



Attempt questions first; check the separate key afterward. Treat gases as ideal. Use absolute temperature; distinguish molecular mass from molar mass.

A. Very short answers - 1 mark each

1. State two assumptions of the kinetic theory of an ideal gas.
2. What is the microscopic origin of gas pressure?
3. Define root-mean-square molecular speed.
4. What is meant by a degree of freedom?
5. Define mean free path.

B. Short answers / practice - 2 marks each

6. Why does gas pressure increase with temperature at fixed volume?
7. State the law of equipartition of energy.
8. At the same temperature, compare rms speeds of H_2 and O_2 . Use molar masses 2 and 32 g/mol.
9. Find translational kinetic energy per molecule at 300 K; use $k = 1.38 \times 10^{-23}$ J/K.
10. What changes in rms speed and pressure occur when absolute temperature doubles at fixed volume?
11. Find pressure if density = 3 kg/m^3 and rms speed = 200 m/s .
12. Does doubling molecular rms speed quadruple mean translational kinetic energy?
13. Find rms-speed ratio at temperatures 300 K and 1200 K.
14. How many translational degrees of freedom does one gas molecule have?
15. Can average molecular velocity be zero while rms speed is non-zero?
16. Explain why molecules at a given temperature do not all have the same speed.
17. Find molar C_v for a monatomic gas in units of R .
18. Find γ when $C_p = 7R/2$ and $C_v = 5R/2$.
19. What happens to mean free path if number density triples at fixed molecular diameter?
20. Explain why ideal-gas internal energy depends only on temperature.

C. Application / reasoning - 3 marks each

21. A gas has density 1.2 kg/m^3 and pressure $1.0 \times 10^5 \text{ Pa}$. Find its rms molecular speed.
22. Find rms speed of nitrogen at 300 K using molar mass 0.028 kg/mol and $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$.
23. Explain why molecular translational kinetic energy depends on temperature rather than the nature of the ideal gas.
24. Find C_v , C_p and γ for a rigid diatomic ideal gas when vibrations are inactive. State the number of active degrees of freedom.
25. A vessel contains 2 mol of a monatomic ideal gas at 300 K. Find total translational energy using $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$.
26. Using $\lambda = 1/(\sqrt{2} n \pi d^2)$, explain how mean free path changes when pressure doubles at fixed temperature and when temperature doubles at fixed pressure.

D. Extended practice - 5 marks each

27. Derive $P = \frac{1}{3} \rho v_{rms}^2$ from molecular collisions with container walls. State the assumptions and explain the factor $\frac{1}{3}$.
28. Use the kinetic-theory pressure relation and ideal-gas equation to derive average translational kinetic energy per molecule and rms speed.
29. Using equipartition, derive molar heat capacities and γ for monatomic and rigid diatomic gases. Explain the role of additional active modes.
30. One mole of helium and one mole of oxygen are separately at 300 K. Compare rms speeds, translational energies and internal energies, with vibrations inactive. Use molar masses 4 and 32 g/mol and $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$.

ANSWER KEY - Numerical / closed questions

- 8) 4:1. 9) $6.21 \times 10^{-21} \text{ J}$. 10) Rms speed $\times \sqrt{2}$; pressure $\times 2$. 11) 40000 Pa. 12) Yes. 13) 1:2. 14) 3. 15) Yes. 17) $3R/2$. 18) $7/5$. 19) It becomes one-third. 21) 500 m/s . 22) 516.8 m/s . 24) $C_v = 5R/2$; $C_p = 7R/2$; $\gamma = 7/5$; 5 degrees of freedom. 25) 7479 J. 26) It halves; it doubles respectively. 29) Monatomic: $3R/2$, $5R/2$, $5/3$; diatomic: $5R/2$, $7R/2$, $7/5$. 30) Speed ratio 8:1; equal translational energy 3739.5 J each; internal energies 3739.5 J and 6232.5 J.