# 5.1 Ideal gases

Name: _____ Class: _____ Date: _____ **Total: 16 marks**

**KEY WORDS** ideal gas • pressure • molar volume • kelvin • real gas • gas constant

## Objective

Build the skills to answer exam questions on **ideal gases** : the gas laws, the ideal gas equation, molar volume and real gases.

**You must be able to:**

- state the assumptions of the ideal gas model
- use the gas laws and $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ with kelvin temperatures
- use $pV = nRT$ (SI units) and the molar volume 22.7 $dm^3$ $mol^{-1}$ at STP
- explain when and why real gases do not behave ideally

## 1 Key knowledge and worked examples

### The ideal gas model

**Assumptions:** particles move randomly in straight lines; their own volume is negligible; there are no forces between them except in collisions; collisions are elastic.

| law | at fixed | relationship |
|---|---|---|
| Boyle | $T$, $n$ | $p \propto \frac{1}{V}$ |
| Charles | $p$, $n$ | $V \propto T$ (kelvin) |
| Gay-Lussac | $V$, $n$ | $p \propto T$ (kelvin) |
| combined | $n$ | $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ |
| ideal gas equation | – | $pV = nRT$: $p$ in Pa, $V$ in $m^3$, $T$ in K, $R = 8.31$ J $K^{-1}$ $mol^{-1}$ |
| molar volume | STP (273 K, 100 kPa) | 22.7 $dm^3$ $mol^{-1}$ |

**Real gases** behave least ideally at **high pressure** (the particles' own volume matters) and **low temperature** (attractions between particles matter).



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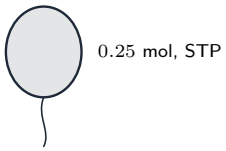
**Worked example 1: units.** 250 $\text{cm}^3 = 2.50 \times 10^{-4}$ $\text{m}^3$; 100 kPa $= 1.00 \times 10^5$ Pa.

**Worked example 2: molar mass.** 0.32 g of a gas occupies 224 $\text{cm}^3$ at STP: $n = \dfrac{0.224}{22.7} = 0.00987$ mol, so $M = \dfrac{0.32}{0.00987} = 32$ **g mol**$^{-1}$.

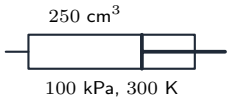
**Answer shapes:** convert to SI units before using $pV = nRT$.

## 2 Practice

**2.1** Calculate the volume occupied by 0.25 mol of an ideal gas at STP. [2]



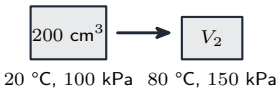

**2.2** 0.50 g of a gas occupies 250 $\text{cm}^3$ at 100 kPa and 300 K. Calculate its molar mass. [3]




**2.3** A sealed can of gas is heated. Use the kinetic model to explain why the pressure inside rises. [3]



**2.4** A gas occupies 200 $\text{cm}^3$ at 20 °C and 100 kPa. Calculate its volume at 80 °C and 150 kPa. [2]



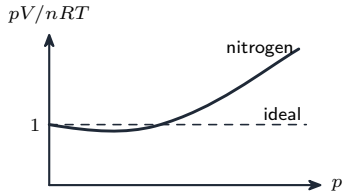



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## 3 Exam-style questions

**3.1** The graph shows $\frac{pV}{nRT}$ against pressure for nitrogen at 300 K, and for an ideal gas.

(a) State two assumptions of the ideal gas model. [2]




(b) Explain why nitrogen is far from ideal at very high pressure. [2]

(c) State the conditions of temperature and pressure at which nitrogen is closest to ideal. [1]

(d) Explain why real gases also move away from ideal behaviour at low temperature. [1]



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