Chapter 13

Kinetic Theory

Solutions

SECTION - A

Objective Type Questions

(Molecular Theory of Matter, Behaviour of Gases)

1. Two thermally insulated vessels 1 and 2 are filled with air at temperatures (T_1, T_2), volume (V_1, V_2) and pressure (P_1, P_2) respectively. If the valve joining the two vessels is opened, the temperature inside the vessel at equilibrium will be

(1) $T_1 + T_2$ (2) $\frac{(T_1+T_2)}{2}$ (3) $\frac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_2+P_2V_2T_1}$ (4) $\frac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_1+P_2V_2T_2}$

Sol. Answer (3)

Total number of moles remain constant.

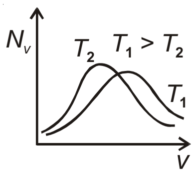
$$n_1 + n_2 = n_1' + n_2'$$

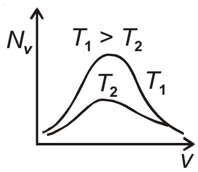
$$\frac{P_1V_1}{T_1}+\frac{P_2V_2}{T_2}=\frac{P_1V_1}{T}+\frac{P_2V_2}{T}$$

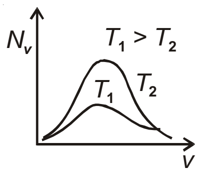
Solving, we get

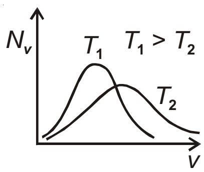
$$T = \frac{P_1V_1+P_2V_2}{\frac{P_1V_1}{T_1}+\frac{P_2V_2}{T_2}}$$

2. The effect of temperature on Maxwell's speed distribution is correctly shown by

(1) 

(2) 

(3) 

(4) 

Sol. Answer (1)

The Maxwell's distribution curve heats at the most probable speed, which depends on temperature.

$$v_{\text{probable}} \propto \sqrt{T}$$

Hence $T_1 > T_2$ is correctly shown in option (1) as it shows with peaks of the curve at higher temperature, furthers along the x-axis.

3. Select the incorrect statement about Maxwell's speed distribution

(1) The distribution function depends only on the absolute temperature

(2) $V_{\text{rms}} > V_{\text{av}} > V_{\text{mp}}$

(3) The area under the distribution curve gives total number of molecules of the gas

(4) The distribution curve is symmetric about the most probable speed

Sol. Answer (4)

The Maxwell's speed distribution is asymmetric due to the fact that the lowest speed possible is zero. While the highest speed possible is infinity.

4. By increasing temperature of a gas by 6°C its pressure increases by 0.4 %, at constant volume. Then initial temperature of gas is

(1) 1000 K (2) 1500 K (3) 2000 K (4) 750 K

Sol. Answer (2)

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

$$T_2 = T + 6$$

$$\frac{P_2}{P_1} - 1 = \frac{T_2}{T_1} - 1$$

$$\frac{P_2 - P_1}{P_1} \times 100 = \left(\frac{T+6}{T} - 1\right)100$$

$$0.4 = \frac{600}{T} \Rightarrow T = 1500 \text{ K}$$

5. Boyle's law is obeyed by

(1) Real gas of constant mass and temperature

(2) Ideal gas of constant mass and temperature

(3) Both ideal and real gases at constant temperature and variable mass

(4) Both ideal and real gases of constant mass and variable temperature

Sol. Answer (2)

Boyle's law states that if m and T are constant.

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

and gas laws are only valid for ideal gases.

6. For an ideal gas the fractional change in its volume per degree rise in temperature at constant pressure is equal to [T is absolute temperature of gas]

(1) T^0 (2) T (3) T^{-1} (4) T^2

Sol. Answer (3)

$PV = n\,RT$ ... (1)

$P\,dv = n\,R\,dT$ ... (2)

Dividing (2) by (1)

$$\frac{dV}{V} = \frac{dT}{T}$$

Fractional change in volume per degree rise in temperature

$$\frac{\frac{dV}{V}}{dT} = \frac{1}{T}$$

7. The raise in the temperature of a given mass of an ideal gas at constant pressure and at temperature 27° to double its volume is

(1) 327°C (2) 54°C (3) 300°C (4) 600°C

Sol. Answer (3)

$PV = nRT$

Initial temperature T_0 = 300 K

$V_0 \propto T_0$

$2V_0 \propto 2T_0$

$2T_0 = 600$ K

$\therefore \Delta T = 600 - 300 = 300$ K = 300°C

8. A container has N molecules at absolute temperature T. If the number of molecules is doubled but kinetic energy in the box remain the same as before, the absolute temperature of the gas is

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

Sol. Answer (2)

Initial energy of gas = Final energy

Let K.E. of each molecule initially be E_0.

$\therefore$ Total kinetic energy = $E_0 \times n$

Let final kinetic energy of each molecule be E_f.

$E_0 \times n = E_f \times 2n$

$$E_f = \frac{E_0}{2}$$

Since temperature is the average kinetic energy of molecules.

$T_0 = KE_0$ $\qquad$ $T_f = \frac{KE_0}{2}$

$\therefore$ Temperature becomes $T_f = \frac{T_0}{2}$

9. During an experiment an ideal gas is found to obey an additional law VP^2 = constant. The gas is initially at temperature T and volume V, when it expands to volume $2V$, the resulting temperature is

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

Sol. Answer (3)

VP^2 = constant ... (i)

As $PV = RT \Rightarrow P = \frac{RT}{V}$. Thus from (i)

$$\frac{VR^2T^2}{V^2} = \text{constant} \Rightarrow \frac{T^2}{V} = \text{constant}$$

$$\frac{T_2^2}{2V} = \frac{T^2}{V} \Rightarrow T_2 = T\sqrt{2}$$

10. When pressure remaining constant, at what temperature will the r.m.s. speed of a gas molecules increase by 10% of the r.m.s. speed at NTP?

(1) 57.3 K (2) 57.3ºC (3) 557.3 K (4) –57.3ºC

Sol. Answer (2)

$$V = \sqrt{\frac{3RT}{M}} \text{ or } V = K\sqrt{T}$$

Let $\frac{V \times 110}{100} = K\sqrt{T_2}$

$$\frac{V}{1.1}\text{V} = \sqrt{\frac{T}{T_2}}$$

T_2 = 1.21 T

Putting T = 273 K

T_2 = 57.33°C

(Kinetic Theory of an Ideal Gas)

11. Select the appropriate property of an ideal gas

(1) Its molecules are infinitesimally small

(2) There are no forces of interaction between its molecules

(3) It strictly obeys the ideal gas laws

(4) All of these

Sol. Answer (4)

All of the statements are true for an ideal gas.

