Unit 6 GASEOUS STATE

CHAPTER MAP

Gaseous State

IDEAL GASES

Obey following gas laws under all conditions

1. Boyle's law $P \propto \frac{1}{V}$ (T, n constant)
2. Charles' law – $V \propto T$, (P, n constant)
3. Gay Lussac – $P \propto T$ (V, n constant)
4. Avogadro's Hypothesis – $V \propto n$ (T, P constant)
5. Ideal gas equation. PV = nRT

REAL GASES

obey Van der Waals equation

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

$\downarrow$

Critical constant

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

and $V_C = 3b$

Gas

- Diffusion → Graham's Law of diffusion
- Critical phenomenon → Critical temperature Critical volume Critical pressure Critical
- Liquefaction of gases → Joule-Thomson effect

Important formula

1. Pressure = $\frac{Force(N)}{Area(m^2)}$
2. Boyle's law = PV = K (or) $P_1V_1 = P_2V_2 = K$
3. Charles' law = $\frac{V}{T}$ = Constant (or) V = KT (or) $\frac{V_1}{T_1}=\frac{V_2}{T_2}=K$
4. Gay-Lussac's law = P $\propto$ T (or) $\frac{P}{T}$ = K (or) $\frac{V_1}{T_1}=\frac{V_2}{T_2}=K$
5. Avogadro's hypothesis = V $\propto$ n (or) $\frac{V_1}{n_1}=\frac{V_2}{n_2}$ = Constant
6. Ideal gas equation = PV = nRT
7. Dalton's law of Partial pressure : $P_{total} = p_1 + p_2 + p_3$ …….
8. $P_{dry\ gas} = P_{total} - P_{water\ vapour}$
9. Graham's law of Diffusion : $\frac{r_A}{r_B}=\sqrt{\frac{M_B}{M_A}}$
10. Compressibility factor = Z = $\frac{PV}{nRT}(or)\frac{V_{real}}{V_{ideal}}$
11. Van der Waals equation of state: $\left(P+\frac{an^2}{V^2}\right)(V-nb)=nRT$
12. Critical volume V_C = 3b
13. Critical pressure $P_C = \frac{a}{27b^2}$
14. Critical temperature $T_C = \frac{8a}{27Rb}$
15. Inversion temperature $T_i = \frac{2a}{Rb}$

- **Gases at STP –** H_2, N_2, O_2, F_2, Cl_2, O_3, He, Ne, Ar, Kr, Xe and Rn (Only 11 elements).
- **The Earth –** The Earth is surrounded by a atmosphere of air whose composition is 78% Nitrogen, 21% Oxygen and 1% other gases.
- **Oxygen –** It is highly essential for our survival.
- **Hydrogen cyanide (HCN) –** Deadly poison
- **Carbon monoxide (CO) –** Highly toxic
- **NO_2 and SO_2 –** less toxic
- **Chemically inert gases –** He, Ne, Ar, Kr, Xe and Rn.
- **Gas –** A substance is normally in a gaseous state at ordinary temperature and pressure.
- **Vapour –** The gaseous form of any substance that is a liquid or solid at NTP.
- **Pressure –** It is defined as the force exerted by a gas on unit area of the wall. Pressure = $\frac{Force}{area} = \frac{F}{a}$
- **Unit of pressure (Pascal) –** 1 Pascal = 1 Nm^{-2}, where 1 N = 1 Kg ms^{-2}. Other units of pressure are Bar, atmosphere, Torr, mm of Hg.
- **Atmospheric pressure –** The force exerted on a unit area of earth by the column of air above it is called atmospheric pressure.
- **1 atm –** 760 mm Hg
- **Boyle's law –** At a given temperature, the volume occupied by a fixed mass of a gas is inversely proportional to its pressure.

  $V \propto \frac{1}{P}$ at constant T (or)

  $PV = K_1$ at constant T (or)

  $P_1V_1 = P_2V_2 = K_1$
- **Charles' law –** For a fixed mass of a gas at constant pressure, the volume is directly proportional to temperature (K).

  $V \propto T$ and constant P and n ; $\frac{V}{T}$ = Constant
- **Absolute zero :** -273.15°C.
- **Gay-Lussac's law –** At constant volume, the pressure of a fixed mass of gas is directly proportional to temperature. $P \propto T$ at constant V ; $\frac{P}{T}$ = Constant.
- **Avogadro's hypothesis –** Equal volumes of all gases under the same condition of temperature and pressure contain equal number of molecules.

