INTERNATIONAL GCSE

Biology, Chemistry & Physics (2017)

CORE PRACTICAL GUIDE

Pearson Edexcel International GCSE in Science

For first teaching September 2017

First examination June 2019

Core Practical Guide

Contents

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.

Changes to practical requirements

There will not be any coursework in the International 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 work. In our exams, we will have questions on the core practicals in our specifications, as well as questions on other 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) that we have adhered to for consistency with the UK qualifications. As long as you carry out all of the core practicals, you will automatically cover the apparatus and techniques list.

Approach to core practicals

In your day-to-day teaching, you should 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

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.

N.B. 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.

International GCSE Biology Practicals

There are 9 core practicals in the biology section of International GCSE Combined Science. International GCSE Biology covers the same 9 practicals as well as an additional 5, to make up 14 core practicals in total.

This section outlines each core practical and gives a brief description of each one. Then the guide goes through each core practical in turn, outlining how to carry out the practical, questions that could be asked, and the key skills involved (including maths skills).

Core practical descriptions

Note: **2.14B**, **2.33B**, **2.45B**, **2.58B** and **4.4B** are separate International GCSE Biology only

No.	Specification Reference	Description
1	*2.9 - Investigate food samples for the presence of glucose, starch, protein and fat*	Carry out the food tests shown below: 1. Identify starch by using potassium iodide solution 2. Identify reducing sugars using Benedict's solution (and a water bath) 3. Identify protein using the Biuret test (adding potassium hydroxide to a solution of the food, followed by copper sulfate) 4. Identify fats and oils (lipids) using the emulsion test to show the formation of a precipitate
2	*2.12 - Investigate how enzyme activity can be affected by changes in temperature*	The digestion of starch by amylase can be used with students using potassium iodide solution to detect the presence of starch. Students are looking for the time at which the digestion mixture no longer contains any starch. This experiment can then be repeated at different temperatures. If the practical is first done at room temperature 25 °C, it can then be repeated by different groups within a class at a range of temperatures and data pooled.
3	***2.14B - Investigate how enzyme activity can be affected by changes in pH***	The digestion of starch by amylase can be used with students using potassium iodide solution to detect the presence of starch. Students are looking for the time at which the digestion mixture no longer contains any starch. This is carried out at different pHs using the same temperature.

4	*2.17 - Investigate diffusion and osmosis using living and non-living systems*	Cubes of agar can be used with $KMnO_4$ or with food colouring as the diffusing substance to explore the relationship between size, volume, surface area and rate of diffusion. They can also look at changes in the mass and volume of potato tissue as it is immersed in solutions of various concentrations. They should also carry out a range of investigations using onion cells to look at osmosis, plasmolysis and turgor in plant cells viewed down a microscope. Visking tubing can also be used to look at osmosis and to demonstrate turgor and flaccidity.
5	*2.23 - Investigate photosynthesis, showing the evolution of oxygen from a water plant, the production of starch and the requirements of light, carbon dioxide and chlorophyll*	To explore the effect of light intensity on rate of photosynthesis students can use *Elodea* or *Myriophyllum scabratum.* Both work well in releasing sufficient oxygen to count bubbles or, if time allows, collect the gas in an inverted measuring cylinder and measure the volume of oxygen evolved per unit time. The other experiments investigate the effect of no light, no carbon dioxide and no chlorophyll on photosynthesis. These are all based on the same procedure of testing leaves for starch using potassium iodide solution on a leaf that has had its chlorophyll removed by boiling in ethanol. The leaves need to be destarched by placing in the dark for 24 hours so that they are free from starch at the start of the experiment.
6	***2.33B - Investigate the energy content in a food sample***	To investigate the energy content of food students can burn a known mass of the food using the heat energy released to heat a known volume of water.
7	*2.39 - Investigate the evolution of carbon dioxide and heat from respiring seeds or other suitable living organisms*	Respiring seeds can be placed in a thermos or vacuum flask and be shown to produce an increase in temperature in the flask if left for two or three days. Respiring seeds or blowfly larvae can be used to show that carbon dioxide is released during respiration.

8	***2.45B - Investigate the effect of light on net gas exchange from a leaf, using hydrogen-carbonate indicator***	This investigation uses sodium hydrogen-carbonate indicator to show the changes in carbon dioxide concentration in the air surrounding leaves in different light conditions. Leaves of, for example, privet are placed in three of four boiling tubes containing a small volume of indicator. One tube is placed in bright light, one is wrapped in foil, one is wrapped in muslin and the tube without a leaf is also left in bright light.
9	*2.50 - Investigate breathing in humans, including the release of carbon dioxide and the effect of exercise*	This investigation uses limewater or hydrogen-carbonate indicator to compare the content of inhaled and exhaled air. The second part of the investigation is to compare breathing rates before and after exercise.
10	***2.58B - Investigate the role of environmental factors in determining the rate of transpiration from a leafy shoot***	This investigation uses a potometer to measure the rate of water uptake and therefore deduce water loss or transpiration from a leafy shoot. Each potometer can be used to collect readings in normal air, windy conditions, increased temperature, increased humidity, darkness and finally with half of the leaves removed.
11	*3.5 - Investigate the conditions needed for seed germination*	This investigation looks at the conditions needed for germination. Suitable conditions to investigate would be the temperature, availability of oxygen, and availability of water.
12	*4.2 - Investigate the population size of an organism in two different areas using quadrats*	This investigation looks at the method used to compare population size of a species in two different areas using quadrats.
13	***4.4B - Investigate the distribution of organisms in their habitats and measure biodiversity using quadrat***	This investigation extends the last practical (12) to look at how biotic and abiotic factors affect the distribution of organisms in their habitats. This requires students to measure abiotic factors, such as light intensity and link this to changes in distribution of species and changes in biodiversity.
14	*5.6 - Investigate the role of anaerobic respiration by yeast in different conditions*	This investigation gives students the chance to experiment on the factors that affect respiration in yeast. The rate of respiration can be measured either by collecting the carbon dioxide given off by downward displacement using a water filled measuring cylinder or by counting the bubbles. The investigation can have a number of alternative independent variables such as temperature, concentration of glucose or even using different sugars as a substrate.

Core practical 1: Food tests

2.9 Core practical: Investigate food samples for the presence of glucose, starch, protein and fat

Links to the specification content

2.7	Identify the chemical elements present in carbohydrates, proteins and lipids (fats and oils)
2.8	Describe the structure of carbohydrates, proteins and lipids as large molecules made up from smaller basic units: starch and glycogen from simple sugars, protein from amino acids, and lipid from fatty acids and glycerol
2.24	Understand that a balanced diet should include appropriate proportions of carbohydrate, protein, lipid, vitamins, minerals, water and dietary fibre
2.25	Identify the sources and describe the functions of carbohydrate, protein, lipid (fats and oils), vitamins A, C and D, the mineral ions calcium and iron, water and dietary fibre as components of the diet
2.26	Understand how energy requirements vary with activity levels, age and pregnancy

Introducing the practical

The chemical test for glucose uses Benedict's solution, which is added to a sample of food and heated in a water bath at 80°C for 5 minutes. A colour change from blue to orange or brick red indicates the presence of a reducing sugar. The test can also be used to indicate the concentration of reducing sugar in the sample with green, yellow, orange and then brick red showing increasing levels of reducing sugar. Care should be taken not to boil the samples for too long in order to avoid any starch is hydrolysed into reducing sugars.

The chemical test for starch is to add a few drops of potassium iodide solution to the sample on a spotting tile. A blue-black colour indicates the presence of starch.

The test for protein is the Biuret test in which the reagent is added to the sample in a test tube and the presence of protein is indicated by a purple colour.

The test for lipid is usually the emulsion test. The food sample is placed in a test tube, a small volume of absolute ethanol is added, and the tube is shaken to dissolve any lipid in the alcohol. An equal volume of water is then added and a cloudy emulsion indicates the presence of lipid.

These tests can be used on food samples or unknown powders or supplements to investigate their nutritional content.

Food tests

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

- Why should the food samples be heated for the same time in the test for glucose?
- Are these tests qualitative and how could we make them quantitative?
- How could we use these tests to indicate enzyme functioning?
- Do food substances contain more than one carbohydrate?
- What foods are good sources of each food molecule?

Skills that are covered in the practical:

- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence

Maths skills:

1C Use ratios, fractions, percentages, powers and roots (if using dilutions for a more quantitative analysis of Benedict's test)

Questions:

(iii) Describe an experiment you could carry out to compare the glucose concentration of samples of plasma and glomerular filtrate. **(4)**

Mark scheme:

Question number	Answer	Mark
(b)(iii)	A description that makes reference to four of the following points: • Benedict's/equivalent (1) • heat (1) • red in high concentration of glucose (1) • orange/yellow-green in low concentration of glucose (1) • control volume of sample/time heated/temperature/ volume of Benedict's/equivalent (1)	**4**

Core practical 2: Temperature and enzyme activity

2.12 Core practical: Investigate how enzyme activity can be affected by changes in temperature

Links to the specification content

2.10	Understand the role of enzymes as biological catalysts in metabolic reactions
2.11	Understand how temperature changes can affect enzyme function, including changes to the shape of the active site

Introducing the practical

The enzyme chosen depends upon student familiarity with different enzymes.

The digestion of starch by amylase can be used with students using potassium iodide to detect the presence of starch. If the concentrations and volumes are appropriate then the digestion of the starch won't be too fast or too slow. Students are looking for the time at which the digestion mixture no longer contains any starch. This experiment can then be repeated at different temperatures.

If the practical is first done at room temperature 25 °C, it can then be repeated by different groups within a class at a range of temperatures and data pooled.

Students will need to understand the relationship between the time taken for digestion to be completed and rate of reaction.

It is of course possible to use other enzymes such as catalase from potato with hydrogen peroxide as the substrate. In this case you can measure the rate of reaction directly by measuring the volume of oxygen evolved at each temperature.

Temperature and enzyme activity

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

- What is the relationship between time taken for starch to be digested and rate of reaction?
- What are the independent, dependent and control variables in the investigation?
- How can we ensure that all the reagents are at the correct temperature during the experiment?
- What happens to the starch during the course of the reaction?
- How could we use our knowledge of other food tests to check what has happened to the starch?
- How can the effect of temperature on enzyme action be explained?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Assess the reliability of an experimental activity
- Evaluate data and methods taking into account factors that affect accuracy and validity

Maths skills:

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

4A Translate information between graphical and numerical form

4C Plot two variables (discrete and continuous) from experimental or other data

4D Determine the slope and intercept of a linear graph

Questions

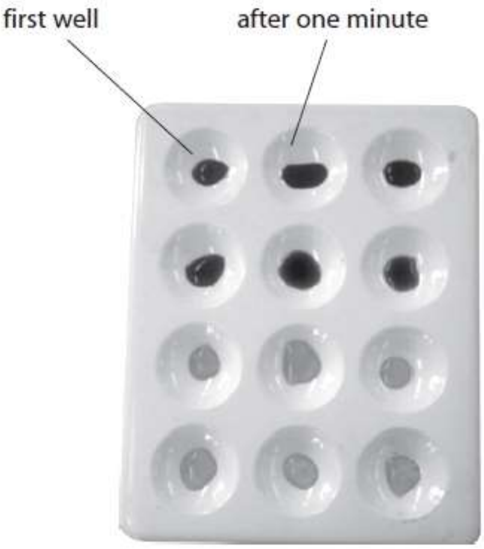
A student investigates the effect of temperature on the rate of starch digestion by amylase. He carries out the first trial of his investigation at a room temperature of 20°C.

He carries out the following steps in his investigation

1 He puts one drop of iodine suspension into each of 12 wells on a spotting tile.
2 He then takes up 10 cm^3 of 10% starch suspension into a syringe.
3 He adds one drop of the starch suspension from the syringe to the first well in the spotting tile and records the colour change.
4 He rinses the outside of the syringe with water from a tap.

5 He then takes up exactly 5 cm^3 of 5% amylase suspension into the same syringe containing the 10% starch suspension.
6 He starts a stopwatch.
7 He then rocks the syringe containing the mixture gently backwards and forwards for one minute.
8 He adds one drop of the mixture from the syringe to the next well in the spotting tile and records the colour change.
9 He repeats this at intervals of one minute until he has added starch and amylase mixture to all of the wells.
10 He then repeats steps 1–9 but this time he uses iodine, amylase and starch suspension that have been stored in a water bath at 40°C.
11 He also keeps the syringe containing the mixture in the water bath at 40°C between drops.

The photograph shows his results for 20°C at the end of the experiment when all the wells have mixture added.



(a) (i) Give one safety precaution the student should take when carrying out this investigation. (1)

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(ii) How many minutes do the samples of mixture added to the spotting tile in the photograph represent? (1)

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(b) Explain the purpose of the following steps in the student's experiment.
(i) step 4 (1)

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____

(ii) step 7 (1)

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____

(iii) step 11 (1)

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(c) (i) Identify two variables that the student controls in his experiment. (2)

1 ____

2 ____

(ii) Name the independent variable that the student is investigating. (1)

____

(d) Using the photograph, explain how many minutes it took for the reaction to be completed at 20°C. (3)

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(e) The results for the spotting tile at 40°C would be different from the trial carried out at 20°C.

(i) Describe how the appearance of the results will be different. (2)

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(ii) Explain the difference in the appearance of the results. (2)

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(Total for question = 15 marks)

Mark scheme

Question number	Answer	Notes	Marks
(a) (i)	safety glasses / wear gloves ;	Ignore lab coat / tie hair back / eq	1
(ii)	11/ eleven;		1
(b) (i)	remove starch / solution from surface of syringe / eq;	Ignore get into syringe	1 1
(ii)	mix <u>contents</u> / mix <u>amylase and starch</u> / eq;	Mix alone = 0 Allow enzyme and starch	1
(iii)	keep at correct temperature / keep temperature constant / eq;	Ignore fair test	

Question number	Answer	Notes	Marks
(c) (i)	1. volume / concentration of amylase; 2. volume / concentration of starch; 3. volume / concentration of iodine / drops of iodine; 4. volume / concentration of mixture;	Allow amount only once	2
(ii)	temperature;	Ignore time	1
(d)	1. 6 minutes / between 5 and 6 minutes / eq; 2. iodine stays yellow / orange / brown / iodine stays same colour / colourless / not blue black; 3. no starch present; 4. digested/broken down ;	Reject 6-7 mins	3
(e)(i)	1. fewer wells with blue black colour / more wells yellow / orange / brown / colourless / eq; 2. starch digested sooner / quicker / reaction completed sooner / eq;		2
(ii)	1. enzymes work faster at 40^{0}C / ref to optimum / eq; 2. more (kinetic) energy / molecules move faster / eq; 3. more collisions / more enzyme substrate complexes /eq;	Ignore ref to denature	2

Core Practical 3: pH and enzyme activity

2.14B Core practical: Investigate how enzyme activity can be affected by changes in pH

Links to the specification content

2.10	Understand the role of enzymes as biological catalysts in metabolic reactions
2.11	Understand how enzyme function can be affected by changes in pH altering the active site
2.31	Understand the role of bile in neutralising stomach acid and emulsifying lipids

Introducing the practical

The enzyme chosen depends upon student familiarity with different enzymes.

The digestion of starch by amylase can be used with students using potassium iodide to detect the presence of starch. If the concentrations and volumes are appropriate then the digestion of the starch will be not too fast or too slow. Students are looking for the time at which the digestion mixture no longer contains any starch. This experiment can then be repeated at different pH.

The pH can be altered by adding 1 cm^3 sodium carbonate solution, 0.5 cm^3 sodium carbonate solution, 2 cm^3 ethanoic (acetic) acid or 4 cm^3 ethanoic (acetic) acid. The pH of each solution can be determined by using universal indicator paper.

If the practical is done at pH 7, nothing added, then it can be repeated by different groups within a class at a range of pH's and data pooled.

Students will need to understand the relationship between time taken for digestion to be completed and rate of reaction.

It is of course possible to use other enzymes such as catalase from potato.

pH and enzyme activity

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

- What is the relationship between time taken for starch to be digested and rate of reaction?
- What are the independent, dependent and control variables in the investigation?
- How can the effect of pH on enzyme action be explained?
- Why would this practical be difficult using protease enzymes?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Assess the reliability of an experimental activity
- Evaluate data and methods taking into account factors that affect accuracy and validity

Maths skills:

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

4A Translate information between graphical and numerical form

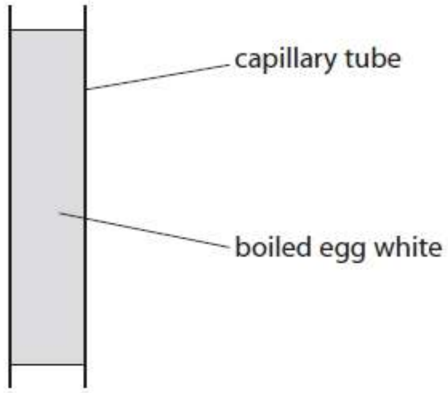
4C Plot two variables (discrete and continuous) from experimental or other data

4D Determine the slope and intercept of a linear graph

Exam Questions

A student wants to investigate the effect of secretions (juice) from the pancreas on the digestion of protein.

The white of an egg is put into fifteen 50 mm long capillary tubes. The tubes are placed in boiling water for 10 minutes until the egg white becomes solid. The diagram shows one of the tubes filled with solid egg white.



The fifteen tubes are put into three groups of five.

- five tubes are placed in a beaker of distilled water
- five tubes are placed into a beaker of juice from the pancreas
- five tubes are placed into a beaker of juice from the pancreas that has been boiled

After three hours, the length of the boiled egg white in each tube is measured in mm. The results are shown in the table.

Length of boiled egg white after three hours in mm		
Distilled water	Juice from the pancreas	Boiled juice from the pancreas
50	14	50
50	12	50
50	13	50
50	14	50
50	14	50

(a) (i) Give the dependent variable in this experiment. **(1)**

____

(ii) Give two reasons why the results obtained by the student are reliable. **(2)**

1. ____

____

2. ____

____

(iii) Suggest how the student can obtain precise measurements of length. **(1)**

____

____

(b) (i) Explain the difference in the results obtained in distilled water compared to juice from the pancreas. (2)

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(ii) Explain the difference in the results obtained in pancreas juice compared to boiled juice from the pancreas. **(2)**

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(c) Suggest how you could modify this investigation to find out the effect of pH on protein digestion by pancreas juice. **(2)**

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(Total for question = 10 marks)

Mark scheme

Question number	Answer	Notes	Marks
(a) (i)	length of egg white;		1
(ii)	1. repeated / five tubes used / eq; 2. similar pattern / no anomalies / small range / eq;		2
(iii)	ruler / scale / eq;	must state apparatus	1
(b) (i)	1. no enzyme / no protease / no named protease; 2. no digestion / no break down;	ignore no change in length allow converse	2
(ii)	1. enzyme denatured / changed active site / enzyme destroyed; 2. high temperature / heat / eq;	2. ignore boiled	2
(c)	1. acid and alkali / range of pH / different pHs / change pH; 2. no boiling of pancreas juice; 3. same volume of juice/enzyme / same concentration of juice/enzyme;	3. ignore amount	2

Core practical 4: Diffusion and osmosis

2.17 Core practical: Investigate diffusion and osmosis using living and non-living systems

Links to the specification content

2.15	Understand the processes of diffusion, osmosis and active transport by which substances move into and out of cells
2.16	Understand how factors affect the rate of movement of substances into and out of cells, including the effects of surface area to volume ratio, distance, temperature and concentration gradient

Introducing the practical

Students should investigate the relationship between temperature, surface area and concentration gradient and the rate of diffusion in non-living systems.

Cubes of agar can be used with $KMnO_4$ or with food colouring as the diffusing substance to explore the relationship between size, volume, surface area and rate of diffusion.

Agar plates with wells cut in them can be used to look at the effect of concentration and temperature on the rate of diffusion of a food colouring.

They can also look at changes in the mass and volume of potato tissue as it is immersed in solutions of various concentrations. They can extend this investigation to determine the water potential of the potato tissue.

They should also carry out a range of investigations using onion cells to look at osmosis, plasmolysis and turgor in plant cells viewed down a microscope.

Visking tubing can also be used to look at osmosis and to demonstrate turgor and flaccidity.

Diffusion and osmosis

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

- How does diffusion differ from osmosis?
- How can we explain the effect of temperature, concentration and surface area on the rate of diffusion?
- How does an understanding of the relationship between size, surface area and volume help explain the need for circulation systems?
- What are the independent, dependent and control variables in the investigation?
- How can the importance of osmosis be explained in plant transport and turgor?
- How might isolated animal cells be affected by immersion in pure water or concentrated sodium chloride solution?
- How can Visking tubing be used as a model for digestion and absorption?
- How might the relationship between active transport and concentration or temperature be different from that between diffusion and concentration or temperature?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Use of microscopes to observe plant cells and animal cells
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Measuring masses (of potato) accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Assess the reliability of an experimental activity
- Evaluate data and methods taking into account factors that affect accuracy and validity

Maths skills:

1C Use ratios, fractions, percentages, powers and roots

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

4A Translate information between graphical and numerical form

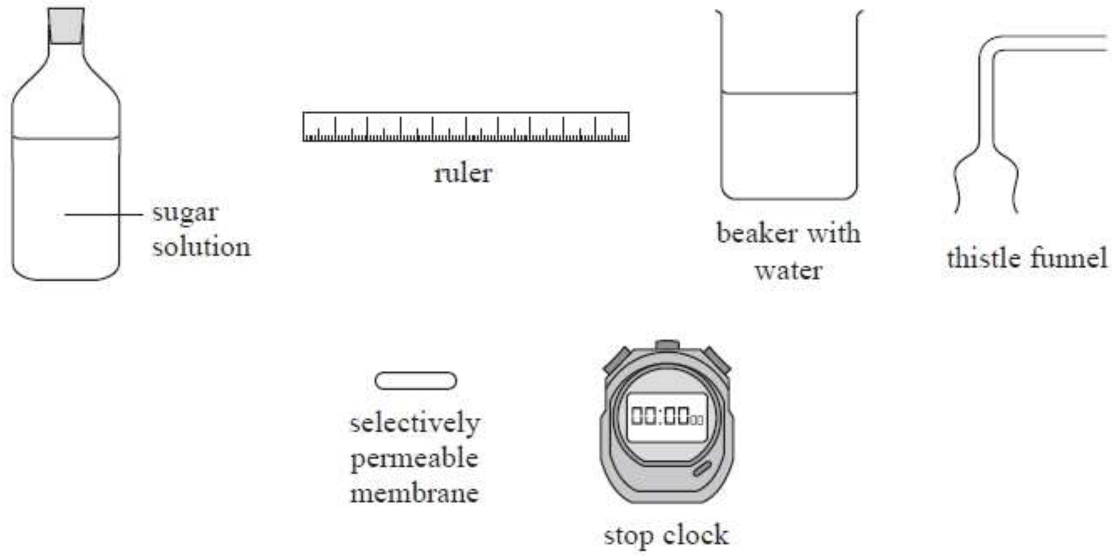
4C Plot two variables (discrete and continuous) from experimental or other data

4D Determine the slope and intercept of a linear graph

5C Calculate areas of triangles and rectangles, surface areas and volumes of cubes

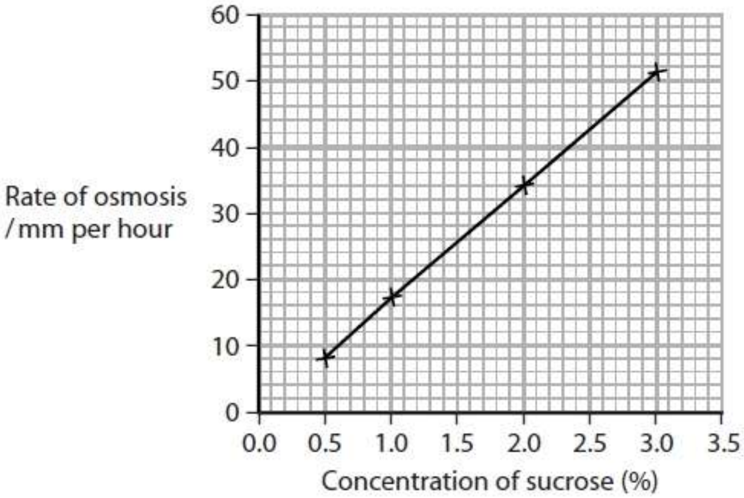
Exam Questions

(b) The diagram shows some of the apparatus used to investigate the rate of osmosis.



In the space below, draw a labelled diagram to show how you would put this apparatus together to investigate the rate of osmosis. **(4)**

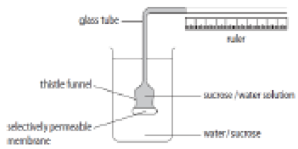
(c) The apparatus is used to find out the effect of different sucrose concentrations on the rate of osmosis.
The graph below shows the results.



Calculate, using information from the graph, the rate of osmosis in mm per minute that would occur for a sucrose concentration of 2.5%. Show your working. **(2)**

rate of osmosis = ... mm per minute

Mark scheme

Question number	Answer	Additional guidance	Mark
(b)	An answer that makes reference to the following four points: • beaker containing water/sucrose/thistle funnel containing sucrose/water (1) • selectively permeable membrane separating sucrose from water (1) • ruler by tube of thistle funnel (1) • level of liquid shown in the tube (1)		4

Question number	Answer	Additional guidance	Mark
(c)	Identification • 42 (1) Division • 42 ÷ 60 = 0.70 (1)	award full marks for correct numerical answer without working	2

Core Practical 5: Photosynthesis

2.23 Core practical: Investigate photosynthesis, showing the evolution of oxygen from a water plant, the production of starch and the requirements of light, carbon dioxide and chlorophyll

Links to the specification content

2.18	Understand the process of photosynthesis and its importance in the conversion of light energy to chemical energy
2.19	Know the word equation and the balanced chemical symbol equation for photosynthesis
2.20	Understand how varying carbon dioxide concentration, light intensity and temperature affect the rate of photosynthesis
2.21	Describe the structure of the leaf and explain how it is adapted for photosynthesis
2.22	Understand that plants require mineral ions for growth, and that magnesium ions are needed for chlorophyll and nitrate ions are needed for amino acids

Introducing the practical

To explore the effect of light intensity on rate of photosynthesis students can use Elodea or Myriophyllum scabratum (note – do not use other Myriophyllum species, as these can be invasive). This is a fast growing aquarium plant, which appreciates bright light and an aquarium tank at room temperature. Both work well in releasing sufficient oxygen to count bubbles or, if time allows, collect the gas in an inverted measuring cylinder and measure the volume of oxygen evolved per unit time.

A small sprig of the pondweed can be put in a boiling tube of pond water and this can then be placed in a beaker, with a thermometer, to act as water bath. The bubbles of oxygen coming out of the freshly cut sprig can easily be counted.

The distance of a bench lamp can be moved to vary the light intensity.

The other experiments investigate the effect of no light, no carbon dioxide and no chlorophyll on photosynthesis.

These are all based on the same procedure of testing leaves for starch using potassium iodide on a leaf that has had its chlorophyll removed by boiling in ethanol. The leaves need to be destarched by placing in the dark for 24 hours so that they are free from starch at the start of the experiment.

In the case of showing light is required, one leaf is covered with foil or a stencil is used so that only the illuminated leaf produces starch.

To show chlorophyll is required, a variegated leaf, in which some of the leaf lacks chlorophyll, is used and starch is only produced in the areas that were green.

To show carbon dioxide is required one leaf of a plant is enclosed in a conical flask containing soda lime to absorb the carbon dioxide and this leaf is compared to another enclosed in a flask but without the soda lime. Only the leaf that had access to carbon dioxide produces starch.

Photosynthesis

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

- Why is collecting gas a more appropriate method that counting bubbles?
- Why might the volume of gas collected not be a valid measure of the rate of photosynthesis?
- What is the function of the water bath?
- What other factors might limit the rate of photosynthesis?
- Why do we need to destarch a plant before we commence our experiment?
- Why do we immerse the leaf in boiling water for a few seconds before we remove the ethanol?
- What precautions do we need to take to safely remove the chlorophyll from the leaf?
- What other methods could we use to demonstrate that photosynthesis has occurred?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Measuring volumes of gas accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Assess the reliability of an experimental activity
- Evaluate data and methods taking into account factors that affect accuracy and validity

Maths skills:

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

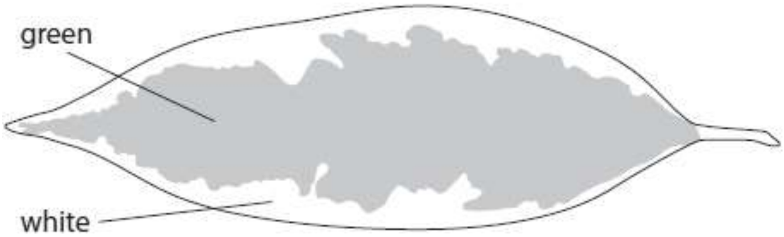
4A Translate information between graphical and numerical form

4C Plot two variables (discrete and continuous) from experimental or other data

4D Determine the slope and intercept of a linear graph

Exam Questions

(b) A student carries out an experiment to investigate the need for chlorophyll in photosynthesis.
He uses a variegated leaf as shown.



The green part of the leaf has cells that contain chlorophyll. The white part of the leaf has cells that do not contain chlorophyll.

(i) Describe the procedure used to test this leaf for starch. **(4)**

(ii) Draw a labelled diagram of the leaf to show its appearance after the student has completed the test for starch. **(2)**

(c) Suggest a method the student could use to measure the area of the green part of the leaf. **(2)**

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Mark scheme

Question number	Answer	Mark
(b)(i)	A description that makes reference to four of the following points: • place leaf in boiling water (1) • place leaf in boiling ethanol (1) • use water bath/safe heating/no naked flame (1) • place leaf in water (1) • place leaf in iodine solution (1) • blue/black indicates starch; orange/yellow indicates no starch (1)	**4**

Question number	Answer	Additional guidance	Mark
(b)(ii)	A drawing showing the following: • white part labelled orange/yellow/no starch (1) • green part labelled blue/black/starch (1)	allow approximate shape	**2**

Question number	Answer	Mark
(c)	A method that includes two of the following points: • trace around the leaf/use transparent paper/equivalent (1) • trace around the green part (1) • put onto squared paper (1) • count the number of squares (1) • reference to both sides of leaf being measured (1)	**2**

Core practical 6: Food energy content

2.33B Core practical: Investigate the energy content in a food sample

Links to the specification content

2.24	Understand that a balanced diet should include appropriate proportions of carbohydrate, protein, lipid, vitamins, minerals, water and dietary fibre
2.25	Identify the sources and describe the functions of carbohydrate, protein, lipid (fats and oils), vitamins A, C and D, the mineral ions calcium and iron, water and dietary fibre as components of the diet
2.26	Understand how energy requirements vary with activity levels, age and pregnancy

Introducing the practical

To investigate the energy content of food students can burn a known mass of the food using the heat energy released to heat a known volume of water.

Suitable foods are potato crisps or puffed wheat snacks. These can be obtained as low fat or reduced fat versions and these can be compared to the normal versions. The foodstuff is lit over a Bunsen then transferred under a boiling tube of water and the temperature change of the water is recorded. If the food stops burning, it needs to be relit until it will no longer burn.

It is also informative to calculate the energy released from the food and compare this to the values given on the packets.

Nuts should not be used as some students may have allergies.

Food energy content

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

- Why is the energy value we calculate much less than the value on the packet?
- Why do individual student results show variation?
- How can we improve our method to obtain the most accurate and valid measurement we can using this apparatus?
- How could we improve our apparatus to deliver an energy value nearer to the published value?
- How does the energy value relate to the nutritional information on the food packet?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Measuring temperature change accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Assess the reliability of an experimental activity
- Evaluate data and methods taking into account factors that affect accuracy and validity

Maths skills:

1D Make estimates of the results of simple calculations, without using a calculator

2A Use an appropriate number of significant figures

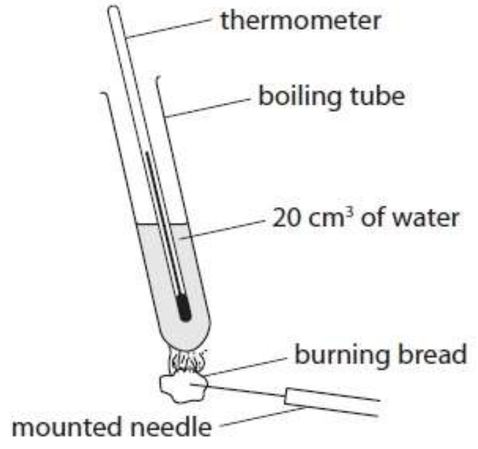
2B Understand and find the arithmetic mean (average)

2C Construct and interpret bar charts

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

Exam question

This apparatus can be used to determine the energy value of food such as dried bread.



(a) John suggested that a more accurate value could be obtained if a larger volume of water was used.

Explain why John's suggestion might be correct. **(2)**

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(b) Suggest **one** other modification and explain how it would improve the accuracy of the result. **(2)**

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(Total for question = 4 marks)

Mark scheme

Question number	Answer	Notes	Marks
(a)	smaller surface area to volume ratio; less heat loss / more energy measured / eq; heats up slowly / avoid boiling / eq;	accept converse	2
(b)	insulation / lid / cover / eq; less heat/energy loss; burning food close to tube / eq; less heat/energy loss; quick transfer of burning food / eq; less heat/energy loss; stir / eq; even temperature; avoid draft / wind; less heat/energy loss; digital thermometer ; precision / eq; use calorimeter / burn in oxygen; all food burnt / less heat/energy loss;	mark in discrete pairs reject idea of more bread ignore repeat	2
		Total	**4**

Core practical 7: Respiration

2.39 Core practical: Investigate the evolution of carbon dioxide and heat from respiring seeds or other suitable living organisms

Links to the specification content

2.34	Understand how the process of respiration produces ATP in living organisms
2.35	Know that ATP provides energy for cells
2.36	Describe the differences between aerobic and anaerobic respiration
2.37	Know the word equation and the balanced chemical symbol equation for aerobic respiration in living organisms
2.38	Know the word equation for anaerobic respiration in plants and in animals

Introducing the practical

Respiring seeds can be placed in a thermos or vacuum flask and be shown to produce an increase in temperature in the flask if left for two or three days. Germinating wheat works well. You can use boiled seeds as a control and should use bleach or hypochlorite solution to sterilise the seeds and prevent microbial respiration from causing an increase in temperature.