12. A real gas behaves as an ideal gas at

(1) Very low pressure and high temperature (2) High pressure and low temperature

(3) High pressure and high temperature (4) Low pressure and low temperature

Sol. Answer (1)

At very low pressure the force of interaction between particles may be considered negligible. Also at high temperature the force of inter molecular interaction decreases

13. A gas at a pressure P_0 is contained in a vessel. If the masses of all the molecules are halved and their velocities doubled, then the resulting pressure P will be

(1) $4P_0$ (2) $2P_0$ (3) P_0 (4) $\frac{P_0}{2}$

Sol. Answer (2)

$$P_0 = \frac{1}{3}\frac{mn}{v}\bar{v}^2$$

$$P' = \frac{1}{3}\frac{mn}{2v}(2\bar{v})^2 = 2P_0$$

14. If E is the energy density in an ideal gas, then the pressure of the ideal gas is

(1) $P = \frac{2}{3}E$ (2) $P = \frac{3}{2}E$ (3) $P = \frac{5}{2}E$ (4) $P = \frac{2}{5}E$

Sol. Answer (1)

$$E = \frac{1}{2}m\bar{v}^2 \times \frac{n}{v}$$

$$P = \frac{1}{3}\frac{mN}{v}\bar{v}^2$$

$$P = \frac{2}{3}E$$

15. A sample of gas in a box is at pressure P_0 and temperature T_0. If number of molecules is doubled and total kinetic energy of the gas is kept constant, then final temperature and pressure will be

(1) T_0, P_0 (2) T_0, $2P_0$ (3) $\frac{T_0}{2}, 2P_0$ (4) $\frac{T_0}{2}, P_0$

Sol. Answer (4)

$$P_0 = \frac{1}{3}\frac{mN}{v}\cdot v_{\text{rms}}^2$$

If E_0 is initial KE of one molecule

$$nE_0 = E'\cdot 2n \Rightarrow E' = \frac{E}{2} \Rightarrow \left(\frac{1}{2}mv^2\right)\frac{1}{2} = \frac{1}{2}mv'^2 = v' = \frac{v}{\sqrt{2}}$$

Thus KE of every molecule becomes half. Hence temperature becomes $\frac{T_0}{2}$.

$$P' = \frac{1}{3}\frac{m2N}{v}\left(\frac{v}{\sqrt{2}}\right)^2 = P_0$$

Thus $T' = \frac{T_0}{2},\ P' = P_0$

16. The average velocity of gas molecules is

(1) Proportional to $\sqrt{T}$

(2) Proportional to T

(3) Zero

(4) Not possible to determine

Sol. Answer (3)

$$\bar{v} = \sqrt{\frac{3RT}{M}}$$

$\therefore \quad v \propto \sqrt{T}$

17. Which of the following methods will enable the volume of ideal gas to be increased four times?

(1) Double the temperature and reduce the pressure to half

(2) Double the temperature and also double the pressure

(3) Reduce the temperature to half and double the pressure

(4) Reduce the temperature to half and reduce the pressure to half

Sol. Answer (1)

$$V_0 = k\frac{T_0}{P_0}$$

$$4V_0 = 4k\frac{T_0}{P_0}$$

$$= k \times \frac{2T_0}{P_0/2}$$

$\therefore$ Temperature is doubled and pressure halved.

18. The average speed of gas molecules is v at pressure P. If by keeping temperature constant the pressure of gas is doubled, then average speed will become

(1) $\sqrt{2}\,v$

(2) v

(3) $2v$

(4) $\frac{v}{\sqrt{2}}$

Sol. Answer (2)

$$v_{av} \propto \sqrt{T}$$

Since temperature is constant v_{av} is constant.

19. Four molecules of a gas have speeds 1, 2, 3 and 4 km/s. The value of the r.m.s. speed of the gas molecules is

(1) $\frac{1}{2}\sqrt{15}$ km/s

(2) $\frac{1}{2}\sqrt{10}$ km/s

(3) 2.5 km/s

(4) $\sqrt{\frac{15}{2}}$ km/s

Sol. Answer (4)

$$\text{R.M.S. speed} = \sqrt{\frac{v_1^2 + v_2^2 + v_3^2 ... v_n^2}{n}}$$

$$\bar{v} = \sqrt{\frac{1^2 + 2^2 + 3^2 + 4^2}{4}}$$

$$\bar{v} = \sqrt{\frac{30}{4}}$$

$$\bar{v} = \sqrt{\frac{15}{2}}$$

20. The r.m.s. speed of the molecules of enclosed gas is V. What will be the r.m.s. speed if pressure is doubled keeping the temperature same?

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

Sol. Answer (2)

Temperature is a quantities which denotes a value which gives the average kinetic energy of molecules in a gas. This depends on velocities of gas molecules and vice-versa. If temperature does not change $V_{\text{r.m.s.}}$ will also not change.

(Law of Equipartition of Energy, Specific Heat Capacity, Mean Free Path)

21. The ratio of number of collisions per second at the walls of containers by He and O_2 gas molecules kept at same volume and temperature, is (assume normal incidence on walls)

(1) 2 : 1 (2) 1 : 2 (3) $2\sqrt{2}:1$ (4) $1:2\sqrt{2}$

Sol. Answer (3)

$$\left(\frac{n_{O_2}}{n_{He}}\right)^2 = \frac{M_{He}}{M_{O_2}}$$

$M_{He} = 4$ $M_{O_2} = 32$

$$\frac{n_{O_2}}{n_{He}} = \frac{1}{2\sqrt{2}}$$

$$\therefore \quad n_{He} : n_{O_2} = 2\sqrt{2} : 1$$

22. An ant is moving on a plane horizontal surface. The number of degrees of freedom of the ant will be

(1) 1 (2) 2 (3) 3 (4) 6

Sol. Answer (2)

The number of degrees of freedom of movement of ant is 2 as it can move only in two independent directions in the plane surface.

23. If a gas has 'f' degree of freedom, the ratio of the specific heats of the gases $\frac{C_p}{C_v}$ is

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

Sol. Answer (4)

$C_p = C_v + R$

and $C_v = \frac{f}{2}R$

$$\frac{C_p}{C_v} = \frac{\frac{f}{2}R+R}{\frac{f}{2}}$$

$$\frac{C_p}{C_v} = \frac{f+2}{f}$$

$$\frac{C_p}{C_v} = \frac{2+f}{f}$$

$$\frac{C_p}{C_v} = 1+\frac{2}{f}$$

24. Molar specific heat at constant volume, for a non-linear triatomic gas is (vibration mode neglected)

(1) $3R$ (2) $4R$ (3) $2R$ (4) R

Sol. Answer (1)

Molar heat capacities for a gas is given by $C_v = \frac{f}{2}RT$

Where $f = 6$ in triatomic molecules

$C_v = 3\ RT$

25. A mixture of ideal gases has 2 moles of He, 4 moles of oxygen and 1 mole of ozone at absolute temperature T. The internal energy of mixture is

(1) 13 RT (2) 11 RT (3) 16 RT (4) 14 RT

Sol. Answer (3)

Degrees of freedom of He (f_{He}) = 3

Degrees of freedom of O_2 (f_{O_2}) = 5

Degrees of freedom of O_3 (f_{O_3}) = 6

$n_{He} = 2$, $n_{O_2} = 4$ $n_{O_3} = 1$

Energy of mixture = Sum of individual energies

$$= \left(n_{He}f_{He} + n_{O_2}f_{O_2} + n_{O_3}f_{O_3}\right)\frac{RT}{2}$$

$$= (2\times3+4\times5+1\times6)\frac{RT}{2}$$

= (3 + 10 + 3) RT

= 16 RT

26. E_O and E_H respectively represents the average kinetic energy of a molecule of oxygen and hydrogen. If the two gases are at the same temperature, which of the following statement is true?

