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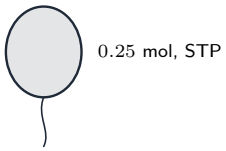
**Worked example 1: units.** 250 $\text{cm}^3 = 2.50 \times 10^{-4}$ $\text{m}^3$; 100 kPa $= 1.00 \times 10^5$ Pa.

**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**$^{-1}$.

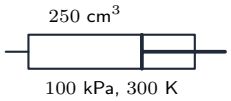
**Answer shapes:** convert to SI units before using $pV = nRT$.

## 2 Practice

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



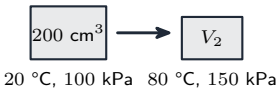

**2.2** 0.50 g of a gas occupies 250 $\text{cm}^3$ at 100 kPa and 300 K. Calculate its molar mass. [3]




**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]



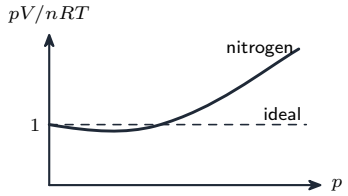



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## 3 Exam-style questions

**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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## Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

**2.1**

$V = 0.25 \times 22.7 = \mathbf{5.7\ dm^3}$

**2.2**

$n = \dfrac{pV}{RT} = \dfrac{1.00 \times 10^5 \times 2.50 \times 10^{-4}}{8.31 \times 300} = 0.0100$ mol; $M = \dfrac{0.50}{0.0100} = \mathbf{50\ g\ mol^{-1}}$

**2.3**

the particles gain kinetic energy and move faster; they hit the walls more often; and with more force, so the pressure rises

**2.4**

$V_2 = 200 \times \dfrac{353}{293} \times \dfrac{100}{150} = \mathbf{161\ cm^3}$

**3.1**

(a) any two: the volume of the particles is negligible; no forces between the particles; random motion; elastic collisions

(b) the particles are pushed close together; their own volume is no longer small compared with the volume of the container

(c) high temperature and low pressure

(d) the particles move slowly, so the attractive forces between them become significant



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