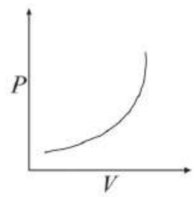
5

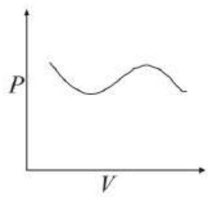
STATES OF MATTER

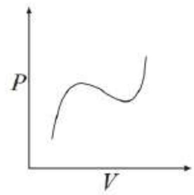
MCQs with One Correct Answer

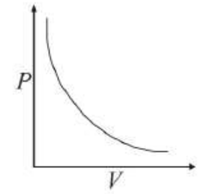
1. 600 c.c. of a gas at a pressure of 750 mm of Hg is compressed to 500 c.c. Taking the temperature to remain constant, the increase in pressure, is
   (a) 150 mm of Hg
   (b) 250 mm of Hg
   (c) 350 mm of Hg
   (d) 450 mm of Hg
2. 16 g of oxygen and 3 g of hydrogen are mixed and kept at 760 mm of Hg pressure and 0°C. The total volume occupied by the mixture will be nearly
   (a) 22.4 litres
   (b) 33.6 litres
   (c) 448 litres
   (d) 44800 mL
3. Equal weights of methane and hydrogen are mixed in an empty container at 25°C. The fraction of the total pressure exerted by hydrogen is :
   (a) $\frac{1}{2}$ (b) $\frac{8}{9}$
   (c) $\frac{1}{9}$ (d) $\frac{16}{17}$
4. X mL of H_2 gas effuses through a hole in a container in 5 seconds. The time taken for the effusion of the same volume of the gas specified below under identical conditions is :
   (a) 10 seconds : He
   (b) 20 seconds : O_2
   (c) 25 seconds : CO
   (d) 55 seconds : CO_2
5. A container contains 1 mole of a gas at 1 atm pressure and 27 °C, while its volume is 24.6 litres. If its pressure is 10 atm and temperature 327 °C, then new volume is
   (a) 2.56 litres (b) 3.15 litres
   (c) 4.92 litres (d) 5.44 litres
6. 14 g of N_2 and 36 g of ozone are at the same pressure and temperature. Their volumes will be related as
   (a) $2V_{N_2} = 3V_{O_3}$
   (b) $3V_{N_2} = 2V_{O_3}$
   (c) $3V_{N_2} = 4V_{O_3}$
   (d) $4V_{N_2} = 3V_{O_3}$

7. The pressure (P) and volume (V) isotherm of a van der Waals' gas, at the temperature at which it undergoes gas to liquid transition, is correctly represented by

(a) 

(b) 

(c) 

(d) 

8. One mole of gas A and three moles of a gas B are placed in flask of volume 100 litres at 27°C. Calculate the total partial pressure of the gases in the mixture.

(a) 1.0 atm. (b) 0.9 atm
(c) 0.985 atm (d) 10.850 atm.

9. Oxygen is present in 1 litre flask at a pressure of 7.6×10^{-10} mm of Hg. Calculate the number of oxygen molecules in the flask at 0ºC.

(a) 2.8×10^{8} (b) 2.7×10^{10}
(c) 0.27×10^{10} (d) 3.0×10^{9}

10. A spherical balloon of 21 cm diameter is to be filled up with hydrogen at N.T.P. from a cylinder containing the gas at 20 atmospheres at 27ºC. If the cylinder can hold 2.82 litres of water, calculate the number of balloons that can be filled up.

(a) 9 (b) 8
(c) 12 (d) 10

11. A given volume of ozonised oxygen (containing 60% oxygen by volume) required 220 sec to effuse while an equal volume of oxygen took 200 sec only under identical conditions. If density of O_2 is 1.6 g/L then find density of O_3.

(a) 1.936 g/L (b) 2.16 g/L
(c) 3.28 g/L (d) 2.24 g/L

12. A container of volume 2.24 L can withstand a maximum pressure of 2 atm at 298 K before exploding. The maximum amount of nitrogen (in g) that can be safely put in this container at this temperature is closest to

(a) 2.8 (b) 5.6
(c) 1.4 (d) 4.2

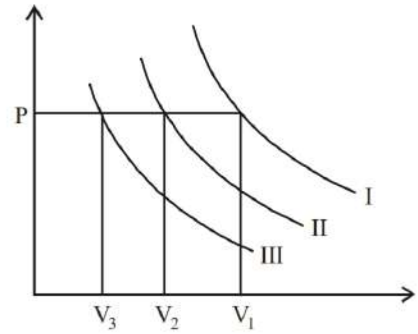
13. At 300 K, the density of a certain gaseous molecule at 2 bar is double to that of dinitrogen (N_2) at 4 bar. The molar mass of gaseous molecule is :

(a) 28 g mol^{-1} (b) 56 g mol^{-1}
(c) 112 g mol^{-1} (d) 224 g mol^{-1}

14. Calculate the total pressure in a 10.0 L cylinder which contains 0.4 g helium, 1.6 g oxygen and 1.4 g nitrogen at 27 °C.

