Chapter 5

States of Matter

Solutions

SECTION - A

Objective Type Questions

(Gas laws and ideal gas equation)

1. A spherical balloon of 21 cm diameter is to be filled up with H_2 at NTP from a cylinder containing the gas at 20 atm at 27°C. The cylinder can hold 2.82 litre of water. The number of balloons that can be filled up

(1) 11 (2) 10 (3) 8 (4) 1

Sol. Answer (2)

Volume of the balloon = $\frac{4}{3}\pi r^3 = \frac{4}{3}\times\frac{22}{7}\times\left(\frac{21}{2}\right)^3$ = 4851 cm^3

Volume of the cylinder = 2.82 L = 2820 cm^3

P = 20 atm

T = 300 K

Converting this to the volume at NTP

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

$$= \frac{20\times2820}{300}$$

$$= \frac{1\times V_2}{273}$$

$\therefore$ V_2 = 51324 cm^3

When the pressure in the cylinder is reduced to one atm, no more H_2 will be released and 2820 cm^3 of H_2 will be left

$\therefore$ Volume of H_2 used in filling ballons = 51324 – 2820 = 48504 cm^3

Number of balloons filled = $\frac{48504}{4851}$ = 10

2. 4 g argon (Atomic mass = 40) in a bulb at a temperature of T K has a pressure P atm. When the bulb was placed in hot bath at a temperature 50°C more than the first one, 0.8 g of gas had to be removed to get the original pressure. T is equal to

(1) 510 K (2) 200 K (3) 100 K (4) 73 K

Sol. Answer (2)

The state of bulb changes from T K to T + 50 K

Final pressure remains the same.

Applying ideal gas equation,

$$P_1V_1 = n_1RT_1$$

or, $$P_1 = \frac{n_1RT_1}{V_1}$$

And, $$P_2V_2 = n_2RT_2$$

or, $$P_2 = \frac{n_2RT_2}{V_2}$$

$\because$ $P_1 = P_2$

$$\therefore \quad \frac{n_1T_1}{V_1} = \frac{n_2T_2}{V_2}$$

Initially, $n_1 = \dfrac{4\text{ g}}{40\text{ g mol}^{-1}} = 0.1$ mol

Finally, $n_2 = \dfrac{(4\text{ g} - 0.8\text{ g})}{40\text{ g mol}^{-1}} = 0.08$ mol

Also, the volume of the bulb remains the same.

Hence, $V_1 = V_2$

So, $n_1T_1 = n_2T_2$

or, $\dfrac{T}{T+50} = \dfrac{0.08}{0.1}$

or, $10\ T = 8\ (T + 50)$

or, $10\ T = 8\ T + 400$

or, $2\ T = 400$

$\Rightarrow$ $T = 200$

Initial temperature = T K = 200 K.

3. A flask containing air (open to atmosphere) is heated from 300 K to 500 K. Then percentage of air escaped to the atmosphere is

(1) 20 (2) 40 (3) 60 (4) 80

Sol. Answer (2)

Pressure and volume of air in the flask remains same throughout.

Temperature changes from 300 K to 500 K

Let number of moles of air change from

n_1 to n_2

$\therefore$ $n_1T_1 = n_2T_2$

or, $\frac{n_1}{n_2} = \frac{T_2}{T_1} = \frac{500\text{ K}}{300\text{ K}} = \frac{5}{3}$

% of air escaped = $\left(\frac{n_1 - n_2}{n_1}\right)\times 100 = \left(1 - \frac{n_2}{n_1}\right)\times 100 = \left(1 - \frac{3}{5}\right)\times 100 = \frac{2}{5}\times 100 = 40$

4. Air contains 23% oxygen and 77% nitrogen by weight. The percentage of O_2 by volume is

(1) 28.1 (2) 20.7 (3) 21.8 (4) 23.0

Sol. Answer (2)

Given: $\frac{w_{O_2}}{w_{total}}\times 100 = 23$

And, $\frac{w_{N_2}}{w_{total}}\times 100 = 77$

$\therefore$ $\frac{w_{O_2}}{w_{N_2}} = \frac{23}{77}$

Now applying ideal gas equation

PV = nRT

or PV = $\frac{wRT}{M}$

or, w = $\frac{PVM}{RT}$

$\therefore$ Temperature and pressure remains same for air,

$\frac{w_{O_2}}{w_{N_2}} = \frac{V_{O_2}\,M_{O_2}}{V_{N_2}\,M_{N_2}}$

or, $\frac{V_{O_2}}{V_{N_2}} = \frac{w_{O_2}}{w_{N_2}}\times\frac{M_{N_2}}{M_{O_2}} = \frac{23}{77}\times\frac{28}{32} = \frac{23}{88}$

Now, % volume of O_2 = $\frac{V_{O_2}}{V_{total}}\times 100$

$\frac{V_{O_2}}{V_{N_2}} = \frac{23}{88}$

or, $\frac{\frac{V_{O_2}}{V_{total}}}{\frac{V_{N_2}}{V_{total}}} = \frac{23}{88}$

Now, $1-\frac{V_{O_2}}{V_{total}}=\frac{V_{N_2}}{V_{total}}$

$$\therefore \quad \frac{\frac{V_{O_2}}{V_{total}}}{1-\frac{V_{O_2}}{V_{total}}}=\frac{23}{88}$$

Let $\frac{V_{O_2}}{V_{total}}=x$

$$\therefore \quad \frac{x}{1-x}=\frac{23}{88}$$

$\Rightarrow$ 88 x = 23 – 23 x

$$\Rightarrow \quad x = \frac{23}{111}$$

$$\therefore \quad \frac{V_{O_2}}{V_{total}}=\frac{23}{111}$$

$$\therefore \quad \%V = \frac{V_{O_2}}{V_{total}}\times 100=\frac{23}{111}\times 100=20.72$$

5. When the temperature of certain sample of a gas is changed from 30°C to 606 K and its pressure is reduced to half, the volume of gas changes from V to V^2. The value of V is

(1) 2 dm^3 (2) 4 dm^3 (3) 8 dm^3 (4) Unpredictable

Sol. Answer (2)

Given:

T_1 = 30°C = 303 K

T_2 = 606 K

P_1 = P

$P_2 = \frac{P}{2}$

V_1 = V

$V_2 = V^2$

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

or, $\frac{V_1}{V_2} = \frac{T_1}{T_2} \times \frac{P_2}{P_1} = \frac{303\text{ K}}{606\text{ K}} \times \frac{\frac{P}{2}}{P}$

or, $\frac{V}{V^2} = \frac{1}{4}$

or, $\frac{1}{V} = \frac{1}{4}$

or, $V = 4\text{ dm}^3$

6. A gas in a vessel is heated in such a way that its pressure and volume both become two times. The temperature of the gas expressed in Kelvin scale becomes

(1) Half

(2) Becomes two times

(3) Becomes 2/3rd of its original value

(4) Becomes four times

Sol. Answer (4)

Given :

If, $P_1 = P_1$; $P_2 = 2P_1$
$V_1 = V_1$; $V_2 = 2V_1$
$T_1 = T_1$; $T_2 = T_2$

Now, we have,

$P_1V_1 = nRT_1$

and $P_2V_2 = nRT_2$

or, $2P_1 \times 2V_1 = nRT_2$

or, $4\,P_1V_1 = nRT_2$

$\Rightarrow \frac{nRT_2}{4} = nRT_1$

or, $T_2 = 4T_1$

7. Which of the following has maximum number of molecules?

(1) 2.7 g of NH_3 (2) 1 L SO_2 at STP (3) 2 L of Cl_2 at STP (4) 0.1 mol of H_2S

Sol. Answer (1)

Maximum number of moles ⇒ maximum number of molecules

$NH_3 \rightarrow n = \frac{2.7}{17}$ moles = 0.15 moles

$SO_2 \rightarrow n = \frac{1}{22.4}$ moles = 0.04 moles

$Cl_2 \rightarrow n = \dfrac{2}{22.4}$ moles = 0.08 moles

$H_2S \rightarrow n = 0.1$ moles

8. The mixture of three gases X, Y and Z is enclosed in a closed vessel at constant temperature. Molecular weight of X is the highest and that of Y is the least. When equilibrium is established the

(1) Gas X will be more at bottom

(2) Gas Y will be more at top

(3) Gas X, Y, Z are homogeneously present

(4) Gas Y will be more at bottom

Sol. Answer (3)

Assuming that the gases are non-reactive, then at equilibrium, all the gases diffuse so as to obtain a homogeneous mixture.

