Determining the relative atomic mass of magnesium

This investigation is part of the **Nuffield practical collection**, developed by the Nuffield Foundation and the Royal Society of Chemistry. Delve into a wide range of chemical concepts and processes with this collection of over 200 step-by-step practicals: rsc.li/43bjGql

Learning objectives

1. Measure the volume of hydrogen gas produced during an acid–metal reaction.
2. Record accurate measurements of mass and volume in a results table.
3. Determine a molar ratio during a chemical reaction using balanced chemical equations.
4. Estimate the relative atomic mass of magnesium using your experimental results.

Success criteria

Learners will first carry out the practical to measure the volume of hydrogen gas produced (LO1, LO2). Using molar volume calculations, they will determine the moles of hydrogen produced. By linking this to the balanced chemical equation, learners will therefore deduce the moles of magnesium required (LO3) and hence the relative atomic mass (using the starting mass recorded)(LO4).

Introduction

In this experiment, learners react magnesium ribbon with dilute hydrochloric acid to produce hydrogen gas. They then use the measured volume of hydrogen gas produced and the mass of magnesium to calculate the mass of magnesium required to produce one mole of hydrogen molecules. From this, learners can deduce the relative atomic mass of magnesium.

This is a class experiment suitable for learners who already have a reasonable understanding of the mole concept and are beginning to use chemical equations to perform calculations.

A total of 45 minutes is adequate for the class to obtain and record their results, including the time taken by the teacher to demonstrate the procedure and allowing an average of five minutes for each learner to measure the mass of their magnesium ribbon. However, the timing depends on the number of top-pan balances available and the skill with which learners can use the balance to sufficient accuracy.

Scaffolding

Two versions of the worksheet are available: scaffolded (✪) and unscaffolded (✪✪). The scaffolded sheet offers more support to allow learners to access the questions. The answers to the worksheets are at the end of this document.

The follow-up calculation uses two different equations and you can choose to work through this collaboratively with your class to support understanding. The equations are given in the scaffolded sheet.

Technician notes

Read our standard health and safety guidance (rsc.li/3zyJLkx) and carry out a risk assessment before running any live practical.

Equipment

Apparatus

- Safety glasses
- Fine emery paper, a few cm, x 2
- Burette, 50 cm^3 (see note below)
- Burette stand
- Funnel, small
- Beaker, 100 cm^3
- Beaker, 250 cm^3
- Access to a top-pan balance, accurate to +/– 0.001 g
- Access to room temperature and pressure measurements

Apparatus notes

- Make sure the burette taps are free from leakage, operate smoothly and are secure in their sockets.
- A balance reading to only +/– 0.01 g does not have sufficient accuracy for the procedure used in this experiment, where the maximum possible volume of hydrogen that can be collected is only 0.002 mol, which would be produced by 0.048 g of magnesium.
- If a balance accurate to 0.001 g is not available, you can obtain reasonable results by measuring the mass of a much longer (e.g. 30 cm) piece of magnesium ribbon beforehand on a balance with an accuracy of 0.01 g, measuring its length and then cutting it accurately into 3 cm lengths. Using the mass and length of the long piece of magnesium, you can calculate the average mass of a 3 cm length with sufficient accuracy.

- If a barometer is not available in the laboratory, obtain an up-to-date reading of atmospheric pressure shortly before the lesson, e.g. from a local weather website. You will also need to measure room temperature.

Chemicals

- 25 cm^3 2M hydrochloric acid, IRRITANT
- Magnesium ribbon, cut into lengths of approximately 3–4 cm
  Clean the magnesium ribbon with emery paper to remove the grey oxide layer, so that it appears shiny and metallic.
  DANGER: flammable solid

Safety and hazards

- Wear eye protection throughout.
- Dilute hydrochloric acid, HCl(aq), IRRITANT at concentration used
    - See CLEAPSS Hazcard HC047a and CLEAPSS Recipe Book RB043, refer to SSERC or contact your local safety advisory body.
    - Provide the hydrochloric acid in small bottles or corked conical flasks, labelled, suitable for pouring the acid into the burette.
- Magnesium ribbon, Mg(s) DANGER: flammable solid
    - See CLEAPSS Hazcard HC059A, refer to SSERC or contact your local safety advisory body.
    - Take steps to prevent theft of magnesium ribbon. Reels of magnesium ribbon should not be left out in the laboratory. It is good practice to have a limited number of pre-cut lengths and to hand these out to learners as needed.
- Magnesium chloride solution, $MgCl_2$(aq), is currently not classified as hazardous.

