

Answers to Cambridge IGCSE® Chemistry Laboratory Practical Book

Experimental skills and abilities

Skills for scientific enquiry

- 1 (a) measuring cylinder (e) stopwatch
(b) digital balance (f) digital timer
(c) metre ruler (g) ruler
(d) liquid in glass thermometer
- 2 (a) Time at least 10 oscillations with a stopwatch and divide the result by 10 to obtain the average time for one oscillation.
(b) Weigh at least 20 pins on a balance and divide the result by 20 to obtain the average mass of one pin.

3

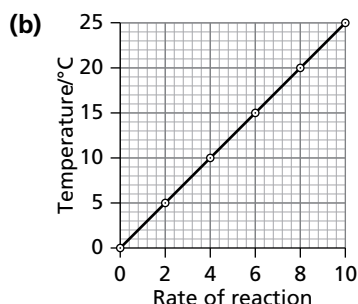
Device	Accuracy
metre ruler	1 mm
vernier scale	0.1 mm
stopwatch	0.5 s
digital timer	1 ms
digital balance	typically 1 g or 0.1 g
liquid in glass thermometer	1.0 °C
100 cm ³ measuring cylinder	1 cm ³

- 4 (a) 9.75 (b) 9.8 (c) 1×10^1

- 5 (a) (i) Effect of temperature on rate
(ii) Light intensity, concentrations of solutions

(iii)

Manipulated variable	Fixed variable	Responding variable
temperature	light, concentration	rate of reaction



- (c) Increase in temperature will result in increase in rate of reaction.

1 The particulate nature of matter

1.1 Rate of diffusion of ammonia and hydrogen chloride

Method

- 1 To ensure that it is a fair test.
- 2 It would be too difficult to deal with the gases. The gases would begin to diffuse before the experiment started.
- 3 Ammonia is toxic. Concentrated hydrochloric acid is corrosive.

Results and calculations

Students should be able to show that the ammonia particles (molecules) have moved along the tube at a faster rate than the hydrogen chloride particles (molecules).

Conclusions

- 1 The longer the tube, the longer the time taken for the white cloud of ammonium chloride to form. This is because the rate of diffusion will be slower for both gases.
- 2 The greater the diameter of the tube, the longer the time taken for the white cloud to form.
- 3 Temperature of the laboratory – the higher the temperature the faster the time; concentration of the gases used – the higher their concentration the faster the time; pressure – the higher the room pressure the slower the time.
- 4 Hydrogen chloride end.
- 5 The hydrogen chloride molecules are heavier and therefore have the slower rate of diffusion, so do not travel as far along the tube as the ammonia particles.

Evaluation

The experiment could be repeated to gain an average times and rates.

Extension

The rate of diffusion is not the same as the speed of the particles. The speed of the particles will be much greater than the rate of diffusion. The reason is that the rate of diffusion is lower due to the random collisions between the particles which prevent the particles from travelling in straight lines.

1.2 Reaction of potassium iodide with lead(II) nitrate

Method

- 1 Because the particles in both solids are vibrating about a fixed point. For the reaction to occur their particles need to be forced to collide with one another. Shaking causes this to happen.
- 2 In case, when you are shaking the tube, you hit a bench or other solid object.
- 3 So that there was no contamination of each chemical.

Results

A yellow tinge should be visible on the solid particles, which takes a long time to form.

When the two colourless solutions are mixed, a yellow precipitate (solid) forms. If left, the yellow precipitate sinks to the bottom of the tube and a colourless solution is visible above it.

Conclusions

- 1 A yellow tinge on the solid particles.
- 2 Two colourless solutions reacted to give another colourless solution and a yellow precipitate.
- 3 The reaction between the solutions.
- 4 The reaction in Procedure 2 occurred faster because, in solutions, the particles are able to move relative to one another. This allows them to collide more frequently with one another, causing the reaction to occur more rapidly.
- 5 Colourless.

Evaluation

In Procedure 1, the same mass, or, better, the same number of moles of each were used. In Procedure 2, the same volume of each solution, of the same concentration, could have been used.

Extension

Any one of:

- 1 The shaking could have been more vigorous, resulting in more collisions, and more successful collisions.
- 2 The solids could have been more finely crushed. With a larger surface area, more collisions and more successful collisions would occur.
- 3 The experiment could have been carried out at a higher temperature, so particles have more kinetic energy. More collisions and more successful collisions would occur.

1.3 Sublimation of iodine

Method

- 1 Iodine is harmful. Its fumes are dangerous for the environment.
- 2 To prevent the majority of the iodine vapour from escaping. The iodine vapour returns to a solid on the large, cool surface area given by the glass wool.
- 3 No. The pressure build up in the tube when the iodine solid changed to iodine vapour would have caused it to be blown off.

Results

Much of the iodine will have moved from the bottom of the tube to the top.

The black/violet solid iodine sublimed on heating to give violet iodine vapour.

The iodine vapour returned to its solid form when it reached the cooler parts of the tube.

Conclusions

- 1 Black/violet.
- 2 Violet.
- 3 At the top of the tube. The top of the tube is cooler than the bottom and so the iodine vapour sublimed to iodine solid.

Evaluation

A longer tube could have been used.

Extension

Any two from: arsenic, carbon and phosphorus (red).

2 Elements, compounds and experimental techniques

2.1 Rock salt: an important raw material

Method

- 1 To dissolve the salt.
- 2 To allow the sample to cool. To allow the earthy material to settle.
- 3 To allow the salt to crystallise slowly. If the solution was evaporated to dryness 'spitting' would occur and good shaped crystals would not be produced.

Results and calculations

During the experiment the solution filtered steadily. White cubic crystals of sodium chloride were produced on slow crystallisation.

Conclusions

Slow crystallisation will produce good crystals due to the particles in solution slowly coming together.

Evaluation

Given the time scale of one practical session, the results can be improved by taking more than one session. The earthy material residue can have more water added and more salt extracted. Carry out the process at least another two times. This will increase the amount of salt in solution to eventually crystallise.

Extension

- 1 The evaporation process should be done very slowly. This is because sugar can easily char as it solidifies around the sides of the evaporating basin during the evaporating process. Also the crystallisation will require a lot longer for crystals to form from the concentrated solution and may need to be seeded with some pure sugar.
- 2 Because of the simplicity of the process it can be scaled up quite readily. Very large vats would be needed so that kg or tonne quantities can be produced. The vats can be supported on swivel supports. The vats would need electric stirrers in them. The heating of the solution would be by gas or electric heaters from below. Large quantities from the vats can be filtered through very large sieves. Slow evaporation of the filtrate from the collection vats would again be by either gas or electric heating from below.

2.2 Ascending chromatography

Method

- 1 The inks present in the ball-point pen will separate also.
- 2 If they are not dry then the separation will not take place efficiently.
- 3 Improves separation of the mixture. (Some of the substances in the black felt-tip mixture are more soluble in ethanol than water.)
- 4 To maintain a constant atmosphere around the chromatogram.
- 5 So no smudging of spots takes place.

Results and calculations

The spots slowly appear from the mixture as the separation takes place. Over time the spots continue to separate (Figure 1) until the time you have allowed is up. A sample chromatogram is shown in Figure 1.

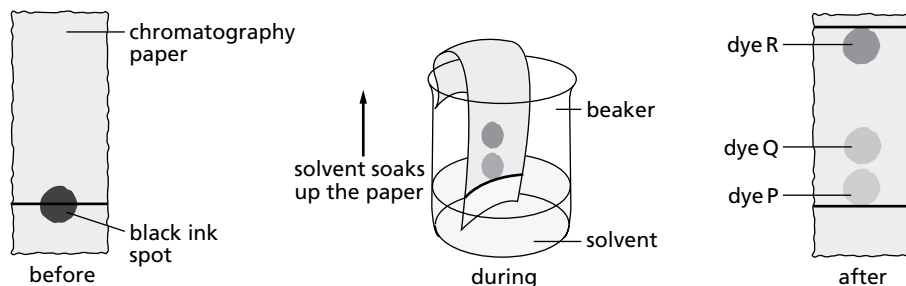


Figure 1

Note: The R_f values will vary depending on the felt-tip pen used and solvent mixture.

Conclusions

- 1 Some dyes have a greater solubility than others in the different solvents. The dyes which have moved the greatest distance have the greatest solubility in the solvents. Their R_f values are also greater.
- 2 The dye which was least soluble is the one which does not travel as far up the chromatogram – lowest R_f value. The dye which was most soluble is the one which travels the furthest up the chromatogram – highest R_f value.

Evaluation

Ensure the plastic bag is a good seal when over the apparatus. Repeat the chromatograms several times to ensure you have an overview of the results and average R_f values.

Extension

- 1 Different results will be obtained using different solvents such as propanone/water. Depending on the felt-tip pen used, the separation may be greater or less depending on how the dyes dissolve in the new solvent.
- 2 The substances to be separated do not have to be coloured. For example, amino acids obtained by hydrolysis of proteins are colourless. Colourless substances can be made visible by spraying the chromatogram with a locating agent such as ninhydrin. The locating agent will react with the colourless substances to form a coloured product. In other situations the position of the substances on the chromatogram may be located using ultraviolet light.

2.3 Elements, mixtures and compounds

Method

- 1 Yes.
- 2 No.
- 3 It is an exothermic reaction. A new substance is being formed in the reaction.

Results and calculations

	Sulfur	Iron	Mixture	Compound (iron sulfide)
appearance	yellow	grey	dirty yellow	very dark grey, almost black
effect of magnet	no effect	attracted	iron is separated from the sulfur	no effect
effect of water	no effect	no effect	no effect	no effect
effect of dilute hydrochloric acid	no effect	bubbles of hydrogen gas are seen (effervescence); gives a 'pop' when tested with a lighted spill	bubbles of hydrogen gas are seen (effervescence); gives a 'pop' when tested with a lighted spill	bubbles of hydrogen sulfide gas are seen; smells of bad eggs and turns lead ethanoate paper black

Conclusions

Mixtures behave as the individual *elements* they are made up from. Compounds differ from the elements or *mixtures* in that they are new *substances* and so behave *differently*.

Evaluation

Experiments should be reproducible. So the experiments should be repeated to show consistency of results. Also, other compounds their elements and mixtures should be tested.

Extension

- (a) Calcium and oxygen.

(b) calcium + oxygen → calcium oxide

$$2\text{Ca(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{CaO(s)}$$
- An **element** – a substance which cannot be further divided into simpler substances by chemical methods.

A **mixture** – a system of two or more substances that can be separated by physical means.

A **compound** – a substance formed by the combination of two or more elements in fixed proportions.

3 Atomic structure and bonding

3.1 Structure of substances

Method

- To ensure the eyes are shielded, in particular, from bromine and soot.
- Bromine is toxic, as well as corrosive, and should only be used in a fume cupboard.

Results and calculations

Substance	Appearance	Inference
Water	colourless liquid	small molecule
polyethene	translucent solid	macromolecule
pencil lead	black solid	macromolecule
Bromine	red liquid	small molecule
buckminster fullerene (soot)	black powder	macromolecule
Nylon	white solid	macromolecule
oxygen	colourless gas	small molecule
sand	brown solid	macromolecule

Conclusion

The substances *water*, *bromine* and *oxygen* contain small molecules while the substances *polyethene*, *pencil lead*, *buckminster fullerene*, *nylon* and *sand* are macromolecular.

