CHAPTER
13

Kinetic Theory

13.3 Behaviour of Gases

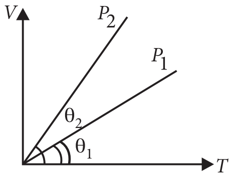
1. A given sample of an ideal gas occupies a volume V at a pressure P and absolute temperature T. The mass of each molecule of the gas is m. Which of the following gives the density of the gas ?

(a) $P/(kT)$ (b) $Pm/(kT)$
(c) $P/(kTV)$ (d) mkT *(NEET-II 2016)*

2. Two vessels separately contain two ideal gases A and B at the same temperature, the pressure of A being twice that of B. Under such conditions, the density of A is found to be 1.5 times the density of B. The ratio of molecular weight of A and B is

(a) 2 (b) 1/2
(c) 2/3 (d) 3/4 *(2015)*

3. In the given (V – T) diagram, what is the relation between pressures P_1 and P_2?



(a) $P_2 < P_1$
(b) Cannot be predicted
(c) $P_2 = P_1$
(d) $P_2 > P_1$

(NEET 2013)

4. At 10°C the value of the density of a fixed mass of an ideal gas divided by its pressure is x. At 110°C this ratio is

(a) $\frac{10}{110}x$ (b) $\frac{283}{383}x$
(c) x (d) $\frac{383}{283}x$ *(2008)*

5. The equation of state for 5 g of oxygen at a pressure P and temperature T, when occupying a volume V, will be

(a) $PV = (5/32)RT$ (b) $PV = 5RT$
(c) $PV = (5/2)RT$ (d) $PV = (5/16)RT$
(where R is the gas constant) *(2004)*

6. The value of critical temperature in terms of van der Waals' constant a and b is given by

(a) $T_C = \frac{8a}{27Rb}$ (b) $T_C = \frac{27a}{8Rb}$
(c) $T_C = \frac{a}{2Rb}$ (d) $T_C = \frac{a}{27Rb}$ *(1996)*

7. Three containers of the same volume contain three different gases. The masses of the molecules are m_1, m_2 and m_3 and the number of molecules in their respective containers are N_1, N_2 and N_3. The gas pressure in the containers are P_1, P_2 and P_3 respectively. All the gases are now mixed and put in one of these containers. The pressure P of the mixture will be

(a) $P < (P_1 + P_2 + P_3)$ (b) $P = \frac{P_1 + P_2 + P_3}{3}$
(c) $P = P_1 + P_2 + P_3$ (d) $P > (P_1 + P_2 + P_3)$ *(1991)*

8. Two containers A and B are partly filled with water and closed. The volume of A is twice that of B and it contains half the amount of water in B. If both are at the same temperature, the water vapour in the containers will have pressure in the ratio of

(a) 1 : 2 (b) 1 : 1
(c) 2 : 1 (d) 4 : 1 *(1988)*

13.4 Kinetic Theory of an Ideal Gas

9. Increase in temperature of a gas filled in a container would lead to

(a) decrease in intermolecular distance
(b) increase in its mass
(c) increase in its kinetic energy
(d) decrease in its pressure *(NEET 2019)*

10. At what temperature will the rms speed of oxygen molecules become just sufficient for escaping from the Earth's atmosphere?
(Given : Mass of oxygen molecule $(m) = 2.76 \times 10^{-26}$ kg, Boltzmann's constant $k_B = 1.38 \times 10^{-23}$ J K^{-1})

(a) 2.508×10^4 K (b) 8.360×10^4 K
(c) 5.016×10^4 K (d) 1.254×10^4 K
(NEET 2018)

11. The molecules of a given mass of a gas have r.m.s. velocity of 200 m s^{-1} at 27°C and 1.0×10^5 N m^{-2} pressure. When the temperature and pressure of the gas are respectively, 127°C and 0.05×10^5 N m^{-2}, the r.m.s. velocity of its molecules in m s^{-1} is

(a) $\frac{100\sqrt{2}}{3}$ (b) $\frac{100}{3}$

(c) $100\sqrt{2}$ (d) $\frac{400}{\sqrt{3}}$ *(NEET-I 2016)*

12. In a vessel, the gas is at pressure P. If the mass of all the molecules is halved and their speed is doubled, then the resultant pressure will be

(a) $2P$ (b) P (c) $P/2$ (d) $4P$

(Karnataka NEET 2013)