(1) $E_O > E_H$ (2) $E_O = E_H$ (3) $E_O < E_H$ (4) Data insufficient

Sol. Answer (2)

Temperature is an approximate value which refers to average kinetic energy per molecule. If temperature of both is same, average energy will be same according to definition.

27. 14 g of CO at 27°C is mixed with 16 g of O_2 at 47°C. The temperature of mixture is (vibration mode neglected)

(1) –5°C (2) 32°C (3) 37°C (4) 27°C

Sol. Answer (3)

1 mole of CO and 1 mole of O_2 are mixed.

Net internal energy = $\frac{f_1}{2}RT_{CO} + \frac{f_2}{2}RT_{O_2}$

$$= \frac{5}{2}R300 + \frac{5}{2}R350$$

$$= \frac{5}{2}R(650)$$

= 5 R(325)

= 1625 R

$$1625 = \frac{5}{2}RT_{final} \times n_{final}$$

$$\frac{1625\times2}{5} = T_{final} \times n_{final}$$

$325 \times 2 = T_{final} \times 2$

T_{final} = 325 K

T_{final} = 37°C

28. When one mole of monatomic gas is mixed with one mole of a diatomic gas, then the equivalent value of γ for the mixture will be (vibration mode neglected)

(1) 1.33 (2) 1.40 (3) 1.50 (4) 1.6

Sol. Answer (3)

Y for monatomic gas = $1+\frac{2}{3}=\frac{5}{3}=\gamma_1$

Y for diatomic gas = $1+\frac{2}{5}=\frac{7}{5}=\gamma_2$

$$\frac{n}{\gamma-1}=\frac{n_1}{\gamma_1-1}+\frac{n_2}{\gamma_2-1}$$

$$\frac{2}{\gamma-1}=\frac{1}{\frac{5}{3}-1}+\frac{1}{\frac{7}{5}-1}$$

Solving, we get $\gamma = 3/2$

29. A box of negligible mass containing 2 moles of an ideal gas of molar mass M and adiabatic exponent γ moves with constant speed v on a smooth horizontal surface. If the box suddenly stops, then change in temperature of gas will be

(1) $\frac{(\gamma-1)Mv^2}{4R}$ (2) $\frac{\gamma Mv^2}{2R}$ (3) $\frac{Mv^2}{2(\gamma-1)R}$ (4) $\frac{(\gamma-1)Mv^2}{2R}$

Sol. Answer (4)

Mass of gas in the box = 2 M

Initial kinetic energy = $\frac{1}{2}\times 2M\times v^2=Mv^2$

$Mv^2 = \frac{1}{2}nfR\Delta T$

$\therefore \quad \Delta T = \frac{2Mv^2}{nfR}$

Substitution $f = \frac{2}{1-r}$ and n = 2

$\Delta T = \frac{(\gamma-1)Mv^2}{2R}$

30. On increasing number density for a gas in a vessel, mean free path of a gas

(1) Decreases (2) Increases (3) Remains same (4) Becomes double

Sol. Answer (1)

Mean free path of a substance is the average distance a molecule may travel without collision.

If the number of molecules per unit volume increases it increases the frequency of collision and decreases the mean free path.

SECTION - B

Objective Type Questions

(Molecular Theory of Matter, Behaviour of Gases)

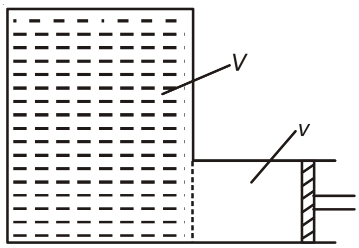
1. An ideal gas is enclosed in a container of volume V at a pressure P. It is being pumped out of the container by using a pump with stroke volume v. What is final pressure in container after n-stroke of the pump? (assume temperature remains same)

(1) $P\left(\frac{V}{V+v}\right)^n$ (2) $\frac{PV}{(V-v)^n}$ (3) $P\frac{V^n}{v^n}$ (4) $P\left(\frac{V}{V-v}\right)^n$

Sol. Answer (1)

After stroke PV = constant

$$PV = P_1(V + v)$$



$$P_1 = \frac{PV}{(V+v)}$$

Similarly after 2[nd] stroke

$$P_2 = P\left(\frac{V}{V+v}\right)^2$$

After n^{th} stroke

$$P_n = P\left(\frac{V}{V+v}\right)^n$$

2. Variation of atmospheric pressure, with height from earth is

(1) Linear (2) Parabolic (3) Exponential (4) Hyperbolic

Sol. Answer (3)

Variation of atmospheric pressure due to height is given by the barometric formula

$$P_h = P_0\, e^{-mgh/RT}$$

Hence the decrease will be exponential.

3. An ideal gas is filled in a closed container and container is moving with uniform acceleration in horizontal direction. Neglect gravity. Pressure inside the container is

(1) Uniform everywhere (2) Less in front (3) Less at back (4) Less at top

Sol. Answer (2)

Each particle closes experience a pseudo force initials, themselves to give low pressure every where. This is because of Pascal's law.

4. A container contains 32 g of O_2 at a temperature T. The pressure of the gas is P. An identical container containing 4 g of H_2 at a temperature $2T$ has a pressure of

(1) $8P$ (2) $4P$ (3) P (4) P_{18}

Sol. Answer (2)

Given, 1 mole of O_2 at temperature T, pressure P

and 2 moles of H_2 at a temperature $2T$

$$P_1 = \frac{n\times RT}{V}$$

$$P_0 = \frac{RT}{V} = P$$

$$P_H = \frac{4RT}{V} = 4P$$

5. An ideal gas is expanding such that PT = constant. The coefficient of volume expansion of the gas is

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

Sol. Answer (2)

PT = Constant

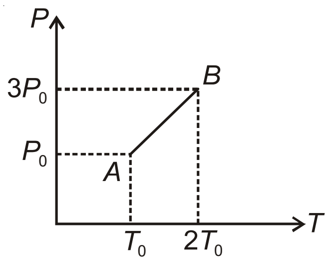
or $\frac{T^2}{V}$ = Constant $[PV = nRT] \Rightarrow T_2 = KV$ ... (i)

