UNIT-6 GASEOUS STATE

MY REVISION TIMELINE:-

SUMMARY:-

- Composition of air in volume % = 78% Nitrogen, 21% oxygen, 1% other gases.
- Gas laws:
  - Boyle's law: At a given temperature the volume occupied by a fixed mass of a gas is inversely proportional to its pressure.
    $P_1V_1 = P_2V_2 = k$
    $P_1\frac{m}{d_1} = P_2\frac{m}{d_2}$
    $\frac{P_1}{d_1} = \frac{P_2}{d_2}$
  - Charle's law: For a mixed of a gas, at constant pressure
    $V \alpha T$
    $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ = constant
  - Gay-Lussac's law: At constant volume
    $P \alpha T$
    $\frac{V_1}{T_1} = \frac{V_2}{T_2}$
  - Avogadro's hypothesis: Equal volumes of all gases under the same conditions of temperature and pressure contain equal number of molecules.
    $V \alpha T$
    $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ = constant
  - Ideal gas equation: PV = nRT
  - Dalton's law of Partial Pressure: The total pressure of a mixture of non-recruiting gases is the sum of partial pressures of the gases present in the mixture.
    $P_{Total} = P_1 + P_2 + P_3$
    $P_i = \frac{n_i}{n_{Total}} P_{total} = X_i P_{Total}$
    $X_i \rightarrow$ mole fraction of i^{th} component
  - Graham's law of Diffusion: The rate of diffusion or effusion is inversely proportional to the square root of molar mass.
    Rate of diffusion $\alpha \frac{1}{\sqrt{M}}$
    $\frac{r_A}{r_B} = \frac{P_A}{r_B}\sqrt{\frac{M_B}{M_A}}$
- Property of gas which involves the movement of the gas molecules through another gases.
- Effusion is another process in which a gas escapes from a container through a very small hole.

- Compressibility factor Z = $\frac{PV}{nRT}$
- Van der Waal's equation: $\left(P+\frac{an^2}{V^2}\right)(V-nb)=nRT$

  Where a and b are Van der Waal's constants

TEXTBOOK EVALUATION

Multiple choice questions:-

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

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 is mixed in an empty container at 298 K. The fraction of total pressure exerted by oxygen

(a) 1/3 (b) 1/2

(c) 2/3 (d) 1/3 × 273 × 298

Explanation:

Mass of methane = mass of oxygen = a

Mole fraction of oxygen = $\frac{\frac{a}{32}}{\frac{a}{16}+\frac{a}{32}}=\frac{1}{3}$

Partial pressure of oxygen = mole fraction × total pressure

$$\boxed{=\frac{\mathbf{1}}{\mathbf{3}}}$$

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

Explanation:

Rate of diffusion $\alpha \frac{1}{\sqrt{M}}$

Mass of NH_3 = 17 = mass of HCl = 36.5

$r_{NH_3} > r_{HCl}$

White fumes first formed near HCl

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

Explanation:

Higher the value of 'a' greater the intermolecular force of attraction easier the liquefaction.

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) 19.5 dm^3

Explanation:

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

$V = \frac{ZnRT}{P}$

$V = \frac{0.8697 \times 1 \times 8.314 \times 10^{-2} \times 400}{71}$

$\boxed{V = 0.41 dm^3}$

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

Explanation:

$T_1 T_2 = 2T_1$

$V_1 V_2 = 2V_1$

$P_1 P_2 = ?$

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

$P_2 = \frac{P_1 V_1}{T_1} \times \frac{T_2}{V_2}$

$P_2 = \frac{P_1 V_1}{T_1} \times \frac{2T_1}{2V_1}$

$\boxed{P_2 = P_1}$

16. At identical temperature and pressure, the rate of diffusion of hydrogen gas is 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

Explanation:

