Pearson
Edexcel

Teacher Guide iPDF
Core Practicals
GCSE Chemistry

GCSE (9–1) Sciences

Pearson Edexcel Level 1/Level 2 GCSE (9–1) Sciences

Contents

Key

PRACTICALS SHOWN IN BOLD ARE THE ADDITIONAL PRACTICALS REQUIRED FOR GCSE CHEMISTRY.

Icons

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Introduction

Purpose of this guide

This guide is designed to support you in delivering the core practicals for Edexcel. The following pages, for *each* core practical, will:

- Give you links to the specification content and highlight key areas to further your students' understanding.
- Contain key questions you can ask to focus your students, and get them thinking about why they are carrying out a particular practical in a certain way.
- Give you a sample question (where possible), with commentary relating to the assessment, which can be used as practice to consolidate students' understanding.

Changes to practical requirements in reformed GCSEs

There will not be any coursework in the GCSE (9–1) Science qualifications. Assessment of practical work is now included as part of the final exam, and a minimum of 15% of the total marks must be allocated to questions related to practical. In our exams, we will have questions on the core practicals in our specifications, as well as other questions on practicals related to the core practicals or techniques that students should be familiar with from their studies.

As well as the practical requirement, there is a list of apparatus and techniques that has been set out by the Department for Education (*Appendix 1*). Specifications must give students opportunities to cover the relevant apparatus and techniques, and this list has been mapped to our core practicals to show you how we are covering all of the requirements. As long as you carry out all of the core practicals, you will automatically cover the apparatus and techniques list. If you want to see how our core practicals map to this list, it is mapped (along with maths skills) in *Appendix 2*.

Approach to core practicals

In order to meet the requirements set out by Ofqual, you need to ensure your centre confirms that reasonable steps have been taken to secure that each learner has completed the practical activities set by us, and has made a contemporaneous record of the practical work and knowledge, skills and understanding derived from those practical activities.

The purpose of this statement is to ensure that practical work remains an important part of GCSE Science. In your day-to-day teaching, this just means that you need to ensure you cover the core practicals outlined by us and that your students are recording the work that they are doing as part of carrying out the core practicals. In practice, this could just be completing worksheets, taking results and doing some analysis or writing notes in their exercise books as a follow up to carrying out the practical. If you prefer, you can use a separate lab book for practical work, but this is not necessary. Indeed, as students will be required to have knowledge of these practical techniques and procedures for the final exam, it may be better to have this practical work sit alongside the relevant theoretical knowledge.

It is important to note that the approach to covering core practicals should be the same approach as you currently take to practical work in your science lessons. If you occasionally cover particular techniques as a carousel, or split students into groups to take readings, there is no reason why you cannot still do this—as long as you have taken reasonable steps to ensure your students all acquire experience of carrying out that particular procedure or technique.

Assessment of practical work

As a centre, you need to confirm that you have taken reasonable steps to ensure that each student has completed the compulsory core practicals and that the evidence for this is recorded. The practical record must include the knowledge, skills and understanding which that student has derived from those practical activities. To confirm that this has been done, centres must complete and submit an *authentication sheet* to confirm that all students have completed these core practicals. This authentication sheet can be found as an appendix in the specifications.

By signing this authentication sheet, you are confirming that reasonable steps have been taken to ensure that all students have been given the opportunity to carry out the core practicals outlined in the specifications. If students are ill or miss core practicals for any reason beyond the school's control, it does not require you to run catch up sessions for those individual students.

In exam papers, practical work will be assessed across the assessment objectives. The sample questions included in this core practical guide outline how you can use that question to consolidate your students' understanding of that particular core practical. The exam papers will assess student's understanding of the practical work, and they will be at an advantage if they have carried out all the core practicals in the course.

Maths skills

Practical activities offer a wide range of opportunities to cover particular mathematical skills. As part of this guide, we have outlined where there are good opportunities to cover mathematical techniques as part of each core practical. There is also a mapping in *Appendix 2* which maps the maths skills outlined by the DfE to the relevant core practical.

Note: There is a Guide to Maths for Scientists which you can download from the Edexcel website. This guide outlines the content that students will have covered in their maths lessons throughout KS3 and KS4. You can use this guide to help you understand how different areas are approached in maths, and therefore support your teaching of mathematical content in science lessons.

Chemistry

There are five core practicals in the chemistry section of GCSE Combined Science. GCSE Chemistry covers the same five practicals as well as an additional three, to make up eight core practicals in total.

This chemistry section outlines each core practical and gives a brief description of each one. The final part goes through each core practical in turn and outlines key skills as well as an extract of a sample exam question that links to the core practical.

Chemistry core practical descriptions

Note: 5.9C, 9.6C and 9.28C are separate GCSE Chemistry only.

Core practical		Description
2.11	*Investigate the composition of inks using simple distillation and paper chromatography*	This core practical is in two parts; a simple chromatography practical to obtain a chromatogram of dyes in ink and using simple distillation apparatus to separate pure water from ink. It needs to cover usage of a Bunsen burner, methods used in chromatography and distillation and safety of handling liquids.
3.6	*Investigate the change in pH on adding powdered calcium hydroxide or calcium oxide to a fixed volume of dilute hydrochloric acid*	This practical focuses on recording the pH at intervals when calcium hydroxide or calcium oxide reacts with dilute hydrochloric acid. An initial mass of the solid must be added to a fixed volume of the acid, and the pH recorded each time more of the solid is added to the acid. The pH can be recorded using a pH meter, or universal indicator paper with a glass rod used to take a pH measurement at each interval.
3.17	*Investigate the preparation of pure, dry hydrated copper sulfate crystals starting from copper oxide including the use of a water bath*	Excess copper oxide must be added to warm dilute sulfuric acid (warmed using a water bath), which will react to produce a blue solution of the salt copper(II) sulfate. The solution then needs to be filtered using filter paper and evaporated using an evaporating basin and Bunsen burner, followed by final drying using a watch glass to allow all the water to evaporate.
3.31	*Investigate the electrolysis of copper sulfate solution with inert electrodes and copper electrodes*	This involves setting up an electrolysis to investigate the effect of changing the current on the mass of the copper electrodes used in the electrolysis of copper sulfate solution. The second part of this investigation covers the products formed during the electrolysis of copper sulfate solution using inert (graphite) electrodes. Quantitative analysis when using copper electrodes will be expected.

5.9C	*Carry out an accurate acid-alkali titration, using burette, pipette and a suitable indicator*	A titration is carried out to determine the volume of hydrochloric acid required to neutralise a solution of unknown concentration of sodium hydroxide. An indicator must be used to determine the end point. Standard procedure for a titration must be carried out, such as the use of a white tile and swirling the conical flask to obtain an accurate end point. The data must then be used to determine the concentration of the unknown solution.
7.1	*Investigate the effects of changing the conditions of a reaction on the rates of chemical reactions by:* *a measuring the production of a gas (in the reaction between hydrochloric acid and marble chips)* *b observing a colour change (in the reaction between sodium thiosulfate and hydrochloric acid)*	This investigation is in two parts. Both parts require the reaction to be observed with respect to time to obtain the rate. In the first part, marble chips must be added to hydrochloric acid, and the volume of gas collected and measured over time. This will lead to graphical analysis to calculate rate, as well as an appreciation for how the rate may change with varying concentration of acid/temperature/surface area of marble chips. The second part involves sodium thiosulfate reacting with dilute hydrochloric acid to produce a precipitate using the idea of a 'disappearing cross' to observe the change in the appearance of the reaction mixture as a precipitate of sulfur is formed. This must be carried out at different temperatures by warming the thiosulfate solution. A graph must be drawn to show the time taken for the reaction to take place at different temperatures.
9.6C	*Identify the ions in unknown salts, using the tests for the specified cations and anions in 9.2C, 9.3C, 9.4C, 9.5C*	Tests must be carried out to determine the ions present as described in specification points 9.2C, 9.3C, 9.4C and 9.5C. This will include gas tests, flame tests and precipitation reactions.
9.28C	*Investigate the temperature rise produced in a known mass of water by the combustion of the alcohols ethanol, propanol, butanol and pentanol*	Apparatus set up to measure the increase in temperature when the different fuels given are burnt. This must lead to a comparison of the results for the four alcohols.

Core practical 1: Investigating the composition of inks

2.11 Core practical: Investigate the composition of inks using simple distillation and paper chromatography

Links to the specification content

2.7	Explain the experimental techniques for separation of mixtures by:	
	a	simple distillation
	e	paper chromatography
2.9	Describe paper chromatography as the separation of mixtures of soluble substances by running a solvent (mobile phase) through the mixture on the paper (the paper contains the stationary phase), which causes the substances to move at different rates over the paper	
2.10	Interpret a paper chromatogram:	
	a	to distinguish between pure and impure substances
	b	to identify substances by comparison with known substances
	c	to identify substances by calculation and use of R_f values

Introducing the practical

This practical is in two sections – simple distillation and paper chromatography of inks. You can carry out the practical in one session or two, depending on the length of your lesson. Many of your students will have carried out these practicals as part of their Key Stage 3 course so this activity can be used to revise the techniques as well as introduce the additional theory required for chromatography.

Link to GCSE Science 2011: 'Using paper chromatography to separate inks, food dyes etc' is a suggested practical in GCSE Chemistry 2011 Unit C2 Topic 3.

Chromatography

Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- Why is it important to draw the lines and write labels on the chromatography paper in pencil and not in ink?
- Why should the spots of ink be above the level of the solvent in the beaker?
- What is meant by the term 'solvent front'?
- What would happen if you used permanent ink instead of water soluble ink? How could you overcome this problem?
- Which is the mobile phase? Which is the stationary phase?
- Which ink(s), if any, contain one dye? Which ink(s) are mixtures of dyes? Which inks contain the same dye?

Skills that are covered in the practical:

- Measuring distance travelled by solvent
- Measuring height of dye above start line (estimate to centre of spot)
- Ability to manipulate apparatus for chromatography, recording observations (e.g. number of dyes in each ink, distance travelled by solvent, height of each dye above start line)
- Ability to carry out investigation safely

Maths skills:

- Interpreting a chromatogram
- Recording measurements accurately (1 dp)
- Substituting values correctly into expression for R_f, calculating the R_f value for the different dyes, giving answer to an appropriate number of significant figures

Distillation

Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- Why do you need to heat the tube of ink gently?
- What is the temperature on the thermometer when the water is distilling off?
- Why does the collection tube need to be surrounded by crushed ice?
- What are the main errors in this procedure?
- How can you improve the procedure?

Skills that are covered in the practical:

- Measuring the temperature
- Ability to heat gently and safely
- Ability to manipulate apparatus for simple distillation
- Recording observations (e.g. colour of distillate)
- Ability to carry out investigation safely

Maths skills – not relevant here.

Edexcel GCSE (9–1)
Sciences

Chem CP1a Chromatography of ink

Your teacher may watch to see if you can:

- follow instructions carefully
- draw conclusions from your results.

Introduction

Many inks contain a mixture of dyes. This method can be used to identify inks – for example inks from crime scenes or from documents that may have been forged.

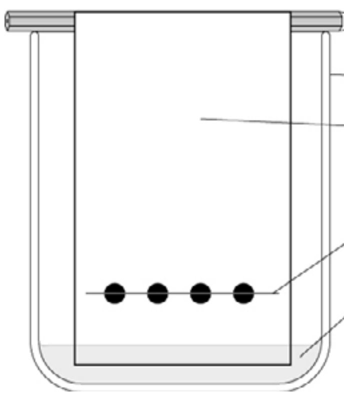
Aim

You are going to test some inks to see how many dyes they contain. You will then plan your own investigation.

Method

Apparatus

- beaker
- **chromatography** paper attached to rod
- 4 black marker pens or felt-tip pens



A Check that your chromatography paper hangs close to the bottom of the empty beaker without touching it (as shown in the diagram).

B Take the paper out of the beaker and draw a pencil line on the paper, about 2 cm from the bottom.

C Put a small spot of ink from each pen on your pencil line.

D Label underneath each spot with a pencil.

E Pour some water into the beaker to a depth of about 1 cm.

F Lower the chromatography paper into the beaker so that the bottom of the paper is in the water, but the water level is below the spots.

G Leave the paper in the beaker until the water reaches near the top of the paper.

H Take the paper out and immediately use a pencil to mark the location of the solvent front (the level the water has reached) before it evaporates. Leave it to dry.

Recording your results

1 Describe the coloured dyes that mixed to produce the black ink in each pen.

2 Measure the distance the solvent has risen from the pencil line.

3 Measure the distance that each dye spot has risen from the pencil line. Write your results in a table.

Considering your results

4 Calculate the **R_f value** for each separate colour in the four inks.

5 Were any of the black inks a pure colour? Explain your conclusion.

6 Did the same coloured dyes appear in more than one ink? If so, do you think they were the same chemical compound? Explain your answer.

Evaluation

7 Why was the starting line drawn in pencil?

8 Why did you have to label the spots?

9 Why is the chromatography paper hung with the bottom just in the water?

10 Why must the water level in the beaker be below the spots?

11 How easy was it to identify the level to which each coloured dye had travelled? How would this affect the accuracy of the R_f values you calculated?

Chromatography investigations

Now you have seen how to investigate the dyes used to make some black inks, you can use the same techniques for other investigations.

1 Choose one of the following questions:

- Do any inks used in felt-tipped pens or marker pens consist of just one dye?
- Are some coloured inks usually a mixture of more dyes than other colours of ink?
- Are similar mixtures of dyes used in the black ink in pens with permanent inks? (‘Permanent’ inks are those that do not dissolve in water, so you will also need to investigate the best solvent to use.)

2 Write a plan for your investigation, explaining which inks you will test and how you will analyse your **chromatogram**.

⚠ Safety

Many solvents are flammable.

3 Show your plan to your teacher before you start.

Poison pen letter

The police have been asked to find out who has been writing nasty letters to people. It is not easy to obtain ink samples from a letter, so only one chromatogram can be made using this ink. You will be allowed to look at this chromatogram.

The police have several suspects, and have taken pens from their houses. Your task is to test the ink in the pens to see if any of them match the ink used on the letter.

4 Write a plan to explain how you will try to find out if any of the pens could have been used to write the letter. In your plan you should explain:

- why you will need to calculate R_f values for the different dyes in the inks you will test
- why you need to use the same solvent and same kind of paper in your investigation as the solvent and paper used for the chromatogram made using ink from the letter
- whether or not the results of your investigation will *prove* that one of the suspects wrote the letter.

5 When you have carried out your investigation, write a short report for the police. Your evidence may be used in court, so your report should include:

- a brief description of what you did to test the inks, and how you decided if any of them matched the ink from the letter
- an evaluation of your results to show how confident you are about your conclusion.

Edexcel GCSE (9–1)
Sciences

Chem CP1b

Distillation

Name ______________ **Class** __________ **Date** __________

Your teacher may watch to see if you can:

- carry out experiments safely, reducing the risks from hazards.

Aim

To use **distillation** to produce pure water from ink.

Method

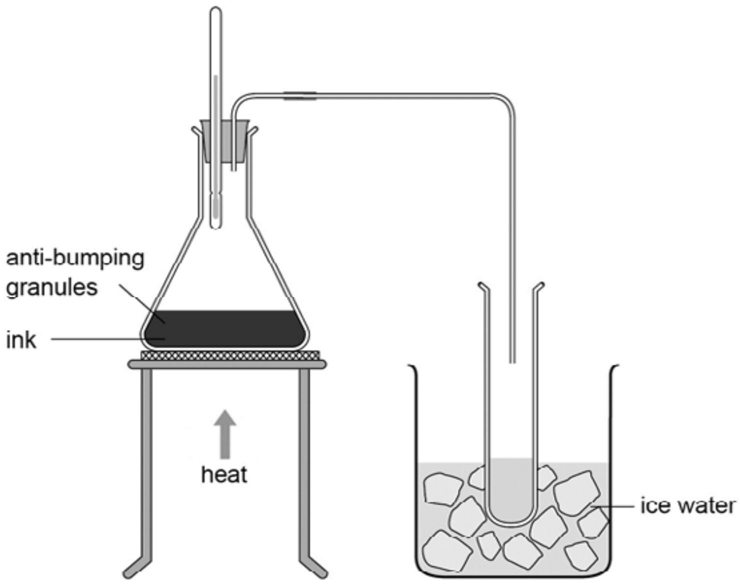
Apparatus

- eye protection
- conical flask
- delivery tube
- test tube
- ink
- Bunsen burner
- gauze
- 2-hole rubber bung with thermometer
- 250 cm^3 beaker
- ice
- tripod
- heat-resistant mat

⚠ Safety

Eye protection should be worn at all times.

Anti-bumping granules should be used to reduce the risk of the liquid boiling over.



A Set up your apparatus as shown in the diagram.

B Adjust the Bunsen burner so that you have a gentle blue flame.
The air hole should be about half open and the gas tap should be about half on.

C Heat the ink until it boils.

D Collect the distillate in the test tube and note the temperature of the vapour.

Planning and predicting

1 When you distil the ink, how will you know if you have successfully purified the water?

2 Predict the temperature reading on the thermometer when the ink is boiling. Explain your answer.

3 What is the purpose of the ice water shown in the diagram?

4 The conical flask might be knocked off the tripod.

a Why is the conical flask a hazard?

b How can the risk of harm from this hazard be reduced?

5 Suggest one other hazard and a way of reducing the risk from this hazard.

6 What air hole and gas settings should you have for the Bunsen burner:

a when you are not using it

b when you are using it to heat the ink?

Considering your results

7 Did you purify the water successfully? Explain your answer.

8 Explain what happened when the ink was distilled. In your explanation, use the following words: boil, condenser, **evaporate**, liquid, steam, temperature, vapour.

Chem CP1a Paper chromatography

Objectives

C2.7 Explain the experimental techniques for separation of mixtures by:

(e) paper chromatography.

