

8.2 Gas laws and the kinetic model (full B.3)

Name: _____ Class: _____ Date: _____

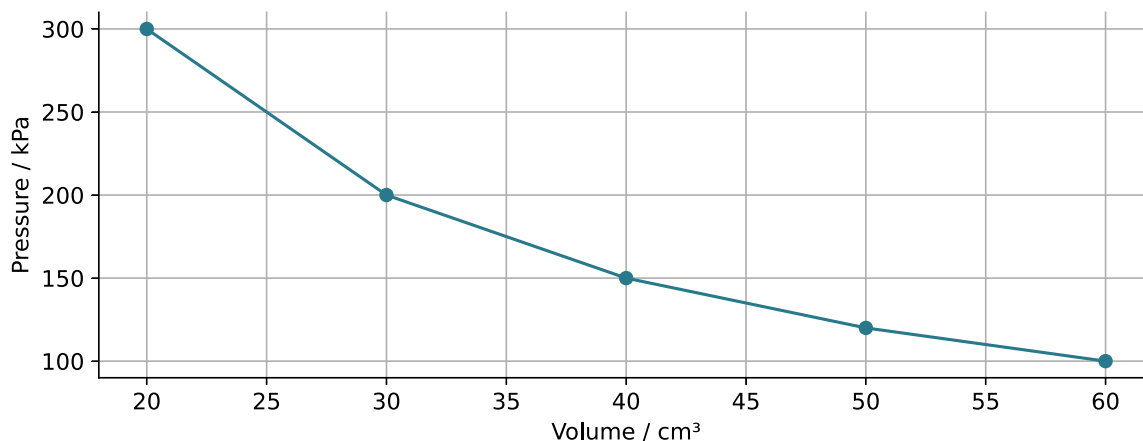
Total: 25 marks

KEY WORDS ideal gas • Avogadro constant • monatomic

Objective

Practise the full guide B.3 toolkit: pressure as F/A , $n = N/N_A$, the ideal gas law in both forms ($PV = Nk_B T$ and $PV = nRT$) with PV/T constant, the kinetic derivation link $P = \frac{1}{3} \rho \langle v^2 \rangle$, internal energy of a monatomic ideal gas, pressure–volume diagrams, and the conditions where the ideal gas approximates a real gas. Original practice; not an official IB paper.

1 Key knowledge and worked examples



■ The B.3 equation set

$$P = \frac{F}{A} \quad n = \frac{N}{N_A} \quad \frac{PV}{T} = \text{constant} \quad PV = Nk_B T = nRT$$

$$P = \frac{1}{3} \rho \langle v^2 \rangle \quad U = \frac{3}{2} Nk_B T = \frac{3}{2} nRT$$

Worked check. 0.50 mol of an ideal gas at 250 K in $8.0 \times 10^{-3} \text{ m}^3$: $P = nRT/V = 0.50 \times 8.31 \times 250 / 8.0 \times 10^{-3} = 1.3 \times 10^5 \text{ Pa}$; $U = 1.5 \times 0.50 \times 8.31 \times 250 = 1.6 \times 10^3 \text{ J}$.

Ideal $\approx$ real at high temperature and low pressure; deviations grow near condensation.

2 Practice

2.1 State the two forms of the ideal gas equation, naming every symbol. [4]

2.2 A gas occupies $3.0 \times 10^{-3} \text{ m}^3$ at 300 K and $1.2 \times 10^5 \text{ Pa}$. It is compressed to $1.0 \times 10^{-3} \text{ m}^3$ at constant temperature. Calculate the new pressure. [3]

2.3 Calculate n for $N = 1.2 \times 10^{24}$ molecules ($N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$). [2]

2.4 State the internal energy formula for an ideal monatomic gas. [1]

2.5 Under what conditions does a real gas behave most ideally? [2]

3 Exam-style questions

3.1 A sealed cylinder holds 0.20 mol of an ideal monatomic gas at 200 K, with volume $6.0 \times 10^{-3} \text{ m}^3$. Calculate the pressure and internal energy; the gas is then heated at constant volume to 400 K – calculate the new pressure. [6]

3.2 Explain, using momentum change at the walls, why gas pressure rises with temperature at constant volume, referencing $P = \frac{1}{3} \rho \langle v^2 \rangle$. [4]

3.3 Sketch or describe the pressure–volume diagram for an isothermal compression, and explain why the hyperbola shape follows from $PV/T = \text{constant}$. [3]

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 $PV = Nk_{\text{BT}}$ (N molecules, Boltzmann constant) and $PV = nRT$ (n moles, gas constant).

2.2 At constant T : $P_1V_1 = P_2V_2$; $P_2 = 1.2 \times 10^5 \times 3.0 \times 10^{-3} / 1.0 \times 10^{-3} = 3.6 \times 10^5 \text{ Pa}$.

2.3 $n = N/N_{\text{A}} = 1.2 \times 10^{24} / 6.02 \times 10^{23} = 2.0 \text{ mol}$.

2.4 $U = 3/2 Nk_{\text{BT}} = 3/2 nRT$.

2.5 High temperature and low pressure (low density) – molecules far from condensing.

3.1 $P = nRT/V = 0.20 \times 8.31 \times 200 / 6.0 \times 10^{-3} = 5.5 \times 10^4 \text{ Pa}$; $U = 1.5 \times 0.20 \times 8.31 \times 200 = 5.0 \times 10^2 \text{ J}$; constant V , $P \propto T$: $P_2 = 5.5 \times 10^4 \times 400 / 200 = 1.1 \times 10^5 \text{ Pa}$.

3.2 Molecules rebounding from a wall reverse momentum component, so each collision gives the wall an impulse; hotter molecules move faster, arriving more often and transferring more momentum per collision; since $P = 1/3 \rho \langle v^2 \rangle$ and ρ is fixed at constant V , the larger $\langle v^2 \rangle$ raises P .

3.3 A smooth hyperbola falling from upper-left to lower-right ($P \propto 1/V$); from $PV/T = \text{constant}$ with T fixed, PV is constant, so $P = \text{constant}/V$; points farther along the curve mark smaller V with proportionally larger P , all at the same T .