Evaluation

Other substances which are small molecules or macromolecules could be included in the table of substances.

Extension

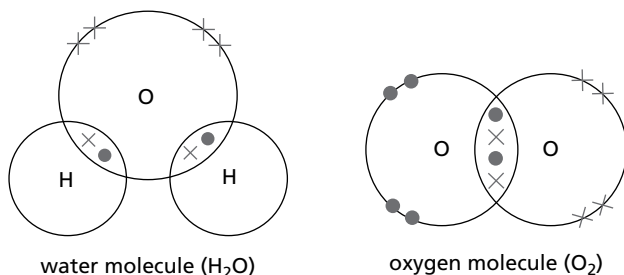
- Simple molecular** – a substance that possesses between one and a few hundred atoms per molecule.

Giant molecular – a substance containing thousands of atoms per molecule.

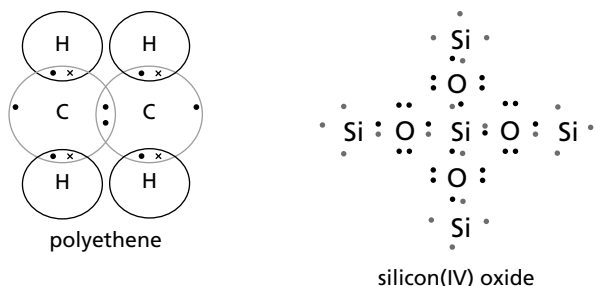
Intramolecular bonds – forces which act within a molecule, for example covalent bonds.

Intermolecular bonds – attractive forces which act between molecules, for example van der Waals' forces.

- 2 Two examples: water and oxygen.



- 3 Two examples: polyethene and silicon(IV) oxide. There is an opportunity to add further CH₂ groups at either end.



3.2 Properties of ionic and covalent substances

Method

Because some of the substances may be harmful.

Results and calculations

Substance	Appearance	Melting point/°C	Boiling point/°C	Solubility in water/g/dm ³	Inference
A (oxygen)	colourless gas	−218.80	−83.00	0.008	covalent
B (sugar)	white crystalline solid	186.00	decomposes	2115.0	covalent (or possibly ionic)
C (sodium chloride)	white crystalline solid	801.00	1413.00	350.0	ionic
D (hexanol)	colourless liquid	−45.00	156.00	5.90	covalent
E (potassium chloride)	white crystalline solid	771.00	1500.00	342.00	ionic
F (lead bromide)	white powder	370.00	914.00	9.73	ionic
G (hexane)	colourless liquid	−95.30	68.70	0.0095	covalent
H (lithium chloride)	White crystalline solid	614.00	1382.00	830.50	ionic

Conclusion

Substances C, E, F and H are ionic while substances A, B, D and G are covalent.

Evaluation

Extend the number of ionic and covalent substances to identify.

Extension

The ionic ones will conduct electricity and electrolysis will take place.

3.3 Electrolysis of solutions

Method

- 1 An electric current is flowing and the substance is ionic.
- 2 So that there is no cross-contamination of substances being tested.

Results and calculations

Solution	Does the bulb light?	Observation at cathode (-ve)	Observation at anode (+ve)	Inference
dilute sulfuric acid	yes	bubbles of a gas seen (hydrogen)	bubbles of a gas seen (oxygen)	ionic
magnesium sulfate	yes	bubbles of a gas seen (hydrogen)	bubbles of a gas seen (oxygen)	ionic
copper(II) sulfate	yes	becomes coated by a pink/brown solid (copper); bubbles of a gas seen (hydrogen)	bubbles of a gas seen (oxygen)	ionic
sugar solution	no	nothing	nothing	covalent

Conclusion

When an electric current is passed through a solution and the bulb *lights* then the dissolved substance is *ionic*. If the bulb does not *light* then it is *covalent*. The substances are broken down by the passage of an electric current – this is *electrolysis*.

Evaluation

Collect and test gases produced.

Extension

- 1 Check melting points or boiling points or solubility, or all three.
- 2 **Anode** – the positive electrode.
Cathode – the negative electrode.
Electrode – a point where the electric current enters and leaves the electrolytic cell.
Electrolysis – a process in which a chemical reaction is caused by the passage of an electric current.

4 Stoichiometry – chemical calculations

4.1 Determination of the formula of magnesium oxide

Method

- 1 So that it sits on the bottom of the crucible where it will be heated most strongly.
- 2 If a coloured flame is used carbon (soot) will collect on the crucible and increase its mass.
- 3 The pipe-clay triangle allows the crucible to be heated more strongly and directly than using a gauze.
- 4 To allow oxygen gas, from the air, into the crucible so that the reaction can take place.

- 5 Magnesium oxide is formed as a white powder which easily escapes from the crucible. Allowing the lid to be removed for only a few seconds prevents too much being lost.
- 6 To ensure that all the magnesium has reacted with oxygen and so causing the maximum amount of magnesium oxide to be formed.

Results and calculations

- 1 Mass of magnesium used = mass of crucible, lid and Mg – mass of crucible and lid.
- 2 Mass of oxygen gas reacting = final mass of crucible, MgO and lid – mass of crucible, lid and Mg.
- 3 Moles of Mg = mass/24.
Moles of O = mass/16.
Simplest ratio = moles of Mg: moles of O.
Converted to a 1:x.

Conclusions

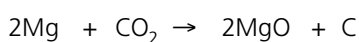
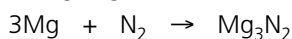
MgO.

Evaluation

- 1 Nitrogen gas could react to form magnesium nitride, Mg_3N_2 ; carbon dioxide could react to form magnesium oxide and carbon. React with only pure oxygen gas, e.g. in a gas jar.
- 2 It could be carried out using a larger initial mass of magnesium ribbon. It could be repeated more than once.

Extension

Nitrogen gas and carbon dioxide.



4.2 Determination of the volume occupied by one mole of a gas

Method

- 1 To ensure that all the magnesium oxide coating on the metal is removed. This allows the reaction with acid to happen straight away.
- 2 To ensure that all of the magnesium metal has reacted.

Results and calculations

- 1 Moles of magnesium used = mass/ 24 = answer.
- 2 Moles of hydrogen gas which could be produced = answer to part 1 due to the 1:1 mole ratio in the balanced equation.
- 3 Volume produced if one mole of gas had been collected = volume collected (cm^3)/moles of H_2 = answer.
- 4 Volume = volume (cm^3)/1000 = volume (dm^3)

Conclusions

- 1 Should be close to 24 dm^3 .
- 2 Answers could include references to the different temperatures and pressures at which the experiment was carried out compared to the standard conditions of 25°C (298 K) and 1 atmosphere of pressure.

Evaluation

- 1 Could be repeated to get a number of results. Use a large initial mass of magnesium metal.
- 2 The gas could be collected by the downward displacement of water in a measuring cylinder or up-turned burette.

Extension

Charles's Law and Boyle's Law.

4.3 Determination of the percentage yield of a chemical reaction

Method

- 1 To ensure that all the sodium carbonate solution had reacted.
- 2 A pipette is a more accurate way of measuring the volume of sodium carbonate added. A measuring cylinder is sufficient for the calcium nitrate as it is in excess and its volume does not need to be measured as accurately.
- 3 So that the mass is not higher due to the presence of water.
- 4 It would be difficult to make sure that all the calcium carbonate had been removed; some would be trapped in the holes of the filter paper.

Results and calculations

- 1 Actual yield = mass of calcium carbonate obtained.
- 2 Moles of sodium carbonate used = $25 \times 1/1000 = 0.025$ moles
- 3 Moles of calcium carbonate produced will be the same, 0.025 moles, due to the 1:1 mole ratio shown by the equation.
- 4 Mass of calcium carbonate that should have been obtained = $0.025 \times 100 = 2.5$ g.
- 5 % yield = mass of calcium carbonate made $\times 100/2.5 =$ answer

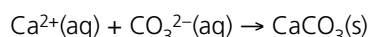
Conclusions

- 1 Comment on the percentage yield of the experiment.
- 2 Suitable comment and explanation.

Evaluation

Could have been repeated. Could have used more of the two chemicals to produce larger masses of calcium carbonate.

Extension



[1] for equation, [1] for correct state symbols.

5 Electricity and chemistry

5.1 Electrolysis of molten lead(II) bromide

Method

- 1 Bromine and lead are toxic elements.
- 2 So that the ions are free to move. They can then be discharged at the different electrodes.

Results and calculations

- 1 No.
Ions are not free to move.

- 2 Yes.
The ions in the molten material are free to move to the electrodes.
- 3 Brown vapour.
Bromide ions (–ve) are discharged at the anode (the +ve electrode).
- 4 Shiny solid.
Lead ions (+ve) are discharged at the cathode (the –ve electrode).

Conclusion

Solid lead bromide(II) does *not* conduct electricity. However, when it is *molten* it does conduct and *electrolysis* takes place. *Lead* is produced at the cathode and *bromine* is produced at the anode.

Evaluation

Carry out chemical tests on the products to show that they contain bromine and lead.

Extension

- 1 **Electrolysis** – a process in which a chemical reaction is caused by the passage of an electric current.
Electrolyte – a substance which will carry electric current only when it is molten or dissolved.
Electrodes – a point where the electric current enters and leaves the electrolytic cell.
Inert – these are electrodes that do not react with the products of electrolysis, e.g. carbon, platinum.
Cathode – the negative electrode. It is negatively charged because an excess of electrons move towards it.
Cations – positive ions; these are attracted to the cathode.
Anode – the positive electrode. It is positively charged because electrons are drawn away from it.
Anions – negative ions; these are attracted to the anode.
- 2 At anode:

$$\text{bromide ion} \rightarrow \text{bromine atom} + \text{electron}$$

$$\text{Br}^-(\text{l}) \rightarrow \text{Br} + \text{e}^-$$

 At cathode:

$$\text{lead ion} + \text{electrons} \rightarrow \text{lead atom}$$

$$\text{Pb}^{2+}(\text{l}) + 2\text{e}^- \rightarrow \text{Pb}(\text{l})$$
- 3 (a) Metal
 (b) A
 (c) Copper(II) oxide
 (d) Sodium chloride (or other metal chloride).

5.2 Electrolysis of water

Method

- 1 All ions that would allow the water to conduct have been removed.
- 2 This is so the solution is not electrolysis during filling of the apparatus, which would change the overall volumes of gas produced.

Results and calculations

Approximate ratio of gases produced: cathode: anode 2:1

Effect of glowing splint with anode tube gas: *relights it*.

The gas is *oxygen*.

Effect of lighted splint with cathode tube gas: *burns with a 'pop'*.

The gas is *hydrogen*.

Do the results fit in with the known formula for water? Yes.

Explain your answer. Formula is H_2O , which should give volume ratio of 2:1 on electrolysis.

Conclusion

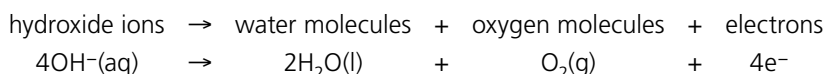
Pure water is a very bad *conductor* of electricity. This is because it has very few *ions* present in the liquid. If dilute *sulfuric acid* is added to water, *ions* are added and this makes the solution a *conducting* one. An electric current passes through this solution and *electrolysis* takes place. Hydrogen gas is produced at the *cathode* and oxygen gas is produced at the *anode*. The ratio of the volumes of the gases produced is 2:1 hydrogen to oxygen. This fits in with the formula for water being H_2O .