C2.9 Describe paper chromatography as the separation of mixtures of soluble substances by running a solvent (mobile phase) through the mixture on the paper (the paper contains the stationary phase), which causes the substances to move at different rates over the paper.

C2.10 Interpret a paper chromatogram:

(a) to distinguish between pure and impure substances

(b) to identify substances by comparison with known substances

(c) to identify substances by calculation and use of Rf values.

C2.11 *Investigate the composition of inks using simple distillation and paper chromatography*.

Maths requirements

1c Use ratios, fractions and percentages.

3a Understand and use the symbols: =, <, <<, >>, >, ∝ and ~.

3c Substitute numerical values into algebraic equations using appropriate units for physical quantities.

4a Translate information between graphical and numeric form.

Learning outcomes

5th **SC2.7** Describe how some mixtures can be separated by chromatography.

6th **SC2.9** Draw and interpret diagrams showing how chromatography is done.

6th **SC2.9** Explain how substances can be separated by chromatography.

5th **SC2.10** Identify pure substances and mixtures on chromatograms.

5th **SC2.10** Identify substances that are identical on chromatograms.

6th **SC2.10** Calculate R_f values and use them to identify substances.

Exploring

1. Chromatography of ink – Core practical

This practical forms part of the core practical requirement of the specification. It is supported by the information in the Student Book *SC2c Paper chromatography*. Students' sheet CP1a(Investigating composition of Ink) provides instructions to help students to compare the mixtures of dyes in the inks used in black marker pens or felt-tip pens. Have a selection of pens available, labelled with letters for ease of identification. These should be tested before the lesson to ensure that they do contain different mixtures of dyes. One set of pens will be sufficient for the whole class. Alternatively bottles of black inks from different manufacturers could be used instead of pens.

This is a relatively simple procedure, similar to chromatography investigations that students will have done during KS3 work. The second side of the worksheet contains two separate sheets that can be used to help students plan a further investigation. The first suggests investigating the mixtures of dyes in inks other than black, or looking at mixtures in 'permanent' inks. Students will need to use solvents other than water for this.

The second sheet uses a crime scenario, asking students to test different pens to see if one of them could have been used to write a 'poison pen' letter. Have a selection of pens available, and also a pre-prepared chromatogram made from one of them, with the final solvent level marked to allow students to make R_f calculations from it. This is the chromatogram supposedly made using ink extracted from the letter. Also have available a short paragraph of text describing how the chromatogram was made. You could follow this up by discussing whether or not identifying the type of pen used for writing the letter actually proves that the suspect from whose home the pen was taken was the writer (no – because many other people own a similar pen; or the pen could have been left in their home by someone else).

⚠ Safety

The solvent suggested for biro ink is flammable and harmful – ensure there are no naked flames in the lab.

Support: The further investigation looking at the range of dyes in different coloured pens is the most suitable for students working at this level. Help them to write a simple plan for their investigation, and check that their apparatus is set up correctly to obtain suitable chromatograms.

Stretch: If doing the 'Poison Pen' activity, some of the pens provided could contain water-soluble inks and some could contain permanent inks – this will allow rapid elimination of some of them. In addition, students could be provided with several types of chromatography paper, so they will need to find out the type of paper used in the pre-prepared chromatogram and use that type so that they can compare R_f values.

Expected results

Black inks usually include black dyes and blue dyes, and sometimes other colours as well. The results of the other investigations will depend on the pens available.

Course resources

Chem Students' sheet CP1a

Equipment

250 cm^3 beaker, chromatography paper cut to fit the beaker used and stapled to a splint or attached to a pencil or glass rod using paper clips, four different black felt pens or water-soluble marker pens labelled A–D

For the chromatography investigations: selection of different coloured marker pens or felt-tip pens, selection of pens with 'permanent' (non-water-soluble) inks, solvent that will dissolve the permanent ink (for biro ink a mixture of butan-1-ol, ethanol, water (3:1:1 by volume) is suitable; and the addition of a few drops of 880-ammonia may produce a better chromatogram). For other permanent inks try ethanol, propanone or propan-2-ol, but test them before the lesson to see if they work with the pens to be used.

For the 'Poison Pen' investigation: selection of four or more pens of one colour (blue or black) with different combinations of dyes, labelled Suspect 1, Suspect 2 etc, pre-prepared chromatogram made using one of the pens using the same paper that students will use, suitable solvent (see above) if the pens to be tested have permanent inks.

Edexcel GCSE (9–1)
Sciences

Chem CP1b

Distillation

Objectives

C0.6 Evaluate the risks in a practical procedure and suggest suitable precautions for a range of practicals including those mentioned in the specification.

C2.7 Explain the experimental techniques for separation of mixtures by:

(a) simple distillation

(b) fractional distillation (links to a Maths statement).

C2.11 *Investigate the composition of inks using simple distillation and paper chromatography*.

Maths requirements

1c Use ratios, fractions and percentages.

4c Plot two variables from experimental or other data.

Learning outcomes

5th **SC2.7** Describe how to carry out, and explain what happens in, simple distillation.

7th **SC2.7** Distinguish between simple distillation and fractional distillation.

7th **SC2.7** Identify when fractional distillation should be used to separate a mixture.

7th **SC2.7** Describe how to carry out fractional distillation.

9th **SC2.7** Explain how the products of fractional distillation are linked to the boiling points of the components.

6th **SC2.7** Explain what precautions are needed to reduce risk in a distillation experiment.

Exploring

1. Distillation – Core practical

This practical forms part of the core practical requirement of the specification. It is supported by the information in the Student Book *SC2d Distillation*. Students follow the instructions on Students' sheet CP1b (Investigating composition of Ink -Distillation). The first page has the experimental instructions. Ink will show an obvious visual indication that the water has been purified. Depending on the precise dimensions of the delivery tube, the beaker of ice water may need to be supported above bench height.

Support: Demonstrate the procedure first, showing how to clamp the flask and how to heat it gently.

Stretch: Give students a list of available apparatus and ask them to design their own set-up to successfully purify the water, instead of giving them the first page of the worksheet with instructions to follow.

⚠ Safety

Wear eye protection.

Warn students of the risk of scalding from hot steam. Explain the use of anti-bumping granules to help the liquid boil more smoothly and reduce the risk of boiling over.

Expected results

Students will produce a clear liquid (pure water) as the distillate. The steam should have a temperature of 100 °C.

Course resources

Chem Students' sheet CP1b

Equipment

For each group: eye protection, conical flask, 2-hole rubber bung with thermometer, delivery tube, test tube, beaker (250 or 400 cm^3), crushed ice, Bunsen burner, tripod, gauze, heat-resistant mat, ink, anti-bumping granules

Sample question

This example is taken from the sample assessment material, paper 1CH0/1H, Q1. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

1 Mixtures of coloured substances can be separated by paper chromatography.

(a) Paper chromatography was used to separate a mixture of blue and red inks.
A spot of the mixture was placed on chromatography paper as shown in Figure 1.

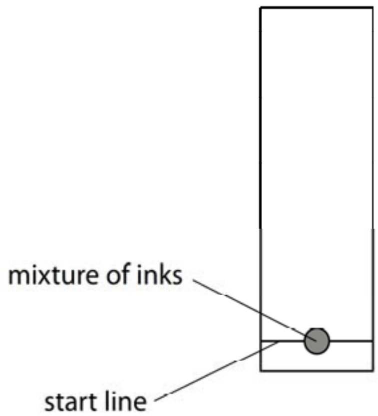


Figure 1

(i) Give a reason why the start line is drawn in pencil rather than in ink.

(1)

....

....

Question number	Answer	Mark
1(a)(i)	Pencil is insoluble in the solvent (but chromatography would separate the ink in an ink line).	**(1)**

Here, students are expected to know a practical detail about chromatography. They will have carried out a method such as this when looking at inks, so this links directly to a core practical they should have experienced as part of the course. It focuses on their understanding of the method, and why certain parts of the method are done in a certain way, such as using pencil instead of pen.

(ii) The chromatography paper, with the spot of mixture on it, was placed in a beaker with the bottom of the paper in water.

On Figure 2, complete the diagram showing the position of the chromatography paper with the spot of mixture at the start of the experiment.

(1)

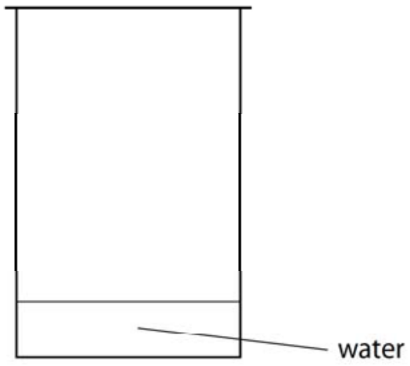
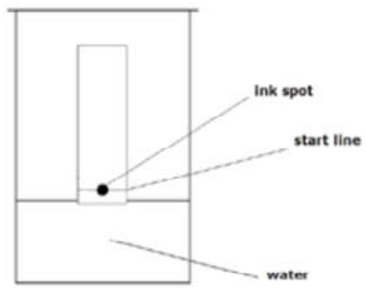


Figure 2

Question number	Answer	Mark
1(a)(ii)	Correct position of chromatography paper with start line and ink spot above surface of water. 	**(1)**

Again, students are expected to know a practical detail about chromatography. It focuses on students being aware of how to place the chromatography paper into a beaker of water, why it is important to make sure the ink spot is above the surface of water, and how the initial ink spot should be set up on the pencil line.

(iii) The chromatography was carried out and the result is shown in Figure 3.

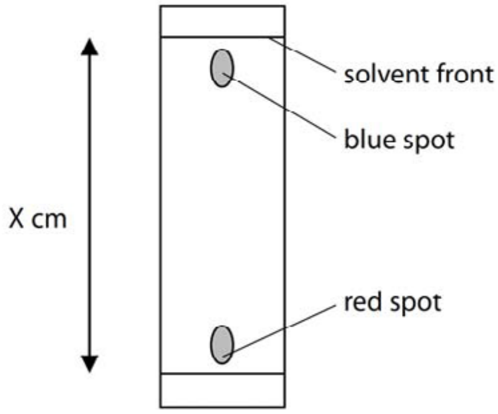


Figure 3

The blue spot had moved 14.5 cm and the solvent front had moved 15.3 cm.

Calculate the R_f value of the substance in the blue spot, giving your answer to 2 significant figures.

$$R_f \text{ value} = \frac{\text{distance travelled by a dye}}{\text{distance travelled by solvent front}}$$

(2)

R_f value = ...

Question number	Answer	Additional guidance	Mark
1(a)(iii)	• R_f = 14.5 / 15.3= 0.9477 (1) • = 0.95 (answer to 2 significant figures) (1)	Award full marks for correct numerical answer without working.	**(2)**

Students should be able to calculate an R_f value and understand the meaning of 2 significant figures. This brings out the mathematical requirement in chemistry, and exemplifies the sort of question that could be asked to focus on the maths requirements.

(b) **P**, **Q**, **R** and **S** are mixtures of food colourings.
They are investigated using paper chromatography.
Figure 4 shows the chromatogram at the end of the experiment.

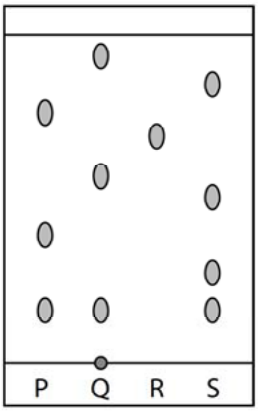


Figure 4

(i) Which mixture contains an insoluble food colouring?

(1)

- ☒ **A** mixture **P**
- ☒ **B** mixture **Q**
- ☒ **C** mixture **R**
- ☒ **D** mixture **S**

Question number	Answer	Mark
1(b)(i)	B	(1)

Students should understand that an insoluble substance will not move up the chromatography paper.

(ii) Give a change that could be made to the experiment to obtain an R_f value for the insoluble colouring.

(1)

....

....

Question number	Answer	Mark
1(b)(ii)	use a different solvent.	(1)

This question tests the understanding that different solvents can be used for chromatography. It applies their knowledge of chromatography as a method of separating mixtures.

(iii) Explain, by referring to Figure 4, which mixture is separated into the greatest number of soluble food colourings by this chromatography experiment.

(2)

....

....

....

....

(Total for Question 1 = 8 marks)

Question number	Answer	Mark
1(b)(iii)	An explanation that combines identification via a judgement (1 mark) to reach a conclusion via justification/reasoning (1 mark): • mixture S (1) • because it gives the greatest number of spots/gives four spots (1)	**(2)**

Students should be able to interpret chromatograms. Here, it is not necessarily the chromatogram they will have looked at, but it focuses on applying their understanding of how to interpret the chromatogram and understanding the meaning of features such as why there may be more spots in some mixtures.

Core practical 2: Investigating pH (neutralisation)

3.6 Core practical: Investigate the change in pH on adding powdered calcium hydroxide or calcium oxide to a fixed volume of dilute hydrochloric acid

Links to the specification content

3.1	Recall that acids in solution are sources of hydrogen ions and alkalis in solution are sources of hydroxide ions
3.2	Recall that a neutral solution has a pH of 7 and that acidic solutions have lower pH values and alkaline solutions higher pH values
3.4	**Recall that the higher the concentration of hydrogen ions in an acidic solution, the lower the pH; and the higher the concentration of hydroxide ions in an alkaline solution, the higher the pH**

Introducing the practical

This practical involves adding different masses of calcium oxide or hydroxide to a fixed volume of hydrochloric acid and measuring the pH after each addition until the base is in excess.

You may wish the students to use universal indicator paper for this experiment. They can place small pieces of the paper on a white tile and use a glass rod to transfer a drop of solution after each addition of calcium hydroxide or calcium oxide to the paper. They then compare the colour with a pH chart and record the pH value. It is helpful if you can demonstrate the use of a digital pH probe for this experiment.

Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- What is the best piece of apparatus to measure the volume of hydrochloric acid?
- Why is that the best piece of apparatus?
- How do you use universal indicator paper to measure the pH of the solution?
- Why is it necessary to stir the mixture when the calcium hydroxide powder is added?
- What are the main errors in this experiment?
- How could you improve the method?
- How do you know when the hydrochloric acid is exactly neutralised?

Skills that are covered in the practical:

- measuring mass of calcium hydroxide
- measuring volume of hydrochloric acid
- measuring pH using universal indicator or a pH probe
- making observations of colour changes with universal indicator
- safe use and careful handling of calcium hydroxide and hydrochloric acid

Maths skills:

- plot a graph of pH against mass of calcium hydroxide or calcium oxide added
- translate information between graphical and numeric form, for example, use the graph to estimate the mass of calcium hydroxide or calcium oxide needed to neutralise the hydrochloric acid

Chem CP2

Neutralising an acid
Core Practical

Your teacher may watch to see if you can…
- carry out an experiment appropriately
- use apparatus accurately and safely.

Aim

Powdered calcium hydroxide reacts with hydrochloric acid. Calcium chloride solution and water are produced:

$$Ca(OH)_2(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$$

You will investigate what happens to the pH of a fixed volume of dilute hydrochloric acid when you add calcium hydroxide to it.

Apparatus

- eye protection
- 100 cm^3 beaker
- 50 cm^3 measuring cylinder
- ±0.1 g balance
- spatula
- stirring rod
- white tile
- universal indicator paper
- pH colour chart
- dilute hydrochloric acid
- calcium hydroxide powder
- graph paper

⚠ Safety

Wear eye protection.
Calcium hydroxide is an irritant with a risk of serious damage to eyes.
Dilute hydrochloric acid is an irritant.

Method

A Use the measuring cylinder to add 50 cm^3 of dilute hydrochloric acid to the beaker.

B Estimate and record the pH of the contents of the beaker:
- Put a piece of universal indicator paper onto the white tile.
- Dip the end of the glass rod into the liquid, then tap it onto the universal indicator paper.
- Wait 30 seconds, then match the colour to the appropriate pH on the pH colour chart.
- Rinse the glass rod with water.

C Measure out 0.3 g of calcium hydroxide powder onto a piece of paper or a ‘weighing boat’.

D Add the calcium hydroxide powder to the beaker, stir, then estimate and record the pH of the mixture.

E Repeat step **D** seven times so that you add a total of 2.4 g of calcium hydroxide powder to the acid.

Recording your results

1 Make a table with columns for the mass of calcium hydroxide powder added, and the pH of the mixture. Remember to leave a row for the first pH measurement (before you have added any calcium hydroxide).

Considering your results

2 Plot a line graph to show pH on the vertical axis and mass of calcium hydroxide added on the horizontal axis. Draw a curve of best fit.

3 Describe what happens to the pH of the reaction mixture as calcium hydroxide continues to be added.

4 Use your graph to determine the mass of calcium hydroxide that must be added to reach pH 7.

Evaluation

5 Explain one way to improve the accuracy of the experiment.

Edexcel GCSE (9–1) **Sciences**

Chem CP2

Alkalis and balancing equations

Objectives

C0.1 Recall the formulae of elements, simple compounds and ions.

C0.2 Write word equations.

C0.3 Write balanced chemical equations, including the use of the state symbols (s), (l), (g) and (aq).

C3.6 *Investigate the change in pH on adding powdered calcium hydroxide or calcium oxide to a fixed volume of dilute hydrochloric acid.*

C3.10 Recall that alkalis are soluble bases.

C3.11c Explain the general reactions of aqueous solutions of acids with metal hydroxides to produce salts.

Maths requirements

1c Use ratios, fractions and percentages.

4a Translate information between graphical and numeric form.

4c Plot two variables from experimental or other data.

Learning outcomes

6th **SC0.1** Recall the chemical formulae of some common compounds.

6th **SC0.3** Recall and use state symbols.

9th **SC0.3** Balance chemical equations.

4th **SC3.10** Recall that alkalis are soluble bases.

6th **SC3.11c** Describe the reactions of alkalis with acids.

