

Exercise walk-through

4.1

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

A-Level Chemistry

Gas pressure

Pressure is the force from molecules hitting the walls.

more molecules

more hits per
second $\Rightarrow$ higher p

higher T

faster molecules
 $\Rightarrow$ harder hits

smaller V

hits more of-
ten $\Rightarrow$ higher p

Ideal gases

An **ideal gas** is a model: point particles, no attractions, elastic collisions.
Real gases approach it at **low pressure** and **high temperature** (far apart, moving fast).

The model fails when molecules take up a real volume (high p) or attract each other (low T).

The ideal gas equation

$$pV = nRT$$

Worked example

$$\begin{aligned} 0.50 \text{ mol at } 27^\circ\text{C, } 100 \text{ kPa: } V &= \frac{nRT}{p} = \\ \frac{0.50 \times 8.31 \times 300}{1.00 \times 10^5} &= 0.0125 \text{ m}^3 \end{aligned}$$

Convert first: $^\circ\text{C} \rightarrow \text{K}$ (+273), volume $\rightarrow \text{m}^3$. From

$$n = m/M: M = \frac{mRT}{pV} \text{ gives the } \mathbf{\text{molar}}$$

mass



Quartz

Exercises 2.1·3.1

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

[2]

2.2 Convert 25 °C to kelvin.

[1]

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

Exercises 2.1·3.1

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

[2]

2.1

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

2.2 Convert 25 °C to kelvin.

[1]

2.2

- $25 + 273 = 298 \text{ K}$
-

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

[1]

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

3.1 B

- Low pressure and high temperature (particles far apart, forces negligible)

Exercises 3.2·3.3

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]

Exercises 3.2·3.3

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A °C

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3.2 B

- Temperature must be in kelvin

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]

3.3

- $T = 400$ K; $V = nRT/p = (2.0 \times 8.31 \times 400)/(2.0 \times 10^5) = 0.0332 \text{ m}^3$

Exercise 3.4

3.4 A gas of mass 1.32 g occupies 750 cm³ at 100 kPa and 27 °C. Calculate its molar mass. ($R = 8.31$). [3]

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

Exercise 3.5 (a)

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. ($R = 8.31 \text{ J K}^{-1}\text{mol}^{-1}$)

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

[3]

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

(a)

$$\begin{aligned} \bullet \quad V &= 250 \times 10^{-6} \text{ m}^3, T = 298 \text{ K}, p = 1.01 \times 10^5 \text{ Pa}; n = \frac{pV}{RT} = \frac{1.01 \times 10^5 \times 2.50 \times 10^{-4}}{8.31 \times 298} \\ &= 1.02 \times 10^{-2} \text{ mol} \end{aligned}$$

Exercise 3.5 (b)

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. ($R = 8.31 \text{ J K}^{-1}\text{mol}^{-1}$)

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

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- $$M_r = \frac{m}{n} = \frac{0.286}{1.02 \times 10^{-2}} = 28.0; \text{ so } \mathbf{G} \text{ could be nitrogen, } \text{N}_2, \text{ or carbon monoxide, CO}$$

Exercise 3.5 (c)

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(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]

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(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

Exercise 3.5 (d)

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

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(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**