# 9. KINETIC THEORY OF GASES

**HOMEWORK SOLUTIONS**

**1. Given :**

$T = 273$ K

$\rho = 1.25$ kg/m³

$P = 1.013 \times 10^5$ N/m²

**To Find :**

$C = ?$

**Formula :**

$$C = \sqrt{\frac{3P}{\rho}}$$

**Solution :**

$$C = \sqrt{\frac{3 \times 1.013 \times 10^5}{1.25}}$$

$$\therefore \quad C = A\!l \frac{1}{2}\left[\log 3 + \log 1.013 + 5 \log 10 - \log 1.25\right]$$

$$\therefore \quad C = A\!l \frac{1}{2}\left[0.4771 + 0.0055 + 5 - 0.0969\right]$$

$$\therefore \quad C = A\!l \frac{1}{2}\left[5.4826 - 0.0969\right]$$

$$\therefore \quad C = A\!l \frac{5.3857}{2}$$

$$\therefore \quad C = A\!l\ (2.6928)$$

$$C = 492.9 \text{ m/s}$$

**2. Given :**

$T = 127^0C + 273 = 400$ K

$\rho = 1.44$ kg/m³

$T_0 = 273$ K

$P = 1.013 \times 10^5$ N/m²

**To Find :**

R.M.S. velocity of oxygen at $127^0C = C = ?$

**Formula :**

i) $C_0 = \sqrt{\frac{3p}{\rho}}$

ii) $C \propto \sqrt{T}$

**Solution :**

$$C_0 = \sqrt{\frac{3p}{\rho}} \quad \text{... at } T_0 = 273 \text{ K}$$

$$= \sqrt{\frac{3 \times 1.013 \times 10^5}{1.44}}$$

$$C_0 = 459.39 \text{ m/s}$$

$$C_0 \propto \sqrt{T}$$

$$\therefore \quad \frac{C_0}{C} = \sqrt{\frac{T_0}{T}}$$

$$\therefore \quad \frac{459.39}{C} = \sqrt{\frac{273}{400}}$$

$$\therefore \quad C = \frac{459.39 \times 20}{\sqrt{273}} = 556.07 \text{ m/s}$$

$$\therefore \quad C = 556.07 \text{ m/s}$$

**3. Given :**

$T_O = 273$ K

$C_O = 460.9$ m/s

$T_H = 273$ K

$M_O = 32$

$M_H = 2$

**To Find :**

$C_H = ?$

**Formula :**

$$\text{As, } C \propto \sqrt{\frac{T}{M}}$$

$$\therefore \quad \frac{C_H}{C_O} = \sqrt{\frac{T_H}{T_O} \times \frac{M_O}{M_H}}$$

**Solution :**

$$\therefore \quad \frac{C_H}{C_O} = \sqrt{\frac{273}{273} \times \frac{32}{2}} = 4$$

$$\therefore \quad C_H = 4 \times 460.9 \text{ m/s}$$

$$\therefore \quad C_H = 1843.6 \text{ m/s}$$

**4. Given :**

$C_H = 1840$ m/s at NTP

$M_H = 2$

$M_O = 32$

**To Find :**

$C_O = ?$

**Formula :**

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

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

**Solution :**

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

$$\therefore \frac{C_O}{C_H} = \sqrt{\frac{M_H}{M_O}}$$

$$\frac{C_O}{C_H} = \sqrt{\frac{2}{32}}$$

$$\frac{C_O}{C_H} = \frac{1}{4}$$

$$\therefore C_O = \frac{1}{4} \times C_H$$

$$\therefore C_O = \frac{1}{4} \times 1840$$

$$\therefore C_O = 460 \text{ m/s}$$

**5. Given :**

$\rho_0 = 1.43$ kg/m³

$\rho = 13600$ kg/m³

$g = 9.8$ m/s²

**To Find :**

$C_{rms} = ?$

**Formula :**

i) $P = h\rho g$

ii) $$C = \sqrt{\frac{3P}{\rho_0}}$$

**Solution :**

$P = h\rho g$

$\therefore P = 0.76 \times 13600 \times 9.8$

$\therefore P = 1.013 \times 10^5$ N/m²

Also, $$C = \sqrt{\frac{3P}{\rho_0}} = \sqrt{\frac{3 \times 1.013 \times 10^5}{1.43}}$$

