Determining the volume of one mole of hydrogen gas

Learning objectives

1. Measure the volume of hydrogen gas produced in a metal–acid reaction.
2. Analyse the results to determine the volume of one mole of a gas.
3. Evaluate the accuracy of the result obtained.

Introduction

In this activity, learners measure the volume of hydrogen gas produced by the reaction of a known mass of magnesium with excess hydrochloric acid. They use the results to determine the volume of one mole of hydrogen gas at room temperature and pressure. Finally, they evaluate the accuracy of their results by comparing their experimental value to the true value.

The student sheets include:

- full details of the activity including the method
- practice calculations, which learners can complete before or after the activity
- a series of further questions to encourage learners to consider the reason for some of the steps in the method

The activity is supported by lesson slides you can use to introduce the activity and to support learners with the analysis and evaluation of their results.

If it is not possible for learners to carry out the experiment, demonstrate the experiment and get learners to analyse and evaluate the results.

Scaffolding

Scaffolded (✪) and unscaffolded (✪✪) versions of the student worksheet are available. In the scaffolded version, steps guide learners through the calculation to determine the volume of one mole of hydrogen gas.

Answers to the practice calculations are provided at the end of this document.

Teaching notes

- Demonstrate the method beforehand.
- Warn learners not to fold the magnesium ribbon, but to push it into the burette so it is retained under its own tension.

- Demonstrate the inversion: rest the end of the burette on the lip of the beaker and swing the tap end round and upward to a vertical position. It is not necessary to put a finger over the open end of the burette.
- It is important that the liquid level starts on the graduated scale of the burette. If the liquid level is not on the scale, opening the tap momentarily allows the liquid to drop onto the scale.

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 (per group)

- Safety glasses
- Burette
- Burette stand
- Beaker, 250 cm^3
- Funnel
- Balance (minimum 2 d.p.)
- Emery paper

Chemicals

- Magnesium ribbon, 3.5 cm length, DANGER, flammable
- Hydrochloric acid, 2.0 mol/dm^3
- Distilled water

Safety and hazards

- Wear safety glasses throughout the experiment.
- Dilute hydrochloric acid. At concentrations <2.7 mol/dm^3 it is not currently classified as hazardous. See CLEAPSS Hazcard HC047a, refer to SSERC or contact your local safety advisory body.
- Magnesium ribbon, DANGER: flammable solid. See CLEAPSS Hazard HC059a, refer to SSERC or contact your local safety advisory body.

  Take steps to prevent theft of magnesium ribbon. Do not leave reels of magnesium ribbon 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 is not currently classified as hazardous.

Answers to evaluation questions ✪/✪✪

1. Answer is dependent on learner result.

2. Reasons why the experimental value could be lower than the true value include:

- the temperature was lower than 20°C
- not all the gas reached the top of the burette/small bubbles of gas remained in the liquid.

Reasons why the experimental value could be higher than the true value include:

- the temperature was higher than 20°C
- not all the magnesium had reacted/the reaction was incomplete.

3. Possible answers include:

- repeat the experiment and record a mean value ignoring any anomalies
- carry out the experiment on a larger scale to minimise errors from uncertainties in the burette readings.

Answers to further questions

4. *Unscaffolded* (✪✪) *and scaffolded* (✪)
Water is added so that the magnesium doesn't react as soon as the burette is inverted, allowing time for the initial burette reading to be taken. The reaction only begins once the hydrochloric acid has diffused through the water and come into contact with the magnesium.

5. *Unscaffolded* (✪✪) *only*

Learners will use their own mass of Mg, but using 0.04 g gives:

$$\text{Number of moles of Mg} = \frac{0.04}{24} = 0.00167 \text{ mol}$$

0.00167 mol Mg needs 0.00333 mol HCl to react with.

$$\text{Number of moles of HCl used} = 2 \text{ mol/dm}^3 \times 0.025 \text{ dm}^3 = 0.05 \text{ mol}$$

Since 0.05 mol > 0.00333 mol, the HCl is in excess.

6. *Unscaffolded* (✪✪) **5.** *Scaffolded* (✪)
The water and acid would mix to produce a 1.0 mol/dm^3 solution of hydrochloric acid if mixed fully. When the burette was inverted, the magnesium would begin to react immediately making it hard to accurately read the initial volume off the burette.

7. *Unscaffolded* (✪✪) *or* **6.** *Scaffolded* (✪)
If a mass of magnesium greater than 0.04 g was used, the volume of hydrogen produced would be too large to accurate record in the burette.
(In theory 0.04 g of Mg will produce 40 cm^3 of hydrogen gas).

Answers to practice calculations (✪✪)

1. Number of moles of Mg $= \frac{0.50}{24} = 0.0208$ mol

   Number of moles of H_2 produced $= 0.0208$ mol

   Volume of 1 mole of $H_2 = \dfrac{0.49\ \text{dm}^3}{0.0208\ \text{mol}} = 23.5\ \text{dm}^3$ (to 3 s. f.)

2. Number of moles of Li $= \frac{17.5}{7} = 2.5$ mol

   Number of moles of H_2 produced $= \dfrac{2.5\ \text{mol}}{2} = 1.25$ mol

   Volume of 1 mole of $H_2 = \dfrac{31.5\ \text{dm}^3}{1.25\ \text{mol}} = 25.2\ \text{dm}^3$(to 3 s. f.)

3. Number of moles of Al $= \frac{3.0}{27} = 0.111$ mol

   Number of moles of H_2 produced $= \dfrac{0.111\ \text{mol}}{2} \times 3 = 0.167$ mol

   Volume of 1 mole of $H_2 = \dfrac{3.75\ \text{dm}^3}{0.167\ \text{mol}} = 22.5\ \text{dm}^3$(to 3 s. f.)

Answers to practice calculations (✪)

1. (a) Number of moles of $H_2 = 0.5$ mol

   (b) Number of moles of Mg $= \frac{6}{24} = 0.25$ mol

   Number of moles of $H_2 = 0.25$ mol

2. (a) Number of moles of $H_2 = \frac{0.5\ \text{mol}}{2} = 0.25$ mol

   (b) Number of moles of Li $= \frac{14}{7} = 2$ mol

   Number of moles of $H_2 = \dfrac{2}{2} = 1$ mol

3. Volume of 1 mol of gas $= \frac{1{,}200\ \text{cm}^3}{0.05\ \text{mol}} = 24{,}000\ \text{cm}^3$