **= 14.25 ml**

6. **(a) A mixture of He and O_2 were used in the 'air' tanks of underwater divers for deep dives. For a particular dive 12 dm³ of O_2 at 298 K, I atm. and 46 dm3 of He, at 298 K, 1 aim. were both pumped into a 5 dm³ tank. Calculate the partial pressure of each gas and the total pressure in the tank at 298 K**

V_{O_2} = 12 dm³, V_{He} = 46 dm³; T = 298, P = 1atm } Constant

V_{total} = 5 dm³

$P_{O2} = X_{O2} \times P_{total}$

$$X_{O_2} = \frac{n_{O_2}}{n_{O_2} + n_{He}} = \frac{0.54}{0.54 + 2.05} = \frac{0.54}{2.59} = 0.21$$

$$n_{O_2} = \frac{1\ mol}{22.4\ L} \times 12\ L$$

n_{O_2} = 0.54 mol

$$n_{He} = \frac{1\ mol}{22.4\ L} \times 46\ L$$

n_{He} = 2.05 mol

$P_{total} \times V_{total}$ = 1 atm × 22.4 l

$$\therefore P_{total} = \frac{1\ atm \times 22.4\ l}{5\ l}$$

P_{total} = 4.48 atm

$\therefore P_{O_2}$ = 0.21 × 4.48 atm = 0.94 atm

$\therefore P_{He} = X_{He} \times P_{total}$

$$X_{He} = \frac{n_{He}}{n_{O_2} + n_{He}} = \frac{2.05}{0.54 + 2.05}$$

$$X_{He} = \frac{2.05}{2.59} = 0.79$$

P_{He} = 3.54 atm

(b) A sample of solid $KClO_3$ (potassium chlorate) was heated in a test tube to obtain O_2 according to the reaction $2KClO_3 \rightarrow 2KCl(s) + 3O_2$ The oxygen gas was collected by downward displacement of water at 295 K. The total pressure of the mixture is 772 mm of Hg. The vapour pressure of water is 26.7 mm of Hg at 300K. What is the partial pressure of the oxygen gas?

$2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$

P_{total} = 772 mm Hg; P_{H2O} = 26.7 mm Hg;

$P_{total} = P_{O2} + P_{H2O}$; rearrange to get, $P_{O2} = P_{total} - P_{H2O}$

P_1 = 26.7 mm Hg; T_1 = 300 K; T_2 = 295 K; P_2 = ?

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad P_2 = \left(\frac{P_1}{T_1}\right)T_2 = \frac{26.7\ mm\ Hg}{300\ K} \times 295\ K$$

P_2 = 26.26 mm Hg $\therefore P_{O2}$ = 772 – 26.26 **= 745.74 mm Hg**

7. **A flammable hydrocarbon gas of particular volume is found to diffuse through a small hole in 1.5 minutes. Under the same conditions of temperature and pressure an equal volume of bromine vapour takes 4.73 min to diffuse through the same hole. Calculate**

UNIT – VI – GASEOUS STATE

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

the molar mass of the unknown gas and suggest what this gas might be, (Given that molar mass of bromine = 159.8 g/ mole)

t_1 = 1.5 minutes $(gas)_{hydrocarbon}$ t_2 = 4.73 minutes $(gas)_{Bromine}$

$$\frac{\gamma_{Hydrocarbon}}{\gamma_{Bromine}} = \frac{t_{Bromine}}{t_{Hydrocarbon}}$$

(∵ Volume constant)

$$= \frac{4.73 \text{ minutes}}{1.5 \text{ minutes}}$$

$$= 3.15$$

$$\frac{\gamma_{Hydrocarbon}}{\gamma_{Bromine}} = \sqrt{\frac{m_{Bromine}}{m_{Hydrocarbon}}}$$

$$3.15 = \sqrt{\frac{159.8 \text{ g mol}^{-1}}{m_{Hydrocarbon}}}$$

$$= 3.15$$

Squaring on both sides and rearranging,

$$m_{Hydrocarbon} = \frac{159.8 \text{ g mol}^{-1}}{(3.15)^2}$$

$$m_{Hydrocarbon} = 16.1 \text{ g mol}^{-1}$$

n (12) + (2n + 2) 1 = 16 (general formula for hydrocarbon C_nH_{2n+2})

12n + 2n + 2 = 16 14n = 16 – 2 So, 14n = 14 ∴ **n = 1**

The hydrocarbon is $\mathbf{C_1H_{2(1)+2} = CH_4}$

8. **Critical temperature of H_2O, NH_3 and CO_2 are 647.4, 405.5 and 304.2 K, respectively. When we start cooling from a temperature of 700 K which will liquefy first and which will liquefy finally?**

Critical temperature of a gas is defined as the temperature above which it cannot be liquefied even at high pressures.

∴ When cooling starts from 700 K, H_2O will liquefied first, then followed by ammonia and finally carbon dioxide will liquefied.