Evaluation

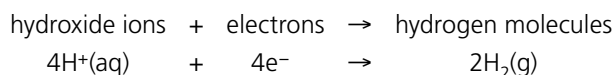
The apparatus should be cleaned out with deionised water beforehand. This will clean out any ions left behind from previous experiments.

Extension

1 At anode:



At cathode:



2 The chlor-alkali industry

The electrolysis of saturated sodium chloride solution (brine) is the basis of the chlor-alkali industry. Three very important substances are produced in this electrolysis process – chlorine, sodium hydroxide and hydrogen. The electrolytic process is a very expensive one, requiring vast amounts of electricity. The process is economical only because all three products have a large number of uses. The major cell used is the membrane cell. This method is now preferred to the other two because it produces a purer product, it causes less pollution and it is cheaper to run. The brine is first purified to remove calcium, strontium and magnesium compounds by a process of ion exchange.

The membrane cell is used continuously, with fresh brine flowing into the cell as the process breaks up the brine. The cell has been designed to ensure that the products do not mix. The ions in this concentrated sodium chloride solution are: from the water $\text{H}^+(\text{aq})$, $\text{OH}^-(\text{aq})$; from the sodium chloride $\text{Na}^+(\text{aq})$, $\text{Cl}^-(\text{aq})$. When the current flows, the chloride ions, $\text{Cl}^-(\text{aq})$, are attracted to the anode. Chlorine gas is produced. This leaves a high concentration of sodium ions, $\text{Na}^+(\text{aq})$, around the anode.

The hydrogen ions, $\text{H}^+(\text{aq})$, are attracted to the cathode and hydrogen gas is produced. This leaves a high concentration of hydroxide ions, $\text{OH}^-(\text{aq})$, around the cathode. The sodium ions, $\text{Na}^+(\text{aq})$, are drawn through the membrane, where they combine with the $\text{OH}^-(\text{aq})$ to form sodium hydroxide, NaOH , solution.

Electroplating

Electroplating is the process involving electrolysis to plate, or coat, one metal with another or a plastic with a metal. Often the purpose of electroplating is to give a protective coating to the metal beneath. For example, bath taps are chromium plated to prevent corrosion, and at the same time are given a shiny, more attractive finish. The electroplating process is carried out in a cell such as the one shown here.

This is often known as the 'plating bath' and it contains a suitable electrolyte, usually a solution of a metal salt. For silver plating, the electrolyte is a solution of a silver salt. The article to be plated is made the cathode in the cell so that the metal ions move to it when the current is switched on. Plastics have been developed that are able to conduct electricity. For example, the plastic poly(pyrrole) can be electroplated in the same way as the metals.

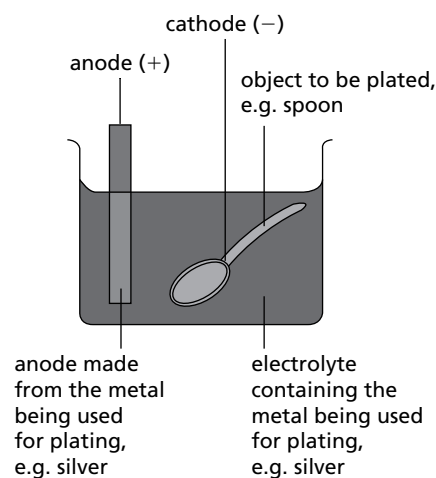


Figure 1 electroplating bath

5.3 Electrolysis of brine

Method

- 1 So that the chlorine gas produced can be identified by the colour changes that take place.
- 2 Chlorine gas is produced, which is a toxic substance.
- 3 This is so the solution is not electrolysis during filling of the apparatus, which would add the hazard of chlorine being produced during the set-up of the apparatus.

Results and calculations

Colour changes of the solution are as follows:

The anode tube: initially: *turns pink*; during the experiment: *pink colour is bleached out (a blue colour is seen in the vicinity of the anode tube also)*.

The cathode tube: initially: *original colour of universal indicator*; during the experiment: *original colour of universal indicator*.

Effect of lighted splint with cathode tube: *gas burns with a 'pop'.*

The gas is *hydrogen*.

Do the results fit in with the expectation of the electrolysis? *Yes.*

Explain your answer. *Three substances are produced: chlorine – bleaching agent, hydrogen gas, sodium hydroxide – an alkali.*

Conclusion

Brine is a very good *conductor* of electricity. This is because it has a lot of *ions* present in the liquid. This makes the solution an *electrolytic* one. An electric current passes through this solution and *electrolysis* takes place. Hydrogen gas is produced at the *cathode* and *chlorine* gas is produced at the *anode*. *Sodium hydroxide* is left in solution.

Evaluation

To ensure the apparatus is free from other ions it should be washed out with the solution of brine to be used – several times.

Extension

- 1 At anode:

$$2\text{Cl}^-(\text{aq}) \rightarrow \text{Cl}_2(\text{g}) + 2\text{e}^-$$
 At cathode:

$$4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2(\text{g})$$
- 2 Hydrogen – making ammonia, rocket fuel, making hydrochloric acid
 Chlorine – water purification, making bleach, making plastics
 Sodium hydroxide – paper manufacture, soaps, aluminium extraction

6 Chemical energetics

6.1 Electrochemical cells: chemical energy to electrical energy

Method

- 1 Copper.
- 2 The concentration of all the solutions is 1 mol/dm³.
- 3 To ensure that there are no impurities on their surfaces.

Results

Voltages should be near those shown in the table: [1] for close answer, [1] for using resolution shown on voltmeter throughout.

Positive terminal	Negative terminal	Voltage/V
copper	lead	0.47
copper	magnesium	2.71
copper	iron	0.78
copper	zinc	1.10
copper	tin	0.48

Conclusions

- 1 Copper and magnesium.
- 2 Copper and lead.
- 3 0.00V.
- 4 Magnesium is the most reactive, lead is the least reactive.
- 5 Lead, tin, iron, zinc, magnesium – 4 in correct order, all correct.
- 6 $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^{-}$

Evaluation

The voltage could have been recorded a number of times to obtain average results. The solution of copper(II) sulfate could have been changed after each cell was finished with.

Extension

- 1 2.24V.

6.2 Calculating the energy of combustion of methanol and ethanol

Method

- 1 Copper is a better conductor of heat than glass so more of the heat is transferred to the water.
- 2 To prevent the fuel in the burner from evaporating as it is carried around the laboratory to and from the balance. This would lead to incorrect mass readings for the mass of fuel burned.
- 3 Difficult to prevent incomplete combustion from occurring. Heat is lost to the surroundings.
- 4 The bottom of the calorimeter will be black, caused by incomplete combustion of the fuel producing carbon (soot).

Results and calculations

- 1 Temperature rise in each experiment = maximum temperature of water – initial temperature of water.
- 2 Energy transferred = mass of water used \times 4.2 \times temperature rise in each experiment.
- 3 Mass of fuel burned in each experiment = final mass of burner, lid and fuel – initial mass of burner, lid and fuel.
- 4 Moles of methanol burned = mass of methanol burned/32.
- 5 Moles of ethanol burned = mass of ethanol burned/46.
- 6 Energy transferred by each fuel = answer to 2/answer to 4.
- 7 Energy of combustion = answers to 5/1000.

Conclusions

- 1 It is an exothermic reaction, and heat is given out to the surroundings from the chemical reaction.
- 2 Non-standard conditions being used. The temperature and pressure are different from those used to produce data-book values. A large amount of the heat energy produced from the burner is lost to the environment, not all is transferred to the water.

Evaluation

Some sort of draught excluder could be placed around the apparatus.

The flame height could be minimised, by shortening the wick length.

The height of the calorimeter above the flame should be adjusted to give the best chance of heating the calorimeter most efficiently.

Extension

Information about the use of a bomb calorimeter should be found.

6.3 Determination of the energy change of a displacement reaction

Method

- 1 It is a better heat insulator so less heat will escape.
- 2 Using a pipette is a more accurate way of measuring a volume of solution, the copper(II) sulfate will be totally used up in the reaction, it is not in excess, so an accurate volume is required for the calculations.
- 3 To ensure that all the copper(II) sulfate has reacted.

Results and calculations

Accurate recording of temperatures [1] to 0.5°C.

- 1 Lines A, B, C, D drawn correctly on their graph.
- 2 ΔT_{max} recorded correctly from the graph, accurately.
- 3 Energy produced (J) = $25 \times 4.2 \times \Delta T_{\text{max}}$ = answer.
- 4 Energy produced from one mole = answer to 3/0.025 = answer.

Conclusions

- 1 Comment made about their result compared to data-book value. Sensible reason for the difference, e.g. heat loss to surroundings.
- 2 Zinc is a more reactive metal than iron and therefore a more vigorous reaction occurs, giving out more heat energy.
- 3 Copper(II) sulfate and tin would give a less exothermic reaction with a smaller energy change because tin is less reactive than both zinc and iron.

Evaluation

A lid could have been put on the polystyrene cup which would prevent heat from escaping to the surroundings.

Larger amounts of both chemicals could have been used which would give a larger temperature rise with a smaller error.

Extension

Extrapolation means extending the line on a graph to values beyond the experimental data collected to estimate the value of a variable.

7 Chemical reactions

7.1 How does changing surface area affect the rate of a reaction?

Method

To prevent acid spray from escaping from the flask which would make the loss in mass greater.

Results and calculations

- 1 Table completed using the resolution shown by the balance.
- 2 Loss in mass worked out for each recorded result to the required accuracy.
- 3 Points plotted correctly, best fit curve/line through the point, correct labels on the axes, correct units shown on the axes.

Conclusions

- 1 The experiment with the smaller marble chips.
- 2 Steeper line at the beginning of the experiment.
- 3 10g of the smaller marble chips has a larger surface area than 10g of the large chips. This allows a larger surface area for collisions to occur with acid particles. More collisions result from this giving more successful collisions and a faster rate of reaction.
- 4 Any three from: same temperature, same volume of acid used, same concentration of acid used, same mass of marble chips

Evaluation

A data logger could have been used to produce a continuous reading of the mass and to plot the graph after each reading.

Extension

Nanotubes have a very large surface area on which reactions can occur, leading to a different reaction pathway with a lower activation energy.

7.2 What is the effect of changing the temperature on the rate of reaction?

Method

- 1 It would take much longer for it to be obscured.
- 2 So that the same amount of sulfur, each time, is needed to obscure it from sight. This allows the times to be compared successfully.

- 3 It will increase the rate of reaction.
- 4 So that you are looking through the same depth of solution each time, ensuring a fair test.

Results and calculations

- 1 Records the temperature and times accurately.
- 2 Rates worked out correctly from each time.
- 3 Points plotted correctly, best fit curve/line through the point, correct labels on the axes, correct units shown on the axes.