  $V \propto n$ (or) $\frac{V_1}{n_1} = \frac{V_2}{n_2}$ = Constant

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- **Ideal gas equation** – PV = nRT where R is universal gas constant.
- **Values of R** –

  R = 0.082057 dm^3 atm mol^{-1} K^{-1}

  R = 8.314 x Pa m^3 K^{-1} mol^{-1}

  R = 8.314 x 10^{-2} bar dm^3 K^{-1} mol^{-1}

  R = 8.314 J K^{-1} mol^{-1}
- **Dalton's law of partial pressures** – It states that the total pressure of a mixture of gases is the sum of partial pressures of the gases present.

  $P_{total} = p_1 + p_2 + p_3$ …….
- **Graham's law of Diffusion** – The rate of effusion or diffusion is inversely proportional to the square of molecular mass of a gas through an orifice.

  $\frac{r_A}{r_B} = \sqrt{\frac{M_B}{M_A}}$
- **Ideal gases** – Gases that obey ideal gas equation PV = nRT are ideal gases.
- **Real gases** – Gases that do not obey the ideal gas equation PV = nRT are real gases. For them either PV > nRT or PV < nRT
- **Van der Waals equation of state** –

  $\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$. Where a and b are Van der Waals constant.
- **Compression factor (Z)** –

  It is the ratio of PV to nRT. Z = $\frac{PV}{nRT}$.

  For ideal gases Z = 1 and for real gases Z > 1 or Z < 1. Z = $\frac{V_{real}}{V_{ideal}}$
- **Critical constants** –

  Critical Volume V_C = 3b

  Critical Pressure $P_C = \frac{a}{27b^2}$

  Critical Temperature $T_C = \frac{8a}{27Rb}$
- **Critical temperature of CO_2** – 303.98 K
- **Critical Temperature -** T_C is defined as the temperature below which a gas can be liquefied by the application of pressure.
- **Critical Pressure -** P_C is the pressure required to liquefy a gas at its critical temperature.

❖ **Critical Volume –** V_C is the volume occupied by one mole of a gas at its critical temperature and critical pressure.

❖ **Joule Thomson effect –** The phenomenon of producing lowering of temperature when a gas is made to expand adiabatically from a region of high pressure into a region of low pressure.

❖ **Inversion temperature (T_i) –** The temperature below which a gas obey Joule Thomson effect is called inversion temperature. $T_i = \frac{2a}{Rb}$

Choose the correct Answer:

1. Gases deviate from ideal behavior at high pressure. Which of the following statement(s) is correct for non-ideality?

a) at high pressure the collision between the gas molecule become enormous
b) at high pressure the gas molecules move only in one direction
c) at high pressure, the volume of gas become insignificant
d) at high pressure the intermolecular interactions become significant

2. Rate of diffusion of a gas is

a) directly proportional to its density
b) directly proportional to its molecular weight
c) directly proportional to its square root of its molecular weight
d) inversely proportional to the square root of its molecular weight

3. Which of the following is the correct expression for the equation of state of van der Waals gas?

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

c) $\boldsymbol{\left[P + \frac{an^2}{v^2}\right](V - nb) = nRT}$ (d) $\left[P + \frac{n^2a^2}{v^2}\right](V - nb) = nRT$

4. When an ideal gas undergoes unrestrained expansion, no cooling occurs because the molecules

a) are above inversion temperature **b) exert no attractive forces on each other** c) do work equal to the loss in kinetic energy d) collide without loss of energy

5. Equal weights of methane and oxygen are mixed in an empty container at 298 K. The fraction of total pressure exerted by oxygen is

(a) 1/3 (b) ½ (c) 2/3 (d) 1/3 × 273 × 298

6. The temperatures at which real gases obey the ideal gas laws over a wide range of pressure is called

a) Critical temperature **b) Boyle temperature**

c) Inversion temperature d) Reduced temperature

7. In a closed room of 1000 m^3 a perfume bottle is opened up. The room develops a smell. This is due to which property of gases?

a) Viscosity b) Density **c) Diffusion** d) None

8. A bottle of ammonia and a bottle of HCl connected through a long tube are opened simultaneously at both ends. The white ammonium chloride ring first formed will be

a) At the center of the tube **b) Near the hydrogen chloride bottle**

c) Near the ammonia bottle d) Throughout the length of the tube

9. The value of universal gas constant depends upon

a) Temperature of the gas b) Volume of the gas

c) Number of moles of the gas **d) units of Pressure and volume.**

10. The value of the gas constant R is

a) 0.082 dm^3*atm*. b) 0.987 cal mol^{-1} K^{-1} **c) 8.3 J $mol^{-1}K^{-1}$** d) 8 erg $mol^{-1}K^{-1}$

