

Chapter 12: Kinetic Theory

NCERT · Class 11 · Physics

Textbook exercises

Question 1

Assumptions of Kinetic Theory of Gas

- (i) The molecules of an ideal gas are in a state of never stopping random motion. They move in all directions with different speeds., (of the order of 500 m/s) and obey Newton's laws of motion.
- (ii) The molecules of an ideal gas do not exert any force of attraction or repulsion on each other, except during collision.
- (iii) The molecules of an ideal gas moves along a straight line between two successive collisions and the average straight distance covered between two successive collisions is called the mean free path of the molecules.
- (iv) The size of ideal gas molecules is very small as compared to the distance between them.
- (v) The molecules of an ideal do not exert any force of attraction or repulsion on each other.

Solution

Solution coming soon.

Question 2

Pressure of an ideal gas is given by, $P = \frac{1}{3} \rho_{gas} v_{rms}^2$

Solution

Solution coming soon.

Question 3

Ideal Gas: That gas which strictly obeys the gas laws, (such as Boyle's Law, Charles', Gay Lussac's Law etc.)

Solution

Solution coming soon.

Question 4

Real Gas: All gases are referred to as real gases. All real gases show the ideal gas behavior at low pressures and temperatures high enough, where they cannot be liquified

Solution

Solution coming soon.

Question 5

Gay Lussac's Law/Boyle's Law: $PV = \text{constant}$ for given mass of gas at constant temperature.

Solution

Solution coming soon.

Question 6

Charle's Law: $PV \propto T$ If P is constant, $V \propto T$.

Solution

Solution coming soon.

Question 7

Constant Volume Law: $PV \propto T$, If V is constant, $P \propto T$

Solution

Solution coming soon.

Question 8

Avogadro's Law: Equal volumes of all ideal gases existing under the same conditions of temperature and pressure contain equal number of molecules.

Solution

Solution coming soon.

Question 9

Ideal Gas Equation: $PV = Nk_bT$

Solution

Solution coming soon.

Question 10

Speed of Gas Molecules:

Solution

Solution coming soon.

Question 11

Degrees of Freedom: The number of degrees of freedom of a dynamical system is defined as the total number of co-ordinates or independent quantities required to describe completely the position and configuration of the system.

Solution

Solution coming soon.

Question 12

Law of Equipartition of Energy: According to this law, for any dynamical system in thermal equilibrium, the total energy is distributed equally amongst all the degrees of freedom, and the energy associated with each molecule per degree of freedom is $\frac{1}{2}k_B T$ where k_B is Boltzman constant, and T is temperature of the system.

Solution

Solution coming soon.

Question 13

Mean Free Path: The path traversed by a molecule between two successive collisions with another molecule is called the mean free path

$$\lambda = \frac{\text{Total distance travelled by a molecule}}{\text{No. of collisions it makes with other molecules}}$$

Thermodynamics

- **The Zeroth Law:** The zeroth law of thermodynamics states that 'two systems in thermal equilibrium with a third system separately are in thermal equilibrium with each other'.
- **Internal energy:** Internal energy of a system is the sum of kinetic energies and potential energies of the molecular constituents of the system.
- **First law of thermodynamics:** This is the general law of conservation of energy applied to any system in which energy transfer from or to the surroundings (through heat and work) is taken into account. It states that

$$\Delta Q = \Delta U + \Delta W$$

Where, ΔQ is the heat supplied to the system.

ΔW is the work done by the system and ΔU is the change in internal energy of the system.

- **Specific heat capacity:** Specific heat capacity of a substance is defined by $s = \frac{1}{m} \frac{\Delta Q}{\Delta T}$

Where m is the mass of the substance and ΔQ is the heat required to change its temperature by ΔT .

- **Molar specific heat capacity:** Molar specific heat capacity of a substance is defined by

$$C = \frac{1}{\mu} \frac{\Delta Q}{\Delta T}$$

Where, μ is the number of moles of the substance.

- **Mayer's Law:** For an ideal gas, the molar specific heat capacities at constant pressure (C_p) and at constant volume (C_v) satisfy the relation.

$$C_p - C_v = R$$

where R is the universal gas constant.

- **State Variables:** Equilibrium states of a thermodynamic system are described by state variables.

The value of a state variable depends only on the particular state, not on the path used to arrive at the state. Examples of state variables are pressure (p), volume (V), temperature (T), and mass (m).

- **Isothermal Process:** In an isothermal expansion of an ideal gas from volume V_1 to V_2 at temperature T the heat absorbed (Q) equals the work done (W) by the gas, each given by

$$Q = W = \mu RT \left(\frac{V_2}{V_1} \right)$$

- **Adiabatic Process:** In an adiabatic process of an ideal gas $PV^\gamma = \text{Constant}$

Where $\gamma = \frac{C_p}{C_v}$

Work done by an ideal gas in an adiabatic change of state from (P_1, V_1, T_1) to (P_2, V_2, T_2) is

$$W = \frac{\mu RT(T_1 + T_2)}{\gamma - 1}$$

- **Second law of thermodynamics:** Second law of thermodynamics disallows some processes consistent with the First Law of Thermodynamics.

Kelvin -Planck statement: No process is possible whose sole result is the absorption of heat from a reservoir and complete conversion of the heat into work.

Clausius statement: No process is possible whose sole result the transfer of heat from a colder object to a hotter object.

The second Law implies that no heat engine can have efficiency η equal to 1 or no refrigerator can have co-efficient of performance α equal to infinity.

- **Reversible Process:** A process is reversible if it can be reversed such that both the system and the surroundings return to their original states, with no other change anywhere else in the universe. Spontaneous processes of nature are irreversible. The idealized reversible process is a quasi-static process with no dissipative factors such as friction, viscosity, etc.
- **Carnot engine:** Carnot engine is a reversible engine operating between two temperatures T_1 (source) and T_2 (sink). The Carnot cycle consists of two isothermal processes connected by two adiabatic processes. The efficiency of a Carnot engine is given by

$$\eta = 1 - \frac{T_2}{T_1}$$

No engine operating between two temperatures can have efficiency greater than that of the Carnot engine.

Solution

Solution coming soon.