

Kinetic Theory — CBSE Pattern Test 1

Class 11 Physics · 90 minutes · 40 marks · Sections A–D with answer key · Narayan Gurukul Academy

Test 1 — CBSE Pattern (90 minutes, 40 marks)

Class 11 Physics · Kinetic Theory · Narayan Gurukul Academy (ClassApna)

General Instructions: (1) This paper has four sections — Section A (1×10), Section B (2×4), Section C (3×4) and Section D (5×2) — total 40 marks. Time allowed: 90 minutes.
(2) All questions are compulsory. No overall choice is given; internal choice, where allowed, is clearly marked.
(3) For MCQ questions choose the single correct option; for VSA answers write a single line.
(4) Take $g = 10 \text{ m/s}^2$. All symbols carry their usual meaning. Use of a calculator is not permitted.

Section A — MCQ & VSA ($10 \times 1 = 10$ marks)

- The rms speed of the molecules of an ideal gas at temperature T is
 - $\sqrt{3RT/M}$
 - $\sqrt{2RT/M}$
 - $\sqrt{RT/M}$
 - $3RT/M$
- According to kinetic theory, the average kinetic energy of a gas molecule is proportional to
 - T
 - T^2
 - $\sqrt{T}$
 - $1/T$
- For a diatomic gas, the number of translational degrees of freedom is
 - 3
 - 5
 - 6
 - 2
- The ideal gas equation is
 - $PV = nRT$
 - $PV = nR/T$
 - $PVT = nR$
 - $P/V = nRT$
- In the kinetic theory of gases, collisions between gas molecules are
 - perfectly elastic
 - perfectly inelastic
 - partly elastic
 - always absorbing
- Boyle's law states that at constant temperature
 - P is inversely proportional to V
 - P is directly proportional to V
 - P is proportional to T
 - P does not change with V
- A real gas behaves most like an ideal gas at
 - low pressure and high temperature

- (B) high pressure and low temperature
 (C) low pressure and low temperature
 (D) high pressure and high temperature
8. For an ideal gas, the correct ordering of the three molecular speeds is
 (A) $v_{rms} > v_{mean} > v_{mp}$
 (B) $v_{mp} > v_{mean} > v_{rms}$
 (C) $v_{rms} > v_{mp} > v_{mean}$
 (D) $v_{mean} > v_{rms} > v_{mp}$
9. Define the mean free path of a gas molecule.
10. State the ideal gas equation in terms of the Boltzmann constant k .

Section B — Short Answer I ($4 \times 2 = 8$ marks)

11. Find the rms speed of oxygen molecules ($M = 32$ g/mol) at 300 K. ($R = 8.31$ J mol⁻¹ K⁻¹)
12. A cylinder contains 0.2 mol of an ideal gas at 27 °C occupying 5 L. Find the pressure it exerts. ($R = 8.31$ J mol⁻¹ K⁻¹)
13. At what temperature will the rms speeds of the molecules of a gas be double their value at 300 K?
14. The density of a gas is 1.5 kg m⁻³ and its molecules have a mean-square speed of 10⁶ m² s⁻². Find the pressure it exerts.

Section C — Short Answer II ($4 \times 3 = 12$ marks)

15. Using kinetic theory, derive the expression $P = (1/3)\rho c^2$ for the pressure exerted by an ideal gas, defining the symbols.
16. Explain the mean free path of a gas molecule and write the factors on which it depends.
17. Distinguish between the rms, mean and most probable speeds of the molecules of a gas and write their relations with temperature.
18. For a diatomic gas, using $f = 5$, find C_V , C_P and γ .

Section D — Long Answers ($2 \times 5 = 10$ marks)

19. Derive the expression for the pressure of an ideal gas using kinetic theory and hence obtain $PV = (1/3)mnc^2$, and the relation between the average kinetic energy of a molecule and the temperature.
20. Explain the degrees of freedom of gaseous molecules, apply the law of equipartition of energy to monatomic, diatomic and polyatomic gases, and obtain the ratio $\gamma = C_P/C_V$ for a diatomic gas.

Answer Key (Marking Scheme)

- Q1 — (A) $\sqrt{3RT/M}$. Q2 — (A) T . Q3 — (A) 3. Q4 — (A) $PV = nRT$.
- Q5 — (A) perfectly elastic. Q6 — (A) P is inversely proportional to V . Q7 — (A) low pressure and high temperature. Q8 — (A) $v_{rms} > v_{mean} > v_{mp}$.
- Q9 — The mean free path is the average distance a molecule travels between successive collisions.
- Q10 — $PV = Nk_B T$, where N is the number of molecules and k_B is the Boltzmann constant.
- Q11 — $v_{rms} = \sqrt{3RT/M} = \sqrt{(3 \times 8.31 \times 300/0.032)} \approx 484$ m/s.
- Q12 — $P = nRT/V = (0.2 \times 8.31 \times 300)/0.005 \approx 9.97 \times 10^4$ Pa.
- Q13 — $v \propto \sqrt{T}$ $\Rightarrow \sqrt{T}/T = 4 \Rightarrow T = 4 \times 300 = 1200$ K.
- Q14 — $P = (1/3)\rho c^2 = (1/3) \times 1.5 \times 10^6 = 5 \times 10^5$ Pa.

Q15 — Consider molecules in a cubical container. Change in momentum per collision = $2mc_x$; force per wall = $\Sigma mc_x^2/L$; with $c^2 = c_x^2 + c_y^2 + c_z^2$ and isotropy $P = (1/3)(mN/V)c^2 = (1/3)\rho c^2$.

Q16 — $\lambda = 1/(\sqrt{2} \pi n d^2)$; it depends on the molecular diameter d and the number density n (also on temperature and pressure through n).

Q17 — $v_{mp} = \sqrt{2RT/M}$, $v_{mean} = \sqrt{8RT/\pi M}$, $v_{rms} = \sqrt{3RT/M}$; all three are proportional to $\sqrt{T}$ and $v_{mp} < v_{mean} < v_{rms}$.

Q18 — $C_V = 5R/2 \approx 20.8 \text{ J mol}^{-1} \text{ K}^{-1}$, $C_P = 7R/2 \approx 29.1 \text{ J mol}^{-1} \text{ K}^{-1}$, $\gamma = C_P/C_V = 7/5 = 1.4$.

Q19 — $PV = (1/3)mnc^2$ and average kinetic energy per molecule = $(3/2)k_B T$; hence for one mole of gas the total energy is $(3/2)RT$.

Q20 — For a diatomic gas (no vibration) $f = 5$: $C_V = 5R/2$, $C_P = 7R/2$ $\gamma = C_P/C_V = 7/5$.