

Mole Gases

Mark Scheme



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1. The “**mole**” allows us to easily convert between gas volumes and amounts, we can do this based on the key fact that one mole of any gas occupies exactly 24dm³ at room temperature and pressure (r.t.p).
Circle the letter of the correct answer for each of the following questions.

- a. At room temperature and pressure (r.t.p.), what volume does 1 mole of any gas occupy?

B – is the only correct answer.	(1)
	Total: 1 mark

- b. Calculate the number of moles in 48 dm³ of oxygen gas at r.t.p.

B – is the only correct answer.	(1)
	Total: 1 mark

- c. Look at the balanced equation for the decomposition of calcium carbonate:



If you thermally decompose 0.5 moles of CaCO₃, what volume of CO₂ gas is produced at r.t.p.?

B – is the only correct answer.	(1)
	Total: 1 mark

- d. A student reacts magnesium with water to produce hydrogen gas:



If 2 moles of water react completely, what volume of hydrogen gas is produced?

B – is the only correct answer.	(1)
	Total: 1 mark

- e. What is the volume of 4 g of helium (He) gas at r.t.p.?
(Relative atomic mass of He = 4)

C – is the only correct answer.	(1)
	Total: 1 mark

(Total for Question 1 is 5 marks)

2. A student investigates the reaction between calcium carbonate (marble chips) and dilute hydrochloric acid.
- Relative atomic masses (Ar): Ca = 40, C = 12, O = 16.
 - Molar volume of gas at room temperature and pressure (r.t.p.) = 24 dm³/mol.
- a. Balance the chemical equation for this reaction.



Award 1 mark for a 2 in front of HCl.	Accept multiples.	(1)
		Total: 1 mark

The reaction produces carbon dioxide gas.

- b. Describe the chemical test for carbon dioxide and the result you would see.

A description to include:	
Test: Bubble the gas through limewater.	(1)
Result: The limewater turns cloudy / milky.	(1)
Total: 2 marks	

The student uses 5.0 g of calcium carbonate (CaCO₃) and excess acid.

- c. Calculate the theoretical maximum volume of carbon dioxide gas produced. Give your answer in dm³.

Step 1: Calculate Mr of CaCO ₃	40 + 12 + (3 × 16) = 100	(1)
Step 2: Calculate moles of CaCO ₃	5.0 ÷ 100 = 0.05 mol	(1)
Step 3: Calculate volume of CO ₂	Ratio 1 : 1 so 0.05 mol gas produced.	
	0.05 × 24 = 1.2 dm ³	(1)
		Total: 3 marks

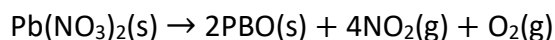
- d. The student collected the gas in a measuring cylinder. The actual volume collected was 0.96 dm³. Calculate the percentage yield of the reaction.

Step 1: Identify actual and theoretical yield.	Actual = 0.96	(1)
Theoretical = 1.2 dm ³ this is from the previous part. Question 2 part (c).		
Step 2: Calculate percentage.	(0.96 ÷ 1.2) × 100 = 80 %	(1)
		Total: 2 marks

(Total for Question 2 is 8 marks)

3. Lead is an element in Group 4 of the Periodic Table.

a. Lead(II) oxide is formed when lead(II) nitrate, $\text{Pb}(\text{NO}_3)_2(\text{s})$, is heated strongly.



i. Lead(II) oxide is a metal oxide. State whether this oxide is acidic or basic.

Basic.	(1)
	Total: 1 mark

ii. State the meaning of the Roman numeral (II) in the name lead(II) nitrate.

The charge on the lead ion is +2 or that the oxidation state is +2.	(1)
	Total: 1 mark

0.0100 moles of $\text{Pb}(\text{NO}_3)_2(\text{s})$ is heated in a crucible.

b. Calculate the mass of 0.0100 moles of $\text{Pb}(\text{NO}_3)_2(\text{s})$.

