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

One mole of any gas occupies the same volume when measured under the same conditions of temperature and pressure. At room temperature and pressure (RTP), this volume is 24.0 dm^3 or 24,000 cm^3.

In chemistry, room temperature and pressure are 20°C and 1 atmosphere.

Magnesium reacts with hydrochloric acid to produce a salt – magnesium chloride – and hydrogen gas.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

In this experiment, you will measure the volume of hydrogen gas produced by the reaction of a known mass of magnesium with excess hydrochloric acid. You will then use the results to determine the volume of one mole of hydrogen gas at room temperature and pressure.

Equipment

- Burette
- Burette stand
- Beaker, 250 cm^3
- Funnel
- Balance (minimum 2 d.p.)
- Emery paper
- Eye protection
- Hydrochloric acid, 2.0 mol/dm^3
- Magnesium ribbon, 3.5 cm DANGER: flammable 

Method

1. Clean a piece of magnesium ribbon by gently rubbing it with emery paper and measure its mass accurately. It should have a mass between 0.02 and 0.04 g. If not, adjust the amount used.
2. Measure 25 cm^3 of 2.0 mol/dm^3 hydrochloric acid into the burette. Slightly tilt the burette and carefully add 25 cm^3 of water on top of the acid by running the water down the inside of the burette. Try not to disturb the acid layer.
3. Push the magnesium into the end of the burette so it will stay in position with its own tension.
4. Add 50 cm^3 of water to a 250 cm^3 beaker.
5. Quickly invert the burette into the water – your teacher will show you how to do this. If this is done quickly and carefully, very little liquid is lost. Clamp the burette vertically.
6. It is important that the liquid level in the burette starts on the graduated scale. If it is not on the scale, momentarily open the tap. This allows the level to drop.
7. Take the burette reading (*Remember*: the burette is upside down).
8. Observe the magnesium reacting as the acid diffuses downwards. Wait until all the magnesium has reacted.
9. Record the new volume in the burette (*Remember*: the burette is upside down)

Results

Mass of magnesium ribbon used (g) _____

Initial burette reading (cm^3) _____

Final burette reading (cm^3) _____

Volume of hydrogen produced (cm^3) _____

Analysis

Use the results to calculate the volume of one mole of hydrogen gas under the conditions used.

Volume of one mole of hydrogen gas = _____ cm^3

Evaluation

1. Calculate the percentage difference between your value and the true value for the volume of one mole of gas at RTP. Use the equation:

$$\%\ \text{difference} = \frac{\text{difference between the experimental value and the true value}}{\text{true value}} \times 100$$

Percentage difference = _____%

2. How close to the true value was the experimental value? Suggest two reasons for the difference.

3. How could you improve the experiment to obtain a more accurate value?

Further questions

Answer the following questions about the method used in this experiment.

4. Why was 25 cm^3 of water added on top of the 2 mol/dm^3 hydrochloric acid in the burette?

5. Show by calculation that the hydrochloric acid was in excess.

6. A student missed the instruction to take care not to disturb the acid layer in step 2 and mixed the acid and water prior to inverting the burette. Describe what impact this would have on the experiment.

7. Explain why it was important to use between 0.02 g and 0.04 g of magnesium ribbon.

Practice calculations

In each example, calculate the volume of one mole of gas based on the experimental results.

1. Magnesium reacts with acid to make a salt and hydrogen gas:

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

0.50 g of magnesium was reacted with excess acid, 0.49 dm^3 of gas was produced.

2. Lithium reacts with water to produce lithium hydroxide and hydrogen gas:

$$2Li(s) + 2H_2O(aq) \rightarrow 2LiOH(aq) + H_2(g)$$

17.5 g of lithium was reacted with excess water, 31.5 dm^3 of gas was produced.

3. Aluminium reacts with acid to make a salt and hydrogen gas:

$$2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$$

3.00 g of aluminium was reacted with excess acid, 3.75 dm^3 of gas was produced.