Exploring

1. Neutralising an acid – Core practical

This is a Core practical in which students add successive weighed portions of calcium hydroxide powder to a fixed amount of dilute hydrochloric acid, and estimate the pH of the reaction mixture using universal indicator paper. They then plot a graph of pH against mass of calcium hydroxide added.

The practical activity on Students' sheet CP2 (Investigating pH) is written for the use of universal indicator paper to estimate pH, but you may prefer to use pH meters to measure the pH instead.

Support: Provide eight 0.3 g pre-weighed portions of calcium hydroxide powder to each group that needs it. Provide graph paper with suitable axes already drawn on it (pH 0–14 on vertical axis; mass of calcium hydroxide 0–2.4 g on horizontal axis). Additionally, or alternatively, Skills Sheets PD5 and PD6 may be useful in helping students to draw their graphs.

Stretch: Give students narrow range indicator paper to increase the precision of their pH estimates.

Expected results

The pH will increase as more calcium hydroxide is added, with the end-point at approximately 1.85 g of calcium oxide. Calcium hydroxide is sparingly soluble (about 0.17 g/100 cm^3 H_2O) so beyond this excess calcium hydroxide will be seen.

Course resources

Chem Students' sheet CP2

Equipment

eye protection, 100 cm^3 beaker, 50 cm^3 measuring cylinder, ±0.1 g balance, spatula, stirring rod, white tile, universal indicator paper, pH colour chart, dilute hydrochloric acid, calcium hydroxide powder, graph paper

⚠ Safety

Eye protection should be worn. Students should wash their hands afterwards. Calcium hydroxide is an irritant, with a risk of serious damage to eyes. Dilute hydrochloric acid is an irritant.

Sample question

This example is taken from the sample assessment material, paper 1CH0/1F, Q2. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

2 Ammonium phosphate and ammonium sulfate are made from ammonia.

These compounds can be used as fertilisers.

(a) Ammonia solution is alkaline.

Which of the following could be used to show that ammonia solution is alkaline?

(1)

☐ **A** conical flask

☐ **B** pH meter

☐ **C** pipette

☐ **D** thermometer

Question number	Answer	Mark
2(a)	B	**(1)**

This multiple-choice question expects students to know that a pH meter is used to show that a solution is alkaline.

This example is taken from the sample assessment material, paper 1CH0/1H, Q9. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

(ii) Give a reason why adding hydroxide ions to an acid solution leads to an increase in pH.

(1)

....

....

Question number	Answer	Mark
9(a)(ii)	hydroxide ions react with hydrogen ions and reduce the hydrogen ion concentration therefore increase pH (1)	**(1)**

This question occurs towards the end of a higher tier paper and expects students to know that hydroxide ions react with hydrogen ions to form water. The lower the concentration of hydrogen ions, the higher the pH of the solution.

Core practical 3: Preparing copper sulfate

3.17 Core practical: Investigate the preparation of pure, dry hydrated copper sulfate crystals starting from copper oxide including the use of a water bath

Links to the specification content

3.9	Recall that a base is any substance that reacts with an acid to form a salt and water only
3.11	Explain the general reactions of aqueous solutions of acids with: b metal oxides to form salts
3.13	Describe a neutralisation reaction as a reaction between an acid and a base
3.15	Explain why, if soluble salts are prepared from an acid and an insoluble reactant: a excess of the reactant is added b the excess reactant is removed c the solution remaining is only salt and water

Introducing the practical

Many students will have carried out this experiment or a similar salt preparation in Key Stage 3. It is important here to emphasise why each step is carried out.

It is important to use a water bath to evaporate some of the water from the copper sulfate solution in this experiment as that is one of the essential practical skills required. The students can use their own water baths by supporting the evaporating basin of copper sulfate solution on top of a beaker half-filled with water, which is heated by a Bunsen burner. You can demonstrate the use of an electric boiling water bath if there is one available.

Link to GCSE Science 2011: 'Carry out simple neutralisation reactions of acids, using metal oxides, hydroxides and/or carbonates' is a suggested practical in C1 Topic 3.

Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- What safety precautions should you take when carrying out this experiment and why?
- Why was it necessary to warm the sulfuric acid?
- What colour was the copper sulfate solution that formed?
- Why was it necessary to add copper oxide until it was present in excess?
- How did you know when the copper oxide was present in excess?
- How did you separate the excess copper oxide from the copper sulfate solution?
- What is meant by the filtrate?
- What is meant by the residue?
- What is the filtrate in this experiment?
- What is the residue in this experiment?
- Why is a water bath used to evaporate the water from the copper sulfate solution instead of heating the evaporating basin directly with a Bunsen burner?
- Why should you not evaporate all of the water from the copper sulfate solution?

Skills that are covered in the practical:

- Measuring the volume of sulfuric acid
- Safe use of a Bunsen burner for warming the sulfuric acid
- Safe use of a water bath or electric heater for evaporating some of the water from the copper sulfate solution
- Safe use of filtration to separate unreacted copper oxide from copper sulfate solution
- Safe use of evaporation to evaporate some of the water from the copper sulfate solution
- Safe use and careful handling of sulfuric acid, copper oxide and copper sulfate

Chem CP3

Preparing a soluble salt Core Practical

Your teacher may watch to see if you can…

- safely and correctly use apparatus.

Aim

To prepare a sample of pure, dry, hydrated copper sulfate crystals starting from copper oxide.

Apparatus

- eye protection
- 100 cm^3 conical flask
- 100 cm^3 beaker
- Bunsen burner
- gauze and tripod
- heat mat
- Petri dish or watch glass
- 100 cm^3 measuring cylinder
- evaporating basin
- spatula
- stirring rod
- filter funnel
- filter paper
- tongs
- water bath (set at 50 °C)
- dilute sulfuric acid
- copper(II) oxide

⚠ Safety

Wear eye protection at all times.

Method

A Pour about 20 cm^3 of dilute sulfuric acid into a conical flask.

B Place the conical flask into a water bath at 50 °C and heat for 3–4 minutes to allow the acid to heat up.

C Use the spatula to add a little copper oxide to the acid and stir or swirl the contents of the flask.

D Keep repeating step **C** until the black powder does not disappear after stirring. (This makes sure the copper oxide is in excess.)

E Return the mixture to the water bath for a few minutes (to make sure there is no more acid left).

F Filter the mixture into a beaker and pour into an evaporating basin.

G Place the evaporating basin on top of a beaker half full of water. Heat the beaker, evaporating basin and contents using a Bunsen burner on a blue flame.

H Heat until about half of the water has evaporated. Then allow the evaporating basin to cool.

I When cool, transfer the solution to a Petri dish or watch glass and leave for a few days to allow the water to evaporate.

J Observe the shape and colour of the copper sulfate crystals formed.

Step F

Step H

Name ______________________ Class __________ Date ____________

Recording your results

1 Describe the colour, shape and size of the copper sulfate crystals produced.

____

____

2 Describe the appearance of:

a the sulfuric acid ______________________________

____

b the copper oxide ______________________________

____

c the solution at the end of the reaction. ______________________________

____

Considering your results

3 Write a word equation to show the reaction you have carried out.

____

4 State why you need to be sure excess copper oxide is added in step **D**.

____

5 What would happen in step **E** if there was still some acid left?

____

6 Name the substance left in the filter paper in step **F**.

____

7 What is dissolved in the solution that went through the filter paper?

____

8 Explain why this is an example of a neutralisation reaction.

____

9 What substance acts as a base in this reaction?

____

10 Write a symbol equation to show the reaction you have carried out. Include the state symbols.

____

Objectives

C0.3	Write balanced equations, including the use of the state symbols (s), (l), (g) and (aq).
C3.9	Recall that a base is any substance that reacts with an acid to form a salt and water only.
C3.11b	Explain the general reactions of aqueous solutions of acids with metal oxides to produce salts.
C3.13	Describe a neutralisation reaction as a reaction between an acid and a base.
C3.15	Explain why, if soluble salts are prepared from an acid and an insoluble reactant: **a** excess of the reactant is added **b** the excess reactant is removed **c** the solution remaining is only salt and water.
C3.17	*Investigate the preparation of pure, dry hydrated copper sulfate crystals starting from copper oxide, including the use of a water bath.*

Maths requirements

1c	Use ratios, fractions and percentages.

Learning outcomes

5th	SC3.9	Describe how a base reacts in a neutralisation reaction.
6th	SC3.11	Describe what happens when an acid reacts with a metal oxide.
7th	SC3.11	Write word equations for the reactions of acids and metal oxides.
8th	SC3.11	Write symbol equations for the reactions of acids and metal oxides.
6th	SC3.13	Explain what happens during a neutralisation reaction.
6th	SC3.15	Describe the steps involved in preparing a soluble salt from an acid and an insoluble reactant.
6th	SC3.15	Explain why ● an excess of insoluble reactant is used when preparing a soluble salt ● the excess reactant is removed when preparing a soluble salt ● the remaining solution contains only a salt and water, when preparing a soluble salt from an acid and an insoluble reactant.

Exploring

1. Preparing a soluble salt – Core Practical

Students work in groups following the instructions on Students' sheet CP3 (Preparation of Copper Sulfate). In this case the salt is hydrated copper sulfate. Briefly discuss the steps involved in the preparation of the salt before the students start the investigation. Students should understand why:

- an excess of copper oxide has to be added
- the excess has to be removed
- only the salt and water are present in the solution after filtration.

There are different ways of carrying out this practical. For example, the experiment could be carried out in a boiling tube and step B could be done by placing the boiling tube in a beaker of water over a Bunsen burner.

To produce the largest and best-formed crystals of copper sulfate, the final solution should be kept dust free and allowed to evaporate as slowly and evenly as possible.

Support: Some students will need help with the word and symbol equations.

Stretch: Ask students to find out why certain salts could *not* be prepared by this method. For example, sodium sulfate cannot be made this way as sodium oxide is soluble and the excess could not be separated. Calcium sulfate could not be formed this way as it is insoluble in water and could not be separated from the metal oxide.

Expected results

Copper oxide and sulfuric acid form a soluble salt, copper sulfate. Students should be able to prepare a dry pure sample of copper sulfate crystals, which are blue in colour and diamond shaped.

⚠ Safety

Eye protection should be worn throughout this experiment.

Course resources

Chem Students' sheet CP3

Equipment (per group)

eye protection, 100 cm^3 conical flask, 100 cm^3 beaker, Bunsen burner, gauze, tripod stand, heat mat, Petri dish or watch glass, 100 cm^3 measuring cylinder, evaporating basin, spatula, stirring rod, filter funnel, filter paper, tongs, water bath (set at 50 °C), 1 mol dm^{-3} sulfuric acid, copper(II) oxide

Sample question

This example is taken from the sample assessment material, paper 1CH0/1F, Q2. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

(iii) Some ammonium phosphate solution was made.

Describe how pure, dry crystals of ammonium phosphate are obtained from the ammonium phosphate solution.

(2)

Question number	Answer	Mark
2(c)(iii)	An answer that combines the following points of application of knowledge and understanding to provide a logical description: • first heat the solution/leave water to evaporate (1) • and then filter off/dry crystals formed (1)	**(2)**

This question tests whether students know how to obtain pure, dry crystals of a soluble salt from a solution.

This example is taken from the sample assessment material, paper 1CH0/1H, Q9.

(b) The salt zinc nitrate can be made by reacting zinc oxide, ZnO, with dilute nitric acid, HNO_3.

Write the balanced equation for this reaction.

(2)

....

Question number	Answer	Mark
9(b)	$ZnO + 2HNO_3 \rightarrow Zn(NO_3)_2 + 2H_2O$ • zinc nitrate formula (1) • full, balanced equation (1)	**(2)**

This question tests whether students can write a balanced equation for a similar reaction to that in the core practical.

This example is taken from the sample assessment material, paper 1CH0/1H, Q9.

*(d) Salts of metals can be made by reacting one of the metal's compounds with the appropriate acid.

Plan an experiment to prepare pure, dry crystals of magnesium sulfate, $MgSO_4$, by reacting a suitable magnesium compound with a suitable acid.

You may use equations if you wish.

(6)

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Question Number	Indicative content
9(d)	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **AO2 (3 marks)** • suitable acid: sulfuric acid • suitable substance : magnesium oxide / magnesium carbonate / magnesium hydroxide / magnesium • equation for reaction: $MgO + H_2SO_4 \rightarrow MgSO_4 + H_2O$/ $Mg(OH)_2 + H_2SO_4 \rightarrow MgSO_4 + 2H_2O$/ $MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + H_2O + CO_2$/ $Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$ **AO3 (3 marks)** • add solid to warmed acid until in excess solid remains (oxide and hydroxide) / add solid a little at a time until no more bubbles (carbonate/metal) • filter off the excess solid, pour remaining solution into an evaporating basin • {heat solution / leave the water to evaporate} • until pure salt crystals form and then dry salt crystals with absorbent paper/leave to dry.

This extended writing question tests whether students can plan the preparation of a salt. Although the core practical is based on the preparation of copper sulfate from copper oxide, students should be able to apply their knowledge to the preparation of other similar salts. Magnesium oxide, magnesium carbonate or magnesium hydroxide would be suitable starting materials for this experiment. Students who have carried out the core practical should find questions like this fairly straightforward to do.

Core practical 4: Electrolysis of copper sulfate solution

3.31 Core practical: Investigate the electrolysis of copper sulfate solution with inert electrodes and copper electrodes

Links to the specification content

3.22	Recall that electrolytes are ionic compounds in the molten state or dissolved in water
3.23	Describe electrolysis as a process in which electrical energy, from a direct current supply, decomposes electrolytes
3.24	Explain the movement of ions during electrolysis, in which: a positively charged cations migrate to the negatively charged cathode b negatively charged anions migrate to the positively charged anode
3.25	Explain the formation of products in the electrolysis, using inert electrodes, of some electrolytes, including: a copper chloride solution c sodium sulfate solution
3.27	**Write half equations for reactions occurring at the anode and cathode in electrolysis**
3.30	Explain the formation of products in the electrolysis of copper sulfate solution, using copper electrodes, and how this can be used to purify copper

Introducing the practical

This practical is in two sections – the electrolysis of copper sulfate solution with inert (graphite) electrodes and the electrolysis of copper sulfate solution with copper electrodes. You can carry out the practical in one session or two, depending on the length of your lesson.

When inert electrodes are used, the students are just expected to identify and explain the formation of the products. The ability to write half equations for the reactions at the electrodes and classify them as oxidation or reduction will only be tested in the higher tier paper. The experiment with copper electrodes is quantitative and students can measure the mass changes at the electrodes when, for example, the current or the time is varied.

Link to GCSE Science 2011: 'Investigate the mass changes at the electrodes during the electrolysis of copper sulfate solution using copper electrodes' is a core practical in C3 Topic 3.

Questions you could ask to enhance learning and focus your students on important aspects of the practical:

Electrolysis of copper sulfate solution using inert electrodes

- What safety precautions should you take when carrying out this experiment and why?
- What did you observe at the anode?
- How do you explain the formation of the product at the anode?
- **Write the half equation for the formation of the product at the anode and explain whether it is oxidation or reduction.**
- What did you observe at the cathode?
- How do you explain the formation of the product at the cathode?
- **Write the half equation for the formation of the product at the cathode and explain whether it is oxidation or reduction.**
- What happens to the colour of the solution during the electrolysis?
- If the electrolysis is continued for a long time, what will be left in the solution?

Electrolysis of copper sulfate solution using copper electrodes

- What safety precautions should you take when carrying out this experiment and why?
- Why is it necessary to clean the copper electrodes with emery paper before using them?
- Why do you use an ammeter in the circuit?
- Why do you use a variable resistor in the circuit?
- Why is it necessary to measure the time taken for the electrolysis?
- Which factors should be kept the same during the electrolysis?
- How do you wash and dry the electrodes at the end of the electrolysis?
- Why is it necessary to dry the electrodes?

Skills that are covered in the practical:

- Measure the mass of the copper electrodes
- Measure time
- Set up an electrical circuit for electrolysis
- Use an electrical circuit to carry out electrolysis
- Safe use and careful handling of copper sulfate solution and propanone (for drying the electrodes)
- Draw a circuit diagram for electrolysis

Maths skills:

- Use numbers in decimal form when calculating mass changes at the electrodes
- Plot graphs of mass changes against time or current
- Understand that $y = mx + c$ represents a linear relationship between the variables
- Translate information between graphical and numeric form, for example, predict the mass change when the current is a given value or vice versa

Edexcel GCSE (9–1) **Sciences** **Chem CP4** **Electrolysis of copper sulfate solution – Core practical**

Your teacher may watch to see if you can…

- follow instructions carefully
- make accurate measurements.

Aim

To electrolyse copper sulfate solution using inert (graphite) **electrodes** and copper electrodes.

Method 1 – Using copper electrodes

Apparatus

- eye protection
- emery paper
- low voltage d.c. supply
- ammeter
- variable resistor
- connecting leads
- crocodile clips
- 100 cm^3 beaker
- stop clock
- 2 graphite rods
- 2 pieces of copper foil
- copper sulfate solution
- access to propanone (in a fume cupboard)
- access to a balance
- graph paper

Safety

Wear eye protection.

Propanone is an irritant. It is highly flammable; there must not be any naked flames in the laboratory.

A Select two pieces of copper foil to use as electrodes and clean them with emery paper.

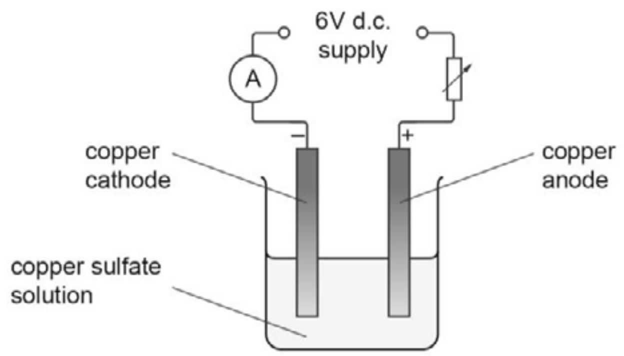
Label one of the electrodes as '**anode**' and the other as '**cathode**'.