Differentiating w.r.t. T, we get

$$\frac{2T}{V} - \frac{K}{V}\frac{dV}{dT} \Rightarrow \frac{2T}{VK} = \frac{dV}{VdT}$$

$$\therefore \quad \frac{dV}{VdT} = \frac{2TV}{VT^2} = \frac{2}{T}$$

6. Pressure versus temperature graph of an ideal gas is as shown in figure. Density of the gas at point A is ρ_0. Density at point B will be



(1) $\frac{3}{4}\rho_0$ (2) $\frac{3}{2}\rho_0$ (3) $\frac{4}{3}\rho_0$ (4) $2\rho_0$

Sol. Answer (2)

$PV = nRT$

$P = \frac{\rho}{M}RT$

Initially $\rho = \rho_0$, $P = P_0$, $T = T_0$

$P_0 = \frac{\rho_0 R}{M}T_0$ initially ... (i)

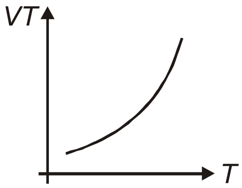
$3P_0 = \frac{\rho_x R}{M}2T_0$ final ... (ii)

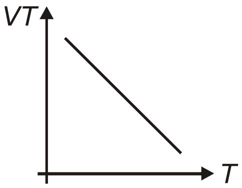
Dividing (ii) by (i)

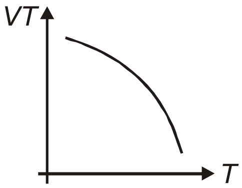
$3 = \frac{\rho_x}{\rho_0}2$

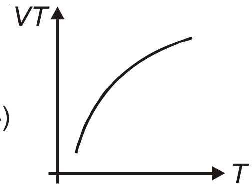
$\frac{3}{2}\rho_0 = \rho_x$

7. If heat energy is given to an ideal gas at constant pressure, then select the graph which best represents the variation of VT with temperature (T).

(1) 

(2) 

(3) 

(4) 

Sol. Answer (1)

$$PV = nRT$$

$$\frac{P}{nR} = \frac{T}{V}$$

and $\frac{V}{T} = \frac{nR}{P}$ = constant (K)

$$VT = KT^2$$

Assuming $VT = y$ and $x = T$

$$y = Kx^2$$

Which is equation of a parabola will focus on y-axis > facing upwards.

8. The temperature (T) of one mole of an ideal gas varies with its volume (V) as $T = -\alpha V^3 + \beta V^2$, where α and β are positive constants. The maximum pressure of gas during this process is

(1) $\frac{\alpha\beta}{2R}$ (2) $\frac{\beta^2 R}{4\alpha}$ (3) $\frac{(\alpha+\beta)R}{2\beta^2}$ (4) $\frac{\alpha^2 R}{2\beta}$

Sol. Answer (2)

$T = -\alpha V^3 + \beta V^2$ ... (i)

and $PV = nRT$ ... (ii)

$n = 1$

So, $P = \frac{RT}{V}$

Multiplying $\frac{R}{V}$ in (i)

$$\frac{RT}{V} = (-\alpha V^2 + \beta V)R$$

or $P = (-\alpha V^2 + \beta V)R$ ... (iii)

$$\frac{dP}{dV} = (-2\alpha V + \beta)R$$

Maxima is when $\frac{dP}{dV} = 0$ and $\frac{d^2P}{dV^2}$ in negative, so

$0 = (-2\alpha V + \beta)R$

$V = \dfrac{\beta}{2\alpha}$

Put in value of V in equation (iii)

$$P = \left(-\alpha\frac{\beta^2}{4\alpha^2} + \frac{\beta^2}{2\alpha}\right)R \Rightarrow P = \frac{\beta^2 R}{4\alpha}$$

9. Nitrogen gas is filled in an insulated container. If α fraction of moles dissociates without exchange of any energy, then the fractional change in its temperature is

(1) $\dfrac{-\alpha}{5+\alpha}$ (2) $\dfrac{\alpha}{3+\alpha}$ (3) $\dfrac{-3\alpha}{2+\alpha}$ (4) $\dfrac{5\alpha}{2+3\alpha}$

Sol. Answer (1)

Degree of freedom of diatomic nitrogen = 5

Degree of freedom of monoatomic nitrogen = 3

Let initial number of moles be n and α fraction dissociated.

So fraction dissociated = $n\alpha$ fraction remaining = $n - n\alpha$.

$n\alpha$ break into two so new atoms formed is actually $2n\alpha$.

Initial energy is given by = $n\times\dfrac{f}{2}\times RT = n\times\dfrac{5}{2}\times RT$

Final energy = $(n-n\alpha)\dfrac{5}{2}RT_2 + 2n\alpha\times\dfrac{3}{2}RT_2$

$$= \frac{5}{2}nRT_2 - \frac{5}{2}n\alpha RT_2 + n\alpha 3RT_2$$

$$= \frac{5}{2}nRT_2 + \frac{n\alpha RT_2}{2}$$

$$= \frac{(5+2)nRT_2}{2}$$

Change in energy is given on zero.

$$\frac{5nRT}{2} = \frac{(5+\alpha)nRT_2}{2}$$

$$\frac{5T}{5+\alpha} = T_2$$

$\Delta T = T_2 - T$

or $\Delta T = \dfrac{5T}{5+\alpha} - T = \dfrac{-\alpha}{5+\alpha}T$

Fractional change in temperature = $\dfrac{\Delta T}{T}$ or $-\dfrac{\alpha}{5+\alpha}$

10. An ideal gas undergoes a polytropic given by equation PV^n = constant. If molar heat capacity of gas during this process is arithmetic mean of its molar heat capacity at constant pressure and constant volume then value of n is

(1) Zero (2) –1 (3) +1 (4) γ

Sol. Answer (2)

Polytropic process

PV^n = constant

Given heat capacities is average of C_P and C_V. So

$$C = \frac{C_P + C_V}{2}$$

or $$C = \frac{2C_V + R}{2}$$

or $$C = \frac{C_V + R}{2} \quad \text{... (i)}$$

Now formula for specific heat of polytropic process is given by

$$C = \frac{R}{y-1} + \frac{R}{1-n} \quad \text{... (ii)}$$

or $$\frac{R}{y-1} + \frac{R}{2} = \frac{R}{y-1} + \frac{R}{1-n} \text{ as } C_V = \frac{R}{y-1}$$

$$\frac{R}{2} = \frac{R}{1-n}$$

or $n = -1$

11. Nitrogen gas N_2 of mass 28 g is kept in a vessel at pressure of 10 atm and temperature 57ºC. Due to leakage of N_2 gas its pressure falls to 5 atm and temperature to 27ºC. The amount of N_2 gas leaked out is

(1) $\frac{5}{63}$g (2) $\frac{63}{5}$g (3) $\frac{28}{63}$g (4) $\frac{63}{28}$g

Sol. Answer (2)

Mass = 28 g

P_i = 10 atm T_i = 57°C = 330 K

P_f = 5 atm T_f = 27°C = 300 K

Volume is kept constant.