GOVERNMENT QUESTIONS AND ANSWERS

1. Distinguish Real and Ideal gas. [HY-18]

	Ideal Gas	Real Gas
1	Ideal gases obey all gas laws under all conditions of temperature and pressure	Real obey gas law only at low pressures and high temperature
2	The volume occupied by the molecules is negligible as compared to the total volume occupied by the gas	The volume occupied by the molecules is not negligible as compared to the total volume of the gas
3	The force of attraction among the molecules is negligible	The force of attraction is not negligible at all temperatures and pressures.

2. Give the expression of critical constants. [HY-18]

The critical constant can be calculated using the values of van der waals constant of a gas and vice versa.

$$a = 3 V_C^2 P_C \quad \text{and} \quad b = \frac{V_C}{3}$$

3. What is the density of N_2 gas at 227°C and 5.00atm pressure? (R=0.082 $LatmK^{-1}mol^{-1}$) [QY-19]

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$= \frac{m}{\left(\frac{nRT}{P}\right)} = \left(\frac{m}{n}\right)\frac{P}{RT}$$

$$= \text{Molar mass} \times \frac{P}{RT}$$

$$= \frac{28 \text{ g mol}^{-1} \times 5 \text{ atm}}{0.082 \text{ L atm K}^{-1} \text{mol}^{-1} \times 500 \text{ K}}$$

$$= 3.41 \text{g L}^{-1}$$

UNIT – VI – GASEOUS STATE

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

4. What is inversion temperature? [JUN-19]

This effect is observed only below a certain temperature, which is a characteristic one for each gas. This temperature below which a gas obeys Joule-Thomson effect is called **inversion temperature (T_i)**. This value is given using van der waals constants a and b.

$$T_i = \frac{2a}{Rb}$$

5. State Dalton's law of partial pressure. [QY-19, MAY-22, MAR-24]

John Dalton stated that "the total pressure of a mixture of non-reacting gases is the sum of partial pressures of the gases present in the mixture" where the partial pressure of a component gas is the pressure that it would exert if it were present alone in the same volume and temperature. This is known as Dalton's law of partial pressures.

i.e., for a mixture containing three gases 1, 2 and 3 with partial pressures p_1, p_2 and p_3 in a container with volume V, the total pressure P_{total} will be give by $P_{total} = p_1 + p_2 + p_3$

6. Write the mathematical formula for compressibility factor 'Z'. [SEP-20]

The deviation of real gases from ideal behaviour is measured in terms of a ratio of PV to nRT. This is termed as compressibility factor. Mathematically,

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

For ideal gases PV = nRT, hence the compressibility factor, Z = 1 at all temperatures and pressures.

7. State the following laws: Gay-Lussac's law. [CRT-22]

At constant volume, the pressure of a fixed amount of a gas is directly proportional to the temperature. $P \propto T$ at constant volume (or) $= \frac{P_1}{T_1} = \frac{P_2}{T_2}$

8. At identical temperature and pressure, the rate of diffusion of hydrogen gas is 3 3 times that of a hydrocarbon having molecular formula C_nH_{2n-2}. What is the value of n? [GMQ-18]

$$\frac{\gamma_{H_2}}{\gamma_{C_nH_{2n+2}}} = \sqrt{\frac{M_{C_nH_{2n+2}}}{M_{H_2}}} \qquad 3\sqrt{3} = \sqrt{\frac{M_{C_nH_{2n+2}}}{2}}$$

Squaring on both sides and rearranging $27 \times 2 = M_{C_nH_{2n-2}}$

54 = n(12) + (2n-2)(1) = 12n + 2n -2 = 14n – 2

n = (54+2)/14 = 56/14 = **4**

9. State Boyle's law and Charles law. [QY-18]

Boyle's law: At a given temperature the volume occupied by a fixed mass of a gas is inversely proportional to its pressure. Mathematically, the Boyle's law can be written as $V \propto \frac{1}{P}$

Charles law: A fixed mass of a gas at constant pressure, the volume is directly proportional to its temperature (K). Mathematically it can be represented as (at constant P and n) V = kT

10. 0.6% solution of urea and 1.8% solution containing a solute (A) are isotonic with each other. Calculate the molecular weight of the solute (A). [HY-18]

x = 0.6%; y = 1.8%; M_x = urea (60g mol-1); M_y = ?

$$\frac{x}{100} \times \frac{1000}{M_x} = \frac{y}{100} \times \frac{1000}{M_y} = \frac{x}{M_x} = \frac{y}{M_y} \qquad M_y = \frac{y \times M_x}{x} = \frac{1.8 \times 60g\ mol^{-1}}{0.6} = \mathbf{180g\ mol^{-1}}$$

11. State Diffusion law. [MAR-19]

When two non -reactive gases are allowed to mix, the gas molecules migrate from region of higher concentration to a region of lower concentration. This property of gas which involves the movement of the gas molecules through another gases is called diffusion.

UNIT – VI – GASEOUS STATE

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

12. Name the different methods of liquefaction of gases. [SEP-20]

- In **Linde's method,** Joule-Thomson effect is used to get liquid air or any other gas.
- In **Claude's process,** the gas is allowed to perform mechanical work in addition to Joule-Thomson effect so that more cooling is produced.
- In **Adiabatic process,** cooling is produced by removing the magnetic property of magnetic material such as gadolinium sulphate. By this method, a temperature of 10-4 K i.e. as low as 0 K can be achieved.