Respiring seeds or blowfly larvae can be used to show that carbon dioxide is released during respiration. The gas released can be bubbled through limewater, which turns cloudy, or through sodium hydrogen-carbonate indicator, which turns from orange to yellow.

Respiration

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

- Why is it important to sterilise the boiled seeds?
- Can we tell if the respiration is aerobic or anaerobic?
- What is the advantage of using limewater rather than another indicator?
- How could we make the investigation into respiration quantitative?
- How else could we show respiration is taking place other than by energy release or carbon dioxide production?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Measuring temperature change accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence

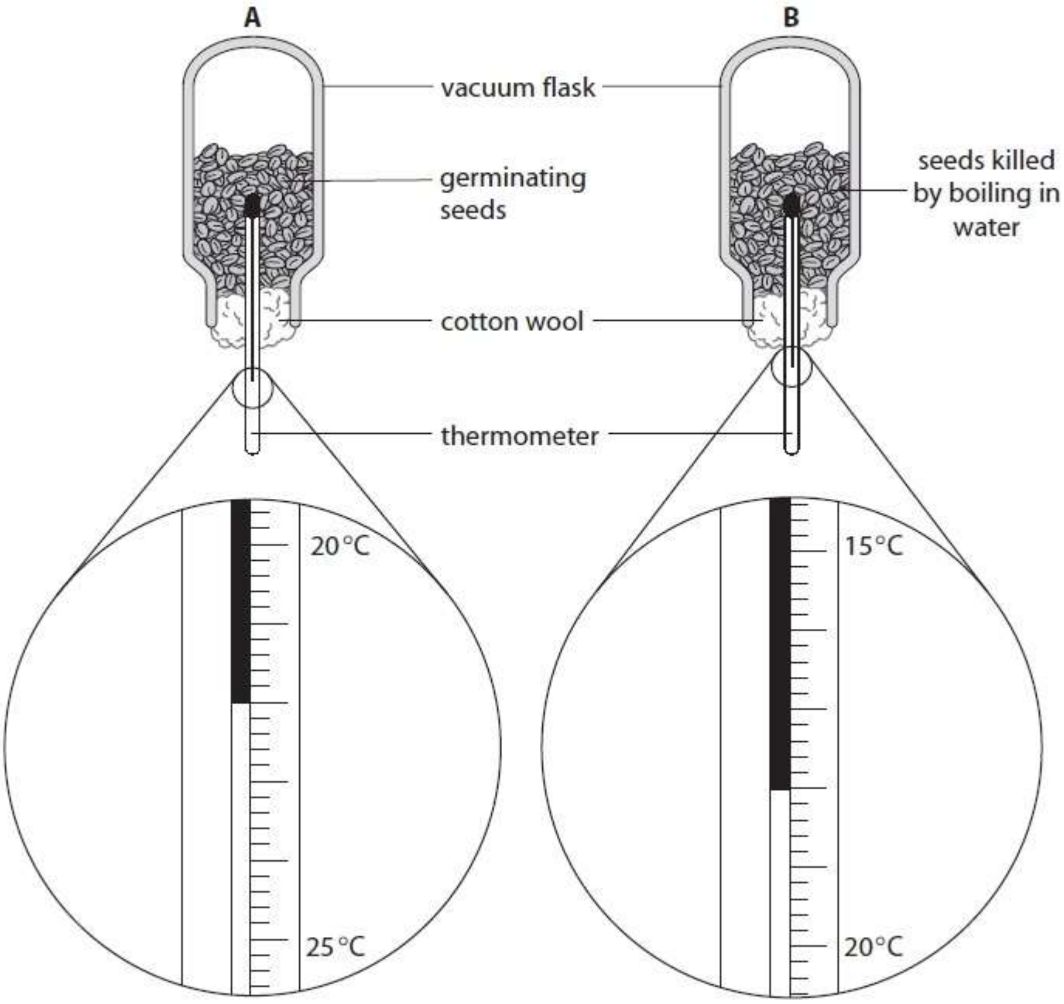
Maths skills:

2B Understand and find the arithmetic mean (average)

2C Construct and interpret bar charts

Exam questions

The diagram shows the apparatus used in a seed germination experiment.



(a) The two samples of seeds started at the same temperature of 18°C.
The diagram shows the temperature reading on each thermometer after 48 hours.

(i) Complete the table to show the temperature of flask A and flask B. (1)

Temperature in °C	
Flask A	Flask B

(ii) Give a biological explanation for the difference in the temperature of flask A compared to flask B. **(2)**

(b) The seeds in both flasks were washed in disinfectant before being put into the flasks. Suggest why this was done. **(1)**

(c) The cotton wool kept the thermometers in place and prevented the seeds from falling out of the flasks.

Suggest why cotton wool was used rather than a rubber bung. **(1)**

(d) The seeds used in the experiment were from the same species.

Suggest **one** other variable that needs to be controlled in this experiment. **(1)**

(Total for question = 6 marks)

Mark scheme

Question number	Answer	Notes	Marks
(a) (i)	flask A 22 and flask B 18 (both temperatures correct) ;	units not required	1
(ii)	respiration; heat released / eq;	allow converse ignore energy / warmth	2
(b)	kill bacteria / kill microorganisms / remove bacteria / no bacteria / fewer bacteria / sterilise / eq;	ignore other organisms	1
(c)	oxygen (in) / carbon dioxide (out);	ignore air / gas / gas exchange; reject oxygen out alone / carbon dioxide in alone eg to allow oxygen in and out = 1 allow movement of oxygen / carbon dioxide	1
(d)	mass / number / age / amount (of seeds) / eq;	ignore health / time / outside temperature ignore size	1
		Total	**6**

Core practical 8: Light intensity and photosynthesis

2.45B Core practical: Investigate the effect of light on net gas exchange from a leaf, using hydrogen-carbonate indicator

Links to the specification content

2.40B	**understand the role of diffusion in gas exchange**
2.41B	**understand gas exchange (of carbon dioxide and oxygen) in relation to respiration and photosynthesis**
2.42B	**understand how the structure of the leaf is adapted for gas exchange**
2.43B	**describe the role of stomata in gas exchange**
2.44B	**understand how respiration continues during the day and night, but that the net exchange of carbon dioxide and oxygen depends on the intensity of light**
2.18	understand the process of photosynthesis and its importance in the conversion of light energy to chemical energy
2.19	know the word equation and the balanced chemical symbol equation for photosynthesis
2.20	understand how varying carbon dioxide concentration, light intensity and temperature affect the rate of photosynthesis

Introducing the practical

This investigation uses sodium hydrogen-carbonate indicator to show the changes in carbon dioxide concentration in the air surrounding leaves in different light conditions.

Leaves of, for example, privet are placed in three of four boiling tubes containing a small volume (2 cm^3) of indicator. Students will sometimes think adding more indicator will produce a quicker change.

It is important that the indicator is in balance with the atmosphere and is red or orange in colour.

One tube is placed in bright light, one is wrapped in foil, one is wrapped in muslin and the tube without a leaf is also left in bright light. The tubes are then left for 40 minutes.

The leaf in the light changes the indicator to a purple colour, the one in darkness changes the indicator to a yellow colour and the one in dim light will remain red. The tube in light without a leaf will also remain red.

Light intensity and photosynthesis

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

- What is the function of the empty tube?
- Why is hydrogen-carbonate indicator used rather than limewater?
- Why is a small volume of indicator used in this experiment?
- What other factors will influence the gas exchange in the tubes?
- How do the each of the three experimental tubes represent a different time of day?
- How do changes in gas exchange reflect processes going on in the leaf cells?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Observing and recording changes
- Producing appropriate results tables
- Analyse and interpret data to draw conclusions that are consistent with the evidence

Exam questions

Ian wanted to investigate how gas exchange in a flowering plant changed with light intensity.

He set up an experiment using four tubes. Each of the tubes contained orange hydrogen carbonate indicator solution and was sealed with a cork. Ian added a fresh leaf to tubes A, B and C. Tube D had no leaf.

The tubes were then left in the following conditions:

- Tube A was placed in direct sunlight.
- Tube B was covered with aluminium foil to prevent any light entering the tube.
- Tube C was covered with thin cloth that allowed some light to enter the tube.
- Tube D was also placed in direct sunlight. He left the tubes in the laboratory for one hour and then returned to look at the colour of the indicator solution in the tubes.

(a) Suggest a hypothesis for Ian's investigation. **(2)**

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(b) Give **two** variables that Ian should keep constant in his investigation. **(2)**

(c) State the purpose of Tube D in the investigation. **(1)**

(d) Ian recorded his results in a table.

Tube	Colour of indicator at start	Colour of indicator after one hour
A	orange	purple
B	orange	yellow
C	orange	orange
D	orange	orange

(i) Explain the change in colour of the indicator in Tube A. **(2)**

(ii) Explain the change in colour of the indicator in Tube B. **(2)**

(e) Suggest why the indicator did not change colour in:

(i) Tube C **(1)**

(ii) Tube D **(1)**

(f) Limewater is an indicator that can be used to show an increase in the level of carbon dioxide.
Suggest why it would **not** be a suitable indicator for use in this investigation. **(1)**

(Total for question = 12 marks)

Mark scheme

Question number		Answer	Notes	Marks
(a)		light (intensity); affects/alters/increases/decreases/changes CO_2 level / gas exchange / photosynthesis;		2
(b)		size / species of leaves / eq; volume/amount/concentration of indicator; temperature;	ignore ref to tube size / time / cork seal / humidity	max 2
(c)		control / allow (valid) comparison / see if indicator changes (with no leaf) / colour change due to leaf / see if gas exchange happens without the leaf / eq;		1
(d)	(i)	photosynthesis / allow photosynthesis more than respiration;	ignore photosynthesis and respiration unqualified	2
		less CO_2 / CO_2 absorbed / eq;	ignore ref to pH	
	(ii)	respiration / <u>no</u> photosynthesis; CO_2 released / more CO_2 / no CO_2 absorbed / eq;	ignore ref pH	2
(e)	(i)	respiration equals photosynthesis / CO_2 in equals CO_2 out / eq;	ignore gas exchange	1
	(ii)	<u>no leaf</u>;	ignore empty tube / nothing in tube	1
(f)		limewater only shows increase in CO_2 / cannot show decrease in CO_2 / cannot show amount of CO_2 / eq;		1

TOTAL 12 MARKS

Core practical 9: Human respiration

2.50 Core practical: Investigate breathing in humans, including the release of carbon dioxide and the effect of exercise

Links to the specification content

2.34	Understand how the process of respiration produces ATP in living organisms
2.36	Describe the differences between aerobic and anaerobic respiration
2.37	Know the word equation and the balanced chemical symbol equation for aerobic respiration in living organisms
2.38	Know the word equation for anaerobic respiration in plants and in animals
2.48	Explain how alveoli are adapted for gas exchange by diffusion between air in the lungs and blood in capillaries

Introducing the practical

This investigation uses limewater or hydrogen-carbonate indicator to compare the content of inhaled and exhaled air. This can be done using a T-tube arrangement going from a mouthpiece into two conical flasks. The inhaled and exhaled air bubbles through the indicator as the student breathes in and out.

The changes in the colour of indicators before and after breathing can be used to illustrate the difference between inhaled and exhaled air.

The second part of the investigation is to compare breathing rates before and after exercise. This would be an ideal opportunity for students to design, plan, review and carry out an investigation perhaps using the CORMS prompt to help them.

Human respiration

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

- How can we tell which flask receives inhaled and which flask receives exhaled air?
- What other differences are there between inhaled and exhaled air?
- How could we show these in a practical?
- How else does breathing change following exercise?
- How could we show these changes in a practical?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Observing and recording changes
- Producing appropriate results tables
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Communicate the findings from experimental activities, using appropriate technical language, relevant calculations and graphs
- Assess the reliability of an experimental activity
- Evaluate data and methods taking into account factors that affect accuracy and validity.

Maths skills:

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average) of breathing rate of class data

2D Construct and interpret frequency tables, diagrams and histograms of class data

2G Understand the terms mode and median

4C Plot two variables (discrete and continuous) from experimental or other data

Exam questions

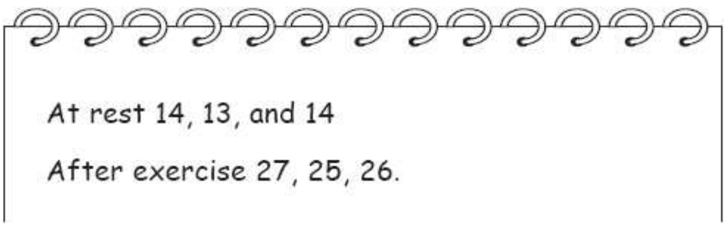
A group of students investigate the effect of exercise on breathing rate.

They measure their breathing rate at rest by counting breaths per minute.

They then exercise by running on the spot.

After exercise, they measure their breathing rate by counting breaths per minute.

These are their results.



(a) Display these results in a table. **(2)**

(b) Explain why breathing rate is higher after exercise. **(4)**

(c) Explain how the students could improve their investigation. **(2)**

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(Total for question = 8 marks)

Mark scheme

Question number	Answer	Notes	Marks
(a)	1. before and after exercise; 2. breaths per minute;	allow interchangeable rows /columns ignore breathing rate no credit for graph	2
(b)	1. muscle(s); 2. respiration; 3. oxygen required; 4. remove lactic acid; 5. oxygen debt; 6. remove carbon dioxide;		4
(c)	1. repeat / use more people / eq; 2. measure breathing rate during exercise; 3. somebody else / machine / data logger / spirometer count breaths / eq; 4. run at same speed / for same time same distance / run on treadmill / eq;		2

Core practical 10: Transpiration

2.58B Core practical: Investigate the role of environmental factors in determining the rate of transpiration from a leafy shoot

Links to the specification content

2.54	Describe the role of xylem in transporting water and mineral ions from the roots to other parts of the plant
2.55B	**Understand how water is absorbed by root hair cells**
2.56B	**Understand that transpiration is the evaporation of water from the surface of a plant**
2.57B	**Understand how the rate of transpiration is affected by changes in humidity, wind speed, temperature and light intensity**

Introducing the practical

This investigation uses a potometer to measure the rate of water uptake and therefore deduce water loss or transpiration from a leafy shoot. A simple bubble potometer consists of a straight length of capillary tube attached to a plastic collar into which the cut end of a leafy shoot is inserted. Commercially produced potometers are not required but you could show one to the students if you have one.

The students will need help to set up the potometer ensuring that the shoot fits snugly into the collar and that there are no leaks or bubbles in the tube. A bucket filled with water that enables the potometer to be immersed vertically will help to remove unwanted bubbles.

When set up, the bottom of the capillary tube can be placed in a beaker of water. It can then be lifted out until a small air bubble appears then replaced in the beaker to 'seal' the bubble.

Once set up the students can measure the transpiration rate as distance the bubble travels in one minute. They should take a number of readings and calculate a mean rate.

If the students are careful they can use the plastic collar to squeeze out the bubble from the bottom of the capillary tube when it gets too high up the capillary tube. They can then lift the tube out of the beaker and allow a new bubble to form, replace the tube in the water and carry on with their readings. This will save a lot of time, as the apparatus will not need to be dismantled.

Each potometer can be used to collect readings in normal air, windy conditions (e.g. using a hairdryer on cold), increased temperature, increased humidity (e.g. using a clear plastic bag), darkness and finally with half of the leaves removed.

Students could decide how they could vary conditions. Class data can be collected and a discussion should ensue on how we can combine data from different shoots and potometers.

Transpiration

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

- What is the best way to vary the environmental conditions around the shoot?
- What assumptions are we making about absorption rate?
- Is all the water absorbed lost?
- Why do we need to calculate % change in transpiration rate for each condition compared to normal transpiration rate?
- What is the best way to display our results in a graph?
- What extra information would a weight potometer provide us with?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques
- Selecting appropriate apparatus
- Observing and recording changes
- Producing appropriate results tables
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Communicate the findings from experimental activities, using appropriate technical language, relevant calculations and graphs
- Assess the reliability of an experimental activity
- Evaluate data and methods taking into account factors that affect accuracy and validity.

Maths skills:

1C Use ratios, fractions, percentages, powers and roots

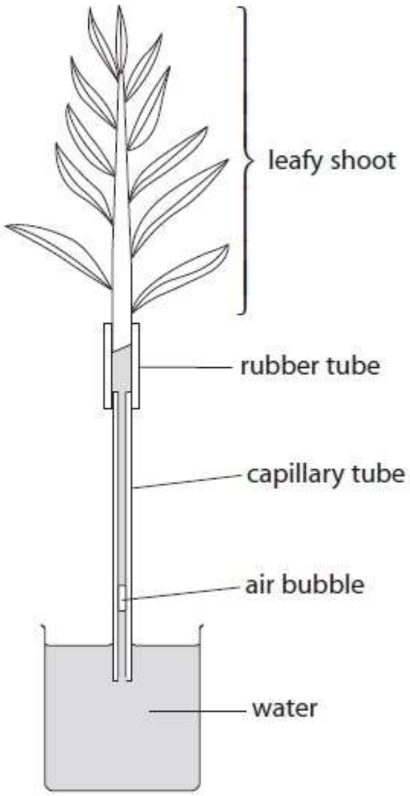
2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average) of class data

2C Construct and interpret bar charts

Exam questions

Steven wanted to measure the rate of water loss from a leafy shoot. He set up this apparatus in normal laboratory conditions.



(a) Name the apparatus Steven used. **(1)**

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(b) Name the process by which a plant loses water. **(1)**

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(c) Describe how Steven should set up the apparatus and how he should then use it to estimate the rate of water loss from the leafy shoot. **(4)**

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(d) Steven carried out three further experiments. He used the same plant, but changed one condition in each experiment.

The table shows the percentage change in rate of water loss for each condition when compared to Steven's original experiment.

Condition	Percentage change in rate of water loss (%)
wind increased	+23
Light intensity reduced	-40
half of the leaves removed	-48

Explain the change in water loss when

(i) wind was increased. **(2)**

(ii) light intensity was reduced. **(1)**

(iii) half of the leaves were removed. **(2)**

(e) Suggest how Steven could increase the wind around the leafy shoot. **(1)**

(Total for question = 12 marks)

Mark scheme

Question number	Answer	Notes	Marks
(a)	potometer;		1
(b)	transpiration / evaporation / diffusion;		1
(c)	1 cut under water; 2 water tight / air tight / seal / eq; 3 how bubble introduced; 4 dry leaves / eq; 5 measure distance bubble moves / length of bubble eq; 6 scale / ruler / cm / eq; 7 time / second / minute / hour / day; 8 repeat;		Max 4
(d) (i)	blows water away / removes water / eq; (maintains) diffusion gradient / conc. gradient / eq;		2
(ii)	stomata close / pores close;	ignore guard cells	1
(iii)	less surface / area; (fewer) idea of reduced number of stomata / pores;		2
(e)	fan / hairdryer / outdoors / put in a draught / put in open window / eq;		1
		Total	**12**

Core practical 11: Seed germination

3.5 Core practical: Investigate the conditions needed for seed germination

Links to the specification content

3.4	Understand that the growth of the pollen tube followed by fertilisation leads to seed and fruit formation
3.6	Understand how germinating seeds utilise food reserves until the seedling can carry out photosynthesis

Introducing the practical

This investigation looks at the conditions needed for germination. Suitable conditions to investigate would be the temperature, availability of oxygen, and availability of water. Cress seeds work well as do peas and results can be obtained within three to four days. The different conditions can be obtained by putting one tube containing seeds in a fridge, one with boiled water and an oxygen absorber such as sodium pyrogallol and one using dry rather than moist cotton wool.

Class results can be combined and % germination calculated for each condition.

Seed germination

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

- How can we tell if a seed has germinated?
- What different molecules do the seeds use as energy stores?
- Explain why each condition is required for successful germination.

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques
- Selecting appropriate apparatus
- Observing and recording changes
- Producing appropriate results tables
- Analyse and interpret data to draw conclusions that are consistent with the evidence

Maths skills:

1C Use ratios, fractions, percentages, powers and roots
2A Use an appropriate number of significant figures
2B Understand and find the arithmetic mean (average) of class data
2C Construct and interpret bar charts

Exam questions

A student wanted to investigate the conditions required for the germination of seeds.

He set up 5 boiling tubes each containing 10 cress seeds on cotton wool sealed with rubber bungs.

- Tube A contained dry cotton wool and was placed at room temperature in the light.
- Tube B contained moist cotton wool and was placed at room temperature in the light.
- Tube C contained moist cotton wool and was placed in a fridge in the dark.
- Tube D contained moist cotton wool and was placed at room temperature in the dark.
- Tube E contained moist cotton wool and was placed at room temperature in the light and contained alkaline pyrogallol to absorb oxygen.

The student left the tubes for 3 days and then returned to observe the results.

He measured the height of the seedlings and recorded how many had germinated.

Some of his results are shown below.

Tube A no seeds germinated.

Tube B 9 seeds germinated with the following heights: 2.0 cm, 2.1 cm, 3.1 cm, 2.2 cm, 2.1 cm, 1.8 cm, 2.3 cm, 2.7 cm and 2.5 cm.

Tube C one seed germinated with a height of 0.3 cm.

(a) Complete the summary table to show the conditions and the results for tubes A, B and C only. **(4)**

Tube	Location	Water	Light	% seeds germinated	Average height in cm
A	room		yes		
B		yes			
C					0.3

(b) Explain how the student could tell whether the seeds had germinated. **(2)**

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(c) The student's teacher commented that there were too many different independent variables in his experiment.
Identify the independent variables in the experiment. **(2)**

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(d) Explain what the results would be for tube D. **(2)**

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(e) Explain why the seeds in tube E failed to germinate. **(1)**

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(Total for question = 11 marks)

Mark scheme

<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>(a)</td><td><table>
<tr><th>tube</th><th>temperature</th><th>water</th><th>light</th><th>% seeds germinated</th><th>average height in cm</th></tr>
<tr><td>A</td><td>(room)</td><td>no</td><td>(yes)</td><td>0</td><td>0.0</td></tr>
<tr><td>B</td><td>room</td><td>(yes)</td><td>yes</td><td>90</td><td>2.3(1);</td></tr>
<tr><td>C</td><td>fridge</td><td>yes</td><td>no;</td><td>10;;</td><td>(0.3)</td></tr>
</table></td><td>First three columns correct for one mark

One mark for two % germination correct

Two marks for all % germination being correct

One mark for both average height being correct</td><td>4</td></tr>
<tr><td>(b)</td><td>1. seeds split / seeds burst / sprouts / eq;

2. root / radicle seen / grows / eq;

3. shoot / plumule / stem seen / grows / eq;</td><td>Ignore leaf/plant emerges / increase in height / become seedlings</td><td>2</td></tr>
<tr><td>(c)</td><td>temperature;

water / moisture;

light;

oxygen;</td><td>Allow one mark for two correctly named and two marks for three correctly named

Location = 0</td><td>2</td></tr>
</table>

Core practical 12: Fieldwork – population size

4.2 Core practical: Investigate the population size of an organism in two different areas using quadrats

Links to the specification content

4.1	Understand the terms population, community, habitat and ecosystem
4.3B	**Understand the term biodiversity**
4.4B	**Practical: investigate the distribution of organisms in their habitats and measure biodiversity using quadrats**
4.5	Understand how abiotic and biotic factors affect the population size and distribution of organisms

Introducing the practical

This investigation looks at the method used to compare population size of a species in two different areas. For example, it could be used to investigate the effect of trampling at a goal area on a football pitch and comparing this to an area away from the goal.

Students will need to be able to distinguish between different species but do not need to be able to name them.

There are keys available to help identify common species.

The important element of this investigation is to demonstrate how a population size can be estimated by random sampling using quadrats. The quadrats should be placed in several locations using tapes to produce coordinates and random number tables to determine where each quadrat is placed.

Students will count how many of the species are found in each quadrat. Class data can be collected and used to produce a best estimate of population size.

Fieldwork – population size

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

- What is meant by a random sample?
- How many quadrats should we use in each area?
- How can we decide where to place our quadrats?
- How do we scale up our data to estimate the population size in each area?
- What biotic or abiotic factors are contributing to the difference in population size?

Skills that are covered in the practical:

- Devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques
- Selecting appropriate apparatus
- Observing and recording changes
- Producing appropriate results tables
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Communicate the findings from experimental activities, using appropriate technical language, relevant calculations and graphs
- Assess the reliability of an experimental activity
- Evaluate data and methods taking into account factors that affect accuracy and validity.

Maths skills:

1C Use ratios, fractions, percentages, powers and roots

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average) of class data

2C Construct and interpret bar charts

2D Construct and interpret frequency tables, diagrams and histograms

2E Understand the principles of sampling as applied to scientific data

2G Understand the terms mode and median

Exam question

The passage describes the study of organisms and their ecosystems.

Complete the passage by writing a suitable word in each of the spaces. **(8)**

Ecology is the study of the interaction of the organisms in an ecosystem with their ______________________. This is made up of biotic or living factors and abiotic or non–living factors.

In an ecosystem, a group of organisms of the same species living in one place is a ______________________. Different groups of species living in the same place or habitat is called a ______________________.

To study the number and distribution of plants in an area, a wooden or metal frame is used. This is called a ______________________. To compare numbers of organisms in two areas several frames need to be placed at ______________________ places in each area.

The numbers in each frame are combined and then divided by the total number of frames.

This is done to calculate the ______________________ for each area. By using several frames we improve the ______________________ of the data and make it easier to detect any ______________________ results.

(Total for question = 8 marks)

Mark scheme

Question number	Answer	Notes	Marks
	environment; population; community; quadrat; random / different; average / mean; reliability; anomalous / unusual / odd ;		8

Core practical 13: Fieldwork – population distribution

4.4B Core practical: Investigate the distribution of organisms in their habitats and measure biodiversity using quadrats

Links to the specification content

4.1	Understand the terms population, community, habitat and ecosystem
4.2	*Practical: investigate the population size of an organism in two different areas using quadrats*
4.3B	**Understand the term biodiversity**
4.5	Understand how abiotic and biotic factors affect the population size and distribution of organisms

Introducing the practical

This investigation extends the last practical (Core practical 12) to look at how biotic and abiotic factors affect the distribution of organisms in their habitats.

This requires students to measure abiotic factors, such as light intensity and link this to changes in distribution of species and changes in biodiversity.

Students will need to be able to distinguish between different species but do not need to be able to name them.

There are keys available to help identify common species.

The quadrats should be placed in several locations within each area using tapes to produce coordinates and random number tables to determine where each quadrat is placed.

Students will count how many of each species are found in each quadrat. Class data can be collected and combined to produce measures of the number of different and how many of each species present in each location.

Different measures of biodiversity can be discussed.

Fieldwork – population distribution

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

- What is meant by a random sample?
- How many quadrats should we use in each area?
- How can we decide where to place our quadrats?
- How do we scale up our data to estimate the population size in each area?
- What is meant by biodiversity and how can we best measure it?
- How do we scale up our data to estimate the biodiversity in each area?
- What are the biotic or abiotic factors in each habitat?
- How can we measure these factors?
- How can we decide which are contributing to the difference in biodiversity?
- What are the problems of generalising from our data to other habitats?

Skills that are covered in the practical:

- Devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques
- Selecting appropriate apparatus
- Observing and recording changes
- Producing appropriate results tables
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Communicate the findings from experimental activities, using appropriate technical language, relevant calculations and graphs
- Assess the reliability of an experimental activity
- Evaluate data and methods taking into account factors that affect accuracy and validity.

Maths skills:

1C Use ratios, fractions, percentages, powers and roots

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average) of class data

2C Construct and interpret bar charts

2D Construct and interpret frequency tables, diagrams and histograms

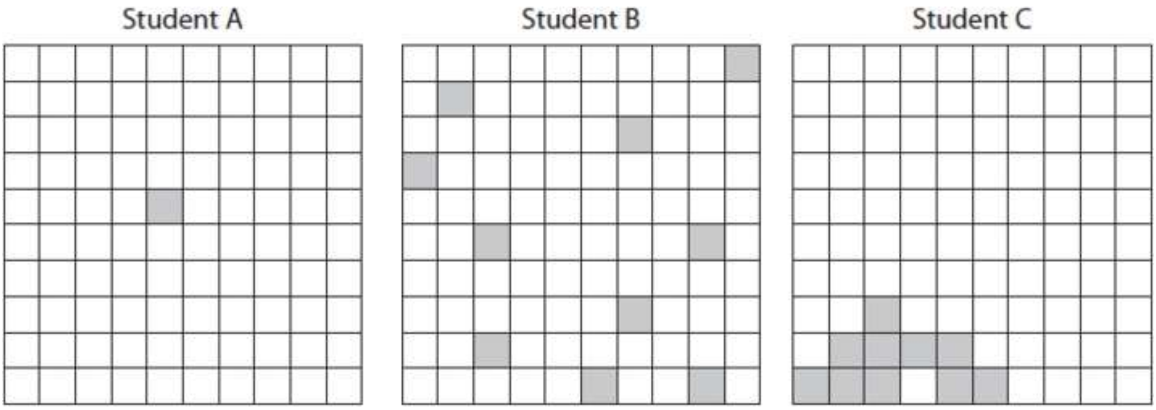
2E Understand the principles of sampling as applied to scientific data

2G Understand the terms mode and median

Exam question

Three students were asked to estimate the population size of a plant species in an area by using a quadrat.

The diagram shows where each student placed their quadrat in the area.



(a) (i) Which student would obtain the most reliable estimate?
Give reasons for your answer. **(2)**

____

____

____

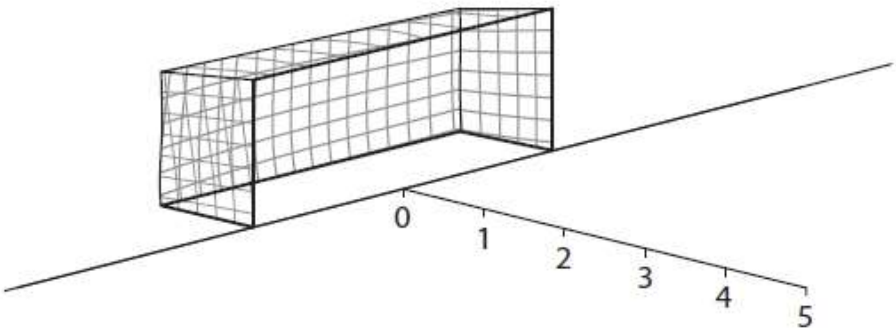
____

(ii) State what is meant by the term population. **(1)**

____

____

(b) Five other students investigated the distribution of grass in the goal area of a football pitch.
They placed a small quadrat at the goal line and then at one metre intervals in a straight line away from the goal line. The diagram shows their method.



The quadrat was 10 cm by 10 cm and was made from clear plastic. It was marked into 100 squares of 1 cm × 1 cm. If grass could be seen in 10 of the squares, the percentage cover would get a score of 10%.

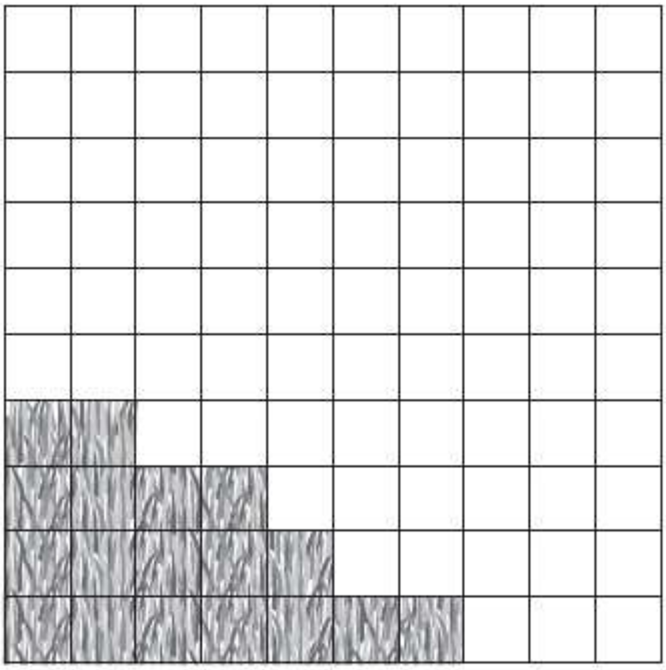
The table shows the results obtained by the five students.

Student	Percentage cover of grass at different distances from the goal line					
	0 m	1 m	2 m	3 m	4 m	5 m
A	14	14	38	41	90	100
B	20	13	5	47	82	90
C	15	14	45	50	86	85
D	10	18	35	50	75	83
E	10	15	30	50	70	90
average	14	15	37	48	81	90

(i) One of the averages of the results has been calculated ignoring an anomalous result.
Which student obtained the anomalous result? **(1)**

____

(ii) The diagram shows a quadrat used by one of the students, and the number of 1cm squares where grass can be seen.



Which student obtained the results shown in this quadrat? **(1)**

____

(Total for question = 5 marks)

Mark scheme

Question number		Answer	Notes	Marks
(a)	(i)	(student B) 1. random / spread out / scattered / eq; 2. used 10 quadrats / repeated use of quadrats / several / eq;		2 max
	(ii)	number / all / total / amount of named species / of a species / of one species;	number of species = 0 number of organisms = 0 number of same organism = 1 number of an organism = 1 Ignore group	1
(b)	(i)	(student) B;		1
	(ii)	(student) D;		1

Core practical 14: Anaerobic respiration

5.6 Core practical: Investigate the role of anaerobic respiration by yeast in different conditions

Links to the specification content

1.2	Fungi: these are organisms that are not able to carry out photosynthesis; their body is usually organised into a mycelium made from thread-like structures called hyphae, which contain many nuclei; some examples are single-celled; their cells have walls made of chitin; they feed by extracellular secretion of digestive enzymes onto food material and absorption of the organic products; this is known as saprotrophic nutrition; they may store carbohydrate as glycogen. Examples include *Mucor*, which has the typical fungal hyphal structure, and yeast, which is single-celled
2.36	Describe the differences between aerobic and anaerobic respiration
2.38	Know the word equation for anaerobic respiration in plants and in animals
2.39	Practical: investigate the evolution of carbon dioxide and heat from respiring seeds or other suitable living organisms
5.5	Understand the role of yeast in the production of food including bread

Introducing the practical

This investigation gives students the chance to experiment on the factors that affect respiration in yeast.