B Measure and record the mass of each electrode.

C Half fill the beaker with copper sulfate solution.

D Set up the circuit as shown in diagram A.

E Turn the power on and adjust the variable resistor to give a current of 0.2 A. Record the current. Leave the power on for 20 minutes, adjusting the variable resistor to keep the current constant, if necessary.



***A** circuit diagram for the **electrolysis** of copper sulfate solution using copper electrodes*

F Turn off the power and remove the electrodes from the beaker.

G Gently rinse the electrodes with distilled water then dip them into propanone. Remove the electrodes from the propanone and gently shake them until the propanone evaporates.

H Measure and record the masses of the dry electrodes.

I Repeat the experiment using currents of 0.3 A, 0.4 A and 0.5 A.

Recording your results

1 Record your results in a table, including the change in mass of each electrode.

Considering your results/Conclusions

2 Plot suitable graphs to look for a correlation between the change in mass of each electrode and the current.

3 Describe the relationship between the change in mass at each electrode and the current.

4 Explain the changes in mass of each electrode.

5 Use the graph to predict the change in mass of the anode when the current is 0.35 A.

6 Suggest a reason why the change in mass at the cathode is not the same as the change in mass at the anode when the same current is used.

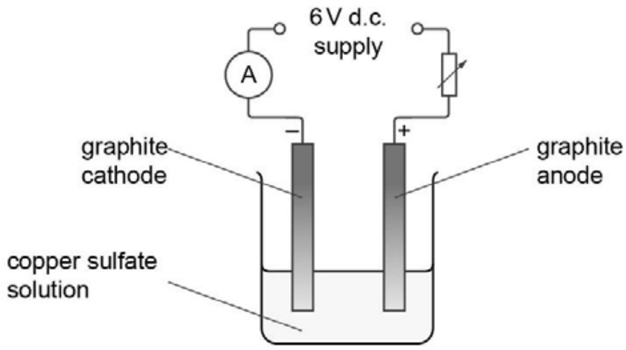
7 Describe how you could improve the experiment to be more certain that the data collected is correct and free from error.

Method 2 – Using inert electrodes

J Set up the circuit as shown in diagram B.

K Turn the power on.

L Observe what happens at each electrode.



***B** circuit diagram for the **electrolysis** of copper sulfate solution using graphite electrodes*

Recording your results

8 Record your observations and the name of the product formed at each electrode.

Considering your results/Conclusions

9 Explain the formation of the product at each electrode.

10 H Write a **half equation** for the formation of the product at each electrode and classify each reaction as **oxidation** or **reduction**.

Objectives

C3.22 Recall that electrolytes are ionic compounds in the molten state or dissolved in water.

C3.23 Describe electrolysis as a process in which electrical energy, from a direct current supply, decomposes electrolytes.

C3.24 Explain the movement of ions during electrolysis, in which:

- **a** positively charged cations migrate to the negatively charged cathode
- **b** negatively charged anions migrate to the positively charged anode.

C3.27 **H** Write half equations for reactions occurring at the anode and cathode in electrolysis.

C3.28 **H** Explain oxidation and reduction in terms of loss or gain of electrons.

C3.29 **H** Recall that reduction occurs at the cathode and that oxidation occurs at the anode in electrolysis reactions.

C3.31 *Investigate the electrolysis of copper sulfate solution with inert electrodes and copper electrodes.*

Maths requirements

1a Recognise and use expressions in decimal form.

1c Use ratios, fractions and percentages.

4a Translate information between graphical and numeric form.

4b Understand that y = mx + c represents a linear relationship.

4c Plot two variables from experimental or other data.

4d Determine the slope and intercept of a linear graph.

Learning outcomes

6th **SC3.22** State the meaning of the term ‘electrolyte’.

7th **SC3.23** Outline what happens during electrolysis.

7th **SC3.24** Explain the movement of the ions during electrolysis.

8th **SC3.27** **H** Write half equations for the reactions at the electrodes.

9th **SC3.28** **H** Explain the meaning of oxidation and reduction in terms of the movement of electrons.

8th **SC3.29** **H** State the electrodes at which oxidation and reduction occur.

Exploring

1. Core practical – Electrolysis of copper sulfate solution

This practical forms part of the core practical requirement of the specification. It is supported by the information on *Students' sheet CP4(Electrolysis-copper sulfate solution)* and in the Student Book.

A set of instructions for this practical is given on Students' sheet CP4 (Electrolysis).

There are two parts to the core practical – electrolysis of copper sulfate solution, first using copper electrodes and second using inert (graphite) electrodes. You may wish to split this over two or more lessons, depending on the length of your lessons.

Method 1 involves the electrolysis using copper electrodes and is quantitative as students measure the mass change of the electrodes using different currents. Students should use fresh copper sulfate solution for this experiment. This does take quite a long time and you could reduce the time for the practical by giving groups different currents to use and asking them to pool their results at the end. The copper electrodes can be dried by dipping the ends in propanone, removing them and shaking until the propanone evaporates. This should be carried out in a fume cupboard. Alternatively, students can leave their labelled electrodes to dry until the next lesson, then measure the electrode masses and carry out the analysis. Students can reuse the same electrodes provided they rub them with emery paper to remove any loose pieces of copper from the surface. The copper sulfate solution can be reused from this experiment.

Method 2 involves the electrolysis using inert electrodes and is qualitative as students observe and explain the formation of copper and oxygen at the electrodes. It is possible that some of the oxygen will react with the graphite to produce carbon dioxide but, at the low temperature of the experiment, this is likely to be minimal and can be ignored.

Support: Select the most appropriate support for students from:

- Students stick the methods on pages 1 and 2 of the worksheet into their books/files and then answer the directed questions on page 2. Students may need to be given additional information to complete question 2 in method 1. You may need to tell them what type of graph to draw and how to label the axes.
- Students stick the method into their books/files and then fill in their results on page 3 of the worksheet and answer the scaffolded questions on their results and conclusions. Students may need to be given additional information to complete question 3 on page 3. You may need to tell them what type of graph to draw and how to label the axes.

Stretch: Students follow the instructions on pages 1 and 2 of the worksheet, and then write up the experiment in their own words, by designing their own results tables, and writing a conclusion and an evaluation (with help from Skills Sheets PD2, PD5, SC1, TR1, TR4 and UE11 as needed). The directed questions on page 3 of the worksheet should not be printed/copied, and consider removing some or all of the directed questions on page 2.

Expected results

Students should obtain a similar pattern in their results to those shown in the table below.

Current (A)	Mass of anode at start (g)	Mass of anode at end (g)	Mass of cathode at start (g)	Mass of cathode at end (g)
0.2	2.77	2.69	2.51	2.58
0.3	2.68	2.55	2.55	2.66
0.4	2.53	2.36	2.62	2.76
0.5	2.36	2.15	2.70	2.87

Safety

Wear eye protection. Propanone is an irritant and highly flammable – there should be no sources of ignition in the laboratory.

Equipment (per group)

eye protection, emery paper, low voltage d.c. supply (0–12 V), ammeter (0–1 A), variable resistor, connecting leads, crocodile clips, 100 cm^3 beaker, stop clock, two graphite rods, two strips of copper foil about 2 cm wide and long enough to reach the bottom of the beaker, copper sulfate solution (about 50 cm^3, 0.5 mol dm^{-3}), access to a beaker of propanone, access to a fume cupboard, access to a balance (at least 2 d.p.), graph paper

Course resources

Chem Students' sheet CP4

Sample question

This example is taken from the sample assessment material, paper 1CH0/1F, Q4. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

(b) Copper sulfate solution was electrolysed for five minutes using copper electrodes.

Figure 5 shows the mass of the anode and of the cathode before electrolysis and after electrolysis.

	anode	**cathode**
mass of electrode before electrolysis / g	1.16	1.28
mass of electrode after electrolysis / g	0.85	1.57

Figure 5

Calculate the mass of copper deposited.

(2)

mass of copper deposited = ... g

Question number	**Answer**	**Additional guidance**	**Mark**
4(b)	• copper is deposited on the cathode, therefore mass deposited = 1.57 – 1.28 (1) • = 0.29 (g) (1)	Award full marks for correct numerical answer without working.	**(2)**

This question tests whether students understand that copper is deposited on the cathode and they can calculate the increase in mass.

This example is taken from the sample assessment material, paper 1CH0/1H, Q6.

(c) When a solution of sodium sulfate, Na_2SO_4, is electrolysed, the products formed at the electrodes are hydrogen and oxygen.

Explain the formation of the products at the electrodes.

(4)

....

....

....

....

....

....

....

....

Question number	Answer	Mark
6(c)	An explanation that combines identification – understanding (1 mark) and reasoning/justification – understanding (3 marks): • hydrogen (H^+) and sodium (Na^+) ions attracted to cathode, hydroxide (OH^-) ions and sulfate (SO_4^{2-}) ions attracted to anode (1) • because the ions are attracted to the oppositely charged electrode (1) • 2 hydrogen ions/2 H^+ accept 2 e to form hydrogen molecule/H_2 (1) • 4 hydroxide ions/4 OH^- lose 4 e to form oxygen molecule/O_2 (1)	**(4)**

This question tests whether students can explain the formation of products at the electrodes. The formation of oxygen at the anode during the electrolysis of copper sulfate solution using inert electrodes can be explained in the same way as the reaction at the anode during the electrolysis of sodium sulfate.

This example is taken from the sample assessment material, paper 1CH0/1H, Q6.

(d) Copper is purified by the electrolysis of copper sulfate solution using an impure copper anode and a pure copper cathode.

Write the half-equation for the formation of a copper atom from a copper ion.

(2)

Question number	Answer	Mark
6(d)	$Cu^{2+} + 2e^{-} \rightarrow Cu$ • all species (1) • balancing (1)	**(2)**

Only higher tier candidates are expected to be able to write half equations for the reactions at the electrodes.

Core practical 5: Acid-alkali titration

5.9C Core practical: Carry out an accurate acid-alkali titration, using burette, pipette and a suitable indicator

Links to the specification content

3.3	Recall the effect of acids and alkalis on indicators, including litmus, methyl orange and phenolphthalein
3.13	Describe a neutralisation reaction as a reaction between an acid and a base
3.14	Explain an acid-alkali neutralisation as a reaction in which hydrogen ions (H^+) from the acid react with hydroxide ions (OH^-) from the alkali to form water
3.16	Explain why, if soluble salts are prepared from an acid and a soluble reactant: a titration must be used b the acid and the soluble reactant are then mixed in the correct proportions c the solution remaining, after reaction, is only salt and water
3.18	Describe how to carry out an acid-alkali titration, using burette, pipette and a suitable indicator, to prepare a pure, dry salt
5.10C	**Carry out simple calculations using the results of titrations to calculate an unknown concentration of a solution or an unknown volume of solution required**

Introducing the practical

All students can carry out an acid-alkali titration to determine the exact volume of an acid needed to neutralise a given volume of alkali or vice versa. Students are expected to know the colour changes for methyl orange and phenolphthalein in dilute solutions of strong acids and strong alkalis, however, they are not expected to know which indicator is suitable if a weak acid or alkali is used.

There is then the opportunity to continue the experiment in two different ways. The students who will be taking the foundation tier paper can use the result of the titration to prepare a pure, dry sample of a salt whereas those taking the higher tier paper can calculate the concentration of one of the solutions.

> Link to GCSE Science 2011: 'Carry out an acid-base titration to prepare a salt from a soluble base' was a core practical in C3 Topic 2. 'Carry out titration reactions to find an unknown concentration of an acid or alkali in solution' was a suggested practical in C3 Topic 2.

Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- What safety precautions should you take when carrying out this experiment and why?
- Why is a burette used to measure the volume of one of the solutions instead of a measuring cylinder?
- Why is it necessary to rinse the burette and pipette with the solutions they will contain before filling them?
- What are the colours of methyl orange in acid, neutral and alkaline solutions?
- What are the colours of phenolphthalein in acid, neutral and alkaline solutions?
- Why is universal indicator not suitable to use in a titration?
- Why is a white tile used?
- Why is it important to swirl the conical flask during the titration?
- What is meant by the end point?
- Why do you repeat the titration?
- What are concordant results?
- Which results are included in the calculation when you determine the mean or average titre?

Skills that are covered in the practical:

- Measure volume of solution using a volumetric pipette
- Measure volume of solution using a burette
- Use a suitable indicator to find the end point during an acid-alkali titration
- Make and record observations of colour change during an acid-alkali titration with an indicator
- Safe use and careful handling of acids and alkalis during an acid-alkali titration
- **Determine the concentrations of strong acids and strong alkalis from the results of a titration experiment**

Maths skills:

- Use expressions in decimal form when calculating a mean titre
- Use mole ratio when calculating an unknown concentration
- Give answers to calculations to an appropriate number of significant figures
- Calculate the number of moles of a solute from the volume and concentration of a solution
- Calculate the concentration of a solute from the number of moles and the volume

Edexcel GCSE (9–1) **Sciences**

Chem CP5

Acid–alkali titration

Your teacher may watch to see if you can…

- follow instructions
- make accurate measurements.

Aim

To find the volume of hydrochloric acid needed to neutralise 25.0 cm^3 of 0.10 mol dm^{-3} sodium hydroxide solution.

Apparatus

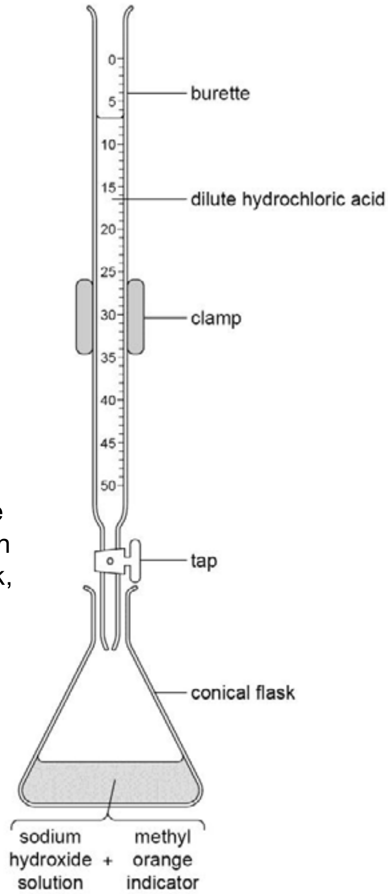
- eye protection
- burette and stand
- funnel
- pipette and filler
- conical flask
- white tile
- wash bottle of distilled or deionised water
- methyl orange indicator
- 0.10 mol dm^{-3} sodium hydroxide solution
- hydrochloric acid of unknown concentration

⚠ Safety

Eye protection must be worn.

Use a pipette filler.

Method



A Place a funnel in the top of the burette, then rinse and fill the burette with the dilute hydrochloric acid.

B Fill the jet below the tap by running some acid out of the burette, then remove the funnel from the top of the burette. Record the initial reading on the burette.

C Following instructions from your teacher, use the pipette filler to rinse and fill the pipette to the 25.0 cm^3 mark with the sodium hydroxide solution.

D Empty the sodium hydroxide solution from the pipette into a conical flask.

E Add a few drops of methyl orange to the conical flask until the solution is yellow, then place the flask on a white tile under the burette.

F Add the hydrochloric acid to the sodium hydroxide solution in small portions while swirling the conical flask.

G Stop adding the hydrochloric acid when the indicator turns a peach/orange colour. Record the burette reading. This is the rough titration to give you an approximate volume of hydrochloric acid needed. If the indicator turns pink, you have added too much hydrochloric acid.

H Repeat steps **A**–**E** (except for rinsing the burette and pipette). Add hydrochloric acid to the sodium hydroxide until you have used 1 cm^3 less than in the rough titration. Use a wash bottle of distilled/deionised water to rinse the tip of the burette with a little water to make sure no hydrochloric acid is left there. Then add hydrochloric acid drop by drop until the solution in the flask is peach/orange. Record the burette reading.

I Repeat step **H** until you have two concordant results within 0.2 cm^3 of each other.

---

1 Repeat the titration using 25.0 cm^3 of sodium hydroxide solution and the mean volume of hydrochloric acid, but do not add any indicator.

2 Pour the sodium chloride solution into an evaporating basin and heat it until crystals start to form. Take care – it starts to spit hot salt if it boils completely dry.

3 Leave the basin until it is cool and the rest of the water has evaporated. You will be left with pure, dry crystals of sodium chloride.

Edexcel GCSE (9–1) **Sciences** **Chem CP5** Acid–alkali titration

Name ______________________ **Class** __________ **Date** ____________

Recording your results

1 Record your results in the table.

Burette reading	Titration 1	Titration 2	Titration 3	Titration 4	Titration 5
Final reading (cm^3)					
Initial reading (cm^3)					
Volume added (cm^3)					

Considering your results/conclusions

2 Calculate the mean of the concordant results (results that are within 0.2 cm^3 of each other).

____

3 Calculate the number of moles of sodium hydroxide in 25.0 cm^3 of 0.10 mol dm^{-3} sodium hydroxide solution. Use the formula:

number of moles of solute = volume of solution (dm^3) × concentration (mol dm^{-3})

Remember to convert the volume in cm^3 to dm^3 by dividing by 1000.

____

4 The equation for the reaction between hydrochloric acid and sodium hydroxide is:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Work out the number of moles of hydrochloric acid that reacted with the number of moles of sodium hydroxide you calculated in question **3**.

____

5 Use the formula in question **3**, the mean volume of hydrochloric acid and your answer to question **4** to calculate the concentration of hydrochloric acid in mol dm^{-3}. Remember to convert the volume in cm^3 to dm^3.

