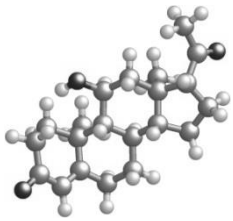

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Chemistry of the Built Environment – Models

Investigating the Properties of Building Materials

The Reactions of Metals and Carbonates with Acids

Introduction

Metals are very common building materials, both in the construction industry, and also in the manufacture of everyday objects, from hand phones and motorcars to pens and paperclips.

	
• Alloys, such as steel, are widely used in the construction industry. Steel is commonly used to form the frames of buildings, and is also used to reinforce concrete.	• Within buildings, metals are used to make gas and water pipes. Metals are also used to make wires that conduct electricity through lights, fans and air conditioners.

There are dozens of metallic elements listed in the Periodic Table, for example, copper, iron and zinc. In addition to the metallic elements, there are thousands of different alloys (a mixture of a metal and at least one other chemical element), for example, brass, bronze and steel.

Although metals generally have the same physical properties (for example, malleable, ductile, high melting points and good conductors of electricity) they vary widely in their chemical properties, *i.e.*, the way that they react. While the metal caesium reacts explosively with water, other metals, such as gold and silver, are almost inert. As a consequence, engineers must carefully consider chemical and physical properties when choosing suitable metals to reinforce concrete and make water pipes.

Another material that is used in construction is calcium carbonate (formula, $CaCO_3$). Calcium carbonate exists in different forms, including limestone and marble which are used to make bricks, floor tiles, ornate pillars and statues. With increasing atmospheric pollution, accompanied by acid rain, structures made out of metal and calcium carbonate are slowly being corroded.

In this experiment, you will investigate the reactions of four different metals with hydrochloric acid and test for the gas that is produced by these reactions. You will also prepare a sample of calcium carbonate and investigate its reaction with hydrochloric acid, again testing for the gas that is produced by the reaction.

Apparatus and Reagents

aqueous calcium chloride	aqueous sodium carbonate	copper foil
dilute hydrochloric acid	iron filings	limewater
magnesium ribbon	zinc granules	Bunsen burner
Bunsen burner lighter	glass delivery tube and bung	safety glasses and gloves
test tubes × 6	test tube rack	wooden splints

Care: Dilute hydrochloric acid is a mild irritant. Avoid contact with eyes and skin.

Emergency Action: Wash eyes with gently-running tap water for 10 minutes. Wash area of affected skin with plenty of running water. Wash mouth out with water. Sips of water may help to cool the throat.

IRRITANT

Method – Part One – Acids and Metals

1. Carefully pour 2 cm depth of hydrochloric acid (formula, HC*l*) into a test tube.

2. Add a 1 cm strip of magnesium ribbon to the test tube of hydrochloric acid. Study the reaction carefully. Record your observations in the results section.

3. Wearing gloves, place your finger or thumb over the mouth of the test tube that contains the dilute hydrochloric acid and magnesium ribbon. Wait 20 – 30 seconds until you feel the pressure of the gas that is being produced by the reaction build up. Ignite a wooden splint using the flame from a Bunsen burner. Remove your finger / thumb from the mouth of the test tube and quickly place a burning splint in the mouth of the test tube (see **Figure 1**). Record your observations in the results section.

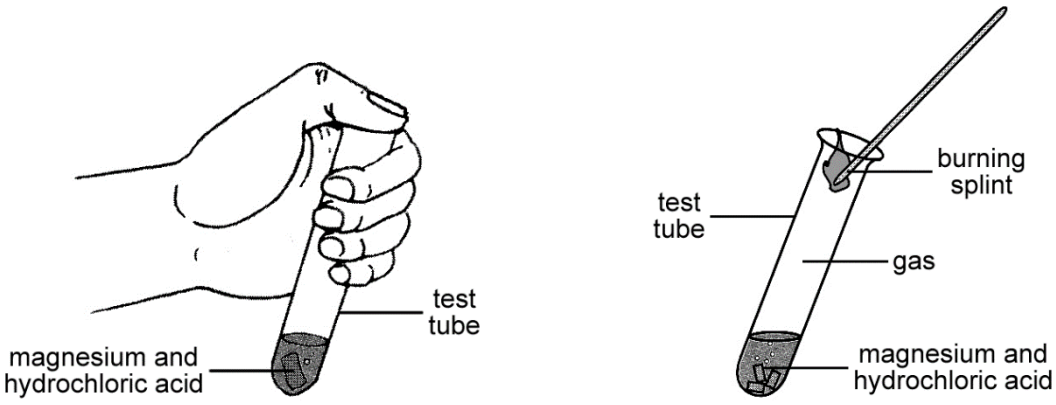

Figure 1. Testing the gas that is produced when a metal reacts with an acid.

4. Repeat **Step 1** and **Step 2** adding small spatulas full of zinc, iron and copper separately to test tubes of hydrochloric acid. Study the reactions carefully. Record your observations in the results section. **Note**: There is no need to test the gas produced by these reactions.

Method – Part Two – Acids and Carbonates

5. Carefully pour 1 cm depth of limewater (also known as calcium hydroxide, formula $Ca(OH)_2$) into a test tube. Stand this in a test tube rack – you will need it later in **Step 7**.

6. Carefully pour 2 cm depth of aqueous calcium chloride (formula, $CaCl_2$) into a test tube. To this solution, add a further 2 cm depth of aqueous sodium carbonate (formula, Na_2CO_3). Record your observations in the results section.

7. To the test tube that contains the mixture of calcium chloride and sodium carbonate, carefully add a 2 cm depth of dilute hydrochloric acid. Immediately stopper the test tube using the rubber bung and glass delivery tube. Bubble any gas produced through the test tube of limewater that you prepared in **Step 5** (see **Figure 2**). Study the reactions carefully. Record your observations in the results section.