The basic experiment uses a mixture of yeast and glucose in a boiling tube with paraffin oil on the surface to prevent entry of air containing oxygen. Diazine green can be added to the mixture. This indicator is blue in the presence of oxygen but turns pink in the absence of oxygen. So initially, the yeast respires aerobically until it has used up all the oxygen. From this point, the yeast cells respire anaerobically.

The rate of respiration can be measured either by collecting the carbon dioxide given off by downward displacement using a water filled measuring cylinder or by counting the bubbles. Students can discuss the advantages and disadvantages of each method.

Using limewater or hydrogen-carbonate indicator, the gas given off can be shown to be carbon dioxide.

The investigation can have a number of alternative independent variables such as temperature, concentration of glucose or even using different sugars as a substrate.

As with other investigations this could be used as an opportunity for students to design, plan, review and carry out an investigation perhaps using the CORMS prompt to help them.

Anaerobic respiration

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

- Why is collecting gas a more appropriate method that counting bubbles?
- Why might the volume of gas collected not be a valid measure of the rate of respiration?
- What is the function of the water bath?
- What other affects might increasing the temperature have on the volume of gas produced?
- What other factors might affect the rate of respiration?
- What other methods could we use to demonstrate that respiration is occurring?
- Why might different sugars produce different rates of anaerobic respiration?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Measuring volumes of gas accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Assess the reliability of an experimental activity
- Evaluate data and methods taking into account factors that affect accuracy and validity

Maths skills:

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

4A Translate information between graphical and numerical form

4C Plot two variables (discrete and continuous) from experimental or other data

4D Determine the slope and intercept of a linear graph

Exam Question

Describe an experiment you could do to find out the effect of pH on the growth of yeast. **(6)**

(Total for question = 6 marks)

Mark scheme

Question number	Answer		Marks
	C	vary pH / acid + alkali / eq;	Max 6
	O	same species / mass / number / concentration / amount of yeast / eq;	
	R	repeat each pH / eq;	
	M1	mass / number / bubbles / carbon dioxide / alcohol / eq;	
	M2	time period stated;	
	S1 and S2	same temp / volume of water / same nutrients / conc. of nutrients / oxygen / eq;; Ignore light	

Total 6 Marks

International GCSE Chemistry Practicals

There are 8 core practicals in the chemistry section of International GCSE Combined Science. International GCSE Chemistry covers the same 8 practicals as well as an additional 4, to make up 12 core practicals in total.

This section outlines each core practical and gives a brief description of each one. Then the guide goes through each core practical in turn, outlining how to carry out the practical, questions that could be asked, and the key skills involved (including maths skills).

Core practical descriptions

Note: **1.7C**, **1.60C**, **2.43C** and **4.43C** are separate International GCSE Chemistry only

No.	Specification Reference	Description
1	**1.7C - Investigate solubility of a solid in water at a specific temperature**	A solid such as sodium chloride is added to water until no more dissolves. After removing any undissolved solid by filtration, the mass of dissolved solid and the water it is dissolved in, is found using weighing and evaporation. The results can be used to find the solubility of the solid per 100g water at the temperature of the experiment.
2	1.13 - Investigate paper chromatography using inks/food colourings	A simple and familiar practical to demonstrate paper chromatography using inks or food colourings. Links to alternative experiments including use of alternative solvents and calculation of R_f values are given.
3	1.36 - Determine the formula of a metal oxide by combustion or by reduction	Combustion of magnesium: Magnesium is weighed and then heated in a crucible. It reacts with oxygen to produce magnesium oxide. It can be seen from the weighings that there has been an increase in mass. The results can be used to find the empirical formula of magnesium oxide. Reduction of copper oxide (demonstration): A known mass of a sample of copper(II) oxide is reduced to copper metal. From the mass of the copper formed, the mass of oxygen present in the sample of copper(II) oxide can be found. The results can be used to find the empirical formula of the oxide.

4	**1.60C - Investigate the electrolysis of aqueous solutions**	A practical to show, on a small scale, the electrolysis of aqueous solutions and to try to collect and identify any gases produced. The set up can be varied according to the apparatus available in centres.
5	2.14 - Determine the approximate percentage by volume of oxygen in air using a metal or non-metal	The practical involves placing some iron wool in a sample of air in an inverted test tube and leaving the experiment for at least a week. By measuring the original and final height of the column of air in the test tube, a calculation can then be done to find the approximate percentage by volume of oxygen in air.
6	2.21 - Investigate reactions between dilute hydrochloric and sulfuric acids and metals	This practical involves test tube reactions of suitable metals with dilute hydrochloric and sulfuric acids allowing practice in making observations including testing for hydrogen. It also allows the idea of a reactivity series to be considered.
7	2.42 - Prepare a sample of pure, dry hydrated copper(II) sulfate crystals starting from copper(II) oxide	This practical enables the practice of a typical method for preparing a pure dry sample of a soluble salt from an acid and a base.
8	**2.43C - Prepare a sample of pure, dry lead(II) sulfate**	This practical enables the practice of a typical method for preparing a pure dry sample of an insoluble salt from solutions of two suitable soluble salts.
9	3.8 - Investigate temperature changes accompanying some of the following types of change: • salts dissolving in water • neutralisation reactions • displacement reactions • combustion reactions	Several simple calorimetry experiments are suggested to allow temperature changes to be measured enabling heat energy changes to be calculated.
10	3.15 - Investigate the effect of changing the surface area of marble chips and of changing the concentration of hydrochloric acid on the rate of reaction between marble chips and dilute hydrochloric acid	Two investigations are suggested involving collecting the carbon dioxide either by using an upturned measuring cylinder or a gas syringe. References are also given for investigations involving the reaction between sodium thiosulfate and hydrochloric acid.
11	3.16 - Investigate the effect of different solids on the catalytic decomposition of hydrogen peroxide solution	The practical involves reactions to investigate if different substances catalyse the decomposition of hydrogen peroxide producing oxygen.

12	**4.43C - Prepare a sample of an ester such as ethyl ethanoate**	This practical involves a small-scale method to make ethyl ethanoate from ethanoic acid and ethanol. Details for making other esters are found from the link provided in the text.

Core practical 1: Solubility

1.7C Core practical: Investigate solubility of a solid in water

Links to the specification content

1.4	Know what is meant by the terms *solvent*, *solute*, *solution*, and *saturated solution*
1.5C	**Know what is meant by the term solubility in the units g per 100g of solvent**
1.6C	**Understand how to plot and interpret solubility curves**

Introducing the practical

- Place approximately 50 cm^3 of water into a beaker
- Add the solid a little at a time, with stirring, until no more will dissolve
- Weigh an empty evaporating basin
- Filter the mixture and collect the filtrate in the evaporating basin
- Weigh the evaporating basin and filtrate
- Evaporate the water

Direct heating with a Bunsen could do this as long as the chosen solid does not decompose on heating or contains water of crystallisation. If direct heating is used, care must be taken not to allow any of the solid to spit out. One method of avoiding this is to place the evaporating basin on top of a beaker containing water, then to heat the water in the beaker. Alternatively, the basin could be placed in a warm oven, if available.

Weigh the evaporating basin and the solid:

A typical set of results for sodium chloride is:

- mass of empty evaporating basin = 30.45 g
- mass of evaporating basin and filtrate = 95.95 g
- mass of evaporating basin + sodium chloride = 47.75 g
- mass of water = 48.20 g
- mass of sodium chloride = 17.30 g
- solubility of sodium chloride = (17.30 ÷ 48.20) × 100
  = <u>35.9 g/100 g of water</u>

If you wish to determine the solubility at different temperatures, then boiling tubes could be used with smaller volumes of water. The tubes can be heated in water baths to reach the desired temperatures.

Solubility

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

- Why does increasing the temperature usually affect the solubility of solids?

Skills that are covered in the practical:

- Measuring mass
- Use of a Bunsen burner
- Use of filtration apparatus
- Safe handling of solids

Maths skills:

1A Recognise and use numbers in decimal form

1C Use ratios and fractions

2A Use an appropriate number of significant figures

Alternative experiments:

An alternative method to investigate the effect of temperature on solubility is provided on the RSC website: Classic chemistry experiment 98.

Questions

This is a method used to measure the solubility of a solid in water:

- add an excess of solid to some water in a boiling tube and stir
- measure the temperature of the saturated solution formed
- weigh an empty evaporating basin
- pour some of the saturated solution into the evaporating basin
- weigh the basin and contents
- heat the evaporating basin to remove all of the water
- weigh the evaporating basin and remaining solid.

(a) The table shows the results of an experiment using this method.

Mass of evaporating basin / g	89.6
Mass of evaporating basin + saturated solution / g	115.8
Mass of evaporating basin+ solid / g	94.9

Calculate the mass of solid obtained and the mass of water removed. **(2)**

mass of solid = ______________________ g

mass of water = ______________________ g

(b) In another experiment, at a different temperature, the mass of solid obtained is 10.5 g and the mass of water removed is 16.8 g.

Calculate the solubility of the solid, in g per 100 g of water, at this temperature. **(2)**

solubility = ______________________ g per 100 g of water

(c) If the evaporating basin is heated too strongly some of the solid decomposes to form a gas.

Explain how this strong heating would affect the value of the calculated solubility of the solid. **(3)**

____

____

____

____

____

____

(Total for question = 7 marks)

Mark Scheme

Question number	Answer	Mark
(a)	• (mass of solid) 5.3 (g) (1) • (mass of water) 20.9 (g) (1)	2
Question number	**Answer**	**Mark**
(b)	• (10.5 ÷ 16.8) × 100 (1) • 62.5 (grams of solid per 100 g of water) (1)	2
Question number	**Answer**	**Mark**
(c)	An explanation that links together the following three points: • the gas will escape (1) • the mass of solid remaining will be less (than it should be) (1) • the value of the calculated solubility will be lower (than it should be) (1)	3

Core practical 2: Chromatography

1.13 Core practical: Investigate paper chromatography using inks/food colourings

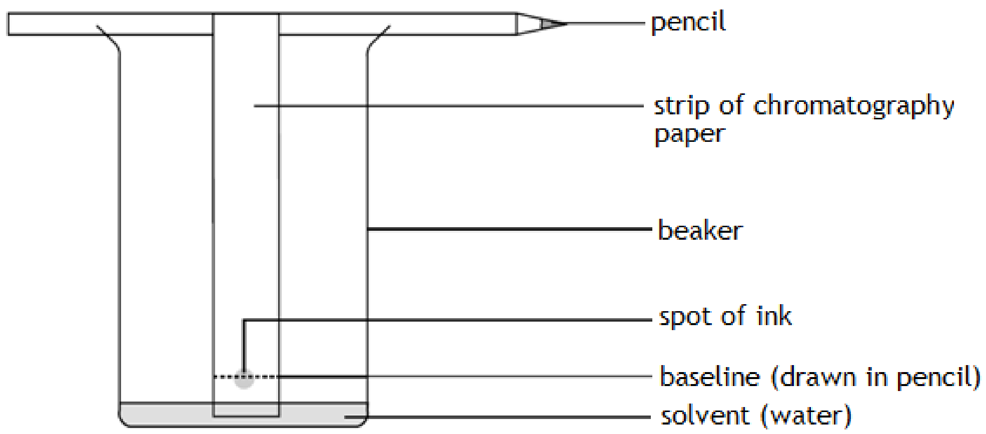
Links to the specification content

1.10	Describe these experimental techniques for the separation of mixtures: simple distillation, fractional distillation, filtration, crystallisation, paper chromatography
1.11	Understand how a chromatogram provides information about the composition of a mixture
1.12	Understand how to use the calculation of R_f values to identify the components of a mixture

Introducing the practical

Water-soluble inks from felt tip pens are suitable here. Black ink usually works particularly well. Other colours should be tested in advance since they often do not separate out very well. If chromatography paper is too expensive, the strips of paper can be cut from circular filter paper.

A typical set up is as shown:



There are many other ways in which this can be performed, including radial chromatography, in which a circle of ink can be drawn in the centre of a circular piece of filter paper and water is added, drop by drop using a teat pipette, into the centre of the circle.

The filter paper can be supported by placing it on top of a beaker.

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:

1A Recognise and use numbers in decimal form

2A Use an appropriate number of significant figures

3C Substitute numerical values into an algebraic equation using appropriate units

3D Solve a simple algebraic equation

Alternative experiments:

Experiment 71 on the RSC website gives instructions about how to carry out chromatography on Smarties.

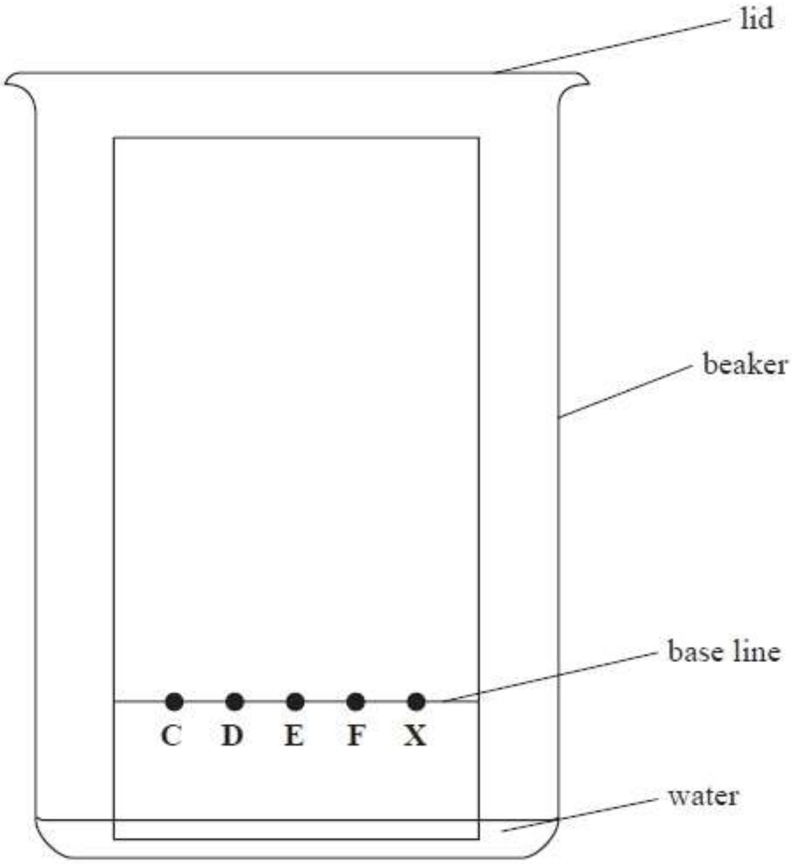
If the Smarties you have bought do not work successfully (they tend not to since the dyes used are natural), then M&Ms can be used instead.

Extension work: Calculation of R_f values

Experiment 4 on the RSC website gives instructions about how to carry out chromatography on leaves. This experiment has the added advantage of using an alternative solvent to water, namely propanone.

Questions

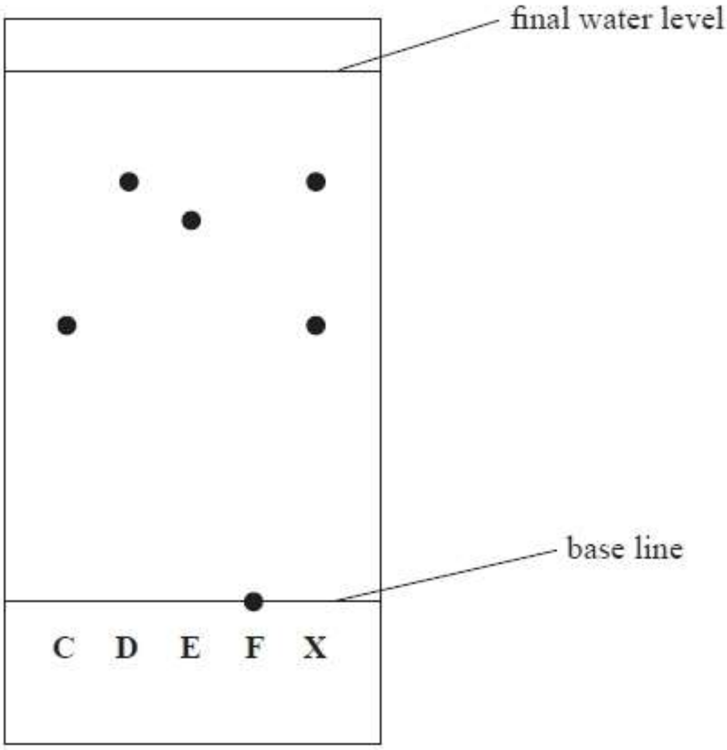
Four separate food dyes (**C**, **D**, **E** and **F**) and a mixture of food dyes (**X**) were investigated using paper chromatography. The diagram shows the apparatus used.



(a) Why should the water level be below the food dyes? **(1)**

(b) During the experiment, the water rises up the paper. The experiment is stopped just before the water reaches the top of the paper.

The diagram shows the paper after it has been removed from the beaker and dried.



(i) Which of the food dyes **C**, **D**, **E** and **F** does **X** contain? **(1)**

____

(ii) Suggest why food dye **F** did not move up the paper during the experiment. **(1)**

____

(c) Each food dye has an R_f value that can be calculated using this expression:

$$R_f = \frac{\text{distance moved by food dye from base line}}{\text{distance moved by solvent from base line}}$$

Record the distances for food dye **D** in the table below and calculate its R_f value. **(3)**

Distance moved by food dye **D** from base line in mm	
Distance moved by solvent from base line in mm	
R_f value	

(Total for question = 6 marks)

Mark Scheme

Question number	Answer	Notes	Marks
(a)	to stop the dyes from {dissolving / running / going / mixing} into water / smudging OWTTE	Ignore refs to correct statements eg "to allow water to rise up paper". Do not penalise refs to inks. Accept reverse argument based on what happens if water level is above dyes. Reject ref to reaction	1
(b) (i) (ii)	C and D insoluble	 Accept does not dissolve in water Reject ref to reaction Reject ref to not enough dye	1 1
(c)	52-55 67-68 0.76-0.82(1)	Penalise use of cm once only in M1 + M2 Do not penalise more than 2sf in M1 – M3 Accept 1sf in M3 M3 CQ on M1 + M2, even for $R_f > 1$	1 1 1

Total 6 marks

Core practical 3: Combustion and reduction

1.36 Core practical: Determine the formula of a metal oxide by combustion or by reduction

Links to the specification content

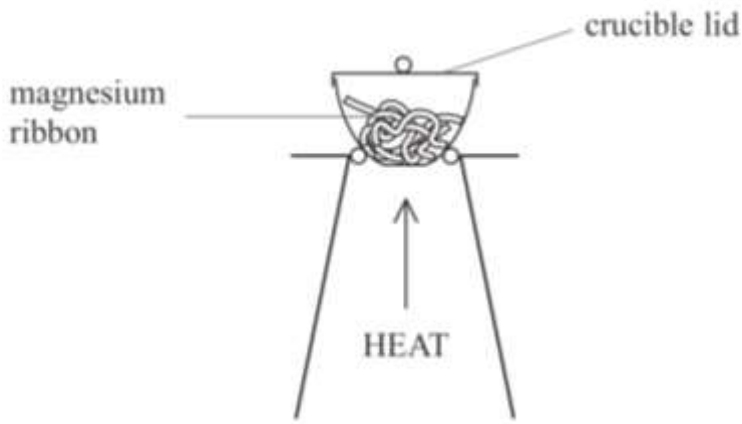
1.28	understand how to carry out calculations involving amount of substance, relative atomic mass (A_r) and relative formula mass (M_r)
1.31	understand how the formulae of simple compounds can be obtained experimentally, including metal oxides, water and salts containing water of crystallisation
1.32	know what is meant by the terms empirical formula and molecular formula
1.33	calculate empirical and molecular formulae from experimental data

Introducing the practical

Combustion

Magnesium is weighed and then heated in a crucible. It reacts with oxygen to produce magnesium oxide. The results can be used to find the empirical formula of magnesium oxide.

A typical set up is as shown in the diagram below.



Students will almost certainly obtain unconvincing results for this experiment. It is worth evaluating what they have done, as there can be several reasons:

- the magnesium oxide product may escape as they lift the lid
- not all the magnesium may have reacted (the product may still look a bit grey rather than white)
- they may have prodded the product with a spill so not all of it got weighed (more common than you might expect!)
- not tareing the balance correctly for one, or more, of the weighings
- having the magnesium coiled too tightly so that not all of it reacts

Further information on the experiment can be found here on the RSC website.

A typical set of results is:

- mass of empty crucible and lid = 23.10g
- mass of crucible, lid and magnesium = 23.70g
- mass of crucible lid and magnesium oxide = 24.10g

Calculation:

- mass of magnesium = 0.60g
- mass of oxygen = 0.40g
- amount of magnesium atoms = (0.60 ÷ 24) = 0.025 mol
- amount of oxygen atoms = (0.04 ÷ 16) = 0.025 mol
- ratio of amount of Mg to amount of O = 1:1

Therefore empirical formula = MgO

N.B. These results are given for guidance only. In practice, the amount of oxygen calculated from measurements made will always be lower than the amount of magnesium since some magnesium oxide will inevitably be lost to the atmosphere during lifting of the lid

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

- Why lift the lid from time to time during the heating?
- Why should you not lift the lid for too long a period of time?
- What is the purpose of re-heating until two consecutive masses are the same?

Skills that are covered in the practical:

- Measuring mass
- Safe use of a Bunsen burner
- Safe handling of hot apparatus
- Safe handling of solids

Maths skills:

1A Recognise and use numbers in decimal form

1C Use ratios and fractions

2A Use an appropriate number of significant figures

Reduction

Copper(II) oxide is weighed and then reduced to copper. The results can be used to calculate the empirical formula of the copper(II) oxide.

Hydrogen, from a hydrogen cylinder, is the best gas to use to reduce the copper(II) oxide.

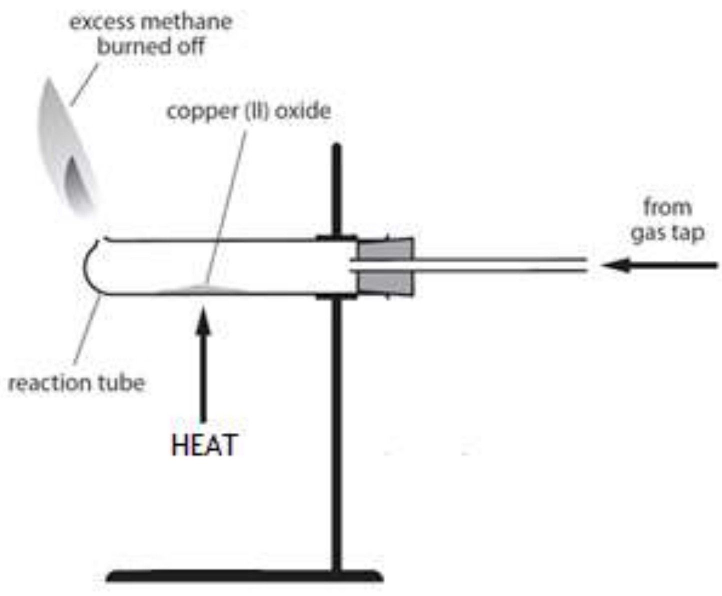
If you do not have access to a hydrogen cylinder, then methane, from the natural gas supply in the laboratory is a suitable alternative, although the rate of reduction is much slower that with hydrogen.

N.B. Under no circumstances should the reduction be attempted by using hydrogen generated by the reaction between an acid and a metal. The risk of explosion is very high.

For best results use wire form copper(II) oxide. Alternatively, use analytical grade copper(II) oxide that has been dried by heating in an open dish at 300-400 °C for ten minutes and then stored in a desiccator.

Depending on the skill level of your students, and also the risk of explosion, you may wish to perform this as a demonstration.

A typical set-up is as shown.



Key safety points are to make sure all of the air is flushed out of the reaction tube before igniting the methane, and to light the Bunsen until the methane has been ignited.

It is best to use a roaring Bunsen flame (air hole fully open). It is necessary to pick up the Bunsen burner (do so by the base) and move the flame around to heat every bit of copper(II) oxide. Make sure that the hottest part of the Bunsen burner flame (the top of the inner cone) is being used for heating.

A video demonstrating this practical, produced by the RSC, can be found on YouTube. Hydrogen from a hydrogen cylinder is used. This video can be used as alternative to demonstrating the reduction. The students could then be provided with a sample set of results from which to perform the calculation.

Further details can be found here on the RSC website.

A typical set of results is:

- mass of empty test tube = 28.93 g
- mass of tube and copper oxide = 33.02 g
- mass of tube and copper = 32.21 g

Calculation:

- mass of copper = 3.28 g
- mass of oxygen = 0.81 g
- amount of copper atoms = (3.28 ÷ 63.5) = 0.052 mol
- amount of oxygen atoms = (0.81 ÷ 16) = 0.051 mol
- ratio of amount of Cu to amount of O = 1:1

Therefore empirical formula = CuO

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

- Why is the natural gas passed through the reaction tube for at least one minute before lighting the gas?
- Why continue to pass the natural gas over the hot copper whilst the copper is cooling?
- What is the purpose of re-heating until two consecutive masses are the same?

Skills that are covered in each practical:

- Measuring mass
- Safe use of a Bunsen burner
- Safe handling of hot apparatus
- Safe handling of solids

Maths skills:

1A Recognise and use numbers in decimal form

1C Use ratios and fractions

2A Use an appropriate number of significant figures

Extension work:

An alternative set of results could also be provided for ‘red’ copper oxide (copper(I) oxide).

Questions

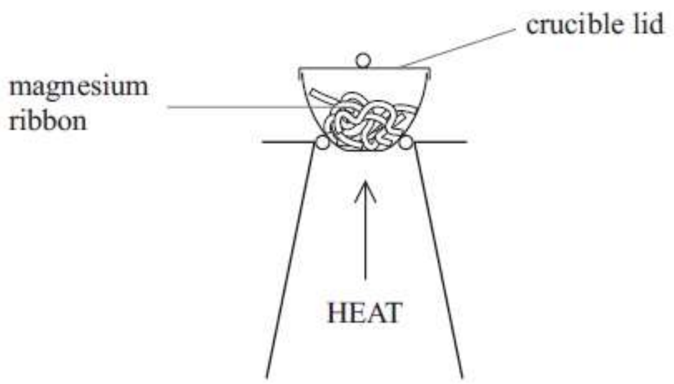
When magnesium is burned in air, it reacts with oxygen, O_2, to form magnesium oxide, MgO

A class of students investigated the relationship between the mass of magnesium burned and the mass of magnesium oxide formed.

Each student was given a different mass of clean magnesium to heat.

The students used the following method.

- Weigh a crucible and lid
- Place the magnesium ribbon in the crucible, replace the lid, and reweigh
- Heat the crucible as shown in the diagram until the magnesium burns



- Lift the lid from time to time until there is no sign of further reaction
- Allow the crucible and lid to cool and reweigh
- Repeat the heating, cooling and reweighing until two consecutive masses are the same
- Calculate the mass of magnesium oxide formed

(a) (i) Why is it necessary to lift the lid from time to time while heating? **(1)**

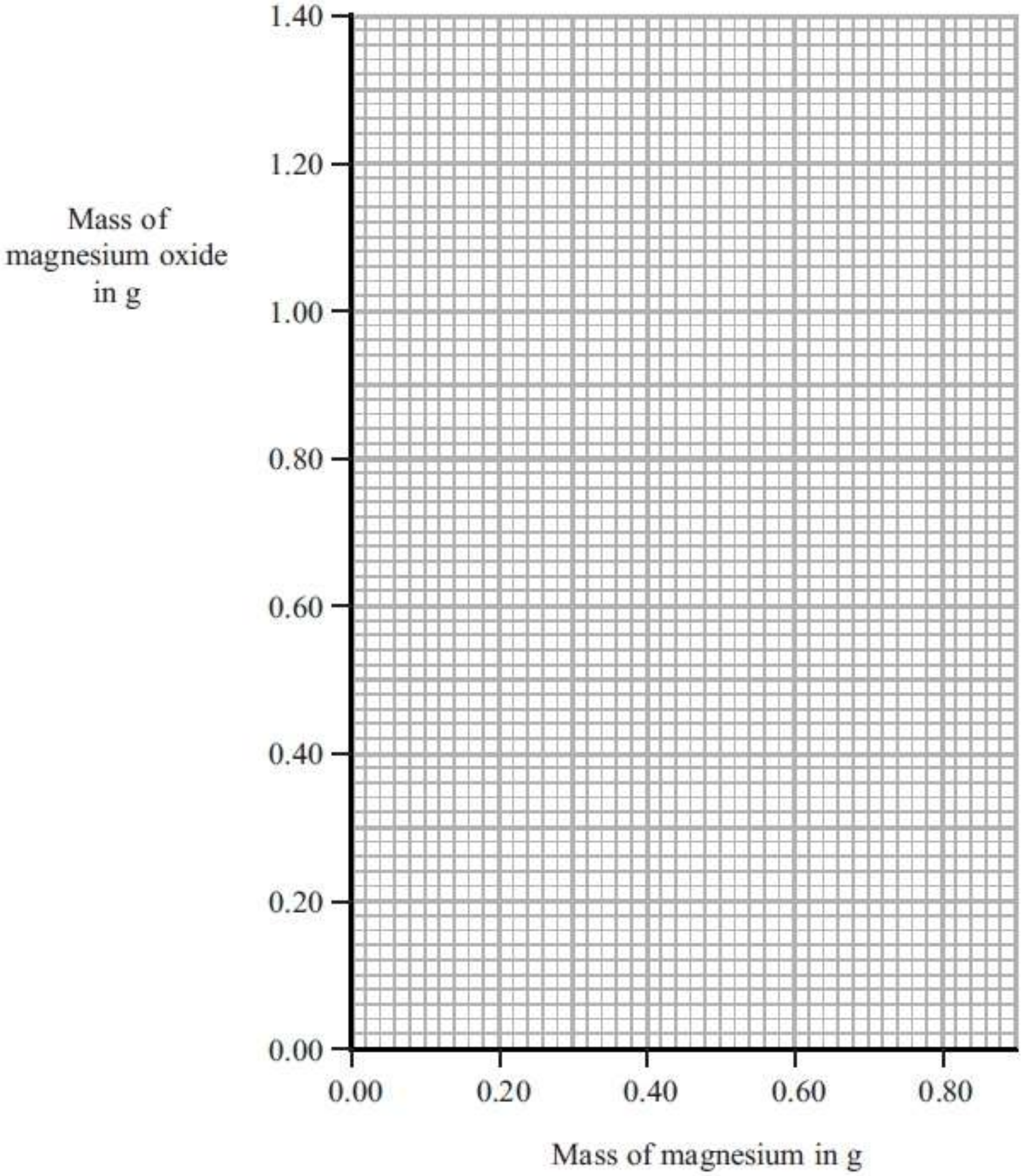
(ii) Why is it necessary to repeat the heating until two consecutive masses are the same? **(1)**

(b) Show how the mass of magnesium oxide formed can be calculated from the readings obtained. **(1)**

(c) The results of each experiment are given in the table.

Mass of magnesium in g	Mass of magnesium oxide in g
0.24	0.40
0.26	0.64
0.42	0.70
0.62	1.04
0.70	1.20
0.80	1.33

(i) Plot the results on the grid and draw a straight line of best fit. **(3)**



(ii) Draw a circle around the anomalous result. **(1)**

(iii) Use your graph to find the mass of magnesium oxide formed when 0.48 g of magnesium is burned. **(1)**

____

____

(Total for Question = 8 marks)

Mark Scheme

Question number	Answer	Accept	Reject	Marks
(a) (i)	to allow air / oxygen to enter (the crucible) / to come into contact with the magnesium / solid Ignore references to visual checks of reaction completion	to allow the magnesium to burn / react		1
(ii)	to make sure that <u>all</u> of the magnesium has reacted	to make sure that the (all) magnesium has reacted to complete the reaction		1
(b)	mass of crucible (and lid) + MgO — mass of crucible (and lid) lids must be in both or neither ignore any references to the table of results on page 8	mass of crucible (and lid) at end — mass of crucible (and lid)		1
(c) (i)	all points plotted correctly to nearest gridline (subtract 1 mark for each error) <u>correct</u> straight line of best fit (need not pass through origin) (must be drawn with the aid of a rule)	line as evidence of correct plotting when points cannot be seen		2 1
(ii)	anomalous point at (0.26, 0.64) circled			1
(iii)	csq on candidate's graph Units not needed, ignore incorrect units			1
			Total	**8**

Core practical 4: Electrolysis

1.60C Core practical: Investigate the electrolysis of aqueous solutions

Links to the specification content

1.56C	**understand why ionic compounds conduct electricity only when molten or in aqueous solution**
1.58C	**describe experiments to investigate electrolysis, using inert electrodes, of molten compounds (including lead(II) bromide) and aqueous solutions (including sodium chloride, dilute sulfuric acid and copper(II) sulfate) and to predict the products**
1.59C	**write ionic half-equations representing the reactions at the electrodes during electrolysis and understand why these reactions are classified as oxidation or reduction**

Introducing the practical

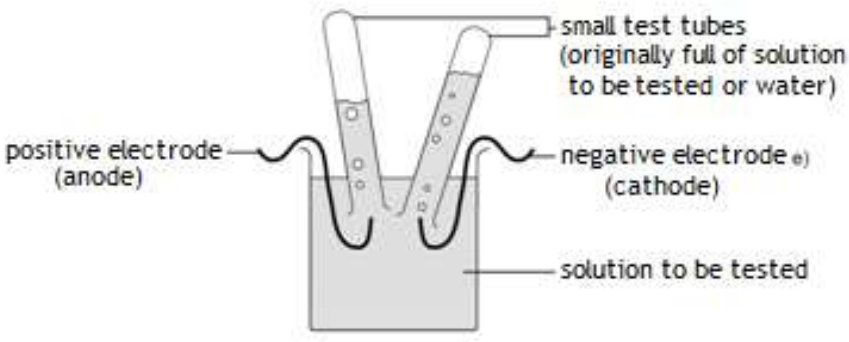
Students should know what happens when molten ionic compounds are electrolysed.

They also need to be familiar with the tests for hydrogen, oxygen and chlorine.

Teachers may need to show students how to fill and invert small test tubes over the electrodes. Using small tubes filled with water rather than the solution to be tested is safer.