$\frac{r_{H_2}}{r_{C_nH_{2n+2}}} = \sqrt{\frac{M_{C_nH_{2n+2}}}{M_{H_2}}}$

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

Squaring on both sides

$27 \times 2 = M_{C_nH_{2n+2}}$

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

54 = 12n + 2n – 2

$n = \frac{54+2}{14}$

$\boxed{n = 4}$

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. (NEET phase 1)

(a) 3/8 (b) 1/2

(c) 1/8 (d) 1/4

Explanation:

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

$$\frac{r_{O_2}}{r_{H_2}} = \sqrt{\frac{2}{32}}$$

$$\boxed{r_{O_2} = \frac{1}{4} r_{H_2}}$$

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

(a) T **(b) 1/T**

(c) P (d) none of these

Explanation:

$$\frac{1}{V}(\frac{\partial V}{\partial T})_P = \frac{1}{V}(\frac{\partial(\frac{nRT}{P})}{\partial T})_P$$

$$\frac{1}{V}(\frac{\partial V}{\partial T})_P = \frac{nR}{nRT}$$

$$\boxed{\frac{1}{V}(\frac{\partial V}{\partial T})_P = \frac{1}{T}}$$

19. Four gases P, Q, R and S have almost same values of ‘b’ but their ‘a’ values (a, b are Van der 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

Explanation:

Greater the ‘a’ value, easier the liquefaction.

20. Maximum deviation from ideal gas is expected from (NEET)

(a) $CH_{4(g)}$ **(b) $NH_{3(g)}$**

(c) $H_{2(g)}$ (d) $N_{2(g)}$

21. The units of Van der 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^{-1} (d) none of these

Explanation:

$\frac{an^2}{V^2}$ = atm

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

nb = L

b = $\frac{L}{mol}$ = $Lmol^{-1}$

22. Assertion : Critical temperature of CO_2 is 304 K, it can be liquefied above 304 K.
Reason : For a given mass of gas, volume is to directly proportional to pressure at constant temperature.
(a) both assertion and reason arc 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
Explanation:
Critical temperature of CO_2 is 304K. Pressure is inversely proportional to volume.

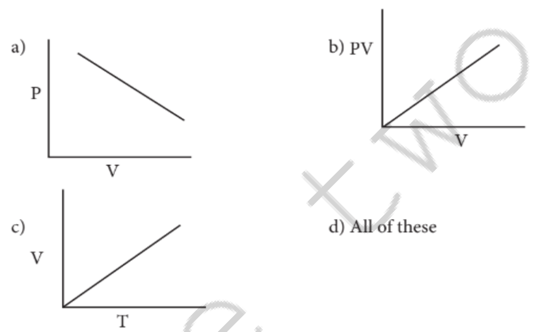
23. What is the density of N, gas at 227°C and 5.00 atm pressure? (R = 0.082 L atm K^{-1} mol^{-1})

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

Explanation:
Density = $\frac{Mass}{Volume}$
Density = $\frac{m}{\frac{nRT}{P}} = \frac{m}{n}\ \frac{P}{RT}$ = Molar mass × $\frac{P}{RT}$
Density = $\frac{28 \times 5}{0.082 \times 500}$

$\boxed{\textit{Density = 3.41 g/L}}$

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



Option c)
Explanation:
V α T

25. 25 g 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**

Explanation:
Volume α $\frac{Mass}{Molar\ mass}$
Volume α $\frac{28}{Molar\ mass}$
(i.e) if molar mass is more, volume is less. Therefore, HI has the least volume.

Write brief answers 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**.

$\mathbf{V}\ \boldsymbol{\alpha} \frac{\mathbf{1}}{\boldsymbol{P}}$ at constant T and n

$P_1V_1 = P_2V_2 = k$

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

The following table gives the pressure of a gas with increasing temperature at constant volume for two cylinders.

