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KINETIC THEORY OF GASES

Heat Capacity and Specific Heat

- The amount of heat required to raise the temperature of its unit mass through 1°C or 1K.
- If an amount of heat ΔQ is required to raise the temperature of a mass m of the solid (or liquid) through Δθ, then the specific heat may be expressed as $C = \frac{\Delta Q}{m\Delta\theta}$
- Thus, the amount of heat required to raise the temperature of a substance is given by:
  ΔQ = Δθ mC
- SI unit of specific heat is J kg^{-1} K^{-1}

Calorimetry

- When two bodies at different temperatures are kept in contact, transfer of heat takes place from the body at higher temperature to the body at lower temperature till both the bodies acquire the same temperature.
- The specific heat of a material and other physical quantises related to this heat transfer are measured with the help of a device called calorimeter and the process of the measurement is called calcorimetry.

Principle of Calorimetry

- The law of conservation of energy, Heat lost = Heat gained.
  $$m_1C_1(\theta_1 - \theta) = m_2C_2(\theta - \theta_2)$$
  $where\ m\ is\ mass, C\ is\ specific\ heat,$
  $and\ \theta_1 > \theta_2$
- This is the principle of calorimetry

Thermal Expansion

- When heat is given to a substance it expands in length, area or volume. This is called thermal expansion.

Linear expansion

- In linear expansion, the change in length is directly proportional to the original length and change in temperature.
- $\Delta l \propto l_0\Delta\theta$
  $$\Delta l = \alpha l_0 \Delta\theta$$
  where α is the coefficient of linear expansion or temperature coefficient of linear expansion. It is given by
  $$\alpha = \frac{\Delta l}{l_0\Delta\theta}$$

Superficial expansion

- The change in area is directly proportional to the original area and change in temperature:
  $$\Delta A \propto A_0\Delta\theta$$
  $$\Delta A = \beta A_0 \Delta\theta$$
- where β is the temperature coefficient of superficial expansion.

$$\beta = \frac{\Delta A}{A_0 \Delta\theta}$$

Cubical expansion,

- the change in volume is directly proportional to the change in temperature and original volume: $\Delta V \propto V_0 \Delta\theta$

  $\Delta V = \gamma V_0 \Delta\theta$

- Where γ in the temperature coefficient of cubical expansion.

$$\gamma = \frac{\Delta V}{V_0 \Delta\theta}$$

Relation between α, β and γ

$\beta = 2\alpha$

$\gamma = 3\alpha$

Anomalous expansion in water and its effect

- The volume of a liquid increases with increase in temperature. The coefficient of expansion of liquids is about 10 times that of solids. However, the volume of water does not increase with temperature between 0 to 4°C.

Thermal Expansion in Gases

The coefficient of volume expansion of a gas at constant pressure is given by

$$\gamma_v = \left(\frac{V_2 - V_1}{V_1 \Delta\theta}\right)_{\Delta p = 0}$$

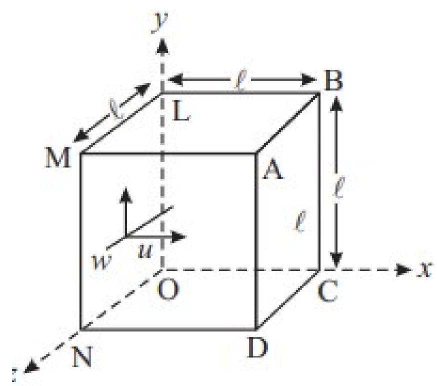
The coefficient of pressure expansion of a gas at constant volume is given by

$$\gamma_p = \left(\frac{P_2 - P_1}{P \Delta\theta}\right)_{\Delta v = 0}$$

KINETIC THEORY OF GASES

Assumptions of Kinetic Theory of Gases

- A gas consists of a very large number of identical rigid molecules, which move with all possible velocities randomly. The intermolecular forces between them are negligible.
- Gas molecules collide with each other and with the walls of the container. These collisions are perfectly elastic.
- Size of the molecules is negligible compared to the separation between them.
- Between collisions, molecules move in straight lines with uniform velocities.
- Time taken in a collision is negligible as compared to the time taken by a molecule between two successive collisions.
- Distribution of molecules is uniform throughout the container



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

Where P= pressure, m= mass, N= number of particle, $\bar{C}^2 = \bar{u}^2 + \bar{v}^2 + \bar{w}^2$

KINETIC INTERPRETATION OF TEMPERATURE

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

PV =nRT

$\frac{1}{3}\boldsymbol{mN\bar{C}^2}$ **= nRT**

$\frac{1}{2}\boldsymbol{m\bar{C}^2} = \frac{3}{2}\left(\frac{R}{N_A}\right)\boldsymbol{T} = \frac{3}{2}$ **kT**

$\left(\frac{\boldsymbol{R}}{\boldsymbol{N_A}}\right) = \boldsymbol{k} = \boldsymbol{Boltzmamn\ Constant}$

$\boldsymbol{=1.38 \times 10^{-23}\, jK^{-1}}$

Kinetic energy of a gram mole of a gas is $\frac{3}{2}RT$ .The kinetic energy of a molecule depends only on the absolute temperature T of the gas and it is quite independent of its mass. This fact is known as the kinetic interpretation of temperature.