Nichrome is a suitable metal to use for the electrodes.

N.B. Graphite is not suitable in any electrolysis in which oxygen is evolved, since the carbon reacts with the oxygen to produce carbon dioxide. It is also worth noting that some of the oxygen will dissolve in the water, so the expected 2:1 ratio of hydrogen to oxygen, in for example the electrolysis of dilute sulfuric acid, will not be obtained.



The specification suggests sodium chloride solution, dilute sulfuric acid and copper(II) sulfate solution as suitable examples for electrolysis. It is by no means necessary to restrict the practical to these three solutions.

Further details about how to perform the experiment, and suggestions for other solutions to electrolyse, can be found here on the RSC website.

N.B. It is important to make sure that the sodium chloride solution is concentrated (preferably saturated) so that an appreciable amount of chlorine is evolved. Most of this chlorine will dissolve in the water present so it may be necessary to test the solution in the test tube above the anode rather than the gas.

The best ionic half-equations to give to the students are:

Hydrogen evolved at the cathode	$\mathbf{2H_2O + 2e^- \rightarrow H_2 + 2OH^-}$
Acceptable if strong acid is electrolysed	$2H^+ + 2e^- \rightarrow H_2$
Oxygen evolved at the anode	$2H_2O \rightarrow 4H^+ + O_2 + 4e^-$
Acceptable if strong alkali is electrolysed	$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
Copper deposited at the cathode	$Cu^{2+} + 2e^- \rightarrow Cu$
Chlorine evolved at the anode	$2Cl^- \rightarrow Cl_2 + 2e^-$

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

- Why is graphite not a suitable material to use as the anode in an electrolysis in which oxygen is evolved at the anode?
- Why is a 2:1 ratio by volume expected when (acidified) water is electrolysed?
- Why is the volume ratio of hydrogen to oxygen greater than 2:1 when (acidified) water is electrolysed?

Skills that are covered in each practical:

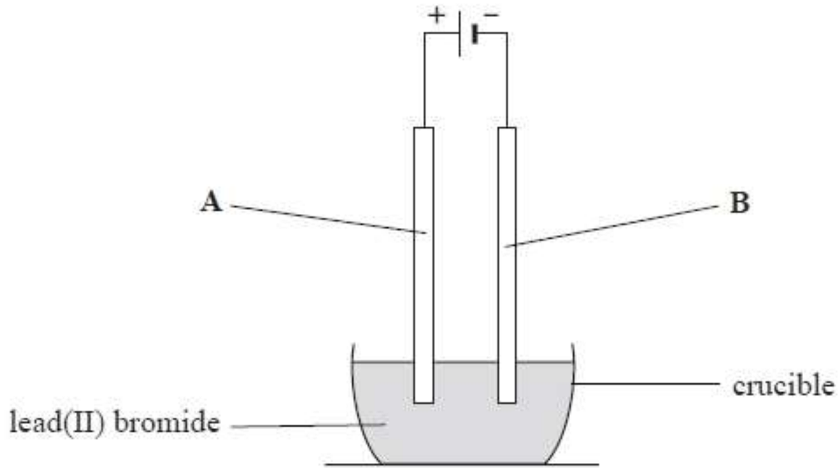
- Setting up an electrical circuit for electrolysis.
- Safe handling of solutions.
- Collecting gases and testing for them.

Questions

Q1

(b) Bromine is formed by the electrolysis of molten lead(II) bromide.

The diagram shows the apparatus used.



(i) Solid lead(II) bromide contains ions.
Why does solid lead(II) bromide not conduct electricity? **(1)**

____

____

(ii) The formula of lead(II) bromide is $PbBr_2$.
During electrolysis, brown fumes of bromine appear at electrode A.
The ionic half-equation for the reaction at electrode A is

$$2Br^- \rightarrow Br_2 + 2e^-$$

Why is this reaction described as oxidation? **(1)**

____

____

(iii) Write an ionic half-equation for the reaction at electrode B and describe the appearance of the product. **(2)**

Ionic half-equation

____

Appearance of product

____

(Total for question = 4 marks)

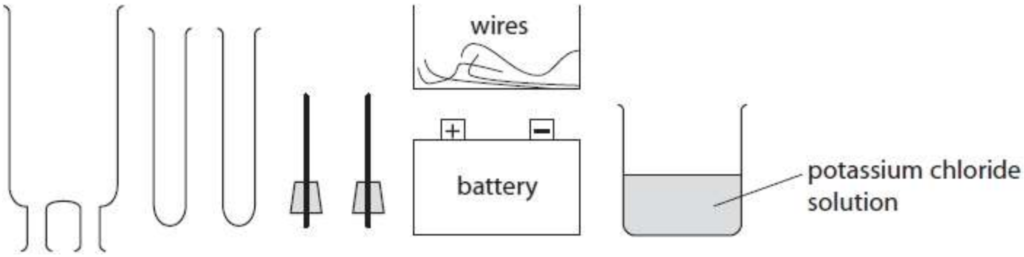
Mark Scheme

Question number	Answer	Notes	Marks
(b) (i)	ions fixed/cannot move/not mobile/not free (to move) OR ions not fixed/can move/mobile/free (to move) when molten	Ignore "electrons cannot move (when solid)" Reject "electrons move (when molten)" Reject refs to atoms / molecules Ignore particles / covalent bonding	1
(ii)	because electron(s) lost (from bromide)	Reject bromine in place of bromide, but allow 'bromine ions' Ignore refs to number of electrons Assume "It" refers to bromide ions	1
(iii)	$Pb^{2+} + 2e^{(-)} \rightarrow Pb$ silver/grey/shiny (liquid)	Ignore state symbols Reject $Pb^{2+} \rightarrow Pb - 2e^{(-)}$ Ignore solid Ignore metallic No CQ from wrong product in M1	1 1

Total 4 marks

Q2.

A student investigates electrolysis using this apparatus.

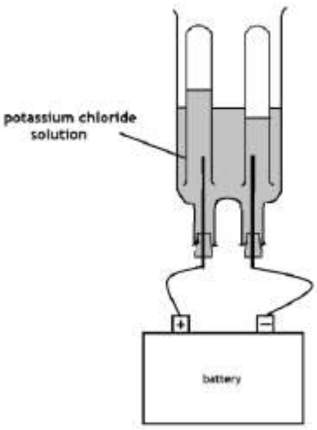


(a) The student electrolyses KCl(aq) and collects samples of any gases formed.

Complete the following diagram to show how to assemble the apparatus.
Label the diagram to show the potassium chloride solution. **(3)**

(Total for question = 3 marks)

Mark Scheme

Question number	Answer	Notes	Marks
a		**M1** both bungs inserted AND electrodes connected to battery **M2** both tubes inverted over electrodes **M3** solution placed in the voltameter and labelled as potassium chloride / KCl(aq) For **M3**, ignore all three liquid levels, except that the level in the voltameter must be above the bottoms of both tubes if present	3

Core practical 5: Rusting

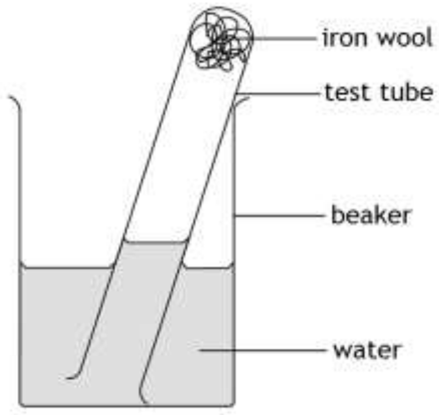
2.14 Core practical: Determine the approximate percentage by volume of oxygen in air using a metal or non-metal

Links to the specification content

2.10	Understand how to determine the percentage by volume of oxygen in air using experiments involving the reactions of metals (e.g. iron) and non-metals (e.g. phosphorus) with air

Introducing the practical

- Use about a 3 cm depth of iron wool, and wet it with water
- Invert the test tube in water contained in a beaker (see diagram below)
- Measure the length of the column of air (when the test tube is vertical)
- Leave for at least one week and then measure the new length of the column of remaining gas (again, with the test tube vertical)



Full details of the experiment can be found here on the RSC website.

Rusting

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

- Why is it necessary to leave the test tube angled as shown in the diagram?
- How could you show that all of the oxygen has reacted (assume the iron wool is in excess)?

Skills that are covered in each practical:

- Measuring length of column of air

Maths skills:

1A Recognise and use numbers in decimal form

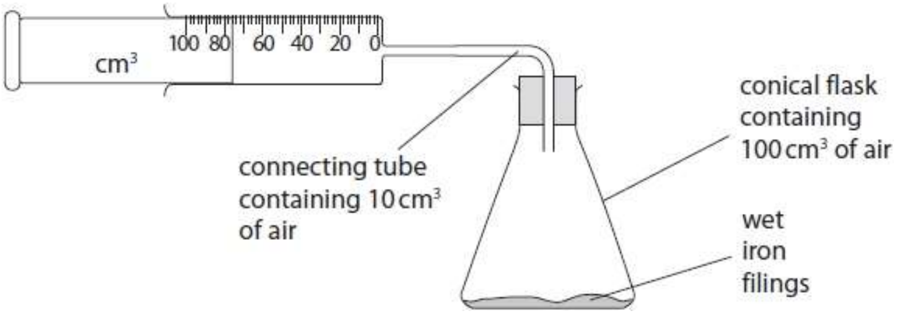
1C Use ratios and fractions

2A Use an appropriate number of significant figures

Questions

The percentage by volume of oxygen in air can be found by using the rusting of iron.

A student sets up this apparatus to measure the volume of oxygen in a sample of air.

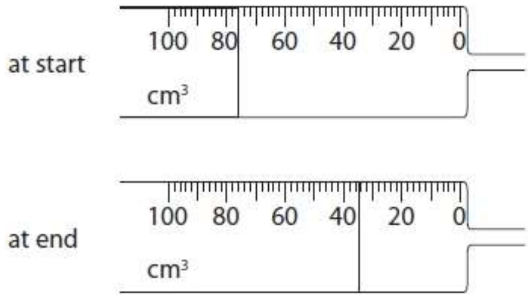


An excess of wet iron filings is used.

At the start of each experiment, the reading on the syringe is recorded and the apparatus is then left for a week so that the reaction is complete.

The reading on the syringe is then recorded again.

(a) The diagram shows the readings in one experiment.



Complete the table to show: **(2)**

- the syringe reading at the end of this experiment
- the volume of oxygen used in the experiment.

syringe reading at start / cm^3	76
syringe reading at end / cm^3	
volume of oxygen used / cm^3	

(b) The table shows the results recorded by a different student in her experiment.

volume of air in conical flask / cm^3	100
volume of air in connecting tube / cm^3	10
original volume of air in syringe / cm^3	80
final volume of air in syringe / cm^3	43

Calculate the percentage of oxygen in air using these results. **(3)**

percentage of oxygen = ______________________________ %

(c) The table shows some possible causes of anomalous results in this experiment.

Use terms from the box to complete the table, showing possible causes and their effects on the volume of oxygen used in this experiment.

decreased	increased	no effect

Each term may be used once, more than once, or not at all. **(3)**

Possible cause	Effect on volume of oxygen used
wet iron filings not in excess	
apparatus left for 1 hour instead of 1 week	
Apparatus left in a warmer place for 1 week	

(Total for question = 8 marks)

Mark Scheme

Question number	Answer	Additional guidance	Mark
(a)	• 35 (1) • 41 (1)	final answer consequential on syringe readings	2

Question number	Answer	Additional guidance	Mark
(b)	• Calculation of volume of oxygen used • Calculation of original volume of air • Calculation of percentage Example calculation: 80 − 43 = 37 (cm^3) (1) 100 + 10 + 80 = 190 (cm^3) (1) (37 × 100) ÷ 190 (= 19.47%) = 19% (1)	accept 19.47% or 19.5%	3

question number	answer	mark
(c)	• Decreased (1) • Decreased (1) • No effect (1)	3

Core practical 6: Acid-metal reactions

2.21 Core practical: Investigate reactions between dilute hydrochloric and sulfuric acids and metals

Links to the specification content

2.15	Understand how metals can be arranged in a reactivity series based on their reactions with a) water and b) dilute hydrochloric or sulfuric acid
2.17	Know the order of reactivity of these metals: potassium, sodium, lithium, calcium, magnesium, aluminium, zinc, iron, copper, silver, and gold

Introducing the practical

N.B. Potassium, sodium and lithium are too reactive and no attempt should be made to add any of these metals to dilute acid. Refer to CLEAPSS Hazcard 16 for details about how to safely add calcium to dilute acid.

Suitable concentrations and type of metal to use to show reaction can be found as follows:

Magnesium (Hazcard 59A), aluminium (Hazcard 1), zinc (Hazcard 107), iron (Hazcard 55A) and copper (Hazcard 26).

The reaction with aluminium and dilute hydrochloric acid will start off very slowly but should then speed up as the oxide coating is removed.

The reaction between calcium and sulfuric acid will be quickly 'arrested' owing to the formation of a coating of insoluble calcium sulfate around the metal.

Procedure

Students can perform the experiments and then produce a table of results to show the reaction, or lack of reaction, between each metal and each acid.

A test could be performed to show that hydrogen gas is evolved. This test is best performed with magnesium and/or calcium. The rate of evolution of hydrogen with the other metals is often too slow to produce a suitable build-up of the gas in the test tube.

Students could then write a chemical equation for each reaction that has taken place.

Acid-metal reactions

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

- Why does the reaction between aluminium and dilute hydrochloric acid start off very slowly but then increase in rate after a while?
- Why does the reaction between calcium and sulfuric acid stop after a while, even though neither the metal nor the acid has fully reacted?

Skills that are covered in each practical:

- Safe handling of dilute acids
- Safe handling of metals
- Testing for hydrogen

Maths skills:

1A Recognise and use numbers in decimal form

1C Use ratios and fractions

2A Use an appropriate number of significant figures

Questions

Q1.

This question is about the reactions of some metals and their compounds.

(a) A student adds a sample of four metals R, S, T and U separately to water and to dilute sulfuric acid.

The table shows the observations in each experiment.

Metal	Observation with water	Observation with dilute sulfuric acid
R	no change	bubbles form slowly
S	bubbles form quickly	bubbles form very quickly
T	no change	no change
U	bubbles form slowly	bubbles form quickly

(i) State two properties of the metals that the student should keep the same in all of the experiments in order to compare their reactivity. **(2)**

1

___

___

2

___

___

(ii) Which is the least reactive metal? **(1)**

☐ **A** metal R

☐ **B** metal S

☐ **C** metal T

☐ **D** metal U

(iii) Which gas forms during the reactions with dilute sulfuric acid? **(1)**

☐ **A** carbon dioxide

☐ **B** hydrogen

☐ **C** oxygen

☐ **D** sulfur dioxide

(Total for question = 4 marks)

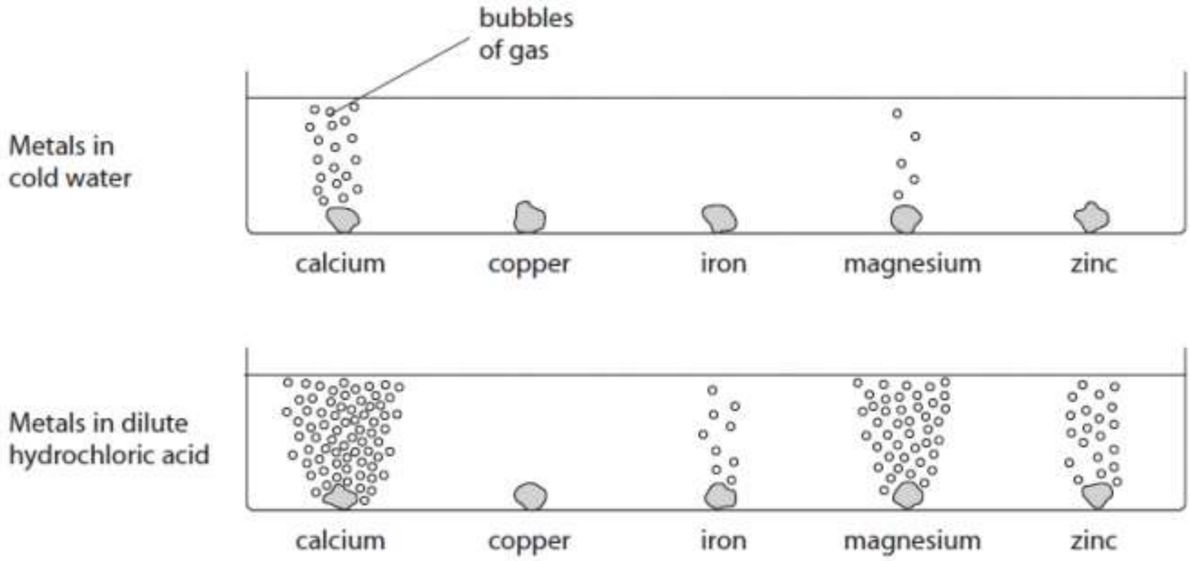
Mark Scheme

Q1.

Question number	Answer	Notes	Marks
a i	amount (in moles)	Accept mass/weight	1
	state of (sub)division / (total) surface area / particle size	OWTTE Accept temperature in place of either of above Ignore references to water or acid	1
ii	cross in box **C** (metal T)		1
iii	cross in box **B** (hydrogen)		1

Q2.

The diagrams show the reactions of some metals with cold water and with dilute hydrochloric acid.



(a) Answer the following questions, using only the metals that appear in the diagrams.

(i) Name **two** metals that react with cold water. **(2)**

____

and ______________________________

(ii) Name **one** metal that reacts with dilute hydrochloric acid but not with cold water. **(1)**

____

(iii) Arrange the five metals in order of reactivity. **(3)**

Most reactive metal ______________________________

____

____

____

Least reactive metal ______________________________

(Total for question = 6 marks)

Mark Scheme

Q2.

Question number	Expected Answer	Accept	Reject	Marks
(a) (i)	M1 calcium M2 magnesium	Ca Mg	any other answers	1 1
(ii)	iron / zinc	Fe / Zn	any other answers	1
(iii)	calcium magnesium zinc iron copper M1 for calcium as most reactive M2 for copper as least reactive M3 for remainder in correct order	Ca Mg Zn Fe Cu		3

Core practical 7: Preparation of copper sulfate

2.42 Core practical: Prepare a sample of pure, dry hydrated copper(II) sulfate crystals starting from copper(II) oxide

Links to the specification content

1.4	Know what is meant by the terms: solvent, solute, solution, and saturated solution
2.39	Describe an experiment to prepare a pure, dry sample of a soluble salt, starting from an insoluble reactant

Introducing the practical

Students should be aware of the solubility rules of salts and of the reactions of metals and bases with dilute acids. They could then be set the task of predicting the reagents required to prepare copper(II) sulfate.

The dilute sulfuric acid needs to be warmed because the reaction with copper(II) oxide is very slow at room temperature. However, care needs to be taken not to get the acid too hot, and certainly not to boiling point, since the copper(II) oxide powder, and also the acid, may 'spit out' of the container and into the atmosphere. Copper(II) oxide can cause respiratory problems when inhaled and can easily bring on an attack with asthmatics. One suitable way to heat the acid is to place it in a boiling tube and heat in a water bath.

The copper(II) oxide is added, with stirring, to the acid a spatula-measure at a time. Each measure should be given time to completely react (i.e. completely disappear) before the next is added. Addition should finish when the oxide stops disappearing.

The mixture is then filtered and crystals obtained from the filtrate by crystallisation.

Crystallisation involves partial evaporation of the copper(II) sulfate solution to produce a hot, saturated solution. This solution is then cooled for crystals to form. The crystals are then removed by filtration and dried using filter paper or blotting paper. They can be dried in a **warm** oven, but not by direct heating with Bunsen flame since the crystals would dehydrate.

Leaving the filtrate for the water to fully evaporate is not suitable, since any water soluble impurities in the original copper(II) oxide will also crystallise and contaminate the copper(II) sulfate.

Preparation of copper sulfate

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

- Why is the acid warmed?
- Why use an excess of copper(II) oxide?
- Why is the mixture filtered after adding excess copper(II) oxide?
- How can you decide when you have produced a hot, saturated solution of copper(II) sulfate?
- At what stage in the process are any (a) insoluble impurities and (b) soluble impurities that may be present in the copper(II) oxide removed?
- What is meant by the term 'saturated solution'?
- Why do crystals of copper(II) sulfate form when the hot, saturated solution is cooled?
- Why should the crystals of copper(II) sulfate not be dried by direct heating with a Bunsen flame?

Skills that are covered in each 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(II) oxide from copper(II) sulfate solution
- Safe use of evaporation to evaporate some of the water from the copper(II) sulfate solution
- Safe use and handling of sulfuric acid, copper(II) oxide and copper(II) sulfate

Questions

Many different salts can be prepared from acids.

(a) The table shows the reactants used in two salt preparations.

Complete the table to show the name of the salt formed and the other product(s) in each case. **(4)**

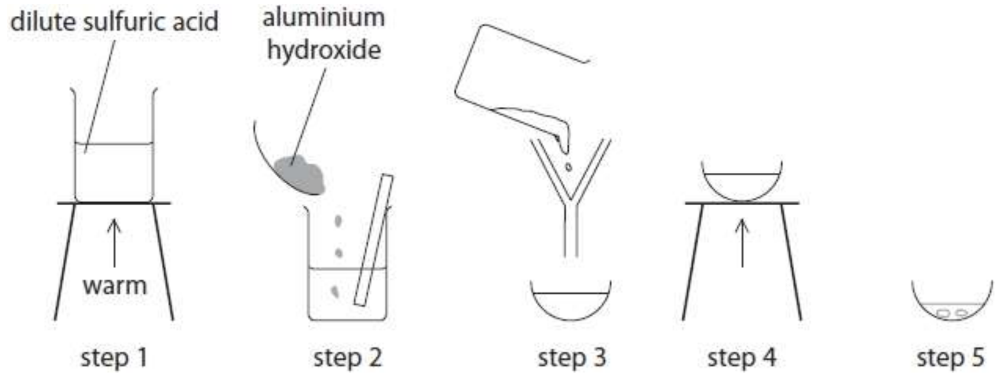
Reactants	Name of salt formed	Other product(s)
zinc + hydrochloric acid		
calcium carbonate + nitric acid		

(b) A student uses the reaction between aluminium hydroxide and dilute sulfuric acid to prepare a pure, dry sample of aluminium sulfate crystals.

The equation for the reaction used to prepare this salt is

$2Al(OH)_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 6H_2O$

The diagram shows the steps in the student's method.



(i) State **two** ways to make sure that all the acid is reacted in step 2. **(2)**

1

____

____

2

____

____

(ii) State the purpose of filtration in step 3. **(1)**

____

____

(iii) In step 5, the basin is left to cool to room temperature to allow crystals of aluminium sulfate to form.

State **one** method of drying these crystals. **(1)**

____

____

(Total for question = 8 marks)

Mark Scheme

Question number	Answer	Mark
(a)	1 mark for each box completed correctly <table><tr><th>Reactants</th><th>Name of salt formed</th><th>Other product(s)</th></tr><tr><td>(zinc + hydrochloric acid)</td><td>zinc chloride</td><td>hydrogen</td></tr><tr><td>(calcium carbonate + nitric acid)</td><td>calcium nitrate</td><td>water + carbon dioxide</td></tr></table>	4

Question number	Answer	Mark
(b)(i)	• Use excess aluminium hydroxide (1) • Stir (thoroughly) (1)	2

Question number	Answer	Mark
(b)(ii)	To remove unreacted aluminium hydroxide/solid	1

Question number	Answer	Mark
(b)(iii)	Any one of: • leave in a warm place (1) • use filter paper or paper towel (1)	1

Core practical 8: Preparation of lead sulfate

2.43C Core practical: Prepare a sample of pure, dry lead(II) sulfate

Links to the specification content

2.41C	**Describe an experiment to prepare a pure, dry sample of an insoluble salt, starting from two soluble reactants**

Introducing the practical

Students should be aware of the solubility rules of salts. They could then be set the task of predicting the reagents required to prepare lead(II) sulfate.

An insoluble salt, such as lead(II) sulfate, is prepared by mixing two aqueous solutions, filtering to remove the precipitate, and then drying the solid.

- One solution needs to contain the cation, in this case lead(II), Pb^{2+}.
- The second solution needs to contain the anion, in this case sulfate, SO_4^{2-}.

Lead(II) nitrate is the obvious choice for solution A. There are a number of suitable sulfates available from which to make solution B, and your choice will most likely depend on cost. Note, however, that dilute sulfuric acid is also a suitable source of sulfate ions.

As a rule, direct heating is not recommended for drying the solid salt, since it may lead to decomposition.

If the concentrations and volumes of the original solutions are known then the maximum theoretical yield of lead(II) sulfate can be calculated. This could then be compared with the mass of lead(II) sulfate obtained, and the percentage yield could be calculated.

Preparation of lead sulfate

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

- How do you decide which reactants to choose?
- Why is the residue of lead(II) sulfate washed before drying?
- Why is deionised water, and not tap water, used to wash the solid lead(II) sulfate?
- Why is the solid lead(II) sulfate not dried by direct heating with a Bunsen burner flame?

Skills that are covered in each practical:

- Safe use of filtration to separate residue of lead(II) sulfate from the reaction mixture
- Safe use and handling of solutions of salts and solid lead(II) sulfate

Extension work:

Students could be asked to make predictions of suitable reactants to take to make given insoluble salts.

Alternatively, they could be asked to complete a table of reactants and products in which some information is given. An example is shown below:

REACTANTS		PRODUCTS	
Solution A	**Solution B**	**Insoluble salt**	**Soluble salt**
silver nitrate	potassium chloride		
barium chloride		barium sulfate	
		lead(II) iodide	sodium nitrate

Finally, they could be asked to write an ionic equation to represent each reaction. This would provide an excellent opportunity to introduce the concept of spectator ions, if this has not already been done when dealing with tests for ions, for example.

Questions

When solutions are mixed together, precipitates sometimes form.

(a) Barium carbonate is an insoluble compound. It is formed as a precipitate when solutions of the soluble compounds barium chloride and sodium carbonate are mixed.

When solutions of the soluble compounds potassium chloride and sodium sulfate are mixed, no precipitate is formed.

Complete the table to show the results of mixing solutions of some compounds. **(3)**

	sodium carbonate solution	**sodium sulfate solution**
barium chloride solution	precipitate of barium carbonate	____________ ____________
potassium chloride solution	____________ ____________	no precipitate
calcium chloride solution	precipitate of calcium carbonate	____________ ____________

(b) When solutions of lead(II) nitrate and potassium bromide are mixed, a precipitate of lead(II) bromide and a solution of potassium nitrate are produced.

The equation for the reaction is

$Pb(NO_3)_2$(................) + 2KBr(................) → $PbBr_2$(................) + $2KNO_3$(................)

Complete the equation by inserting the state symbols. **(1)**

(c) In order to prepare a **pure, dry** sample of lead(II) bromide, a student took the mixture produced in part (b).

He then

- filtered the mixture
- washed the solid residue with distilled water
- left the solid in a warm place for several hours

(i) Why did the student filter the mixture? **(1)**

____

____

____

(ii) Why did he wash the solid residue? **(1)**

____

____

____

(iii) Why is it better to use distilled water rather than tap water to wash the solid residue? **(1)**

____

____

____

(iv) Why did he leave the solid in a warm place? **(1)**

____

____

____

(Total for Question = 8 marks)

Mark Scheme

Question number	Expected Answer	Accept	Reject	Marks
(a)	M1 precipitate of barium sulfate	sulphate for sulfate insoluble barium sulphate / $BaSO_4$	incorrect name of ppt.	1
	M2 no precipitate	no (visible) change solution (formed)		1
	M3 precipitate of calcium sulfate IGNORE colours penalise incorrect extra observations (e.g. effervescence) ONCE only For M1 and M3 only: if only precipitate appears twice (with no names), penalise <u>missing</u> names once only if only names correct (with no precipitates), penalise omission of precipitate once only	sulphate for sulfate insoluble calcium sulfate / $CaSO_4$	incorrect name of ppt.	1
(b)	aq aq s aq			1
(c) (i)	obtain the lead(II) bromide/the residue/the solid OR remove the liquid/solution/potassium nitrate/water	separate the solid and liquid		1
(ii)	to wash away/remove the (remaining) potassium nitrate / lead(II) nitrate / potassium bromide / solution IGNORE clean	wash away / remove (remaining soluble) impurities to make it pure	make the mixture pure	1

(iii)	distilled water is pure / does not contain (dissolved) impurities / ions / substances / compounds / other chemicals (that would contaminate the lead(II) bromide) / residue / solid) IGNORE elements IGNORE references to distilled water being cleaner (ORA)	reverse argument for tap water	any suggestion that the water / impurities react	1
(iv)	to evaporate the water / to dry (the solid/crystals) / increase rate of evaporation (of water) IGNORE liquid	to avoid decomposition (if heated strongly)	to evaporate the potassium nitrate / solution any reference to crystallisation	1

Core Practical 9: Endothermic & exothermic reactions

3.8 Core practical: Investigate temperature changes accompanying some of the following types of change: salts dissolving in water, neutralisation reactions, displacement reactions, and combustion

Links to the specification content

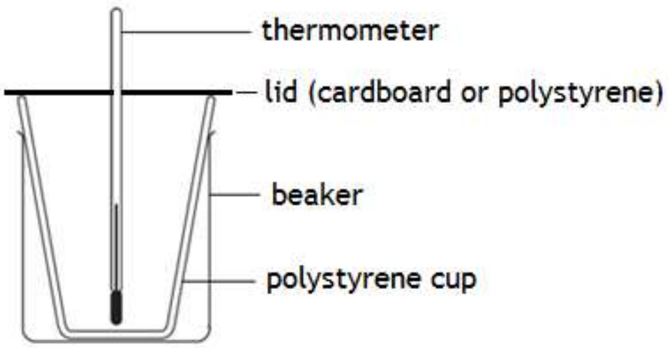
3.1	Know that chemical reactions in which heat energy is given out are described as exothermic, and those in which heat energy is taken in are described as endothermic
3.2	Describe simple calorimetry experiments for reactions such as combustion, displacement, dissolving and neutralisation
3.3	Calculate the heat energy change from a measured temperature change using the expression $Q = mc\Delta T$
3.4	Calculate the molar enthalpy change (ΔH) from the heat energy change, Q

Introducing the practical

Students should be aware of exothermic and endothermic reactions. They should also be aware that, for reactions taking place in solution, an exothermic reaction produces an increase in temperature of the reaction mixture, whereas an endothermic reaction produces a decrease in temperature.

Students also need to be aware that, in physics, heat energy is described as thermal energy, and that these two terms are interchangeable as far as chemistry is concerned.

Following the temperature change for salts dissolving in water, for neutralisation reactions and for displacement reactions can be performed using the apparatus shown in the diagram below:



A polystyrene cup is preferred to a glass beaker since it has a lower specific heat capacity.

For safety reasons, it is best to place the polystyrene cup in a beaker in case the thermometer is allowed to rest against its side.

The reaction mixture can be stirred with the thermometer as long as this is done gently.

Salts dissolving in water

A suitable salt to use is ammonium chloride, which dissolves endothermically producing a decrease in temperature.

Use a mass of NH_4Cl between 2.5 and 3.0 g, with a mass of water between 80.0 and 100.0 g.

A mass of 2.67 g (0.0500 mol) dissolved in 90.0 g (5.00 mol) of water should produce a temperature change in the region of − 1.8 °C.

The calculation for the results is as follows:

$Q = m c \Delta T$

$Q = 90.0\text{ g} \times 4.18\text{ J/g/°C} \times -1.8\text{ °C}$

$= -677\text{ J}$

$\Delta H = -Q \div n$ (where n = the amount, in moles, of NH_4Cl)

$= -(-677\text{ J}) \div 0.0500\text{ mol}$

$= +13\,540\text{ J/mol}$

$= +14\text{ kJ/mol}$ (final answer to 2 sf since ΔT is determined to only 2 sf)

This compares favourably with the data book value of + 16.4 kJ/mol. The ammonium chloride usually dissolves very quickly so heat energy transfer from the surroundings to the solution is kept to a minimum.

However, the temperature change is very small and hence even a small error in measurement of 0.1 °C would result in a difference of around 1 kJ/mol to the final answer. This sort of error is not unreasonable to expect since the measurement uncertainty of a − 10 to 110 °C thermometer is likely to be ± 0.5 °C. Since two readings of temperature are made, the maximum potential error is ± 1 °C. If your thermometers have a greater degree of precision than ± 0.5 °C, then this uncertainty is reduced.

Assumptions made are:

- The specific heat capacity of the polystyrene cup and the thermometer are both negligible compared to that of the solution
- The specific heat capacity of the solution is the same as that of water

Salts dissolving in water

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

- Why use a polystyrene cup rather than a glass beaker?
- Why is it important that the ammonium chloride dissolve as quickly as possible?
- Why is the value obtained from your experiment lower (i.e. less positive) than the data book value?
- What assumptions have you made in performing the calculation?

Skills that are covered in the practical:

- Measure mass
- Measure temperature rise

Maths skills:

1A Recognise and use numbers in decimal form

1C Use ratios

2A Use an appropriate number of significant figures

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

Neutralisation reactions

The obvious choice is dilute hydrochloric acid (HCl) and aqueous sodium hydroxide (NaOH).

As a class practical, the values obtained could be pooled and a mean value calculated. Alternatively, different groups could determine the enthalpy change for other combinations of acid and alkali, e.g. HCl and KOH, H_2SO_4 and NaOH, CH_3COOH and NaOH.

The most straightforward and quickest method is to use known volumes of known concentrations of HCl and NaOH. Measure the initial temperature of each solution (hopefully they will be the same; if not calculate a mean of the two and use this as the initial temperature) and then add one solution to the other, in a polystyrene cup, and measure the highest temperature reached.

It is good practice to use a sodium hydroxide solution that has a slightly greater concentration that that of the hydrochloric acid. This ensures complete neutralisation of the acid.