9. Density of gaseous mixture A and B from percentage volume is given as

(1) $d_{mix} = \dfrac{d_A}{(\%A)} + \dfrac{d_B}{(\%B)}$

(2) $d_{mix} = d_A \times (\%A) + d_B \times (\%B)$

(3) $d_{mix} = \dfrac{d_A \times (\%A) + d_B \times (\%B)}{100}$

(4) $d_{mix} = \dfrac{d_A + d_B}{100}$

Sol. Answer (3)

$$d_{mix} = \frac{w_{mix}}{V_{total}} = \frac{w_A + w_B}{V_{total}} = \frac{w_A}{V_{total}} + \frac{w_B}{V_{total}}$$

Now, $w_A = d_A \times V_A$

$$\therefore \quad d_{mix} = \frac{d_A \times V_A}{V_{total}} + \frac{d_B V_B}{V_{total}} = \frac{d_A \times \left(\dfrac{V_A}{V_{total}} \times 100\right) + d_B \times \left(\dfrac{V_B}{V_{total}} \times 100\right)}{100} = \frac{d_A(\%A) + d_B(\%B)}{100}$$

10. Which of the following is incorrect for pressure units?

(1) 1 atmosphere is equal to 1.01325 bar

(2) 1.01325 bar is equal to 0.875 atmosphere

(3) 1.01325×10^5 Pa is equal to 1.01325 bar

(4) 1 atmosphere is equal to 1.01325×10^5 kg m^{-1} s^{-2}

Sol. Answer (2)

We know, 1 bar = 10^5 Pa ⇒ 1 Pa = 10^{-5} bar

and 1 atm = 101325 Pa

1 atm = 101325 Pa = 101325×10^{-5} bar

⇒ 1 atm = 1.01325 bar

11. For a given mass of a gas, if pressure is reduced to half and temperature is increased two times then the final volume would become (V = initial volume)

(1) $\frac{V}{4}$ (2) $2V^2$ (3) 6V (4) 4V

Sol. Answer (4)

Given: $P_1 = P_1$; $P_2 = \frac{P_1}{2}$

$V_1 = V$; $V_2 = V_2$

$T_1 = T_1$; $T_2 = 2T_1$

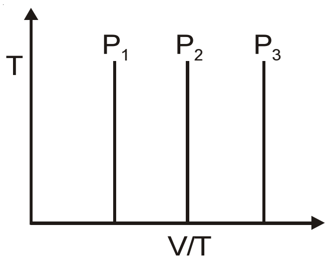
We have (for a fixed mass of gas)

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

$$\therefore \quad V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2}$$

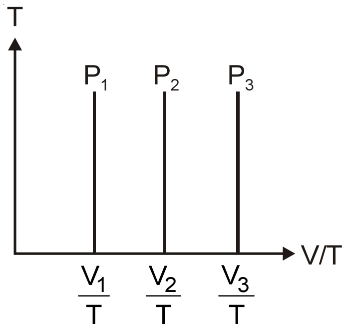
$$= \frac{P_1V}{T_1} \times \frac{2T_1}{\frac{P_1}{2}} = 4\text{ V}$$

12. Three lines at three different values of constant pressure are given, which of the following relation is correct?



(1) $P_1 = P_2 = P_3$ (2) $P_1 > P_2 > P_3$ (3) $P_3 > P_2 > P_1$ (4) Can't predicted

Sol. Answer (2)



According to Boyle's law,

$$P \propto \frac{1}{V}$$

So, at a constant temperature,

$$\because \quad \frac{V_1}{T} < \frac{V_2}{T} < \frac{V_3}{T}$$

$$\Rightarrow \quad P_1 > P_2 > P_3$$

13. At constant volume, pressure and temperature are related as (T_0 = STP temp.)

(1) $P_t = P_0\left(1+\frac{t}{273}\right)$ (t = °C)

(2) $P_t = P_0\frac{T_0}{T}$ (T = in K)

(3) $P_0 = P_t\left(\frac{273+t}{273}\right)$

(4) All of these

Sol. Answer (1)

At STP, temperature = T_0

pressure = P_0

At time 't', temperature = t°C

∴ temperature = (t + 273) K

Applying Gay Lussac's law,

$$\frac{P_t}{P_0} = \frac{(t+273)K}{T_0}$$

Now, T_0 = 273 K

$$\therefore \quad P_t = P_0\frac{(273+t)}{273}$$

14. The slope of the graph between log P and log V at constant temperature for a given mass of a gas is

(1) +1 (2) –1 (3) $\frac{1}{T}$ (4) $\frac{1}{n}$

Sol. Answer (2)

According to Boyle's law,

$$P \propto \frac{1}{V}$$

or, $P = \frac{k}{V}$

Applying log on both sides,

log P = log k – log V

Comparing with y = mx + c

We get slope, m = –1

(Dalton's law of partial pressures/Graham's law of diffusion)

15. Equal mass of H_2, He and CH_4 are mixed in empty container at 300 K, when total pressure is 2.6 atm. The partial pressure of H_2 in the mixture is

(1) 0.5 atm (2) 1.6 atm (3) 0.8 atm (4) 0.2 atm

Sol. Answer (2)

Let mass of all 3 gases mixed be x g.

$\therefore$ Number of moles of $H_2 = \frac{x}{2}$

Number of moles of He $= \frac{x}{4}$

Number of moles of $CH_4 = \frac{x}{16}$

$$\therefore \quad \chi_{H_2}\text{, mole fraction of } H_2 = \frac{n_{H_2}}{n_{total}} = \frac{\frac{x}{2}}{\frac{x}{2}+\frac{x}{4}+\frac{x}{16}} = \frac{8}{13}$$

$\therefore$ Partial pressure of H_2, $p_{H_2} = P_{total}\,\chi_{H_2}$

$$= 2.6 \text{ atm} \times \frac{8}{13} = 1.6 \text{ atm}$$

16. At STP 16 mL of O_2 diffused through a porous partition in t seconds. What volume of CO_2 will diffuse in the same time and under the same conditions?

(1) 13.65 mL	(2) 10.5 mL
(3) 20.2 mL	(4) 224.8 mL

Sol. Answer (1)

Applying Graham's law of diffusion,

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

$\because$ Time of diffusion is same,

$$\therefore \quad \frac{V_1}{V_2} = \sqrt{\frac{M_2}{M_1}}$$

$V_1 = 16$ mL

$M_1 = 32 \text{ g mol}^{-1}$

$M_2 = 44 \text{ g mol}^{-1}$

$$\therefore \quad \frac{V_1}{V_2} = \sqrt{\frac{44}{32}}$$

$$\text{or, } V_2 = \frac{16 \text{ mL}}{\sqrt{\frac{44}{32}}} = 13.8 \approx 13.65 \text{ mL}$$

17. The density of gas A is twice that of gas B at the same temperature. The molecular weight of gas B is thrice that of A. The ratio of pressure acting on A and B will be

(1) 6 : 1 (2) 7 : 8 (3) 2 : 5 (4) 1 : 4

Sol. Answer (1)

According to ideal gas equation,

$$P_A = \frac{d_A RT}{M_A}$$

$$P_B = \frac{d_B RT}{M_B}$$

$$\therefore \quad \frac{P_A}{P_B} = \frac{d_A}{d_B} \times \frac{M_B}{M_A} = \frac{2}{1} \times \frac{3}{1} = 6 : 1$$

18. In what ratio by mass, the gases CO and 2 butene (C_4H_8) be mixed in a vessel so that they cause same partial pressures?