11. Use of hot air balloon in sports at meteorological observation is an application of

a) Boyle's law b) Newton's law c) Kelvin's law d) Brown's law

12. The table indicates the value of van der Waals constant 'a' in $(dm^3)^2$*atm*. mol^{-2}

Gas	O_2	N_2	NH_3	CH_4
A	1.360	1.390	4.170	2.253

The gas which can be most easily liquefied is

a) O_2 b) N_2 **c) NH_3** d) CH_4

13. Consider the following statements

i) Atmospheric pressure is less at the top of a mountain than at sea level

ii) Gases are much more compressible than solids or liquids

iii) When the atmospheric pressure increases the height of the mercury column rises

Select the correct statement

a) I and II b) II and III c) I and III **d) I, II and III**

14. Compressibility factor for CO_2 at 400 K and 71.0 bar is 0.8697. The molar volume of CO_2 under these conditions is

a) 22.04 dm^3 b) 2.24 dm^3 **c) 0.41 dm^3** d) 19.5dm^3

15. If temperature and volume of an ideal gas is increased to twice its values, the initial pressure P becomes

a) 4P b) 2P **c) P** d) 3P

16. 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 ?

a) 8 **b) 4** c) 3 d) 1

17. Equal moles of hydrogen and oxygen gases are placed in a container, with a pin-hole through which both can escape what fraction of oxygen escapes in the time required for one-half of the hydrogen to escape.

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

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18. The variation of volume V, with temperature T, keeping pressure constant is called the coefficient of thermal expansion ie $\alpha = \frac{1}{v}\left(\frac{\partial V}{\partial T}\right)_P$. For an ideal gas α is equal to

a) T **b) 1/T** c) P d) none of these

19. Four gases P, Q, R and S have almost same values of 'b' but their 'a' values (a, b are Vander Waals Constants) are in the order Q < R < S < P. At a particular temperature, among the four gases the most easily liquefiable one is

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

20. Maximum deviation from ideal gas is expected from

a) $CH_{4\,(g)}$ **b) $NH_{3\,(g)}$** c) $H_{2\,(g)}$ d) $N_{2\,(g)}$

21. The units of Vander Waals constants 'b' and 'a' respectively

a) mol L^{-1} and L atm^2 mol^{-1} b) mol L and L atm mol^2

c) mol^{-1}L and L^2 atm mol^{-2} d) none of these

22. Assertion : Critical temperature of CO_2 is 304K, it can be liquefied above 304K.

Reason : For a given mass of gas, volume is to directly proportional to pressure at constant temperature

a) both assertion and reason are true and reason is the correct explanation of assertion

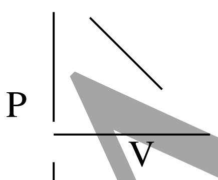
b) both assertion and reason are true but reason is not the correct explanation of assertion

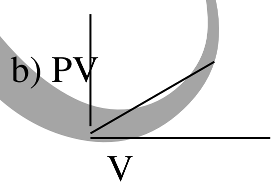
c) assertion is true but reason is false **d)both assertion and reason are false**

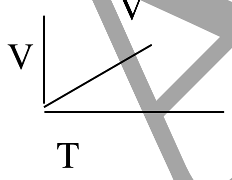
23. What is the density of N_2 gas at 227°C and 5.00 atm pressure? (R = 0.082 L atm K^{-1} mol^{-1})

a) 1.40 g/L b) 2.81 g/L **c) 3.41 g/L** d) 0.29 g/L

24. Which of the following diagrams correctly describes the behaviour of a fixed mass of an ideal gas? (T is measured in K)

a)


b)


c)


d) all the above

25. 25g of each of the following gases are taken at 27°C and 600 mm Hg pressure. Which of these will have the least volume ?

a) HBr b) HCl c) HF **d) HI**

Answer these questions briefly

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, the Boyle's law can be written as

$$V \propto \frac{1}{P} \quad \text{------ (1)}$$

(T and n are fixed, T-temperature, n- number of moles)

$$V = k \times \frac{1}{P} \quad \text{------ (2)}$$

k – proportionality constant When we rearrange equation (2)

PV = k at constant temperature and mass

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

P α T at constant volume.

(i) Pressure in well inflated tyre is almost constant but when temperature increases in summer days it increases the pressure and sometimes tyres may burst.