$$\therefore C = \sqrt{\frac{3.039}{0.143}} \times 10^2$$

$$\therefore C = \sqrt{\frac{3.019}{0.143}} \times 10^2$$

$= A\mathit{l}\,[1/2\,(\log 3.019 - \log 0.143)] \times 10^2$

$$\therefore C = A\mathit{l} \times \frac{1}{2}\left[-\frac{0.4799}{\overline{1}.1553}\right] \times 10^2$$

$\therefore C = A\mathit{l}\,(0.6623) \times 10^2$

$\therefore C = 4.595 \times 10^2$ m/s

$\therefore C = 460.9$ m/s

**6. Given :**

$C_0 = 459.3$ m/s

$T_0 = 273$

$T_N = 340$ K

$M_N = 28$

$M_O = 32$

**To Find :**

$C_N$ at 340 K = ?

**Formula :**

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

**Solution :**

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

$$\therefore C_0 = \sqrt{\frac{3RT_0}{M_0}}$$

$$\therefore C_N = \sqrt{\frac{3RT_N}{M_N}}$$

$$\therefore \frac{C_0}{C_N} = \sqrt{\frac{T_0}{T_N}} \times \sqrt{\frac{M_N}{M_0}}$$

$$\therefore \frac{C_0}{C_N} = \sqrt{\frac{273}{340} \times \frac{28}{32}}$$

$\therefore \quad \frac{C_0}{C_N} = Al\frac{1}{2}\left[2.4362 + 1.4472 - 2.5315 - 1.5051\right]$

$\therefore \quad \frac{C_0}{C_N} = Al\left(\frac{3.8834 - 4.0366}{2}\right)$

$\therefore \quad \frac{C_0}{C_N} = Al\left(\frac{\bar{1}.8468}{2}\right)$

$\therefore \quad \frac{C_0}{C_N} = Al\left(\frac{\bar{2} + 1.84468}{2}\right)$

$\therefore \quad = Al\ (\bar{1} + 0.9234)$

$\therefore \quad = Al\ (\bar{1}.9234)$

$\therefore \quad \frac{C_0}{C_N} = 0.8381$

$\therefore \quad C_N = \frac{459.3}{0.8381}$

$\therefore \quad C_N = Al\ (2.6621 - \bar{1}.92\ 34)$

$\therefore \quad C_N = Al\ (2.7387)$

$\therefore \quad C_N = 547.9\ m/s$

**7. Given :**

Let suffix '1' & '2' represent Nitrogen & Oxygen respectively.

| Nitrogen | Oxygen |
|---|---|
| $T_1 = ?$ | $T_2 = 400\ K$ |
| $C_1 = C$ | $C_2 = C$ |
| $M_1 = 28$ | $M_2 = 32$ |

**To Find :** $T_1 = ?$

**Formula :** $C \propto \sqrt{T/M}$

**Solution :**

As, $C \propto \sqrt{T/M}$

$\frac{C_1}{C_2} = \sqrt{\frac{T_1}{T_2} \times \frac{M_2}{M_2}}$

$1 = \frac{T_1}{400}\ \frac{32}{28}$

$1 = \frac{T_1}{50 \times 7}$

$T_! = 350\ K$

**8. Given :**

| H | He |
|---|---|
| $T_1 = 388\ K$ | $T_2 = 388\ K$ |
| $P_1 = 6\ atm$ | $P_2 = ?$ |
| $M_1 = 2$ | $M_2 = 4$ |

**To Find :**

$P_2 = ?$

**Solution :** As mass, volume, temperature remains constant

$\therefore \quad \frac{P_1}{P_2} = \frac{C_1^2}{C_2^2}$ [$\because \rho$ is same ]

