Reaction rates: surface area and concentration

Student activity • rate investigation

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The question

How can we change reaction speed without changing the amount of marble?

Measure carbon dioxide from equal masses of marble with hydrochloric acid. Compare chip size while keeping acid fixed, then compare acid concentration while keeping chip size fixed. Share repeats across pairs to fit the lesson; never use powdered marble or a blocked gas outlet.

Equipment

- Eye protection; 100 cm^3 gas syringe with freely moving plunger, clamp and stand
- 100 cm^3 conical flask, fitted bung/tube to syringe, tray and timer
- 10 cm^3 measuring cylinder; balance reading to 0.01 g; weighing boats
- 0.20 g marble per run, in large or smaller chips; 10.0 cm^3 HCl per run, 0.5 or 1.0 mol dm^{-3}

Wear eye protection; avoid acid splashes and report them immediately. Keep the syringe plunger free and tubing unobstructed. Stop if apparatus sticks or pressurises; call the teacher. Handle glassware carefully. No flames or heating.

Course coverage: 3.9–3.11: investigating surface area and concentration; rate measurements and collision explanations. Temperature is controlled here, not varied.

Plan, model or apparatus sketch

Draw a flask connected to a freely moving gas syringe; label the gas path.

Method and reasoning

Read the whole sequence before starting

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1. Wear eye protection and inspect the teacher-checked apparatus. The syringe must be free to move, connected without kinks, and set near zero. Do not cap its outlet or clamp the plunger.

2. Assign pairs to A: large chips with 1.0 mol dm^{-3} acid; B: smaller chips with 1.0 mol dm^{-3} acid; or C: large chips with 0.5 mol dm^{-3} acid. Each run uses 0.20 g marble and 10.0 cm^3 acid at the same starting temperature.

3. Measure the acid into the flask. Add the weighed chips, start the timer immediately and fit the bung promptly. Record any delay; do not shake the flask or point apparatus at anyone.

4. Read gas volume every 15 seconds for three minutes or until the volume has stopped changing. Stop and tell the teacher if the plunger sticks, pressure builds or a leak occurs; do not force it.

5. When gas production has stopped, disconnect under teacher direction. Repeat your assigned condition with fresh materials and cleaned apparatus. Share the raw curves and repeats with the class.

6. Compare A with B for surface area and A with C for concentration. Plot volume against time with units. Estimate initial rate from the early slope, explaining any gas lost before bunging.

7. Compare final volumes only when reactions have completed. Explain why the same marble mass should give a similar final amount when acid is in excess; faster is not the same as more product.

Cleanup

• After reaction stops, staff direct collection/disposal of dilute mixtures and leftover chips. Rinse equipment as instructed; return dry apparatus and wash hands.

Record your evidence

Blank spaces are for your own work

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Reference and task data

Record assigned condition, chip description and starting temperature. Reaction: $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$. For 0.20 g pure $CaCO_3$, the theoretical CO_2 volume is about 48 cm^3 at room conditions; this is a capacity estimate, not a measured result. Use a 100 cm^3 syringe.

Time / s	Run 1 / cm^3	Run 2 / cm^3
0		
15		
30		
45		
60		
75		
90		
105		
120		
135		
150		
165		
180		

Show your calculations, labelled model or correction here.

Explain and evaluate

Use evidence and show calculation steps where relevant

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1. Identify independent, dependent and controlled variables for each comparison.

2. Plot both repeat curves and estimate an early rate in $cm^3\ s^{-1}$.

3. Explain the chip-size effect in terms of exposed surface and collisions.

4. Explain the concentration effect without claiming particles gain extra energy.

5. Explain why completed final gas volumes may be similar despite different rates.

6. Evaluate gas loss, leaks, chip variability and syringe friction; suggest a practical improvement.