

Kinetic Theory — CBSE Pattern Test 2

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

Test 2 — 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)

1. The pressure of an ideal gas is directly proportional to the
 - (A) mean-square speed of the molecules
 - (B) average speed of the molecules
 - (C) most probable speed of the molecules
 - (D) volume of the gas
2. If the mean-square speed of gas molecules is doubled at constant volume, the pressure
 - (A) doubles
 - (B) halves
 - (C) remains the same
 - (D) quadruples
3. The average translational kinetic energy of a gas molecule at temperature T is
 - (A) $(3/2)k_B T$
 - (B) $(1/2)k_B T$
 - (C) $(3/2)RT$
 - (D) $k_B T$
4. Two different gases at the same temperature have
 - (A) the same average translational kinetic energy per molecule
 - (B) the same rms speed
 - (C) the same most probable speed
 - (D) the same molar volume
5. At a given temperature, which molecules move fastest on average?
 - (A) the lighter molecules
 - (B) the heavier molecules
 - (C) the larger-mass gas molecules
 - (D) all molecules equally fast
6. The rms speed of the molecules of a gas is proportional to
 - (A) $\sqrt{T}$
 - (B) T
 - (C) T^2
 - (D) $1/T$
7. At a given temperature, a lighter gas has
 - (A) a higher rms speed

- (B) a lower rms speed
 (C) the same rms speed as a heavier gas
 (D) fewer molecules per mole
8. The most probable speed of gas molecules is
 (A) $\sqrt{2k_B T/m}$
 (B) $\sqrt{3k_B T/m}$
 (C) $\sqrt{8k_B T/\pi m}$
 (D) $\sqrt{k_B T/m}$
9. Define the most probable speed.
10. Write the value of C_V for a monatomic gas.

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

11. Find the number of moles in 44 g of CO_2 . (Molar mass = 44 g mol^{-1} .)
12. Compare the rms speeds of hydrogen and oxygen molecules at the same temperature. ($M_H = 2 \text{ g/mol}$, $M_O = 32 \text{ g/mol}$.)
13. If the temperature of a gas is raised from 300 K to 1200 K, by what factor does the rms speed of its molecules increase?
14. Find the most probable speed of nitrogen molecules at 300 K. ($M = 28 \text{ g/mol}$, $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$.)

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

15. Derive an expression for the root-mean-square speed of the molecules of a gas in terms of T and the molar mass M .
16. At what temperature will the rms speed of oxygen molecules ($M = 32 \text{ g/mol}$) equal the value at which hydrogen has an rms speed of 2000 m/s at 300 K? Derive your answer.
17. Compute the total translational kinetic energy of 2 moles of an ideal gas at 400 K. ($R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$.)
18. Compute the most probable, mean and rms speeds of argon atoms at 300 K. ($M = 40 \times 10^{-3} \text{ kg mol}^{-1}$, $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$.)

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

19. State the law of equipartition of energy and use it to obtain the specific heats and γ for a monatomic gas.
20. (a) Using kinetic theory, derive the expression $P = (1/3)\rho c^2$ for the pressure exerted by an ideal gas. (b) A gas of density 1.5 kg m^{-3} has a mean-square molecular speed of $10^6 \text{ m}^2 \text{ s}^{-2}$. Find the pressure it exerts.

Answer Key (Marking Scheme)

- Q1 — (A) mean-square speed of the molecules. Q2 — (A) doubles. Q3 — (A) $(3/2)k_B T$. Q4 — (A) the same average translational kinetic energy per molecule.
- Q5 — (A) the lighter molecules. Q6 — (A) $\sqrt{T}$. Q7 — (A) a higher rms speed. Q8 — (A) $\sqrt{2k_B T/m}$.
- Q9 — The most probable speed is the speed possessed by the largest fraction of molecules.
- Q10 — $C_V = 3R/2$.
- Q11 — $n = m/M = 44/44 = 1$ mole.
- Q12 — $v_H/v_O = \sqrt{M_O/M_H} = \sqrt{32/2} = 4$, i.e. hydrogen molecules move 4 times as fast (ratio 4 : 1).
- Q13 — $v \propto \sqrt{T}$ or factor = $\sqrt{(1200/300)} = 2$ (rms speed doubles).

Q14 — $v_{mp} = \sqrt{2RT/M} = \sqrt{2 \times 8.31 \times 300/0.028} \approx 422 \text{ m/s}$.

Q15 — $v_{rms} = \sqrt{3RT/M} = \sqrt{3k_B T/m}$: combining $P = (1/3)\rho c^2$ with $c^2 = 3k_B T/m$ for a molecule of mass m .

Q16 — Equal rms speeds $\sqrt{T_O/M_O} = \sqrt{T_H/M_H}$ $\Rightarrow c^2 M/3R = (2000^2 \times 0.032)/(3 \times 8.31) \approx 5.13 \times 10^3 \text{ K}$.

Q17 — $KE = (3/2)nRT = (3/2) \times 2 \times 8.31 \times 400 \approx 9.97 \times 10^3 \text{ J}$.

Q18 — $v_{mp} = \sqrt{2RT/M} \approx 353 \text{ m/s}$, $v_{mean} = \sqrt{8RT/\pi M} \approx 398 \text{ m/s}$, $v_{rms} = \sqrt{3RT/M} \approx 432 \text{ m/s}$.

Q19 — Equipartition: each degree of freedom contributes $(1/2)k_B T$ per molecule. Monatomic $f = 3$: $C_V = 3R/2$, $C_P = 5R/2$, $\gamma = C_P/C_V = 5/3 \approx 1.67$.

Q20 — (a) derivation as in Q15 of Test 1; (b) $P = (1/3)\rho c^2 = (1/3) \times 1.5 \times 10^6 = 5 \times 10^5 \text{ Pa}$.