As temperature is same, avg. K.E. is same

$\therefore \quad \frac{1}{2} M_1 C_1^2 = \frac{1}{2} M_2 C_2^2$

$\therefore \quad \frac{M_2}{M_1} = \frac{C_1^2}{C_2^2}$

$\therefore \quad \frac{P_1}{P_2} = \frac{M_2}{M_1} = \frac{4}{2}$

$\therefore \quad P_2 = \frac{2}{4} \times 6$

$= 3\ atm$

As mass is same

$M_1 = M_2$

$\therefore \quad N_1 M_1 = N_2 M_2$

$\therefore \quad \frac{N_1}{N_2} = \frac{M_2}{M_1}$

$\therefore \quad \frac{N_1}{N_2} = \frac{2}{1}$

**9. Given :**

$V = 10\ cc$

$\therefore \quad V = 10^{-5}\ m^3$

$T = 273\ K$

$P = 1 \times 10^5\ N/m^2$

$C = 400\ m/s$

**To Find :**

$M = ?$

**Formula :**

$$P = \frac{1}{3}\frac{M}{V}C^2$$

**Solution :**

$$M = \frac{3PV}{C^2}$$

$$\therefore \quad M = \frac{3 \times 1 \times 10^5 \times 10^{-5}}{400 \times 400}$$

$$\therefore \quad M = \frac{3}{16} \times 10^{-4}$$

$$\therefore \quad M = 1.875 \times 10^{-5} \text{ kg}$$

**10. Given :**

$C = 420 \text{ m/s}$

$m = 6.8 \times 10^{-26} \text{ kg}$

$P = 10^5 \text{ N/m}^3$

$V = 10^3 \text{ m}$ ($\because$ per cubic meter)

**To Find :**

$N = ?$

**Formula :**

$$P = \frac{1}{3}\frac{mNc^2}{V}$$

**Solution :**

$$N = \frac{3PV}{mc^2}$$

$$\therefore \quad N = \frac{3 \times 10^5 \times 10^3}{6.8 \times 10^{-26} \times 420 \times 420}$$

$$\therefore \quad N = \frac{3 \times 10^{8+26-2}}{6.8 \times 42 \times 42}$$

$$\therefore \quad N = \frac{3}{6.8 \times 1764} \times 10^{32}$$

$$\therefore N = Al\,[\log 3 - (\log 6.8 + \log 1764)] \times 10^{32}$$

$$\therefore N = Al\left[0.4771 - \left(\begin{array}{l}0.8325\\ +\ 3.2465\\ \hline 4.0790\end{array}\right)\right] \times 10^{32}$$

$$\therefore N = Al\left[\begin{array}{l}0.4771\\ -4.0790\\ \hline 4.3981\end{array}\right] \times 10^{32}$$

$$\therefore N = Al\,(4.3981) \times 10^{32}$$

$$\therefore \quad N = 2.5 \times 10^{-4} \times 10^{32}$$

$$\therefore \quad N = 2.5 \times 10^{28}$$

**11. Given :**

$V = 16 \text{ dm}^3$

$\therefore \quad V = 16 \times 10^{-3} \text{ m}^3$

$m = 4\text{gm}$

$T = 10^0\text{C} = 283 \text{ K}$

$R = 8.315 \text{ J/mol K}$

mol. wt of $H_2 = 2$

**To Find :**

$P = ?$

**Formula :**

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

$$PV = nRT$$

**Solution :**

$$\text{No. of moles of } H_2 = \frac{\text{Given weight in grams}}{\text{Molecular weight}}$$

**Solution :**

$$\text{No. of moles of } H_2 = \frac{\text{Given weight in grams}}{\text{Molecular weight}}$$

$$\therefore \quad n = \frac{4}{2}$$

$$\therefore \quad n = 2$$

$$\therefore \quad PV = nRT$$

$$\therefore \quad P = \frac{nRT}{V} = \frac{2 \times 8.315 \times 283}{16 \times 10^{-3}}$$

$$\therefore \quad P = \frac{8.315 \times 283 \times 10^3}{8}$$

$$\therefore \quad P = Al\,[\log 8.315 + \log 283 + 3 - \log 8]$$

$$\therefore \quad P = Al\,[0.9198 + 2.4518 + 3 - 0.903]$$

$$\therefore \quad P = Al\,[6.3716 - 0.903]$$

$$\therefore \quad P = Al\ 5.4685$$

$$P = 2.941 \times 10^5 \text{ N/m}^2$$

**12. Given :**

M = $5.313 \times 10^{-26}$ kg

C = 461.2 m/s

P = $1.013 \times 10^5$ N/m² (NTP)