$P_i = K \times n_i T_i$ ... (i)

$P_f = K \times n_f T_f$ ... (ii)

Dividing (i) by (ii)

$$\frac{P_i}{P_f} = \frac{n_i}{n_f}\frac{T_i}{T_f}$$

$$\frac{n_i}{n_f} = \frac{10}{5}\times\frac{300}{330}$$

or $$\frac{n_i}{n_f} = 2\times\frac{10}{11}$$

$$\frac{n_i}{n_f} = \frac{20}{11}$$

Now n_i = 1 mole of N_2

$$n_f = \frac{11}{20} \text{ moles}$$

or Mass of N_2 left $= \frac{11}{20} \times 28$

$\therefore$ Quantity released $= 28 - \frac{11}{20} \times 28$

$$= \frac{9}{20}\times 28 = \frac{63}{5}\text{g}$$

(Kinetic Theory of an Ideal Gas)

12. At room temperature the rms speed of the molecules of a certain diatomic gas is found to be 1920 m/s. The gas is

(1) H_2 (2) F_2 (3) Cl_2 (4) O_2

Sol. Answer (1)

$$V_{\text{r.m.s.}} = \sqrt{\frac{3RT}{M}}$$

$$1920 = \frac{\sqrt{3\times 8.314\times 300}}{M}$$

$$M = \frac{3\times 8.314\times 300}{1920}$$

M = 0.00202 kg

On molar weight = 2.02 g.

Hence it is hydrogen.

13. One mole of monatomic gas and three moles of diatomic gas are put together in a container. The molar specific heat (in JK^{-1} mol^{-1}) at constant volume is (Let R = 8 JK^{-1} mol^{-1})

(1) 18 (2) 19 (3) 20 (4) 21

Sol. Answer (1)

n_1 = 1 mole $f_1 = 3$

n_2 = 3 moles $f_2 = 5$

R = 8 JK^{-1} mol^{-1}

Molar specific heat are given by the weighted means of the gases.

$$C_{v_f} = \frac{n_1 \times C_{v_1} + n_2 \times C_{v_2}}{n_1 + n_2}$$

$$C_{v_f} = \frac{1 \times \frac{3}{2}R + 3 \times \frac{5}{2}R}{4}$$

$$= \frac{3}{8}R + \frac{15}{8}R$$

$$= \frac{18}{8}R$$

$$C_{v_f} = 18$$

14. A narrow glass tube, 80 cm long and opens at both ends, is half immersed in mercury, now the top of the tube is closed and is taken out of mercury. A column of mercury 20 cm long remains in the tube. Find atmospheric pressure

(1) 20 cm of air column
(2) 60 cm of Hg column
(3) 60 cm of air column
(4) 20 cm of Hg column

Sol. Answer (2)

PV = constant

$P_1V_1 = P_2V_2$ [$P_1 = P_0$ atmospheric pressure]

$P_0 \times 40 = P_1 \times 60$ ... (i)

$P_1 + 20 = P_0$ ... (ii)

From (i)

$$P_1 = \frac{2P_0}{3}$$

From (ii)

$$\frac{2P_0}{3} + 20 = P_0 \Rightarrow P_0 = 60 \text{ cm of Hg.}$$

15. Two closed containers of equal volume filled with air at pressure P_0 and temperature T_0. Both are connected by a narrow tube. If one of the container is maintained at temperature T_0 and other at temperature T, then new pressure in the containers will be

(1) $\frac{2P_0T}{T+T_0}$
(2) $\frac{P_0T}{T+T_0}$
(3) $\frac{P_0T}{2(T+T_0)}$
(4) $\frac{T+T_0}{P_0}$

Sol. Answer (1)

$$\frac{P}{T} = \text{constant}$$

Initially $\frac{P_0}{T_0}+\frac{P_0}{T_0}=\frac{2P_0}{T_0}$

For two containers

$$\frac{P_0}{T_0}+\frac{P}{T}=\frac{2P_0}{T_0}$$

$$P = \frac{2P_0 \times T \times T_0}{T_0(T+T_0)}$$

or $P = \frac{2P_0T}{(T+T_0)}$

16. If different ideal gases are at the same temperature, pressure and have same volume, then all gases have same

(1) Density
(2) Number of molecules
(3) Most probable speed
(4) Internal energy per mole

Sol. Answer (2)

$$PV = nRT$$

or $\frac{PV}{RT}=n$

At the same pressure volume and temperature each molecule will have same number of moles *i.e*. same number of molecules of gas.

17. According to C.E. van der Waal, the interatomic potential varies with the average interatomic distance (R) as

(1) R^{-1}
(2) R^{-2}
(3) R^{-4}
(4) R^{-6}

Sol. Answer (4)

Interatomic potential varies with average interatomic distance as R^{-6} which is a fact.

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

(1) $T_C=\frac{8a}{27Rb}$
(2) $T_C=\frac{27a}{8Rb}$
(3) $T_C=\frac{a}{2Rb}$
(4) $T_C=\frac{a}{27Rb}$

Sol. Answer (1)

Critical temperature is given as :

$$T_C = \frac{8a}{27R_b}$$

(Law of Equipartition of Energy, Specific Heat Capacity, Mean Free Path)

19. Three perfect gases at absolute temperatures T_1, T_2 and T_3 are mixed. If number of molecules of the gases are n_1, n_2 and n_3 respectively then temperature of mixture will be (assume no loss of energy)

(1) $\dfrac{T_1+T_2+T_3}{3}$ (2) $\dfrac{n_1^2T_1+n_2^2T_2+n_3^2T_3}{n_1+n_2+n_3}$ (3) $\dfrac{n_1T_1+n_2T_2+n_3T_3}{n_1+n_2+n_3}$ (4) $\dfrac{T_1+T_2+T_3}{n_1+n_2+n_3}$

Sol. Answer (3)

Absolute temperature = T_1, T_2, T_3.

Internal energy of gases = $\dfrac{n_1RT_1}{2}+\dfrac{n_2RT_2}{2}+\dfrac{n_3RT_3}{2}$

Average temperature = $\dfrac{\text{Internal energy of mixture}}{(n_1+n_2+n_3)\dfrac{R}{2}}$

20. The temperature of a gas is –68°C. At what temperature will the average kinetic energy of its molecules be twice that of –68°C?

(1) 137°C (2) 127°C (3) 100°C (4) 105°C

Sol. Answer (1)

Average kinetic energy = $\dfrac{f}{2}RT$

or K.E.$_{avg} \propto T$

For K.E. energy to be doubles that of K.E. at – 68°C or 205 K.