(a) 0.492 atm (b) 49.2 atm
(c) 4.52 atm (d) 0.0492 atm

15. I, II, and III are three isotherms, respectively, at T_1, T_2 and T_3. Temperature will be in order



(a) $T_1 = T_2 = T_3$ (b) $T_1 < T_2 < T_3$
(c) $T_1 > T_2 > T_3$ (d) $T_1 > T_2 = T_3$

16. The root mean square speeds at STP for the gases H_2, N_2, O_2 and HBr are in the order :

(a) $H_2 < N_2 < O_2 < HBr$
(b) $HBr < O_2 < N_2 < H_2$
(c) $H_2 < N_2 = O_2 < HBr$
(d) $HBr < O_2 < H_2 < N_2$.

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

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

18. The root mean square speed of hydrogen in $\sqrt{5}$ times than that of nitrogen. If T is the temperature of the gas, then :
(a) $T_{H_2} = T_{N_2}$ (b) $T_{H_2} > T_{N_2}$
(c) $T_{H_2} < T_{N_2}$ (d) $T_{H_2} = \sqrt{7}T_{N_2}$

19. For one mole of a van der Waals gas, the compressibility factor $Z\left(= \frac{PV}{RT}\right)$ at a fixed volume will certainly decrease if [**Given:** "a", "b" are standard parameters for van der Waals gas]
(a) "b" increases and "a" decreases at constant temperature
(b) "b" decreases and "a" increases at constant temperature
(c) temperature increases at constant "a" and "b" values
(d) "b" increases at constant '"a" and temperature

20. A mixture of Ne and Ar kept in a closed vessel at 250 K has a total K.E. = 3kJ. The total mass of Ne and Ar is 30 g. Find mass % of Ne in gaseous mixture at 250 K.
(a) 61.63 (b) 38.37
(c) 50% (d) 28.3

Numeric Value Answer

21. A gas diffuse1/5 times as fast as hydrogen. If its molecular weight is 10y. What will be the value of y?

22. The rate of diffusion of methane at a given temperature is twice that of a gas *X*. If the molecular weight of *X* is 8y then what will be the value of y?

23. At 400 K, the root mean square (rms) speed of a gas X (molecular weight = 40) is equal to the most probable speed of gas Y at 60 K. The molecular weight of the gas Y is

24. One mole of a gas changed from its initial state (15L, 2 atm) to final state (4L, 10 atm) reversibly. If this change can be represented by a straight line in P – V curve maximum temperature (approximate), the gas attained is $x \times 10^2$K. Then find the value of x.

25. A flask containing air at 107°C and 722 mm of Hg is cooled to 100 K and 760 mm of Hg. If density in the initial condition 1 g/cm^3, then what is the final density (g/cm^3)?

26. If an ideal gas at 100 K is heated to 109 K in a rigid container, the pressure increases by X%. What is the value of X?

27. A flask has 10 gas particles, out of which four particles are moving at 7 ms^{-1} and the remaining are moving at the same speed of 'X' ms^{-1}. If the r.m.s. of the gas is 5 ms^{-1}, what is the value of X?

28. At 300 K, the average kinetic energy of a deuterium molecule is *n* times than that of a hydrogen molecule. Find the value of *n*.

29. The root mean square speed of 4g of helium gas is 450 m/s. What is the value of total kinetic energy (J) of this sample?

30. If the ratio of critical temperature to critical pressure for a real gas is mb/R, then what is the integer value of m?