Conclusions

- 1 A smaller time gives a faster rate. They are inversely proportional to one another.
- 2 As temperature increases the rate increases.
- 3 Two from: same volumes of acid and sodium thiosulfate, same concentrations of acid and sodium thiosulfate, same equipment/same size of flask used each time, same amount of swirling each time.
- 4 As the temperature increases the particles gain more kinetic energy, they move faster and collide more frequently with one another, which results in more successful collisions and a faster rate of reaction.

Evaluation

Use some type of data logger to accurately measure the formation of the same amount of sulfur being formed by looking through the reaction solution at a light.

Repeat the experiment more times for each temperature in order to find an average time.

Extension

Research into Maxwell-Boltzmann distribution curves.

7.3 What is the effect of changing the concentration on the rate of a reaction?

Method

- 1 It would take much longer for it to be obscured.
- 2 So that the same amount of sulfur, each time, is needed to obscure it from sight. This allows the times to be compared successfully.
- 3 It will increase the rate of reaction.
- 4 So that you are looking through the same depth of solution each time, ensuring a fair test.

Results and calculations

- 1 Records the times accurately.
- 2 Rates worked out correctly from each time.
- 3 Points plotted correctly, best fit curve/line through the point, correct labels on the axes, correct units shown on the axes.

Conclusions

- 1 The concentration is decreasing because water is being added.
- 2 Increasing the concentration increases the rate of the reaction.
- 3 Any two of: same total volume, same volume of acid, same concentration of acid, flask swirled only once each time, same temperature.
- 4 As concentration increases there are more particles in a given volume. This results in more collisions between the particles. Some of these extra collisions are successful collisions and so the rate increases.

Evaluation

One of: use some type of data logger to accurately measure the formation of the same amount of sulfur by looking through the reaction solution at a light.

Repeat the experiment more times for each concentration in order to find an average time.

Extension

First order simply means that there is a direct relationship between the concentration of a reactant and the rate. If the concentration of a reactant doubles, the rate will also double.

8 Acids, bases and salts

8.1 Hydrated salts: how much water do they contain?

Method

- 1 So the flame can be directed at the bottom of the crucible and the sample will be heated most strongly.
- 2 If a coloured flame is used carbon (soot) will collect on the crucible and increase its mass.
- 3 The steam (water) needs to be allowed to evaporate away.
- 4 To ensure that all the water had been driven off and that only anhydrous magnesium sulfate remained.

Results and calculations

- 1 All masses recorded to the accuracy of the balance used.
- 2 Mass of hydrated magnesium sulfate = mass of crucible and hydrated MgSO_4 – mass of crucible correctly calculated.
- 3 Mass of water removed = mass of crucible and hydrated MgSO_4 – mass after final heating.
- 4 Mass of anhydrous magnesium sulfate = mass after final heating – mass of crucible = answer.
- 5 Moles of anhydrous magnesium sulfate = answer to 4/84 = answer.
- 6 Number of moles of water removed = answer to 3/18 = answer.
- 7 x = moles of water/moles of anhydrous MgSO_4 = answer.
- 8 Formula of hydrated magnesium sulfate = $\text{MgSO}_4 \cdot x\text{H}_2\text{O}$.

Conclusions

- 1 Comment about how their result compares to the actual formula of $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$.
- 2 Magnesium sulfate could have been lost from the crucible as a powder whilst being heated.

Evaluation

It could be repeated more than once using the same starting mass of hydrated magnesium sulfate to get an average. A larger mass of hydrated magnesium sulfate could have been used to have larger mass readings and, therefore, a lower percentage error in the readings.

Extension

Anhydrous magnesium sulfate is used as a drying agent to remove traces of water from substances.

8.2 Determination of the concentration of a solution of hydrochloric acid

Method

- 1 So that the correct volume can be read from the scale.
- 2 To see the colour change more clearly.
- 3 Phenolphthalein is a weak acid so putting different numbers of drops into each experiment would give different results.
- 4 So that the end-point/colour change is not missed giving an inaccurate volume needed for the point of neutralisation.

Results and calculations

- 1 Results recorded. All burette readings to two decimal places.
- 2 Average volume of acid used calculated correctly using the three results within 0.10 cm^3 of one another to two decimal places.
- 3 Moles of sodium hydroxide used = $25 \times 1/1000 = 0.025$ moles.
- 4 Moles of HCl which would react = 0.025 moles due to the 1:1 mole relationship in the balanced chemical equation.
- 5 Concentration of acid = $0.025 \times 1000/\text{average volume} = \text{answer}$.

Conclusions

Comparison with range of acid combinations given in the apparatus and chemicals list.

Evaluation

Use of a pH probe to find the end-point at exactly pH 7.

Extension

They can be used to find the acidity of soil samples, the pH of acids used in the flavouring of foods, e.g. citric acid, any suitable example.

8.3 Preparation of hydrated magnesium sulfate

Method

- 1 To mix the reactants together. It increases the rate of reaction.
- 2 The production of carbon dioxide gas causes the effervescence.
- 3 No more carbon dioxide was being produced because the reaction had stopped.
- 4 It means that the magnesium carbonate was in excess which ensures that all of the sulfuric acid had reacted.
- 5 To leave some water which will be taken into the crystals as they are formed as water of crystallisation.
- 6 Prevents impurities landing in the magnesium sulfate as the crystals form.

Results

Colourless crystals.

Conclusions

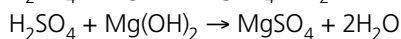
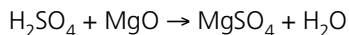
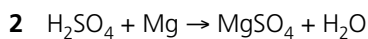
- 1 Soluble.
- 2 Anhydrous magnesium sulfate. A white powder.
- 3 Water is part of the crystals and gets locked inside the crystals between the ions for the crystals to form their correct shapes.

Evaluation

You could leave the solution obtained after the filtration to evaporate slowly to form crystals. This would ensure sufficient water would be present to form perfect crystals.

Extension

1 Reacting dilute sulfuric acid with: magnesium metal, magnesium oxide, magnesium hydroxide.



9 The Periodic Table

9.1 Reactions of the Group 1 metals

Method

- 1 To prevent the possibility of the hot metals from spitting out of the water towards the students.
- 2 So that it does not start to react with the oxygen or water in the air.
- 3 The shiny surface rapidly tarnishes. This is because the metal reacts rapidly with water and oxygen in the environment.
- 4 So that the reaction can be controlled easily/so that the reaction will not be too vigorous.
- 5 Removing the oil exposes the metal's surface so that the reaction starts more quickly when it is put into the water.
- 6 Because the metals float and move around the surface of the water – there is less chance, if placed in the centre of the trough, that they will reach the side. If they do reach the side, the exothermic nature of the reaction can cause the glass trough to crack.

Results

Each row completed correctly.

Metal	Colour of metal	Observations when added to water	Colour of solution formed with universal indicator solution	pH of the solution formed
lithium	silvery	lithium floats on the surface and moves around as a gas is produced	blue	10–12
potassium	silvery	potassium floats on the surface and moves around rapidly, orange flames are observed; the metal melts	violet	12–14
sodium	silvery	sodium floats around on the surface and moves around rapidly; the metal melts	blue/violet	12

Conclusions

- 1 Because they float on water they have a density lower than that of water.
- 2 Potassium.
- 3 Lithium.
- 4 Lithium, sodium, potassium.
- 5 When metals react they lose electrons. As you go down Group 1, the metal atoms get bigger and they lose electrons more easily due to the lessening of the attraction between the positive nucleus and the outer shell electron.
- 6 $2\text{K} + 2\text{H}_2\text{O} \rightarrow 2\text{KOH} + \text{H}_2$.

- 7 All three metals react to give the relevant metal hydroxide. These are soluble in water forming aqueous hydroxide ions.
- 8 They are far too reactive.
- 9 Francium. The trend is that, as you go down the group, the metals get more reactive and francium is at the bottom of Group 1.

Evaluation

- 1 Comment using something from the results.

Extension

- 1 The videos are available on www.youtube.com.
- 2 Three suitable uses.

9.2 Halogen displacement reactions

Method

- 1 Bromine is corrosive and iodine will stain your fingers.
- 2 The halogens themselves are too dangerous to use. Chlorine is a toxic gas and bromine is a very toxic and corrosive liquid.
- 3 Too reactive.
- 4 It is very rare and is radioactive.
- 5 Immiscible.

Results

For completing each row, one mark.

Halogen	Colour in water	Colour in cyclohexane
chlorine	pale green/colourless	pale green/colourless
bromine	orange/red	more intense orange/red
iodine	brown/yellow	violet

		Chlorine water	Bromine water	Iodine water
colour after shaking with sodium iodide solution		brown	brown	
colour of each layer with cyclohexane	upper	violet	violet	
	lower	brown/yellow	brown/yellow	
colour after shaking with sodium bromide solution		orange/red		brown
colour of each layer with cyclohexane	upper	intense orange/red		brown
	lower	orange/red		brown/yellow
colour after shaking with sodium chloride solution			orange/red	brown/yellow
colour of each layer with cyclohexane	upper		intense orange/red	violet
	lower		orange/red	brown/yellow

Conclusions

- 1 Three.
- 2 $\text{Cl}_2 + 2\text{NaI} \rightarrow 2\text{NaCl} + \text{I}_2$
 $\text{Cl}_2 + 2\text{NaBr} \rightarrow 2\text{NaCl} + \text{Br}_2$
 $\text{Br}_2 + 2\text{NaI} \rightarrow 2\text{NaBr} + \text{I}_2$
- 3 They have been reduced; they have gained electrons.

- Least reactive: iodine, bromine, chlorine: most reactive.
- Fluorine – colourless, astatine – brown/black.
- Fluorine. It has the smallest atoms and is able to attract the incoming electron most strongly.

Evaluation

- Yes, chlorine showed two displacement reactions, bromine one and iodine none.
- The pure halogens could have been used.

Extension

- Any suitable use for each of the five halogens or their compounds.
- Starch. Starch turns blue/black in the presence of iodine.

9.3 Using transition metal ions as catalysts

Method

- To avoid cross-contamination of the solutions. The reaction may start sooner than expected.
- In one mole of iron(III) sulfate, $\text{Fe}_2(\text{SO}_4)_3$, there are 2 moles of $\text{Fe}^{3+}(\text{aq})$ ions. In one mole of the other catalysts being used there is only one mole of the transition metal ion.
- Potassium peroxodisulfate is one of the reactants so the reaction will not start until it is added.
- To ensure a fair test. Swirling will help to mix the chemicals, increasing the rate of reaction.

Results and calculations

- Recording results to the resolution allowed by the stopwatch used.
- Calculating rates correctly for the six experiments.
- Suitable scale for both axes. Labelling of axes. Correct units used on axes. Graph drawn correctly.

Conclusions

- States the compounds which increased the rate, from their results.
- States the compound which had the greatest effect on increasing the rate, from their results.
- States any of the compounds which decreased the rate, from their results – inhibitors.
- A catalyst must not be changed chemically at the end of the reaction.
- A catalyst increases the rate of reaction by providing an alternative route from reactants to products with a lower activation energy. Because of the lower activation energy, more of the collisions become successful collisions, increasing the rate of the reaction.

Evaluation

Repeat for each catalyst. This would allow an average time to be calculated and would allow anomalous results to be identified. Some sort of white background, e.g. paper or white tile, could be used behind the boiling tube in which the reaction is occurring to make it easier to spot the blue/black colour of the indicator.

Extension

Ammonia gas – finely divided iron.