____

Edexcel GCSE (9–1)
Sciences

Chem CP5 Titrations and calculations

Objectives

C5.9C	Carry out an accurate acid-alkali titration, using burette, pipette and a suitable indicator.
C5.10C	H Carry out simple calculations using the results of titrations to calculate an unknown concentration of a solution or an unknown volume of solution required.

Maths requirements

1a	Recognise and use expressions in decimal form.
1c	Use ratios, fractions and percentages.
2a	Use an appropriate number of significant figures.
2b	Find arithmetic means.
3a	Understand and use the symbols: =, <, <<, >>, >, ∝, ~.
3b	Change the subject of an equation.
3c	Substitute numerical values into algebraic equations using appropriate units for physical quantities.

Learning outcomes

5th	SC5.9C	Describe the steps in carrying out an acid-alkali titration.
7th	SC5.10C	H Calculate the number of moles of solute in a given volume of solution.
9th	SC5.10C	H Deduce the mole ratio of acid to alkali from a balanced equation.
9th	SC5.10C	H Calculate the concentration of a solution using the results of an acid-alkali titration.
9th	SC5.10C	H Calculate the volume of solution required in an acid-alkali titration, given the concentrations of both the acid and the alkali.

Exploring

1. Core practical – Acid–alkali titration

This practical forms part of the core practical requirement of the specification. It is supported by the information on *Students' sheet CP5(Titration)* and in the Student Book.

A set of instructions for this practical is given on Students' sheet CP5(Titration). The practical could also be used to see whether students can follow instructions and make accurate measurements.

The worksheet has the details for using methyl orange, but you can use phenolphthalein if you prefer. Students need to know the colour changes of both indicators, and either is suitable for this titration. Students are not expected to know that a particular indicator is not suitable for certain titrations; for example, phenolphthalein is not suitable for a titration between a weak acid and a strong alkali. However, they should know why universal indicator is not suitable in a titration. (It has too many different colours and so there is no clear change in colour.)

This method has more detail than the method used previously in Worksheet SC8e.1, and these additional techniques, such as rinsing the burette and pipette, may be needed for the examination. You may need to demonstrate the whole titration experiment first – see Explaining 2. Students usually obtain a high volume for the first (rough) titration, because they add the acid too quickly. Students should repeat the titration until they obtain two concordant results within 0.2 cm^3. They should take the mean of these concordant results. A common error in examinations is that students take the mean of all the titration results.

Students could either use the results of the titration experiment to prepare pure, dry crystals of sodium chloride (as revision of *SC8e Alkalis and neutralisation*) or use them to calculate the concentration of hydrochloric acid. If needed, the instructions for preparing sodium chloride crystals are at the bottom of page 1 of the worksheet.

The results table on page 2 of SC14d.1 has space for five sets of results, but students do not need to do five titrations. Explain that students need to repeat the titration until they have two concordant results (i.e. results that are within 0.2 cm^3 of each other).

Support: Students who are not preparing for the Higher Tier papers can follow the method on page 1 of Worksheet SC14d.1 and then record their results in the table on page 2. They can work out the mean titre and then carry out the additional steps to help them prepare pure, dry crystals of sodium chloride.

Stretch: Students can follow the practical instructions on the first page of Worksheet SC14d.1 and then write up the experiment in their own words. This should include designing their own results table and calculating the concentration of the hydrochloric acid (with help from Skills Sheets as needed).

⚠ Safety

Eye protection must be worn.

Show how to use a pipette filler.

If students heat the solution to obtain sodium chloride crystals, they should: take care when heating the sodium chloride solution, because hot salt may spit out of the basin when almost all the water has evaporated; stop heating once crystals start to form; not touch the tripod and gauze when they are hot.

Equipment (per group)

eye protection, burette, burette stand or retort stand with burette clamp, plastic funnel to fit top of burette, 25.0 cm^3 pipette, pipette filler, conical flask, white tile, methyl orange (few drops, or phenolphthalein can be used), hydrochloric acid (about 100 cm^3, 0.1 mol dm^{-3} – the concentration should not be written on the label), sodium hydroxide solution (about 100 cm^3, 0.10 mol dm^{-3}), distilled/deionised water in a wash bottle

Optional (for sodium chloride crystal preparation): Bunsen burner, heat-resistant mat, tripod, gauze, tongs, evaporating basin

Course resources

Chem Students' sheet CP5

Sample question

This example is taken from the sample assessment material, paper 1CH0/1F, Q8. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

8 A titration is to be carried out to find the concentration of a solution of sodium hydroxide.

The sodium hydroxide solution is titrated with dilute sulfuric acid.

The available apparatus includes a burette, a pipette, a funnel, a conical flask and an indicator.

(a) State one safety precaution that must be taken when using sodium hydroxide solution and dilute sulfuric acid.

(1)

....

....

....

Question number	Answer	Mark
8(a)	any **one** precaution from: • wear gloves to prevent contact with skin/safety (1) • spectacles to prevent contact with eyes (1)	**(1)**

This question tests whether students are aware of appropriate safety precautions to take when performing a titration.

(c) Write the balanced equation for the reaction of dilute sulfuric acid, H_2SO_4, with sodium hydroxide.

(2)

....

Question number	Answer	Additional guidance	Mark
8(c)	$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$ • correct formulae (1) • balancing (1)	Do not award 2 if incorrect balancing added.	**(2)**

Students should be able to write balanced equations for common acids and alkalis reacting in titration experiments.

(d) The results of titrations to determine how much of an acid is required to neutralise a given volume of an alkaline solution are shown in Figure 14.

	titration 1	titration 2	titration 3	titration 4
final burette reading (cm^3)	27	27.40	29.20	29.30
initial burette reading (cm^3)	0	2.10	4.00	3.50
volume of acid used (cm^3)	27	25.30	25.20	25.80

Figure 14

Two of the titrations in Figure 14 should **not** be used to calculate the mean volume of acid required.

Identify each titration and give a reason why it should not be used in the calculation of the mean.

(2)

Question number	Answer	Mark
8(d)	• {titration 1/27 cm^3} should not be used because burette readings {not precise/not accurate/not read to 2 d.p.} (1) • {titration 4/25.80 cm^3} should not be used because volume of used (25.80 cm^3) not concordant with other two (1)	**(2)**

Students should understand which titration results should be used in calculating the mean.

*(e) Describe the experimental procedure to carry out a titration to find the exact volume of sulfuric acid needed to neutralise 25.0 cm^3 of sodium hydroxide solution and obtain pure, dry crystals of sodium sulfate.

(6)

Question number	Indicative content
*8(e)	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material that is indicated as relevant. Additional content included in the response must be scientific and relevant. **AO1 (6 marks)** • rinse pipette with alkali and burette with acid • measure alkali using a pipette into suitable container e.g. flask/beaker and place flask on a white tile • add a few drops of indicator/suitable named indicator (eg methyl orange/phenolphthalein) • fill burette with acid and read volume of acid in burette • add acid from burette to the flask slowly swirling the flask until {indicator just changes colour/correct colour change for named indicator (eg methyl orange yellow to peach/orange, phenolphthalein pink to colourless)/solution is neutral} • read volume of acid in burette at end of titration • repeat experiment until concordant results • mix the same volume of alkali with the volume of acid determined from the titration but do not add indicator • pour solution into an evaporating basin then {heat solution/leave the water to evaporate} until pure salt crystals are left • dry crystals using absorbent paper

This extended writing question expects students to give the detailed method of a titration experiment and how to obtain pure, dry crystals of a salt. Students who have carried out this type of experiment themselves will find it much easier to score a high mark.

Core practical 6: Investigating reaction rates

7.1 Core practical: Investigate the effects of changing the conditions of a reaction on the rates of chemical reactions by:

a measuring the production of a gas (in the reaction between hydrochloric acid and marble chips)

b observing a colour change (in the reaction between sodium thiosulfate and hydrochloric acid)

Links to the specification content

7.2	Suggest practical methods for determining the rate of a given reaction
7.3	Explain how reactions occur when particles collide and that rates of reaction are increased when the frequency and/or energy of collisions is increased
7.4	Explain the effects on rates of reaction of changes in temperature, concentration, surface area to volume ratio of a solid and pressure (on reactions involving gases) in terms of frequency and/or energy of collisions between particles
7.5	Interpret graphs of mass, volume or concentration of reactant or product against time

Introducing the practical

There are two investigations to carry out and they are likely to take a lesson each. Students could investigate the effect of changing the concentration of hydrochloric acid or the size of marble chips on the rate of reaction between hydrochloric acid and marble chips. They could investigate the effect of changing the concentration of sodium thiosulfate solution or the temperature on the rate of reaction between sodium thiosulfate and hydrochloric acid.

The volume of gas can be measured by collecting it in an upturned measuring cylinder over water or in a gas syringe. It would be helpful to demonstrate the method that the students do not use so they are familiar with both methods.

Some students are sensitive to the sulfur dioxide produced in the sodium thiosulfate experiment so it is important to have a well-ventilated room and make an appropriate risk assessment.

Students should plot appropriate graphs using their results, for example, volume of gas produced against time. They can then draw a tangent to the curve and calculate the gradient to determine the rate of reaction at a particular time.

Link to GCSE Science 2011: 'Investigate the effect of temperature, concentration and surface area of a solid on the rate of a reaction such as hydrochloric acid and marble chips' was a core practical in C2 Topic 5. 'Investigate the rate of reactions, such as magnesium and hydrochloric acid, or sodium thiosulfate and hydrochloric acid' was a suggested practical in C2 Topic 5.

Questions you could ask to enhance learning and focus your students on important aspects of the practical:

Reaction between hydrochloric acid and marble chips

- What is the balanced equation for the reaction?
- What are the state symbols for the reactants and products?
- What is the best practical method to determine the rate of this reaction and why?
- What are two different methods of collecting and measuring the volume of gas produced?
- What is the biggest error in this experiment?
- How could you reduce this error?
- How do you decrease the size of the marble chips?
- What specific safety precaution should you take when decreasing the size of the marble chips?
- How does this affect the surface area of the marble chips?
- What effect does this have on the rate of reaction?
- How can you explain this effect from graphs of volume of gas plotted against time for two different sizes of marble chips?
- How can you calculate the rate of reaction from these graphs?
- What needs to be kept the same when you repeat the first experiment but use different size marble chips?
- How could you decrease the concentration of the hydrochloric acid?
- What effect will decreasing the concentration of hydrochloric acid have on the rate of reaction?
- How do you explain this effect in terms of particles and collisions?

Reaction between sodium thiosulfate and hydrochloric acid

- What is the balanced equation for this reaction?
- What are the state symbols for the reactants and products?
- What is seen when sodium thiosulfate solution reacts with dilute hydrochloric acid?
- What safety precautions should you take in this investigation?
- What is the best practical method to determine the rate of this reaction and why?
- How do you change the temperature of the solutions?
- What happens to the time taken for the reaction to occur as the temperature increases?
- How do you explain this change in terms of the energy of the particles and collisions?

Skills that are covered in the practical:

- Use appropriate apparatus to make and record measurements of mass, volume of solutions, time, temperature and volume of gas
- Safe use of a water bath to investigate the effect of temperature on the rate of a reaction
- Use appropriate apparatus and techniques for monitoring chemical reactions, for example, a gas syringe or collecting gas over water in an upturned measuring cylinder
- Make and record observations and measurements of rate of reaction when a gas is produced or there is a colour change
- Safe use and careful handling of hydrochloric acid, marble chips and sodium thiosulfate solution

Maths skills:

- Use expressions in decimal form when calculating gradients
- Use ratios in balanced equations
- Use an appropriate number of significant figures when calculating rate
- Determine the mean of experimental data
- Compare experimental data to see which has the greater rate
- Plot a graph involving two variables from experimental data
- Draw and use the slope of a tangent to a curve as a measure of rate of reaction
- Translate information between graphical and numeric form

Edexcel GCSE (9–1) **Sciences**

Chem CP6a

Investigating rates of reaction

Your teacher may watch to see if you can…
- carefully control variables during investigations
- measure change accurately.

Aim

To investigate the effect on the **rate** of reaction of changing the surface area of solids and the concentration of solutions, by measuring the production of a gas.

Method

Apparatus
- eye protection
- balance
- water trough
- 100 cm^3 measuring cylinder
- stop clock
- conical flask
- delivery tube and bung
- stand and clamp
- five dilute hydrochloric acid solutions (1.0, 0.8, 0.6, 0.4 and 0.2 mol dm^{-3})
- marble chips (small)
- marble chips (large)

⚠ Safety

Wear eye protection at all times.

Care is needed with acid solutions. Wash off splashes immediately.

Task 1

A Set up the apparatus as shown in the diagram.

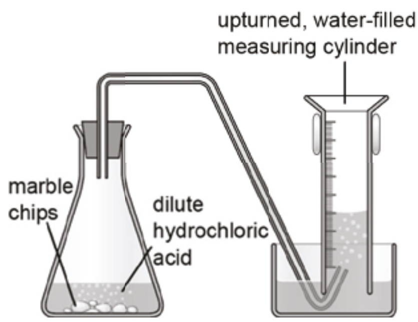
B Measure 40 cm^3 of 1.0 mol dm^{-3} hydrochloric acid into a conical flask.

C Add 5 g of small marble chips to the flask.

D Immediately stopper the flask and start the stop clock.

E Note the total volume of gas produced after every 30 seconds for five minutes or until the reaction has finished.

F Repeat steps **A–E** using 5 g of larger marble chips.



Task 2

G Follow steps **A–D** above.

H Note the amount of carbon dioxide produced in one minute.

I Repeat steps **G** and **H** using 0.8, 0.6, 0.4 and 0.2 mol dm^{-3} acid.

Recording your results

1 Record your results for each task separately, in tables with suitable headings.

Considering your results/conclusions

2 Use your results to draw a scatter diagram, including lines of best fit, to look for correlations between the **variables** under investigation.

3 Use your results and graphs to write a conclusion for each of the tasks.

Evaluation

4 Suggest possible sources of error in these investigations and possible changes to the method that could improve the reliability of the results.

Edexcel GCSE (9–1) Sciences

Chem CP6a Investigating rates of reaction

Name ______________________ **Class** __________ **Date** __________

Task 1

Recording your results

1 Record your results in the table below.

Time (min)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Small chips – volume of gas (cm^3)											
Large chips – volume of gas (cm^3)											

Considering your results/conclusions

2 Use your results to draw a graph of volume of gas against time for small chips and the same graph for large chips on the same axes. Put time on the horizontal axis and volume of gas on the vertical axis. Draw a line of best fit for each graph, using different coloured lines and labels.

3 Explain how you can tell from the graphs when the reactions were finished.

4 Describe how the size of the marble chips is related to the surface area for a fixed mass of chips.

5 Describe how increasing the surface area affects the rate of reaction.

6 Explain how your results and graph fit with your conclusion in question **5**.

Evaluation

7 Suggest possible sources of error in this investigation.

8 Suggest possible changes to the method that could improve the reliability of the results.

Task 2

Recording your results

9 Record your results in the table below.

Concentration of acid (mol dm^{-3})	0.2	0.4	0.6	0.8	1.0
Volume of gas produced in one minute (cm^3)					

Considering your results/conclusions

10 Use your results to draw a scatter graph of concentration of acid against volume of gas produced in one minute. Put volume of gas on the horizontal axis and concentration on the vertical axis.

11 Describe how the rate of the reaction is related to the concentration of the acid.

12 Explain how your results and graph fit with your conclusion in question **11**.

Evaluation

13 Suggest possible sources of error in this investigation.

14 Suggest possible changes to the method that could improve the reliability of the results.

Chem CP6b Temperature and reaction rates

Your teacher may watch to see if you can…

- carefully control variables during investigations
- measure change accurately

Aim

To investigate the effect of changing the temperature on the rate of reaction between sodium thiosulfate and hydrochloric acid, by observing a colour change in the solutions.

Method

Apparatus

- eye protection
- 250 cm^3 conical flask
- 10 cm^3 measuring cylinder
- 50 cm^3 measuring cylinder
- stop clock
- test tube and rack
- water bath
- white paper with cross
- sodium thiosulfate solution
- dilute hydrochloric acid

⚠ Safety

Wear eye protection at all times.

Care is needed with acid solutions. Wash off splashes immediately.

A Decide on four temperatures between 20 °C and 50 °C, which you are going to investigate.

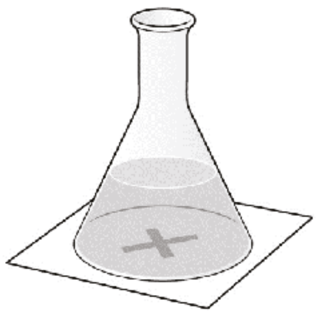
B Place 10 cm^3 of sodium thiosulfate solution and 40 cm^3 of water into a 250 cm^3 conical flask.

C Measure 5 cm^3 of dilute hydrochloric acid into a test tube.

D Clamp the conical flask in place in a water bath at your first chosen temperature. Place the test tube in a rack in the same water bath.

E Record your chosen temperature.

F After five minutes, remove the flask and place it on a piece of white paper marked with a cross, as shown opposite.



G Add the acid to the thiosulfate and start the stop clock.

H Looking down from above, stop the clock when the cross disappears.

I Note this time and the final temperature of the mixture.

J Repeat steps **A–I** for the other chosen temperatures.

Recording your results

1 Draw a table with two columns: one for average temperature, and the other for the time taken for the cross to disappear. Record the results of your experiments.

Considering your results/conclusions

2 Draw a scatter graph of your results, with temperature on the *x*-axis.) Draw a line of best fit.

3 **a** Describe how temperature affects the rate of the reaction.

b Explain your answer to part **a** by referring to the shape of your graph.

4 If the rate of reaction doubled, what would happen to the time taken for the cross to disappear?

5 **a** What temperature rise roughly doubles the rate of the reaction?

b Use the values from your graph to explain your answer to part **a**.