13. Define Graham's law of diffusion. [FMT-18, QY-19]

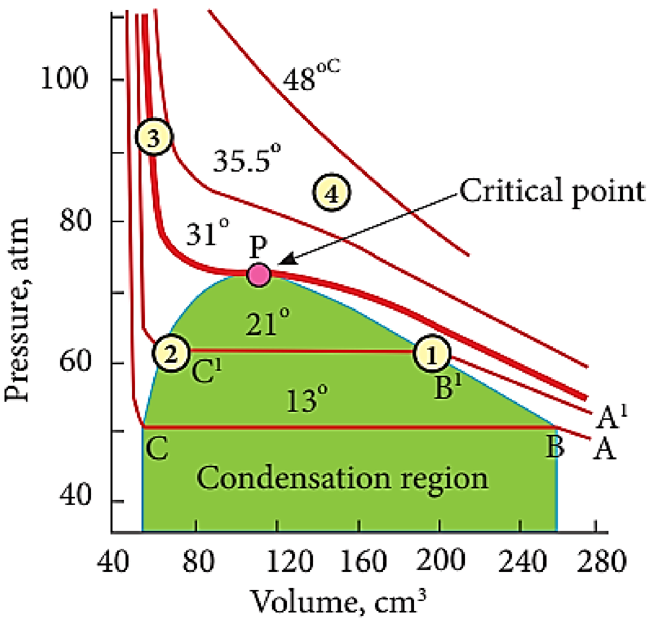
- Gases have a tendency to occupy all the available space. When two non-reactive gases are allowed to mix, the gas molecules migrate from region of higher concentration to a region of lower concentration. This property of gas which involves the movement of the gas molecules through another gases is called diffusion. Effusion is another process in which a gas escapes from a container The rate of diffusion or effusion is inversely proportional to the square root of molar mass. This statement is called Graham's law of diffusion/effusion.
- Mathematically rate of diffusion M, $\propto \frac{1}{\sqrt{M}}$
- Otherwise $\frac{r_A}{r_B} = \sqrt{\frac{M_B}{M_A}}$
- When diffusing gases are at different pressures (P_A, P_B),

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

- where r_A and r_B are the rates of diffusion of A and B and the M_A and M_B are their respective molar masses.

14. Explain the pressure – volume isotherms of Carbon dioxide Andrew's isotherm. (or) Explain Andrew's Experimental isotherms of CO_2 gas. [HY-18]

- Thomas Andrew gave the first complete data on pressure-volume temperature of a substance in the gaseous and liquid states. He plotted isotherms of carbon dioxide at different temperatures which is shown in Figure. From the plots we can infer the following.



- At low temperature isotherms, for example, at 13°C as the pressure increases, the volume decreases along AB and is a gas until the point B is reached.
- At B, a liquid separates along the line BC, both the liquid and gas co-exist and the pressure remains constant.
- At C, the gas is completely converted into liquid. If the pressure is higher than at C, only the liquid is compressed so, there is no significant change in the volume.
- The successive isotherms shows similar trend with the shorter flat region. i.e. The volume range in which the liquid and gas coexist becomes shorter.
- At the temperature of 31.1°C the length of the shorter portion is reduced to zero at point P.

- In other words, the CO_2 gas is liquefied completely at this point. This temperature is known as the liquefaction temperature or critical temperature of CO_2. At this point the pressure is 73 atm.
- Above this temperature CO_2 remains as a gas at all pressure values.

15.Derive Ideal gas equation [HY,JUN-19, CRT-22, MAR-23]

Boyle's law $V \alpha \frac{1}{P}$ Charles law $V \alpha T$ Avogadro's law $V \alpha n$

We can combine these equations into the following general equation that describes the physical behaviour of all gases.

$V \alpha \frac{nT}{P}$ $V = \frac{nRT}{P}$

where, R is the proportionality constant called universal gas constant.

16.(i) What is compressibility factor Z? [QY-18,19]

The deviation of real gases from ideal behaviour is measured in terms of a ratio of PV to nRT. This is termed as compressibility factor. Mathematically,

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

For ideal gases PV = nRT, hence the compressibility factor, Z = 1 at all temperatures and pressures.

(ii) State Joule Thomson effect. [MAR-24]

This phenomenon of lowering of temperature when a gas is made to expand adiabatically from a region of high pressure into a region of low pressure is known as Joule-Thomson effect.

17.What is Boyle's temperature? What happens to real gases above and below the Boyle's temperature? [JUN-19]

- The temperature at which a real gas obeys ideal gas law over an appreciable range of pressure is called Boyle temperature or Boyle point.
- The Boyle point varies with the nature of the gas. Above the Boyle point, for real gases, Z > 1, ie., the real gases show positive deviation.
- Below the Boyle point, the real gases first show a decrease for Z, reaches a minimum and then increases with the increase in pressure.
- So, it is clear that at low pressure and at high temperature, the real gases behave as ideal gases.