(1) 1 : 1 (2) 2 : 1 (3) 1 : 2 (4) 1 : 3

Sol. Answer (3)

We know,

partial pressure, $p_{CO} = p_{total} \times \chi_{CO}$

$$p_{C_4H_8} = p_{total} \times \chi_{C_4H_8}$$

Given, $\frac{p_{CO}}{p_{C_4H_8}} = 1$

$\Rightarrow \quad \frac{\chi_{CO}}{\chi_{C_4H_8}} = 1$

or, $\frac{n_{CO}}{n_{C_4H_8}} = 1$

i.e., Ratio of moles = 1 : 1

$\Rightarrow$ Ratio of weight = Ratio of weight of 1 moles = 28 : 56 = 1 : 2

19. The rate of diffusion of a gas having molecular weight just double of hydrogen gas is 30 ml s^{-1}. The rate of diffusion of hydrogen gas will be

(1) 42.42 ml s^{-1} (2) 60 ml s^{-1} (3) 120 ml s^{-1} (4) 21.21 ml s^{-1}

Sol. Answer (1)

According to Graham's law of diffusion,

$$\frac{r_{H_2}}{r_2} = \sqrt{\frac{M_2}{M_{H_2}}} = \sqrt{\frac{2}{1}} \qquad (\because M_2 = 2M_{H_2})$$

$$\therefore \quad r_{H_2} = \sqrt{2} \times r_2 = 1.414 \times 30 \text{ ms}^{-1} = 42.42 \text{ ms}^{-1}$$

20. 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

(1) At the centre of the tube
(2) Near the hydrogen chloride bottle
(3) Near the ammonia bottle
(4) Throughout the length of the tube

Sol. Answer (2)

According to Graham's law of diffusion

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

i.e., Rate of diffusion is inversely proportional molar mass.

Molar mass of HCl > Molar mass of NH_3

$\Rightarrow$ Rate of diffusion of HCl < Rate of diffusion of NH_3

Hence, NH_3 diffuses (travels) faster and forms NH_4Cl near HCl chamber.

21. The rates of diffusion of gases A and B of molecular weights 100 and 81 respectively are in the ratio of

(1) 9 : 10
(2) 10 : 9
(3) 100 : 18
(4) 81 : 100

Sol. Answer (1)

According to Graham's law of diffusion,

$$\frac{r_A}{r_B} = \sqrt{\frac{M_B}{M_A}} = \sqrt{\frac{81}{100}} = \frac{9}{10} = 9:10$$

22. 100 mL of O_2 gas diffuses in 10 s. 100 mL of gas 'X' diffuses in 't' second. Gas 'X' and time 't' can be

(1) H_2, 2.5 s
(2) SO_2, 16 s
(3) CO, 10 s
(4) He, 4 s

Sol. Answer (1)

Same volume of gas is being diffused.

$\therefore$ As per Graham's law diffusion,

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

or, $\frac{t_1}{t_2} = \sqrt{\frac{M_2}{M_1}}$

Let gas 1 be O_2

$$\therefore \quad \frac{\sqrt{M_{O_2}}}{t_{O_2}} = \frac{\sqrt{M_2}}{t_2} \text{ or } \sqrt{\frac{M_{O_2}}{t_{O_2}^2}} = \sqrt{\frac{M_2}{t_2^2}}$$

$$\text{or,} \quad \sqrt{\frac{M_2}{t_2^2}} = \sqrt{\frac{32}{10\times10}} = \sqrt{\frac{2}{6.25}} = \sqrt{\frac{2}{(2.5)^2}}$$

Which is possible when M_2 = 2 g mol^{-1} and t_2 = 2.5 s

Which is possible for H_2, 2.5 s

23. The time taken for a certain volume of gas to diffuse through a small hole was 2 min. Under similar conditions an equal volume of oxygen took 5.65 minute to pass. The molecular mass of the gas is

(1) 32.0 (2) 11.33 (3) 4.0 (4) 8.0

Sol. Answer (3)

As per Graham's law of diffusion,

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}} \qquad \ldots(1)$$

∴ Volume of gas diffused is same,

$$\therefore \quad \frac{r_1}{r_2} = \frac{t_2}{t_1} \qquad \ldots(2)$$

Combining (1) and (2), we get

$$\frac{t_2}{t_1} = \sqrt{\frac{M_2}{M_1}}$$

$$\text{or,} \quad \frac{t_2^2}{t_1^2} = \frac{M_2}{M_1}$$

$$\text{or,} \quad M_1 = \frac{M_2 \times t_1^2}{t_2^2} = \frac{32\ \text{g mol}^{-1} \times 4\ \text{min}^2}{5.65 \times 5.65\ \text{min}^2} = 4.0.$$

24. The rate of diffusion of a gas is proportional to

(1) $\frac{P}{\sqrt{d}}$ (2) $\frac{P}{d}$

(3) $\sqrt{\frac{P}{d}}$ (4) $\frac{\sqrt{P}}{d}$

Sol. Answer (1)

25. The ratio of average speed of an O_2 molecule to the rms speed of N_2 molecule at the same temperature is

(1) $\left(\frac{3\pi}{7}\right)^{1/2}$ (2) $\left(\frac{7}{3\pi}\right)^{1/2}$ (3) $\left(\frac{3}{7\pi}\right)^{1/2}$ (4) $\left(\frac{7\pi}{3}\right)^{1/2}$

Sol. Answer (2)

26. The ratio between rms speed of H_2 at 50 K and that of O_2 at 800 K is

(1) 4 (2) 2 (3) 1 (4) $\frac{1}{4}$

Sol. Answer (3)

27. Which of the following postulate of kinetic theory of gas is responsible for deviation from ideal behaviour?

(1) Kinetic energy of the gas molecules increase with increase in temperature

(2) Collisions among the gas molecules are perfectly elastic

(3) There is no forces of attraction or repulsion among gas molecules

(4) Molecules in a gas follow zig-zag path

Sol. Answer (3)

28. What is average kinetic energy of 1 mole of SO_2 at 300 K?

(1) 4578 J/mol (2) 3134 J/mol (3) 3741 J/mol (4) 4173 J/mol

Sol. Answer (3)

29. If a gas expands at constant temperature

(1) Its pressure increases

(2) Kinetic energy of the molecules increases

(3) Kinetic energy of the molecules remains the same

(4) Number of molecules of the gas increases

Sol. Answer (3)

30. If pressure of a gas increases upto nine times keeping temperature constant, then its rms velocity will become

(1) 9 times (2) 3 times (3) Remains same (4) $\frac{1}{3}$ time

Sol. Answer (3)

31. V ml of H_2 gas diffuses through a small hole in a container in time t_1. How much time will be required by oxygen gas for the diffusion of same volume?

(1) $2t_1$ (2) $4t_1$ (3) $\frac{1}{2}t_1$ (4) $\frac{1}{4}t_1$

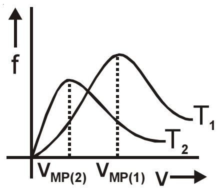
Sol. Answer (2)

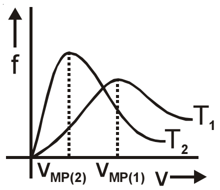
32. Average kinetic energy per molecule of an ideal gas is given as

(1) $\overline{KE} = \frac{1}{3}mnu^2$ (2) $\overline{KE} = \frac{3}{2}RT$ (3) $\overline{KE} = \frac{3}{2}kT$ (4) Both (2) & (3)

Sol. Answer (3)

33. The correct graph and values of temperature in them is given as

(A) 

(B) 

(1) (A) & $T_1 > T_2$ (2) (A) & $T_1 < T_2$ (3) (B) & $T_1 > T_2$ (4) (B) & $T_1 < T_2$

Sol. Answer (3)

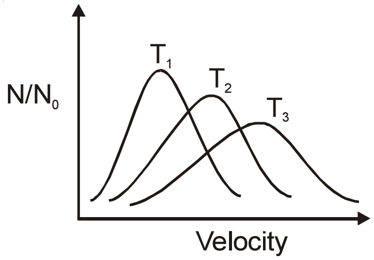
34. Pressure exerted by one mole of an ideal gas kept in a vessel of ‘V’ L having root mean square speed of molecules ‘v’ and ‘m’ mass of each molecule is correctly given by the equation

(1) $P=\frac{1}{2}\frac{N_A}{V}mv^2$ (2) $P=\frac{1}{3}\frac{N_A}{V}mv^2$ (3) $P=\frac{2}{3}\frac{N_A}{V}mv^2$ (4) $P=\frac{3}{2}\frac{N_A}{V}mv^2$

Sol. Answer (2)

(Kinetic molecular theory of gases, kinetic energy and molecular speed, Maxwell-Boltzmann distribution of molecular speeds)

35. A graph of Maxwell distribution of molecular velocities is plotted below.



Correct order of temperature

(1) $T_1 > T_2 > T_3$ (2) $T_1 < T_2 < T_3$ (3) $T_1 = T_2 > T_3$ (4) $T_1 = T_2 = T_3$

Sol. Answer (2)

As temperature increases, most probable velocity also increases, although fraction of molecules having most probable velocity decreases.