The temperature must be 2 T or 410 K

When converted to °C = 410 – 273 = 137°C

21. One kg of a diatomic gas is at pressure of 8 × 10^4 N/m^2. The density of the gas is 4 kg/m^3. The energy of the gas due to its thermal motion will be

(1) 3 × 10^4 J (2) 5 × 10^4 J (3) 6 × 10^4 J (4) 7 × 10^4 J

Sol. Answer (2)

$PV = n\ RT$ ... (1)

f = 4 kg/m^3

$\therefore$ v = 0.25 m^3

8 × 10^4 × $\dfrac{1}{4}PV$ ... (2)

Energy of gas is given by = $\dfrac{f}{2}RT\times n$

$=\dfrac{5}{2}\times PV$ [From (1)]

$=\dfrac{5}{2}\times 2\times 10^4 = 5\times 10^4$ J

22. 50 cal of heat is required to raise the temperature of 1 mole of an ideal gas from 20°C to 25°C, while the pressure of the gas is kept constant. The amount of heat required to raise the temperature of the same gas through same temperature range at constant volume is (R = 2 cal/mol/K)

(1) 70 cal (2) 60 cal (3) 40 cal (4) 50 cal

Sol. Answer (3)

$$C_P = \frac{50}{AT} = 10 \text{ cal K}^{-1} \text{ mol}^{-1}$$

$$C_P = C_V + R$$

$$C_V = C_P = R$$

$$C_V = 8 \text{ cal K}^{-1} \text{ mol}^{-1}$$

23. The energy (in eV) possessed by a neon atom at 27°C is

(1) 1.72×10^{-3} (2) 4.75×10^{-4} (3) 3.88×10^{-2} (4) 3.27×10^{-5}

Sol. Answer (3)

Neon is a monoatomic gas.

So, at 300 K its internal energy is given by $\frac{1}{2}fkT$

For one molecule $\frac{3}{2}kT$

24. If hydrogen gas is heated to a very high temperature, then the fraction of energy possessed by gas molecules correspond to rotational motion

(1) $\frac{3}{5}$ (2) $\frac{2}{7}$ (3) $\frac{3}{7}$ (4) $\frac{2}{5}$

Sol. Answer (2)

Hydrogen is a diatomic molecules and if vibrational degrees of freedom are increased the degrees of freedom will be 3 translation 2 rotational and two vibrational.

∴ So total 7 degree of freedom.

Fraction of energy possessed due to rotational motion : Degree of freedom due to rotation total degree of freedom = $\frac{2}{7}$

25. If α moles of a monoatomic gas are mixed with β moles of a polyatomic gas and mixture behaves like diatomic gas, then [neglect the vibrational mode of freedom]

(1) $2\alpha = \beta$ (2) $\alpha = 2\beta$ (3) $\alpha = -3\beta$ (4) $3\alpha = -\beta$

Sol. Answer (1)

26. The internal energy of 10 g of nitrogen at N.T.P. is about

(1) 2575 J (2) 2025 J (3) 3721 J (4) 4051 J

Sol. Answer (2)

Number of moles of $N_2 = \frac{10}{28}$

$$U = \frac{f}{2} nRT$$

$$= \frac{5}{2} \times \frac{5}{14} \times R \times 273$$

$$= 2025 \text{ J}$$

27. The mean free path of a molecule of He gas is α. Its mean free path along any arbitrary coordinate axis will be

(1) α (2) $\frac{\alpha}{3}$ (3) $\frac{\alpha}{\sqrt{3}}$ (4) 3α

Sol. Answer (3)

Mean free path of a molecule is the resultant of path along three separate axis and they will be equal.

So, $\alpha = \sqrt{\alpha_x^2 + \alpha_y^2 + \alpha_2^2}$

where $\alpha_x = \alpha_y^2 \alpha_2 = \text{(say) } a$

$$\alpha = \sqrt{a^2 + a^2 + a^2}$$

or $a = \frac{\alpha}{\sqrt{3}}$

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

(1) $f = \frac{2}{\gamma - 1}$ (2) $f = \frac{\gamma + 1}{2}$ (3) $f = \frac{2}{\gamma + 1}$ (4) $f = \frac{1}{\gamma + 1}$

Sol. Answer (1)

$C_V = \frac{f}{2} R$ $C_P = C_V + R = \frac{f}{2} R + R = \frac{(f+2)}{2} R$

$$\gamma = \frac{C_P}{C_V}$$

$$= \frac{(f+2) R \times 2}{2 \times f R}$$

$$\gamma = 1 + \frac{2}{f}$$

$$\gamma - 1 = \frac{2}{f}$$

$$f = \frac{2}{\gamma - 1}$$

29. A diatomic gas of molecular mass 40 g/mol is filled in a rigid container at temperature 30ºC. It is moving with velocity 200 m/s. If it is suddenly stopped, the rise in the temperature of the gas is

(1) $\frac{32}{R}$ °C (2) $\frac{320}{R}$ °C (3) $\frac{3200}{R}$ °C (4) $\frac{3.2}{R}$ ºC

Sol. Answer (2)

Let there by n moles of gas.

Mass of gas = 40ng or $\frac{40n}{1000}$ or $0.04n$ kg

K.E. of gas in container = $\frac{1}{2} \times 0.04\, n \times (200)^2$

$= 0.02 \times n \times 4 \times 10^4$

$= 8 \times 10^2 \times n$ J

Now heat capacity of gas (C) $= \frac{f}{2}nR$

or $C = \frac{5}{2} R \times n$

or $C\Delta T = 8 \times 10^2 \times n$

or $\frac{5}{2} \times R \times n\, \Delta T = 8 \times 10^2 \times n$

$\Delta T = \frac{8 \times 10^2}{R} \times \frac{2}{5}$

$\Delta T = \frac{16}{5} \times 10^2 = \frac{320}{R}$ °C

30. The ratio of average translatory kinetic energy of He gas molecules to O_2 gas molecules is

(1) $\frac{25}{21}$ (2) $\frac{21}{25}$ (3) $\frac{3}{2}$ (4) 1

Sol. Answer (4)

Both He and O_2 have 3 translatory degrees of freedom. At the same temperature, energy is divided equally in all degrees of freedom. Hence ratio of the translatory kinetic energy is one.

SECTION - C

Previous Years Questions

1. 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) = 2.76×10^{-26} kg, Boltzmann's constant $k_B = 1.38 \times 10^{-23}$ JK^{-1})

[NEET-2018]

(1) 2.508×10^4 K (2) 8.360×10^4 K

(3) 1.254×10^4 K (4) 5.016×10^4 K

Sol. Answer (2)

V_{escape} = 11200 m/s

Say at temperature T it attains V_{escape}

$$\text{So,} \sqrt{\frac{3k_BT}{m_{O_2}}} = 11200 \text{ m/s}$$

On solving,

$T = 8.360 \times 10^4$ K

2. 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 **[NEET-2017]**

(1) 4 RT (2) 15 RT (3) 9 RT (4) 11 RT

Sol. Answer (4)

$$U = n_1\frac{f_1}{2}RT + n_2\frac{f_2}{2}RT$$

$$= 2\times\frac{5}{2}RT + 4\times\frac{3}{2}RT = 5\,RT + 6\,RT$$

$\Rightarrow U = 11\,RT$

3. 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?