(ii) **Guns and other firing equipment's** are thrilling examples of Gay Lussac's law. When gun pin strikes, it ignites the gun powder and this increases the temperature which in turn increases the pressure and bullet is fired from the gun.

iii) **Heating a closed aerosol cane.** The increased pressure may cause the container to explode. You don't toss an "empty" can of hair spray into a fire.

iv) **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 the pressure. By sealing the bottle with egg, the fire goes on, dropping the temperature and pressure. This causes the egg to be sucked into the bottle.

28. Give the mathematical expression that relates gas volume and moles. Describe in words what the mathematical expression means.

- The Mathematical expression between the volume of gas and number of moles is **V α n**
  $V_1/n_1 = V_2/n_2$ = constant
- **where** V_1 & n_1 are the volume and number of moles of a gas,
  V_2 & n_2 are a different set of values of volume and number of moles of the same gas at same temperature and pressure.
- The above relation is expressed as " **Equal volumes of all gases under the same condition of temperature and pressure contain equal number of molecules".**

29. What are ideal gases? In what way real gases differ from ideal gases.

An ideal gas a gas which obeys the gas laws and ideal gas equation

PV=nRT.

An ideal gas is defined as **"one in which all collisions between atoms or molecules are perfectly elastic forces".**

The difference between ideal gas and real gas is

Ideal gas	**Real gas**
1. It obeys gas laws under all conditions of temperature and pressure	It obeys gas laws only under low pressure and high temperature
2. No gas is ideal	All gases are real

3. Volume occupied by the molecules is negligible as compared to the total volume occupied by the gas.	Volume occupied by the molecules is not negligible as compared to the total volume occupied by the gas.
4. The forces of attraction among the molecules of the gas are negligible.	The forces of attraction among the molecules cannot be neglected at high pressure and low temperature
5. It obeys ideal gas equation PV = nRT	It obeys Van der Waals equation $(P + an^2/V^2)$ (V-nb) = nRT

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

- The van der Waals constant 'a' is a measure of the attractive forces among the molecules of the gas
- Greater the value of 'a' larger the intermolecular force of attraction and the gas can be liquefied.
- Here a=0 means there is intermolecular attraction and the gas **cannot be liquefied.**

31. Suppose there is a tiny sticky area on the wall 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?

- Molecule hitting the tiny sticky area on the wall of the container of gas moves faster as they get closer to adhesive surface, but this effect is not permanent.
- The pressure on the sticky wall is greater than on the ordinary area of walls.

32. Explain the following observations

a) Aerated water bottles are kept under water during summer

- In aerated water bottles the CO_2 is passed through the aqueous solution under pressure.
- The solubility of gas is decreases with increase of temperature. In summer season the temperature is raise the solubility is decreases.
- Due to this will increase very high pressure above the surface of the liquid inside the bottle and bottle will not able to withstand the pressure and bottle may explode.
- To avoid this Aerated water bottles are kept under water during summer.
- As a result, the temperature decrease and solubility of CO_2 is increases in aqueous solution resulting the pressure inside the bottle decreases.

b) Liquid ammonia bottle is cooled before opening the seal

- Liquid ammonia bottle contains the gas under very high pressure. If the bottle is opened, the sudden decrease in pressure will increase the volume of gas.
- As result, the gas is come out the bottle with greater force will cause breakage of bottle and accident.
- The pressure of the gas over liquid ammonia is decreased by dipping H_2O.
- Once it attains the temperature of water, it can be opened so that no gas will come out of the mouth of the tube with force.

c) The tyre of an automobile is inflated to slightly lesser pressure in summer than in winter.

- In summer due to high temperature the air expands and hence to avoid tyre burst, the pressure is kept less.
- As a result, when the vehicle runs and the tyre air gets heated and expands, resulting increased pressure is still kept below the bursting limit.

d) The size of a weather balloon becomes larger and larger as it ascends up into larger altitude.

- According Boyle's law the volume of gas is inversely proportional to the pressure at a given temperature.
- As the weather balloon ascends, the atmospheric pressure is less, pressure of the gas tends to decrease and so volume as well as the size of the balloon increases.

33. Give suitable explanation for the following facts about gases.

a) Gases don't settle at the bottom of a container

- Gases are less denser than solids and liquids. They have negligible intermolecular force of attraction between free particles, so are free to move.
- Hence gases don't settle at bottom of the container.

b) Gases diffuse through all the space available to them

- Gases have the tendency to mix with one another spontaneously and form a homogeneous mixture.
- This is due to the fact that gas particles are mainly in random at very high velocities and there in so much of inter molecular empty space in the volume of any gas.
- This permit them to mix spontaneous and this phenomenon is known as diffusion.