$\therefore\ T_3 > T_2 > T_1$

36. The molecular velocities of two gases at the same temperature are u_1 and u_2 and their molar masses are m_1 and m_2 respectively. Which of the following expressions are correct?

(1) $\frac{m_1}{u_1^2}=\frac{m_2}{u^2}$ (2) $m_1u_1=m_2u_2$ (3) $\frac{m_1}{u_1}=\frac{m_2}{u_2}$ (4) $m_1u_1^2=m_2u_2^2$

Sol. Answer (4)

$\because$ Temperature is same,

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

where, V = molecular velocity

M = molecular mass

$$\therefore\ \frac{V_1}{V_2}=\sqrt{\frac{M_2}{M_1}}$$

or, $$\frac{V_1^2}{V_2^2}=\frac{M_2}{M_1}$$

Replacing the values,

$$\frac{u_1^2}{u_2^2} = \frac{m_2}{m_1}$$

or, $m_1u_1^2 = m_2u_2^2$

37. Correct statement

(1) At constant temperature, the KE of all the gas molecules is the same

(2) At constant temperature, average KE of gas molecules remain constant but KE of individual molecule may differ

(3) At constant temperature, the KE is greater for heavier gas molecules

(4) At constant temperature, the KE is less for heavier gas molecules

Sol. Answer (2)

According to kinetic theory of gases, at constant temperature, average K.E. of gas molecules remain constant but K.E. of individual molecules differ since they have different velocities.

38. Molar mass of certain gas A is half that of B. If rms speed of molecules of A at certain temperature is 200 ms^{-1}. The rms speed of B at the temperature half that of A will be

(1) 200 ms^{-1} (2) 100 ms^{-1} (3) 300 ms^{-1} (4) 400 ms^{-1}

Sol. Answer (2)

$$V_{rms} \propto \sqrt{\frac{T}{M}}$$

$$\therefore \quad \frac{(V_{rms})_A}{(V_{rms})_B} = \sqrt{\frac{T_A}{T_B} \times \frac{M_B}{M_A}}$$

Now, $T_A = 2T_B$

and $M_B = 2\ M_A$

$$\therefore \quad \frac{(V_{rms})_A}{(V_{rms})_B} = \sqrt{\frac{2T_B \times 2M_A}{T_B \times M_A}} = \sqrt{2 \times 2} = 2$$

or, $(V_{rms})_B = \dfrac{(V_{rms})_A}{2} = \dfrac{200}{2}\ ms^{-1} = 100\ ms^{-1}$

39. A sample of gas contains N_1 molecules and the total kinetic energy at –123°C is E_1 ergs. Another sample of gas at 27°C has total kinetic energy as $2E_1$ ergs. Assuming gases to be ideal, the number of gas molecules in the second sample will be

(1) N_1 (2) $N_1/2$ (3) $2N_1$ (4) $4N_1$

Sol. Answer (1)

Total kinetic energy of n molecules is given as

$$\text{K.E.} = \frac{3}{2}\text{nKT}$$

∴ At – 123°C (or 150 K)

$$\text{KE}_1 = \frac{3}{2}\ \text{N}_1\ \text{k} \times 150\ \text{k} = \text{E}_1$$

At 27°C (or 300 K)

$$\text{K.E}_2 = \frac{3}{2}\ \text{n}'\ \text{k} \times 300\ \text{K} = 2\ \text{E}_1$$

$$\therefore\ \frac{3}{2}\ \text{n}'\ \text{k} \times 300\ \text{K} = 2 \times \frac{3}{2} \times \text{N}_1\text{k} \times 150\ \text{K}.$$

$$\text{N}' = \frac{2 \times \text{N}_1}{2} = \text{N}_1$$

40. At constant volume for a fixed number of a moles of a gas, the pressure of the gas increases with the rise in temperature due to

(1) Increase in average molecular speed

(2) Increase in rate of collisions amongst

(3) Increase in molecular attraction

(4) Increase in mean free path

Sol. Answer (1)

When number of moles of a gas and volume is fixed, then increase in temperature results in an increase in velocity of molecules. As a result change in momentum increases and hence force increases. Increase in force results in increase in pressure.

41. The root mean square velocity of an ideal gas at constant pressure varies with density as

(1) d^2 (2) d (3) $\sqrt{d}$ (4) $\frac{1}{\sqrt{d}}$

Sol. Answer (4)

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

Now, we know, PV = nRT

$$\text{or,}\ \ P = \frac{n}{V}RT$$

$$\text{or,}\ \ P = \frac{dRT}{M}$$

$$\text{or,}\ \ \frac{P}{d} = \frac{RT}{M}$$

$$\Rightarrow V_{rms} = \sqrt{\frac{3P}{d}}$$

$$\Rightarrow V_{rms} \propto \frac{1}{\sqrt{d}}$$

42. Which of the following is not correct in case of kinetic theory of gases?

(1) Gases are made up of small particles of negligible size as compared to container size

(2) The molecules are in random motion always

(3) When molecules collide they lose energy

(4) When the gas is heated, the average kinetic energy of gas molecules increase

Sol. Answer (3)

According to kinetic theory of gases, the molecules collides in an elastic manner, i.e. energy is not lost.

43. If the ratio of C_P and C_V for a gas is 1.4. The number of atoms present in 11.2 litre of it at STP is

(1) 6.02×10^{23} (2) 1.2×10^{23} (3) 3.01×10^{23} (4) 12.04×10^{23}

Sol. Answer (1)

Ratio of C_P and C_V gives an idea about atomicity

When $\frac{C_P}{C_V} = 1.4$

$\Rightarrow$ The gas is diatomic

Now, at STP, 22.4 L corresponds to 1 mole of gas molecules

$\therefore$ 11.2 L corresponds to 0.5 mole of gas molecules.

$\therefore$ Number of atms in 11.2 L

$= 2 \times 0.5 \times 6.023 \times 10^{23}$ ($\therefore$ gas is diatomic)

$= 6.023 \times 10^{23}$

44. What is the ratio of the average molecular kinetic energy of UF_6 to that of H_2 both at 300 K?

(1) 1 : 1 (2) 349 : 2 (3) 2 : 349 (4) None of these

Sol. Answer (1)

Average molecular kinetic energy,

$$\overline{KE} = \frac{3}{2}kT$$

For, UF_6, $\overline{K.E.}_{UF_6} = \frac{3}{2}k \times 300\text{ K}$

H_2, $\overline{K.E.}_{H_2} = \frac{3}{2}k \times 300\text{ K}$

$$\therefore \frac{\overline{K.E.}_{UF_6}}{\overline{K.E.}_{H_2}} = 1:1$$

45. If pressure of a fixed quantity of a gas is increased 4 times keeping the temperature constant, the r.m.s. velocity will be

(1) 4 times (2) 2 times (3) Same (4) $\frac{1}{2}$ times

Sol. Answer (3)

rms velocity, $C_{rms} = \sqrt{\frac{3RT}{M}}$

$\therefore$ Change in pressure is not going to affect the root mean square velocity.

46. The total kinetic energy (in joules) of the molecules in 8 g of methane at 27°C is

(1) 3741.30 J (2) 935.3 J (3) 1870.65 J (4) 700 J

Sol. Answer (3)

According to equipartition theorem,

Total energy = $\frac{3}{2}nRT$

Moles = $\frac{8\text{ g}}{16\text{ g mol}^{-1}} = 0.5\text{ mol}^{-1}$

$\therefore$ Total kinetic energy = $0.5\text{ mol} \times \frac{3}{2} \times 8.314\text{ J K}^{-1}\text{ mol}^{-1} \times 300\text{ K}$

$$= \frac{3\times300\times8.314}{4}\text{ J} = 1870.65\text{ J}$$

47. At what temperature the RMS velocity of oxygen will be same as that of methane at 27°C?

(1) 54°C (2) 327 K (3) 600 K (4) 573 K

Sol. Answer (3)

$$(C_{rms})_{O_2} = \sqrt{\frac{3RT}{32}}$$

$$(C_{rms})_{CH_4} = \sqrt{\frac{3R\times300\text{ K}}{16}}$$

$$(C_{rms})_{O_2} = (C_{rms})_{CH_4}$$

or, $\sqrt{\frac{3RT}{32}} = \sqrt{\frac{3R\times300\text{ K}}{16}}$

or, $\frac{T}{32} = \frac{300}{16} \Rightarrow T = 600\text{ K}$

48. The temperature at which the root mean square velocity of SO_2 molecules is the same as that of O_2 at 27°C is

(1) 600°C (2) 300°C (3) 327°C (4) 27°C

Sol. Answer (3)

$$(C_{rms})_{SO_2} = \sqrt{\frac{3RT}{64}}$$

$$(C_{rms})_{O_2} = \sqrt{\frac{3R \times 300\text{ K}}{32}}$$

$$(C_{rms})_{O_2} = (C_{rms})_{SO_2}$$

$$\therefore \quad \sqrt{\frac{3RT}{64}} = \sqrt{\frac{3R \times 300\text{ K}}{32}}$$