13. At 0 K which of the following properties of a gas will be zero?

(a) vibrational energy

(b) density

(c) kinetic energy

(d) potential energy *(1996)*

14. Relation between pressure (P) and kinetic energy per unit volume (E) of a gas is

(a) $P = \frac{2}{3}E$ (b) $P = \frac{1}{3}E$

(c) $P = E$ (d) $P = 3E$ *(1991)*

15. According to kinetic theory of gases, at absolute zero of temperature

(a) water freezes

(b) liquid helium freezes

(c) molecular motion stops

(d) liquid hydrogen freezes. *(1990)*

16. At constant volume temperature is increased then

(a) collission on walls will be less

(b) number of collisions per unit time will increase

(c) collisions will be in straight lines

(d) collisions will not change. *(1989)*

13.5 Law of Equipartition of Energy

17. The average thermal energy for a mono-atomic gas is (k_B is Boltzmann constant and T, absolute temperature)

(a) $\frac{1}{2}k_BT$ (b) $\frac{3}{2}k_BT$

(c) $\frac{5}{2}k_BT$ (d) $\frac{7}{2}k_BT$ *(NEET 2020)*

18. The degrees of freedom of a triatomic gas is

(a) 6 (b) 4

(c) 2 (d) 8 *(1999)*

19. The number of translational degrees of freedom for a diatomic gas is

(a) 2 (b) 3

(c) 5 (d) 6 *(1993)*

20. A polyatomic gas with n degrees of freedom has a mean energy per molecule given by

(a) $\frac{nkT}{N}$ (b) $\frac{nkT}{2N}$ (c) $\frac{nkT}{2}$ (d) $\frac{3kT}{2}$ *(1989)*

13.6 Specific Heat Capacity

21. The value of $\gamma\left(=\frac{C_p}{C_v}\right)$, for hydrogen, helium and another ideal diatomic gas X (whose molecules are not rigid but have an additional vibrational mode), are respectively equal to

(a) $\frac{7}{5}, \frac{5}{3}, \frac{9}{7}$ (b) $\frac{5}{3}, \frac{7}{5}, \frac{9}{7}$

(c) $\frac{5}{3}, \frac{7}{5}, \frac{7}{5}$ (d) $\frac{7}{5}, \frac{5}{3}, \frac{7}{5}$

(Odisha NEET 2019)

22. A gas mixture consists of 2 moles of O_2 and 4 moles of Ar at temperature T. Neglecting all vibrational modes, the total internal energy of the system is

(a) 15 RT (b) 9 RT (c) 11 RT (d) 4 RT

(NEET 2017)

23. The amount of heat energy required to raise the temperature of 1 g of Helium at NTP, from T_1 K to T_2 K is

(a) $\frac{3}{4}N_ak_B(T_2 - T_1)$ (b) $\frac{3}{4}N_ak_B\left(\frac{T_2}{T_1}\right)$

(c) $\frac{3}{8}N_ak_B(T_2 - T_1)$ (d) $\frac{3}{2}N_ak_B(T_2 - T_1)$

(NEET 2013)

24. The molar specific heat at constant pressure of an ideal gas is (7/2)R. The ratio of specific heat at constant pressure to that at constant volume is

(a) 9/7 (b) 7/5

(c) 8/7 (d) 5/7 *(2006)*

25. To find out degree of freedom, the expression is

(a) $f = \frac{2}{\gamma - 1}$ (b) $f = \frac{\gamma + 1}{2}$

(c) $f = \frac{2}{\gamma + 1}$ (d) $f = \frac{1}{\gamma + 1}$ *(2000)*

26. If for a gas, $\frac{R}{C_V} = 0.67$, this gas is made up of molecules which are

(a) diatomic

(b) mixture of diatomic and polyatomic molecules
(c) monoatomic
(d) polyatomic. *(1992)*

27. For hydrogen gas $C_P - C_V = a$ and for oxygen gas $C_P - C_V = b$, so the relation between a and b is given by
(a) $a = 16b$ (b) $16b = a$
(c) $a = 4b$ (d) $a = b$ *(1991)*

28. For a certain gas the ratio of specific heats is given to be $\gamma = 1.5$. For this gas
(a) $C_V = 3R/J$ (b) $C_P = 3R/J$
(c) $C_P = 5R/J$ (d) $C_V = 5R/J$ *(1990)*

13.7 Mean Free Path

29. The mean free path for a gas, with molecular diameter d and number density n can be expressed as
(a) $\frac{1}{\sqrt{2}n\pi d}$ (b) $\frac{1}{\sqrt{2}n\pi d^2}$
(c) $\frac{1}{\sqrt{2}n^2\pi d^2}$ (d) $\frac{1}{\sqrt{2}n^2\pi^2 d^2}$ *(NEET 2020)*

