OCR A A Level Ideal Gases 1 worksheet

35-40 minutes independent practice + 15-20 minutes review

Specification points covered

- 5.1.4(a) Define amount of substance in moles and state the Avogadro constant $N_A = 6.02 \times 10^{23}$ mol^{-1}.
- 5.1.4(d)(i) Use and apply the equation of state of an ideal gas $pV = nRT$.
- 5.1.4(d)(ii) Apply Boyle's law and pressure-temperature relationships; for a fixed amount of gas, pV/T is constant.
- 5.1.4(g) State and use the Boltzmann constant $k = R/N_A$.
- 5.1.4(h) Use $pV = NkT$.

Aurora balloon mission

A research team prepares a helium balloon to carry atmospheric instruments through the aurora. A rigid chamber calibrates the gas supply, and a sealed canister returns an argon sample.
Show working, keep intermediate values unrounded and give an appropriate unit for every numerical answer.

Use throughout

$R = 8.31$ J mol^{-1} K^{-1} $N_A = 6.02 \times 10^{23}$ mol^{-1} $T/\text{K} = \theta/°\text{C} + 273$
After question 4, you may use $k = 1.38 \times 10^{-23}$ J K^{-1}.

1. Prepare the data

1. The launch laboratory is at 18.0 °C. Convert this temperature to kelvin. [1 mark]

2. The rigid calibration chamber has volume 3.60 L. Convert this volume to m^3. [1 mark]

3. The initial helium pressure is 125 kPa. Convert this pressure to Pa. [1 mark]

4. Use $k = R/N_A$ and the data given to calculate the Boltzmann constant k. [1 mark]

2. Moles and particles in the chamber

Initial chamber state
p = 125 kPa   V = 3.60 L   θ = 18.0 °C   gas = helium

5. The chamber contains helium at 125 kPa, 3.60 L and 18.0 °C. Calculate the amount of helium n in moles. [1 mark]

6. Use your answer to question 5 and N_A to calculate the number N of helium atoms in the chamber. [1 mark]

7. Use pV = NkT to calculate the number of helium atoms independently. [1 mark]

8. Explain why questions 6 and 7 give the same result, apart from rounding. Your answer should link R, N_A and k. [2 marks]

3. The ground gas-handling rig

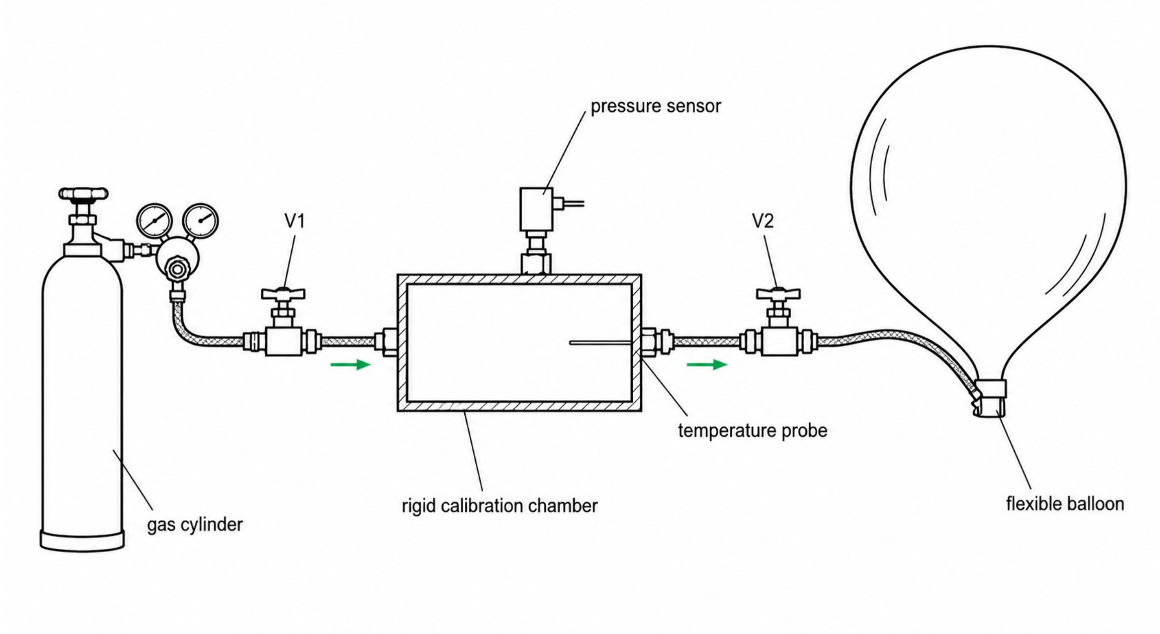

Figure 1: research-balloon gas-handling system

9. Figure 1 shows the gas-handling rig. State why pV/T = constant may be used to compare two chamber readings only when the valves are closed and no gas enters or leaves. [1 mark]