34. Suggest why there is no hydrogen (H_2) in our atmosphere. Why does the moon have no atmosphere?

- Under ordinary conditions on earth, hydrogen exist as diatomic (H_2). Because of its light weight, which enable into escape from earth gravity more easily than heavier gases. So, no hydrogen is there in atmosphere.
- Moon has no atmosphere because the value of acceleration due to gravity (g) on the surface of moon is small. The molecules of atmospheric gases on the surface of the moon have thermal velocities greater than escape velocity.

35. Explain whether a gas approaches ideal behavior or deviates from ideal behaviour if

a) it is compressed to a smaller volume at constant temperature.

When the gas is compressed, there is a decrease in volume and molecules are close to each other and hence inter molecular attraction becomes more and hence it deviates from ideal behavior.

b) the temperature is raised at while keeping the volume constant

- When volume constant, the pressure is directly proportional to the temperature.

- The temperature is raised the pressure is always increases which leads the intermolecular force of attraction between the gas molecules.
- So it deviates from the ideal behavior

c) more gas is introduced into the same volume and at the same temperature.

- If more gas is introduced in the same volume and temperature is constant, more will be the pressure.
- The increase in pressure is always increases which leads the intermolecular force of attraction between the gas molecules.
- So it deviates from the ideal behavior

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.

- These molecules are held together by a weak van der Waals forces.
- The forces of attraction between the molecules with increase in the size of the molecule.
- Br_2 deviate from ideal behavior, since the Br_2 has the biggest size provides maximum attraction between bromine molecules.

37. Distinguish between diffusion and effusion.

Diffusion	**Effusion**
1. The spreading of the molecules of a gas throughout the available space or second substance is called diffusion.	Effusion is the escape of gas molecules through a very small hole.
2. Diffusion refers to the ability of the gases to mix with each other	Effusion is a ability of a gas to travel through a small pin-hole.
3. **Example:** spreading of something such as brown tea liquid spreading through the water in a tea cup.	**Example:** pouring out something like the soap studs bubbling out from a bucket of water.

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

- Aerosols are colloids in which air (gas) is dispensed in liquid. On heating the can, the pressure of the gas increases and it can burst out.
  - Hence they carry clear warning that they should not be heated or kept in near fire.

39. Would it be easier to drink water with a straw on the top of Mount Everest?

- Drinking through a straw is slightly more difficult on the top a mountain.
- This is because the atmospheric pressure and the temperature is low at top mountain.
- When you drink through a straw you are decreasing the pressure in your mouth, so the atmospheric pressure pushes the liquid up the straw.
- On mountain there is less pressure so there is less pressure to push the water into the straw.

40. Write the Van der Waals equation for a real gas. Explain the correction term for pressure and volume.

The Vander Waals equation for a real gas is

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

Pressure Correction:

The pressure of a gas is directly proportional to the force created by the bombardment of molecules on the walls of the container. The speed of a molecule moving towards the wall of the container is reduced by the attractive forces exerted by its neighbours . Hence, the measured gas pressure is lower than the ideal pressure of the gas. Hence, Vander Waals introduced a correction term to this effect.

Inter-molecular forces of attraction

Van der Waals found out the forces of attraction experienced by a molecule near the wall are directly proportional to the square of the density of the gas.

$$p` \alpha \rho^2 \qquad \rho = \frac{n}{V}$$

Where n is the number of moles of gas and V is the volume of the container

$$\Rightarrow P' \alpha \frac{n^2}{V^2}$$

$$\Rightarrow P' = \frac{an^2}{V^2}$$

Where a is proportionality constant and depends on the nature of gas

Therefore, $\mathbf{P_{ideal} = P + \frac{an^2}{V^2}}$

Volume Correction:

As every individual molecule of a gas occupies a certain volume, the actual volume is less than the volume of the container, V. Van der Waals introduced a correction factor V' to this effect. Let us calculate the correction term by considering gas molecules as spheres.