A typical set of results is shown:

- Concentration of HCl = 1.0 mol/dm^3
- Volume of HCl = 50 cm^3
- Volume of NaOH = 50 cm^3
- Temperature rise (ΔT) = + 6.6 °C

The calculation for these results is as follows:

$$n(\text{HCl}) = 0.050\ \text{dm}^3 \times 1.0\ \text{mol/dm}^3 = 0.050\ \text{mol}$$

$$Q = 100\ \text{g} \times 4.18\ \text{J/g/°C} \times +6.6\ \text{°C}$$

$$= +2758.8\ \text{J}$$

$$\Delta H = -(+2758.8\ \text{J} \div 0.050\ \text{mol})$$

$$= -5517.6\ \text{J/mol}$$

$$= -55\ \text{kJ/mol (to 2 sf)}$$

This compares favourably with the data book value of – 57.2 kJ/mol. The reaction is fast and hence the heat energy transfer to the surroundings in minimal.

The assumptions that have been made are:

- The specific heat capacity of the polystyrene cup and the thermometer are both negligible compared to that of the solution
- The specific heat capacity of the solution is the same as that of water
- The density of the solution is 1 g/cm^3

Neutralisation reactions

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

- Why use a polystyrene cup rather than a glass beaker?
- Why is it important that the reaction occur as quickly as possible?
- Why is the value obtained from your experiment smaller (i.e. less negative) than the data book value?
- What assumptions have you made in performing the calculation?

Skills that are covered in the practical:

- Measure mass
- Measure volume of solution
- Measure temperature rise

Maths skills:

1A Recognise and use numbers in decimal form

2A Use an appropriate number of significant figures

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

3D Solve simple algebraic equations

Displacement reactions

The major problem with displacement reactions is that they tend to be rather slow and hence an appreciable amount of heat energy transfer to the surroundings can take place before the reaction is complete.

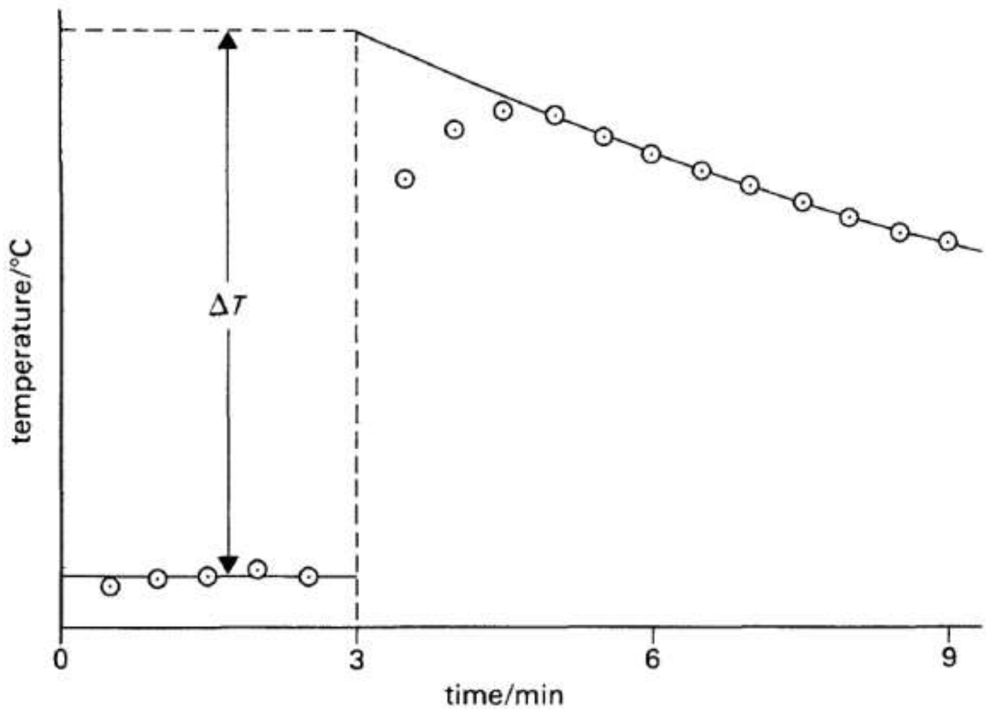
One reaction that should take place reasonably quickly to obtain suitable results is that between magnesium powder and aqueous copper(II) sulfate.

However, it is safer to use zinc powder (about 6 g) and copper(II) sulfate (25 cm^3 of 1 mol/dm^3). The zinc is in excess so there is no necessity for it to be weighed accurately.

The procedure is as follows:

- measure the temperature of the copper(II) sulfate solution should be measured every half minute for 2.5 minutes
- add the zinc after exactly three minutes
- measure the temperature after three and a half minutes, and every half minute afterwards for a total of six minutes.

Plot a graph of temperature against time.



Extrapolation of the curve to three minutes allows the temperature rise, ΔT, to be found.

Displacement reactions

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

- What assumptions have you made in performing the calculation?
- Why does the temperature continue to increase for a short period after adding the zinc?

(Answer: the reaction takes a few minutes to complete because the copper first precipitated shields some of the zinc atoms from the copper(II) ions)

Skills that are covered in the practical:

- Measure mass
- Measure volume of solution
- Measure temperature rise

Maths skills:

1A Recognise and use numbers in decimal form

4C Plot two continuous variables from experimental data

2A Use an appropriate number of significant figures

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

3D Solve simple algebraic equations

Extension work:

The results could be used to calculate the molar enthalpy change of reaction using:

$Q = mc\Delta T$ and $\Delta H = -Q/n$

…where n is the amount of copper(II) sulfate used (the zinc is in excess).

The values obtained could then be compared with the data book value of −217 kJ/mol.

Combustion (e.g. alcohols)

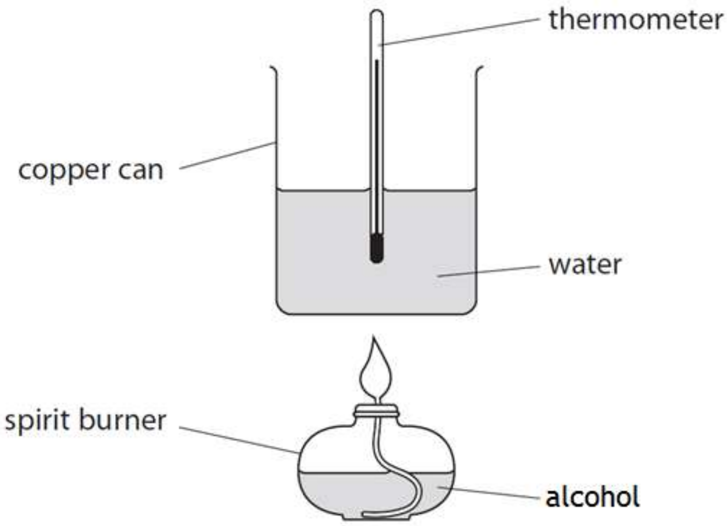
Students burn the alcohols in spirit burners and heat water in a beaker or copper can.

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 be encouraged to notice possible procedural errors in the experiment, e.g. heat energy loss to the surroundings, difficulty in having the same height of flame from each spirit burner, incomplete combustion of the alcohol, evaporation of alcohols during weighing, evaporation of the water.

If the results from the class are pooled, then a mean value for each alcohol can be calculated.

A typical set up is shown in the diagram below:



Combustion

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?
- Which 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 procedural errors?
- How is the temperature rise of water related to the number of carbon atoms in the alcohol molecules?
- If you want to show the results in graphical form, should you draw a bar chart or a line graph? Justify your answer.

Skills that are covered in the practical:

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

Maths skills:

1A Recognise and use numbers in decimal form (when calculating the mass of alcohol burned)

1C Use ratios (in the formulae of the alcohols)

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

2C Construct and interpret bar charts

Extension work:

The results could be used to calculate the molar enthalpy change of combustion (ΔH) of each alcohol using:

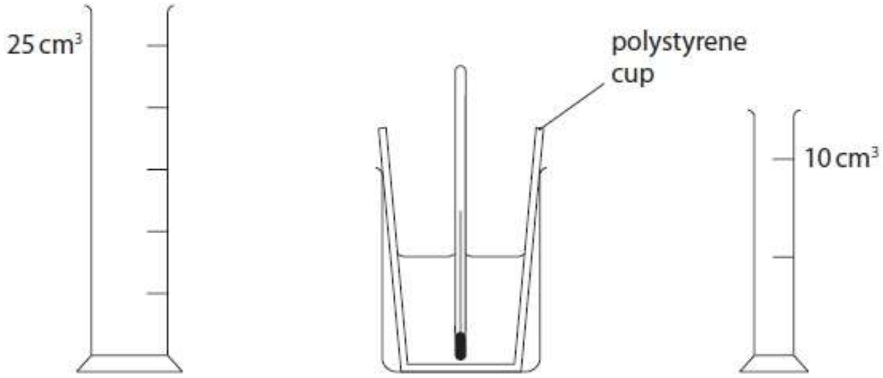
$Q = m c \Delta T$ and $\Delta H = - Q/n$

…where n is the amount of alcohol burned

The values obtained could then be compared with the data book values.

Questions

When aqueous solutions of potassium hydroxide and nitric acid are mixed together, an exothermic reaction occurs. The diagram shows the apparatus used in an experiment to measure the temperature increase.



This is the student's method:

- use the larger measuring cylinder to add 25 cm^3 of aqueous potassium hydroxide to the polystyrene cup
- record the steady temperature
- use the smaller measuring cylinder to add 5 cm^3 of dilute nitric acid to the cup, stir the mixture with the thermometer
- record the highest temperature of the mixture
- continue adding further 5 cm^3 portions of dilute nitric acid to the cup, stirring and recording the temperature, until a total volume of 35 cm^3 has been added.

(a) A teacher advises the student to use a 50 cm^3 burette instead of the 10 cm^3 measuring cylinder.

Suggest two reasons why it would be better to use a burette instead of a measuring cylinder to add the acid in this experiment. **(2)**

1

____

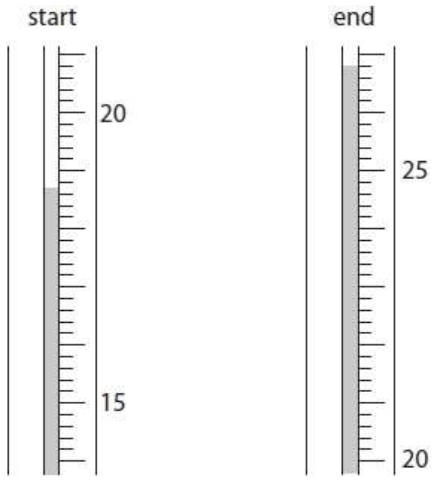
____

2

____

____

(b) The diagram shows the thermometer readings at the start and at the end of one experiment.



Complete the table to show: **(2)**

- the thermometer reading at the start of the experiment
- the temperature rise in the experiment.

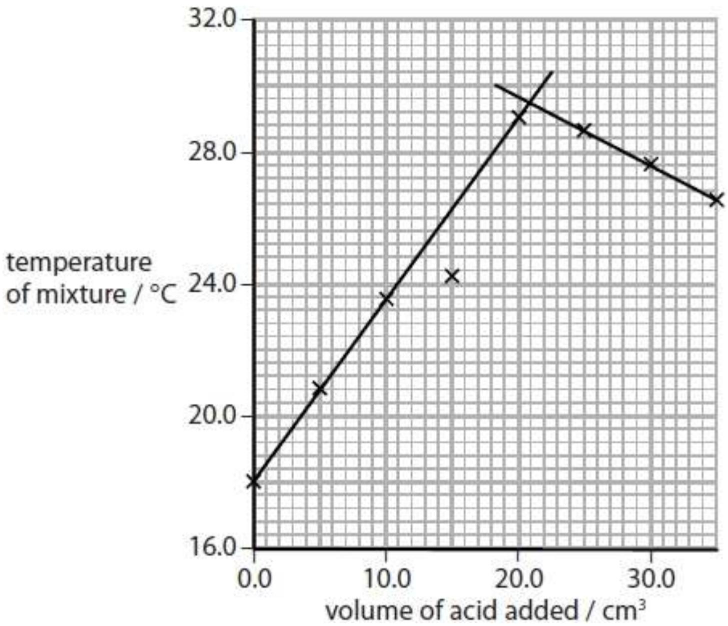
thermometer reading at end / °C	26.8
thermometer reading at start / °C	
thermometer rise / °C	

(c) Another student uses the same method, adding the dilute nitric acid from a burette.

The table shows his results.

volume of acid added / cm^3	0.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0
temperature of mixture / °C	18.0	20.8	23.5	24.2	29.0	28.6	27.6	26.5

This is the student's graph.



The point where the lines cross represents complete neutralisation.

(i) Identify the maximum temperature reached during the experiment. **(1)**

maximum temperature = ______________________________ °C

(ii) Identify the volume of dilute nitric acid that exactly neutralises the 25 cm^3 of aqueous potassium hydroxide. **(1)**

volume = ______________________________ cm^3

(d) Another student records these results.

volume of aqueous potassium hydroxide	= 20.0 cm^3
starting temperature of aqueous potassium hydroxide	= 18.5 °C
maximum temperature of mixture	= 30.0 °C
volume of dilute nitric acid	= 20.0 cm^3

Calculate the heat energy released in this experiment.

c = 4.2 J/g / °C

mass of 1 cm^3 of mixture = 1 g **(4)**

heat energy = ______________________________ J

(e) In another experiment, the heat energy released is 1600 J when 0.040 mol of potassium hydroxide is neutralised.

Calculate the value of ΔH, in kJ/mol, for the neutralisation of potassium hydroxide.

(2)

ΔH = ____________________________ kJ/mol

(Total for question = 12 marks)

Mark Scheme

Question number	Answer	Mark
(a)	• Increment in volume smaller/more precise (1) • Avoids refilling the measuring cylinder (1)	2

Question number	Answer	Additional guidance	Mark
(b)	<table><tr><td>thermometer reading at end/°C</td><td>(26.8)</td></tr><tr><td>thermometer reading at start/°C</td><td>18.7</td></tr><tr><td>temperature rise/°C</td><td>8.1</td></tr></table>	1 mark for temperature at start 1 mark for temperature rise consequential on readings	2

Question number	Answer	Mark
(c)(i)	29.5	1

Question number	Answer	Mark
(c)(ii)	20.8	1

Question number	Answer	Mark
(d)	• Calculation of volume/mass of mixture • Calculation of temperature increase • Substitution of values into $q=mc\Delta T$ • Calculation of heat energy released with unit Example calculation: 20.0 + 20.0 = 40.0 (cm^3) (1) 30.0−18.5 = 11.5 (°C) (1) q = 40.0 × 4.2 × 11.5 (1) q = 1900 J (1) (accept 1932 J)	4

Question number	Answer	Mark
(e)	• Setting out of ΔH calculation • Division by 1000 to obtain answer in kJ/mol Example calculation: 1600 ÷ 0.040 (1) = −40 (kJ/mol) (1)	2

Core practical 10: Rates of reaction

3.15 Core practical: Investigate the effect of changing the surface area of marble chips and of the concentration of hydrochloric acid on the rate of reaction between marble chips and dilute hydrochloric acid

Links to the specification content

3.9	describe experiments to investigate the effects of changes in surface area of a solid, concentration of a solution, temperature and the use of a catalyst on the rate of a reaction
3.10	describe the effects of changes in surface area of a solid, concentration of a solution, pressure of a gas, temperature and the use of a catalyst on the rate of a reaction
3.11	explain the effects of changes in surface area of a solid, concentration of a solution, pressure of a gas and temperature on the rate of a reaction in terms of particle collision theory

Introducing the practical

There are two investigations to carry out and they are likely to take a lesson each.

In investigation 1, students investigate the effect of changing the concentration of hydrochloric acid on the rate of reaction between hydrochloric acid and marble chips.

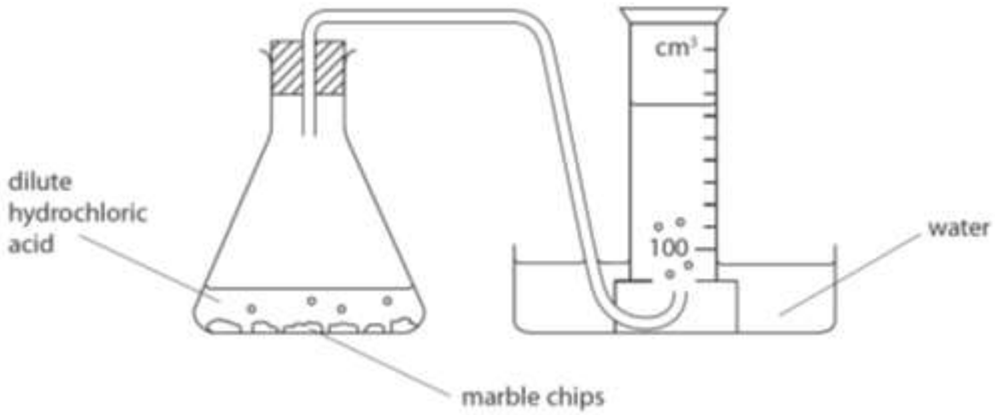
In investigation 2, students investigate the effect of changing the size of marble chips on the rate of reaction between hydrochloric acid and marble chips.

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.

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.

Investigation 1

A typical set up for collection over water is shown in the diagram:



It is impossible to maintain an exactly constant surface area from one experiment to the next, but it can be partly controlled by taking the same mass of chips, the same number of the chips and similar size of chips in each case.

The exact concentrations of acid to use are best determined in advance by trial and error using the supply of marble chips at your disposal.

A good starting point would be 2mol/dm^3 and work downwards from there.

Investigation 2

In the investigation, it is necessary to vary the surface area of the marble chips.

This can be done if you have access to marble chips of different size. Alternatively, you can start with large marble chips and hit them with a hammer (first wrap the chips in a towel) to produce smaller chips.

Once again, it is best to trial the experiments beforehand to determine the most effective concentration of hydrochloric acid to use. A concentration of 2mol/dm^3 often works well, providing times that are neither too long nor too short.

If the reaction in the first investigation has been followed by measuring the total volume of gas collected at set time intervals, it may be worthwhile to follow this reaction by measuring the time taken to collect a fixed volume of gas each time. The overall rate of reaction could then be calculated for each reaction by dividing the volume of gas collected by the time taken, giving typical units of say cm^3/s for the rate.

Additional investigations

1. Investigate the change in concentration of sodium thiosulfate on the rate of reaction between sodium thiosulfate and hydrochloric acid.
2. Investigate the effect of temperature of the rate of reaction between sodium thiosulfate and hydrochloric acid.

These two investigations are described here and here on the RSC website.

Rates of reaction

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

- 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 procedural error in this experiment?
- How could you reduce this procedural 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?

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
- 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
- Safe use and handling of hydrochloric acid and marble chips

Maths skills:

1A Use expressions in decimal form (e.g. when calculating gradients)

1B Use ratios (in balanced equations)

2A Use an appropriate number of significant figures (when calculating rate)

4A Translate information between graphical and numeric form

4C Plot two continuous variables from experimental data

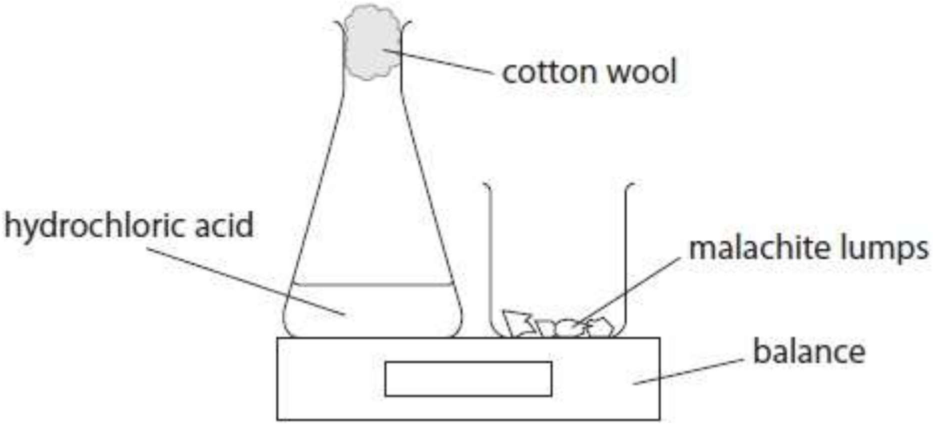
4D Draw and use the slope of a tangent to a curve as a measure of rate of reaction

Questions

The copper(II) carbonate in the mineral, malachite, reacts with hydrochloric acid according to this equation.

$$CuCO_3(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(g) + CO_2(g)$$

Some students investigate the effect of changing the concentration of acid on the rate of this reaction. The diagram shows the apparatus they use.



This is the method they use:

- set the balance to zero
- add an excess of malachite lumps to the conical flask and replace the cotton wool
- start a timer and record the balance reading after one minute.

The experiment is repeated using different concentrations of hydrochloric acid. The mass and number of malachite lumps are kept the same in each experiment.

(a) The table shows the results obtained in one series of experiments.

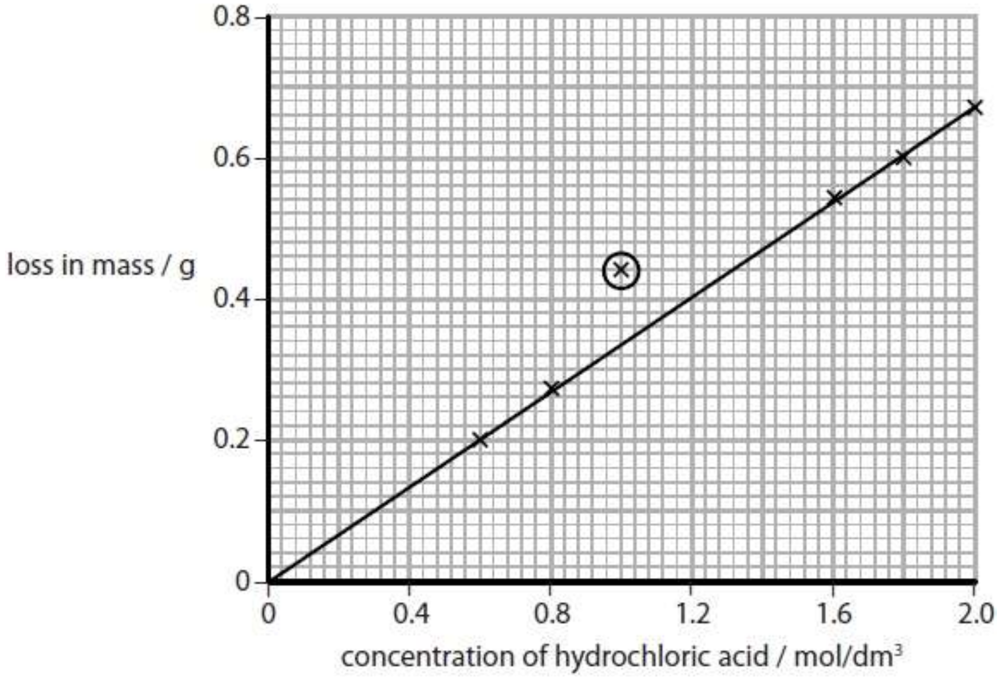
concentration of hydrochloric acid / mol/dm^3	0.6	0.8	1.0	1.6	1.8	2.0
balance reading / g	−0.20	−0.27	−0.44	−0.54	−0.60	−0.67

State why the balance readings have negative values. **(1)**

____

____

(b) The graph shows the results of this series of experiments.



The circled point indicates an anomalous result.

(i) Suggest **one** mistake the students could have made to produce this result. **(1)**

____

(ii) State the relationship shown by the graph. **(1)**

____

____

(c) Explain why an increase in the concentration of the acid causes an increase in the rate of the reaction. You should use the particle collision theory in your answer. **(2)**

____

____

____

____

____

(Total for question = 5 marks)

Mark Scheme

Question number	Answer	Mark
(a)	One reaction product is a gas and so escapes from the flask	1

Question number	Answer	Mark
(b)(i)	Any one of: • balance reading recorded too late • acid concentration greater than recorded	1

Question number	Answer	Mark
(b)(ii)	Loss in mass directly proportional to acid concentration	1

Question number	Answer	Additional guidance	Mark
(c)	An explanation that makes reference to the following two points: • more particles in the same volume (1) • so collide more frequently (with malachite) (1)	accept particles closer together	2

(Total for question = 5 marks)

Core practical 11: Catalytic decomposition

3.16 Core practical: Investigate the effect of different solids on the catalytic decomposition of hydrogen peroxide solution

Links to the specification content

3.9	Describe experiments to investigate the effects of changes in surface area of a solid, concentration of a solution, temperature and the use of a catalyst on the rate of a reaction
3.10	Describe the effects of changes in surface area of a solid, concentration of a solution, pressure of a gas, temperature and the use of a catalyst on the rate of a reaction
3.12	Know that a catalyst is a substance that increases the rate of a reaction, but is chemically unchanged at the end of the reaction
3.13	Know that a catalyst works by providing an alternative pathway with lower activation energy

Introducing the practical

An excellent problem solving activity is described here (an extract from the RSC booklet ‘Creative Problem Solving in Chemistry’).

Students do not need to know much in advance about catalysis, as they are encouraged in the exercise to consult textbooks and other sources of information.

Demonstration

A good demonstration is described here on the RSC website.

This demonstration extends the catalysts to those involving enzymes. Although this is not directly on the specification for the catalysis of hydrogen peroxide, it does provide a good link to the enzyme catalysis involved in fermentation.

The RSC has produced a short video that can be found on YouTube.

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

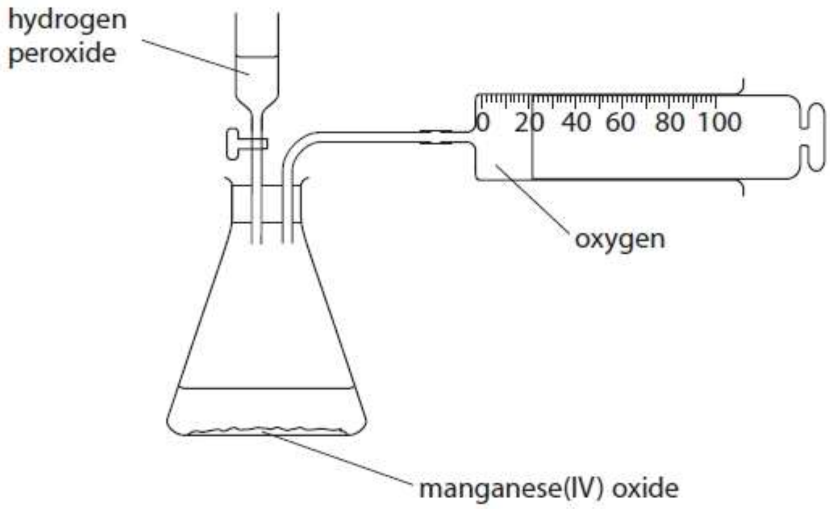
- How did you decide which catalyst was the most effective?

Skills that are covered in the practical:

- Safe handling of chemicals, such as hydrogen peroxide, which is a strong oxidising agent
- Planning and then carrying out an investigation

Questions

The apparatus in the diagram is used to collect the oxygen produced by the decomposition of hydrogen peroxide, H_2O_2



(a) Write a chemical equation for the decomposition of hydrogen peroxide. **(2)**

____

(b) Describe a test to show that the gas collected in the syringe is oxygen. **(1)**

____

____

(c) Manganese(IV) oxide is a catalyst for this reaction.

State and explain the effect of a catalyst on the rate of this reaction. **(3)**

____

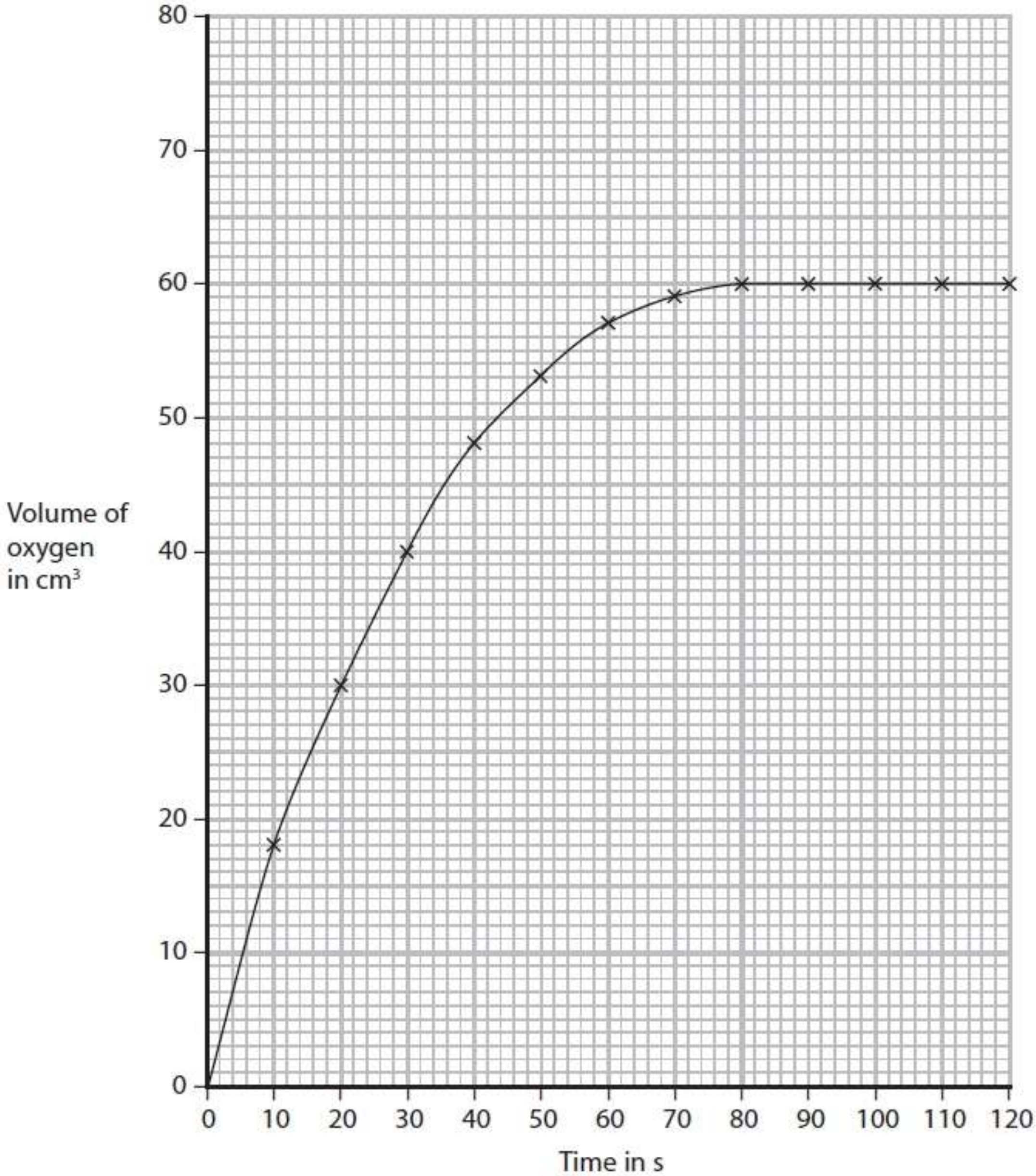
____

____

____

____

(d) The graph shows the results from an experiment using a 0.50 mol/dm^3 solution of hydrogen peroxide at 25 °C.



(i) On the same axes, sketch the curve you would expect with the same volume of a 0.25 mol/dm^3 solution of hydrogen peroxide at 25 °C. Label this curve **A**. **(2)**

(ii) On the same axes, sketch the curve you would expect with the same volume of a 0.50 mol/dm^3 solution of hydrogen peroxide at 35 °C. Label this curve **B**. **(2)**

(Total for Question = 10 marks)

Mark Scheme

Question number	Expected Answer	Accept	Reject	Marks
(a)	$2H_2O_2 \rightarrow 2H_2O + O_2$ M1 all formulae correct (including catalyst if given) M2 correct balancing M2 DEP on M1 If catalyst included in equation, must be MnO_2 on both sides IGNORE MnO_2 above the arrow	$H_2O_2 \rightarrow H_2O + ½O_2$ multiples		2
(b)	relights a glowing spill IGNORE reference to popping	splint for spill smouldering/embering for glowing		1
(c)	M1 (rate) increases	speeds up / goes faster / decreases time (for decomposition)		1
	M2 provides an alternative pathway / route / mechanism (for the reaction) OR hydrogen peroxide) particles / molecules / reactant(s) adsorb (onto catalyst)	lowers the activation energy by going a different way = M2 and M3 Absorb / sticks to / bonds to /provides a surface for particles /molecules / reactant(s) to react	gives particles more kinetic energy for M2 and M3	1
	M3 with a lower activation energy OR more particles / molecules have the (required) activation energy OR weakens the (covalent) bonds (in the hydrogen peroxide)	description of activation energy eg particles have enough energy to react	atoms atoms	1
(d) (i)	M1 curve starting at origin **and** below original curve M2 levelling off at 30 cm^3 (+/- 0.5) **and** anywhere between 30s and 120s	 curve reaching right vertical axis below $30cm^3$ but still 'going up'		1 1
(ii)	M1 curve starting at origin **and** above original curve M2 levelling off at 60 cm^3 (+/- 0.5) **and** before 80s if curves incorrectly labelled then penalise each curve 1 mark, so max. 2 for the question	 both curves unlabelled		1 1

Core practical 12: Preparation of ethyl ethanoate

4.43C Core practical: Prepare a sample of an ester such as ethyl ethanoate

Links to the specification content

4.39C	**Know that ethyl ethanoate is the ester produced when ethanol and ethanoic acid react in the presence of an acid catalyst**

Introducing the practical

There is an excellent description of how to make esters on a test tube scale here in the learn chemistry section of the RSC website.

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

- What is the purpose of the concentrated sulfuric acid?
- Why does adding the final reaction mixture to sodium carbonate solution help you to better smell the ester?

Skills that are covered in the practical:

- Safe handling of alcohols, carboxylic acids and concentrated sulfuric acid.

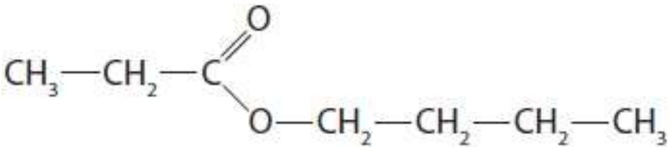
Extension work:

- Write a chemical equation, using structural formulae, for each ester made.
- Draw a displayed formula give a name for each ester made.

Questions

(c) Grapes contain esters.

The formula of an ester is shown.