T° C	32° C	69° C	94° C	130° C
P(atm) 50 L container	0.51	0.56	0.6	0.66
P(atm) 75 L container	0.34	0.37	0.40	0.44

Both the models explain Gay-Lussac's law, P α T at constant V and n

For 50 L container:

The pressure increases with rise in temperature (at constant volume)

For 75 L container:

The pressure increases with rise in temperature (at constant volume)

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

- According to **Avogadro's hypothesis**: **V $\boldsymbol{\alpha}$ n**
- $\frac{V_1}{n_1} = \frac{V_2}{n_2}$ constant
- 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 volume and number of moles of the same gas at **same temperature and pressure**.

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

Gases which obey **Boyle's law** and **Charle's law** or ideal gas equation PV = nRT are called ideal gases.

All gases whose behaviour is consistent with the assumption of **kinetic theory of gases** under all condition are called **ideal gases**.

S.No	Ideal gases	Real gases
1	They obey all gas laws under all conditions of temperature and pressure.	They obey gas laws only at high temperature and low pressure.
2	The volume occupied by the gas molecule is negligible when compared to the total volume of the gas.	The volume occupied by a gas molecule is not negligible when compared to the total volume of the gas.
3	The attractive forces between the molecules are negligible.	The attractive forces between the molecules are not negligible at all temperature of pressures.

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

For **ideal gases, a = 0**. The value of a is a measure of the **attractive forces** between the molecules. There will not be any **intermolecular forces of attraction**. So it 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?

If there is a tiny sticky area on the wall of a container of gas, then the **collision** of the molecules will **not be elastic**. So the gas will behave as a **real gas**. So the pressure will be **less than the calculated value**.

32. Explain the following observations

a) Aerated water bottles are kept under water during summer

b) Liquid ammonia bottle is cooled before opening the seal

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

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

- Aerated water bottle contains **excess dissolved oxygen/CO_2** bottled at high pressure. During summer due to **high temperature**, **O_2 / CO_2** escapes from the solution increasing the pressure inside the bottle which may cause bursting of the bottle. To **maintain low T**, it is kept under water.
- The vapour pressure of ammonia at **room temperature** is **very high**. Cooling **decreases** the vapour pressure of **NH_3** so that the liquid remains in the same state. Hence the bottle is cooled before opening.
- According to **Gay-Lussac's law** at **constant volume**, the pressure of a fixed mass of a gas varies directly with temperature **($P \alpha T$)**
- The **volume of the gas** is **inversely proportional** to **pressure** at a given **temperature** according to **Boyle's law**. As the **weather balloon ascends**, the pressure tends to **decrease**. As a result, the volume of the gas inside the balloon or the size of the balloon is likely to increase.

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

- Gases have **negligible intermolecular forces of attraction** between the molecules. They are in continuous **kinetic motion**. So they won't settle at the bottom due to **gravitational forces**.
- The molecules move **very fast** and **collide** with one another, causing them to **diffuse** or **spread out** until they are evenly distributed throughout the volume of the container.

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

- **Hydrogen** being **lightest rises up** and **other gases** which are **heavier** like O_2 and N_2 come down towards the surface of the earth according to Graham's law of diffusion $\mathbf{r} \sqrt{\frac{1}{M}}$.
- Hydrogen **diffuses very fast**.

- Its **mean speed** is **greater than the escape velocity from the earth**. As a consequence, H_2 would have escaped from the atmosphere long time ago.
- The molecules of the atmosphere gases on the moon's surface have **thermal velocities greater than the escape velocity**.
- All the molecules have escaped and so the **atmosphere** is so **thin**.

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.
b) the temperature is raised while keeping the volume constant
c) more gas is introduced into the same volume and at the same temperature

- In the compressed state, the **inter molecular forces** will be **very high** as the molecules are very close, so it will behave as a real gas.
- P α T at constant volume, so, when T is raised P will also increase. The **gas deviates from ideal gas behaviour** and will be a **real gas** only.
- Pressure will increase and there will be more intermolecular forces. So the **gas deviates from ideal gas behaviour** and will be a **real gas** only.

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 will deviate more from ideal behaviour because it has **bigger atoms**.