Sulfuric acid – vanadium(V) oxide.

Margarine – nickel.

Nitric acid – platinum.

10 Metals

10.1 Metal displacement reactions

Method

- 1 To ensure that there are no impurities, e.g. oxide coatings, on the surface of the metal which might hinder its reaction.
- 2 They are too reactive.
- 3 So that all sides of the metal are able to react with the solution. It may increase the rate by providing a larger surface area.
- 4 Some of the reactions may be slow and may need time to show any sign of reaction.

Results

Correct completion of each row, one mark.

	Metal nitrate solutions					
Metals	Magnesium	Copper	Iron	Tin	Lead	Zinc
Magnesium		✓	✓	✓	✓	✓
Copper	X		X	X	X	X
Iron	X	✓		✓	✓	X
Tin	X	✓	X		✓	X
Lead	X	✓	X	X		X
Zinc	X	✓	✓	✓	✓	

Conclusions

- 1 Magnesium.
- 2 Copper.
- 3 Magnesium, zinc, iron, tin, lead, copper.
- 4 $\text{Mg} + \text{CuSO}_4 \rightarrow \text{MgSO}_4 + \text{Cu}$
- 5 The more reactive metal is being oxidised because it is losing electrons.
- 6 $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$
- 7 They are being reduced because the ions are gaining electrons.
- 8 $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$
- 9 The more reactive metal is the one which is able to lose its electrons most easily.

Evaluation

- 1 Comment.
- 2 The reaction needed a longer time to occur OR there was no obvious colour change but the reaction did occur. Any suitable answer.
- 3 Any two suitable answers, e.g. give the reaction longer than 5 minutes before recording the results. Repeat the reaction more than once.

Extension

No. In halogen displacement reactions the more reactive halogen gains electrons and is reduced, whereas in metal displacement reactions the more reactive metal is oxidised and loses electrons.

10.2 Rusting of iron

After setting up the experiment, it is best to leave the tubes for a week before results are recorded.

Method

- 1 Boiling water removes dissolved air, and oxygen, from the water. Covering the water with a layer of oil prevents air from re-dissolving into the water from the atmosphere.
- 2 By placing a drying agent, anhydrous calcium sulfate, in the tube which will absorb any water which is present in the tube.

Results

Observations recorded in the table.

Tube		Observation
1	water and oxygen	brown/orange rust can be observed on the iron nail
2	without oxygen	no rust observed
3	without water	no rust observed
4	with salt solution	a lot of brown/orange rust observed; more than in the tube with water and oxygen
5	with zinc	no rust observed

Conclusions

- 1 In tubes 1 and 4.
- 2 Because both water and oxygen/air were present.
- 3 Tubes 2, 3 and 5. In Tube 2 there was no oxygen/air. In Tube 3 there was no water, both need to be present for rusting to occur. In Tube 5 the iron nail was in contact with a more reactive metal which reacted with the oxygen/air and water in preference to the iron.
- 4 In Tube 4.
- 5 Oxidation, loss of electrons. $\text{Fe} \rightarrow \text{Fe}^{3+} + \text{e}^-$
- 6 Reduction, gain of electrons. $\text{O}_2 + 4\text{e}^- \rightarrow 2\text{O}^{2-}$

Evaluation

Suitable answer.

Extension

- 1 Corrosion.
- 2 Any two more reactive metals, e.g. magnesium, calcium.

10.3 Metal reactivity

Method

Any three of: same mass of metal, same concentration of acid, same volume of acid, swirled each tube once, same temperature, all the metals were powders.

Results

Observations and times recorded correctly for each metal.

Conclusions

- 1 Copper.
- 2 Magnesium.
- 3 Copper, lead, iron, zinc, magnesium.
- 4 $\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$
[1] for formulae of reactants, [1] for formulae of products, [1] for correctly balanced.

Evaluation

It could be repeated to gain an average time for each metal. The powders used could be newly obtained/fresh, some may have had an oxide coating which slowed down their reaction. Any suitable answers.

Extension

- 1 Any three more reactive metals, e.g. potassium, sodium, lithium, calcium.
- 2 Any suitable, e.g. platinum, gold, silver.

11 Air and water

11.1 The active part of the air

Method

- 1 Oxygen is used up.
- 2 Copper is oxidised to copper(II) oxide.
- 3 The mass of copper is added to the mass of oxygen in copper(II) oxide.
- 4 Copper + oxygen \rightarrow copper(II) oxide

$$2\text{Cu(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{CuO(s)}$$

Results and calculations

Initial colour of the copper is *pink/brown*.

Final colour of the copper after heating in air is *black*.

Mass of glass tube + copper at start = 50.00 g

Mass of glass tube + copper oxide after heating = 50.15 g

Difference in mass = 0.15 g

Initial volume of air in the syringe = 100 cm³

Final volume of gas left in the syringe after the apparatus has cooled = 79 cm³

Volume change = 21 cm³

The percentage, %, of oxygen gas in the air = $\frac{21 \times 100}{100} = 21\%$

What happened to the candle in the beaker when the remaining gas from the cooled syringe was squeezed gently onto it? *It goes out.*

Conclusion

21%.

Evaluation

Use a more reactive metal (e.g. calcium) to react with the oxygen in the air, but note that it will increase the hazards.

Extension

- | 1 | Component | % | | |
|---|----------------|-------|------------------------------------------|---------|
| | Nitrogen | 78.08 | Neon | 0.002 |
| | Oxygen | 20.95 | Helium | 0.0005 |
| | Argon | 0.93 | Krypton | 0.0001 |
| | Carbon dioxide | 0.04 | Xenon plus minute amounts of other gases | 0.00001 |
- 2 glucose + oxygen → carbon dioxide + water + energy
 $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) + 6\text{O}_2(\text{g}) \rightarrow 6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}) + \text{energy}$
- 3 By the fractional distillation of dry and carbon-dioxide free liquid air.

11.2 Making a fertiliser

Method

- 1 Overflow can take place and also adds errors to the titration figure.
- 2 So you can see the end-point of the titration better.
- 3 To make sure the crystals are their actual colour.
- 4 It was put aside to cool. Then slow crystallisation can take place. If you evaporate to dryness, spitting occurs and the crystals will not form properly.

Results and calculations

This will vary.

Conclusion

Crystals of the *fertiliser* ammonium sulfate can be made by the *titration* of aqueous ammonia with dilute *sulfuric acid*.

Evaluation

Repeat the titration several times and take the average of the results to ensure that the titre is as accurate as possible.

Extension

- 1 The first titration would be the rough one. The titrations would be repeated and the average of the three values within 0.1 cm^3 would be taken. The concentration of the ammonia solution can then be found using:

$$\frac{M_1 V_1}{M_{\text{acid}}} = \frac{M_2 V_2}{M_{\text{alkali}}}$$

where:

M_1 = concentration of the acid used

V_1 = average volume of acid used (cm^3)

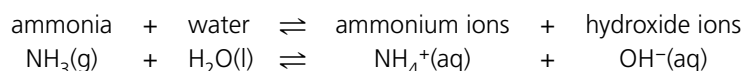
M_{acid} = number of moles of acid shown in the chemical equation

M_2 = concentration of the alkali used

V_2 = volume of the alkali used (cm^3)

M_{alkali} = number of moles of alkali shown in the chemical equation.

- 2 A 'weak alkali', such as ammonia, produces fewer hydroxide ions when it dissolves in water than a strong soluble base of the same concentration. It is only partially ionised. It has a lower pH than a strong base, but still above 7.



The ammonia molecules react with the water molecules to form ammonium ions and hydroxide ions. However, fewer ammonia molecules do this, so only a low concentration of hydroxide ions is produced.

- 3 Formula is $(\text{NH}_4)_2\text{SO}_4$. RFM = 116.

$$\% \text{ N} = \frac{2 \times 14}{116} \times 100 = 21.21\%$$

11.3 The effects of acid rain

Method

- 1 Because it is a dilute solution of acid and so more of it is required to show the effect of time for reaction.
- 2 Some of the reactions will be slow. This means observations are necessary over a period of time.

Results and calculations

Material	Observation after 2 minutes	Suitability of the material for construction
copper	no reaction	suitable
limestone	bubbles of a gas produced	unsuitable*
brick	some bricks produce a few bubbles of gas.	suitable*
lead	no reaction	suitable
steel	small amount of bubbles of gas produced (only a few)	suitable
zinc	bubbles of gas produced and zinc dissolves	unsuitable
aluminium	no reaction	suitable
concrete	a few bubbles of gas produced	suitable*

* Limestone and concrete in very large lumps show a very slow reaction.

Conclusion

- 1 Copper, lead, steel, aluminium.
- 2 Limestone, concrete, brick, zinc.

Evaluation

Add some other materials, such as cast iron and plated metals. Use nitric acid as well as sulfuric acid in the acid rain.

Extension

- 1 This is due to the fact that the materials are used in large lumps, e.g. limestone, brick, concrete, which slows the reaction down considerably. Also metals like zinc are used because they are relatively cheap when used in galvanising.
- 2 Reduce the amount of fossil fuels burned and turn to renewables like solar, wind and tidal power. Also reduce the amount of rotting vegetation by cutting down on food waste.

12 Sulfur

12.1 Sulfuric acid: a useful quantitative analytical chemical

Method

- 1 Overflow can take place and also adds errors to the titration figure.
- 2 So you can see the end-point of the titration better.
- 3 To ensure a good mixing of the reactants.
- 4 Because the first value is carried out not knowing where the end-point will be.

Results and calculations

	Rough	1	2	4
final burette reading/cm ³	25.3	25.5	25.3	25.4
initial burette reading/cm ³	0.0	0.0	0.0	0.0
volume of acid used/cm ³	25.3	25.5	25.3	25.4

- 1 From this balanced equation it can be seen that: 1 mole reacts with 2 moles.

$$\frac{\text{average titration} \times \text{molarity}}{1000} = \frac{(25.5 + 25.3 + 25.4/3) \times 0.05}{1000} = 0.0013 \text{ moles}$$

Since 1 mole of sulfuric acid reacts with 2 moles of sodium hydroxide, the number of moles of sodium hydroxide which will react with 2×0.0013 moles of sulfuric acid = 0.0026 moles which is found in 25 cm^3 of solution.

The concentration of the alkali is:

$$\text{moles of alkali in } 25 \text{ cm}^3 \times \frac{1000}{25} = 0.10 \text{ mol/dm}^3$$

- 2 $\frac{0.05 \times 25.4}{1} = \frac{M_2 \times 25.0}{2}$
 $M_2 = 0.10 \text{ mol/dm}^3$

Conclusion

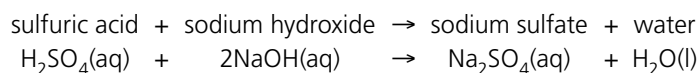
0.10M.

Evaluation

Carry out more titrations to ensure you have an accurate average for the volume of sulfuric acid added.