$\Rightarrow$ T = 600 K = (600 – 273)°C = 327°C

49. The average velocity of an ideal gas molecule at 27°C is 0.3 m/s. The average velocity at 927°C will be

(1) 0.6 m/s (2) 0.3 m/s (3) 0.9 m/s (4) 3.0 m/s

Sol. Answer (1)

$$(\bar{v}_{av})_{300\text{ K}} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8R \times 300\text{ K}}{\pi M}}$$

$$(\bar{v}_{av})_{1200\text{ K}} = \sqrt{\frac{8R \times 1200\text{ K}}{\pi M}}$$

Dividing both expressions,

$$\frac{(\bar{v}_{av})_{300\text{ K}}}{(\bar{v}_{av})_{1200\text{ K}}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

or, $(\bar{v}_{av})_{1200\text{ K}} = 2 \times (\bar{v}_{av})_{300\text{ K}} = 2 \times 0.3\text{ ms}^{-1} = 0.6\text{ ms}^{-1}$

50. At what temperature will the total KE of 0.3 mol of He be the same as the total KE of 0.4 mol of Ar at 400 K?

(1) 533 K (2) 400 K (3) 346 K (4) 300 K

Sol. Answer (1)

$$(\text{Total K.E.})_{He} = \frac{3}{2}RT \times 0.3\text{ mol}$$

$$(\text{Total K.E.})_{Ar} = \frac{3}{2}R \times 400\text{ K} \times 0.4\text{ mol}$$

$\therefore$ Total energy of both the gases are same,

$$\therefore \quad \frac{3}{2}RT \times 0.3\text{ mol} = \frac{3}{2}R \times 400\text{ K} \times 0.4\text{ mol}$$

$$\Rightarrow \quad T = \frac{0.4}{0.3} \times 400\text{ K} = 533.3\text{ K}$$

51. The r.m.s. velocity of hydrogen is $\sqrt{7}$ times the r.m.s. of nitrogen. If T is the temperature of the gas then

(1) $T_{H_2} = T_{N_2}$ (2) $T_{H_2} > T_{N_2}$ (3) $T_{H_2} < T_{N_2}$ (4) $T_{H_2} = \sqrt{7}\,T_{N_2}$

Sol. Answer (3)

$$(v_{rms})_{H_2} = \sqrt{7}\,(v_{rms})_{N_2}$$

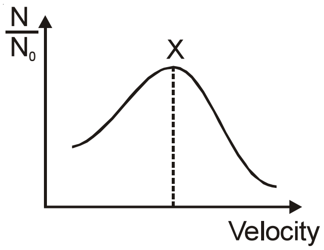
or, $\sqrt{\dfrac{3\,R\,T_{H_2}}{M_{H_2}}} = \sqrt{\dfrac{3\,R \times T_{N_2} \times 7}{M_{N_2}}}$

or, $\dfrac{T_{H_2}}{2} = \dfrac{T_{N_2}}{28} \times 7$

or, $2\,T_{H_2} = T_{N_2}$

$\Rightarrow$ $T_{H_2} < T_{N_2}$ [$\because$ 2 × 4 = 8 $\Rightarrow$ 4 < 8]

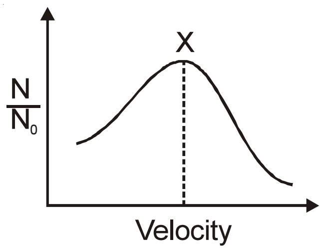
52. Distribution of fraction of molecules with velocity is represented in the figure.



Velocity corresponding to point X is

(1) $\sqrt{\dfrac{2RT}{M}}$ (2) $\sqrt{\dfrac{3RT}{M}}$ (3) $\sqrt{\dfrac{8RT}{\pi M}}$ (4) $\sqrt{\dfrac{2RT}{\pi M}}$

Sol. Answer (1)



The highest point in the graph corresponds to the most probable speed which is represented as

$v_{mps} = \sqrt{\dfrac{2\,RT}{M}}$.

(Real Gas, Equation of state for real gas, Compressibility factor(Z))

53. The compressibility of a gas is less than unity at STP. Therefore,

(1) V > 22.4 L (2) V < 22.4 L (3) V = 22.4 L (4) V = 44.8 L

Sol. Answer (2)

Compressibility factor, $Z = \frac{V_{real}}{V_{ideal}}$

$Z < 1$

$\Rightarrow \quad \frac{V_{real}}{V_{ideal}} < 1$

$\Rightarrow \quad V_{real} < V_{ideal} = 22.4\ L$

$\Rightarrow \quad V_{real} < 22.4\ L$ (at STP)

54. Temperature at which gas behave ideally over a wide range of pressure is called as

(1) Boyle's temperature (2) Inversion temperature (3) Critical temperature (4) Kraft temperature

Sol. Answer (1)

The temperature above which a real gas behaves ideally over an appreciable range of pressure is called Boyle's temperature.

55. van der Waal's constant 'a' and 'b' are related with _____ respectively

(1) Attractive force and bond energy of molecules (2) Attractive force and volume of molecules

(3) Volume and repulsive force of molecules (4) Shape and repulsive force of molecules

Sol. Answer (2)

'a' represents attractive force i.e. pressure correction

'b' represents occupied volume i.e. volume correction

56. At high temperature and low pressure van der Waal's equation can be expressed as

(1) $\left(P + \frac{a}{V^2}\right)(V - b) = RT$ (2) $\left(P + \frac{a}{V^2}\right)V = RT$ (3) $P(V - b) = RT$ (4) $PV = RT$

Sol. Answer (4)

At high temperature and low pressure, volume becomes very large $\left(V \propto \frac{T}{P}\right)$

Also, magnitude of 'a' and 'b' becomes very less.

Now, van der Waal's equation is given as

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

or, $\left(P + \frac{an^2}{V^2}\right)\left(\frac{V}{n} - b\right) = RT$

$\because$ V is very high and 'a' and 'b' are low

So, the equation reduces to

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

or, $PV = nRT$ *i.e.*, ideal gas equation

The equation becomes

$PV = RT$; when $n = 1$ mole

(Liquefaction of Gases, Critical parameters)

57. What is the correct increasing order of liquefiability of the gas?

(1) $H_2 < N_2 < CH_4 < CO_2$

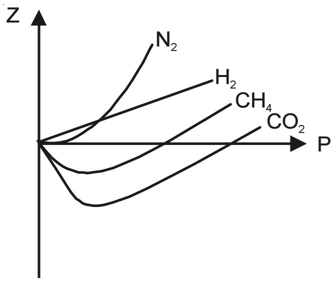
(2) $H_2 < CO_2 < CH_4 < N_2$

(3) $CO_2 < CH_4 < N_2 < H_2$

(4) $CO_2 < CH_4 < H_2 < N_2$

Sol. Answer (1)

The graph of Z versus P is given as



The higher the compressibility factor at a pressure, the more difficult would it be to liquify the gas.

∴ Ease of liquefaction

$CO_2 > CH_4 > N_2 > H_2$

58. The Critical temperature, Boyle's temperature and Inversion temperature respectively are given as

(1) $\frac{a}{Rb}, \frac{8a}{27Rb}, \frac{2a}{Rb}$

(2) $\frac{8a}{27Rb}, \frac{a}{Rb}, \frac{2a}{Rb}$

(3) $\frac{8a}{Rb}, \frac{a}{Rb}, \frac{2a}{Rb}$

(4) $\frac{a}{Rb}, \frac{a}{27Rb}, \frac{2a}{Rb}$

Sol. Answer (2)

Critical temperature , T_C is given as,

$$T_C = \frac{8a}{27\,Rb}$$

Boyle's temperature is given as

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

and inversion temperature is given as

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

59. If for the gases, the critical temperature are mentioned below *i.e.*,

Gas	**Critical temp.**
A	T_{C_1}
B	T_{C_2}
C	T_{C_3}
D	T_{C_4}

$T_{C_1} > T_{C_2} > T_{C_3} > T_{C_4}$

Which of the following can be predicted?