37. Distinguish between diffusion and effusion.

S.No	Diffusion	Effusion
1	Spreading of molecules of a substance throughout a space or second substance.	Escape of the gas molecules through membrane pores into an evacuated area.
2	Occurs in solid, liquid and gas molecules.	Occurs only in gas molecules.
3	Collision occur among the molecules	There is no collision among the molecules

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

On heating, **incineration** might take place due to the **increase of pressure**.

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

The **reduced atmospheric pressure** is less effective in **pushing water up** into the straw below the water surface. The force that propels water through a straw is **atmospheric pressure** which is **less at high altitude**.

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

- Van der Waals equation for real gas: $\left(\boldsymbol{P}+\frac{\boldsymbol{an^2}}{\boldsymbol{V^2}}\right)(\boldsymbol{V}-\boldsymbol{nb})=\boldsymbol{nRT}$
- Correction term for pressure: $\frac{\boldsymbol{an^2}}{\boldsymbol{V^2}}$ It represents the intermolecular interaction that causes the non ideal behaviour.
- Correction term for volume: $(\boldsymbol{V}-\boldsymbol{nb})$ It is the effective volume occupied by real gas.

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

- Van der Waals equation is: $\left(\boldsymbol{P}+\frac{\boldsymbol{an^2}}{\boldsymbol{V^2}}\right)(\boldsymbol{V}-\boldsymbol{nb})=\boldsymbol{nRT}$

- From this equation, the values of critical constant $\mathbf{P_C}$,$\mathbf{V_C}$ and $\mathbf{T_C}$ arc derived in terms of **a** and **b** the Van der Waals constants.
- For one mole $\left(\boldsymbol{P}+\frac{\boldsymbol{an^2}}{\boldsymbol{V^2}}\right)(\boldsymbol{V}-\boldsymbol{nb}) = \boldsymbol{RT} \rightarrow (1)$
- On expanding the equation 1: PV + $\frac{a}{V}$ – pb - $\frac{ab}{V^2}$ –RT = 0 → (2)
- Multiplying equation 2 by $\frac{V^2}{P}$, $\frac{V^2}{P}$ (PV + $\frac{a}{V}$ – pb - $\frac{ab}{V^2}$ –RT) = 0

  $\boldsymbol{V^3}+\frac{\boldsymbol{aV}}{\boldsymbol{P}}-\boldsymbol{bV^2}-\frac{\boldsymbol{ab}}{\boldsymbol{P}}-\frac{\boldsymbol{RTV^2}}{\boldsymbol{P}} = \mathbf{0} \rightarrow (3)$
- The above equation is rearranged in powers of V

  $\boldsymbol{V^3}-\left[\frac{\boldsymbol{RT}}{\boldsymbol{P}}+\boldsymbol{b}\right]\boldsymbol{V^2}+\left[\frac{\boldsymbol{a}}{\boldsymbol{P}}\right]\boldsymbol{V}-\frac{\boldsymbol{ab}}{\boldsymbol{P}} = \mathbf{0} \rightarrow (4)$
- The above equation (4) is a cubic equation of V, which can have three roots. At the critical point all the three values of V are equal to the **critical volume $\mathbf{V_C}$**.

  i.e. $V = V_C$.

  $\mathbf{V - V_C = 0} \rightarrow (5)$

  $\mathbf{(V - V_C)^3 = 0} \rightarrow (6)$

  $\mathbf{(V^3 - 3V_CV^2 + 3V_C{}^3V - V_C{}^3 = 0} \rightarrow (7)$
- As the equation (4) is identical to equation (7), comparing the ‘V’ terms in (4) and (7)

  $-3\boldsymbol{V_C}\boldsymbol{V^2} = -\left[\frac{\boldsymbol{RT_C}}{\boldsymbol{P_C}}+\boldsymbol{b}\right]\boldsymbol{V^2} \rightarrow (8)$

  $\mathbf{3}\boldsymbol{V_C} = \boldsymbol{b}+\frac{\boldsymbol{RT_C}}{\boldsymbol{P_C}} \rightarrow (9)$