Boyle's Law

- At constant temperature, the pressure of a given mass of a gas is inversely proportional to the volume of the gas.
- PV = constant

Charle's Law

- The volume of a given mass of a gas at constant pressure is directly proportional to temperature.
$$V \propto T$$

Gay Lussac's Law

- The pressure of a given mass of a gas is directly proportional to its absolute temperature T, if its volume remains constant
- $P \propto T$

Avogadro's Law

- Equal volume of ideal gases under the same conditions of temperature and pressure contains equal number of molecules.
- **Dalton's Law of Partial Pressure** The total pressure exerted by a gaseous mixture is the sum of the partial pressures that would be exerted, if individual gases occupied the space in turn. This is Dalton's law of partial pressures.

Graham's law of diffusion of gases

- The rate of diffusion of a gas through a porous partition is inversely proportional to the square root of its density. This is known as Graham's law of diffusion.

Degrees of Freedom

- Degrees of freedom of a system of particles are the number of independent ways in which the particles of the system can move.

THE LAW OF EQUIPARTITION OF ENERGY

HEAT CAPACITIES OF GASES

An amount of heat to a gas to raise its temperature through the heat capacity is

Heat Capacity $= \frac{\Delta Q}{\Delta T}$

- The heat capacity of a body per unit mass of the body is termed as specific heat capacity of the substance and is usually denoted by c.
  Specific heat capacity $= \frac{\Delta Q}{m\Delta T}$
- specific heat capacity of a material is the heat required to raise the temperature of its unit mass by 1 ºC (or 1 K)

The specific heat capacity of a gas at constant volume (cv)

- the amount of heat required to raise the temperature of unit mass of a gas through 1K, when its volume is kept constant

$$c_v = \left(\frac{\Delta Q}{\Delta T}\right)_v$$

The specific heat capacity of a gas at constant pressure (cP)

- the amount of heat required to raise the temperature of unit mass of a gas through 1K when its pressure is kept constant.

$$c_p = \left(\frac{\Delta Q}{\Delta T}\right)_p$$

Relation Between C_p and C_v

$$C_p - C_v = R$$

Check Yourself

1. Specific heat of substance depends on
   A. Mass
   B. Volume
   C. Temperature
   D. Nature
2. The ratio of molar specific heat capacities for a mole of diatomic gas molecule is
   A. 9/7
   B. 7/9
   C. 7/5
   D. 5/7
3. Increase in temperature of the body is proportional to
   A. Amount of heat evolved
   B. Average kinetic energy
   C. Amount of heat absorbed
   D. Density of substance
4. When solid iron ball is heated,which one of the following will have minimum percentage increase
   A. Density
   B. Volume
   C. Surface area
   D. Radius
5. Coefficient of cubical expansion of water is minimum at
   A. 100^0C
   B. 150^0C
   C. 4^0C
   D. 0^0C
6. When a metal rod is heated it expands because
   A. All of these
   B. The size of its atom increase
   C. The distance among its atom increase
   D. The actual cause is unknown

7. If α and γ are the coefficient of linear and volume expansion respectively,then the correct relationship between them is
   A. 3 α = γ
   B. 1/3 α = γ
   C. **2** α= γ
   D. ½ α = γ
8. The constant quantity of Boyle's law is
   A. Only mass of the gas
   B. Only temperature of a gas
   C. Mass and pressure of a gas
   D. Mass and temperature of a gas
9. Which is the constant quantity in Ideal Gas Equation
   A. P
   B. V
   C. T
   D. R
10. **The dimension of universal gas constant is**
   A. $M L^{2}T^{-1}N^{-1}$
   B. $M L^{-1}T^{-1}N^{2}K^{-1}$
   C. $ML^{2}T^{-1}N^{-2}K$
   D. $\mathbf{ML^{-1}T^{-2}N^{-1}K^{-1}}$

Stretch Yourself

1) Explain what is meant by the root-mean square velocity of the molecules of a gas. Use the concepts of kinetic theory of gases to derives an expression for the root-mean square velocity of the molecules in term of pressure and density of the gas.

2) State the assumptions of kinetic theory of gases.

3) Calculate the pressure in mm of mercury exerted by hydrogen gas if the number of molecules per m^3 is 6.8×10^{24} and the root-mean square speed of the molecules is 1.90 × 10 m s–1. Avogadro's number 6.02×10^{23} and molecular weight of hydrogen = 2.02).

4) Define specific heat of a gas at constant pressure. Derive the relationship between C_p and C_v.

5) Find an expression for the pressure of a gas.