(1) Ease of liquefaction is minimum in gas D

(2) Gas A has maximum value of van der Waal's constant 'a'

(3) Ease of liquefaction is directly proportional to van der Waal's constant 'a'

(4) All of these

Sol. Answer (4)

Higher the critical temperature, T_C,

$\Rightarrow$ More will be the region where the gas can exist as a liquid.

If T_C is low, therefore, the gas attains gaseous form more easily, and hence it is more difficult to liquify it.

Also, van der Waal's constant 'a' represents intermolecular forces. Higher the magnitude of intermolecular forces, higher the value of 'a'. Again, higher the value of 'a', more easily can the gas be liquified

($\therefore$ intermolecular forces are high and hence intermolecular distance is also low)

$\Rightarrow$ Ease of liquefaction is directly proportional to 'a'

In the given data, A can be most easily liquified,

($\therefore$ T_C is highest) $\Rightarrow$ 'a' is highest.

60. Boyle's temperature and inversion temperature are related as

(1) $T_i = T_b$ (2) $2T_i = T_b$ (3) $T_i = 2T_b$ (4) $T_i = \sqrt{T_b}$

Sol. Answer (3)

Boyle's temperature is the temperature at which real gases obey ideal gas equation over an appreciable range of pressure.

It is given as, $T_B = \dfrac{a}{Rb}$

Inversion temperature is the temperature at which no heating or cooling of gas can occur. It is given as

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

$\therefore$ $T_i = 2\ T_B$

SECTION - B

Previous Years Questions

1. The correction factor ‘a’ to the ideal gas equation corresponds to **[NEET-2018]**

(1) Density of the gas molecules
(2) Volume of the gas molecules
(3) Forces of attraction between the gas molecules
(4) Electric field present between the gas molecules

Sol. Answer (3).

In real gas equation, $\left(P+\frac{an^2}{V^2}\right)(V-nb)=nRT$. van der Waal’s constant, ‘a’ signifies intermolecular forces of attraction.

2. Given van der Waals constant for NH_3, H_2, O_2 and CO_2 are respectively 4.17, 0.244, 1.36 and 3.59, which one of the following gases is most easily liquefied? **[NEET-2018]**

(1) NH_3
(2) H_2
(3) CO_2
(4) O_2

Sol. Answer (1)

- van der waal constant ‘a’, signifies intermolecular forces of attraction.
- Higher is the value of ‘a’, easier will be the liquefaction of gas.

3. 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?

[NEET-2016]

(1) $\frac{1}{2}$
(2) $\frac{1}{8}$
(3) $\frac{1}{4}$
(4) $\frac{3}{8}$

Sol. Answer (2)

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

$$\Rightarrow \frac{n_{O_2}}{0.5}=\sqrt{\frac{2}{32}}$$

$$\therefore\ n_{O_2}=\frac{1}{8}$$

4. A gas such as carbon monoxide would be most likely to obey the ideal gas law at **[Re-AIPMT-2015]**

(1) High temperatures and high pressures
(2) Low temperatures and low pressures
(3) High temperatures and low pressures
(4) Low temperatures and high pressures

Sol. Answer (3)

On increasing temperature and decreasing pressure, gases tend to behave ideal.

5. 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 **[AIPMT-2014]**

(1) 8 : 16 : 1
(2) 16 : 8 : 1
(3) 16 : 1 : 2
(4) 8 : 1 : 2

Sol. Answer (3)

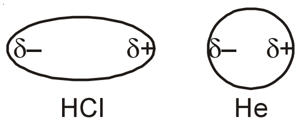
6. Dipole-induced dipole interactions are present in which of the following pairs **[NEET-2013]**

(1) Cl_2 and CCl_4 (2) HCl and He atoms

(3) SiF_4 and He atoms (4) H_2O and alcohol

Sol. Answer (2)

Dipole moment is present in HCl. Due to this dipole, a dipole is induced in He atms as well.



7. Maximum deviation from ideal gas is expected from **[NEET-2013]**

(1) $N_2(g)$ (2) $CH_4(g)$

(3) $NH_3(g)$ (4) $H_2(g)$

Sol. Answer (3)

Since NH_3 shows hydrogen bonding (due to high electronegativity of nitrogen) so intermolecular forces are maximum. Hence it shows maximum deviation.

8. A certain gas takes three times as long to effuse out as helium. Its molecular mass will be

[AIPMT (Mains)-2012]

(1) 27 u (2) 36 u

(3) 64 u (4) 9 u

Sol. Answer (2)

According to Graham's law of diffusion (since effusion is a form of diffusion)

$$\frac{r_{H_e}}{r'} = \sqrt{\frac{M'}{M_{H_e}}}$$

∵ Volume of gas diffused is same,

$$\therefore \frac{r_{H_e}}{r'} = \frac{t'}{t_{H_e}}$$

$$\therefore \frac{t'}{t_{H_e}} = \sqrt{\frac{M'}{M_{H_e}}}$$

$$\text{or, } \frac{3t_{H_e}}{t_{He}} = \sqrt{\frac{M'}{M_{H_e}}}$$

$$\text{or, } 9 = \frac{M'}{4} \Rightarrow M' = 36 \text{ u.}$$

9. For real gases van der Waals equation is written as $\left(p+\frac{an^2}{V^2}\right)(V-nb)=n\,RT$, where 'a' and 'b' are van der Waals constants. Two sets of gases are :

(I) O_2, CO_2, H_2 and He

(II) CH_4, O_2 and H_2

The gases given in set-I in increasing order of 'b' and gases given in set-II in decreasing order of 'a', are arranged below. Select the correct order from the following : **[AIPMT (Mains)-2012]**

(1) (I) $He < H_2 < CO_2 < O_2$ (II) $CH_4 > H_2 > O_2$

(2) (I) $O_2 < He < H_2 < CO_2$ (II) $H_2 > O_2 > CH_4$

(3) (I) $H_2 < He < O_2 < CO_2$ (II) $CH_4 > O_2 > H_2$

(4) (I) $H_2 < O_2 < He < CO_2$ (II) $O_2 > CH_4 > H_2$

Sol. Answer (3)

'a' represents intermolecular forces in van der Waal's equation

While 'b' represents the volume correction *i.e.*, volume that cannot be occupied.

$b \propto$ volume of molecules

$\Rightarrow$ order of b $\rightarrow H_2 < H_e < O_2 < CO_2$

On the other hand, 'a' represents pressure correction 'a' is directly related to Z i.e. Higher the value of 'a' higher is ease of liquefaction (more negative value of Z)

Now, Z value is

$$\underset{\substack{\uparrow \\ \text{most negative}}}{CH_4} < O_2 < \underset{\substack{\uparrow \\ \text{least negative}}}{H_2}$$

$\therefore$ order of a

$CH_4 > O_2 > H_2$

10. By what factor does the average velocity of a gaseous molecule increase when the temperature (in Kelvin) is doubled? **[AIPMT (Prelims)-2011]**

(1) 1.4

(2) 2.0

(3) 2.8

(4) 4.0

Sol. Answer (1)

$$(V_{av})_1 = \sqrt{\frac{8\,RT_1}{\pi M}}$$

$$(V_{av})_2 = \sqrt{\frac{8\,RT_2}{\pi M}}$$

It is given that $T_2 = 2T_1$

$$\therefore \quad (V_{av})_2 = \sqrt{\frac{8\,R\times 2T_1}{\pi M}} = 1.41\sqrt{\frac{8\,RT_1}{\pi M}}$$

$$\Rightarrow \quad (V_{av})_2 = 1.41 \times (V_{av})_1$$

11. 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 **[AIPMT (Prelims)-2011]**

(1) 1 atm (2) 0.5 atm (3) 0.8 atm (4) 0.98 atm

Sol. Answer (2)

Total pressure, p_{total} = 1 atm

Partial pressure of N_2, $p_{N_2} = p_{total} \times \chi_{N_2}$

$$\chi_{N_2}\,(\text{mole fraction}) = \frac{x}{x+x} = \frac{x}{2x} = \frac{1}{2}$$

$$\therefore \quad p_{N_2} = 1\,\text{atm} \times \frac{1}{2} = 0.5\,\text{atm}$$

12. 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 **[AIPMT (Prelims)-2011]**

(1) 25.00 u (2) 50.00 u (3) 12.25 u (4) 6.50 u

Sol. Answer (3)

According to Graham's law of diffusion,

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

$\because$ Volume of gas diffused is same,

$$\therefore \quad \frac{r_B}{r_A} = \frac{t_A}{t_B}$$

$$\therefore \quad \frac{t_A}{t_B} = \sqrt{\frac{M_A}{M_B}}$$

$$\text{or,} \quad \left(\frac{t_A}{t_B}\right)^2 = \frac{M_A}{M_B}$$

$$\text{or,} \quad \left(\frac{20}{10}\right)^2 = \frac{49}{M_B}$$

$$\Rightarrow \quad M_B = \frac{49}{4} = 12.25\text{ u}$$

13. 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?