  $\mathbf{3}\boldsymbol{V_C^2} = \frac{\boldsymbol{a}}{\boldsymbol{P_C}} \rightarrow (10)$

  $\boldsymbol{V_C^2} = \frac{\boldsymbol{ab}}{\boldsymbol{P_C}} \rightarrow (11)$
- Dividing equation (11) by (10)

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

  $\frac{V_C}{3} = b$

  $\boldsymbol{V_C} = \mathbf{3}\boldsymbol{b} \rightarrow (12)$
- When equation (12) is substituted in (10)

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

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

  $\boldsymbol{P_C} = \frac{\boldsymbol{a}}{\mathbf{27}\boldsymbol{b^2}} \rightarrow (13)$
- Substituting the values of V_C and P_C in equation (9)

  $3V_C = b+\frac{RT_C}{P_C}$

  $3\times 3b = b+\frac{RT_C}{\frac{a}{27b^2}}$

  9b – b = $\frac{RT_C}{a}\times 27b^2$

  8b = $\frac{RT_C}{a}\times 27b^2$

  $\boldsymbol{T_C} = \frac{\mathbf{8}\boldsymbol{a}}{\mathbf{27}\boldsymbol{Rb}} \rightarrow (14)$
- Critical constants a and b can be calculated using Van der Waals constant or vice versa.

  a = $\mathbf{3}\boldsymbol{V_C^2}\boldsymbol{P_C} \rightarrow (15)$

  $\boldsymbol{b} = \frac{\boldsymbol{V_C}}{\mathbf{3}} \rightarrow (16)$

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

- In space there is **no air to breathe** and **no air pressure**.
- Space is **extremely cold** and filled with **dangerous radiations**.
- If they do not wear space suits, there may be **bleeding due to high body pressure**.
- The space suits prevent astronauts from **impacts of small bits of space dust**.
- There is **no atmosphere** on the moon and there are dangers from **micro-meteorite impacts.**
- Thus, the astronauts are protected from these dangers on wearing space suits.

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

Rate of diffusion $\alpha \frac{1}{\sqrt{M}}$

Mass of NH_3 = 17 = mass of HCl = 36.5

$\boldsymbol{r_{NH_3} > r_{HCl}}$

So **white fumes** are first formed near **HCl**.

44. A sample of gas at 15°C at 1 atm has a volume of 2.58 dm^3. When the temperature is raised to 38°C at 1 atm does the volume of the gas increase? If so, calculate the final volume.

Given:

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)

Formula used:

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

Solution:

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

$V_2 = \left[\frac{V_1}{T_1}\right] \times T_1$

$V_2 = \left[\frac{2.58}{288}\right] \times 311$

V_2 = 2.78 dm^3 i.e. volume increased from 2.58 to 2.78 dm^3

45. A sample of gas has a volume of 8.5 dm^3 at an unknown temperature. When the sample is submerged in ice water at 0°C, its volume gets reduced to 6.37 dm^3. What is its initial temperature?

Given:

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

T_1 = ? T_2 = 0°C = 273 K

Formula used:

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

Solution:

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

$T_1 = \left[\frac{T_2}{V_2}\right] \times V_1$

$\boxed{T_1 = 364.28\ K}$

46. Of two samples of nitrogen gas, sample A contains 1.5 moles of nitrogen in a vessel of volume of 37.6 dm^3 at 298K, and the sample B is in a vessel of volume 16.5 dm^3 at 298 K. Calculate the number of moles in sample B.

Given:

$n_A = 1.5$ mol $\quad n_B = ?$

$V_A = 37.6\ dm^3 \quad V_B = 16.5\ dm^3$

T = 298 K (constant)

Formula used:

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

Solution:

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

$$n_B = \left[\frac{n_A}{V_A}\right] \times V_B$$

$$n_B = \left[\frac{1.5}{37.6}\right] \times 16.5$$

$\boxed{n_B = 0.66\ mol}$

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 dm^3 at 69.5°C, assuming ideal gas behaviour.