Deduce the name of the carboxylic acid and the alcohol that can react together to make this ester. **(2)**

carboxylic acid

____

alcohol

____

(Total for question = 2 marks)

Mark Scheme

Question number	Answer	Additional guidance	Mark
(c)	(Carboxylic acid) propanoic acid (1) (Alcohol) butanol-1-ol/butanol (1)	accept propionic acid accept (*n*-)butyl alcohol	2

International GCSE Physics Practicals

There are 8 core practicals in the physics section of International GCSE Combined Science (and 1 practical related to required skills and techniques). International GCSE Physics covers the same 9 practicals as well as an additional 4 (and 1 more related to required skills and techniques), to make up 14 practicals in total.

This section outlines each core practical and gives a brief description of each one. Then the guide goes through each core practical in turn, outlining how to carry out the practical, questions that could be asked, and the key skills involved (including maths skills).

Core practical descriptions

Note: **2.23P**, **3.25P**, **3.27P**, **5.14P** and **5.11P** are separate International GCSE Physics only

No.	Specification Reference	Description
1	*1.5 - Investigate the motion of everyday objects such as toy cars or tennis balls.*	Everyday objects can be rolled, dropped or otherwise projected in such a way that they undergo uniform motion. Techniques to measure distance, displacement, average speed and instantaneous speed can be employed to produce distance-time and velocity-times graphs, to find the acceleration of the object.
2	*1.22 - Investigate how extension varies with applied force for helical springs, metal wires and rubber bands.*	The stretching of a spring must be investigated by measuring the length of a spring with no weights, followed by adding varying masses and measuring the new length. This must include calculating the work done and an appreciation of the forces involved.
3	***2.23P - Investigate how insulating materials can be charged by friction.***	**Simple experiments using rods, dusters, insulating threads and other readily available items to illustrate that objects can be charged and that there are only two 'types' of charge, positive and negative.**
4	*3.17 - Investigate the refraction of light, using rectangular blocks, semi-circular blocks and triangular prisms.*	A light source must be used to produce a beam of light, which must then be used to investigate the effect of refraction using the variety of named glass blocks. An appreciation of the interaction of the light ray with the glass block and the effect of changing medium on the light ray (moving towards and away from the normal) and total internal reflection (where appropriate) must be included.

5	*3.19 - Investigate the refractive index of glass, using a glass block.*	By measuring the corresponding angles of refraction for several angles of incidence of a beam of light on a glass block, sufficient data may be gathered to produce a reliable value for the refractive index, ideally by using a graphical method.
6	***3.25P - Investigate the speed of sound in air.***	**Students can expect to measure the speed of sound directly by measuring the distance and time taken between two points and then using the equation:** **Average speed = distance travelled/time taken.** **A variety of methods is discussed.**
7	***3.27P - Investigate the frequency of a sound wave using an oscilloscope.***	Students should become familiar with the time base and y-amplification of an oscilloscope, so that several periods can be displayed and measured, leading to a calculation of frequency by using the formula: Frequency = 1 / (time period)
8	*4.9 - Investigate thermal energy transfer by conduction, convection and radiation.*	**A variety of simple experiments are described to demonstrate or investigate the three main methods of heat transfer.**
9	*5.4 - Investigate density using direct measurements of mass and volume.*	The density of a solid object must be determined by measuring the mass and volume of the object, and then using the equation: Density = mass/volume The volume of irregular solids must be determined by putting the object into water, and measuring the volume of water that has been displaced. The density of a liquid can be calculated by weighing the mass of the liquid using a balance, and determining the volume.
10	***5.14P - Investigate the specific heat capacity of materials including water and some solids.***	**By using an electrical heater of either known or measurable power, different known masses of materials can be heated between an initial and a final temperature.** **Once sufficient data has been collected, the specific heat capacity can be calculated using the equation:** $\Delta Q = m \times c \times \Delta T$
11	*6.6 - Investigate the magnetic field pattern for a permanent bar magnet and between two bar magnets.*	The region of space around magnets can be probed with suitable magnetic materials and devices such as plotting compasses. By sampling the magnetic field in multiple positions, a field line pattern can be built up quickly.

12	*7.6 - Investigate the penetration powers of different types of radiation using either radioactive sources or simulations.*	By aiming the output of radioactive sources at different thicknesses of paper, aluminium or lead and measuring the activity using a Geiger-Muller tube and counter, the three principal ionising radiations can be identified by their differing penetration power. It must be stressed that computer simulation is perfectly acceptable instead.

Note: **2.9** and **5.11P** are not 'required' practicals, but are mentioned on the specification as skills and techniques.

13	*2.9 - Describe how current varies with voltage in wires, resistors, metal filament laps and diodes and how to investigate this experimentally.*	**This investigation involves constructing a circuit that can provide a varying potential difference to investigate voltage and current characteristics for a wire, a resistor, a metal filament lamp and a diode.** **Resistance can then be calculated at any point by using the formula** **Voltage = current × resistance.**
14	***5.11P - Obtain a temperature-time graph to show the constant temperature during a change of state.***	**The temperature of crushed ice must be recorded using a thermometer. This must then be melted using a Bunsen burner and beaker of water as a water bath. The temperature must be monitored as the ice melts.**

Core practical 1: Motion

1.5 Core practical: Investigate the motion of everyday objects such as toy cars or tennis balls

Links to the specification content

1.6	Know and use the relationship between acceleration, change in velocity and time taken
1.7	Plot and explain velocity-time graphs
1.8	Determine acceleration from the gradient of a velocity-time graph
1.10	Use the relationship between final speed, initial speed, acceleration and distance travelled
1.21	Describe the forces acting on falling objects (and explain why falling objects reach a terminal velocity)

Introducing the practical

While dropping a ball from a specified height, or rolling a toy car down a slope is a simple activity, much Physics and measurement skills can be gleaned. It is also an activity that allows for straightforward differentiation between abilities.

In each case, the object travels a range of distances and for each distance, the time taken to travel that distance is recorded.

The students can plot a distance-time graph and verify that it is not a straight line, provided they have sufficient data for a wide range of distances. Tangents to the graph at successive points would also give velocity-time data.

Students could also test different angles of the slope and compare their findings for the acceleration, if all other variables were controlled i.e. using the same type and model of toy car.

Motion

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

- Is the initial velocity really zero? If not, how could you ensure it?
- Why is the final velocity not equal to the distance travelled divided by the time taken for that distance?
- If the object uniformly accelerates, what is the relationship between the average velocity and the final velocity?
- For a vertical drop, how close is the experimental value to the accepted value of g?
- Why is timing by stopwatch likely to be a large source of uncertainty?
- How could you time the elapsed time more accurately?
- How can you be sure that your distance is correct?
- Why should you measure from the bottom of the ball (or the front of the car?)
- What happens if you use larger distances (such as several metres for the tennis ball)?
- From what height are the effects of drag noticeable?

Skills that are covered in the practical:

- Timing using a stopwatch
- Accurate measurement of distance (and possible height)
- Consideration of the limitations introduced by reaction times
- Producing repeatable results
- Planning an investigation
- Extending an investigation beyond the original range
- Prediction
- Graphical analysis

Maths skills:

1A Recognise and use numbers in decimal form

1D Make estimates of the results of simple calculations, without using a calculator

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

3B Change the subject of an equation

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

3D Solve simple algebraic equations

4A Translate information between graphical and numerical form

4B Understand that $y=mx + x$ represents a linear relationship

4C Plot two variables from experimental or other data

4D Determine the slope and intercept of a linear graph

4E Understand, draw and use the slope of a tangent to a curve as a measure of rate of change

4F Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate

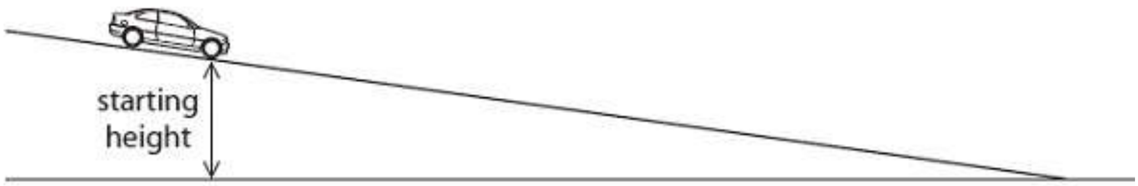
5A Use angular measures in degrees

5C Calculate areas of triangles and rectangles, surface areas and volumes of cubes

Question

This example is taken from the 4PH0/1P paper, January 2014, Question 5. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

A student investigates the motion of a toy car as it moves freely down a slope.



The student wants to find the link between the starting height of the car and the speed of the car at the bottom of the slope.

(a) (i) State the independent variable in this investigation. **(1)**

(ii) Suggest a link between the starting height of the car and its speed at the bottom of the slope. **(1)**

Question number			Answer	Notes	Marks
	(a)	(i)	starting height (of the toy car);		1
		(ii)	a positive correlation between the 2 key variables, eg The higher the (starting) height, the faster the (final) speed / speed at bottom;	NB response needs to mention both key variables	1

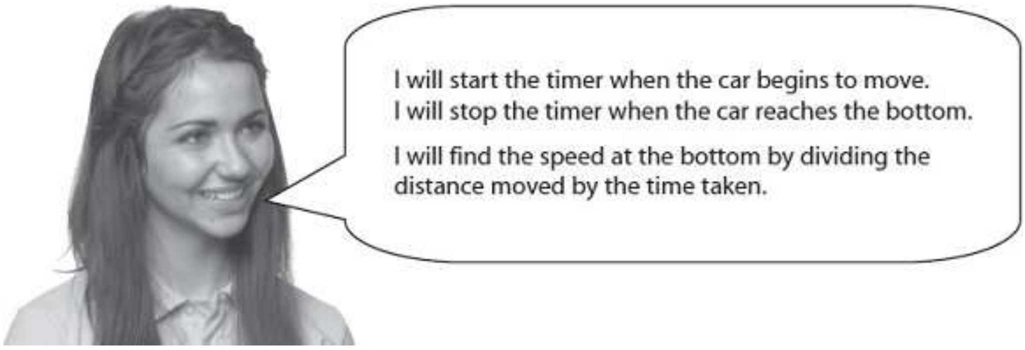
These items require knowledge of independent and dependent variables, as well as a reasonable attempt at the link between the two variables, communicated in an appropriate way.

(b) Describe how the student should measure the starting height of the car. **(2)**

	(b)		use a ruler or a set square ; further detail; e.g. held vertically check for zero error thickness of board taken into account avoid parallax errors	Allow suitably labelled diagram drawn in the space below perpendicular to bench	2

For maximum credit, the candidate will need to have practised measuring distances as correctly as possible, i.e. taken some reasonable precaution to get the right height.

(c) The student describes how she will find the speed of the car at the bottom of the slope.



(i) Explain why the student will not be able to calculate the correct speed using this method. **(2)**

	(c)	(i)	any one of the following ideas; o speed might have increased / changed on slope o car might have accelerated o other forces could be acting hence (she has) calculated the average speed;	accept slowed down ignore timing errors	2

This challenging item requires the candidate to be aware of what it is they are finally calculating, rather than merely remembering the formula.

(ii) Describe how the student should take the measurements needed to find the speed of the car at the bottom of the slope.

You should name any additional equipment needed. **(3)**

		(ii)	any **three** from: MP1. Suitable equipment / method chosen; MP2. Detail of measuring the distance; MP3. Detail of measuring the time; MP4. Detail of experimental set-up;	*Acceptable approaches, e.g. -* Light gate and data logger computer; Placed at end of ramp; With interrupter of some description on toy car; OR Attach ticker tape to car; Find the part of the tape that matches end of the ramp; Work out distance over time for a small section; OR Film with video camera; With scale marked in background; Measure from frame by frame	Max 3

			MP5. Speed at bottom = 2 x total distance ÷ total time (assuming constant acceleration from rest) / idea of doubling; allow MP5 independent of other marks	playback; OR motion sensor(near bottom of ramp); facing up the ramp; readings taken at the bottom;	

There was considerable scope in this question for reasonable suggestions of varying degrees of technical difficulty.

(d) The student repeats the experiment using the same equipment and the same starting height.

She finds out that the time taken for the car to move down the slope is not exactly the same for each experiment.

Suggest three reasons why the student gets different results when she repeats the experiment. **(3)**

	(d)		Any three of timing variation; distance variation /accuracy of starting position; friction effect; poor 'launch';	Acceptable ideas include- error from starting / stopping stopclock / effect of reaction time (IGNORE 'human error') car not running straight/ramp not even effect of (rolling) friction effect of air resistance/drag friction not constant car pushed at start car hits side of ramp ignore different car/changing slope height	Max 3

Total 12 marks

A challenging item, although again there was considerable scope for sensible suggestions. Note that 'human error' or similar vague answer was not acceptable.

(Total for Question = 12 marks)

Core practical 2: Extension

1.22 Core practical: Investigate how extension varies with applied force for helical springs, metal wires and rubber bands

Links to the specification content

1.18	Know and use the relationship between weight, mass and gravitational field strength (W = mg)
1.23	Know that the initial linear region of a force-extension graph is associated with Hooke’s Law
1.24	Describe elastic behaviour as the ability of a material to recover its original shape after the forces causing deformation have been removed

Introducing the practical

Safety spectacles/goggles should be worn always while any material is under tension.

Typically, 100g masses are added one at a time (for springs). Pointers or other fiducial marks should be used to measure the lengths of the spring accurately to find their original and extended lengths, with a ruler clamped vertically and checked using a set square.

Using copper wire is best, as there is an extended plastic region. Use SWG 28-32, so that there is measurable extension in the 10-30 N range.

Try not to kink the wire. Fix the wire between two scrap pieces of wooden ruler at one end, and wrap the wire multiple times around the mass hanger until it is secure. Make sure you use metal guards over the wire to prevent wire flying up and hitting the experimenter and some form of crash pad to protect the floor, reminding the students to keep their feet away from where the masses may land). Suitable metal guards are iron yokes designed for holding flat magnadur magnets in electric motor making kits.

It is worthwhile to test several brands and thicknesses of rubber band so that the force-extension graph obviously curves at both minimum and maximum load. Choosing the right interval of load is also important; otherwise, this detail will be missed and the students will think that the trend is linear.

Extension

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

- What happens if you put springs in series or in parallel?
- What happens to the F-x graph if the spring is stiffer than the original spring?
- Does the spring go back to the original length if you remove the loading force? If not, why not?
- What happens if the wire is thicker?
- What would happen if you did this experiment on the surface of a different planet, but kept the same spring/wire/band?

Skills that are covered in the practical:

- Measuring small changes in length accurately
- Consideration of the precision of an instrument
- Consideration of safety procedures for objection under tension (i.e. risk assessment)
- Construction of data tables and calculated quantities e.g. extension
- Description of different trend lines
- Fitting a trend line to data
- Selection of an appropriate interval and range

Maths skills:

1A Recognise and use numbers in decimal form

1D Make estimates of the results of simple calculations, without using a calculator

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

3B Change the subject of an equation

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

3D Solve simple algebraic equations

4A Translate information between graphical and numerical form

4B Understand that y=mx + x represents a linear relationship

4C Plot two variables from experimental or other data

4D Determine the slope and intercept of a linear graph

4E Understand, draw and use the slope of a tangent to a curve as a measure of rate of change

4F Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate.

5A Use angular measures in degrees

Questions

This example is taken from the 4PH0/1P paper, January 2016, Question 11 (items within part b)). The commentary below outlines how the skills gained by carrying out the practical may be demonstrated in the final exams.

(b) The student obtains this data as he first adds weights to the elastic band (loading) and as he then removes weights from the band (unloading).

Force in N	Extension in cm
	Loading
0	0.0
2	2.3
4	5.3
6	9.8
8	15.3
10	20.0

Force in N	Extension in cm
	Unloading
0	0.0
1	1.4
3	5.0
7	14.8
9	19.1
10	20.0

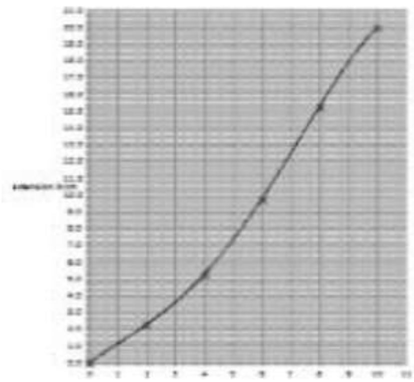
He plots the loading data on a graph as shown.

(i) Suggest how the student could improve the quality of his data. **(2)**

(b)(i)	any two suggestions from:- MP1. unloading and loading at same intervals; MP2. filling in the (large) gap in the unloading data; MP3. more readings (where curve is most pronounced); MP4. increase the range of loads;	ignore repeat and average allow 'go up in ones'	(2)

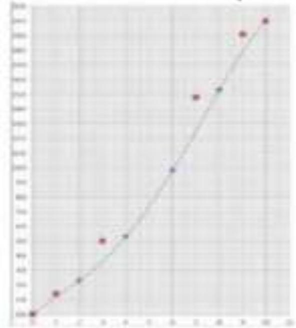
> There were a relatively wide variety of acceptable answers, all of which were sensible. Note that "repeat and average" was ignored on this occasion. Whilst repeating and averaging is always a good idea in practical science where possible, the poor interval, range and general sufficiency was deemed to be a larger problem. This question was late in the paper. Had it been earlier, "repeat and average" may have been acceptable.

(ii) Draw a curve of best fit through the loading data. **(1)**

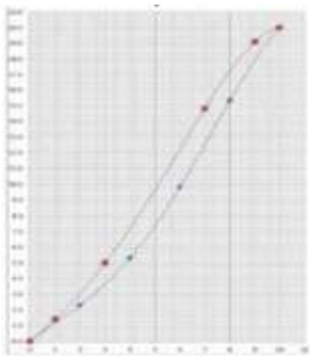


(iii) On the same axes, plot the unloading data. **(2)**

4 points plotted correctly;;
-1 for each incorrect point



(iv) Draw a curve of best fit through the unloading data. **(1)**



Unusually, these items required a curve through already plotted data and a similar curve sketched through the second set of tabulated data. Candidates typically "joined the points", plotted blobs rather than crosses or produced curves that had been overdrawn several times, making the trend line difficult to pick out.

(v) The student concludes that the band is an elastic material and that it obeys Hooke's law.

Discuss whether his conclusion is correct.

You should support your argument with data. **(3)**

(v)	a discussion to include any three points: MP1. does not obey Hooke's law; MP2. because graph is not linear throughout; MP3. Hooke's law requires extension directly proportional to force; MP4. it does show elastic behavior; MP5. because it returns to its original length; MP6. data points quoted to support other MP;	MP1 should only be awarded if there is an attempt at an explanation	(3)

The candidates could score 2 or 3 marks by discussing the elastic nature of the material, whether the material obeyed Hooke's Law or both. Items like this typically invite the candidates to support the argument with data, such as quoting points or numbers to support other marking points.

Core practical 3: Electrostatic charging

2.23P Core practical: Investigate how insulating materials can be charged by friction

Links to the specification content

2.22P	**Identify common materials which are electrical conductors or insulators, including metals and plastics**
2.24P	**Explain how positive and negative electrostatic charges are produced on materials by the loss and gain of electrons**
2.25P	**Know that there are forces of attraction between unlike charges and forces of repulsion between like charges**
2.26P	**Explain electrostatic phenomena in terms of the movement of electrons**
2.27P	**Explain the potential dangers of electrostatic charges, e.g. when fuelling aircraft and tankers**
2.28P	**Explain some uses of electrostatic charges, e.g. in photocopiers and inkjet printers**

Introducing the practical

You require two types of insulator, at different points in the triboelectric series, so that when the insulators are rubbed one will be charged positively and the other negatively.

Polythene rods and standard household dusters generally leave the polythene charged negatively. Balloons can work well but tend to drift (and may even attract if they are charged the same way, as the like charged areas will repel so that they are then close to a neutral area of the opposite balloon). Trial and error well in advance is advised!

Suspending the objects to be charged before they are charged is a good idea, and fishing line works well here.

Using a foil electroscope is an excellent idea, as it can be demonstrated that one type of charged object will make the foil lift up and the other will make the foil drop back down again.

Electrostatic charging

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

- What would happen if the materials were conductors?
- How do you know that there can only be two 'types' of charge, positive and negative?
- What are the hazards associated with large build-ups of electrostatic charge?

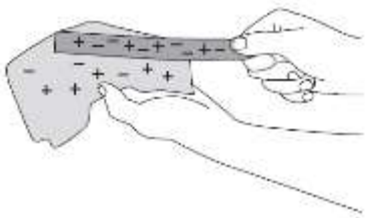
Skills that are covered in the practical:

- Qualitative description of phenomena
- Construction of apparatus from a diagram
- Taking care not to accidentally earth any charged object

Questions

This example is taken from the 4PH0/2P paper, June 2014, Question 2. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

When a plastic rod is rubbed with a cloth, the rod gains charge.



(a) How could you show that the plastic rod gains charge? **(1)**

Question number	Answer	Notes	Marks
(a)	Any ONE simple effect, e.g. attract scraps of paper / deflect water stream / deflect (gold leaf) electroscope/use a coulomb-meter	Ignore theoretical approaches e.g. use a charged "object" Allow any practical suggestion e.g. attracts hair/balloon	1

As mentioned in the notes, any practical suggestion was acceptable.

(b) Explain how the plastic rod gains charge when it is rubbed. **(2)**

(b)	(charges) are transferred / lost; electrons;	Allow move or jump Allow • "negative electrons" • e- reject for 1 mark "positive electrons"	2

This maps directly to the specification point that electrostatic phenomena happen because of a movement of electrons.

(c) There are two types of charge.

Describe how you could demonstrate this using different insulating rods and a cloth.

In your answer, you should name any other equipment you would use. **(3)**

(Total for question = 6 marks)

(c)	MP1. Charge rods (of different plastics); MP2. Method to allow to swing freely (suspend / watch glasses); MP3. Observation of attraction <u>and</u> repulsion;	Points may be shown on a labelled diagram Methods that would not distinguish charge (e.g. picking up paper scraps, bending a water stream) can score ONLY MP1 Allow rubbing with the cloth as charging by friction Accept alternative method e.g. induction Allow method describing deflections of a charged gold leaf electroscope (GLE) for up to 3 marks MP1 (GLE) Charge rods; MP2 (GLE) Use of (charged) GLE; MP3 (GLE) Looking for rise <u>and</u> fall of leaves;	3

This is a challenging item, as it required advanced experimental knowledge that could only reasonably be gained by having attempted a relevant practical.

Core practical 4: Refraction

3.17 Core practical: Investigate the refraction of light, using rectangular blocks, semi-circular blocks and triangular prisms

Links to the specification content

3.14	Know that light waves are transverse waves and that they can be reflected and refracted
3.15	Use the law of reflection
3.16	Draw ray diagrams to illustrate reflection and refraction
3.18	Know and use the relationship between refractive index, angle of incidence and angle of refraction
3.21	Explain the meaning of critical angle, *c*
3.22	Know and use the relationship between critical angle and refractive index

Introducing the practical

Standard ray boxes or other light sources with a slit can be employed but be aware that they can get hot.

If the students are allowed to experiment with the rectangular block, they will almost certainly discover that the rays of light can be internally reflected and that if total internal reflection does not occur, then the emergent ray will be parallel to the incident ray.

It is worth pointing out that the angle of refraction is inside the block and measured from the normal at the point where the incident ray hits the block.

A semi-circular block can be used to directly measure the critical angle, by shining the ray along the radius of the block at the centre of the flat portion. Fixing the block is important, as is measuring to find the centre of the flat portion (which should then be marked on the paper.

By increasing the angle of incidence stepwise, the internally reflected ray can be observed getting brighter, re-affirming the law of reflection by measurement. After the critical angle, there will be no transmitted ray. The critical angle can be found and then, using the sin (c) = 1/n relationship, a value for the refractive index can be found. This value would be equal to 1 divided by the 'standard' critical angle.

Triangular blocks can be used in two ways. Firstly, the students can observe dispersion by shining a white ray of light at the face of an equilateral triangle prism, high enough up the face so that the light does not totally internally reflect at the second face. As the angle of incidence is increased, the emergent ray becomes more spread out and the rainbow pattern is observed.

By using a right-angled prism, total internal reflection can be employed to divert the beam through two 90-degree turns, as if in a periscope. Multiple blocks can be put together to simulate an optical fibre.

Refraction

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

- Which method is more accurate for the refractive index?
- What are some other uses for total internal reflection and optical fibres?
- How would you measure the angle of refraction inside the block?

Skills that are covered in the practical:

- Construction of light rays
- Risk assessment (e.g. hot bulbs)
- Accurate measurement of angles using a protractor
- Finding the centre of the semi-circular block by measurement
- Construction of data tables
- Suitable selection of range and interval
- Construction of a normal line
- Recording qualitative data e.g. position of blocks, appearance of rainbow, total internal reflection

Maths skills:

1A Recognise and use numbers in decimal form

1E Use calculators to handle sin x and $\sin^{-1} x$ where x is measured in degrees

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

3B Change the subject of an equation

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

3D Solve simple algebraic equations

4A Translate information between graphical and numerical form

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

4C Plot two variables from experimental or other data

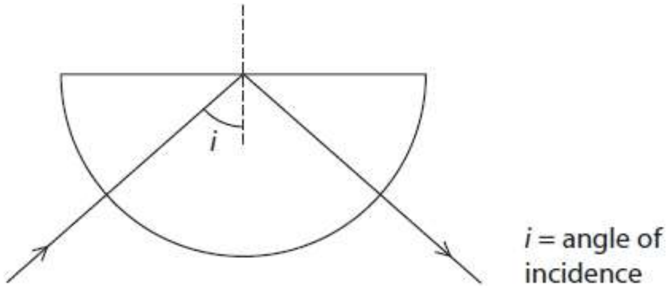
4D Determine the slope and intercept of a linear graph

5A Use angular measures in degrees

Questions

This example is taken from the 4PH0/1P paper, June 2016, Question 7. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

A student watches a demonstration of the total internal reflection of light in a semi-circular glass block.



(a) He takes notes, but some of his notes are wrong.

Place a tick (✓) or a cross (✗) in the table to show which statements are right or wrong.

The first statement is right and has been done for you. **(2)**

Notes about the total internal reflection of light	Right or wrong
the angle of incidence equals the angle of reflection	✓
light changes speed when it is internally reflected	
every ray entering the semicircular glass block is reflected by total internal reflection	
if $i = 0$ then the ray does not deviate	
the refractive index of glass is bigger than the refractive index of air	

Question number	Answer	Notes	Marks
(a)	3 or more correct lines = 2 marks Any two correct lines = 1 mark		2

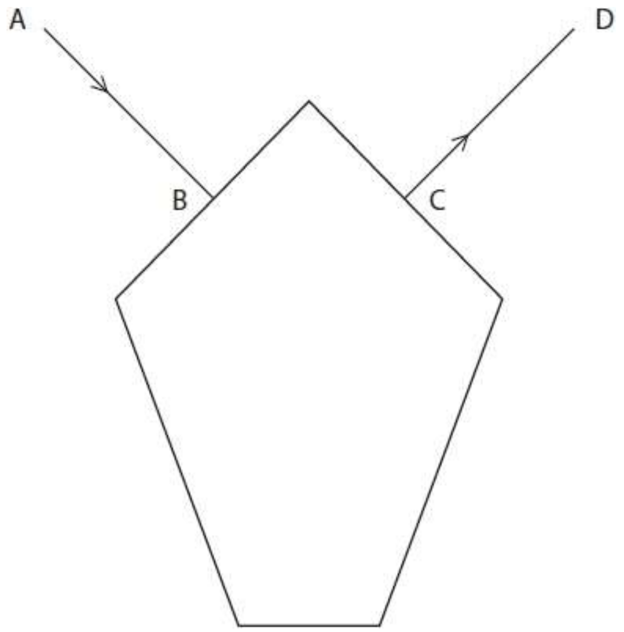
Notes about the total internal reflection of light	Right or wrong
the angle of incidence equals the angle of reflection	✓
light changes speed when it is internally reflected	x
every ray entering the semicircular glass block is reflected by total internal reflection	x
if i = 0 then the ray does not deviate	✓
the refractive index of glass is bigger than the refractive index of air	✓

This item really does test understanding of the nature of refraction, without relying on mathematics. Full marks could be achieved with 3 correct out of 4, reflecting the challenging nature of the language involved.

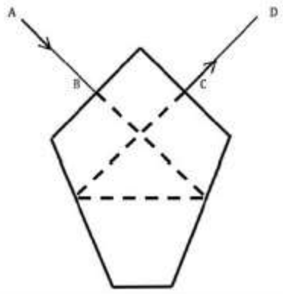
(b) Jewellers cut jewels so that total internal reflection is more likely.

Light enters a jewel along the normal AB and leaves along the normal CD as shown.

Between B and C, there are **two** total internal reflections.



Complete the path of the light through the jewel. **(3)**

(b)	MP1 only **two** internal reflections attempted; MP2 horizontal line from first TIR to second TIR; MP3 ray does not deviate on exit; 	horizontal line by eye ignore arrows	3

The question refers to the fact that there are only two internal reflections, so any different number could not score the first marking point. Successful candidates drew normal and measured angles, finally ensuring that the ray

(c) (i) Show, by calculation, that the critical angle for a refractive index of 1.5 is about 42°. **(3)**

Question number	Answer	Notes	Marks
(c) (i)	Statement of sin c = 1/n; Substitution; Calculation; e.g. sin c = 1/n ....worth 1 sin c = 1/1.5...........................worth 2 (= 0.667) so c = 41.8º ....worth 3	Value of c (or n) to at least 3 s.f. Allow reverse argument for max 2. Sin 42º = 0.669, giving n = 1.49 ("about 1.5") Sin 42 x 1.5 =1.0036 ≈1 (sin 42 =1/1.5) Beware spurious maths that gives about 42 degrees	3

The command word 'show' means that the working is all important here. Typically, a final value should have at least one more significant figure than the quoted value, in this case 42 degrees.

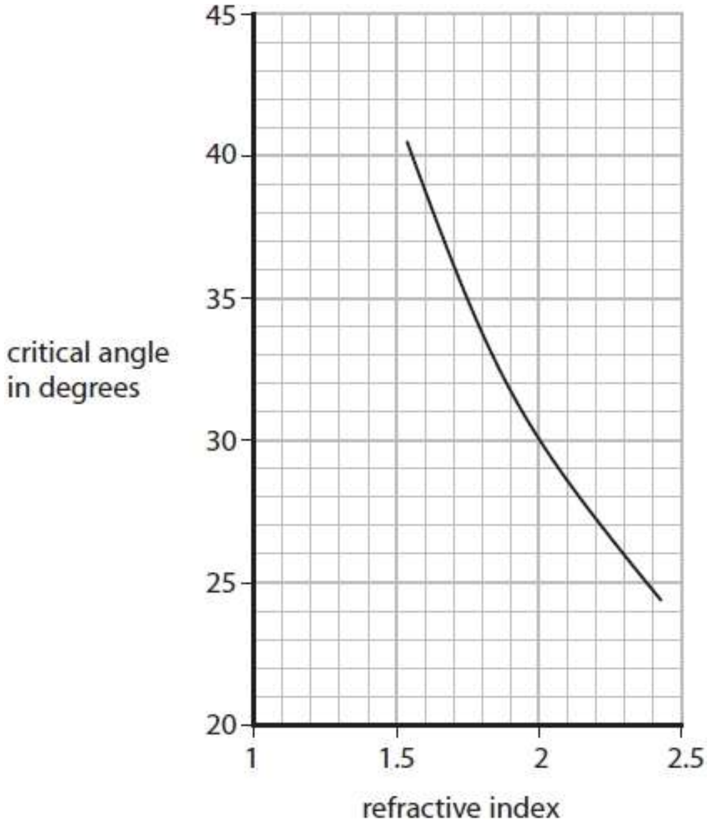
(ii) Explain why the quantity called refractive index has no unit. **(2)**

(ii)	Any two of the following ideas:-	allow	2
	• RI= sin i /sin r	n= speed $_1$/speed$_2$ n= 1/sin c	
	• RI(n) is (only) a number /ratio;	proportion for ratio	
	• a sine is a number /ratio;	units cancel out	

Quoting the relevant equation is a good idea here, as it would have given a clue to look at the units of sine (i.e. none). The ratio of speeds equation is not on the specification, yet is correct physics.

(d) The graph shows how critical angle varies with refractive index.

(i) Add the point (1.5, 42°) to the graph. **(1)**



(ii) How can you tell that the point (1.5, 42°) is not anomalous? **(1)**

(d)	(i)	Plot at 1.5, 42;	no tolerance	1
	(ii)	Any one of - Fits the trend/pattern; (point is on) an extrapolation of line to;	May be shown on graph OR e.g. "where the line would go"	1

Two straight forward items. Any indication, graphical or verbal, that indicated that the point fitted the trend was acceptable.

(iii) Suggest two reasons why the axes of the graph do not start from zero. **(2)**

(iii)	Any two of - MP1. Idea that a reduced scale gives full(er) use of grid; MP2. RI is always more than 1 (for incidence in air) MP3. angle c greater than ~20°;	allow reduced scale fits the data ranges (of RI or c) ignore RI >0 allow angle c never zero	2

As the graph does not intend to show direct proportionality, it makes sense to ensure that the data fill as large a proportion as possible of the grid, hence the first marking point. The second marking point gives credit for realising that some space can be saved as there can be no refractive index less than one.

Core practical 5: Refractive Index

3.19 Core practical: Investigate the refractive index of glass, using a glass block

Links to the specification content

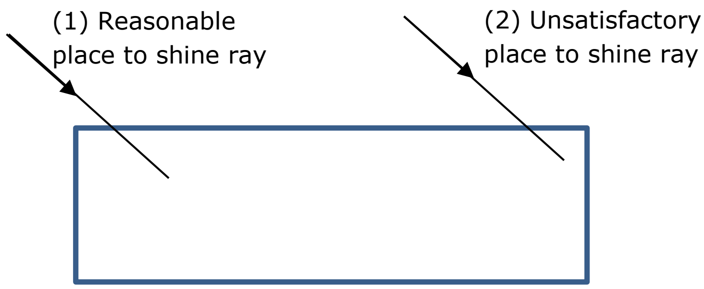
3.14	know that light waves are transverse waves and that they can be reflected and refracted
3.15	use the law of reflection
3.16	draw ray diagrams to illustrate reflection and refraction
3.17	Investigate the refraction of light, using rectangular blocks, semi-circular blocks and triangular prisms
3.18	know and use the relationship between refractive index, angle of incidence and angle of refraction
3.20	describe the role of total internal reflection in transmitting information along optical fibres and prisms
3.21	explain the meaning of critical angle, *c*
3.22	know and use the relationship between critical angle and refractive index

Introducing the practical

The students are required to recall the equation for Snell's Law, from which refractive index may be calculated. While it is possible to find a single angle of incidence (taking the class mean), it is preferable for the students to use a range of angles of incidence.

