KINETIC THEORY OF GASES

01 DEGREES OF FREEDOM

- For monoatomic gas, $f = 3$
- For diatomic gas,
  - (a) at room temperature, $f = 5$
  - (b) at high temperature, $f = 7$
- For triatomic gas,
  - (a) Linear $f = 5$
  - (b) Non-linear $f = 6$
- For each vibrational mode, $f = 2$

Q1 Ideal gas is composed of polyatomic molecule that has 4 vibrational modes. Total degrees of freedom is

a) 12 b) 14 c) 8 d) 6

02 SPECIFIC HEAT CAPACITY

a) $C_P - C_V = R$

b) $C_P - C_V = \frac{R}{M}$ (specific heat per unit mask)

c) $C_V = \frac{R}{\gamma - 1} = \frac{f}{2}R$

d) $C_P = \frac{\gamma R}{\gamma - 1} = \left(1 + \frac{f}{2}\right)R$

e) $\gamma = \frac{C_P}{C_V} = 1 + \frac{2}{f}$

Mono-$\gamma = \frac{5}{3}$

Dia-$\gamma = \frac{7}{5}$

Tri-$\gamma = \frac{4}{3}$

Q2 If C_P and C_V denote the specific heats of unit mass of nitrogen at constant pressure and volume respectively, then

a) $C_P - C_V = \frac{R}{28}$ b) $C_P - C_V = \frac{R}{14}$ c) $C_P - C_V = \frac{R}{7}$ d) $C_P - C_V = R$

03 MIXING OF GASES

$$C_{V mix} = \frac{n_1 C_{V_1} + n_2 C_{V_2} + \ldots\ldots}{n_1 + n_2 + \ldots\ldots}$$

$$C_{P mix} = \frac{n_1 C_{P_1} + n_2 C_{P_2} + \ldots\ldots}{n_1 + n_2 + \ldots\ldots}$$

$$\gamma_{mix} = \frac{C_{P\ mix}}{C_{V\ mix}}$$

Q3 Consider a mixture of *n* moles of helium gas and 2n moles of oxygen gas (molecules taken to be rigid) as an ideal gas. It's C_P/C_V value will be:

a) 19/13 b) 67/45 c) 40/27 d) 23/15

04 LAW OF EQUIPARTITION OF ENERGY

Energy for each molecule per f $= \frac{1}{2}K_B T$

Total energy for molecule $= \frac{f}{2}K_B T$

Monoatomic Molecule $= \frac{3}{2}K_B T$

Total energy for a mole $= \frac{f}{2}RT$

Total energy for n moles $= \frac{nfRT}{2}$

Monoatomic $= \frac{3}{2}RT$ (1 mole)

Diatomic $= \frac{5}{2}RT$ (1 mole)

Translatory Kinetic energy $= \frac{3}{2}RT$ (1 mole, f= 3)

Q4 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) 4*RT* b) 15*RT* c) 9*RT* d) 11*RT*

05 FIRST LAW OF THERMODYNAMICS

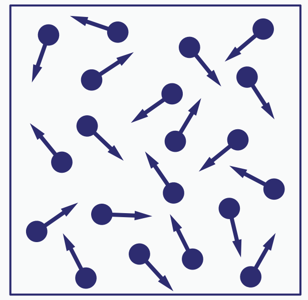
$Q_P = \Delta U + W$

$\Delta U = nC_V \Delta T$

$W = \int P dv$

$\frac{\Delta U}{Q_P} = \frac{1}{\gamma}$

$\frac{W}{Q_P} = 1 - \frac{1}{\gamma}$



06 VELOCITY OF GAS

$V_{mp} : V_{avg} : V_{rms} = 1 : 1.13 : 1.225$

Root Mean square speed:

Square root of mean of square of speeds of different molecules,

$$V_{rms} = \sqrt{\frac{V_1^2 + V_2^2 + \ldots\ldots\ldots\ldots + V_n^2}{n}}$$

$$V_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3k_B T}{m}}$$

Average Speed:

Arithmetic mean of speed of molecules of gas at given temperature.

$$V_{avg} = \frac{|\vec{V_1}| + |\vec{V_2}| + \ldots\ldots + |\vec{V_n}|}{n}$$

$$V_{avg} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8P}{\pi \rho}}$$

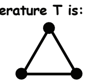
Most probable speed:

Speed possessed by maximum number of molecules of gas.

$$V_{mp} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2P}{\rho}} = \sqrt{\frac{2k_B T}{m}}$$

Q5 Consider a gas of triatomic molecules. The molecules are assumed to be triangular, made up of massless rigid rods whose vertices are occupied by atoms. The internal energy of a mole of the gas at temperature T is:

a) $\frac{5}{2}RT$ b) $\frac{3}{2}RT$ c) $\frac{9}{2}RT$ d) $3RT$



Q6 The rms speeds of the molecules of Hydrogen, Oxygen & Carbon dioxide at the same temparature are V_H, V_O and V_C respectively, then:

a) $V_H > V_O > V_C$ b) $V_C > V_O > V_H$
c) $V_H = V_O > V_C$ d) $V_H = V_O = V_C$

07 MEAN FREE PATH

Average distance travelled by molecules between two successive collisions

$$\lambda_{mean} = \frac{1}{\sqrt{2}\,\pi d^2 n}$$

d = diameter of molecules.

n = no. of molecules per unit volume

$\lambda \propto \frac{1}{d^2}$

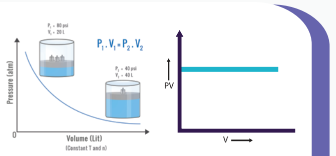
$\lambda \propto \frac{1}{r^2}$

$\lambda \propto \frac{T}{P}$

Q7 The mean free path of molecules of gas, (radius r) is inversely proportional to

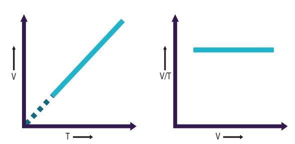
a) r^3 b) r^2
c) r d) $\sqrt{r}$

BOYLE'S LAW



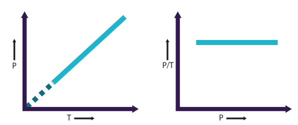
- PV = constant, if T = Constant
- $P_1V_1 = P_2V_2$, when gas changes it's state under constant temperature.

CHARLE'S LAW



- $V \propto T$; $\frac{V}{T}$ = constant; P = constant.
- $\frac{V_1}{T_1} = \frac{V_2}{T_2}$, when gas change its state under constant pressure.

GAY LUSSAC'S LAW



- $P \propto T$; $\frac{P}{T}$ = constant; V = constant.
- $\frac{P_1}{T_1} = \frac{P_2}{T_2}$, when gas changes its state under constant Volume.

PRESSURE OF GAS

$$PV = \frac{1}{3}mn V_{rms}^2 = \frac{1}{3}mn\overline{V^2}$$

Relation between pressure and Kinetic Energy.

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

IDEAL GAS LAW

$PV = nRT$

$R = 8.314\ JK^{-1}mol^{-1}$

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

Specific heat of Solids = 3R
WATER = 9R