ANSWER KEY																			
1	(a)	**4**	(b)	**7**	(b)	**10**	(d)	**13**	(c)	**16**	(b)	**19**	(b)	**22**	(8)	**25**	(4)	**28**	(1)
2	(d)	**5**	(c)	**8**	(c)	**11**	(d)	**14**	(a)	**17**	(c)	**20**	(d)	**23**	(4)	**26**	(9)	**29**	(405)
3	(b)	**6**	(b)	**9**	(b)	**12**	(d)	**15**	(c)	**18**	(c)	**21**	(5)	**24**	(7)	**27**	(3)	**30**	(8)

Hints & Solutions

CHAPTER 5

States of Matter

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

$P_1V_1 = P_2V_2$

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

or $P_2 = \dfrac{750 \times 600}{500} = 900$ mm of Hg

Therefore increase of pressure = (900 – 750) = 150 mm of Hg

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

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

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

The total volume occupied $= 2 \times 22.444.8\text{L}$
$= 44800\text{mL}$

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

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

4. **(b)** Under identical conditions, $\dfrac{r_1}{r_2} = \sqrt{\dfrac{M_2}{M_1}}$

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

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

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

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

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

5. **(c)** According to question :

For initial stage of a gas,

$P_1 = 1$ atm, $V_1 = 24.6$ litres,

$T_1 = 273 + 27 = 300$ K

For final stage of a gas,

$P_2 = 10$ atm, $V_2 = ?$

$T_2 = 327 + 273 = 600$ K

By gas equation,

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

$$\frac{1 \times 24.6}{300} = \frac{10 \times V_2}{600}$$

$$\Rightarrow V_2 = \frac{24.6 \times 600}{300 \times 10}$$

= 4.92 litres.

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

$n_{N_2} = \dfrac{14}{28} = \dfrac{1}{2}$; $V_{N_2} \propto \dfrac{1}{2}$

$n_{O_3} = \dfrac{36}{48} = \dfrac{3}{4}$; $V_{O_3} \propto \dfrac{3}{4}$

Hence, $V_{N_2}/V_{O_3} = \dfrac{1}{2} \times \dfrac{4}{3} = \dfrac{2}{3}$

$\therefore 3V_{N_2} = 2V_{O_3}$

7. **(b)** The correct graph which represents the van der Waal's gas under the given condition is option (b).

8. **(c)** Total pressure; $P = \frac{nRT}{V} = \frac{4 \times 0.0821 \times 300}{100}$

$= 0.985$ atm.

$p_A = \frac{n_A}{n_A + n_B}.P = \frac{1}{4} \times 0.985 = 0.246$ atm.

$p_B = \frac{n_B}{n_A + n_B}.P = \frac{3}{4} \times 0.985 = 0.739$ atm.

Total partial pressure $(P_A + P_B) = 0.985$ atm.

9. **(b)** First we should calculate the number of moles of the gas under the given conditions by the relation $PV = nRT$

Here $P = 7.6 \times 10^{-10}$ mm Hg

$= \frac{7.6 \times 10^{-10}}{760}$ atm. $= 1 \times 10^{-12}$ atm.

$V = 1$ litre

$T = 273 + 0 = 273$K

$R = 0.082$ litre atm./K/mol

Putting the values in equation

$n = \frac{PV}{RT} = \frac{1 \times 10^{-12} \times 1}{0.082 \times 273}$ moles

Now since 1 mole contains $= 6.023 \times 10^{23}$ molecules

$\frac{10^{-12}}{0.082 \times 273}$ moles will have

$= \frac{6.023 \times 10^{23} \times 10^{-12}}{0.082 \times 273}$ molecules

$= 2.7 \times 10^{10}$ molecules

10. **(d)** No. of balloons that can be filled

$= \frac{\text{V of } H_2 \text{ available}}{\text{V of one balloon}}$

Calculation of total volume of hydrogen in the cylinder at N.T.P.

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

$P_1 = 1$ atm $\quad P_2 = 20$ atm

$V_1 = ?$ $\quad V_2 = 2.82\ l$

$T_1 = 273$ K $\quad T_2 = 273 + 27 = 300$ K

$\therefore V_1 = \frac{20 \times 2.82 \times 273}{300 \times 1} = 51.324l = 51324$ mL

Actual volume to be transferred into balloons

$= 51324 - 2820$ mL $= 48504$ mL

[$\because$ 2820 mL of H_2 will remain in cylinder]

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

$\left[\because r = \frac{\text{diameter}}{2}\right]$

$= 4851$ ml $= 4.851$L

No. of balloons that can be filled up $= \frac{48504}{4851}$

$= 9.999 = 10$

11. **(d)** Let V mL of gas is effused

$\frac{V/220}{V/200} = \sqrt{\frac{d_{O_2}}{d_{mix}}} \Rightarrow d_{mix} = 1.936$ g/L

Let density of ozone is d. In 100 volume ozonised oxygen, 60% O_2 and 40% by volume O_3 is present