Whilst the specification refers to a glass block, an acrylic block is an acceptable and safer alternative. The refractive indices of both materials is similar at approximately 1.5.

N.B. By aiming the light source as in (1), the ray will refract at both boundaries between the block and the air in the expected way. The ray in (2) may well strike the right hand edge and even totally internally reflect, making the situation difficult to record and interpret.



Pencil crosses can be used to record the locations of the rays on plain paper, as long as those crosses are separated by as large a distance as possible.

It is advisable to plot the graph of the angle of refraction against the angle of incidence, if only to practice describing the relationship between the two variables as a non-linear relationship in which the angle of refraction increases at a decreasing rate.

Care should be taken with the sources of light; filament lamps can get hot. LEDs can be used as a safer alternative, which also produces more monochromatic light that does not suffer dispersion in the block, so the ray does not spread out as much.

The students should plot a graph of sin(i) against sin(r), such that the gradient of the best-fit line gives the refractive index. Plotting the graph this way around may take some explanation, especially as the independent variable on the x-axis guidance is suspended.

Refractive Index

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

- Why should we use a range of angles of incidence?
- What precautions should we take to make sure that the angles we measure are as accurate as possible?
- What are the possible sources of uncertainty (i.e. scatter) in our data
- Is there a better method of measuring angles than with a protractor
- Are there any other rays of light, other than the observed refracted ray?

Skills that are covered in the practical:

- Construction of light rays
- Risk assessment (e.g. hot bulbs)
- Accurate measurement of angles using a protractor
- Construction of data tables
- Suitable selection of range and interval
- Construction of a normal line
- Recording qualitative data e.g. position of blocks, appearance of rainbow, total internal reflection

Maths skills:

1A Recognise and use numbers in decimal form

1E Use calculators to handle sin x and $\sin^{-1}$ x, where x is expressed in degrees

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

3B Change the subject of an equation

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

3D Solve simple algebraic equations

4A Translate information between graphical and numerical form

4B Understand that y=mx + x represents a linear relationship

4C Plot two variables from experimental or other data

4D Determine the slope and intercept of a linear graph

5A Use angular measures in degrees

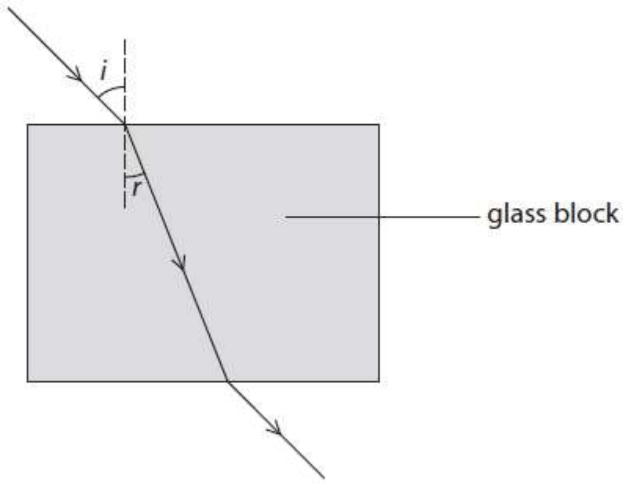
Questions

This example is taken from the 4PH0/2P paper, June 2014, Question 6. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

A student investigates refraction using a glass block.

She wants to find the refractive index of the glass.

She sends rays of light into the block at different angles and measures the angle of incidence and the angle of refraction.



The table shows her results.

Angle of incidence, *i*	Angle of refraction, *r*	sin *i*	sin *r*
0°	0°	0.00	0.00
15°	10°	0.26	0.17
25°	16°	0.42	
35°	22°	0.57	
45°	28°	0.71	0.47

(a) (i) Complete the table by calculating the missing values of sin r. **(1)**

Question number	Answer	Notes	Marks
a (i)	0.28 0.37	(both for 1 mark)	1

Whilst merely a calculator operation, the answers were required to 2 s.f., in keeping with the rest of the table (and with the 2 s.f of the angles of incidence)

(ii) Draw a graph of sin(i) (y-axis) against sin(r) (x-axis). **(5)**

(iii) Use your graph to find the refractive index of the glass. **(2)**

refractive index = ______________________

This is standard graphical question, requiring clear plotting skills and an ability to find the gradient of the line of best fit. The final answer required some evidence of gradient finding for two marks, such as a drawn triangle or a calculation. An unsupported answer would only have scored one mark.

(b) Suggest two reasons why using a graph to find the refractive index is a better method than simply calculating it using a pair of angles from the table. **(2)**

(Total for question = 10 marks)

b	Any two of - MP1. Idea that value relates to all the data collected; MP2. Idea that method allows for anomalies; MP3. Idea that effects of uncertainty/error can be reduced or accounted for;	Method checks reliability, anomalies can be seen graph is an averaging technique Ignore comments about accuracy	2

Often students comment on whether it is acceptable to find the refractive index from one or more different angles of incidence and then average. This item demonstrates why a graphical approach does just that, but also indicates about the quality of the data.

Core practical 6: Speed of Sound

3.25P   Core practical: Investigate the speed of sound in air

Links to the specification content

1.4	Know and use the relationship between average speed, distance moved and time taken
3.23	Know that sound waves are longitudinal waves which can be reflected and refracted

Introducing the practical

There are many ways of determining the speed of sound, both directly and indirectly. At GCSE level, however, a direct method of recording a distance that a sound has travelled and the time it has taken, and then dividing the distance by the time is sufficient.

Using some method of making a loud noise, which is also visible at some considerable distance can be a challenge. Two wooden blocks, lifted above so that they are visible, and then banging the blocks together can work well.

Starting mechanisms for races, such as devices that bleep and flash at the same time can also be very effective.

The distance of separation is crucial if the time taken for the sound to travel is to be measured by hand (such as students with stopwatches). The distance should be at least 100m, but much over 200m and both the difficulty of recording sound and visual aspects are likely to be obvious.

By having multiple students recording the stopwatch times, it can be pointed out that everyone has a different reaction time, and that the reaction time need not ‘cancel out’ for the start and stop events.

Other more challenging methods include:

- Clapping repeatedly at a flat wall and either changing the clapping frequency until the echo returns half way between each clap.
- Using two microphones separated by a short distance and connected to a dual beam or storage oscilloscope. If a sound made, then the oscilloscope can be triggered by the first microphone and the period between the sound arriving at the first and second microphones can be measured.

Speed of sound

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

- Why does everyone in the group get a different stopwatch time?
- What is the minimum distance we could use to measure the time taken for the sound to travel? What is the limiting factor?
- What assumption are we making about speed of the visual signal?

Skills that are covered in the practical:

- Measurement of a long distance using a trundle wheel or tape measure
- Measurement of a short time using a stopwatch or other means
- Value of repeated readings and averaging
- Appreciation of poor quality of stopwatch readings due to human reaction time

Maths skills:

1A Recognise and use numbers in decimal form

1D Make estimates of the results of simple calculations, without using a calculator

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

3B Change the subject of an equation

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

3D Solve simple algebraic equations

Questions

This example is taken from the 4PH0/1P paper, June 2015, Question 13b. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

(b) Two students investigate the speed of sound waves in air.

They use a stopwatch that shows times to the nearest 0.1 s.

They use an outdoor running track as their measure of distance.

The track is straight and 100 m long.

Describe what else they must do to obtain a value for the speed of sound. **(5)**

(b)	Any five of - MP1. A method to make a loud enough sound; MP2. Speed = $\frac{\text{distance}}{\text{time}}$; MP3. Need for still air; MP4. Repeat AND average; MP5. Need to check/reset stopwatch zero reading; MP6. Idea of clear visual signal; MP7. measurement of time **interval** (between visual signal and sound); MP8. Idea of reaction time(s) (could be a problem);	ignore measurement of distance bald 'clap' • wooden blocks • noise has to heard over 100m RA allow repeat AND sort out anomalies e.g. • when the sound is seen to be made • smoke from starting pistol (because) light travels faster than sound	5

In this item, the distance is already selected and measured, so no credit was given for measuring it. Candidates often quote a relevant equation as a starting point, yet merely stating 'make a noise' wasn't sufficient, just as 'measure the time' wasn't. Many of the marking points are for a good working knowledge of the experiment, certainly after discussing the pitfalls of an otherwise simple method.

Core practical 7: Frequency of sound

3.27P Core practical: Investigate the frequency of a sound wave using an oscilloscope

Links to the specification content

3.24P	**Know that the frequency range for human hearing is 20–20 000 Hz**
3.25P	**Practical: investigate the speed of sound in air**
3.26P	**Understand how an oscilloscope and microphone can be used to display a sound wave**
3.28P	**Understand how the pitch of a sound relates to the frequency of vibration of the source**
3.29P	**Understand how the loudness of a sound relates to the amplitude of vibration of the source**

Introducing the practical

The best input signals come from either skilful whistling, a signal generator connected to a loudspeaker or, more recently, a tone from an app on a suitable smart phone.

The microphone should be connected to the y-input of an oscilloscope.

Both time base and y-amplification can be altered for the same signal to get between 3 and 10 complete oscillations on the display.

Once the time base and y-amplification are fixed, the frequency and amplitude of the sound source can be altered.

The number of divisions for several periods can be measured and an average calculated. This average is then multiplied by the time-base to give the period.

The frequency is then given by 1/period.

The period is likely to be in milliseconds, so care must be taken to complete the conversion correctly.

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

- Can you demonstrate that the source of sound is still emitting even though you cannot hear it?
- What is the maximum and minimum frequencies that can be heard by members of the class? Why is that range different for the teacher and the students?
- Why are those maximum and minimum frequencies different for different people?

Skills that are covered in the practical:

- Use of an oscilloscope
- Use of a signal generator and loudspeaker to produce a sound
- Appreciation of orders of magnitude

Maths skills:

1A Recognise and use numbers in decimal form

1B Recognise and use numbers in standard form

1D Make estimates of the results of simple calculations, without using a calculator

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

3B Change the subject of an equation

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

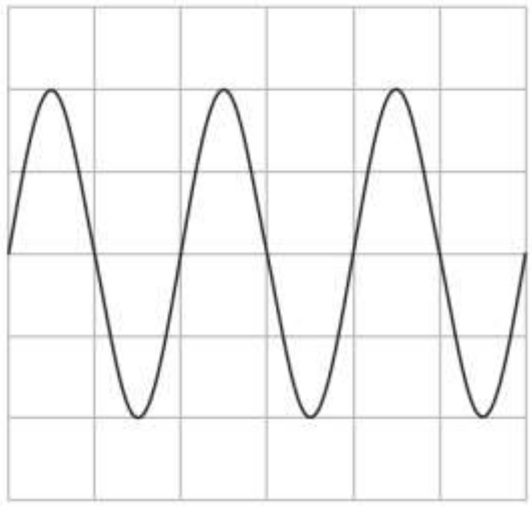
3D Solve simple algebraic equations

Questions

This example is taken from the 4PH0/1P paper, June 2012, Question 2. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

A microphone is connected to an oscilloscope to display a sound wave.

The diagram shows the trace on the oscilloscope screen.



The oscilloscope settings are:

Y direction: 1 square = 1 V

X direction: 1 square = 0.001 s

(a) (i) How many time periods are shown on the trace? **(1)**

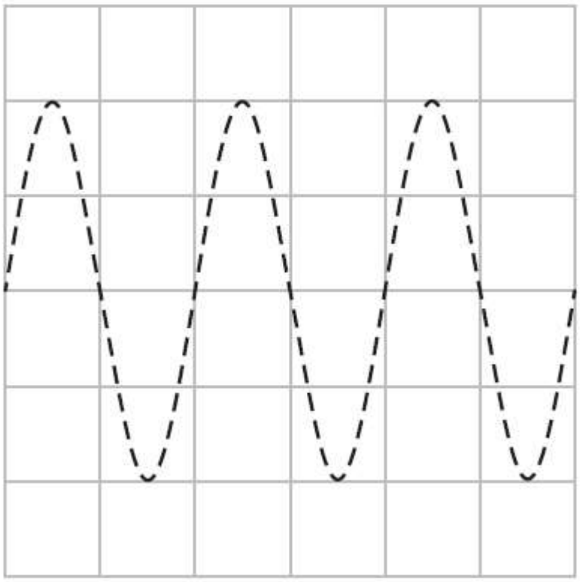
(ii) What is the frequency of the sound wave? **(2)**

Frequency = ____________________ Hz

Question number	Answer	Accept	Reject	Marks
(a) (i)	3;	Three /3.0		1
(ii)	0.002 (s) / 2ms ; 500 (Hz) / 0.5kHz	0.001 ecf only if 2ai=6 correct answer without working for 2 marks 1000 ecf only if 2ai =6		2

In a)i), students commonly misunderstand and suggest that there are six complete oscillations. In part a)ii), error carried forward was applied if part i) was incorrect. The basic skills of reading the number of divisions and converting that to a time period (and hence the frequency) are tested.

(b) On the grid below, sketch the trace of a sound wave with a smaller amplitude and a higher frequency than the wave shown by the dotted line. **(2)**



(Total for question = 5 marks)

(b)	All of waves at smaller amplitude (can vary); All of complete waves at higher frequency (can vary);	Any wave form Accept two diagrams that clearly show the candidate's intention		2

This item tests the understanding of what the oscilloscope trace is, i.e. what the y-axis stands for as well as the link between a higher frequency and shorter period.

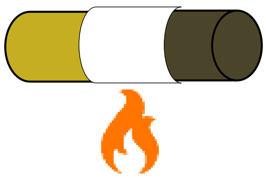
Core practical 8: Thermal energy transfer

4.9 Core practical: Investigate thermal energy transfer by conduction, convection and radiation

Links to the specification content

4.6	describe how thermal energy transfer may take place by conduction, convection and radiation
4.7	explain the role of convection in everyday phenomena
4.8	explain how emission and absorption of radiation are related to surface and temperature
4.10	explain ways of reducing unwanted energy transfer, such as insulation
5.3	know and use the relationship between density, mass and volume (convection context)

Introducing the practical



Conduction
There are many demonstrations and experiments that exhibit conductive behaviour:

Construct or purchase a wooden rod attached at one end to an equal diameter brass (or other metal) tube. Cover the junction with paper (only once) and heat the junction gently in a flame (e.g. a Bunsen on a luminous flame). The paper will char at the wooden end, rather than the metal end where heat is conducted away quite rapidly.

Any arrangement where various metal rods (with an object attached at one end with wax) are heated together. The ends without an attached object are heated from the same source and objects will fall off the best conductors first as the wax melts.

Two spoons or other kitchen utensils, which are identical except that one has a wooden/plastic handle and the other a metal handle, can be left in a beaker of hot water. The dry end of the metal-handled utensil will get hot first.

Convection
Heat a beaker of tomato soup with two wooden blocks to model continents. The two wooden blocks will either separate or come together depending on the position of the heat source.

Place a crystal of potassium manganate(VII) crystal at the bottom of a beaker of water and warm the beaker underneath the crystal (or underneath the furthest point on the bottom away from the crystal for contrast.

Radiation
Place a source of heat equidistant from two thermometers, one of which has its bulb/temp sensing area painted silver and the other black. The students can predict and then observe which has the larger temperature increase when exposed to the source of heat. An alternative is to use two conical flasks or boiling tubes in the same way.

N.B. This can also provide a nice data logging opportunity if two temperature sensors are used.

Thermal energy transfer

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

- How easy it is to keep control variables constant?
- How is the speed of convection affected by an increase in fluid temperature?
- What affects the rate of heat transfer via convection in solids?
- Is the rate of heat transfer via conduction faster in ice or in liquid water?
- How does a thermos flask work?
- Why do polar bears have black skin yet white fur?

Skills that are covered in the practical:

- Recording and description of qualitative data
- Appreciation of controlling variables
- Measuring temperature with a thermometer
- Recording of quantitative data in tables
- Prediction using prior knowledge
- Reaching a valid conclusion
- Spotting limitations of an experiment and suggesting improvements or alternatives

Maths skills:

1A Recognise and use numbers in decimal form

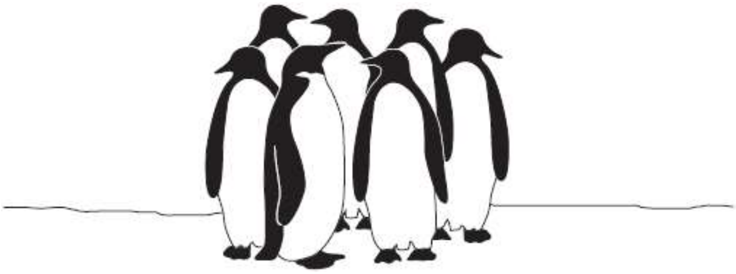
1D Make estimates of the results of simple calculations, without using a calculator

Questions

This example is taken from the 4PH1/1P paper, from the Specimen Assessment Materials, Question 12 (parts a)i) to a) iv)). The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

Penguins are adapted to survive in cold conditions.

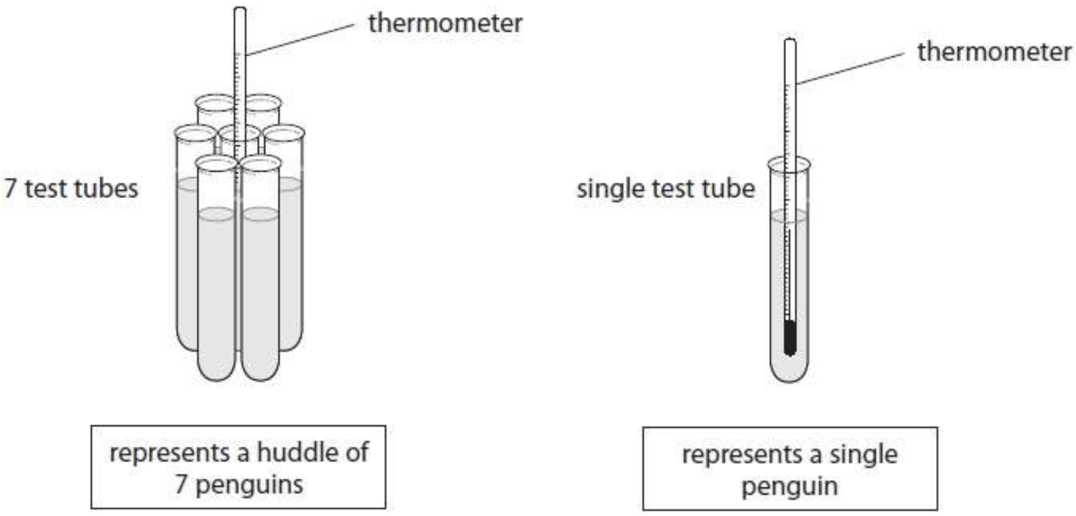
The adaptations help them to maintain a constant body temperature of 39 °C. Penguins also crowd together in groups of many penguins.



(a) A student wants to investigate how the temperature of a penguin is affected when they crowd together in groups.

She uses this apparatus.

Each test tube represents a penguin.



(i) These statements describe the method she should use.

The statements are in the wrong order.

Put them into the correct order by numbering the boxes.

Some have been done for you. **(3)**

Statements	Order
record the data in a table	8
take the temperature of the two test tubes	
tie 7 test tubes together	1
heat the water to 90 °C	2
take the temperatures every minute	
place equal volumes of water in all test tubes	
put thermometers into the middle test tube and single test tube	
record data for 15 minutes	

<table>
<tr><th>Question number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>(a)(i)</td><td>

- answer 3 correct (1)
- answers 4 and 5 in either order (1)
- answers 6 and 7 in either order (1)

Statements	Order
record the data in a table	8
take the temperature of the two test tubes	5
tie 7 test tubes together	1
heat the water to 90 °C	2
take the temperatures every minute	6
place equal volumes of water in all test tubes	3
put thermometers into the middle test tube and single test tube	4
record data for 15 minutes	7

</td><td>3</td></tr>
</table>

A straightforward item, which allows for reasonable minor variation in the order of experimental method.

(ii) The student draws a table to record her results.

Add suitable headings to her table. **(2)**

<table>
<tr><td rowspan="2">Time/ ....</td><td colspan="2">..........</td></tr>
<tr><td>..........</td><td>..........</td></tr>
</table>

Question number	Answer	Mark
(a)(ii)	• correct units shown (1) • temperature and indication of two different thermometers' readings (1)	2

A check to see whether the candidates can annotate a table's headings correctly, having worked out what the independent variable and corresponding dependent variables are.

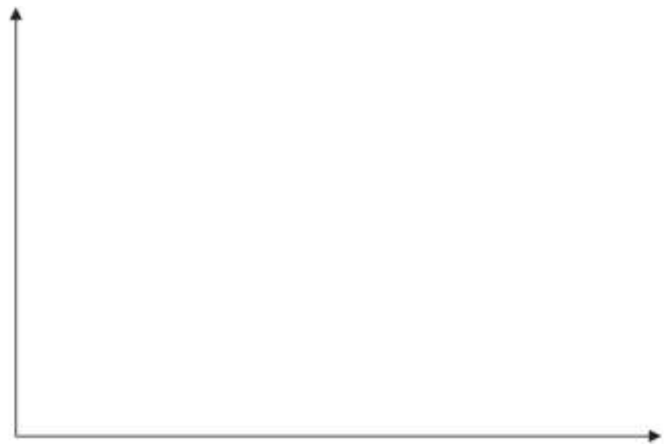
(iii) Predict how the temperature change for the single test tube will differ from the temperature change for the group of test tubes. **(1)**

Question number	Answer	Mark
(a)(iii)	The single test tube will cool faster/RA	1

A brief item which requires understanding of the relevant specification content in an unusual context.

(iv) Draw a sketch graph of the results you predict the student will obtain.

Label and use the axes below. **(4)**



Question number	Answer	Mark
(a)(iv)	• correct labels on axes (x = time, y = temperature) (1) • both lines start on y-axis at the same temperature (1) • both lines show that temperature decreases with time (1) • line for single tt thermometer is below other line at all points (1)	4

This item expects the candidates to recognise which variable goes on which axis in standard scientific practice as well as an understanding of the relevant specification points

Core practical 9: Measuring Density

5.4 Core practical: Investigate density using direct measurements of mass and volume

Links to the specification content

1.2	Know and use the relationship between density, mass and volume

Introducing the practical

There are three key investigations of density:

Measurement of density of regular-shaped mass

This works best when a range of different materials of different sizes can be obtained (as well as different sizes of the same material if possible). The data are best recorded in a table with all raw results as the students are measuring volume or height, length and breadth, rather than directly measuring the volume.

Measurement of density of irregular mass

This is most readily achieved by using a displacement technique, either with a eureka / displacement can (taking care to fill the can up to the spout) or with a measuring cylinder that is broad enough to take the object and have enough water for the object to be fully submerged.

Taking a measurement of the mass before finding volume will mean that the object is dry when it is placed on the balance, therefore not giving a false reading for the mass with any extra water.

Measurement of density of a liquid.

Put measuring cylinder on balance first and either record the mass of the cylinder or press the "zero" or "tare" button on the balance. Add the liquid and read off both the volume and the new mass. The mass of the liquid is the difference between the two mass readings.

If the volume is found first, then the cylinder will need to be dried completely to find its mass.

Measuring density

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

- How many significant figures is appropriate for the final density calculation?
- Why measure the mass of the stones before finding their volume?
- Why do you have to be careful not to splash any water when you're finding the volume of a stone?
- Why put the measuring cylinder on the balance first?
- Why can't you use a beaker for measuring the volume of water?
- Why is the density of differently sizes objects of the same material the same?

Skills that are covered in the practical:

- Measurements of dimensions of a regular shape leading to calculation of a volume
- Measurement of the volume of an irregular shape using a displacement technique
- Measurement of volumes of liquids using a measuring cylinder
- Measurement of mass using a balance
- Consideration of the order of following instructions
- Tabulation of data

Maths skills:

1A Recognise and use numbers in decimal form

1B Recognise and use numbers in standard form

1D Make estimates of the results of simple calculations, without using a calculator

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

2I Make order of magnitude calculations

3B Change the subject of an equation

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

3D Solve simple algebraic equations

5B Visualise and represent 2D and 3D objects, including two dimensional representations of 3D objects

5C Calculate areas of triangles and rectangles, surface areas and volumes of cubes.

Questions

This example is taken from the 4PH0/1P paper, January 2017, Question 2. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

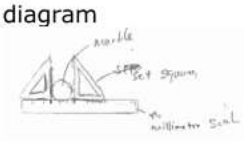
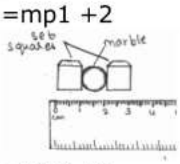
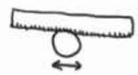
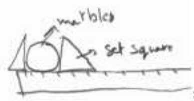
2 Marbles is a game played with small balls of coloured glass.

Each ball is known as a marble.

(a) Describe how a millimetre scale and two set squares can be used to measure the diameter of a marble.

You may draw a diagram to help your answer.

(3)

Question number	Answer	Notes	Marks
2 (a)	MP1. set squares used correctly to mark diameter of marble; MP2. Set squares measured against ruler; MP3. EITHER repeat and find average (mean); OR measure 2 or more marbles (in a line);	allow labelled diagram  =mp1 +2  =mp1 +2  =mp2  =0  = mp1 +2	3

In this previous papers, the volume of liquids or irregular shapes has been required. In this paper, the measurement of the dimensions of a regular object which wasn't cuboidal proved challenging, showing that candidates did not recall having used set squares frequently.

b) Describe an experiment to find the density of a marble.

You may draw a diagram to help your answer. **(5)**

(b)	Any 5 from MP1. mass measured; MP2. suitable device for measuring mass; MP3. suitable container named e.g. measuring cylinder, displacement can; MP4. displacement method described (can be shown on diagram); MP5. volume determined e.g.=volume after-volume before or volume displaced;	Allow labelled/annotated diagram uses diameter to calculate the volume states V= $4/3\ \pi\ r^3$	5

	MP6. repeats and averages OR more than 2 marbles used; MP7. uses density= mass/volume;	 allow recognisable symbols		

Even though in the previous part of the question, the candidates had described how to find the diameter of a marble, it was perfectly acceptable for them to use a displacement method provided it was suitably described.

The suitable device for measuring the mass was most likely to be a balance. There has usually been credit for quoting the relevant equation that enables the calculation of the quantity in question, in this case, the density.

Core practical 10: Specific heat capacity

5.14P Core practical: Investigate the specific heat capacity of materials including water and some solids

Links to the specification content

5.12P	**Know that specific heat capacity is the energy required to change the temperature of an object by one degree Celsius per kilogram of mass (J/kg °C)**
5.13P	**Use the equation: change in thermal energy = mass × specific heat capacity × change in temperature: $\Delta Q = m \times c \times \Delta T$**

Introducing the practical

Make sure the object under test is suitably lagged and with water, a lid must be used to avoid evaporative losses. Commonly aluminium blocks can be drilled (or obtained pre-drilled) to accept both the electrical heater and the thermometer.

Make sure that the heating element is as fully submerged as possible.

The students should ideally keep measuring the voltage and current to check that it isn’t changing, although with most modern power supplies it probably will not change very much at all.

Plotting a temperature-time graph is a good idea, as it will show how the heater takes a while to heat up, and for the heat to conduct through the block. It is a good idea to keep measuring the temperature even when the heater is switched off, as the temperature will keep going up and then go back down again as the heat conducts through and is eventually lost to the surroundings.

The difference between the initial temperature and the maximum temperature will get a better estimate of the SHC. Advanced students could use the gradient of the thermometer-time graph and relate it to the power of the electrical heater.

e.g. P x t = m x c x (T2-T1)

…where P is the power of the heater, t is the time of heating in seconds, m is the mass of the object, c is the specific heat capacity and (T2-T1) is the change in temperature.

Alternatively:

Gradient of temperature time graph = power of heater / (mass x SHC)

A simpler version, which stimulates discussion regarding experimental errors and assumptions, is to use a kettle, which has a nominal power rating on its label. By measuring the temperature of the water before heating, assuming a boiling point of 100oC, and that the mass of the water in grams is equal to the volume of water in cm^3, a rough and ready value for the SHC can be calculated.

Specific heat capacity

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

- What is the accepted value for the SHC of the substance? How far out is your result?
- Why might your result be incorrect?
- Why are most people's results too high compared with the accepted value?

Skills that are covered in the practical:

- Data collection and suitable tabulation
- Connecting an electrical circuit from a circuit diagram
- Appreciation of heat losses and their reduction
- Simultaneous measurement of temperature with a thermometer and time with a stopwatch
- Measurement of mass with a balance

Maths skills:

1A Recognise and use numbers in decimal form

1D Make estimates of the results of simple calculations, without using a calculator

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

3B Change the subject of an equation

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

3D Solve simple algebraic equations

4A Translate information between graphical and numerical form

4C Plot two variables from experimental or other data

4D Determine the slope and intercept of a linear graph

4E Understand, draw and use the slope of a tangent to a curve as a measure of rate of change

Questions

This example is taken from the 4PH0/2P paper, from the Specimen Assessment Materials, Question 4 (parts b) and c)). The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

(b) A teacher uses a 2200 W kettle to heat water.

The kettle is switched on for 2 minutes.

(i) Calculate the energy transferred by the kettle. **(3)**

energy transferred = ______________________________ J

Question number	Answer	Additional guidance	Mark
(b)(i)	Process includes: • Conversion of time into seconds substitution into or rearrangement of • $P = W/t$ • Evaluation e.g. time = 120 seconds (1) 2200 = W/120 (1) W = 260 000 (joules) (1)	seen anywhere in working allow 264 000 answer of 4400 (joules) gains 2 marks max	3

A standard calculation item which requires a substitution, rearrangement and a conversion between units.

(ii) State the equation relating change in thermal energy, mass, specific heat capacity and change in temperature. **(1)**

____

Question number	Answer	Additional guidance	Mark
(b)(ii)	Energy transferred = mass × specific heat capacity × change in temperature	equation can be given in words or symbols e.g. $\Delta Q = m \times c \times \Delta\theta$ allow E for Q, T for θ	1

The inclusion of this equation is new for this specification.

(iii) The mass of water in the kettle is 1.1 kg and its initial temperature is 20 °C.

Calculate the final temperature of the water after it has been heated for 2.0 minutes.

[the specific heat capacity of water is 4200 J/kg °C] **(4)** final temperature = ______________________ °C

Question number	Answer	Additional guidance	Mark
(b)(iii)	Process includes: • rearrangement of equation (1) • substitution into correct equation (1) • evaluation of temperature difference (1) • calculation of final temperature (1) e.g. $264\,000 = 1.1 \times 4200 \times \Delta\theta$ (1) $\Delta\theta = \frac{264\,000}{1.1 \times 4200}$ (1) ($\Delta\theta$ =) 57 (°C) (1) final temperature = 77 (°C) (1)	allow ecf from (b)(i)	4

This calculation is a two-step process and is indicative of the enhanced mathematical content of the new specification.

(c) The teacher measures the final temperature of the water after heating it for 2 minutes.

(i) Name a piece of equipment the teacher could use to measure the temperature of the water. **(1)**

Question number	Answer	Additional guidance	Mark
(c)(i)	Thermometer	allow temperature sensor AND data logger	1

A low demand item which has a couple of acceptable alternative items.

(ii) Explain why the measured final temperature is different from your calculated value. **(2)**

Question number	Answer	Mark
(c)(ii)	An explanation that makes reference to the following points: • actual temperature lower than calculated (1) • energy is lost to the surroundings not all the energy is transferred to the water (1)	2

The candidates should be aware not the water does not store all the energy transferred to it and indeed conducts energy to surrounding objects. This could be done in finding the SHC and comparing it with an accepted value.

Core practical 11: Magnetic fields

6.6 Core practical: Investigate the magnetic field pattern for a permanent bar magnet and between two bar magnets

Links to the specification content

6.2	Know that magnets repel and attract other magnets and attract magnetic substances
6.3	Describe the properties of magnetically hard and soft materials
6.4	Understand the term magnetic field line
6.5	Know that magnetism is induced in some materials when they are placed in a magnetic field
6.7	Describe how to use two permanent magnets to produce a uniform magnetic field pattern

Introducing the practical

Although traditionally, iron filings are employed to display magnetic field line patterns, this takes some practice as well as an idea of what the field lines are supposed to look like anyway.

Much more accessible (and safer) for younger students is the plotting compass method.

The piece of paper needs to be away from ANY magnetic material, such as pencil cases, zips, power lines, steel supports under the bench, screws etc., else the field pattern will be disrupted.

The field around a single magnet is readily obtained by this method. The field line pattern around two magnets is slightly trickier, unless the two magnets are separated by a reasonable distance so that the compass can fit multiple times.

Even then, the neutral point for two like facing poles takes a little interpretation. This can be helped by observing the direction of the needle either side of the neutral point. This helps to show that the two lines on either side are probably not connected.

Magnetic fields

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

- How could you tell which way the field lines are going?
- Do the field lines start and stop at the boundaries of the magnet?
- What is happening to the field lines inside the magnet?
- Why do we need to join up the points?
- Would the experiment be more precise with smaller compasses?

Skills that are covered in the practical:

- Plotting of points with a compass
- Interpolating lines between points
- Qualitative description of data

Questions

This example is taken from the 4PH0/1P paper, June 2015, Question 6 part a)i). The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

Magnetic fields can have different shapes.

(a) (i) Describe an experiment to show the shape of the magnetic field around a bar magnet. **(2)**

Question number	Answer	Notes	Marks
(a) (i)	Any two of: MP1. Idea of marking the line/points; MP2. Idea of moving the compass (to a new point along the line); MP3. Idea of starting a new line from a different place;	accept a labelled diagram allow use of iron filings use a compass allow • tapping paper to line up iron filings • multiple compasses	2

> This particular idea has been examined a number of times. Both compass and iron filings methods are acceptable.