[AIPMT (Mains)-2011]

(1) Volume will become smaller by a factor of 0.70 (2) Volume will become greater by a factor of 2.5

(3) Volume will become greater by a factor of 1.6 (4) Volume will become greater by a factor of 1.1

Sol. Answer (3)

The mass of gas remains constant inside the bubble.

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

$$\text{or,} \quad \frac{V_2}{V_1} = \frac{P_1T_2}{P_2T_1}$$

Given: $P_2 = 1$ bar $\quad T_2 = 298$ K

$P_1 = 1.5$ bar $\quad T_1 = 288$ K

$$\frac{V_2}{V_1} = \frac{1.5\text{ bar} \times 298\text{ K}}{1\text{ bar} \times 288\text{ K}} = 1.6$$

or, $V_2 = 1.6\ V_1$

$\therefore$ Volume increase by a factor of 1.6.

14. The pressure exerted by 6.0 g 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 JK^{-1} mol^{-1}) **[AIPMT (Mains)-2010]**

(1) 215216 Pa (2) 13409 Pa

(3) 41648 Pa (4) 31684 Pa

Sol. Answer (3)

15. A monatomic gas at pressure P_1 and volume V_1 is compressed adiabatically to $\frac{1}{8}$th its original volume. What is the final presssure of the gas ? **[AIPMT (Mains)-2010]**

(1) 64 P_1 (2) P_1

(3) 16 P_1 (4) 32 P_1

Sol. Answer (4)

16. If a gas expands at constant temperature, it indicates that **[AIPMT (Prelims)-2008]**

(1) Number of the molecules of gas increases

(2) Kinetic energy of molecules decreases

(3) Pressure of the gas increases

(4) Kinetic energy of molecules remains the same

Sol. Answer (4)

$\because$ Temperature remains constant and K.E. depends upon temperature

$\therefore$ Kinetic energy of molecules remains same before and after expansion

17. The surface tension of which of the following liquid is maximum? **[AIPMT (Prelims)-2005]**

(1) H_2O (2) C_6H_6 (3) CH_3OH (4) C_2H_5OH

Sol. Answer (1)

Since hydrogen bonding is strongest in case of H_2O, so H_2O molecules at surface experience maximum forces and hence surface tension is maximum for H_2O molecules.

18. What is the density of N_2 gas at 227°C and 5.00 atm pressure ? ($R = 0.0821$ atm K^{-1} mol^{-1})

(1) 0.29 g/ml (2) 1.40 g/ml (3) 2.81 g/ml (4) 3.41 g/ml

Sol. Answer (4)

We know, density, $d = \dfrac{PM}{RT} = \dfrac{5\text{ atm} \times 28\text{ g mol}^{-1}}{0.082\text{ L atm mol}^{-1}\text{ K}^{-1} \times 500\text{ K}}$ = 3.41 g mol^{-1}

19. Equal weight of CH_4 and H_2 are mixed in a container at 25°C. Fraction of total pressure exerted by methane is

(1) $\frac{1}{2}$ (2) $\frac{1}{3}$ (3) $\frac{1}{9}$ (4) $\frac{8}{9}$

Sol. Answer (3)

Let weights of CH_4 and H_2 mixed be x g

$$\therefore \quad \text{Moles of } CH_4 = \frac{x\text{ g}}{16\text{ g mol}^{-1}} = \frac{x}{16}\text{ mol}$$

$$\text{Moles of } H_2 = \frac{x}{2}\text{ mol}$$

$$\therefore \quad \chi_{CH_4}\left(\text{mole fraction of } CH_4\right) = \frac{\frac{x}{16}}{\frac{x}{16}+\frac{x}{2}} = \frac{1}{9}$$

Partial pressure of CH_4,

$$p_{CH_4} = p_{tot} \times \chi_{CH_4} = \frac{1}{9}\text{ of total pressure}$$

20. 50 ml of hydrogen diffuses out through a small hole of a vessel, in 20 minutes. The time taken by 40 ml of oxygen to diffuse out is

(1) 32 minutes (2) 64 minutes (3) 8 minutes (4) 12 minutes

Sol. Answer (2)

According to Graham's law of diffusion,

$$\frac{r_{H_2}}{r_{O_2}} = \sqrt{\frac{M_{O_2}}{M_{H_2}}} \qquad \ldots(1)$$

$$\text{Now, } \frac{r_{H_2}}{r_{O_2}} = \frac{\frac{V_{H_2}}{t_{H_2}}}{\frac{V_{O_2}}{t_{O_2}}} = \frac{V_{H_2} \times t_{O_2}}{V_{O_2} \times t_{H_2}} \qquad \ldots(2)$$

Combining (1) and (2), we get

$$\frac{V_{H_2} \times t_{O_2}}{V_{O_2} \times t_{H_2}} = \sqrt{\frac{M_{O_2}}{M_{H_2}}} = \sqrt{\frac{32}{2}} = \sqrt{16} = 4$$

$$\text{or, } t_{O_2} = \frac{4 \times V_{O_2} \times t_{H_2}}{V_{H_2}} = \frac{4 \times 40 \text{ mL} \times 20 \text{ min}}{50 \text{ mL}} = 64 \text{ mins.}$$

21. The temperature of a gas is raised from 27°C to 927°C. The root mean square speed of the gas

(1) Remains same (2) Gets $\sqrt{\frac{927}{27}}$ times (3) Gets halved (4) Gets doubled

Sol. Answer (4)

$$V_{rms} \propto \sqrt{T}$$

$$\therefore \quad \frac{(V_{rms})_{927°C}}{(V_{rms})_{27°C}} = \sqrt{\frac{T_{927°C}}{T_{27°C}}} = \sqrt{\frac{(927+273)\,K}{(27+273)\,K}} = \sqrt{\frac{1200}{300}} = \sqrt{4} = 2$$

$$\therefore \quad (V_{rms})_{927°C} = 2 \times (V_{rms})_{27°C}$$

22. An ideal gas, obeying kinetic theory of gases can not be liquefied, because

(1) It solidifies before becoming a liquid

(2) Forces acting between its molecules are negligible

(3) Its critical temperature is above 0°C

(4) Its molecules are relatively small in size

Sol. Answer (2)

For an ideal gas, intermolecular interaction is negligible. Hence, the particles cannot approach each other to result in a decrease in volume and condense to form liquid.

23. Which of the following mixture of gases does not obey Dalton’s Law of partial pressure?

(1) Cl_2 and SO_2 (2) CO_2 and He (3) O_2 and CO_2 (4) N_2 and O_2

Sol. Answer (1)

Dalton's law of partial pressure is valid only for a mixture of non-reacting gases SO_2 and Cl_2 react to form SO_2Cl_2

$$SO_2(g) + Cl_2(g) \longrightarrow \underset{\left(\substack{\text{Sulfuryl}\\ \text{chloride}}\right)}{SO_2Cl_2(g)}$$

24. 0.24 g of a volatile substance, upon vapourisation, gives 45 ml vapour at NTP. What will be the vapour density of the substance?

(1) 95.93 (2) 59.73 (3) 95.39 (4) 5.993

Sol. Answer (2)

Vapour obtained at NTP = 45 mL

Volume of 1 mole vapour = 22400 mL

$\therefore$ Number of moles in 45 mL = $\frac{45}{22400}$

Now, weight of substance = 0.24 g

and $\frac{\text{weight of substance}}{\text{Molecule weight}} = \text{number of moles}$

or, Molecular weight = $\frac{\text{weight of substance}}{\text{number of moles}} = \frac{0.24}{45} \times 22400$

Vapour density = $\frac{\text{Molecular wt.}}{2} = \frac{0.24 \times 22400}{45 \times 2} = 59.73$

25. The average kinetic energy of an ideal gas, per molecule in S.I. units, at 25°C will be

(1) 6.17×10^{-20} J
(2) 7.16×10^{-20} J
(3) 61.7×10^{-21} J
(4) 6.17×10^{-21} J

Sol. Answer (4)

Total kinetic energy = $\frac{3}{2}$ kT = $\frac{3}{2} \times 1.3 \times 10^{-23} \times 298 \text{ K} \times \text{JK}^{-1} = 6.17 \times 10^{-21}$ J

26. At 25°C and 730 mm pressure, 380 ml of dry oxygen was collected. If the temperature is constant, what volume will the oxygen occupy at 760 mm pressure?