Extension

- 1 Having obtained an accurate value for the volume of sulfuric acid required to neutralise the 25 cm^3 of sodium hydroxide solution, now mix these values of volumes together. This is carried out without the phenolphthalein indicator. Then take a sample of this mixture, now sodium sulfate solution, in an evaporating basin and slowly evaporate on a water bath. Once the solution is quite concentrated (small volume), place to one side to allow the crystals to form.
- 2 Equation:



Moles of sulfuric acid used in the titration: $0.0013 \text{ moles} = \text{moles of sodium sulfate produced}$

Mass of sodium sulfate produced = $0.0013 \times \text{RFM sodium sulfate}$

$$= 0.0013 \times 142$$

$$= 0.1846 \text{ g}$$

12.2 Concentrated sulfuric acid

Method

- Concentrated sulfuric acid is a very dangerous acid. Noxious fumes may be produced.
- If the acid gets onto skin, it will badly damage the skin within seconds.

Results and calculations

Substance	Formula	Observation with concentrated sulfuric acid	Inference	Equation for reaction taking place
sugar	$C_6H_{12}O_6$	turns brown and then black lots of steam and fumes produced volume of substance tested quadruples – at least! gets very hot	carbon left elements of water, H and O, removed by acid	sucrose (sugar) \rightarrow carbon + water $C_{12}H_{22}O_{11}(s) \rightarrow 12C(s) + 11H_2O(l)$
copper(II) sulfate hydrate	$CuSO_4 \cdot 5H_2O$	turns from blue to white lots of steam produced volume of substance tested shrinks a little gets very hot	water of crystallisation is removed substance is now anhydrous	hydrated \rightarrow anhydrous + water copper(II) sulfate copper(II) sulfate $CuSO_4 \cdot 5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$

Conclusion

Concentrated sulfuric acid is an excellent dehydrating agent. It will remove water from salt *hydrates* such as hydrated copper(II) sulfate or the *elements* of water from substances such as sugar. When this happens the reactions are very *exothermic*.

Evaluation

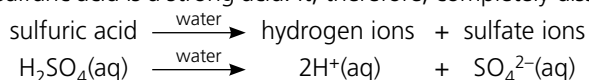
Test other salts such as iron(II) sulfate or other sugars and starch.

Extension

- hydrated cobalt(II) chloride \rightarrow anhydrous cobalt(II) chloride + water
 $CoCl_2 \cdot 6H_2O(s) \rightarrow CoCl_2(s) + 6H_2O(l)$
- ethene (C_2H_4)

12.3 Properties of dilute sulfuric acid

Dilute sulfuric acid is a strong acid. It, therefore, completely dissociates in aqueous solution.



The normal salts produced in the experiments in this practical are sulfates.

Method

- To trap the gas inside so it can be tested.
- If the temperature rises, this suggests that a reaction has taken place.
- To pass the gas through the limewater.
- To speed up the reaction.

Results and calculations

Substance	Reaction with dilute sulfuric acid	Inference	Name of salt produced
magnesium	effervescence; 'pops' with lighted splint	reaction occurs; a salt and hydrogen produced	magnesium sulfate
sodium hydroxide	no observable reaction but temperature rises	reaction has taken place to produce a salt and water	sodium sulfate
sodium carbonate	effervescence; turns limewater cloudy white	reaction occurs; a salt, carbon dioxide and water produced	sodium sulfate
copper(II) oxide	no reaction unless warmed; solution goes blue	copper(II) sulfate produced along with water	copper(II) sulfate

Conclusion

Dilute sulfuric acid is a *strong* acid. It reacts with MAZIT metals such as magnesium to produce a *salt* and release *hydrogen* gas. When it reacts with sodium hydroxide the *neutralisation* reaction forms the sodium *sulfate* and water only. In the reaction with sodium carbonate it forms sodium *sulfate* and releases the gas *carbon dioxide*. In the final experiment with copper(II) oxide, on warming, copper(II) sulfate a blue *hydrate* salt is produced.

These are general reactions of strong acids. Another example of a strong acid would be *hydrochloric* acid.

Evaluation

Other substances can be tested, e.g. iron, zinc, as per the reaction with magnesium. Compare with reactions of a weak acid, such as ethanoic acid.

Extension

- Normal salt** – a substance formed when all the replaceable hydrogen of an acid is completely replaced by metal ions or the ammonium ion.
Acid salt – a substance formed when only some of the replaceable hydrogen of an acid is replaced by metal ions or the ammonium ion.
Neutralisation reaction – the process by which the acidity or alkalinity of a substance is cancelled out.
MAZIT metals – the metals magnesium, aluminium zinc, iron, tin.
- with magnesium:

$$\text{Mg(s)} + \text{H}_2\text{SO}_4\text{(aq)} \rightarrow \text{MgSO}_4\text{(aq)} + \text{H}_2\text{(g)}$$
 - with sodium hydroxide

$$2\text{NaOH(aq)} + \text{H}_2\text{SO}_4\text{(aq)} \rightarrow \text{Na}_2\text{SO}_4\text{(aq)} + 2\text{H}_2\text{O(g)}$$
 - with sodium carbonate

$$\text{Na}_2\text{CO}_3\text{(s)} + \text{H}_2\text{SO}_4\text{(aq)} \rightarrow \text{Na}_2\text{SO}_4\text{(aq)} + \text{CO}_2\text{(g)} + \text{H}_2\text{O(g)}$$
 - with copper(II) oxide

$$\text{CuO(s)} + \text{H}_2\text{SO}_4\text{(aq)} \rightarrow \text{CuSO}_4\text{(aq)} + \text{H}_2\text{O(g)}$$
- with magnesium

$$\text{Mg(s)} + 2\text{H}^+\text{(aq)} \rightarrow \text{Mg(s)} + \text{H}_2\text{(g)}$$
 - with sodium hydroxide

$$\text{H}^+\text{(aq)} + \text{OH}^-\text{(aq)} \rightarrow \text{H}_2\text{O(l)}$$

- (c) with sodium carbonate
 $\text{CO}_3^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
- (d) with copper(II) oxide
 $\text{O}^{2-}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$

13 Inorganic carbon chemistry

13.1 Limestone: a useful resource

Method

- 1 Calcium oxide is corrosive and calcium hydroxide is an irritant.
- 2 Alkali produced – calcium hydroxide.
- 3 Calcium carbonate was produced when carbon dioxide was blown through the calcium hydroxide solution.

Results and calculations

Procedure step	Observation	inference
3	white-powder coating appears on the surface of the limestone	new substance produced upon heating – calcium oxide
10	indicator solution goes blue	alkali produced
11	goes cloudy white	carbon dioxide from breath is interacting with calcium hydroxide solution

Conclusion

When limestone is heated strongly it is converted to *calcium oxide* (quicklime). When water is added to the *calcium oxide*, a new substance is produced called *calcium hydroxide* (slaked lime) which is an *alkali*. When carbon dioxide is blown through the solution it forms *calcium carbonate*.

Evaluation

Repeat the experiments a number of times to show the results are reproducible. Also, compare the results with actual substances and how they behave.

Extension

- 1 (a) calcium carbonate \rightleftharpoons calcium oxide + carbon dioxide
 $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
 (b) calcium oxide + water \rightarrow calcium hydroxide
 $\text{CaO}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{Ca}(\text{OH})_2(\text{s})$
 (c) calcium hydroxide + carbon dioxide \rightarrow calcium carbonate + water
 $\text{Ca}(\text{OH})_2(\text{aq}) + \text{CO}_2(\text{g}) \rightarrow \text{CaCO}_3(\text{s}) + \text{H}_2\text{O}(\text{l})$
- 2 carbonate ion (from CaCO_3) + hydrogen ion (from acid soils) \rightarrow carbon dioxide + water
 $\text{CO}_3^{2-}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$

- 3 **Thermal decomposition** – the breakdown of a substance under the influence of heat.

Neutralisation reaction – the process in which the acidity or alkalinity of a substance is cancelled out.

Flue gas desulfurisation – the process by which sulfur dioxide gas is removed from the waste gases of power stations by passing them through calcium hydroxide slurry.

Alkali – a soluble base which produces $\text{OH}^-(\text{aq})$ ions in water.

13.2 Does the food we eat contain carbon?

Method

- 1 To ensure the foodstuffs decompose to carbon.
- 2 Carbon dioxide, CO₂.
- 3 The carbon in the foodstuffs reacts with oxygen in air.

Results and calculations

Food	Effect of heat	Effect of extracted gas on limewater	Does the food contain carbon?
bread	eventually turns black as the food chars	turns limewater slightly cloudy white	yes
rice	eventually turns black as the food chars	turns limewater slightly cloudy white	yes
cornflakes	eventually turns black as the food chars	turns limewater slightly cloudy white	yes
macaroni	eventually turns black as the food chars	turns limewater slightly cloudy white	yes
spaghetti	eventually turns black as the food chars	turns limewater slightly cloudy white	yes

Conclusion

From the results of my experiments I can say that the foods I tested contain *carbon*.

Evaluation

Include other foodstuffs. At times during the experiments allow more air into the test.

Extension

- 1 carbon + oxygen → carbon dioxide

$$\text{C(s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$$
- 2 **Aerobic respiration** – this is respiration that takes place using the oxygen from the air. During the process, carbon dioxide and energy are released.
- 3 **Hydrocarbons** – these are substances that contain carbon and hydrogen only.
Carbon cycle – the continuous process by which carbon is exchanged between organisms and the environment. It involves photosynthesis, respiration and decay of animals, plants and other organisms, as well as the burning of fossil fuels.
Photosynthesis – the chemical process by which green plants synthesise their carbon compounds from atmospheric carbon dioxide, using light as the energy source and chlorophyll as the catalyst.

13.3 Carbon dioxide

Method

- 1 Because one of the products is insoluble calcium sulfate. This would prevent further reaction of the acid with the limestone.
- 2 Carbon dioxide is not very soluble in water, otherwise it could not be collected in this way.
- 3 To ensure the gas does not escape from the test tube.

Results and calculations

Test on the carbon dioxide	Observation	Inference
colour	colourless	
smell	no smell	
what happens to the burning splint	goes out	does not support combustion
pH of the solution	should be around 5	acidic gas
effect of limewater	turns it cloudy white	useful test for carbon dioxide
burning magnesium	white powder and black specks produced	supports combustion of strongly burning substances
burning candle	flame goes out	denser than air and does not support combustion
density experiments	gas can be poured	denser than air

Conclusion

It has *no* colour.

It has *no* smell.

It will not support *combustion*.

Its solution has a pH of 5 which makes it an *acidic* gas.

It turns limewater cloudy *white*. This is used as a chemical test for carbon dioxide.

It is *denser* than air.

Evaluation

Tests with the gas should be repeated to show they are reproducible. Demonstrate that sulfuric acid is not the acid to use to produce the gas efficiently.

Extension

- (a)** A reaction which involves the two processes of reduction and oxidation.

(b) Oxidised – magnesium, reduced – carbon dioxide.
- An acid such as carbonic acid which produces a low concentration of $\text{H}^+(\text{aq})$ in water solution. It is only partially ionised.
- Fire extinguishers, carbonated drinks, refrigerants, special smoke effects (less so as this can be dangerous), heat transfer agent.

14 Organic chemistry 1

14.1 Is methane a hydrocarbon?

Method

- Limewater contains water. The cobalt chloride paper is a test for the presence of water.
- Plastic one would melt.
- So the glass is not cracked.

Results and calculations

- 1 Turns from blue to pink. This is caused by the effect of the water produced by burning a substance that contains hydrogen.
- 2 Turns cloudy white. This is caused by the effect of the carbon dioxide produced by burning a substance that contains carbon burning.
- 3 Elements present are C and H.

