Limiting reactants and gas volumes

Student activity • teacher demonstration

YEAR 10 / LESSON 44 / CHEMISTRY ONLY

The question

Which reactant sets the maximum gas volume?

Predict three small-scale marble/acid demonstrations, then compare the predictions with actual collected volumes. Calculate the amount allowed by each reactant before choosing the smaller value.

Equipment

- Calculator and periodic table; eye protection for observers
- Teacher: 100 cm^3 gas syringe, clamp/stand, 100 cm^3 flask, bung/tube and tray
- Teacher: balance (0.01 g), 10 cm^3 cylinder, marble chips and prepared 0.20 / 0.50 mol dm^{-3} HCl

Wear eye protection and observe from the teacher's designated position. Staff handle acid and glassware. Keep syringe free to move; stop for obstruction or leaks. No heating or flames.

Course coverage: Chemistry-only timetable lesson: 1.35C gas volumes at rtp, supported by shared reacting-mass point 1.29. Use 24 $dm^3\ mol^{-1}$ only for the stated room conditions.

Plan, model or apparatus sketch

Sketch the teacher gas-collection apparatus and mark the free-moving plunger.

Method and reasoning

Read the whole sequence before starting

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1. Before the demonstration, use $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$. For each condition in the table calculate $n(CaCO_3)$, $n(HCl)/2$ and hence the maximum $n(CO_2)$.

2. Calculate predicted CO_2 volume using $V = n \times 24\,000$ cm³ mol⁻¹. Identify the limiting reactant and any solid expected to remain. Predictions are not observations.

3. Observe the teacher run A, B and C separately using fresh materials: A 0.10 g marble + 10.0 cm³ 0.50 mol dm⁻³ HCl; B 0.20 g + 10.0 cm³ 0.20 mol dm⁻³; C 0.20 g + 10.0 cm³ 0.50 mol dm⁻³.

4. Record actual measured masses, starting/final syringe volumes and room temperature as supplied by the teacher. Read the final volume only after collection stops; subtract the starting reading.

5. Compare A/B, then B/C. Explain why extra marble does not always mean extra gas. Record any unfinished reaction or collection problem without inventing readings.

6. Evaluate gas lost before bunging, dissolution, leaks and temperature differences. Use your calculated maximum as a comparison, not a target to force the results towards.

Cleanup

- After reaction stops, staff collect residues and rinses under the school disposal plan; wash hands.

Record your evidence

Blank spaces are for your own work

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Reference and task data

Every run uses 10.0 cm^3 acid. $M(CaCO_3)$ = 100 g mol^{-1}. Supplied amounts of HCl: 0.50 M gives 0.0050 mol; 0.20 M gives 0.0020 mol. One mole $CaCO_3$ needs two moles HCl and can form one mole CO_2. At rtp, 1 mol gas ≈ 24 dm^3 = 24 000 cm^3. M means mol dm^{-3} in the condition labels.

Condition	Predicted CO_2 / cm^3	Observed CO_2 / cm^3
A: 0.10 g; 0.50 M		
B: 0.20 g; 0.20 M		
C: 0.20 g; 0.50 M		

Show your calculations, labelled model or correction here.

Explain and evaluate

Use evidence and show calculation steps where relevant

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1. Calculate the limiting reactant, theoretical amount and gas volume for A, B and C.

2. For B, calculate the mass of marble theoretically left after the acid is used up.

3. Explain why B and C have the same initial marble mass but different maximum gas volumes.

4. Convert 0.072 dm^3 to cm^3 and calculate the amount of gas at rtp.

5. Explain why the reactant with the smaller mass is not necessarily limiting.

6. Give two reasons why collected volume may be below the calculated value without changing the equation.