Evaluation

6 Describe two possible sources of error in this investigation.

7 Suggest a way of reducing one of these errors.

Chem CP6a Rates of reaction

Objectives

C7.1 *Investigate the effects of changing the conditions of a reaction on the rates of chemical reactions by:*

- **a** *measuring the production of a gas (in the reaction between hydrochloric acid and marble chips)*
- **b** *observing a* colour *change (in the reaction between sodium thiosulfate and hydrochloric acid).*

C7.2 Suggest practical methods for determining the rate of a given reaction.

C7.5 Interpret graphs of mass, volume or concentration of reactant or product against time.

Maths requirements

1a Recognise and use expressions in decimal form.

1c Use ratios, fractions and percentages.

4a Translate information between graphical and numeric form.

4d Determine the slope and intercept of a linear graph.

4e Draw and use the slope of a tangent to a curve as a measure of rate of change.

Learning outcomes

6th **SC7.2** Describe different changes that can occur as a reaction proceeds.

7th **SC7.2** Suggest different experimental methods to investigate rates of reaction (e.g. measurements of mass of reactants against time, volume of gas released against time, concentration of reactant or product against time).

7th **SC7.5** Use graphs of changes (in mass, volume or concentration of reactant or product) against time, to interpret what is happening during reactions.

Exploring

1. Core practical – Investigating rates of reaction

This practical forms part of the core practical requirement of the specification. It is supported by the information on Students' sheet CP6a (Rates of reaction-Vol of gas) and in the Student Book.

Investigate the effects of changing the conditions of a reaction on the rates of chemical reactions by measuring the production of a gas (in the reaction between hydrochloric acid and marble chips). This is part a of the core practical; part b, 'by observing a colour change (in the reaction between sodium thiosulfate and hydrochloric acid)', is covered in the next topic, *SC18b Factors affecting reaction rates*.

Students should work in groups and follow the instructions on Students' sheet CP6a (Rates of reaction-Vol of gas) to investigate the effect of changing variables on the rate of a chemical reaction. In task 1, students investigate the effect of changing the surface area of solids (the size of solid lumps) in the reaction between marble chips and hydrochloric acid. In task 2, students investigate the effect of changing the concentration of acid in the same reaction. Most students will use the method on the first page of Worksheet SC18a.1. If time allows, students can carry out both investigative tasks. Alternatively, half the groups can carry out task 1, the others doing task 2, with the groups then sharing their results.

Note that the concentrations of hydrochloric acid to be used in task 2 are given in mol dm^{-3}. They are 1.0, 0.8, 0.6, 0.4 and 0.2 mol dm^{-3}. However, these units and the concept of moles will only be covered by students studying higher tier. For teachers who would prefer to use concentrations in g dm^{-3}, the equivalent concentrations are 36.5, 29.2, 21.9, 14.6 and 7.3 g dm^{-3}.

After the activity, ask groups picked at random to explain what the tasks tell us about the effects of surface area and concentration on reaction rates.

If necessary, students can stick the method from the first page of Worksheet SC18a.1 into their books and then answer the directed questions at the bottom of the page.

Support: Some students will need help to set up experiments, may need to be told how to make measurements, and may need help to ensure that they measure the changes as soon as the reactions start. These students should record their results and draw conclusions using the second page of Worksheet SC18a.1.

Stretch: Students follow the instructions above the cutting line on page 1 of Worksheet SC18a.1. They then write up the experiment in their own words, design their own results tables, and write a conclusion and an evaluation (with help from Skills Sheets as needed). The directed questions on the worksheet should be covered or removed before photocopying/printing.

Expected results

The results will depend on the conditions used.

In task 1 for both experiments, the volume of gas produced in each 30 second interval will be greatest at the start of the experiment and decrease until the reaction is finished and no more gas is formed. The reaction using the small chips will produce the gas more quickly at first and be finished in a shorter time than the reaction using the large chips.

In task 2, the volume of gas produced should be directly proportional to the concentration of acid used. (For example, the 0.8 mol dm^{-3} hydrochloric acid should produce twice the volume of gas in one minute as produced by the 0.4 mol dm^{-3} hydrochloric acid.)

⚠ Safety

Wear eye protection at all times. Wash off all spills immediately.

Equipment

For each group:

Task 1 – eye protection, balance, 100 cm^3 measuring cylinder, stop clock, water trough, 250 cm^3 conical flask, bung with delivery tube, stand and clamp, dilute hydrochloric acid (1.0 mol dm^{-3}), large marble chips, small marble chips, graph paper

Task 2 – as above plus 0.8, 0.6, 0.4 and 0.2 mol dm^{-3} hydrochloric acid solutions

Course resources

Chem Students' sheet CP6a

Edexcel GCSE (9–1)
Sciences

Chem CP6b

Factors affecting reaction rates

Objectives

C7.1 *Investigate the effects of changing the conditions of a reaction on the rates of chemical reactions by:*

- **a** *measuring the production of a gas (in the reaction between hydrochloric acid and marble chips)*
- **b** *observing a colour change (in the reaction between sodium thiosulfate and hydrochloric acid).*

C7.3 Explain how reactions occur when particles collide and that rates of reaction are increased when the frequency and/or energy of collisions is increased.

C7.4 Explain the effects on rates of reaction of changes in temperature, concentration, surface area to volume ratio of a solid and pressure (on reactions involving gases) in terms of frequency and/or energy of collisions between particles.

Maths requirements

1a Recognise and use expressions in decimal form.

1c Use ratios, fractions and percentages.

4a Translate information between graphical and numeric form.

4d Determine the slope and intercept of a linear graph.

4e Draw and use the slope of a tangent to a curve as a measure of rate of change.

Learning outcomes

8th **SC7.3** Explain what has to happen for reactions to take place.

9th **SC7.3** Explain why changes in the energy of particles affect rates of reaction.

9th **SC7.3** Explain why changes in the frequency of collisions between particles affect the rate of reaction.

9th **SC7.4** Explain why changes in temperature, concentration, surface area and pressure affect the rate of reaction (surface area for solids, pressure for gases only).

8th SC7.4 Describe ways of speeding up or slowing down chemical reactions.

Exploring

1. Core practical – Investigating reaction rates

This practical forms part of the core practical requirement of the specification. It is supported by the information on *Students' sheet CP6b(Rates of reaction-colour change)* and in the Student Book.

This core practical investigates the effects of changing the conditions of a reaction on the rate of a chemical reaction, by observing a colour change. This is part b of the core practical; part a, 'by measuring the production of a gas (in the reaction between hydrochloric acid and marble chips)' is covered in *SC18a Rates of reaction*. Both sections of this practical are covered in the unit *SC18 Rates of Reaction* in the Student Book.

Students should work in groups, following the instructions in Students' sheet CP6b(Rates of reaction-colour change) , to investigate the effect of temperature on the rate of the reaction between sodium thiosulfate and hydrochloric acid. To save time, students could share results.

⚠ Safety

Wear eye protection at all times.

Support: Some students may need to be observed when making their first measurements and given advice about how to ensure they are measuring the temperature and time correctly.

Stretch: Ask students to consider the relationship between the time taken for the cross to disappear and the rate of the reaction. The rate increases as the time decreases, and so the rate is proportional to 1/time. Students could create a graph with 1/time (min^{-1}) on the vertical axis and temperature (°C) on the horizontal axis. This will show the direct relationship between temperature and rate in this reaction.

Expected results

The results should show that for every 10 °C rise in temperature, the time for the cross to disappear halves and so the rate of the reaction doubles.

Equipment

For each group: eye protection, 250 cm^3 conical flask, 10 cm^3 measuring cylinder, 50 cm^3 measuring cylinder, stop clock, test tube, test-tube rack, water bath, white paper with cross, sodium thiosulfate solution (40 g dm^{-3}), dilute hydrochloric acid (2 mol dm^{-3}), graph paper

Course resources:
Chem Students' worksheet CP6b

Sample question

This example is taken from the sample assessment material, paper 1CH0/2F, Q5. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

5 A student used the equipment in Figure 6 to investigate the rate of reaction between zinc and excess dilute hydrochloric acid.

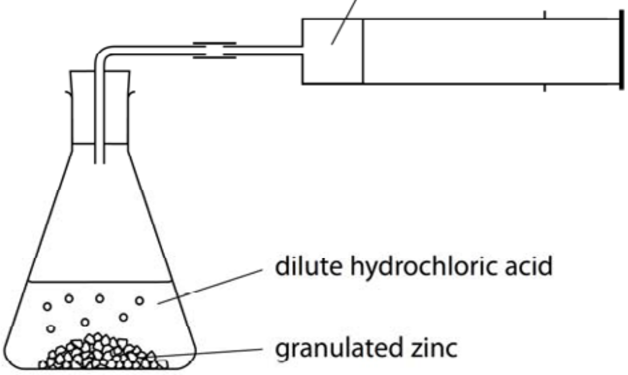


Figure 6

The student uses the following method:

- place a known mass of granulated zinc into the conical flask
- pour 25 cm^3 of dilute hydrochloric acid (an excess) into the conical flask and fit the bung quickly into the neck of the flask
- measure the volume of gas produced every 20 seconds until after the reaction finishes.

Figure 7 shows the results.

time / s	volume of hydrogen / cm^3
0	0
20	42
40	66
60	75
80	80
100	82
120	82
140	82

Figure 7

(a) Give the name of a piece of equipment that can be used to measure 25 cm^3 of dilute hydrochloric acid accurately.

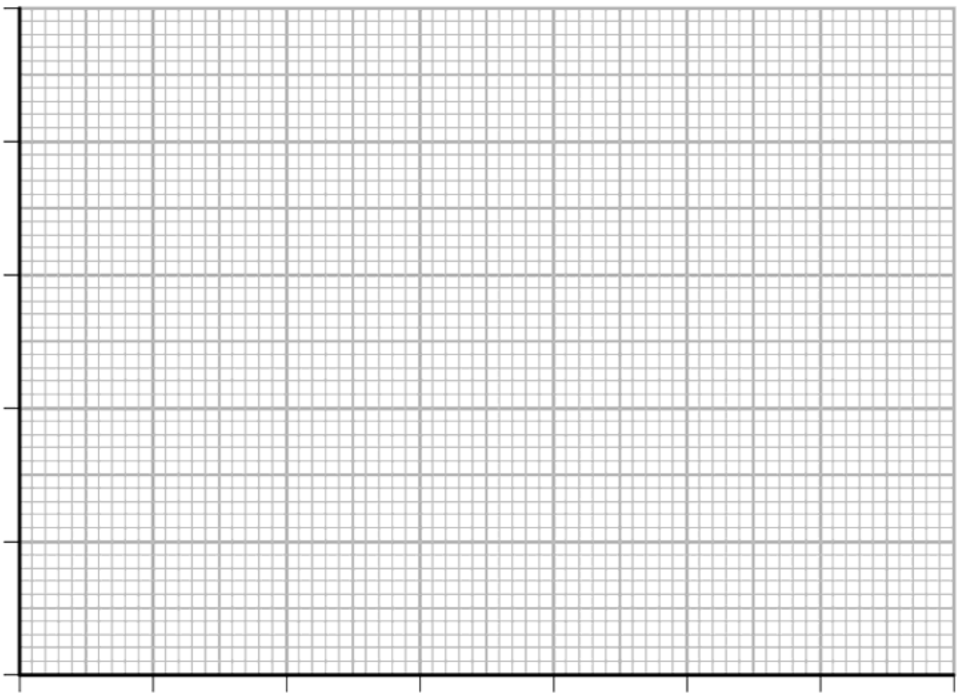
(1)

Question number	Answer	Mark
5(a)	Measuring cylinder/burette/pipette	(1)

This question expects students to know that a (25 cm^3) measuring cylinder is suitable for measuring the volume of hydrochloric acid.

(b) Draw a graph of the volume of hydrogen gas produced against time using the grid.

(3)



Question number	Answer	Additional guidance	Mark
5(b)	• axes with linear scale that use more than half of each edge of the grid and labelled with units from the table (1). • all points correctly plotted to ± half a square (1). • single straight line passing through all points and the origin (1).	7 points plotted correctly (i.e. one error) (1) allow ecf from plotting error.	(3)

Students should be able to plot a graph of the data provided. They will normally be expected to draw their own axes, select a suitable scale and label the axes, including units, where appropriate. They should plot the points accurately and join them with a best-fit straight line or curve, as appropriate for the data.

(c) The average rate of reaction in the first 20 seconds in cm^3 of hydrogen produced per second is

(1)

☒ **A** 2.1

☒ **B** 8.4

☒ **C** 21

☒ **D** 84

Question number	**Answer**	**Mark**
5(c)	A	**(1)**

Students are not expected to draw a tangent and calculate the gradient for this multiple choice question, but they should see from the data that the volume of hydrogen collected in 20 seconds is 42 cm^3 so be able to deduce the average rate of reaction.

(d) The student repeated the experiment keeping all conditions the same but using the same mass of powdered zinc instead of granulated zinc.

On the grid above sketch the graph you would expect when the experiment is repeated using powdered zinc.
Label your line **A**.

(2)

Question number	**Answer**	**Mark**
5(d)	Line A on graph: • steeper curve/curve drawn to left of original (1) • levelling off at 82 cm^3 (1)	**(2)**

Students are expected to sketch, with reasonable accuracy, the graph they would expect when one of the conditions is change. They should consider the steepness of the initial part of the curve and where the graph ends.

(e) Sodium thiosulfate solution, $Na_2S_2O_3$, reacts with dilute hydrochloric acid as shown in the equation.

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(s) + H_2O(l) + S(s) + SO_2(g)$$

The rate of this reaction can be investigated by mixing the reactants and finding the time taken for a precipitate of sulfur to become visible.

A student wants to investigate the effect of changing the temperature on the rate of this reaction.

Devise a method the student could use to find out how the time taken for the precipitate of sulfur to become visible changes with temperature.

(3)

....

....

....

....

....

....

Question number	**Answer**	**Mark**
5(e)	An answer that combines the following points to provide a method: • suitable method of warming the solutions, e.g. water bath, Bunsen burner with tripod and gauze and measure the temperature of each solution using a thermometer (1) • use the same volumes of the solutions in each experiment (1) • measure the time for the precipitate to form (and obscure a cross placed under the reaction vessel) using a stop watch/clock (1)	**(3)**

Students who have carried out this core practical should score high marks on this question.

Core practical 7: Identifying ions

9.6C Core practical: Identify the ions in unknown salts, using the tests for the specified cations and anions in 9.2C, 9.3C, 9.4C, 9.5C

Links to the specification content

9.2C	Describe flame tests to identify the following ions in solids: a lithium ion, Li^{+} (red) b sodium ion, Na^{+} (yellow) c potassium ion, K^{+} (lilac) d calcium ion, Ca^{2+} (orange-red) e copper ion, Cu^{2+} (blue-green)
9.3C	Describe tests to identify the following ions in solids or solutions as appropriate: a aluminium ion, Al^{3+} b calcium ion, Ca^{2+} c copper ion, Cu^{2+} d iron(II) ion, Fe^{2+} e iron(III) ion, Fe^{3+} f ammonium ion, NH_4^{+} using sodium hydroxide solution
9.4C	Describe the chemical test for ammonia
9.5C	Describe tests to identify the following ions in solids or solutions as appropriate: a carbonate ion, CO_3^{2-}, using dilute acid and identifying the carbon dioxide evolved b sulfate ion, SO_4^{2-}, using dilute hydrochloric acid and barium chloride solution c chloride ion, Cl^{-}, bromide ion, Br^{-}, iodide ion, I^{-}, using dilute nitric acid and silver nitrate solution
3.12	Describe the chemical test for b carbon dioxide (using limewater)
9.7C	Identify the ions in unknown salts, using results of the tests above

Introducing the practical

Students could carry out a series of tests with known substances so they become familiar with the technique used for each test and the observation for a positive result. You could then give them some unknown substances and they carry out tests to identify the ions present. All students should be able to combine the symbols of the ions to produce the formula of the unknown compound.

Students taking the higher tier paper can write ionic equations, with state symbols, for the precipitation reactions in the tests.

Link to GCSE Science 2011: 'Identify the ions in unknown salts, using the tests in C3 Topic 1 and C2 Topic 2' was a core practical in C3 Topic 1.

Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- How do you carry out a flame test?
- A flame test was carried out and a lilac flame was seen. Which ions are present?
- Which ion in solution gives a blue precipitate when sodium hydroxide solution is added?
- Which two ions in solution give the same colour precipitate when sodium hydroxide solution is added to them?
- What further test can be done to distinguish between those two ions?
- What is the test, and its result, for ammonia gas?
- What is the test for a sulfate ion?
- Which ion gives carbon dioxide gas when hydrochloric acid is added to it?
- A yellow precipitate was formed when nitric acid and silver nitrate were added to a solution. Which ion is in the solution?
- Why is nitric acid added to the solution before silver nitrate solution?

Skills that are covered in the practical:

- use appropriate reagents for measuring the pH of solutions
- safe use and careful handling of gases, liquids and solids in unknown substances and reagents used to identify the ions they contain
- use appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including gas tests, flame tests and precipitation reactions

Edexcel GCSE (9–1) Sciences

Chem CP7a

Metal hydroxide precipitate tests

Your teacher may watch to see if you can:

- carry out an experiment appropriately
- use apparatus accurately and safely.

Aim

Dilute sodium hydroxide solution is used to identify metal ions in solution. With certain dissolved metal compounds it forms metal hydroxide **precipitates**. The appearance of the precipitate is different for different metal ions.

You will determine the metal hydroxide precipitate colours for aluminium, calcium, copper, iron(II) and iron(III) ions. You will then use these tests to identify the metal ions present in different unknown solutions.

Method

Apparatus

- eye protection
- dropping pipettes
- test tubes
- test-tube rack
- dilute sodium hydroxide solution
- known solutions (containing Al^{3+}, Ca^{2+}, Cu^{2+}, Fe^{2+} or Fe^{3+} ions)
- unknown solutions

Safety

Wear eye protection.