(Relative atomic masses: Pb = 207, N = 14, O = 16)

Step 1: Calculate Mr of $\text{Pb}(\text{NO}_3)_2$ $207 + [2 \times (14 + 48)] = 331$	(1)
Step 2: Calculate mass. $0.0100 \times 331 = 3.31 \text{ (g)}$	(1)
	Total: 2 marks

c. Calculate the total volume of gas, in dm^3 at r.t.p., produced when 0.0100 moles of $\text{Pb}(\text{NO}_3)_2$ is heated.
(Molar volume of gas at r.t.p. = 24 dm^3)

Step 1: Determine mole ratio of gas. Equation shows 2 moles solid reacts to give 4 moles of NO_2 gas and 1 mol of O_2 gas. Ratio is 2 : 5 or 1 : 2.5	(1)
Step 2: Calculate volume. $\text{Moles gas} = 0.0100 \times 2.5 = 0.025 \text{ mol}$ $\text{Volume} = 0.025 \times 24 = 0.6 \text{ dm}^3$	
	Total: 2 marks

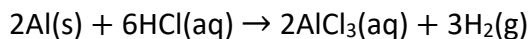
Carbon can be used to remove the oxygen from lead(II) oxide.

d. Write the symbol equation for the reaction between lead(II) oxide and carbon to form lead and carbon dioxide.

$2\text{PbO} + \text{C} \rightarrow 2\text{Pb} + \text{CO}$	
Award 1 mark for the correctly balanced reactants.	(1)
Award 1 mark for the correctly balanced products.	(1)
	Total: 2 marks

(Total for Question 3 is 8 marks)

4. A student investigates the reaction between a piece of aluminium foil and excess dilute hydrochloric acid. The balanced equation for the reaction is:



The student uses **1.35 g** of aluminium.

- a. Calculate the volume of hydrogen gas produced at room temperature and pressure.
Give your answer in **dm³** and show your working.

- Relative atomic masses (Ar): Al = 27
- Molar volume of gas at room temperature and pressure (r.t.p.) = 24 dm³/mol.

Step 1: Calculate moles of Aluminium. $1.35 \div 27 = 0.05$ $1.35 \div 27 = 0.05 \text{ mol}$	(1)
Step 2: Use mole ratio. Equation ratio: 2Al : 3H ₂	(1)
Step 3: Calculate moles of Hydrogen. $(0.05 \div 2) \times 3 = 0.075 \text{ mol}$	(1)
Step 4: Calculate volume. $0.075 \times 24 = 1.8 \text{ dm}^3$	(1)
Total: 4 marks	

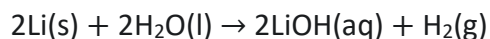
- b. The student collected the hydrogen gas in a measuring cylinder inverted in a trough of water.
The actual volume collected was less than the calculated value.

Suggest **two** reasons why the volume collected was less than expected.

Any two from:	
• Gas escaped (before bung replaced). • The reaction was incomplete. • The aluminium was impure. • Some gas dissolved in the water.	
Total: 2 marks	

(Total for Question 4 is 6 marks)

5. A teacher demonstrates the reaction between lithium metal and water.
The balanced equation for the reaction is:



The teacher uses 0.7 g of lithium.

- a. Calculate the volume of hydrogen gas produced at room temperature and pressure.
Give your answer in dm^3 .
- Relative atomic masses (Ar): Li = 7
 - Molar volume of gas at room temperature and pressure (r.t.p.) = $24 \text{ dm}^3/\text{mol}$.

Step 1: Calculate moles of Lithium. $0.7 \div 7 = 0.1 \text{ mol}$	(1)
Step 2: Use mole ratio. $2\text{Li} : 1\text{H}$	(1)
Step 3: Calculate moles of Hydrogen. $0.1 \div 2 = 0.05 \text{ mol}$	(1)
Step 4: Calculate volume. $0.05 \times 24 = 1.2 \text{ dm}^3$	(1)
	Total: 4 marks

After the reaction is complete, the teacher adds a few drops of Universal Indicator to the solution formed.