[NEET(Phase-2)-2016]

(1) $\frac{P}{(kT)}$ (2) $\frac{Pm}{(kT)}$ (3) $\frac{P}{(kTV)}$ (4) mkT

Sol. Answer (2)

$$\frac{P}{\rho} = \frac{kT}{m}$$

$$\rho = \frac{Pm}{kT}$$

4. The molecules of a given mass of a gas have r.m.s. velocity of 200 ms^{-1} at 27°C and 1.0 × 10^5 Nm^{-2} pressure. When the temperature and pressure of the gas are respectively, 127°C and 0.05 × 10^5 Nm^{-2}, the r.m.s. velocity of its molecules in ms^{-1} is **[NEET-2016]**

(1) $\frac{100}{3}$ (2) $100\sqrt{2}$ (3) $\frac{400}{\sqrt{3}}$ (4) $\frac{100\sqrt{2}}{3}$

Sol. Answer (3)

$v_{rms} = 200$ ms^{-1}, $T_1 = 300$ K, $P_1 = 10^5$ Nm^{-2}

$v_{rms} = \sqrt{\frac{3RT}{M}}$, $T_2 = 400$ K, $P_2 = 0.05 \times 10^5$ N/m^2

$$\Rightarrow \frac{V_2}{v_1} = \sqrt{\frac{T_2}{T_1}}$$

$$\Rightarrow v_2 = \sqrt{\frac{400}{300}}\times 200\text{ ms}^{-1} = \frac{400}{\sqrt{3}}\text{ ms}^{-1}$$

5. 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 **[Re-AIPMT-2015]**

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

Sol. Answer (3)

$\boxed{A}$	$\boxed{B}$
$2P$	P
$1.5\ d$	d

We known,

$$PV = nRT$$

$$PV = \frac{m}{M}RT$$

$$P = \left(\frac{m}{V}\right)\frac{1}{M}RT$$

$$P = \frac{d}{M}RT$$

So, $$\frac{P_1}{P_2} = \frac{d_1}{M_1}\cdot\frac{M_2}{d_2}$$

$$\frac{2P}{P} = \frac{1.5\,d}{M_1}\cdot\frac{M_2}{d}$$

$$\boxed{\frac{M_1}{M_2} = \frac{15}{20} = \frac{3}{4}}$$

6. The ratio of the specific heats $\frac{C_P}{C_v} = \gamma$ in terms of degrees of freedom (n) is given by **[AIPMT-2015]**

(1) $\left(1+\frac{n}{2}\right)$ (2) $\left(1+\frac{1}{n}\right)$ (3) $\left(1+\frac{n}{3}\right)$ (4) $\left(1+\frac{2}{n}\right)$

Sol. Answer (4)

We known

$$C_v = \frac{n}{2}R \quad \text{...(i)}$$

So, $$C_P = R + C_v = R + \frac{n}{2}R = R\left(1+\frac{n}{2}\right) \quad \text{...(ii)}$$

On dividing equation (ii) by (i)

$$\frac{C_P}{C_v} = \frac{R\left(1+\frac{n}{2}\right)}{R\frac{n}{2}} = Y$$

So, $$\left(1+\frac{n}{2}\right) = Y\frac{n}{2}$$

$$\boxed{Y = 1+\frac{2}{n}}$$

7. The mean free path of molecules of a gas, (radius r) is inversely proportional to **[AIPMT-2014]**

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

Sol. Answer (2)

The mean free path of molecules of gas is given by

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 n} \qquad \text{where} \quad d = \text{diameter of molecule}$$

$$d = 2r$$

So, $\boxed{\lambda \propto \frac{1}{r^2}}$

8. The amount of heat energy required to raise the temperature of 1 g of Helium at NTP, from T_1K to T_2K is **[NEET-2013]**

(1) $\frac{3}{2}N_a k_B(T_2 - T_1)$ (2) $\frac{3}{4}N_a k_B(T_2 - T_1)$ (3) $\frac{3}{4}N_a k_B\left(\frac{T_2}{T_1}\right)$ (4) $\frac{3}{8}N_a k_B(T_2 - T_1)$

Sol. Answer (4)

Mole of helium is 4 g

So, number of moles of helium = $\frac{1}{4}$ moles

NTP there is constant pressure

C_P of gas = $\frac{f}{2}R = \frac{3R}{2}$

$$\Delta Q = C_P \times n\,\Delta T$$

$$= \frac{3}{2}R \times \frac{1}{4} \times (T_2 - T_1) = \frac{3R}{8}(T_2 - T_1)$$

9. Two container 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 same temperature, the water vapour in the container will have pressure in the ratio of

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

Sol. Answer (2)

Vapour pressure for the same liquid is always the same. So the ratio will be $P : P$ or 1 : 1.

10. At constant volume, temperature is increased then

(1) Collision on walls will be less

(2) Number of collisions per unit time will increase

(3) Collisions will be in straight lines

(4) Collisions will not change

Sol. Answer (2)

At constant volume if temperature is increased pressure will increase. Since pressure is increased due to collisions of particles will the wall of the container. So collisions per unit time will increase.

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

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

Sol. Answer (3)

Numbers of degrees of freedom = n.

Internal energy of gas = $\frac{n}{2}RT$

$K = \frac{R}{N}$ where N is the Avogadro's number.

or $NK = R$

Internal energy = $\frac{n}{2}NKT$

Internal energy per molecule = $\frac{n}{2}\frac{NKT}{N}$ or $\frac{nKT}{2}$

12. For a certain gas the ratio of specific heats is given to be $\gamma = 1.5$. For this gas

(1) $C_v = \frac{3R}{J}$ (2) $C_p = \frac{3R}{J}$ (3) $C_p = \frac{5R}{J}$ (4) $C_v = \frac{5R}{J}$

Sol. Answer (2)

For a certain gas $\frac{C_p}{C_v} = 1.5$

$C_p = C_v + R$

$1 + \frac{R}{C_v} = 1.5$

$R = \frac{C_v}{2}$ or $C_v = 2R$

$C_p = 3R$

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

(1) Water freezes

(2) Liquid helium freezes

(3) Molecular motion stops

(4) Liquid hydrogen freezes

Sol. Answer (3)

According to kinetic energy of gases at absolute temperature molecular motion stops as for ideal gases only in kinetic energy of gases is considered which is given by

K.E. = $\frac{f}{2}nKT$

So, T = 0 K and motion will be zero.