Sodium hydroxide solution is corrosive. Avoid skin contact.

Determining metal hydroxide precipitate colours

A Using a dropping pipette, fill a test tube to a depth of about 2 cm with one of the five known solutions.

B Using a different dropping pipette, add a few drops of sodium hydroxide solution to the tube. Hold the test tube near the top and shake the bottom gently from side to side to mix its contents.

C Observe and record the colour of the precipitate produced.

D If a white precipitate is obtained in step **C**, add more sodium hydroxide solution until the test tube is about half full. Observe and record whether the precipitate disappears to leave a colourless solution.

E Repeat steps **A**–**D** with the other known solutions. Do not contaminate one solution with another.

Identifying metal ions

F Carry out steps **A**–**D** on the five unknown solutions. Observe and record the colour of each precipitate and whether any white precipitate formed disappears when excess sodium hydroxide solution is added.

Recording your results

Make tables like these to record the metal hydroxide precipitate colours of the known and unknown solutions.

Metal ion	Precipitate colour	Effect of adding excess sodium hydroxide
aluminium, Al^{3+}		
calcium, Ca^{2+}		
copper, Cu^{2+}		
iron(II), Fe^{2+}		
iron(III), Fe^{3+}		

Unknown	Precipitate colour
1	
2	
3	
4	
5	

Considering your results

1 Use your results to identify the metal ions in each unknown solution.

Evaluation

2 Explain why step **D** is needed to identify certain metal ions in solution.

Edexcel GCSE (9–1) **Sciences**

Chem CP7b Testing for anions

Your teacher may watch to see if you can:

- carry out an experiment appropriately
- use apparatus accurately and safely.

Aim

You will use simple chemical tests to identify **halide ions** (Cl^-, Br^- or I^-), sulfate ions (SO_4^{2-}) or carbonate ions (CO_3^{2-}) in known solutions. You will then use these tests to identify the **anions** in different unknown solutions.

Method

Apparatus

- eye protection
- dropping pipettes
- test tubes
- test-tube rack
- dilute nitric acid
- silver nitrate solution
- dilute hydrochloric acid
- barium chloride solution
- known solutions
- unknown solutions

Safety

Wear eye protection and avoid skin contact with the substances used.

Barium chloride solution is harmful.

Dilute nitric acid is an irritant.

Testing for halide ions

A Fill a test tube to a depth of about 2 cm with one of the solutions containing halide ions (Cl^-, Br^- or I^- ions).

B Add a few drops of dilute nitric acid then shake the test tube to mix its contents.

C Add a few drops of silver nitrate solution. Record the colour of the precipitate produced.

D Repeat steps **A**–**C** with the other known solutions that contain halide ions (Cl^-, Br^- or I^- ions).

Testing for sulfate ions

E Fill a test tube to a depth of about 2 cm with the solution containing sulfate ions, SO_4^{2-}.

F Add a few drops of dilute hydrochloric acid then shake the test tube to mix its contents.

G Add a few drops of barium chloride solution. Record the colour of the precipitate produced.

Testing for carbonate ions

H Fill a test tube to a depth of about 2 cm with the solution containing carbonate ions, CO_3^{2-}.

I Add a few drops of dilute nitric acid or dilute hydrochloric acid. Record whether bubbling occurs.

Identifying anions in solution

J Fill a test tube to a depth of about 2 cm with one of the unknown solutions.

K Carry out a test for halide ions or sulfate ions. Also look for bubbling (and so the presence of carbonate ions) when you acidify the solution with dilute nitric acid or dilute hydrochloric acid.

L Repeat steps **J** and **K** until you have determined which anions each unknown solution contains.

Recording your results

Make suitable tables, for example to record the silver **halide** precipitate colours of the known solutions and the results of the tests carried on the unknown solutions. Some suitable table headings are shown below.

Halide ion	Silver halide precipitate colour

Unknown	Test	Observations

Considering your results

1 Use your results to identify the anions in each unknown solution.

Evaluation

2 Silver carbonate and barium carbonate are insoluble solids. Suggest an explanation for why dilute acids are added to the test solutions in steps **B** and **F**.

Chem CP7a Tests for positive ions

Objectives

C9.1 Explain why the test for any ion must be unique.

C9.3 Describe tests to identify the following ions in solids or solutions as appropriate:

- **a** aluminium ion, Al^{3+}
- **b** calcium ion, Ca^{2+}
- **c** copper ion, Cu^{2+}
- **d** iron(II) ion, Fe^{2+}
- **e** iron(III) ion, Fe^{3+}
- **f** ammonium ion, NH_4^+

using sodium hydroxide solution.

C9.4 Describe the chemical test for ammonia.

C9.6 *Core Practical (part): Identify the ions in unknown salts, using the tests for the specified cations and anions.*

C9.7 Identify the ions in unknown salts, using results of the tests above.

Maths requirements

1c Use ratios, fractions and percentages.

Learning outcomes

5th **SC9.1C** Explain why the test for a given ion must be unique to that ion.

5th **SC9.3C** Recall some metal hydroxide precipitate colours.

6th **SC9.3C** Describe how to identify metal ions using sodium hydroxide solution.

6th **SC9.4C** Describe how to identify ammonium ions and ammonia.

Exploring

1. Metal hydroxide precipitate tests

This practical forms one part of the core practical requirement of the specification. It is further supported by the information on Students' sheet CP7a(Identifying Ions -Positive ions) and on *SC25c Core practical – Identifying ions* in the Student Book and on , in which the various methods for identifying anions and cations (met in *SC25a, SC25b* and *Sc25c*) are brought together.

Ask students to carry out hydroxide precipitate tests on solutions containing Al^{3+}, Ca^{2+}, Cu^{2+}, Fe^{2+} or Fe^{3+}. If a white precipitate forms, the students should add excess sodium hydroxide solution and record any changes. Students should use sodium hydroxide solution to identify the metal ion present in unknown samples.

You may wish to set each known solution at five or ten stations around the lab to avoid cross-contamination, and run the first part of the activity as a circus. Once the expected metal hydroxide precipitate colours have been identified and agreed, the students could then test five unknown solutions.

Support: Check that students keep the volumes of solution small, because it becomes difficult to mix the contents of the test tube if the excess occupies a large part of the test tube.

Stretch: Challenge the students to write a balanced ionic equation for the formation of each precipitate.

⚠ Safety

Eye protection should be worn. 1.0 mol dm^{-3} sodium hydroxide solution is corrosive, so avoid skin contact.

Expected results

Copper compounds produce a blue precipitate, iron(II) compounds produce a green precipitate (which turns brown on standing), and iron(III) compounds produce a brown precipitate. Aluminium compounds and calcium compounds both produce white precipitates, but only the aluminium hydroxide precipitate reacts with excess sodium hydroxide solution and disappears to form a colourless solution.

Course resources

Chem Students' sheet CP7a

Equipment

eye protection, dropping pipettes, test tubes, test-tube rack, 1.0 mol dm^{-3} sodium hydroxide, 0.1 mol dm^{-3} aluminium nitrate labelled Al^{3+}, 0.1 mol dm^{-3} calcium chloride labelled Ca^{2+}, 0.1 mol dm^{-3} copper(II) sulfate labelled Cu^{2+}, 0.1 mol dm^{-3} iron(II) sulfate labelled Fe^{2+}, 0.1 mol dm^{-3} iron(III) nitrate labelled Fe^{3+}, unknown solutions labelled 1–5 and randomly assigned from the five labelled solutions above

Edexcel GCSE (9–1) Sciences

Chem CP7b Tests for negative ions

Objectives

C9.5 Describe tests to identify the following ions in solids or solutions as appropriate:

- **a** carbonate ion, CO_3^{2-}, using dilute acid and identifying the carbon dioxide evolved
- **b** sulfate ion, SO_4^{2-}, using dilute hydrochloric acid and barium chloride solution
- **c** chloride ion, Cl^-, bromide ion, Br^-, iodide ion, I^-, using dilute nitric acid and silver nitrate solution.

C9.6 *Core Practical (part): Identify the ions in unknown salts, using the tests for the specified cations and anions.*

C9.7 Identify the ions in unknown salts, using results of the tests above.

Maths requirements

1c Use ratios, fractions and percentages.

Learning outcomes

6th **SC9.5aC** Describe how to identify carbonate ions.

6th **SC9.5aC** Describe how to identify carbon dioxide.

6th **SC9.5bC** Describe how to identify sulfate ions in solution.

5th **SC9.5cC** Recall the colours of silver halide precipitates.

6th **SC9.5cC** Describe how to identify halide ions in solution.

Exploring

1. Identifying anions

This practical forms one part of the core practical requirement of the specification. It is further supported by the information on *Students' sheet CP7b(Identifying Ions-Negative)* and information in the Student Book, in which the various methods for identifying anions and cations (met in *SC25a, SC25b* and *Sc25c*) are brought together.

Students should use: silver nitrate solution to identify Cl^-, Br^- and I^- ions; barium chloride solution to detect sulfate ions; and dilute acid to detect carbonate ions in sodium carbonate solution via effervescence. They should then identify the negatively charged ions present in unknown samples.

You may wish to set each known solution at five or ten stations around the lab to avoid cross-contamination, and run the first part of the activity as a circus. Once the expected results have been identified and agreed upon, the students could then test the five unknown solutions.

Support: Check that the students appreciate that they can use either acid for their carbonate test, but they must use dilute nitric acid with silver nitrate and dilute hydrochloric acid with barium chloride solution.

Stretch: Challenge the students to investigate why they must use dilute nitric acid with silver nitrate and dilute hydrochloric acid with barium chloride solution. (They will already have the solutions needed to show the precipitate formed by carbonate ions if barium chloride solution is used without acidifying first; and the precipitates formed if the wrong acid is used to acidify the sample when testing for sulfate and halide ions).

⚠ Safety

Eye protection should be worn.

Avoid skin contact with the substances used.

Barium chloride solution is harmful.

Dilute nitric acid is an irritant.

Expected results

Chloride salts produce a white precipitate, bromide salts produce a cream precipitate, and iodide salts produce a yellow precipitate. Sulfate salts produce a white precipitate, and carbonate salts produce bubbles of carbon dioxide gas (which turns limewater milky).

Course resources

Chem Students' sheet CP7b

Equipment

eye protection, dropping pipettes, test tubes, test tube rack, 0.1 mol dm^{-3} barium chloride, 0.05 mol dm^{-3} silver nitrate, 0.4 mol dm^{-3} nitric acid, 1.0 mol dm^{-3} hydrochloric acid, 0.1 mol dm^{-3} potassium chloride labelled Cl^-, 0.1 mol dm^{-3} potassium bromide labelled Br^-, 0.1 mol dm^{-3} potassium iodide labelled I^-, 0.1 mol dm^{-3} sodium sulfate labelled SO_4^{2-}, 0.5 mol dm^{-3} sodium carbonate labelled CO_3^{2-}, unknown solutions labelled 1–5 and randomly assigned from the five labelled solutions above

Sample question

This example is taken from the sample assessment material, paper 1CH0/2F, Q10. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

10 Qualitative tests can be used to identify ions in substances.

(a) Sodium hydroxide solution is warmed with a solution of ammonium ions.
Ammonia gas is given off.

Describe the test to show the gas is ammonia.

(2)

....

....

....

....

Question number	Answer	Additional guidance	Mark
10(a)	An answer that provides a description by making reference to: • test gas with moist (red) litmus paper (1) • turns blue (1)	Allow universal indicator paper/pH paper (1) and yellow to blue/purple (1).	**(2)**

Students should learn the test for the gases in the specification and should always include the description of the test and the result.

(b) Two tests were carried out on copper sulfate solution.

(i) Sodium hydroxide solution was added to a small amount of copper sulfate solution.
A blue precipitate of copper hydroxide formed.

Complete the word equation for the reaction.
Include state symbols.

(2)

copper sulfate (aq) + sodium hydroxide (aq) → .... (........) + ... (........)

Question number	Answer	Additional guidance	Mark
10(b)(i)	(copper sulfate(aq) + sodium hydroxide(aq) →) copper hydroxide(s) + sodium sulfate(aq) • sodium sulfate identified as a product (1) • (sodium sulfate)(aq) **and** copper hydroxide(s) both state symbols matched to the correct product (1)	allow Na_2SO_4 allow copper(II) hydroxide/ $Cu(OH)_2$	**(2)**

(ii) Dilute hydrochloric acid was added to a different sample of copper sulfate solution. Barium chloride solution was then added.

State what would be **seen**.

(1)

....

Question number	Answer	Mark
10(b)(ii)	white precipitate/ppt/solid	**(1)**

Students should be able to write equations for the reactions in the qualitative analysis tests, although ionic equations will only be expected in the higher tier paper. Students should be familiar with all the observations from these tests.

*(c) A technician found some colourless crystals in an unlabelled beaker in a laboratory.

The technician knew that the substance was potassium chloride, potassium carbonate, sodium chloride or sodium iodide.

Plan a series of tests the technician could carry out to identify the colourless crystals.

(6)

Question number	Indicative content
***10(c)**	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **AO3 (6 marks)** Any logical description of tests which result in identification of all four substances. Plans may include: • flame test • description of carrying out a flame test • if the flame is yellow/not lilac, sodium ions present • if the flame is lilac/not yellow, potassium ions present • add dilute {hydrochloric/nitric} acid to the solid • if bubbles of gas form then carbonate ions present • bubble gas through limewater • if limewater turns milky/cloudy, carbon dioxide present • make a solution of the crystals in water • add dilute nitric acid • (if no reaction with acid) add silver nitrate solution • if there is a white precipitate, chloride ions present • if there is a yellow precipitate, iodide ions present. Alternative test for halide ions: • make a solution of the crystals in water • add chlorine water • then cyclohexane • if the cyclohexane/top layer turns purple, iodide ions present.

This extended writing question expects students to be familiar with the tests in the specification and to be able to plan a series of tests to identify unknown substances. Their answer should follow a logical sequence.

Core practical 8: Combustion of alcohols

9.28C Core practical: Investigate the temperature rise produced in a known mass of water by the combustion of the alcohols ethanol, propanol, butanol and pentanol

Links to the specification content

9.26C	Recall the formulae of molecules of the alcohols, methanol, ethanol, propanol (propan-1-ol only) and butanol (butan-1-ol only), and draw the structures of these molecules, showing all covalent bonds
9.27C	Recall that the functional group in alcohols is -OH
9.32C	Recall members of a given homologous series have similar reactions because their molecules contain the same functional group and use this to predict the products of other members of these series

Introducing the practical

Students burn the alcohols in spirit burners and heat water in a beaker or copper can. They can heat the water for a given amount of time and measure the temperature rise of water and the mass of alcohol that was burned.

Students should notice many possible errors in the experiment, including: heat loss to the surroundings, difficulty in having the same height of flame from each spirit burner, incomplete combustion, evaporation of alcohols during weighing.

There is an opportunity for students taking the higher tier to process their experimental data before plotting a graph, for example, they could calculate the temperature rise of water per gram of alcohol burned.

Link to GCSE Science 2011: 'Compare the temperature rise produced when the same volume of water is heated by different fuels' was a core practical in C1 Topic 5.

Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- What safety precautions should you take in this investigation and why?
- Which variables should be controlled?
- How will you control these variables?
- What measurements will you take?
- What measuring instruments will you use?
- What are the formulae of methanol, ethanol, propanol, butanol and pentanol?
- What are the main errors in this investigation?
- How could you improve the investigation to reduce the errors?
- How is the temperature rise of water related to the number of carbon atoms in the alcohol molecules?

Skills that are covered in the practical:

- Measure mass of alcohol
- Measure volume of water
- Measure temperature rise of water
- Measure time
- Monitor these reactions by measuring the temperature rise of water
- Make and record measurements for these reactions
- Safe use and careful handling of alcohols

Maths skills:

- Use expressions in decimal form when calculating the mass of alcohol burnt
- Use ratios in the formulae of the alcohols
- Use an appropriate number of significant figures in calculations
- Calculate mean values from experimental data
- Construct bar charts or graphs of the experimental results

Edexcel GCSE (9–1) **Sciences**

Chem CP8 Combustion of alcohols

Your teacher may watch to see if you can:

- keep careful control of control variables.

Aim

To investigate the temperature rise produced in a known mass of water by the combustion of the alcohols ethanol, propanol, butanol and pentanol.

Method

Apparatus

- 100 cm^3 measuring cylinder
- 250 cm^3 conical flask
- stand boss head and clamp
- heat-resistant mat
- eye protection
- thermometer
- insulation/draught shield
- electronic balance
- spirit burners with caps containing: ethanol, propanol, butanol and pentanol

⚠ Safety

Wear eye protection at all times.

All alcohols are flammable: handle with care and keep the tops on burners when not in use.

A Measure the mass of an alcohol burner and cap. Record the mass and the name of the alcohol.

B Place the alcohol burner in the centre of a heat-resistant mat.

C Use a measuring cylinder to add 100 cm^3 of cold water to a conical flask.

D Measure and record the initial temperature of the water and carefully clamp the flask above the alcohol burner.

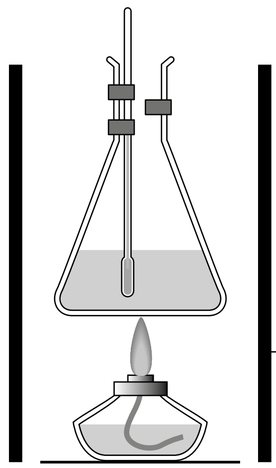
E Surround the apparatus with a draught screen/insulation.

F Remove the cap from the burner, then light the wick of the burner and allow the water to heat up by around 40 °C.

G Replace the cap on the burner and measure and record the final temperature of the water.

H Measure the mass of the alcohol burner and cap again and record the mass.

I Wash out the flask with cold water and repeat steps **A–H** using fresh cold water and a different alcohol.



