A-LEVEL CHEMISTRY • EXERCISE SHEET

4.1 The gaseous state: ideal and real gases and pV = nRT

Name: ____________ Class: ________ Date: __________ **Total: 23 marks**

KEY WORDS pressure 压强 • ideal gas 理想气体 • ideal gas equation 理想气体方程 • intermolecular forces 分子间作用力 • ion 离子

Objective

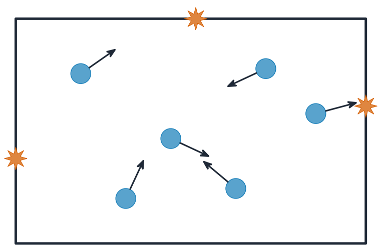
Build the skills to answer exam questions on **the gaseous state** — the origin of gas **pressure** 压强, the **ideal gas** 理想气体 model, and the ideal gas equation $pV = nRT$.

You must be able to:

- explain the origin of pressure in terms of collisions with the container walls
- state the assumptions of an ideal gas
- use $pV = nRT$ in calculations, including finding M_r

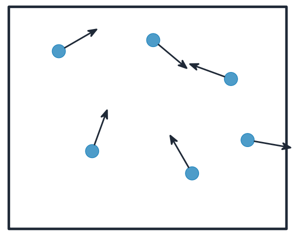
1 Worked examples

Gas pressure and the ideal gas

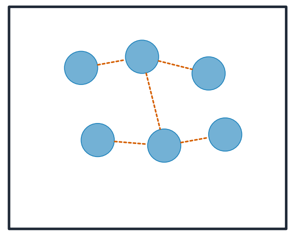


fast particles collide with the walls; the many pushes make the **pressure**

Pressure comes from the many collisions of fast gas molecules with the container walls



ideal gas (model)
point particles, *no* forces



real gas: high p, low T
real size + attractions (dashed)

An ideal gas has zero particle volume and no intermolecular forces — real gases obey it best at low pressure, high temperature

The ideal gas equation

$$pV = nRT$$

(p in Pa, V in m^3, T in K, $R = 8.31$ J K^{-1}mol^{-1}). **Convert first:** °C → K (+273); cm^3/dm^3 → m^3.

Example. Volume of 0.50 mol at 27 °C, 100 kPa: $T = 300$ K, $p = 1.00 \times 10^5$ Pa; $V = nRT/p = (0.50 \times 8.31 \times 300)/(1.00 \times 10^5) = 0.0125$ m^3.

Finding M_r. Since $n = m/M$: $M = \dfrac{mRT}{pV}$.

2 Practice

2.1 State the **two** assumptions made about an ideal gas. [2]

2.2 Convert 25 °C to kelvin. [1]

3 Exam-style questions

3.1 A real gas behaves **most** like an ideal gas at: [1]

- **A** high pressure and low temperature
- **B** low pressure and high temperature
- **C** high pressure and high temperature
- **D** low pressure and low temperature

3.2 In the equation $pV = nRT$, the temperature T must be in: [1]

- **A** °C
- **B** kelvin
- **C** °F
- **D** joules

3.3 Calculate the volume, in m^3, of 2.0 mol of an ideal gas at 127 °C and a pressure of 2.0×10^5 Pa. ($R = 8.31$). [3]

3.4 A gas of mass 1.32 g occupies 750 cm^3 at 100 kPa and 27 °C. Calculate its molar mass. ($R = 8.31$). [3]

3.5 A 250 cm^3 glass vessel is evacuated, sealed and weighed. It is then filled with an unknown gas **G** at 101 kPa and 25 °C and reweighed; the mass rises by 0.286 g. ($R = 8.31\ \mathrm{J\,K^{-1}mol^{-1}}$)

(a) Calculate the amount, in mol, of **G** in the vessel. [3]

(b) Hence calculate the relative molecular mass of **G** and suggest its identity. [3]

(c) State **two** assumptions of the ideal gas model, and explain which is more likely to fail if the measurement is repeated at 500 kPa. [4]

(d) State and explain the effect on the calculated M_r if the vessel had not been fully evacuated first. [2]

Solutions

2.1 the particles have zero volume; there are no intermolecular forces of attraction.

2.2 $25 + 273 = 298$ K.

3.1 **B**. Low pressure and high temperature (particles far apart, forces negligible).

3.2 **B**. Temperature must be in kelvin.

3.3 $T = 400$ K; $V = nRT/p = (2.0 \times 8.31 \times 400)/(2.0 \times 10^5) = 0.0332$ m^3.

3.4 convert: $V = 7.50 \times 10^{-4}$ m^3, $T = 300$ K, $p = 1.00 \times 10^5$ Pa; $M = \dfrac{mRT}{pV} = \dfrac{1.32 \times 8.31 \times 300}{(1.00 \times 10^5)(7.50 \times 10^{-4})} = 43.9$ g mol^{-1}.

3.5 (a) $V = 250 \times 10^{-6}$ m^3, $T = 298$ K, $p = 1.01 \times 10^5$ Pa; $n = \dfrac{pV}{RT} = \dfrac{1.01 \times 10^5 \times 2.50 \times 10^{-4}}{8.31 \times 298} = 1.02 \times 10^{-2}$ mol.
(b) $M_r = \dfrac{m}{n} = \dfrac{0.286}{1.02 \times 10^{-2}} = 28.0$; so **G** could be nitrogen, N_2, or carbon monoxide, CO.
(c) The molecules themselves occupy a negligible fraction of the container's volume; there are no attractive forces between them. At 500 kPa the molecules are five times closer together, so it is the **no-attraction** assumption that fails first — the attractions pull the molecules together, so the real gas is more compressible than $pV = nRT$ predicts.
(d) Air left behind means the measured mass increase is less than the true mass of **G**, while n is still calculated from the full pressure — so the M_r comes out **too low**.