Core practical 12: Radiation penetrating power

7.6 Core practical: Investigate the penetration powers of different types of radiation using either radioactive sources or simulations.

Links to the specification content

7.4	Know that alpha (α) particles, beta (β−) particles, and gamma (γ) rays are ionising radiations emitted from unstable nuclei in a random process
7.5	Describe the nature of alpha (α) particles, beta (β) particles, and gamma (γ) rays, and recall that they may be distinguished in terms of penetrating power and ability to ionise
7.9	Know that photographic film or a Geiger−Müller detector can detect ionising radiations
7.10	Explain the sources of background (ionising) radiation from Earth and space
7.16	Describe the dangers of ionising radiations, including: - that radiation can cause mutations in living organisms - that radiation can damage cells and tissue - the problems arising from the disposal of radioactive waste and how associated risks can be reduced

Introducing the practical

Take advice and follow any local rules regarding the storage and use of radioactive sources.

It is perfectly acceptable to use a simulation if radioactive sources are not available due to local restrictions. An example can be found here in the 'Penetrating Power of Alpha, Beta and Gamma' section.

Make sure you take a background count without any sources present. Do this for several minutes and take an average.

The alpha source will almost certainly emit at least one other type of radiation. Radium sources work well, as the beta and gamma components are relatively low.

The alpha content is absorbed completely by a piece of paper or card. This card should be disposed of in accordance with the local rules.

Kits of suitable absorbing materials are available. Typically, a strontium-90 source will emit virtually nothing else but beta particles, the most energetic will pass through approximately 30 cm of air or 3-4 cm of aluminium.

Gamma sources such as cobalt-60 or caesium-137 are obtainable, although other sources with an appreciable gamma content can be used. The gamma content requires several cm of lead in order to be appreciably absorbed.

Radiation penetrating power

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

- Why is it important to remove any sources to take the background count?
- Why is it important to take an average of any count rate?
- What safety precautions must be employed during this experiment?
- Is there any short or long-term risk in handling these sources?
- Can this difference in penetration power be put to any safe or helpful use? If so how?
- How does the count rate change with thickness of material?

Skills that are covered in the practical:

- Use of a Geiger-Muller tube and counter to detect ionising radiation
- Finding an estimate of background radiation and using it to correct a count rate
- Risk assessment in using sources of ionisation radiation
- Tabulation and comparison of either qualitative or quantitative data

Maths skills:

1A Recognise and use numbers in decimal form

1D Make estimates of the results of simple calculations, without using a calculator

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

3B Change the subject of an equation

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

3D Solve simple algebraic equations

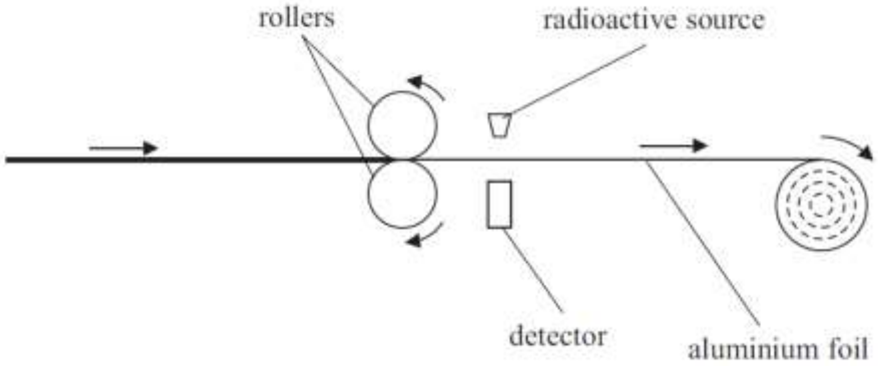
4A Translate information between graphical and numerical form

4C Plot two variables from experimental or other data

Questions

This example is taken from the 4PH0/2P paper, January 2013, Question 1b). The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

b) The diagram shows a machine that makes aluminium foil.
The machine uses a radioactive source to measure the thickness of the foil.



The radioactive source emits beta particles.
The output from the detector indicates the thickness of the foil.
Explain why beta particle are used, rather than alpha particles or gamma rays. **(3)**

Question number			Answer	Accept	Reject	Marks
1	(b)		Any three of: MP1 - Idea that alpha particles would not penetrate (enough); e.g. alpha particles absorbed / stopped by {aluminium / foil / a few cm air / paper / card} MP2 - Idea that gamma rays would be too penetrative; e.g. gamma rays {are not absorbed / are unaffected} MP3 - Idea that some beta particles will pass through the foil; e.g. not all of the beta particles are absorbed MP4 - Idea of a correlation between thickness and absorption; e.g. thinner aluminium absorbs fewer beta particles	Ignore references to danger or harm All ideas may be expressed in terms of penetration or absorption. No need to see the word "aluminium," provided the meaning is clear. Accept paper or card will stop alpha for MP1 Accept comparisons of aluminium thickness for MP4		3

> This item tests whether the candidate has learnt the differing penetration powers, along with why that might be useful in a context. Note that to answer this question successfully, the candidate needed to follow the instruction to explain why the system rejects the use of alpha and beta radiation.

Core practical 13: I-V characteristics

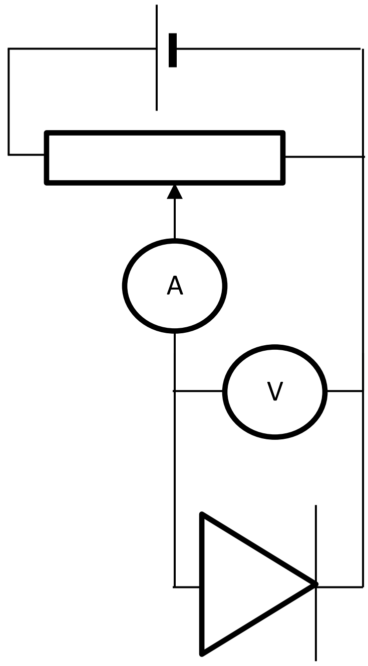
2.9 Core practical: Describe how current varies with voltage in wires, resistors, metal filament laps and diodes and how to investigate this experimentally

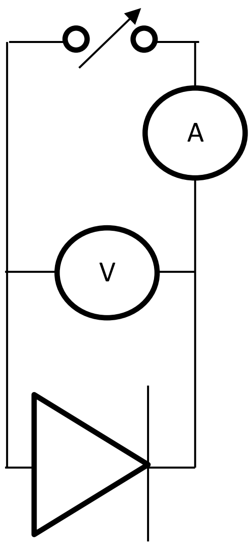
N.B. Not a 'required' practical, but is mentioned on the specification as skills and techniques.

Links to the specification content

2.10	Describe the qualitative effect of changing resistance on the current in a circuit
2.12	Know that lamps and LEDs can be used to indicate the presence of a current in a circuit
2.13	Know and use the relationship between voltage, current and resistance: voltage = current × resistance (V = I × R)

Introducing the practical





Any reasonable method can be employed to vary the voltage across the component under test, apart from merely putting a variable resistor in series with the component. Doing this will restrict the range of voltages that can be applied.

Two reasonable diagrams for the diode are shown on the right. Test circuits for the other components can be made by simply replacing the diode with the metal wire, resistor or filament lamp.

Any simple diode will be acceptable. Be careful with LEDs that the protective resistor is not included in the circuit, yet always check the safe range of voltage for the diode before using it with a class (some LEDs have knee voltages which are considerably higher than 0.60V). A suitable ammeter is required that can measure up to 200 milliamps accurately, such as an inexpensive multimeter. This could also be a data-logging opportunity.

There is always a minimum wire length that can be employed with a given voltage before the wire gets dangerously hot or burns through. This should be checked for any specimen and ideally with a low voltage such as that supplied by a single cell or 2 V power supply.

It is worth observing and recording the colour of the light from the filament lamp during the experiment. This provides a direct link with the variability of the surface temperatures of stars for the new Astrophysics section.

As ever, it is always worth leaving the addition of the voltmeter to the circuit until last. Demonstrating building the circuit, slowly, is worthwhile, as is leaving the demonstration set out so that students can compare with their own.

In any case, the circuit should be switched off between readings to ensure that the current doesn't flow for too long and inadvertently warm the components.

I-V characteristics

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

- How does a current make conductors hot?
- If the component gets warm, how does that effect the I-V graph?
- How does the resistance change with different voltage or current? How can you tell this from the graph?
- Is it appropriate to have an even interval in voltage for these components?
- Is there a link between the colour of the filament lamp and its temperature?
- Why is the low voltage part of the filament lamp straight?
- How could you tell if there was a current flowing through the filament lamp if it isn't glowing?
- What happens to the diode I-V graph if you reverse the voltage? Why is that different to the wire and the filament lamp?
- Should you repeat your readings for these circuits? How do you know that the conditions are the same each time?
- How can you guarantee that the wire is the same temperature each time for different voltages?

Skills that are covered in the practical:

- Construction of an electrical circuit from a diagram
- Appropriate use of digital or analogue meters e.g. multimeters, shunts and multipliers
- Appropriate selection of range and interval in independent variable
- Selection of the correct variable as the independent variable
- Risk assessment e.g. appreciation of how quickly a component may get hot
- Data table skills and calculations
- Qualitative observation of colour

Maths skills:

1A Recognise and use numbers in decimal form

1D Make estimates of the results of simple calculations, without using a calculator

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

3B Change the subject of an equation

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

3D Solve simple algebraic equations

4A Translate information between graphical and numerical form

4B Understand that $y=mx + x$ represents a linear relationship

4C Plot two variables from experimental or other data

4D Determine the slope and intercept of a linear graph

4E Understand, draw and use the slope of a tangent to a curve as a measure of rate of change

4F Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate.

5A Use angular measures in degrees

Questions

This example is taken from the 4PH0/1PR paper, June 2013, Question 10. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

A student investigates how the resistance of a piece of wire changes with voltage across the wire.

The student connects an ammeter, a voltmeter, a battery, a variable resistor and the wire in an electrical circuit.

(a) (i) Complete the diagram to show how the student should connect the circuit. **(3)**

Question number	Answer	Notes	Marks
10 (a) I	MP1 Any circuit including **correct circuit symbols** for • battery /cell / d.c. power supply • ammeter • voltmeter ;	ignore other components for MP1	3

(ii) Describe what she should do to obtain a set of results for her investigation. **(3)**

ii	MP2 ammeter clearly measures current through the wire; MP3 voltmeter clearly across wire; Idea of measuring current through the wire; Idea of measuring voltage across the wire; Idea of a range of values (of I and V); e.g. alter variable resistor OR repeat for different voltages	allow even if voltmeter in series with ammeter allow circuit line drawn through meter allow voltmeter across a section of the test wire	3

These items ran through together on the original mark scheme. The circuit is a simple version and the focus is on the correct positioning of the two meters.

For part ii), the emphasis is on what results the student should take and on how they can achieve sufficient data to construct a current-voltage graph.

(b) The student keeps the temperature of the wire constant during the investigation.

(i) Suggest why she does this. **(1)**

(ii) Suggest how she does this. **(1)**

(b) i	any one of		1
	resistance changes (with temperature) ;	Reject incorrect relationship between R and Θ	1
ii	wire gets hot **and** melts/burns/catches fire/dangerous;	Ignore damage to wire	
		Reject insulating the wire	1
	V proportional to I only at constant temperature;		
(c)	Ohms Law is only true if temperature constant;	Allow to return to room temperature	
i	any one of	Allow V = I × R and rearrangements	
	putting the wire in a water bath ;		
	taking the reading quickly;		
	switching off between readings;		
	using only small currents;		
	voltage = current × resistance ;		

As these items have the command word 'suggest' then anything reasonable yet physical was acceptable. Insulating the wire does not work, as the wire will not be able to radiate heat as effectively and so will get hotter. Switching off the current or only letting the current run for a short time were also acceptable.

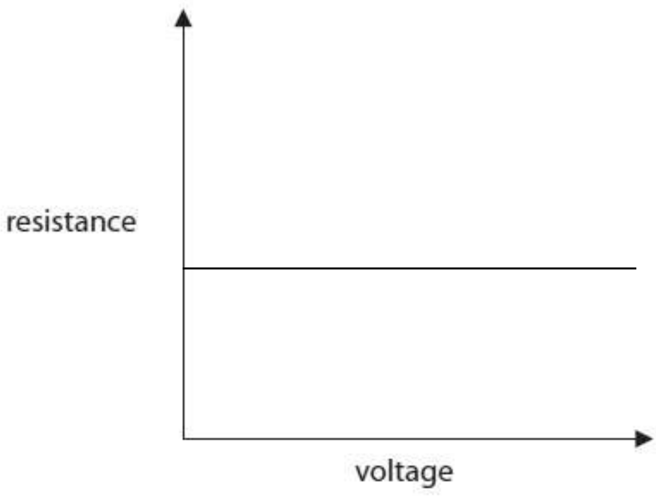
(c) When the student looks at her results, she notices that the voltage across the wire is directly proportional to the current in it.

(i) State the relationship linking voltage, current and resistance. **(1)**

Any rearrangement of the equation voltage = current x resistance was acceptable, as was any standard symbol, i.e. V, I and R. A common error is to state 'C' for current.

(ii) The student calculates the resistance and then plots a graph of resistance against voltage.

On the axes, sketch the shape of her graph. **(1)**



This is a challenging item as the answer is not directly stated in the specification and so requires some thought. Assuming that the temperature does not change, then the resistance should be constant with voltage.

(Total for question = 10 marks)

Core practical 14: Temperature-time graphs

5.11P Core practical: Obtain a temperature-time graph to show the constant temperature during a change of state

N.B. Not a 'required' practical, but is mentioned on the specification as skills and techniques

Links to the specification content

5.8P	**Explain why heating a system will change the energy stored within the system and raise its temperature or produce changes of state**
5.9P	**Describe the changes that occur when a solid melts to form a liquid, and when a liquid evaporates or boils to form a gas**
5.10P	**Describe the arrangement and motion of particles in solids, liquids and gases**

Introducing the practical

The students can use ice in a beaker, which is then heated via Bunsen or similar apparatus, rather than an electrical heater because it probably won't get the melt water hot enough.

The students should keep stirring to ensure as constant a temperature as possible throughout the water.

The thermometer should be kept off the bottom of the beaker, which is almost certainly hotter than the water itself.

An alternative to water is the cooling curve of stearic acid, which has a freezing point of 69 °C. Care must be taken, and the local H & S advisory board (such as CLEAPSS) should be consulted. A relatively fresh sample must be used; otherwise, the freezing temperature plateau can be missed altogether.

Either example is a good opportunity for data logging.

Temperature-time graphs

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

- Why keep the thermometer off the bottom of the glass?
- Why keep stirring?
- What is happening inside the material when it is freezing or boiling?
- How does the motion of the particles change throughout this process?

Skills that are covered in the practical:

- Simultaneous reading of temperature using a thermometer and time using a stopwatch.
- Ensuring constant temperature throughout the liquid.
- Risk assessment associated with heating apparatus
- Tabulation of data and subsequent graph plotting
- Evaluation of data (e.g. does all the heat from the source remain in the object being heated?)

Maths skills:

1A Recognise and use numbers in decimal form

1D Make estimates of the results of simple calculations, without using a calculator

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

3B Change the subject of an equation

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

3D Solve simple algebraic equations

4A Translate information between graphical and numerical form

4B Understand that y=mx + x represents a linear relationship

4C Plot two variables from experimental or other data

4D Determine the slope and intercept of a linear graph

4E Understand, draw and use the slope of a tangent to a curve as a measure of rate of change

4F Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate.

Questions

There is no sample question available for this practical, as it was not on the legacy specification, nor is it covered on the Specimen Assessment Materials.

Appendix 1

Department for Education: apparatus and techniques list

	BIOLOGY	CHEMISTRY	PHYSICS
1	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH	Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.
2	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater	Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs
3	Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes	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	Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration)
4	Safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment	Safe use of a range of equipment to purify and/or separate chemical mixtures including evaporation, filtration, crystallisation, chromatography and distillation	Making observations of waves in fluids and solids to identify the suitability of apparatus to measure speed/frequency/wavelength. Making observations of the effects of the interaction of electromagnetic waves with matter.

5	Measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator	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	Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associated values such as work done
6	Application of appropriate sampling techniques to investigate the distribution and abundance of organisms in an ecosystem via direct use in the field	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	Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements
7	Use of appropriate apparatus, techniques and magnification, including microscopes, to make observations of biological specimens and produce labelled scientific drawings	Use of appropriate apparatus and techniques to draw, set up and use electrochemical cells for separation and production of elements and compounds	Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements
Separate science only			
8	Use of appropriate techniques and qualitative reagents to identify biological molecules and processes in more complex and problem-solving contexts, including continuous sampling in an investigation.	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	Making observations of waves in fluids and solids to identify the suitability of apparatus to measure the effects of the interaction of waves with matter.

Appendix 2

GCSE Sciences: Equipment list

The apparatus you choose to use will depend upon the individual circumstances and availability at each centre. A risk assessment will need to be carried out for each practical based upon individual circumstances and experience of teacher and students.

Biology

No.	Specification Reference	Equipment needed (per group)
1	*2.9 - Investigate food samples for the presence of glucose, starch, protein and fat*	Eye protection, food samples, spatula, paper towels, test tubes, racks and bungs, stirrer, iodine solution (1 g iodine in 100 cm^3 0.5 mol dm^{-3} potassium iodide solution) in dropper bottle, Benedict's solution (prepared according to CLEAPSS Recipe sheet 11 (qualitative), 5% potassium hydroxide and 1% copper sulfate solution or biuret solution (prepared according to CLEAPSS Recipe sheet 15) in dropper bottle, absolute ethanol, water bath.
2	*2.12 - Investigate how enzyme activity can be affected by changes in temperature*	In amylase/starch investigation in the effect of pH, for each pH tested: test tube containing 5 cm^3 freshly made 1% starch suspension (mix 5 g soluble starch with a little cold water, pour into 500 cm^3 of boiling water and stir well, then boil until you have a clear solution), test tube containing 2 cm^3 1% amylase solution, water bath 5 cm^3 syringe or pipette, beaker of water for washing pipette, eye protection, 0.01 mol dm^{-3} iodine solution, well tray (spotting tile), stop clock/stopwatch.
3	***2.14B - Investigate how enzyme activity can be affected by changes in pH***	In amylase/starch investigation in the effect of pH, for each pH tested: test tube containing 5 cm^3 freshly made 1% starch suspension (mix 5 g soluble starch with a little cold water, pour into 500 cm^3 of boiling water and stir well, then boil until you have a clear solution), test tube containing 2 cm^3 1% amylase solution, water bath 5 cm^3 syringe buffer solution at a set pH (or pipette, beaker of water for washing pipette, eye protection, 0.01 mol dm^{-3} iodine solution, well tray (spotting tile), stop clock/stopwatch. Large baking potatoes, 1 per working group, access to balances, Beaker, 100 cm^3, or boiling tube, white tile, scalpel, ruler, cork borers to cut potatoes, or potato chipper, measuring cylinder, 50 cm^3, teat pipettes, distilled water, in wash bottle.

4	*2.17 - Investigate diffusion and osmosis using living and non-living systems*	4 Potato strips four boiling tubes and rack (or beakers) waterproof pen, 550 g/dm^3 sucrose solution forceps agar cubes containing sodium hydroxide and universal indicator or phenolphthalein (one cube each of side lengths 2 cm, 1 cm and 0.5 cm or an agar block large enough for students to cut their own cubes), 20 cm^3 0.1 mol/dm^3 hydrochloric acid, 100 cm^3 beaker forceps white tile knife stop clock or watch
5	*2.23 - Investigate photosynthesis, showing the evolution of oxygen from a water plant, the production of starch and the requirements of light, carbon dioxide and chlorophyll*	Ethanol (IDA) kettles of boiling water, boiling tube rack, Iodine in potassium iodide, solution in dropper bottles, beaker (at least 250 cm^3), leaves, different types, such as pelargonium (pot geranium), eye protection, forceps. Plants, variegated and fully green, de-starched by keeping in the dark for 48 hours. Bell jar, covering a de-starched plant, and a beaker of soda lime, secured to a glass plate or plastic tray with Vaseline or silicone grease Beaker, 600 cm^3, metre ruler, *Elodea* or other oxygenating pond plant scissors, forceps, electric lamp, clamp stand with boss and clamp.
6	***2.33B - Investigate the energy content in a food sample***	Food samples, range of foods in small pieces (cut to approximately 1 cm square/ 0.5 cm cubed if necessary) – for example, cheese, pulses, bread, biscuits, pasta, packet snacks such as crisps and others, breakfast cereals. Nuts should not be used. Balance, accurate to ± 0.1 boiling tube, clamp stand, boss and clamp, Bunsen burner, heatproof mat, measuring cylinder, 50 cm^3 or 100 cm^3, mounted needle with wooden handle, tongs or forceps for food samples that cannot be impaled, thermometer (–10 °C–110 °C), eye protection..
7	*2.39 - Investigate the evolution of carbon dioxide and heat from respiring seeds or other suitable living organisms*	Germinating seeds or blowfly larvae, Three to four days before the experiment, soak the wheat for 24 hours and then allow the seeds to germinate in a closed container for two to three days. 2 vacuum flasks, The best results will be obtained with small vacuum flasks. Cut strips of cotton wool about 30 cm x 5 cm. thermometers 2 per group. Dilute commercial bleaching solution with four times its volume of water. Allow 300 cm^3 for each group. *Blowfly larvae* are available in shops catering for anglers from mid-June to mid-March. Allow 10g per group. The control in this case can be an empty tube or an equivalent volume of inert material such as glass or plastic beads. Lime water. Allow 10 cm^3 per group Tubing and bungs to connect material with test tube containing limewater or Sodium hydrogen carbonate solution, eye protection.

8	***2.45B - Investigate the effect of light on net gas exchange from a leaf, using hydrogen-carbonate indicator***	*Leaves or leaf portions* from deadnettle, iris, rose, plantain, dandelion, dock, forsythia have given satisfactory results in 30-45 minutes. Allow two leaves per group. *Hydrogen carbonate indicator*. Dissolve 0.2 thymol blue and 0.1 g cresol red powders in 20 cm^3 ethanol. Dissolve 0.84 g sodium hydrogen carbonate (analytical quality) in 900 cm^3 distilled water. Add the alcoholic solution to the hydrogen carbonate solution and make the volume up to 1 litre with distilled water. Shortly before use, dilute the appropriate amount of this solution 10 times, i.e. add 9 times its own volume of distilled water. To bring the solution into equilibrium with atmospheric air; bubble air from outside the laboratory through the diluted indicator using a filter pump or aquarium pump. After about 10 minutes, the dye should be red. Allow 10 cm^3 per group, Note that the glassware and bungs must be clean. Any trace of acid or alkali will affect the indicator. 3 test-tubes and rubber bungs, 1 bench lamp (in the absence of sunlight) test-tube rack, piece of aluminium foil, about 120 x 140 mm, graduated pipette or syringe, 5 or 10 cm^3, 3 labels or a spirit marker, forceps, eye protection.
9	*2.50 - Investigate breathing in humans, including the release of carbon dioxide and the effect of exercise*	Using 5-6 mm glass delivery tubing, cut two 20 cm and two 7 cm lengths and flame polish the cut ends. Fit these two tubes through a two-hole No.21 rubber bung so that the longer one reaches nearly to the bottom of a boiling tube (25 mm X 150 mm) when the bung is securely inserted. Cut two 10-15 cm lengths of rubber tubing, 5 mm bore and 1.5 mm wall. After use, the tubes can be sterilized in a little antiseptic and washed. The apparatus must be clean and free from any trace of acid otherwise the limewater will not go milky. Each group needs one set of tubes A and B. ***Lime water***. Shake tap water with an excess of calcium hydroxide. Allow to settle overnight and decant the clear liquid. Each group needs 20 cm^3. Before the experiment, check that the limewater is effective by blowing through a sample for 30 seconds. 2 sets of apparatus as described above, 1 graduated pipette or syringe (10 cm^3) rack for holding boiling tubes. For breathing rate stopwatch clipboard.

10	***2.58B - Investigate the role of environmental factors in determining the rate of transpiration from a leafy shoot***	Plant material ,large sink – to assemble apparatus under water or bucket, potometer – designs vary, scalpel or scissors, clamp stand with boss and clamp, marker pen, stop clock, beaker, water, plastic ruler, paper towels, thermometer (-10 °C to 110 °C), lamp, black plastic bags, clear plastic bags, fan, vaseline or nail varnish, graph paper.
11	*3.5 - Investigate the conditions needed for seed germination*	seeds, boiling tubes, fridge, thermometer (-10 °C to 110 °C), paraffin oil, cotton wool, sodium pyrogallate (you may choose to demonstrate this rather than let students handle the pyrogallate).
12	*4.2 - Investigate the population size of an organism in two different areas using quadrats*	quadrat (e.g. 1 metre square), long tape measure (at least 20 m) with securing pegs, clipboards, recording sheets. Species keys.
13	***4.4B - Investigate the distribution of organisms in their habitats and measure biodiversity using quadrat***	quadrat (e.g. 1 metre square), long tape measure (at least 20 m) with securing pegs, equipment for measuring appropriate physical factors (e.g. thermometer, light meter, data recorder with light, moisture or temperature sensors, soil pH meter), clipboards, recording sheets. Species keys.
14	*5.6 - Investigate the role of anaerobic respiration by yeast in different conditions*	dried yeast 1 g, dried yeast heated to 100 °C 1 g, 5% glucose solution made with boiled water 20 cm^3, limewater 15 cm^3 or sodium hydrogen carbonate solution. Paraffin oil. Diazine green if available. Boiling tube with bung and delivery tube, beaker as water bath, thermometer, eye protection.

Chemistry

No.	Specification Reference	Equipment needed (per group)
1	**1.7C - Investigate solubility of a solid in water at a specific temperature**	100 cm^3 or 250 cm^3 beaker 50 cm^3 or 100 cm^3 measuring cylinder spatula stirring rod evaporating basin filter funnel and paper access to a balance that reads to at least 2 d.p. thermometer Bunsen burner tripod gauze eye protection
2	1.13 - Investigate paper chromatography using inks/food colourings	250 cm^3 beaker chromatography paper pencil to draw baseline pencil or splint or glass rod or plastic rod and paper clips depending on chosen set up selection of water-soluble inks such as from black felt tip pens
3	1.36 - Determine the formula of a metal oxide by combustion or by reduction	Combustion of magnesium: Bunsen burner tripod heat resistant mat tongs pipe clay triangle eye protection crucible and lid clean magnesium ribbon access to a balance which reads to at least 2 d.p. Reduction of copper oxide from RSC link here : One reduction tube, i.e. a Pyrex boiling tube with a small hole blown about 1cm from the closed end A one-hole rubber bung to fit the reduction tube fitted with a short length of glass tubing Rubber tubing to connect the reduction tube to the hydrogen cylinder or gas tap stand, boss and clamp. Bunsen burner Access to a top pan balance that weighs to 0.01 g eye protection

4	**1.60C - Investigate the electrolysis of aqueous solutions**	Several alternatives are possible depending on available apparatus but if the RSC method found here is used: 100 cm^3 beaker connecting leads DC supply (6V suggested) electrodes (S shaped suggested) crocodile clips small test tubes to collect gas eye protection solutions as suggested in method
5	2.14 - Determine the approximate percentage by volume of oxygen in air using a metal or non-metal	250cm^3 beaker test tube ruler iron wool eye protection
6	2.21 - Investigate reactions between dilute hydrochloric and sulfuric acids and metals	6 test tubes (depending on number of metals used) test tube rack splints spatula eye protection
7	2.42 - Prepare a sample of pure, dry hydrated copper(II) sulfate crystals starting from copper(II) oxide	spatula beaker (100cm^3 or 250cm^3) filter funnel filter papers evaporating basin Bunsen burner tripod heat resistant mat deionised water eye protection
8	**2.43C - Prepare a sample of pure, dry lead(II) sulfate**	Apparatus for small-scale preparation: boiling tubes or 100cm^3 beakers filter funnel filter papers deionised water eye protection

9	3.8 - Investigate temperature changes accompanying some of the following types of change: • salts dissolving in water • neutralisation reactions • displacement reactions • combustion reactions	Apparatus required may vary slightly depending on the practical but will typically involve use of: thermometer 250cm^3 beaker polystyrene cup with lid (with hole in for thermometer) eye protection For combustion reactions: Also a spirit burner and copper can (or equivalent)
10	3.15 - Investigate the effect of changing the surface area of marble chips and of changing the concentration of hydrochloric acid on the rate of reaction between marble chips and dilute hydrochloric acid	Apparatus required will vary depending on method chosen to collect gas: conical flask with delivery tube gas syringe measuring cylinder trough and beehive-shelf or equivalent eye protection
11	3.16 - Investigate the effect of different solids on the catalytic decomposition of hydrogen peroxide solution	Apparatus below is for method suggested by RSC link here several 250cm^3 measuring cylinders large tray or equivalent stopwatch/timer eye protection
12	**4.43C - Prepare a sample of an ester such as ethyl ethanoate**	Apparatus below is for method suggested by RSC link here eye protection glass specimen tubes plastic dropping pipettes beaker (100cm^3 or 250cm^3) test tubes test tube rack Bunsen burner heat resistant mat tripod and gauze tongs

Physics

No.	Specification Reference	Equipment needed (per group)
1	*1.5 - Investigate the motion of everyday objects such as toy cars or tennis balls.*	Core: suitable mobile objects, stopwatch/timer, metre rule or tape measure depending on the distance, ramp or track plus means of changing angle of descent. Ticker timers or light gates may also be useful. Advanced: data logging apparatus employing distance sensors
2	*1.22 - Investigate how extension varies with applied force for helical springs, metal wires and rubber bands.*	Range of samples i.e. copper wire, different diameters/pitches/stiffnesses of spring, different brands of rubber band. Set square. Metre or half-metre rule. Clamp, boss, clampstand, g-clamp to fix clampstand to bench. Pin/pointer affixable to base of spring/band. Range of masses capable of being hooked onto the sample. Blocks, pulley, g-clamp and wire guards for wire experiments.
3	***2.23P - Investigate how insulating materials can be charged by friction.***	A range of insulating materials cut into rods/strips such as Perspex, acrylic, PVC, rubber balloons etc. Squares/strips of materials such as wool, polyester. Insulting thread to suspend objects, such as fishing line.
4	*3.17 - Investigate the refraction of light, using rectangular blocks, semi-circular blocks and triangular prisms.*	Blocks of acrylic or other suitable colourless, translucent material cut and polished into or purchased as rectangular, semi-circular and triangular prisms. Ideally, there should be a mix of equilateral triangular prisms and 45-90-45 prisms. Light source, ideally a filament lamp with a metal slit and lens to produce a thin beam of light. Laser pens might be employed instead if adequately risk assessed and precautions taken. Protractors, pencils and paper for recording and measuring beam angles.
5	*3.19 - Investigate the refractive index of glass, using a glass block.*	Blocks of acrylic or other suitable colourless, translucent material either cut and polished into or purchased as rectangular or semi-circular blocks. Light source, ideally a filament lamp with a metal slit and lens to produce a thin beam of light. Laser pens might be employed instead if adequately risk assessed and precautions taken. Protractors, pencils and paper for recording and measuring beam angles.
6	***3.25P - Investigate the speed of sound in air.***	Means of making a loud noise and a visible signal at the same time e.g. wooden blocks, athletics starting mechanism etc. Stopwatches. Tape measure, metre wheel or other long distance measuring system. Advanced: microphones, dual beam oscilloscope with sufficient triggering mechanism, metre rule, connecting wires.
7	***3.27P - Investigate the frequency of a sound wave using an oscilloscope.***	Tone generating mechanism such as tuning fork, pure toned whistle, oscilloscope, microphone, amplifier as an optional extra. Signal generator and loudspeaker or smartphone app may be applicable.

8	*4.9 - Investigate thermal energy transfer by conduction, convection and radiation.*	Wooden/brass rod as described on page 85. Paper and tape. Metals rods, Bunsen or other gas flame, wax, paper clips (attached to metal rods with wax). Two kitchen utensils with different handles i.e. one metal and one wooden. Beaker of hot water. Beaker of tomato soup and two small wooden blocks. Beaker of water that can be warmed at one side. Small supply of potassium manganate (VII) crystal. 4 beakers, test tubes or thermometers; coloured paper, foil or paint to cover at least 3 tubes, or 3 of the tubes painted different colours and card or foil to make lids; stop clock; hot water.
9	*5.4 - Investigate density using direct measurements of mass and volume.*	Samples of various materials (e.g. materials kit), liquids, displacement can, measuring cylinder, access to balance, beakers
10	***5.14P - Investigate the specific heat capacity of materials including water and some solids.***	Thermometer, beaker, tripod, gauze, Bunsen burner/kettle/electrical immersion heater, polystyrene cup, balance, joulemeter (or ammeter and voltmeter) , stopclock, metal blocks pre-drilled to accept immersion heater and thermometer, access to balance, lagging material.
11	*6.6 - Investigate the magnetic field pattern for a permanent bar magnet and between two bar magnets.*	Two bar magnets, paper, plotting compass(es), pencil. Alternatively use iron filings but suitable precautions should be used to ensure that fillings do not go into eyes (wrapping the magnets in cling-film or keeping the filings in a petri dish may be sensible.)
12	*7.6 - Investigate the penetration powers of different types of radiation using either radioactive sources or simulations.*	Consult local rules e.g. CLEAPPS (in the UK) regarding the storage and safe use of radioactive sources in their document L93. Suitable sources such as radium-226, strontium-90 are plutonium-239, available from reputable and licensed suppliers. Different thicknesses of materials for absorption can be constructed or obtained as a kit.

Note: **2.9** and **5.11P** are not ‘required’ practicals, but are mentioned on the specification as skills and techniques.

13	*2.9 - Describe how current varies with voltage in wires, resistors, metal filament lamps and diodes and how to investigate this experimentally (not named as a ‘core practical’ but listed in the spec as something the candidates should know how to do!).*	Power supply, ammeters, voltmeters, variable resistors or rheostat, filament lamp, resistor, diode, connecting wires
14	***5.11P - Obtain a temperature-time graph to show the constant temperature during a change of state.***	Ice, thermometer, beaker, tripod, gauze, Bunsen burner, kettle, polystyrene cup, balance, electric immersion heater, joule meter (or ammeter and voltmeter), stopclock, thermometer data logging apparatus potentially (care with trailing wires!)