$\therefore$ Mass of mixture = mass of ozone + mass of oxygen

$100 \times 1.936 = 40 \times d + 60 \times 1.6$

$\therefore$ Density of O_3 is 2.44 g/L

12. **(d)** From ideal gas equation

PV = nRT

Maximum number of moles in container,

$n = \frac{PV}{RT} = \frac{2 \times 2.4}{0.0821 \times 298} = 0.18$ moles

Maximum weight of N_2 in container

$= 0.183 \times 28 = 5.127$ g

Hence, at 5.127 g exploding can occur. Thus, the maximum amount of nitrogen that can be safely put in this container at 298 K temperature and exert pressure less than 2 atm will be closest to 4.2 g.

13. **(c)** Density $(\rho) = \frac{PM}{RT}$ (1 bar = 0.987 atm)

$\rho_{N_2} = \frac{4 \times 0.987 \times 28}{R \times 300}$

Let the molar mass of gas be x

$\rho_{gas} = \frac{2 \times 0.987 \times x}{R \times 300}$

Given $\rho_{gas} = \rho_{N_2} \times 2$

$\frac{2 \times 0.987 \times x}{R \times 300} = \frac{4 \times 0.987 \times 28}{R \times 300} \times 2$

$\therefore x = 112$ g/mol.

14. (a) Given T = 27 °C = 27 + 273 = 300 K

V = 10.0 L

Mass of He = 0.4 g

Mass of oxygen = 1.6 g

Mass of nitrogen = 1.4 g

$n_{He} = 0.4/4 = 0.1$

$n_{O_2} = 1.6/32 = 0.05$

$n_{N_2} = 1.4/28 = 0.05$

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

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

15. (c) Draw a line at constant P parallel to volume axis. Take volume corresponding to each temperature.

From volume axis, $V_1 > V_2 > V_3$

Hence, $T_1 > T_2 > T_3$.

16. (b) $PV = \frac{1}{3}\ mNu^2 = \frac{1}{3}\ mu^2$

or $u = \sqrt{3\ PV/M}$

at STP, $u \propto \sqrt{\frac{1}{M}}$

i.e., higher the molar mass lesser will be the value of urms.

Molecular masses of H_2, N_2, O_2 and HBr are 2,28,32 and 81. Hence the correct order is $HBr < O_2 < N_2 < H_2$.

17. (c) $K.E. = \frac{3}{2}nRT;\ K.E(H_2) = \frac{3}{2} \times \frac{w}{2} \times R \times 300;$

$$K.E.(CH_4) = \frac{3}{2} \times \frac{w}{16} \times R \times 600;$$

Hence $\frac{K.E.(H_2)}{K.E.(CH_4)} = 4$

18. (c) $U_{rms}\sqrt{\frac{3RT}{M}}$

$$= \frac{(U_{rms})H_2}{(U_{rms})N_2} = \sqrt{\frac{T_{H_2}}{M_{H_2}} \times \frac{M_{N_2}}{T_{N_2}}};$$

$(U_{rms})H_2 = \sqrt{5}\ (U_{rms})N_2$

$$\therefore \quad \frac{(U_{rms})H_2}{(U_{rms})H_2} \times \sqrt{5} = \sqrt{\frac{T_{H_2}}{T_{N_2}} \times \frac{28}{2}}$$

$$= \frac{\sqrt{5}}{1} = \sqrt{\frac{T_{H_2}}{T_{N_2}} \times 14}$$

$$= 5 = \frac{T_{H_2}}{T_{N_2}} \times 14$$

$T_{N_2} \times 5 = T_{H_2} \times 14$

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

19. (b) Compressibility factor $Z = \frac{PV_m}{RT}$

$$Z = \frac{PV_m}{RT} = \left(\frac{V_m}{V_m - b}\right) - \left(\frac{a}{RTV_m}\right)$$

$$= \frac{1}{1 - \frac{b}{V_m}} - \frac{a}{RTV_m} \qquad \text{... (i)}$$

Considering the equation (i) the value of compressibility factor *Z* decreases as the value of '*b*' decreases and the value of compressibility factor *Z* decreases as the value of '*a*' increases at constant temperature and fixed volume.