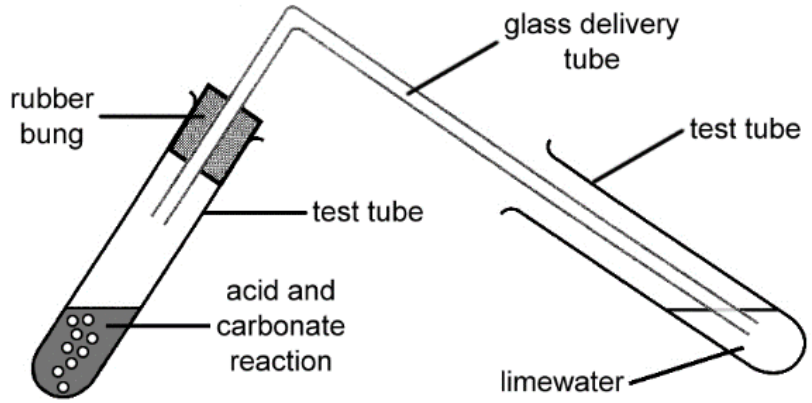

Figure 2. Testing the gas that is produced when a carbonate reacts with an acid.

Results

1. Observations for the reaction between magnesium and dilute hydrochloric acid.

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2. Observations testing the gas produced by the reaction between magnesium and hydrochloric acid.

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3. Observations for the reaction between zinc and dilute hydrochloric acid.

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4. Observations for the reaction between iron and dilute hydrochloric acid.

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5. Observations for the reaction between copper and dilute hydrochloric acid.

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6. Observations for the reaction between aqueous sodium carbonate and aqueous calcium chloride.

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7. Observations for the reaction between the mixture of sodium carbonate and calcium chloride with dilute hydrochloric acid, including any observed change in the limewater.

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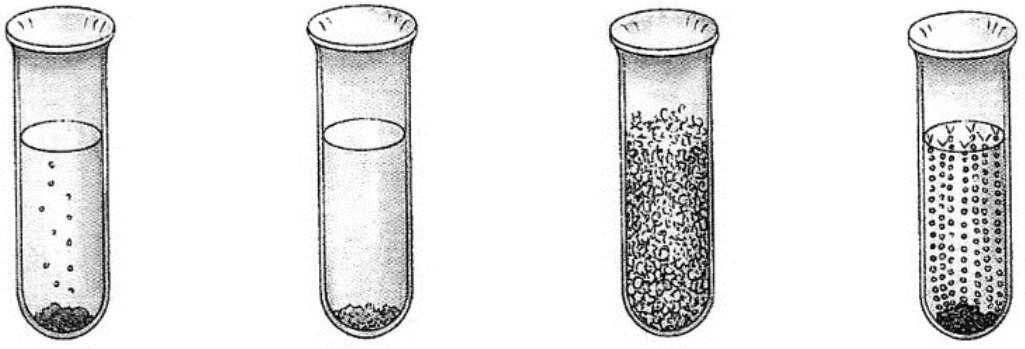
Conclusion

1. The diagram below shows the reactions between four different metals and hydrochloric acid. Label the diagrams to indicate which reaction best illustrates the reaction between hydrochloric acid and; **a)** copper, **b)** iron, **c)** magnesium and **d)** zinc.



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2. Place copper, iron, magnesium and zinc in order of reactivity, from the least reactive to the most reactive.

• least reactive → …… …… …… …… → • most reactive

3. **a)** Which gas is produced when a metal reacts with an acid?

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b) What is the chemical test for the gas that is produced when a metal reacts with an acid?

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4. **a)** What is the name of the insoluble product that is formed when calcium chloride reacts with sodium carbonate?

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b) Which gas is produced when calcium carbonate reacts with hydrochloric acid?

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c) What is the chemical test for the gas that is produced when calcium carbonate reacts with hydrochloric acid?

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5. Which metal is most suitable for making water pipes, copper, iron, magnesium or zinc? Explain your answer.

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6. **a)** Which metal would be most rapidly corroded by acid rain, copper, iron, magnesium or zinc?

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b) Describe the effect of acid rain on marble (calcium carbonate) floor tiles and statues.

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7. These experiments model how metals and carbonates that are used in construction react with dilute acids in the environment, *e.g.* how objects made out of iron and marble might react with acid rain. Give a specific example of another discipline in which models are used to either explain or predict some type of phenomenon.

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More to Explore

A balanced chemical equation can be written for each one of the reactions that has been carried out as part of this experiment. The balanced chemical equation gives the formulae of the starting materials (reagents) and products. Numbers (coefficients) are written in front of the formulae to ensure that the number of atoms of each element are the same at the start of the reaction as they are at the end. State symbols are used to indicate whether the chemical is solid (s), liquid (l), gaseous (g) or aqueous / dissolved in water (aq).

iron + hydrochloric acid → iron(II) chloride + hydrogen

$Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$

zinc + hydrochloric acid → zinc chloride + hydrogen

$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

magnesium + hydrochloric acid → magnesium chloride + hydrogen

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

calcium chloride + sodium carbonate → calcium carbonate + sodium chloride

$CaCl_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2NaCl(aq)$

calcium carbonate + hydrochloric acid → calcium chloride + water + carbon dioxide

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

carbon dioxide + limewater → calcium carbonate + water

$CO_2(g) + Ca(OH)_2(aq) + CaCO_3(s) + H_2O(l)$

- Scan the QR code below for the answers to this practical.

http://www.nygh.sg/interdisciplinary/sec_one/the_built_environment/reactions_of_metals_ans.pdf