10. Both valves are closed. The helium in the rigid chamber warms from 291 K to 328 K. Its initial pressure is 125 kPa. Calculate the final pressure. [1 mark]

11. In another fixed-volume test, the pressure increases from 125 kPa at 291 K to 136 kPa. Calculate the final temperature in °C. [2 marks]

4. Expansion, loss and ascent

12. The chamber is at 160 kPa and 291 K. Valve V2 is opened to an initially empty flexible balloon. The temperature remains 291 K and the final pressure is 104 kPa. The hose volume is negligible. Calculate the final volume of the balloon. [2 marks]

13. After the chamber is sealed again, 4.0% of its helium atoms escape through a faulty joint. The chamber volume and gas temperature remain constant. Calculate the new pressure from an initial value of 125 kPa. [1 mark]

Balloon states

Launch: p_1 = 102 kPa, V_1 = 8.40 m^3, T_1 = 295 K.
Altitude before venting: p_2 = 35.0 kPa, T_2 = 245 K.

14. At launch, a sealed research balloon has volume 8.40 m^3, pressure 102 kPa and temperature 295 K. At altitude its pressure is 35.0 kPa and its temperature is 245 K. Calculate its volume at altitude before any gas is vented. [2 marks]

15. Calculate the percentage increase in the balloon volume between launch and altitude. [1 mark]

5. Particle count and balloon safety

16. Calculate the amount of helium in the balloon at launch, in moles. [1 mark]

17. Use pV = NkT and your altitude volume from question 14 to calculate the number of helium atoms in the sealed balloon. [1 mark]

18. The balloon's maximum safe volume is 19.0 m^3. Calculate the external pressure at which it reaches this volume if its temperature is 245 K and no gas has yet been vented. [1 mark]

19. A relief valve holds the balloon at 19.0 m^3 by venting gas. At 35.0 kPa and 245 K, calculate the percentage of the original helium atoms that have been vented. Use your answer to question 17. [2 marks]

6. The sealed sample canister

Argon return sample

At altitude: V = 1.80 L, p = 36.0 kPa and T = 248 K. The canister is rigid.

20. A rigid 1.80 L sample canister is sealed at altitude with argon at 36.0 kPa and 248 K. Calculate its pressure after descent when the gas reaches 303 K. [1 mark]

21. At 303 K, the canister pressure falls from 44.0 kPa to 41.8 kPa while its volume remains constant. Calculate the percentage of the argon atoms that have escaped. [1 mark]

22. A technician claims that the pressure fall in question 21 could be caused by the gas cooling rather than by a leak. The temperature record remains constant at 303 K. Evaluate the claim using the gas relationships. [2 marks]

23. The canister has a maximum safe pressure of 55.0 kPa. Starting from 44.0 kPa at 303 K, calculate the maximum safe gas temperature in °C if the canister does not leak. [2 marks]

7. Emergency pouch and a useful gas-density result

24. An emergency instrument pouch contains 3.50×10^{22} nitrogen molecules at 265 K in a volume of 4.80 L. Calculate the pressure inside the pouch. **[1 mark]**

25. At the same temperature and volume, calculate the number of additional molecules required to raise the pouch pressure to 40.0 kPa. **[2 marks]**

26. The molar mass of a gas is M and its mass is m. Starting from $pV = nRT$, together with $m = nM$ and $\rho = m/V$, show that $\rho = pM/(RT)$. **[3 marks]**

27. Use the expression from question 26 to calculate the density of helium at 35.0 kPa and 245 K. The molar mass of helium is 4.00×10^{-3} kg mol^{-1}. **[1 mark]**

Review and improve

- □ I convert pressure, volume and temperature to SI units before substitution.
- □ I choose n with R and N with k, and I can link the two forms using N_A.
- □ I use pV/T = constant only when the amount of gas is fixed.