30. The mean free path of molecules of a gas, (radius r) is inversely proportional to
(a) r^3 (b) r^2 (c) r (d) $\sqrt{r}$ *(2014)*

ANSWER KEY

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

Hints & Explanations

1. **(b) :** As $PV = nRT$

or $n = \frac{PV}{RT} = \frac{\text{mass}}{\text{molar mass}}$ ...(i)

Density, $\rho = \frac{\text{mass}}{\text{volume}} = \frac{(\text{molar mass})P}{RT} = \frac{(mN_A)P}{RT}$

$\therefore \quad \rho = \frac{mP}{kT}$ $(\because R = N_A k)$

2. **(d) :** According to an ideal gas equation, the molecular weight of an ideal gas is

$M = \frac{\rho RT}{P}$ $\left(\text{as } P = \frac{\rho RT}{M}\right)$

where P, T and ρ are the pressure, temperature and density of the gas respectively and R is the universal gas constant.

$\therefore$ The molecular weight of A is

$M_A = \frac{\rho_A RT_A}{P_A}$ and that of B is $M_B = \frac{\rho_B RT_B}{P_B}$

Hence, their corresponding ratio is

$$\frac{M_A}{M_B} = \left(\frac{\rho_A}{\rho_B}\right)\left(\frac{T_A}{T_B}\right)\left(\frac{P_B}{P_A}\right)$$

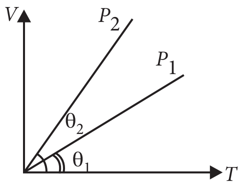
Here, $\frac{\rho_A}{\rho_B} = 1.5 = \frac{3}{2}, \frac{T_A}{T_B} = 1$ and $\frac{P_A}{P_B} = 2$

$\therefore \quad \frac{M_A}{M_B} = \left(\frac{3}{2}\right)(1)\left(\frac{1}{2}\right) = \frac{3}{4}$

3. **(a) :** According to ideal gas equation

$PV = nRT$

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



For an isobaric process,
P = constant and $V \propto T$
Therefore, $V - T$ graph is a straight line passing through origin. Slope of this line is inversely proportional to P.
In the given figure,
$(\text{Slope})_2 > (\text{Slope})_1 \quad \therefore \quad P_2 < P_1$

4. **(b) :** Mass of the gas = m.
At a fixed temperature and pressure, volume is fixed.

Density of the gas $\rho = \frac{m}{V} \Rightarrow \frac{\rho}{P} = \frac{m}{V.P} \Rightarrow \frac{m}{nRT} = x$

$\therefore \quad xT$ = constant.

At 10°C *i.e.*, 283 K, $xT = x \cdot 283$ K ...(i)
At 110°C, $xT = x' \cdot 383$ K ...(ii)

From eq. (i) and (ii) we get $x' = \frac{283}{383}x$

5. **(a) :** As $PV = nRT$

$n = \frac{m}{\text{molecular mass}} = \frac{5}{32} \Rightarrow PV = \left(\frac{5}{32}\right)RT$

6. **(a)**

7. **(c) :** According to Dalton's law of partial pressure, we have $P = P_1 + P_2 + P_3$

8. **(b) :** Vapour pressure does not depend on the amount of substance. It depends on the temperature alone.

9. (c) : As per kinetic theory of gases, kinetic energy of gas molecules is directly proportional to the temperature of the gas.

10. (b) : Escape velocity from the Earth's surface is

$v_{\text{escape}} = 11200 \text{ m s}^{-1}$

Say at temperature T, oxygen molecule attains escape velocity.

$$\text{So, } v_{\text{escape}} = \sqrt{\frac{3k_BT}{m_{O_2}}} \Rightarrow 11200 = \sqrt{\frac{3\times1.38\times10^{-23}\times T}{2.76\times10^{-26}}}$$

On solving, $T = 8.360 \times 10^4$ K

11. (d) : As, $v_{\text{rms}} = \sqrt{\frac{3k_BT}{m}}$

$$\therefore \frac{v_{27}}{v_{127}} = \sqrt{\frac{27+273}{127+273}} = \sqrt{\frac{300}{400}} = \frac{\sqrt{3}}{2}$$

$$\text{or } v_{127} = \frac{2}{\sqrt{3}}\times v_{27} = \frac{2}{\sqrt{3}}\times 200 \text{ m s}^{-1} = \frac{400}{\sqrt{3}} \text{ m s}^{-1}$$

12. (a) : As $P = \frac{1}{3}\frac{mN}{V}v_{\text{rms}}^2$ ...(i)

where m is the mass of each molecule, N is the total number of molecules, V is the volume of the gas.