Conclusion

When the gases produced by burning methane in air are passed through the apparatus, various observations can be made.

The cobalt chloride paper tests for *water* and turns from a *blue* colour to a *pink* colour. This shows the presence of the element *hydrogen* in methane.

The limewater tests for *carbon dioxide* and goes *white*. This shows the presence of the element *carbon* in methane.

Overall this shows that methane and, hence, other alkanes contain the elements *carbon* and *hydrogen* only. They are, therefore, *hydrocarbons*.

Evaluation

Repeat the experiment with other hydrocarbons such as hexane, looking for the same results.

Extension

- 1 **Complete combustion** – a chemical reaction in which a substance reacts rapidly with a plentiful supply of oxygen with the production of heat and light.
Hydrocarbon – a substance that contains carbon and hydrogen only.
- 2 (a) In complete combustion of methane, one of the products is carbon dioxide, whilst in the case of incomplete combustion carbon monoxide is produced.
(b) methane + oxygen → carbon monoxide + water

$$\text{CH}_4(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{CO}(\text{g}) + 2\text{H}_2\text{O}(\text{g})$$
- 3 Sulfur dioxide will turn acidified potassium manganate(VII) solution from purple to colourless.

14.2 Difference between alkanes and alkenes

Method

- 1 The hydrocarbons may affect your skin.
- 2 Vapours are harmful.

Results and calculations

Substance	Appearance	Smell	Shake with bromine in an organic solvent	Effect of a lighted splint
hexane	colourless liquid	petroleum smell	no change	burns cleanly
hexene	colourless liquid	sweet petroleum smell	decolourises the bromine in an organic solvent	burns with more of a smoky flame

Conclusion

It is possible to identify an alkene using the fact that it will *decolourise* bromine dissolved in an organic solvent. In this reaction the bromine *adds* across the *double* bond in the alkene. The reaction is an example of an *addition* reaction.

Evaluation

Test other alkanes and alkenes. Compare, therefore, a greater selection.

Extension

- 1 (a) Used in the manufacture of ethanol. It is formed when water (as steam) is added across the double bond in ethene. For this reaction to take place, the reactants have to be passed over a catalyst of phosphoric(V) acid (absorbed on silica pellets) at a temperature of 300°C and pressure of 60 atmospheres.
- (b) Ethane is produced. This reaction is called hydrogenation. The conditions necessary for this reaction to take place are a temperature of 200°C in the presence of a nickel or platinum catalyst.

14.3 Hydrocarbons can form isomers

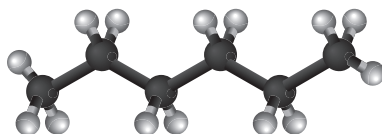
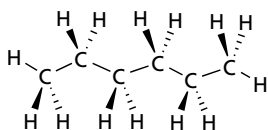
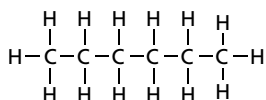
Method

Hexane. The molecules can approach each other closely due to the 'linear' nature of the molecules. This will maximise the weak intermolecular forces.

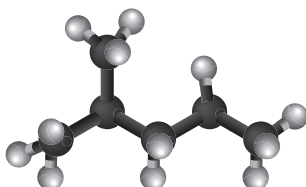
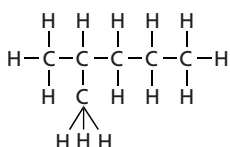
Results and calculations

- 1 Drawings (3D) and names of the five isomers of C_6H_{14} :

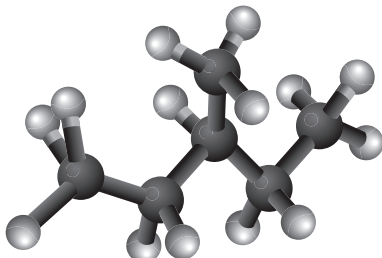
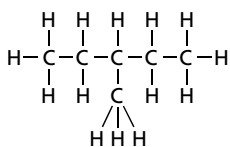
(a) Hexane



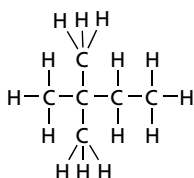
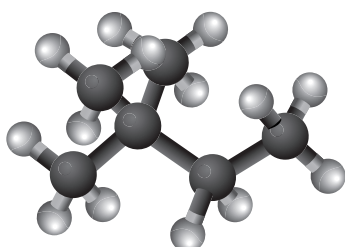
(b) 2-Methylpentane



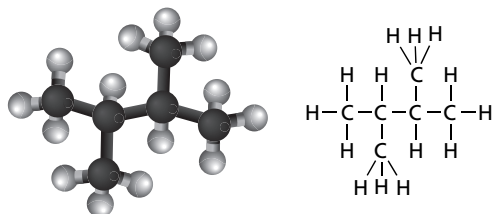
(c) 3-Methylpentane



(d) 2,2-Dimethylbutane



(e) 2,3-Dimethylbutane



Conclusion

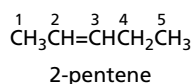
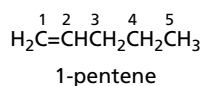
There are *five* isomers of hexane. There is one which has *no* branch chains while the other four *have* branched chains. The molecule with a straight chain has the *highest* melting and boiling points. This is the case because the forces of attraction between the molecules are at a *maximum* when there are *no* branched chains.

Evaluation

Try to draw the 3D structures of the molecules to see how they look in reality.

Extension

- 1 Due to the presence of many isomers in a variety of organic molecules.
- 2 Position of functional group



15 Organic chemistry 2

15.1 Organic structures and functional groups

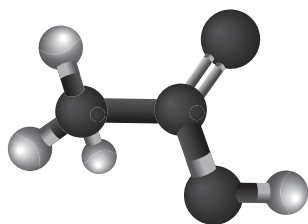
Method

- 1 (b). They have the same functional group but (b) is a bigger molecule and has a greater RMM. So the intermolecular forces will be larger.
- 2 Because they have the same functional group.

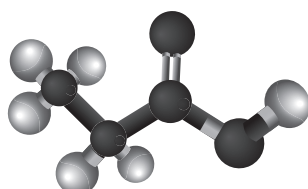
Results and calculations

- 1 3D drawing:

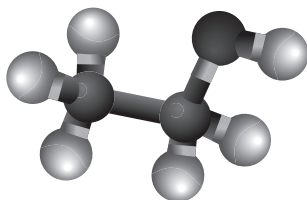
(a) Ethanoic acid



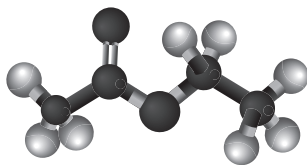
(b) Propanoic acid



(c) Ethanol



(d) Ethyl ethanoate

2 (e) 120° (f) $109^\circ 28'$

3

Molecule	Number of elements present	*Relative formula mass	Total number of atoms present	Number of single covalent bonds	Number of double covalent bonds
A ethanoic acid	3	60	8	6	1
B propanoic acid	3	74	11	9	1
C ethanol	3	46	9	8	0
D ethyl ethanoate	3	88	14	12	1

*To calculate the relative formula mass (RFM) you need to add together all the relative atomic masses (RAM) of the atoms present in a molecule: RAM: H = 1, C = 12, O = 16.

Conclusion

Organic molecules have a *3D* structure. Their melting and boiling points depend on this *3D* structure, *RMM* and *functional* groups present. The bond angles found in organic molecules are the *same* throughout organic chemistry.

Evaluation

Build a series of other molecules. Perhaps those that contain nitrogen, such as amino acids.

Extension

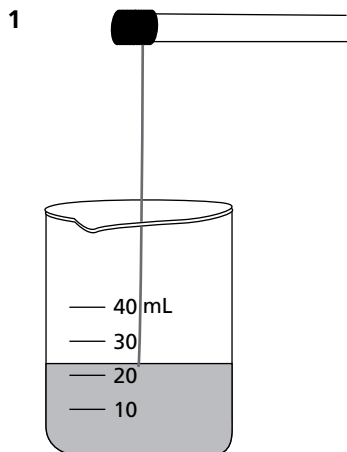
- (a), (b) – carboxylic acid (COOH), (c) – alcohol (OH), (d) – ester (–OR).
- (a), (b) – carboxylic acid, (c) – alcohol, (d) – ester.
- Ethyl propanoate.

15.2 Nylon rope trick

Method

- The chemicals involved in the experiment are harmful to skin.
- In case of splashing.
- To produce two separate layers. You do not want mixing.
- To leave so that the solvents evaporate, giving nylon.

Results and calculations



2 It is a white slimy looking solid. Looks quite soft.

Conclusion

The *polymer* nylon is made by the mixing of 1,6-diaminohexane and sebacyl chloride. During this reaction the small molecule *hydrogen chloride* is produced (or *condensed out*). The name of this type of reaction is *condensation* polymerisation.

Evaluation

Increase the amount of chemicals to produce a larger sample. Use a better set of apparatus.



[Photo credit © Charles D. Winters/Science Photo Library]

Extension

1 **Monomer** – a simple molecule, such as ethene, which can be polymerised.

Polymer – a substance possessing very large molecules consisting of repeated units or monomers. Polymers, therefore, have a very large relative molecular mass.

$\text{H}_2\text{N}(\text{CH}_2)_6\text{NHOC}(\text{CH}_2)_4\text{COOH}$ – this is the amide link

2 (a) Ethane-1,2-diol, benzene-1,4-dicarboxylic acid

(b) Uses of nylon: making ropes, clothing

Uses of terylene: making clothing, in mixed plastics, e.g. with PVC to form braided terylene-reinforced PVC for hosepipes.

15.3 Properties of dilute ethanoic acid

Method

- 1 To ensure gas does not escape.
- 2 A temperature rise indicates that a chemical reaction has taken place.
- 3 To easily pass gas through limewater.
- 4 It acts as a catalyst for reaction.

Results and calculations

Substance	Reaction with dilute ethanoic acid	Inference
magnesium	effervescence, gas 'pops' with lighted splint	hydrogen gas produced
sodium hydroxide	temperature rises	chemical reaction takes place – neutralisation
sodium carbonate	effervescence, gas turns limewater cloudy white	carbon dioxide gas produced
ethanol	sweet smelling substance produce	an ester was formed

Conclusion

Dilute ethanoic acid is a *weak* acid. It reacts with MAZIT metals such as magnesium to produce a *salt* and releases *hydrogen* gas. When it reacts with sodium hydroxide, the *neutralisation* reaction forms sodium *ethanoate* and water only. In the reaction with sodium carbonate, it forms sodium *ethanoate* and releases the gas *carbon dioxide*. In the final experiment with ethanol, ethyl ethanoate, an *ester*, is produced.

Evaluation

Test the acid with other MAZIT metals. Compare reactions with those that take place with propanoic acid, another member of the carboxylic acids.