Given:

n = 1.82 moles

V = 5.43 dm^3

T = 69.5° C + 273 = 342.5 K

P = ?

Formula used:

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

Solution:

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

$$P = \frac{1.82 \times 0.0821 \times 342.5}{5.43}$$

$\boxed{P = 9.425\ atm}$

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.

Given:

$P_1 = 1.2$ atm $\quad P_2 = ?$

$T_1 = 18°C + 273 = 291K \quad T_2 = 85°\ C + 273 = 358K$

Formula used:

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

Solution:

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

$$P_2 = \left[\frac{P_1}{T_1}\right] \times T_2$$

$P_2 = \left[\frac{1.2}{291}\right] \times 358$

$\boxed{P_2 = 1.48 \text{ atm}}$

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.

Given:

T_1 = 6° C + 273 = 279K T_2 = 25° C + 273 = 298K
P_1 = 4atm P_2 = 1atm
V_1 = 1.5 mL V_2 = ?

Formula used:

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

Solution:

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

$V_2 = \frac{P_1 V_1}{T_1} \times \frac{T_2}{P_2}$

$V_2 = \frac{4 \times 1.5 \times 298}{279 \times 1}$

$\boxed{V_2 = 6.41 mL}$

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?

Given:

V = 154.4 × 10^{-3} dm^3
P = 742 mm of Hg
T = 298K
Mass = ?

Formula used:

n = $\frac{PV}{RT}$
Mass = n × Molar mass

Solution:

n = $\frac{PV}{RT} = \frac{742 \times 154.4 \times 10^{-3}}{62 \times 298}$
n = 0.006 mol
Mass = n × Molar mass
Mass = 0.006 × 2.016

$\boxed{\text{Mass} = 0.0121g = 12.1mg}$

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?

Given:

$t_{unknown}$ = 192 sec
t_{N_2} = 84 sec
M_{N_2} = 28 g mol^{-1}

$M_{unknown}$ = ?

Formula used:

$$\frac{t_{N_2}}{t_{unknown}} = \sqrt{\frac{M_{N_2}}{M_{unknown}}}$$

Solution:

$$\frac{t_{N_2}}{t_{unknown}} = \sqrt{\frac{M_{N_2}}{M_{unknown}}}$$

$$\frac{84}{192} = \sqrt{\frac{28}{M_{unknown}}}$$

Squaring on both sides and rearranging,

$M_{unknown}$ = 28 $\left[\frac{192}{84}\right]$

$\boxed{M_{unknown} = 146\ g\ mol^{-1}}$

52. A tank contains a mixture of 52.5 g of oxygen and 65.1 g of CO2 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.

Given:

m_{O_2} = 52.5g m_{CO_2} = 65.1g

P_{O_2} = ? m_{CO_2} = ?

T = 300K P = 9.21 atm

Formula used:

$P_{O_2} = X_{O_2} \times Total\ pressure$

$P_{CO_2} = X_{CO_2} \times Total\ pressure$

Solution:

$n_{O_2} = \frac{Mass\ of\ O_2}{Molar\ mass\ of\ O_2} = \frac{52.5}{32}$ = 1.64 mol

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

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

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

$P_{O_2} = X_{O_2} \times Total\ pressure$ = 0.53 × 9.21

$\boxed{P_{O_2} = 4.88\ atm}$

$P_{CO_2} = X_{CO_2} \times Total\ pressure$ = 0.47 × 9.21

$\boxed{P_{CO_2} = 4.33\ atm}$

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).

Given:

Pressure of the gas in the tank at its melting point

P_1 = 2.98atm P_2 = ?

T_1 = 298K T_2 = 1100K

Formula used:

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

Solution:

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

$$P_2 = \left[\frac{P_1}{T_1}\right] \times T_2$$

$$P_2 = \left[\frac{2.98}{298}\right] \times 1100$$

$$\boxed{P_2 = 11 atm}$$

At 1100K 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.