

Core practical 1: Measure the molar volume of a gas

Objective	
<ul style="list-style-type: none"> To find the volume of one mole of carbon dioxide gas 	
Safety	Specification links
<ul style="list-style-type: none"> Wear eye protection. Ensure the delivery tube does not become blocked. Ethanoic acid will sting if it gets into cuts in the skin. 	<ul style="list-style-type: none"> Practical techniques 1, 4, 11 CPAC statements 1a, 2a, 2b, 3a, 3b, 4a
Procedure	Notes on procedure
<ol style="list-style-type: none"> Place 30 cm³ of 1 mol dm⁻³ ethanoic acid in the boiling tube. Set the apparatus up as shown in the diagram. Place approximately 0.05 g of calcium carbonate in a test tube. Weigh the test tube and its contents accurately. Remove the bung from the boiling tube and tip the calcium carbonate into the boiling tube. Quickly replace the bung in the boiling tube. Once the reaction is over, measure the volume of gas collected in the measuring cylinder. Reweigh the test tube that had contained the calcium carbonate. Repeat the experiment six more times, increasing the mass of calcium carbonate by about 0.05 g each time. Do not exceed 0.40 g of calcium carbonate. 	<ul style="list-style-type: none"> Use of over 0.40 g of calcium carbonate will result in the volume of gas produced exceeding the capacity of the measuring cylinder. If larger masses of calcium carbonate are to be used (such as if only a 1 d.p. mass balance is available) then a larger measuring cylinder will be required. Ensure the bung is replaced quickly during step 5 to minimise gas loss. Use of a stronger acid will result in a faster reaction and so a greater loss of gas when the calcium carbonate is added to the acid.
Answers to questions	
<ol style="list-style-type: none"> $\text{CaCO}_3 + 2\text{CH}_3\text{COOH} \rightarrow \text{Ca}(\text{CH}_3\text{COO})_2 + \text{CO}_2 + \text{H}_2\text{O}$ Allows for the mass of any calcium carbonate that remains in the test tube after tipping it out. Gas loss before replacing the bung. Use tube containing the acid inside the vessel containing the calcium carbonate – tip to mix the reagent. When 0.40 g of calcium carbonate is used: moles $\text{CaCO}_3 = 0.4 / 100.1 = 0.003996$ moles ethanoic acid = $c \times v = 1 \times 30/1000 = 0.03$ moles acid > 2 × moles calcium carbonate – hence ethanoic acid in excess. 	

Sample data

Mass calcium carbonate/g	Volume of carbon dioxide collected/cm ³
0.05	11
0.11	27
0.17	32
0.21	50
0.24	59
0.32	74
0.33	80

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- To find the volume of one mole of carbon dioxide gas

Safety

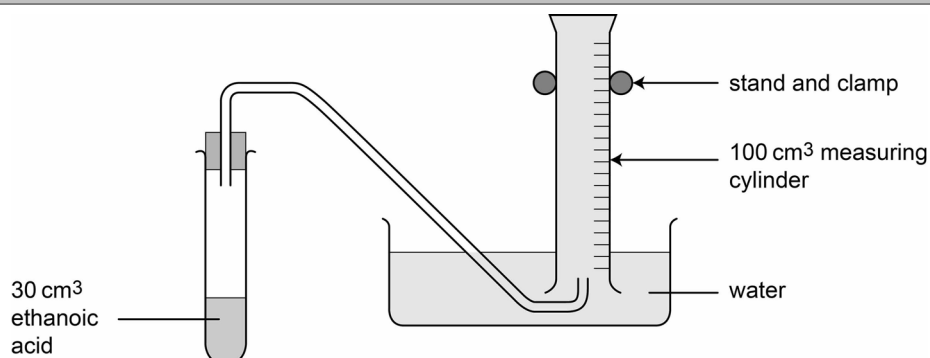
- Wear eye protection.
- Ensure the delivery tube does not become blocked.
- Ethanoic acid will sting if it gets into cuts in the skin.

All the maths you need

- Recognise and make use of appropriate units in calculations.
- Use ratios, fractions and percentages.
- Translate information between graphical, numerical and algebraic forms.
- Plot two variables from experimental or other data.

Equipment

- boiling tube
- stand and clamp
- bung fitted with delivery tube to fit boiling tube
- water bath for gas collection
- 100 cm³ measuring cylinder
- 50 cm³ measuring cylinder
- test tube
- mass balance (2 d.p.)
- 1 mol dm⁻³ ethanoic acid
- Powdered calcium carbonate

Diagram

Procedure

1. Place 30 cm³ of 1 mol dm⁻³ ethanoic acid in the boiling tube.
2. Set the apparatus up as shown in the diagram.
3. Place approximately 0.05 g of calcium carbonate in a test tube.
4. Weigh the test tube and its contents accurately.
5. Remove the bung from the boiling tube and tip the calcium carbonate into the boiling tube. Quickly replace the bung in the boiling tube.
6. Once the reaction is over, measure the volume of gas collected in the measuring cylinder.
7. Reweigh the test tube that had contained the calcium carbonate.
8. Repeat the experiment six more times, increasing the mass of calcium carbonate by about 0.05 g each time. Do not exceed 0.40 g of calcium carbonate.

Analysis of results

1. Record your results in a suitable way.
2. Plot a graph of mass of calcium carbonate (x) against volume of carbon dioxide collected (y). Draw a straight line of best fit – this line must pass through the origin.
3. Use the graph to find the volume of carbon dioxide that would be made from 0.25 g of calcium carbonate.
4. In this reaction, one mole of calcium carbonate makes one mole of carbon dioxide. Calculate the number of moles of calcium carbonate in 0.25 g and hence calculate the volume of one mole of carbon dioxide gas in dm³.

Learning tips

- Ensure that points plotted on a graph take up more than half the available space on both scales. Axes must occupy half of the space on graph paper.
- Keep scales simple: one big square as 5 or 10 or 20 is ideal, one big square as 3 or 7 is very difficult to plot on and often leads to errors.
- Always consider whether or not the graph line should go through the origin. Straight lines should be drawn with aid of a rule – one long enough to cover the full length of the line.

Questions

1. Write a chemical equation for the reaction between ethanoic acid, CH₃COOH and calcium carbonate.
2. Why is it more accurate to find the mass of the calcium carbonate used by weighing the test tube with calcium carbonate in, then tipping it out and reweighing the test tube, rather than weighing the empty tube at the start?
3. Identify the major source of error caused by the procedure used.
4. What change to the procedure/apparatus could be made to eradicate this error?
5. Carry out two calculations to show that the ethanoic acid was in excess in all experimental runs.

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Safety

- If new delivery tubes need to be made, take great care when pushing glass tubing through the rubber bung. A suitable lubricant should be used.

Equipment per student/group**Notes on equipment**

boiling tube

stand and clamp

bung to fit boiling tube, fitted with delivery tube

water bath for gas collection

100 cm³ measuring cylinder50 cm³ measuring cylinder

test tube

mass balance (2 d.p.)

Place a test tube rack or 250 ml beaker on the balance to support the test tube while being weighed.

1 mol dm⁻³ ethanoic acidThe students will require about 250 cm³ each.

powdered calcium carbonate

The students will require about 2 g each.

Notes