Extension

- 1 (a) with magnesium

$$\text{ethanoic acid} + \text{magnesium} \rightarrow \text{magnesium ethanoate} + \text{water}$$

$$2\text{CH}_3\text{COOH}(\text{aq}) + \text{Mg}(\text{s}) \rightarrow (\text{CH}_3\text{COO})_2\text{Mg}(\text{aq}) + \text{H}_2(\text{g})$$
 (b) with sodium hydroxide

$$\text{ethanoic acid} + \text{sodium hydroxide} \rightarrow \text{sodium ethanoate} + \text{water}$$

$$\text{CH}_3\text{COOH}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{CH}_3\text{COONa}(\text{aq}) + \text{H}_2\text{O}(\text{l})$$
 (c) with sodium carbonate

$$\text{ethanoic acid} + \text{sodium carbonate} \rightarrow \text{sodium ethanoate} + \text{carbon dioxide} + \text{water}$$

$$2\text{CH}_3\text{COOH}(\text{aq}) + \text{Na}_2\text{CO}_3(\text{aq}) \rightarrow 2\text{CH}_3\text{COONa}(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$$
 (d) with ethanol

$$\text{ethanoic acid} + \text{ethanol} \leftarrow \text{ethyl ethanoate} + \text{water}$$

$$\text{CH}_3\text{COOH}(\text{l}) + \text{C}_2\text{H}_5\text{OH}(\text{l}) \leftarrow \text{CH}_3\text{COOC}_2\text{H}_5(\text{aq}) + \text{H}_2\text{O}(\text{l})$$
- 2 (a) with magnesium $\text{Mg}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{H}_2(\text{g})$
 (b) with sodium hydroxide $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$
 (c) with sodium carbonate $\text{CO}_3^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
- 3 **Weak acid** – an acid which produces a low concentration of $\text{H}^+(\text{aq})$ in water solution, for example ethanoic acid. It is only partially ionised.
Neutralisation reaction – the process in which the acidity or alkalinity of a substance is cancelled out.
MAZIT metals – the metals magnesium, aluminium, zinc, iron, tin
Homologous series – a series of compounds in which each member differs from the next by a specific number and kind of atom. These compounds have the same general formula and similar properties.

16 Experimental chemistry

16.1 Missing labels from reagent bottles: what a problem!

Method

a – test for chloride, b – test for carbonate, c – test for sulfate.

Results and calculations

Unknown solution	Test	Observation	Inference
A (sodium carbonate)	a	effervescence colourless solution	not a chloride but could be a carbonate
	b	effervescence colourless solution	could be a carbonate
	c	colourless solution	it is not a sulfate
B (sodium chloride)	a	white precipitate	it is a chloride
	b	colourless solution	not a carbonate
	c	colourless solution	not a sulfate
C (sodium sulfate)	a	colourless solution	not a chloride
	b	colourless solution	not a carbonate
	c	white precipitate	it is a sulfate

Conclusion

Solution A is *sodium carbonate*.

Solution B is *sodium chloride*.

Solution C is *sodium sulfate*.

Evaluation

Leave the chloride precipitate in light – it should go grey.

Add a little acid to the sulfate to check the precipitate does not dissolve in an acid. (If it had, this would have shown it to be a sulfite.)

Extension

- $$\text{A} - \text{CO}_3^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$$

$$\text{B} - \text{Cl}^-(\text{aq}) + \text{Ag}^+(\text{aq}) \rightarrow \text{AgCl}(\text{s})$$

$$\text{C} - \text{SO}_4^{2-}(\text{aq}) + \text{Ba}^{2+}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$$
- Carry out a series of flame tests to identify the metal ions present:
 Potassium – lilac
 Copper – green
 Calcium – brick red
- Sulfite present.

16.2 Using flame colours to identify unknown metal ions

Method

- 1 Hottest part of flame – cleans best.
- 2 So that we take even more care about its use. The acid is corrosive and should be handled very carefully. Eye protection on all the time!
- 3 They could spit and crackle, and be thrown in all directions.

Results and calculations

Solution	Flame colour	Metal ion present
A	brick red	calcium
B	blue/white (but could just be pale blue)	lead
C	green (turquoise)	copper
D	lilac (or pale purple)	potassium
E	yellow with little sparks	iron(III)
F	pale green	barium
G	intense yellow	sodium

Conclusion

Metal ions can be identified by carrying out flame tests. These tests are *straightforward* in nature.

Evaluation

Take all the class experimental results and compare all the results. This will give a better overall set of results for the class.

Extension

Carry out experiments using aqueous ammonia and/or sodium hydroxide solutions to identify the metal ions.

16.3 How pure is your water supply?

Method

- 1 Looking for slight changes after each drop.
- 2 To see whether any precipitates dissolve.

Results and calculations

Appearance of sample at start	Effect of the addition of dilute hydrochloric acid	Effect of the addition of dilute sodium hydroxide to excess
A	colourless solution	white precipitate which dissolves in excess
B	no change to the pale blue solution	pale blue precipitate which does not dissolve in excess
C	effervescence	colourless solution
D	no change to the pale green solution	pale green precipitate which does not dissolve in excess
E	colourless solution	white precipitate which does dissolve in excess

Conclusion

Water samples may be tested for the presence of metal *ions* by adding dilute hydrochloric acid. If a carbonate is present then bubbles of the gas *carbon dioxide* will be seen. The samples may also be tested for the presence of metal ions which may be harmful using *sodium hydroxide*. White or a coloured *precipitate* may be produced, from which an indication of the metal ion present can be obtained. If excess of dilute sodium hydroxide is used then this will also help in the identification of specific metal ions.

Evaluation

Include test for carbon dioxide gas. Also use flame test to compare results.

Extension

- Slightly different results can be obtained from those tests with sodium hydroxide. For example, in the case of iron a dirty green precipitate is produced.
- Bubble the gas through limewater. If it turns cloudy white it is carbon dioxide.

Practical test past exam questions

- (c) table of results
 initial readings completed correctly [1]
 final readings completed correctly [1] all readings to 1 decimal place [1]
 differences completed correctly [1]
 readings comparable to supervisor's [2] [6]

(d) pink [1] to colourless [1] (not clear) [2]

(e) neutralisation/exothermic [1]

(f) (i) C/3 smallest B/2 largest [1] one correct = 1 [1]
 (ii) order is C/3 A/1 B/2 [2] one correct = 1 [2]

(g) experiment 2 is twice the volume of experiment 1 or converse [1]

(h) twice value from table result for experiment 3 [1] cm³ [1] [2]

(i) use a pipette/burette [1]

(j) effect: none [1]
 reason: no change in concentration/temperature has no effect on quantities or moles/only affects speed [1] [2]

(k) any correct method that would work – precise details not needed
 reagents [1] method [1] result [1] [3]
 using same method with different acids = 0
 e.g. to sodium hydroxide add named acid
 measure temperature change
 largest change = strongest/more concentrated solution
 e.g. to sodium hydroxide add named (excess) metal salt solution
 filter precipitate
 largest mass = strongest/more concentrated solution
- (a) green [Total: 21]
 [1]

(b) green [1] (precipitate)
 turns brown/rusty at top [1] [2]

(c) effervescence/fizz/bubbles [1]
 glowing splint [1] glows brighter/relights/burns [1] [3]

(d) green precipitate [1] [1]

(e) no reaction/change [1] [1]

(f) white [1] precipitate [1] [2]

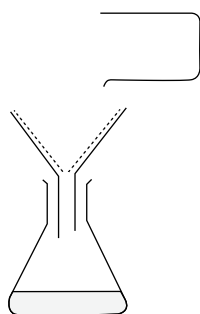
(g) blue [1] [1]

- (h) green/white/blue [1] according to supervisor's precipitate [1]
turns green [1] [3]
- (i) fizz/bubbles/ammonia [1]
litmus/indicator paper blue/purple [1] [2]
- (j) iron [1] (II) [1]
sulfate [1] [3]
- (k) transition metal
nitrate [2]
- 3 (c)** Table of results for Experiments 1–4
mass of solids correctly recorded [1]
initial and maximum temperature boxes correctly completed [1]
temperature differences correct [1]
temperature changes increasing [1] [4]
- (d)** results for Experiment 5
initial and final temperatures completed [1]
temperature change completed correctly and shown as negative [1] [2]
- (e)** appropriate scale on y-axis which uses at least half of the grid [1]
all points correctly plotted [2], –1 for any incorrect (ignore origin)
best fit straight line graph drawn with a ruler [1] [4]
- (f) (i)** value from graph [1] extrapolation shown clearly [1] [2]
(ii) value from graph [1]
shown clearly [1] [2]
- (g)** endothermic [1]
- (h)** lower temperature change [1]
greater volume/more acid [1] [2]
note: halved = 2 marks
- (i)** room temperature/initial temperature from table [1]
reaction: finished [1] [2]
- (j)** advantage, e.g. comparability of results/fair test [1]
(ignore reference to accuracy or reliability)
disadvantage, e.g. reaction not finished/temperature still changing [1] [2]
- 4 (a)** table of results for Experiment 1
initial final and difference volume boxes completed correctly [1]
readings to 1 decimal place [1]
comparable to supervisor's [1] $\pm 2 \text{ cm}^3$ [3]
- (b)** table of results for Experiment 2
initial and final boxes completed correctly [1]
difference box completed correctly [1]
comparable to supervisor's [1] $\pm 5 \text{ cm}^3$ [3]
- (c)** colourless [1] pink/magenta [1] [2]
- (d)** neutralisation/acid–base [1] [1]
- (e)** $2 \times$ volume for Experiment 1 from table [1] cm^3 [1] [2]
(allow 1 mark for double the volume)
- (f) (i)** reacts with [1] neutralises the acid [1] [1]
less sodium hydroxide needed [1] [2]
(ii) volume in (e) – volume added in Experiment 2, [1] e.g. 50–17
correct value, [2] e.g. 33 [2]
(iii) estimate based on (ii) answer to (ii)/3 divided into 50×0.1 , e.g. 0.5
(allow 1 mark for 0.45–0.6 g) [1]
- (g)** no effect [1]
reason – reaction not affected by temperature/volumes/concentrations the same [1] [2]

- (h) (i) more accurate [1] than a measuring cylinder [1]
(not more accurate than a burette = 0) [2]
- (ii) no effect/advantage [1]
not measuring temperature changes/no temperature difference [1] [2]

Alternative to Practical past exam questions

- 1 (a) (i) (gas) syringe [1]
(ii) arrow shown under copper [1]
- (b) spatula [1]
- (c) black [1]
- (d) to return to room or initial temperature [1]
correct volume of gas [1] [2]
- 2 (a) pestle [1], mortar [1] [2]
- (b) stir/mix/shake or heat/boil [1]
- (c) diagram showing funnel [1]
indication of filter paper [1] (labels are not necessary) [2]



- (d) by heat (evaporation) [1]
to crystallising point (or description of this process) [1]
in fume cupboard [1] [2]
- (e) melting point or chromatography [1]
- 3 (a) (i) silver/grey metal [1]
(ii) white [1]
- (b) oxygen [1]
- (c) to let air/oxygen enter or to make sure all magnesium reacted [1]
- (d) 2 from: error in weighing
loss of magnesium oxide
some magnesium unreacted [2]
- 4 (a) any of: trough, tub, beaker, bowl, water bath, basin [1]
- (b) arrow to space in boiling tube above liquid in water trough [1]
- (c) any of: to absorb, contain, store, trap, hold the alkane/liquid [1]
- (d) one of: gives large surface area, acts as catalyst, speeds up reaction [1]
- (e) test with bromine (water or in organic solvent) [1]
Result: goes colourless [1] [2]