20. (d) $K = \frac{3}{2}n_T RT \Rightarrow n_T = \frac{3000 \times 2}{3 \times 250 \times 8.314}$

$3 \times 10^3 = \frac{3}{2}\ n_T \times 8.314 \times 250$

$$\frac{x}{20} + \frac{30 - x}{40} = \frac{2}{8.314}$$

% Ne = 28.3

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

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

$10\ y = 50 \Rightarrow y = 5$

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

$8y = 64 \Rightarrow y = 8$

23. **(4)** v_{rms} of $X = \sqrt{\frac{3RT_x}{M_x}}$; v_{mp} of $Y = \sqrt{\frac{2RT_y}{M_y}}$

Given $v_{rms} = v_{mp}$

$$\Rightarrow \sqrt{\frac{3RT_x}{M_x}} = \sqrt{\frac{2RT_y}{M_y}}$$

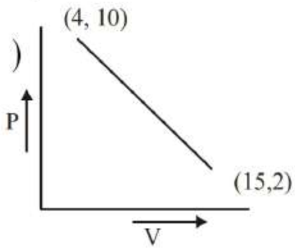
$$\Rightarrow M_y = \frac{2RT_yM_x}{3RT_x} = \frac{2\times 60\times 40}{3\times 400} = 4$$

24. **(7)** Equation of line is =

$$p - 2 = \frac{10-2}{4-15}(V - 15\quad)$$

$$p - 2 = -\frac{8}{11}(V - 15\quad)$$

$$p = 2 - \frac{8V}{11} + \frac{15\times 8}{11}$$



$$p = \left(\frac{142}{11} - \frac{8V}{11}\right)$$

$$f(T) = \frac{1}{nR}\left(\frac{142V}{11} - \frac{8V^2}{11}\right)$$

$$\frac{d(F(T))}{dV} = \frac{1}{nR}\left(\frac{142}{11} - \frac{8V^2}{11}\right) = 0$$

$$V = \frac{142}{11\times 16} = 8.875$$

$$p = \frac{142}{11} - \frac{8}{11}\times\frac{8.875}{16} = \frac{71}{11}$$

$$T_{Max} = \frac{PV}{nR} = \frac{71}{11}\times\frac{142}{16\times 0.0821} = 700$$

$\Rightarrow 7\times 10^2$ K

25. **(4)** $P_i = 722$ mm $\quad P_f = 760$ mm

$T_i = 107 + 273 = 380$ K $\quad P_f = 100$ K

$d_i = 1g/cm^3$ $\quad d_f = ?$

$$\frac{d_iT_iR}{P_i} = \frac{d_fT_fR}{P_f}$$

$$\Rightarrow d_f = \left(\frac{P_f}{P_i}\right)\left(\frac{T_i}{T_f}\right)d_i = \left(\frac{760}{722}\right)\left(\frac{380}{100}\right)\times 1g/cm^3$$

$= 4$ g/cm^3

26. **(9)** V, n constant.

$$\frac{P_i}{T_i} = \frac{P_f}{T_f} \Rightarrow P_f = \frac{T_f}{T_i}P_i = \left(\frac{109}{100}\right)P_i$$

$$\Rightarrow P_{increases} = \Delta P = P_f - P_i = \frac{9}{100}P_i$$

$\therefore$ % Pressure increases

$$= \frac{\Delta P_f}{P_i}\times 100 = \frac{9P_i}{100P_i}\times 100\%$$

X % = 9 %

X = 9

27. **(3)** $u_{rms} = \sqrt{\frac{u_1^2N_1 + u_2^2N_2}{N_1 + N_2}}$

$$\Rightarrow u_{rms}^2 = \frac{u_1^2N_1 + u_2^2N_2}{N_1 + N_2}$$

$$25 = \frac{4\times 7^2 + 6u_2^2}{10} \Rightarrow u_2\sqrt{\frac{54}{6}} = 3ms^{-1}$$

28. **(1)** Average kinetic energy depends only on the temperature. Thus, $n = 1$

29. **(405)** $\mu_{rms} = \sqrt{\frac{3RT}{M}}$

$$450 = \sqrt{\frac{3RT}{4\times 10^{-3}}}$$

(molecular mass of He = 4 ∞ 10^{-3} kg)

RT = 270

Total K.E. of He gas $= \frac{3}{2}nRT = \frac{3}{2}\times\frac{4}{4}\times 270 = 405$ J

30. **(8)** $T_c = \frac{8a}{27Rb}$ and $P_c = \frac{a}{27b^2}$

$$\Rightarrow \frac{T_c}{P_c} = \frac{8b}{R} \quad \left[\because \frac{T_c}{P_c} = \frac{mb}{R}\right]$$

$$\Rightarrow \frac{mb}{R} = \frac{8b}{R}$$

$\therefore$ m = 8