Disposal

- Dispose of hydrochloric acid by diluting in water to below 0.1M. Pour the diluted solution down a foul-water drain with further dilution.
- Dispose of **small amounts** of magnesium by adding slowly to 1 M ethanoic acid solution. Test the solution with indicator and add more ethanoic acid until the mixture is just acidic. The reaction generates a lot of heat. Pour the neutralised mixture down a foul-water drain with further dilution. NEVER dispose of flammable chemicals in the normal refuse.
- Dispose of the product, magnesium chloride, by pouring the solution down a foul-water drain.

Method

A full method, including diagrams, is provided in the student worksheet.

Teaching notes

Demonstrate the procedure beforehand. The inversion is not difficult and it is not necessary to put a finger over the open end. Warn learners not to fold the magnesium ribbon, but to push it into the burette so that it is retained under its own tension.

You can collect results from the class on a spreadsheet to enable a discussion about their reliability.

Learners can perform the resulting calculation at various levels. They need to be able to understand the equation:

$$\mathrm{Mg} + 2\mathrm{HCl} \rightarrow \mathrm{MgCl_2} + \mathrm{H_2}$$

and to use it to recognise that one mole of magnesium will yield one mole of hydrogen molecules. From the results, the least required of students would be to perform a proportionality calculation to determine the mass of magnesium that would have yielded 24,000 cm^3 of hydrogen.

As an additional challenge, show some learners the ideal gas equation and ask them to convert the volume of gas collected under known conditions in the experiment to standard temperature and pressure, then determine the mass of magnesium that would have yielded 24,000 cm^3 of hydrogen.

Answers

1. *Scaffolded*
   (a) Learner's reading from burette
   (b) Number of moles = (answer to part a)/24,000

Unscaffolded
Number of moles = (learner's volume)/24,000

2. *Scaffolded and unscaffolded*

(a) $\mathrm{Mg} + 2\mathrm{HCl} \rightarrow \mathrm{MgCl_2} + \mathrm{H_2}$

Scaffolded
(b) 1:1
(c) Learner's answer to question 1 = number of moles of magnesium
(d) $\text{Learner's calculated } M_r \text{ of magnesium} = \frac{\text{mass of magnesium (from results table)}}{\text{answer to 1(b)}}$

Unscaffolded
(b) $\text{Learner's calculated } M_r \text{ of magnesium} = \frac{\text{mass of magnesium (from results table)}}{\text{answer to 1}}$

3. *Scaffolded and unscaffolded*

$$\%\ \text{error} = \left(\frac{\text{difference}}{24}\right) \times 100$$

4. *Scaffolded and unscaffolded*
   Sources of error could include:
   - volume of gas produced not read from '0' on the scale (by not letting out some air before the reaction began)
   - not all the magnesium reacted
   - letting out some solution when inverting the burette

Answers to further practice

5. *Scaffolded and unscaffolded*

(a) Volume of hydrogen = 30.00 cm^3
(b) Number of moles of hydrogen = 30.00/24,000 = 1.25 x 10^{-3} mol

6. *Scaffolded and unscaffolded*

(a) $Ca + 2HCl \rightarrow CaCl_2 + H_2$

Scaffolded
(b) Molar ratio = 1:1
(c) So, number of moles of calcium = 1.25 x 10^{-3} mol
(d) Relative atomic mass = 0.05/1.25 x 10^{-3} = 40.0

Unscaffolded
(b) Number of moles of calcium = 1.25 x 10^{-3} mol
Relative atomic mass = 0.05/1.25 x 10^{-3} = 40.0

7. *Scaffolded and unscaffolded*
   $\% \text{ error} = \left(\frac{0.1}{40.1}\right) \times 100 = 0.3\% \text{ (1 d.p.)}$