# Reacting masses and collected yield

Student activity • yield investigation

YEAR 10 / LESSON 43 / CHEMISTRY + SCIENCE (DOUBLE AWARD)

## The question

**Why can the amount of product collected be less than the theoretical amount?**

Calculate reacting masses, then measure collected carbon dioxide from a small marble/acid reaction. Distinguish chemical conversion from gas-collection losses. Report an apparent collected yield using the stated room-temperature approximation.

## Equipment

- Eye protection; checked 100 $cm^3$ gas syringe, stand, flask and unobstructed bung/tubing
- Balance reading to 0.01 g, weighing boat, 10 $cm^3$ measuring cylinder and tray
- 0.20 g marble chips and 10.0 $cm^3$ of 0.5 mol $dm^{-3}$ HCl per run; two fresh runs per pair
- Calculator and supplied molar-mass/gas-volume reference

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: 1.28–1.30: amount calculations, reacting masses and percentage yield. Gas-volume conversion is supplied as a measurement aid, not assumed prior knowledge.

## Plan, model or apparatus sketch

**Draw the gas collection apparatus; label the measured quantities.**

# Method and reasoning

Read the whole sequence before starting

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**1.** Write the balanced marble/acid equation and calculate the maximum $CO_2$ from 0.20 g pure $CaCO_3$. Use the supplied acid-amount fact to identify the limiting reactant.

**2.** Wear eye protection. Check that the 100 $cm^3$ syringe moves freely and that the gas path is clear. Record actual marble mass, syringe starting reading and room temperature.

**3.** Measure 10.0 $cm^3$ of 0.5 mol $dm^{-3}$ HCl into the flask. Add about 0.20 g weighed chips and promptly fit the bung. Record delays; do not heat or shake.

**4.** Leave until no more gas is collected and the apparatus is near its starting temperature. Read the final syringe volume; subtract the start reading. Stop and call staff if flow is blocked or the plunger sticks.

**5.** After reaction stops, disconnect under staff direction. Repeat with fresh reactants and clean apparatus. Keep both measured masses and gas volumes.

**6.** Convert each collected volume to an approximate amount of $CO_2$ using 24 000 $cm^3$ $mol^{-1}$, then to mass using $M(CO_2)=44$ g $mol^{-1}$. Calculate collected mass/theoretical mass × 100%.

**7.** Compare the repeats and discuss leaks, dissolution, residual gas, temperature and marble purity. A low collected yield does not by itself prove incomplete chemical reaction. Complete the separate reacting-mass practice.

## 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

Use $M(CaCO_3)=100$ and $M(CO_2)=44$ g mol$^{-1}$; 1 mol gas ≈ 24 000 cm$^3$ at the stated room conditions. 10.0 cm$^3$ of 0.5 mol dm$^{-3}$ HCl contains 0.0050 mol HCl. $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$. Percentage collected yield = collected $CO_2$ mass/theoretical $CO_2$ mass × 100. Separate invented practice: 8.0 g Mg gives 12.0 g dry MgO; use $M(Mg)=24$, $M(MgO)=40$ g mol$^{-1}$.

| Run | Actual marble mass / g | Collected $CO_2$ / cm$^3$ |
|---|---|---|
| 1 | | |
| 2 | | |

**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 theoretical $CO_2$ mass and volume for 0.20 g pure $CaCO_3$ and identify the limiting reactant.

**2.** Use your actual marble mass and collected volume to calculate the apparent collected yield for each run.

**3.** For the separate Mg practice, calculate theoretical MgO mass and percentage yield.

**4.** Explain the difference between mole ratios and mass ratios in balanced equations.

**5.** Explain two ways a complete reaction can still give a low collected gas yield.

**6.** Explain a possible apparent yield above 100% and propose one improvement or uncertainty estimate.