

Exercise walk-through

8.2

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

International Baccalaureate · IB Diploma · Physics · HL

Gases · 3.1

Reasoning

At fixed amount and volume, pressure is proportional to kelvin temperature. At fixed temperature and amount, pressure is inversely proportional to volume. State which quantities are fixed before choosing a relationship. Use approved apparatus with a temperature range and pressure limit set by the teacher. Allow thermal equilibrium and record pressure against kelvin temperature. Never heat an improvised sealed vessel.

Gases · 4.1

Reasoning

State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution. Known: pressure is 100 kPa at 300 K, with fixed volume and amount. At 330 K, $p_2/p_1 = T_2/T_1$. $p_2 = p_1$
 $T_2/T_1 = 100 \times 330/300 = 110$ kPa. A 30 °C rise is a 30 K change, but the temperature ratio must use kelvin.

A monatomic ideal gas

- 1 Set the model** A 2.0 mol monatomic ideal gas is at 300 K and 1.01×10^5 Pa.
- 2 Calculate** $V = nRT/P = 0.0494 \text{ m}^3$. Internal energy $U = \frac{3}{2}nRT = 7.48 \times 10^3 \text{ J}$.

Decision

Use absolute temperature. The internal-energy formula here is for a monatomic ideal gas.

Exercises 2.1·2.3

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]

Exercises 2.1·2.3

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

2.1 $PV = Nk_B T$ (N molecules, Boltzmann constant) and $PV = nRT$ (n moles, gas constant).

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]

2.2 At constant T: $P_1 V_1 = P_2 V_2$; $P_2 = 1.2 \times 10^5 \times 3.0 \times 10^{-3} / 1.0 \times 10^{-3} = 3.6 \times 10^5 \text{ Pa}$.

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

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

Exercises 2.4·3.1

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]

3.1 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]

Exercises 2.4·3.1

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

2.4 $U = \frac{3}{2} Nk_B T = \frac{3}{2} nRT$.

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

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

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]

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

Exercises 3.2·3.3

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]

Exercises 3.2·3.3

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

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 .