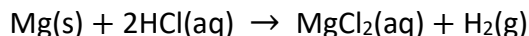
- b. State the colour the Universal Indicator would turn and explain why.

Purple / Blue	(1)
Lithium hydroxide formed is alkaline / contains OH^- ions.	(1)
	Total: 2 marks

(Total for Question 5 is 6 marks)

6. A student investigates the reaction between magnesium powder and hydrochloric acid.

The equation for the reaction is:



The student mixes 1.20 g of magnesium with 2.19 g of hydrogen chloride (dissolved in water).

Calculate the volume of hydrogen gas produced at room temperature and pressure.

You **must** show your working to determine which reactant is limiting.

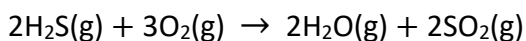
Relative atomic masses (Ar): Mg = 24, H = 1, Cl = 35.5

Molar volume of gas at room temperature and pressure (r.t.p.): 24 dm³/mol.

Step 1: we calculate moles of Mg. $1.20 \div 24 = 0.05 \text{ mol}$	(1)
Step 2: we calculate moles of HCl. $2.19 \div 36.5 = 0.06 \text{ mol}$	(1)
Step 3: we identify limiting reactant. Ratio 1Mg : 2HCl 0.05 mol Mg needs 0.10 mol HCl. We have only 0.06 mol, so HCl is limiting.	(1)
Step 4: we calculate moles of H ₂ produced. Based on the HCl ratio (2HCl : 1H ₂) $0.06 \div 2 = 0.03 \text{ mol}$	(1)
Step 5: we calculate volume. 0.03×24	(1)
$= 0.72 \text{ dm}^3$	(1)
Total: 6 marks	

(Total for Question 6 is 6 marks)

7. Hydrogen sulfide burns in oxygen to produce steam and sulfur dioxide.



50 dm³ of hydrogen sulfide is mixed with 60 dm³ of oxygen and ignited.

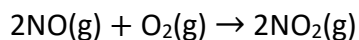
Calculate the final total volume of the gas mixture at the end of the reaction.

Assume all gases are measured at the same temperature and pressure.

Step 1: we identify the limiting reactant. Ratio 2H ₂ S : 3O ₂ 50 cm ³ H ₂ S requires 75 cm ³ O ₂ We have 60 cm ³ O ₂ So, O ₂ is limiting.	(1)
Step 2: we calculate the product volumes. Using 60 dm ³ O ₂ (Ratio 3 : 2 for both products): SO ₂ = 40 dm ³ H ₂ O = 40 dm ³	(1)
Step 3: we calculate the excess reactant volume. H ₂ S used = 40 dm ³ H ₂ S remaining = 50 – 40 = 10 dm ³	(1)
Step 4: we calculate the total volume. 40(SO ₂) + 40(H ₂ O) + 10(excess) = 90dm ³	(1)
Total: 4 marks	

(Total for Question 7 is 4 marks)

8. Nitrogen monoxide reacts with oxygen to form nitrogen dioxide.



10 cm³ of nitrogen monoxide is mixed with 10 cm³ of oxygen.

Calculate the total volume of gas remaining at the end of the reaction.

Assume all gases are measured at the same temperature and pressure.

Step 1: we identify the limiting reactant. The ratio of 2NO : 1O ₂ (2 : 1) 10 cm ³ of NO requires 5cm ³ O ₂ So NO is limiting.	(1)
Step 2: we calculate the excess O₂. 10 – 5 = 5 cm ³	(1)
Step 3: we calculate the product volume. Ratio 2NO : 2NO ₂ (1:1). 10 cm ³ of NO produces 10 cm ³ NO ₂	(1)
Step 4: we calculate the total volume. 10(product) + 5(excess) = 15 (cm ³)	(1)
Total: 4 marks	

(Total for Question 8 is 4 marks)