T = 273 K (NTP)

**To Find :** N per unit volume

**Formula :**

$$P = \frac{1}{3}\frac{mN}{V}C^2$$

**Solution :**

$$P = \frac{1}{3}\frac{mN}{V}C^2$$

$$N = \frac{3PV}{mC^2} = \frac{3 \times 1.013 \times 10^5 \times 1 \times 10^{-6}}{5.313 \times 10^{-26} \times 462 \times 462}$$

$$= A\mathit{l}\ [\log 1.013 - \{\log 1.771 + \log 462 + \log 462\}]$$

$$= A\mathit{l}\left[3.0055 - \left\{\begin{matrix}3.2483\\2.6646\\\frac{2.6646}{8.5775}\end{matrix}\right\}\right] \times 10^{30}$$

$$= A\mathit{l}\ [5.5720] \times 10^{30}$$

$$N = 2.689 \times 10^{25}$$

**13. Given :**

m = 2 kg

M = 28

T = 300 k

R = 8.31 J/mol k

= 8310 J/kmol k

**To Find :**

KE = ?

**Formula :**

$$KE = \frac{3}{2}nRT$$

**Solution :**

$$KE = \frac{3}{2}nRT$$

$$\therefore\ KE = \frac{3}{2}\frac{m}{M}RT$$

$$\therefore\ KE = \frac{3}{2} \times \frac{2}{28} \times 8310 \times 300$$

$$\therefore\ KE = \frac{3 \times 8310 \times 150}{14}$$

$$\therefore\ KE = A\mathit{l}\ (0.4771 + 3.9196 + 2.1761 - 1.1461)$$

$$\therefore\ KE = A\mathit{l}\ (6.5728 - 1.1461)$$

$$\therefore\ KE = A\mathit{l}\ 5.4267$$

$$\therefore\ KE = 2.671 \times 10^5\ J$$

**14. Given :**

M = $20 \times 10^{-3}$ kg

T = 300 K

**To Find :**

KE = ?

**Formula :**

$$K.E = \frac{3}{2}nRT$$

**Solution :**

$$K.E = \frac{3}{2}nRT$$

$$\therefore\ K.E = \frac{3}{2}\frac{m}{M}RT$$

$$\therefore\ K.E = \frac{3}{2}\frac{20}{44} \times 10^{-3} \times 8.314 \times 10^3 \times 300$$

$$\therefore\ K.E = \frac{3}{2}\frac{10}{22} \times 24.93 \times 10^2 = 1699\ J$$

**15. Given :**

R = 8.31 J/k mole

M = 17.03 g/mol

m = $15 \times 10^{-3}$ kg

T = 310 K

**To Find :**

KE = ?

**Formula :**

$$KE = \frac{3}{2}nRT$$

**Solution :**

$$KE = \frac{3}{2}nRT$$

$$KE = \frac{3}{2}\frac{m}{M}RT$$

$$KE = \frac{3}{2}\frac{15 \times 10^{-3}}{17.03} \times 8.31 \times 10^3 \times 310$$

$$= \frac{115924 \times 10^3 \times 10^{-3}}{34.06}$$

$$KE = 3403.3 \text{ J}$$

**16. Given :**

$m = 1$ kg

$T = 127^oC = 400$ K

$R = 8320$ J/koml K

$M = 28$

**To Find :** KE per kg

**Formula :** $\frac{3RT}{2M}$

**Solution :**

$$\text{KE per kg} = \frac{3RT}{2M}$$

$$\text{KE per kg} = \frac{3}{2} \times \frac{8320 \times 400}{28}$$

$$\text{KE per kg} = \frac{600 \times 2080}{7}$$

$$\text{KE per kg} = \frac{1248000}{7}$$

$$\text{KE per kg} = 178.2 \times 10^3 \text{ J/kg}$$