When mass of all the molecules is halved and their speed is doubled, then the pressure will be

$$P' = \frac{1}{3}\left(\frac{m}{2}\right)\times\frac{N}{V}\times(2v_{\text{rms}})^2 = \frac{2}{3}\frac{mN}{V}v_{\text{rms}}^2 = 2P \quad \text{(Using (i))}$$

13. (c)

14. (a) : $PV = \frac{1}{3}Nmv^2 = \frac{2}{3}\left(\frac{1}{2}Nm\right)v^2 \Rightarrow P = \frac{2}{3}E$

15. (c) : According to classical theory all motion of molecules stop at 0 K.

16. (b) : As the temperature increases, the average velocity increases. So, the number collisions per unit time will increase.

17. (b) : For mono-atomic gas, degree of freedom = 3

Energy associated with each degree of freedom = $\frac{1}{2}k_BT$

So, energy is $\frac{3}{2}k_BT$.

18. (a) : 3 translational, 3 rotational.

19. (b) : Number of translational degrees of freedom are same for all types of gases that is 3.

20. (c) : According to law of equipartition of energy, the energy per degree of freedom is $\frac{1}{2}kT$. For a polyatomic gas with n degrees of freedom, the mean energy per molecule $= \frac{1}{2}nkT$

21. (a) : $\gamma = 1+\frac{2}{n}$; For H_2, $\gamma = 1+\frac{2}{5} = \frac{7}{5}$

For He, $\gamma = 1+\frac{2}{3} = \frac{5}{3}$; For X, $\gamma = 1+\frac{2}{7} = \frac{9}{7}$

22. (c) : The internal energy of 2 moles of O_2 atom is

$$U_{O_2} = \frac{n_1f_1}{2}RT = 2\times\frac{5}{2}\times RT = 5RT$$

The internal energy of 4 moles of Ar atom is

$$U_{Ar} = \frac{n_2f_2RT}{2} = 4\times\frac{3}{2}\times RT = 6RT$$

$\therefore$ The total internal energy of the system is

$$U = U_{O_2} + U_{Ar} = 5RT + 6RT = 11RT$$

23. (c) : As here volume of the gas remains constant, therefore the amount of heat energy required to raise the temperature of the gas is

$$\Delta Q = nC_V\Delta T$$

Here, number of moles, $n = \frac{1}{4}$

$C_V = \frac{3}{2}R$ ($\because$ He is a monatomic.)

$\Delta T = T_2 - T_1$

$$\therefore \Delta Q = \frac{1}{4}\times\frac{3}{2}R(T_2-T_1) = \frac{3}{8}N_ak_B(T_2-T_1) \left(\because k_B = \frac{R}{N_a}\right)$$

24. (b) : Molar specific heat at constant pressure

$$C_P = \frac{7}{2}R \quad \therefore C_V = C_P - R = \frac{7}{2}R - R = \frac{5}{2}R.$$

$$\therefore \frac{C_P}{C_V} = \frac{(7/2)R}{(5/2)R} = \frac{7}{5}$$

25. (a) : Here, $\gamma = 1+\frac{2}{f}$ where f is the degree of freedom

$$\therefore \frac{2}{f} = \gamma - 1 \text{ or } f = \frac{2}{\gamma-1}$$

26. (c) : Since $\frac{R}{C_V} = 0.67 \Rightarrow \frac{C_P - C_V}{C_V} = 0.67$

$\Rightarrow \gamma = 1.67 = \frac{5}{3}$ Hence gas is monoatomic.

27. (d) : $C_P - C_V = R$ for all gases.

28. (b) : $\gamma = \frac{C_P}{C_V} = \frac{15}{10} = \frac{3}{2} \Rightarrow C_V = \frac{2}{3}C_P$

$$C_P - C_V = \frac{R}{J} \text{ or } C_P - \frac{2}{3}C_P = \frac{R}{J}$$

$$\text{or } \frac{C_P}{3} = \frac{R}{J} \text{ or } C_P = \frac{3R}{J}$$

29. (b) : Mean free path for a gas, $\lambda = \frac{1}{\sqrt{2}n\pi d^2}$

30. (b) : Mean free path, $\lambda = \frac{1}{\sqrt{2}n\pi d^2}$

where n is the number density and d is the diameter of the molecule.

As $d = 2r$, $\therefore \lambda = \frac{1}{4\sqrt{2}n\pi r^2}$ or $\lambda \propto \frac{1}{r^2}$

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