V = excluded volume

Excluded volume for two molecules = $\frac{4}{3}\pi(2r)^3$

$$= 8\left(\frac{4}{3}\pi r^3\right) = 8\,V_m$$

Where V is a volume of a single molecule $= \frac{8V_m}{2} = 4V_m$

Excluded volume for n molecule = $n(4V_m) = nb$

Where b is van der waals constant

Which is equal to $4V_m \Rightarrow V = nb$

$$V_{ideal} = V - nb$$

Replacing the corrected pressure and volume in the ideal gas equation PV = nRT we get the van der Waals equation of state for real gases as below,

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

The constants a and b are van der Waals constants and their values vary with the nature of the gas. It is an approximate formula for the non-ideal gas.

41. Derive the values of van der Waals equation constants in terms of critical constants.

The van der waals equation for n moles is

$$\left(p+\frac{an^2}{V^2}\right)(V-nb)=\mathrm{nRT} \quad \text{------- (1)}$$

For 1 mole

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

From the equation we can derive the values of critical constants Pc, Vc and Tc in terms of a and b, the van der waals constant, on expanding the above equation

$$\mathrm{PV}+\frac{a}{V}-\mathrm{Pb}-\frac{ab}{V^2}-\mathrm{RT}=0 \quad \text{-------- (3)}$$

Multiply equation (3) by $\frac{V^2}{P}$

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

$$V^3+\frac{aV}{P}+-\mathrm{b}V^2-\frac{ab}{V^2}-\frac{RTV^2}{P} \quad \text{------- (4)}$$

When the above equation is rearranged in powers of V.

$$V^3+\left[\frac{RT}{P}+b\right]V^2+\left[\frac{a}{P}\right]\mathrm{V}-\left[\frac{ab}{P}\right]=0 \quad \text{------- (5)}$$

When equation (5) 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 temperatures becomes Pc and Tc respectively

i.e., V = Vc;

V – Vc=0

$(V-Vc)^3=0$ $\quad [(a-b)^3 = a3-3a^2b+3ab^2-b^3]$

$$V^3-3VcV^2+3Vc^2V-Vc^3=0 \quad \text{------- (6)}$$

As equation (5) is identical with equation (6), we can equate the coefficients of V2, V and constant terms in (5) and (6)

$$-3VcV^2=-\left[\frac{RT_c}{P_c}+b\right]V^2$$

$$3Vc=\frac{RT_c}{P_c}+\mathrm{b} \quad \text{--------- (7)}$$

$$3Vc^2=\frac{a}{P_c} \quad \text{-------- (8)}$$

$$3Vc^2=\frac{ab}{P_c} \quad \text{-------(9)}$$

Divide equation (9) by equation (8)

$$\frac{{V_c}^3}{3{V_c}^2}=\frac{ab/P_c}{a\,/P_c}$$

$$\frac{V_c}{3}=\mathrm{b}$$

i.e., $V_c = 3b$ -------- (10)

when equation (10) is substituted in (8)

$$3V_c^2 = \frac{a}{P_c}$$

$$P_c = \frac{a}{3V_c^2} = \frac{a}{3(3b^2)} = \frac{a}{3 \times 9b^2} = \frac{a}{27b^2}$$

$$P_c = \frac{a}{27b^2} \quad \text{------- (11)}$$

Substituting the values of Vc and Pc in equation (7),

$$3V_c = b + \frac{RT_c}{P}$$

$$3(3b) = b + \frac{RT_c}{\left(\frac{a}{27b^2}\right)}$$

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

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

$$T_c = \frac{8ab}{27Rb^2} = \frac{8a}{27Rb} \quad \text{------- (12)}$$

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

$$a = 3V_c^2 P_c \text{ and } b = \frac{V_c}{3}$$

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

- Astronauts must wear space suits since the surface of moon, there is no air to breath and no air pressure.
- Space is extremely cold and filled with dangerous radiation.
- Space suits are specially designed to protect astronauts from the cold, radiation and low pressure in space. It also provide air to breathe.

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

$NH_3 + HCl \rightarrow NH_4Cl$

- The rate of diffusion is inversely proportional to the molecular weight of the gas.
- Lower the molecular weight faster is the diffusion.
- The molar mass of HCl is 36.5 $g.mol^{-1}$ while the molar mass of NH_3 is 17 $g.mol^{-1}$.
- Hence NH_3 diffuses faster than HCl. Hence white fumes appear near HCl.

(Or)

i) When ammonia combines with HCl, NH_4Cl is formed as white dense fumes. The reaction takes place in neutralization between a weak base and a strong acid.

ii) The property of the gas is diffusion.

iii) Diffusion of gases- Ammonia and hydrogen chloride. Concentrated ammonia solution is placed on a pad in one end of a tube and concentrated HCl on the pad at the other. After