14. One mole of an ideal monoatomic gas requires 207 J heat to raise the temperature by 10 K when heated at constant pressure. If the same gas is heated at constant volume to raise the temperature by the same 10 K, the heat required is [Given the gas constant R = 8.3 J/mol-K]

(1) 198.7 J (2) 29 J (3) 215.3 J (4) 124 J

Sol. Answer (4)

$$C_P = \frac{207}{10} = 20.7 \text{ J/mol-K}$$

$$R = 8.3$$

and $C_V = C_P - R = 12.4$ J/mol-K

$$\Delta Q = C_V \Delta T = 124 \text{ J}$$

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

(1) $P = \frac{2}{3}E$ (2) $P = \frac{1}{3}E$ (3) $P = \frac{1}{2}E$ (4) $P = 3E$

Sol. Answer (1)

Relation between pressure (P) and average kinetic energy is given by

$$P = \frac{1}{3}mN\bar{v}^2 \quad \text{... (i)}$$

$$E = \frac{1}{2}m\bar{v}^2 \quad \text{... (ii)}$$

Using (i) and (ii)

$$P = \frac{2}{3}E$$

16. If C_s be the velocity of sound in air and C be the rms velocity, then

(1) $C_s < C$ (2) $C_s = C$ (3) $C_s = C\left(\frac{\gamma}{3}\right)^{1/2}$ (4) None of these

Sol. Answer (3)

Velocity of sound in air is given by

$$C_s = \sqrt{\frac{\gamma P}{\rho}} \text{ or } \sqrt{\frac{\gamma RT}{M}}$$

$$C = \sqrt{\frac{3RT}{M} = P}$$

$$C_s = C\sqrt{\frac{\gamma}{3}}$$

17. The temperature of gas is raised from 27°C to 927°C. The rms speed is

(1) $\sqrt{\frac{927}{27}}$ times the earlier value (2) Remain the same

(3) Gets halved (4) Get doubled

Sol. Answer (4)

$$V = \sqrt{\frac{3RT}{M}}$$

$$V = K\sqrt{T}$$

$V_1 = K\sqrt{300}$

$V_2 = K\sqrt{1200}$

$\frac{V_1}{V_2} = \frac{\sqrt{300}}{\sqrt{1200}}$

$\frac{2\sqrt{300}}{\sqrt{300}} V_1 = V_2$

or $V_2 = 2V_1$

18. The equation of state, corresponding to 8 g of O_2 is

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

Sol. Answer (2)

8 g of O_2 = $\frac{1}{4}$ moles

$PV = nRT$

$PV = \frac{1}{4}RT$ $\left[\text{as } n = \frac{1}{4}\right]$

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

(1) Kinetic energy (2) Potential energy (3) Density (4) Mass

Sol. Answer (1)

By definition at absolute zero the kinetic energy of a gas is zero.

20. 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

(1) $\frac{283}{383}x$ (2) x (3) $\frac{383}{283}x$ (4) $\frac{10}{110}x$

Sol. Answer (1)

$PV = nRT$

$\frac{P}{\rho} = \frac{RT}{M}$

$x = \frac{RT}{M}$

$T_1 = 283$ K $T_2 = 383$ K

$x_1 = \frac{R}{M}\times 283$ $x_2 = \frac{R}{M}\times 383$

$\frac{x_1}{x_2} = \frac{283}{383}$

$x_2 = \frac{383}{283}$

21. The degrees of freedom of a triatomic gas is (consider moderate temperature)

(1) 6 (2) 4 (3) 2 (4) 8

Sol. Answer (1)

A non-linear triatomic gas has 3 translators and 3 rotatory degrees of freedom.

22. The equation of state for 5 g of oxygen at a pressure P and temperature T, when occupying a volume V, will be (where R is the gas constant)

(1) $PV = \frac{5}{32}RT$ (2) $PV = 5RT$ (3) $PV = \frac{5}{2}RT$ (4) $PV = \frac{5}{16}RT$

Sol. Answer (1)

Number of moles (n) = $\frac{5}{32}$

$-PV = nRT$

$PV = \frac{5}{32}RT$

SECTION - D

Assertion-Reason Type Questions

1. A : For a real gas internal energy depends on its temperature as well as volume also.

R : For a real gas interatomic potential energy depends on volume and kinetic energy depends on temperature.

Sol. Answer (1)

The assertion is correct and the reason is the correct explanation of assertion.

2. A : The gravitational force between the gas molecules is ineffective due to extremely small size and very high speed.

R : No force of interaction acts between molecules of an ideal gas.

Sol. Answer (2)

Both the statements are true but reason is the incorrect explanation of assertion. The assertion happens to be self explanatory.

3. A : Average velocity of gas molecules is zero.

R : Due to random motion of gas molecules, velocities of different molecules cancel each other.

Sol. Answer (1)

The assertion is true but reason is correct explanation of assertion.

4. A : At constant volume on increasing temperature the collision frequency increases.

R : Collision frequency $\propto$ temperature of gas.

Sol. Answer (3)

The assertion is true but collision frequency does not increase linearly with temperature.

5. A : Two gases with the same average translational kinetic energy have same temperature even if one has greater rotational energy as compared to other.

R : Only average translational kinetic energy of a gas contributes to its temperature.

Sol. Answer (1)

The assertion is true and reason is correct explanation of assertion.

6. A : All molecular motion ceases at –273.15°C.

   R : Temperature below –273.15°C cannot be attained.

Sol. Answer (2)

Both the statements are correct but reason is not the correct explanation for assertion.

7. A : Magnitude of mean velocity of the gas molecules is same as their mean speed.

   R : The only difference between mean velocity and mean speed is that mean velocity is a vector and mean speed is a scalar.

Sol. Answer (4)

Mean velocity of a gas is not the same as mean speed. Hence both the statements are correct.

8. A : Mean free path of gas molecules varies inversely as density of the gas.

   R : Mean free path varies inversely as pressure of the gas.

Sol. Answer (2)

Mean free path is given by = $\dfrac{V}{\sqrt{2}N\pi d^2}$

Where

N is total number of molecules.

V is volume.

d is the diameter of molecule.

$\dfrac{N}{V}$ is the number velocity of gas hence assertion is true. But the mean free path does not depend on pressure.

9. A : Number of air molecules in a room in winter is more than the number of molecules in the same room in summer.

   R : At a given pressure and volume, the number of molecules of a given mass of a gas is directly proportional to the absolute temperature.

Sol. Answer (3)

The assertion is true as at a lower temperature there is a higher density.

According to $PV = nRT$

$$\pi \propto \frac{1}{n}$$

Hence reason is false.

10. A : Evaporation occurs at any temperature whereas the boiling point depends on the external pressure.

    R : Evaporation of a liquid occurs from the surface of a liquid at all temperature whereas boiling takes place at a temperature determined by the external pressure.

Sol. Answer (1)

The assertion is true and the reason is the correct explanation of the assertion.

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