Recording your results

1 Record all your measurements in a suitable table.

Considering your results/conclusions

2 For each alcohol calculate:

a the change in mass of the burner and lid

b the change in temperature of the water.

c Use your answers to **a** and **b** to calculate the mass of each alcohol burned to produce a 1 °C rise in temperature.

3 **a** Describe any trends that can be seen in your results.

b Explain why these alcohols show such a regular trend in these values. (*Hint:* think about molecular structures.)

Evaluation

4 State four possible sources of error in this experiment and explain which is the main source of error.

Chem CP8 Alcohols

Objectives

C9.26C	Recall the formulae of molecules of the alcohols, methanol, ethanol, propanol (propan-1-ol only) and butanol (butan-1-ol only), and draw the structures of these molecules, showing all covalent bonds.
C9.27C	Recall that the functional group in alcohols is –OH.
C9.28C	*Core practical: Investigate the temperature rise produced in a known mass of water by the combustion of the alcohols, ethanol, propanol, butanol and pentanol.*
C9.32C	Recall members of a given homologous series have similar reactions because their molecules contain the same functional group and use this to predict the products of other members of these series.

Maths requirements

1a	Recognise and use expressions in decimal form.
2c	Construct and interpret frequency tables and diagrams, bar charts and histograms.
5b	Visualise and represent 2D and 3D forms including two dimensional representations of 3D objects.

Learning outcomes

6th	SC9.26C	State the names, formulae and structures of the first four members of the alcohol homologous series.
6th	SC9.27C	State the functional group present in all alcohols.
6th	SC9.32C	Describe some chemical reactions of alcohols.
6th	SC9.32C	Explain why alcohols have similar chemical properties.
7th	SC9.32C	Use the chemical properties of the first four alcohols to predict the properties of other alcohols.

Exploring

1. Core practical – Combustion of alcohols

This practical forms part of the core practical requirement of the specification. It is supported by the information on *Students' sheet CP8(The combustion of alcohols)* and in the Student Book.

Students work in groups following the instructions of Students' sheet CP8(The combustion of alcohols) to investigate the temperature rise produced in a known mass of water by the combustion of the alcohols ethanol, propanol, butanol and pentanol. In this investigation pentanol has been substituted for methanol, due the specific hazards and toxicity of methanol. During the investigation the students measure the mass of alcohol burned to produce a particular temperature rise. To compare the alcohols, the students then calculate the mass burned to produce a 1 °C rise in temperature. There are other ways to compare the 'heat energy' given out by the alcohols, e.g. they could calculate the temperature rise produced by burning a set mass (1 g) of alcohol. If time is short each student group could use a different alcohol and share the results for analysis. Emphasise to the students that the main source of error in this investigation is the 'heat' lost during the experiment. Therefore the use of draught excluders and insulation needs to be as consistent as possible from one experiment to the next.

Most students should be able to carry out the practical and draw conclusions using the first page of the worksheet, which contains some directed questions at the bottom.

⚠ Safety

Wear eye protection at all times.

All alcohols are flammable. Handle the alcohols with care and keep the tops on burners when not in use.

Refer to CLEAPSS LABORATORY HANDBOOK (2009), Section 9.4.3 Using spirit burners in calorimetry.

Support: Some students will need to be shown how to set up and use the apparatus so that heat losses are kept to a minimum. Students should use the second page of the worksheet to fill in their results and draw conclusions.

Stretch: Ask students to calculate the actual energy released during each combustion by using the equation: $\Delta Q = m \times c \times \Delta\theta$ (energy transferred = mass of water × specific heat capacity of water (4.2) × change in water temperature). If the mass of water is in grams, the energy transferred is in joules. This could be extended by asking students to calculate the energy released per gram or even per mole. Some students could be challenged to write up the practical in their own words, without the help of the directed questions at the bottom of the first page of the worksheet; these can be removed before printing/photocopying.

Expected results

The theoretical calculated values for results are given in the table below. These have been calculated using the standard enthalpies of combustion of the alcohols. Note that students will not have used methanol.

Alcohol	Methanol	Ethanol	Propanol	Butanol	Pentanol
Energy released per gram of alcohol burned (kJ/g)	22.7	29.7	33.6	36.1	37.7
Mass of alcohol to produce a 40 °C rise in temperature 100 cm^3 of water (g)	0.74	0.57	0.50	0.47	0.44
Mass of alcohol to produce a 1 °C rise in temperature 100 cm^3 of water (g)	0.0185	0.0143	0.0125	0.0118	0.0110

Students' results will indicate that energy released per gram is lower than these theoretical values (so the mass of alcohol needed to produce a 1 °C rise in temperature is higher). This is due to heat loss in the practical and evaporation of the alcohol. However, the trend should be the same. The mass of alcohol needed to produce a 1 °C rise in temperature in 100 cm^3 of water will decrease as you go down the alcohol series.

Course resources

Chem Students' sheet CP8

Equipment

For each group: eye protection; spirit burners with lids, containing ethanol, propanol, butanol and pentanol; 100 cm^3 measuring cylinder; 250 cm^3 conical flask; stand, boss head and clamp; heat mat; thermometer; 2 × heat mats for insulation/draughts shield; electronic balance

Sample question

This example is taken from the sample assessment material, paper 1CH0/2F, Q6. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

(d) The temperature rise in water when liquid fuels burn can be found using the equipment shown in Figure 9.

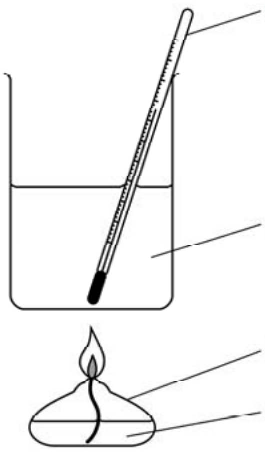


Figure 9

(i) A student compares the temperature rise produced in the water when propanol burns with the temperature rise produced when ethanol burns.

State **two** factors that the student must keep the same in both experiments in order to have a fair comparison.

(2)

1 ....

....

2 ....

....

Question number	Answer	Mark
6(d)(i)	Any two from: • mass/volume of water (1) • height of container above wick (1) • length of wick/height of flame (1) • the container needs to be the same {shape/size/material} (1) • same number of moles of alcohol (1)	**(2)**

Students should be able to identify factors that need to be kept the same in a fair test.

(ii) The results for the two alcohols are shown in Figure 10.

alcohol	mass of alcohol burned / g	temperature rise / °C
ethanol	0.33	20
propanol	0.28	20

Figure 10

Explain, using only the information in Figure 10, why propanol might be the better fuel.

(2)

Question number	Answer	Mark
6(d)(ii)	An explanation that combines identification via a judgement (1 mark) to reach a conclusion via justification/reasoning (1 mark): • the same temperature rise is achieved (1) • using a lower mass of alcohol/propanol (1)	**(2)**

Students may be given results to interpret, as in this question.

Appendix 1

Department for Education: apparatus and techniques list

	CHEMISTRY
1	Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases
2	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater
3	Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations
4	Safe use of a range of equipment to purify and/or separate chemical mixtures including evaporation, filtration, crystallisation, chromatography and distillation
5	Making and recording of appropriate observations during chemical reactions including changes in temperature and the measurement of rates of reaction by a variety of methods such as production of gas and colour change
6	Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products
7	Use of appropriate apparatus and techniques to draw, set up and use electrochemical cells for separation and production of elements and compounds
	Separate science only
8	Use of appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including gas tests, flame tests, precipitation reactions, and the determination of concentrations of strong acids and strong alkalis

Appendix 2

Core practical mapping

The tables on the following pages show how each core practical in chemistry offers opportunities for students to develop some of the mathematical skills and how the practicals map to the practical techniques in Appendix 1.

Chemistry

Chemistry Core Practical	Practical technique								Mathematical skills
	1	2	3	4	5	6	7	8	
1. Investigate the composition of inks using simple distillation and paper chromatography (2.11)	✓	✓		✓		✓			1c Use ratios, fractions and percentages 2a Use an appropriate number of significant figures 3a Understand and use the symbols: =, <, <<, >>, >, ∝, ~ 3c Substitute numerical values into algebraic equations using appropriate units for physical quantities 4a Translate information between graphical and numeric form
2. Investigate the change in pH on adding powdered calcium hydroxide/calcium oxide to a fixed volume of dilute hydrochloric acid (3.6)	✓		✓		✓	✓			4c Plot two variables from experimental or other data
3. Investigate the preparation of pure, dry hydrated copper sulfate crystals starting from copper oxide including the use of a water bath (3.17)	✓	✓		✓		✓			None

Chemistry Core Practical	Practical technique								Mathematical skills
	1	2	3	4	5	6	7	8	
4. Investigate the electrolysis of copper sulfate solution with inert electrodes and copper electrodes (3.31)	✓		✓			✓	✓		1a Recognise and use expressions in decimal form 1c Use ratios, fractions and percentages 2a Use an appropriate number of significant figures 2b Find arithmetic means 3a Understand and use the symbols: =, <, <<, >>, >, ∝, ~ 4a Translate information between graphical and numeric form 4b Understand that y = mx + c represents a linear relationship 4c Plot two variables from experimental or other data
5. Carry out an accurate acid-alkali titration, using burette, pipette and a suitable indicator (5.9C)	✓		✓		✓	✓		✓	1a Recognise and use expressions in decimal form 1c Use ratios, fractions and percentages 2a Use an appropriate number of significant figures 2b Find arithmetic means 3a Understand and use the symbols: =, <, <<, >>, >, ∝, ~ 3b Change the subject of an equation 3c Substitute numerical values into algebraic equations using appropriate units for physical quantities

Chemistry Core Practical	Practical technique 1	2	3	4	5	6	7	8	Mathematical skills
6. Investigate the effects of changing the conditions of a reaction on the rates of chemical reactions by: a measuring the production of a gas (in the reaction between hydrochloric acid and marble chips) *b* observing a colour change (in the reaction between sodium thiosulfate and hydrochloric acid) (7.1)	✓	✓	✓		✓	✓			1a Recognise and use expressions in decimal form 1c Use ratios, fractions and percentages 2a Use an appropriate number of significant figures 2b Find arithmetic means 3a Understand and use the symbols: =, <, <<, >>, >, ∝, ~ 3b Change the subject of an equation 3c Substitute numerical values into algebraic equations using appropriate units for physical quantities 4a Translate information between graphical and numeric form 4c Plot two variables from experimental or other data 4d Determine the slope and intercept of a linear graph 4e Draw and use the slope of a tangent to a curve as a measure of rate of change 5c Calculate areas of triangles and rectangles, surface area and volumes of cubes
7. Identify the ions in unknown salts, using the tests for the specified cations and anions in *9.2C, 9.3C, 9.4C, 9.5C* (9.6C)			✓			✓		✓	None

Chemistry Core Practical	Practical technique								Mathematical skills
	1	2	3	4	5	6	7	8	
8. Investigate the temperature rise produced in a known mass of water by the combustion of the alcohols ethanol, propanol, butanol and pentanol (9.28C)	✓		✓		✓	✓			1a Recognise and use expressions in decimal form 1c Use ratios, fractions and percentages 2a Use an appropriate number of significant figures 2b Find arithmetic means 3a Understand and use the symbols: =, <, <<, >>, >, ∝, ~ 3b Change the subject of an equation 3c Substitute numerical values into algebraic equations using appropriate units for physical quantities 4a Translate information between graphical and numeric form

Appendix 3

GCSE Sciences: Equipment list

The list below is for all core practicals in GCSE Combined Science and Separate sciences. The separate science equipment is draft, and will be updated with a final version on the Edexcel website soon.

Chemistry

Spec statement	Equipment needed (per group)
2.11 Investigate the composition of inks using simple distillation and paper chromatography	250 cm^3 beaker chromatography paper a splint or pencil or glass rod/paper clips four different black felt pens or water-soluble marker pens labelled A–D selection of different coloured marker pens or felt-tip pens selection of pens with 'permanent' (non-water-soluble) inks solvent that will dissolve the permanent ink (for biro ink a mixture of butan-1-ol, ethanol, water (3:1:1 by volume) 880-ammonia ethanol, propanone or propan-2-ol eye protection a conical flask with side-arm, (an alternative is to use a two-hole bung with a thermometer and delivery tube) rubber bung with thermometer delivery tube test tube beaker (250 or 400 cm^3) crushed ice Bunsen burner tripod gauze heat-resistant mat ink antibumping granules

Spec statement	Equipment needed (per group)
3.17 Investigate the preparation of copper sulfate crystals	eye protection 250 cm^3 conical flask 100 cm^3 beaker Bunsen burner gauze tripod stand heat mat Petri dish or watch glass 100 cm^3 measuring cylinder evaporating basin spatula stirring rod filter funnel filter paper tongs water bath 1 mol dm^{-3} sulfuric acid copper(II) oxide
3.6 Investigate the change in pH on adding powdered calcium hydroxide or calcium oxide to a fixed volume of dilute hydrochloric acid	eye protection 100 cm^3 beaker 50 cm^3 measuring cylinder ±0.1 g balance spatula stirring rod white tile universal indicator paper pH colour chart dilute hydrochloric acid calcium hydroxide powder
3.31 Investigate the electrolysis of copper sulfate solution	emery paper low voltage supply (0-12 V) ammeter (0-1 A) variable resistor connecting leads crocodile clips 100 cm^3 beaker stop watch/clock 2 graphite rods 2 strips of copper foil about 2 cm wide and long enough to reach the bottom of the beaker copper sulfate solution (about 50 cm^3, 0.5 mol dm^{-3}) access to a beaker of propanone (about 50 cm^3) access to a balance (at least 2 d.p.)

Spec statement	Equipment needed (per group)
5.9C Carry out an accurate acid-alkali titration, using burette, pipette and a suitable indicator	Each group needs: burette burette stand or retort stand with burette clamp plastic funnel to fit in top of burette 25.0 cm3 pipette pipette filler conical flask white tile methyl orange or phenolphthalein indicator (few drops) hydrochloric acid (about 100 cm3, 0.1 mol dm-3) sodium hydroxide solution (about 100 cm3, 0.1 mol dm-3) access to distilled/de-ionised water
7.1 Investigate the effects of changing the conditions of a reaction on the rates of chemical	Eye protection, large sized marble chips, small sized marble chips, 0.5 mol dm^{-3} hydrochloric acid 250 cm^3 conical flask,100 cm^3 measuring cylinder or gas syringe, 0.1 mol dm^{-3} sodium thiosulfate, 1.0 mol dm^{-3}, 50 cm^3 measuring cylinder, stop clock or stopwatch, 10 cm^3 measuring cylinder
reactions etc..	thermometer water bath,
9.6C Identify the ions in unknown salts, using the tests for the specified cations and anions in 9.2C, 9.3C, 9.4C, 9.5C	Eye protection, Bunsen burner, heat-resistant mat, test tubes, test tube rack, test tube holder, flame test loops (or wooden splints soaked in water), spatula, dropping pipettes, 0.1 mol dm–3 barium chloride solution, 0.4 mol dm–3 hydrochloric acid, 2 mol dm–3 hydrochloric acid (if using flame test loops), 0.05 mol dm–3 silver nitrate solution, 0.4 mol dm–3 nitric acid, 0.4 mol dm–3 sodium hydroxide solution, red litmus paper, distilled water or deionised water. Solid substances for flame tests and carbonate test, e.g. lithium chloride, sodium chloride, potassium chloride, calcium chloride, copper(II) chloride, calcium carbonate. Approx. 0.2 mol dm–3 solutions for precipitate tests, e.g. sodium chloride, potassium bromide, potassium iodide, aluminium sulfate, calcium chloride, copper(II) sulfate, iron(II) sulfate, iron(III) sulfate, ammonium chloride.
9.28C Investigate the temperature rise produced in a known mass of water by the combustion of the alcohols ethanol, propanol, butanol and pentanol	Eye protection, alcohol burners, 150 cm^3 conical flasks, thermometers (-10 to 110 ^{O}C, retort stands and clamps, electronic balance +/- 0.01 g, 100 cm^3 measuring cylinders, lighters or matches, methanol, ethanol, propan-1-ol, butan-1-ol, pentan-1-ol.

Appendix 4 Mapping to lab book

The table below can be used to map between the core practicals in the lab book (which follow the teaching order) and the core practicals in the specification (which is the ordering used in this guide).

specification reference		lesson ref from schemes of work	numbering in this guide	published lab book numbering
Chemistry				
2.11	*Investigate the composition of inks using simple distillation and paper chromatography*	*CC2c.1*	Core practical 1	Core practical 1
3.6	*Investigate the change in pH on adding powdered calcium hydroxide or calcium oxide to a fixed volume of dilute hydrochloric acid*	*CC8d*	Core practical 2	Core practical 5
3.17	*Investigate the preparation of pure, dry hydrated copper sulfate crystals starting from copper oxide including the use of a water bath*	*CC8c.1*	Core practical 3	Core practical 3
3.31	*Investigate the electrolysis of copper sulfate solution with inert electrodes and copper electrodes*	*CC10a.1*	Core practical 4	*[Lab book 2]*
5.9C	*Carry out an accurate acid-alkali titration, using burette, pipette and a suitable indicator*	*SC14d.1*	Core practical 5	*[Lab book 2]*
7.1	*Investigate the effects of changing the conditions of a reaction on the rates of chemical reactions by:* *a measuring the production of a gas (in the reaction between hydrochloric acid and marble chips)* *b observing a colour change (in the reaction between sodium thiosulfate and hydrochloric acid)*	*CC14b*	Core practical 6	*[Lab book 2]*
9.6C	*Identify the ions in unknown salts, using the tests for the specified cations and anions in 9.2C, 9.3C, 9.4C, 9.5C*	*SC22c*	Core practical 7	*[Lab book 2]*
9.28C	*Investigate the temperature rise produced in a known mass of water by the combustion of the alcohols ethanol, propanol, butanol and pentanol*	*SC25b*	Core practical 8	*[Lab book 2]*