(1) 569 ml
(2) 365 ml
(3) 265 ml
(4) 621 ml

Sol. Answer (2)

Since temperature is constant, Boyle's law can be applied.

$\therefore$ $P_1V_1 = P_2V_2$

$$V_2 = \frac{P_1V_1}{P_2} = \frac{730 \text{ mm} \times 380 \text{ ml}}{760 \text{ mm}} = 365 \text{ ml}$$

27. Which of the following statements is wrong for gases?

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

Sol. Answer (4)

Mass of a gas can be determined by weighing the container since there is nothing but gas in the container. The other statements are correct.

28. Average molar kinetic energy of CO and N_2 at same temperature is

(1) $KE_1 = KE_2$

(2) $KE_1 > KE_2$

(3) $KE_1 < KE_2$

(4) Can't say any thing. Both volumes are not given

Sol. Answer (1)

$\because$ Average molar K.E. = $\frac{3}{2}$ RT

$\therefore$ At same temperature, for CO and N_2,

$$(\text{K.E.})_{N_2} = (\text{K.E.})_{CO}$$

29. The beans are cooked earlier in pressure cooker because

(1) Boiling point increases with increasing pressure

(2) Boiling point decreases with increasing pressure

(3) Extra pressure of pressure cooker softens the beans

(4) Internal energy is not lost while cooking in pressure cooker

Sol. Answer (1)

In a pressure cooker, pressure is increased. As a result, the boiling point of water (the medium of cooking) increases and cooking can be carried out at higher temperature without boiling of water. Thus more heat can be transferred to the beans for faster and more efficient cooking.

30. van der Waal's real gas acts as an ideal gas, at which conditions?

(1) High temperature, low pressure

(2) Low temperature, high pressure

(3) High temperature, high pressure

(4) Low temperature, low pressure

Sol. Answer (1)

van der Waal's acts as an ideal gas only at low pressure and high temperature.

31. What is the dominant intermolecular force or bond that must be overcome in converting liquid CH_3OH to a gas?

(1) London dispersion force

(2) Hydrogen bonding

(3) Dipole-dipole interaction

(4) Covalent bonds

Sol. Answer (2)

In CH_3OH, the most dominant intermolecular force is hydrogen bonding.

SECTION - C

Assertion - Reason Type Questions

1. A : The value of van der Waals constant 'a' of Cl_2 is larger than that of F_2.

R : Larger the surface area, higher will be intermolecular forces of attraction.

Sol. Answer (1)

van der Waal's constant 'a' of Cl_2 is larger since 'a' depends on intermolecular interactions and intermolecular interaction increases with an increase in surface area.

2. A : On increasing the temperature, the height of the peak of the Maxwell curve decreases.

R : The total area under the curve remains constant for fixed amount of gas.

Sol. Answer (2)

The height of peak, i.e., the fraction of molecules having mps velocity decreases. However, the total area under the curve remains the same since number of molecules remains the same.

3. A : A real gas will approach ideal behaviour at high temperature and low pressure.

R : At low pressure and high temperature Z = 1, for all gases.

Sol. Answer (1)

At high temperature and low pressure, $\frac{PV}{nRT} \approx 1$ i.e., Z becomes 1.

Thus a real gas behaves as an ideal gas at high temperature and low pressure.

4. A : Rate of diffusion of H_2 is 1.44 times of He.

R : Under similar conditions of temperature and pressure all gases diffuse with same velocity.

Sol. Answer (3)

Under similar conditions of temperature and pressure, rate of diffusion depends on molecular mass of gases and hence is different for different gases $r \propto \frac{1}{\sqrt{M}}$, where M ≡ molecular mass

Now, $\frac{r_{H_2}}{r_{H_e}} = \sqrt{\frac{M_{H_e}}{M_{H_2}}} = \sqrt{\frac{4}{2}} = 1.41$

or, $r_{H_e} = 1.41\, r_{H_e}$

5. A : At constant temperature, if the pressure of the gas is doubled, the density is also doubled.

R : At constant temperature and pressure, the molecular mass of gas is directly proportional to the density.

Sol. Answer (2)

∵ For an ideal gas

$$PV = nRT$$

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

$n = \frac{m}{M}$

or, $P = \frac{mRT}{MV} = \frac{dRT}{M}$

or, $dRT = PM$.

$\therefore$ $M \propto d$ (at constant T and P)

Also, if pressure is doubled, i.e.

$d = \frac{PM}{RT}$

$d' = \frac{2PM}{RT} = 2d$

$\Rightarrow$ density is doubled.

6. A : For a certain amount of gas, PV is always constant at constant temperature.

   R : On increasing temperature PV increases for fixed amount of ideal gas.

Sol. Answer (2)

As per ideal gas equation,

$PV = nRT$

for a fixed amount of gas, nR is constant

$\Rightarrow PV \propto T$

Also, as per Boyle's law, at constant temperature PV is constant for a fixed amount of gas.

7. A : The pressure of real gas is less than the pressure of ideal gas.

   R : Intermolecular forces of attraction in real gases are greater than in ideal gas.

Sol. Answer (1)

In ideal gas, intermolecular forces are negligible. In real gases, intermolecular forces are greater than that in an ideal gas. As a result, the gas molecules hitting the wall (exerting pressure) does so with lesser force, thus leading to a decrease in pressure.

8. A : Helium shows only positive deviation from ideal behaviour.

   R : Helium is a noble gas.

Sol. Answer (2)

Helium shows only positive deviation since repulsive forces are dominant between He atoms.

Also, H_e is a noble gas.

9. A : Hot air balloon rises up by displacing the denser air of the atmosphere.

R : The given mass of a gas becomes less denser.

Sol. Answer (1)

In a hot air balloon, temperature is high

$\because \quad d \propto \frac{1}{T}$

$\because$ density is lower as a result of which it displaces denser air and rises up.

10. A : H_2 when allowed to expand at room temperature it causes heating effect.

R : H_2 has inversion temperature much below room temperature.

Sol. Answer (1)

H_2 has inversion temperature much below room temperature. So, any change above inversion temperature, say room temperature, results in heating of gas.

11. A : At very high pressures, compressibility factor is greater than 1.

R : At very high pressure, ‘b’ can be neglected in van der Waal’s gas equation.

Sol. Answer (3)

At very high pressures, PV > nRT

$\Rightarrow \quad \frac{pV}{nRT} > 1 \Rightarrow Z > 1$

At very high pressure, 'b' is appreciably high and hence cannot the neglected.

12. A : Greater is the critical temperature, more difficult is to liquefy the gas.

R : Stronger are the intermolecular forces lower would be the critical temperature of that gas.

Sol. Answer (4)

Stronger the intermolecular forces, easier is to liquify the gas, hence higher would be critical temperature.

13. A : For a real gas if molar volume is less than 22.4 litres, at S.T.P., compressibility factor (Z) is less than unity.

R : Z = PV/RT, if PV < RT then Z < 1.

Sol. Answer (1)

Since, $Z = \frac{PV}{RT} = \frac{V_{real}}{V_{ideal}}$

If V_{real} < 22.4 L which is V_{ideal}

$\therefore \quad \frac{V_{real}}{V_{ideal}} < 1$

$\Rightarrow \quad Z < 1$

14. A : Vapour pressure of the liquid increases with increase in temperature.

R : At elevated temperature kinetic energy of the liquid molecules increases.

Sol. Answer (1)

At high temperature, kinetic energy of molecules increases as a result of which liquid molecules gain velocity and escapes into vapour phase, thereby increasing vapour pressure.

15. A : At constant temperature, the gas density is directly proportional to pressure.

R : More is the pressure on the gas, the denser it becomes.

Sol. Answer (1)

For an ideal gas,

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

or, $$d = \frac{PM}{RT}$$

So, $d \propto P$ (at constant temperature)

$\therefore$ More the pressure, higher is the density.

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