

Practical handbook for A-level Chemistry

Version 1.4



This is the **Chemistry** version of this Practical handbook.

Sections J to N are particularly useful for students and could be printed as a student booklet by schools.

The information in this document is correct, to the best of our knowledge as of September 2016. This document is expected to be revisited throughout the lifetime of the specification. Please check you have the latest version by visiting our website.

Thank you to all the teachers, technicians and associates who have commented on previous versions of this document. We're grateful for all the feedback and hope that your comments have been acted on.


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Key

There have been a number of changes to how practical work will be assessed in the new A-levels. Some of these have been AQA specific, but many are by common agreement between all the exam boards and Ofqual.

The symbol  signifies that **all boards** have agreed to this.

The symbol  is used where the information relates to **AQA only**.

A. Introduction

Practical work brings science to life, helping students make sense of the universe around them. That's why we've put practical work at the heart of our Biology, Chemistry and Physics A-levels. Practical science allows scientific theory to transform into deep knowledge and understanding – scientific thinking. Through investigation, students uncover the important links between their personal observations and scientific ideas.

“In the best schools visited, teachers ensured that pupils understood the ‘big ideas’ of science. They made sure that pupils mastered the investigative and practical skills that underpin the development of scientific knowledge and could discover for themselves the relevance and usefulness of those ideas.”

Ofsted report
Maintaining curiosity in science
November 2013, No. 130135

The purpose of this Practical handbook

This handbook has been developed to support you in advancing your students to fluency in science.

Over the years, there have been many rules developed for practical work in Biology, Chemistry and Physics. Some have been prescriptive, some have been intended as guidance. Although we have always attempted to be consistent within subjects, differences have emerged over time. Worse, students taking Chemistry may also be taking Physics and find themselves confronted with contradictory rules and guidance.

This practical handbook is an attempt to harmonise the rules and guidance for Biology, Chemistry and Physics. There are occasions where these will necessarily be different, but we will try to explain why on the occasions where that happens.

The new A-level specifications accredited for first teaching in September 2015 bring with them a complete change in the way practical work is assessed. No longer will teachers have to force their students to jump through hoops set up by exam boards or worry about how much help they are giving students and whether it's allowed or not.

We have worked with teachers, technicians and examiners to produce this handbook. This is an evolving document, but one that we hope you will be able to use with your students, whether they're doing A-level Biology, Chemistry or Physics, or a combination of subjects, to improve their practical skills: in the classroom, in the laboratory, in exams, for the endorsement and on to university or the workplace. The latest version will always be on our website.

Unless specified, all guidance is common to Biology, Chemistry and Physics at both AS and A-level and subject-specific examples are for illustration only. However, the extent to which a particular aspect is assessed will differ. Teachers should refer to the specifications and specimen materials on our website for more information.

The purpose of practical work

There are three interconnected, but separate reasons for doing practical work in schools and colleges. They are:

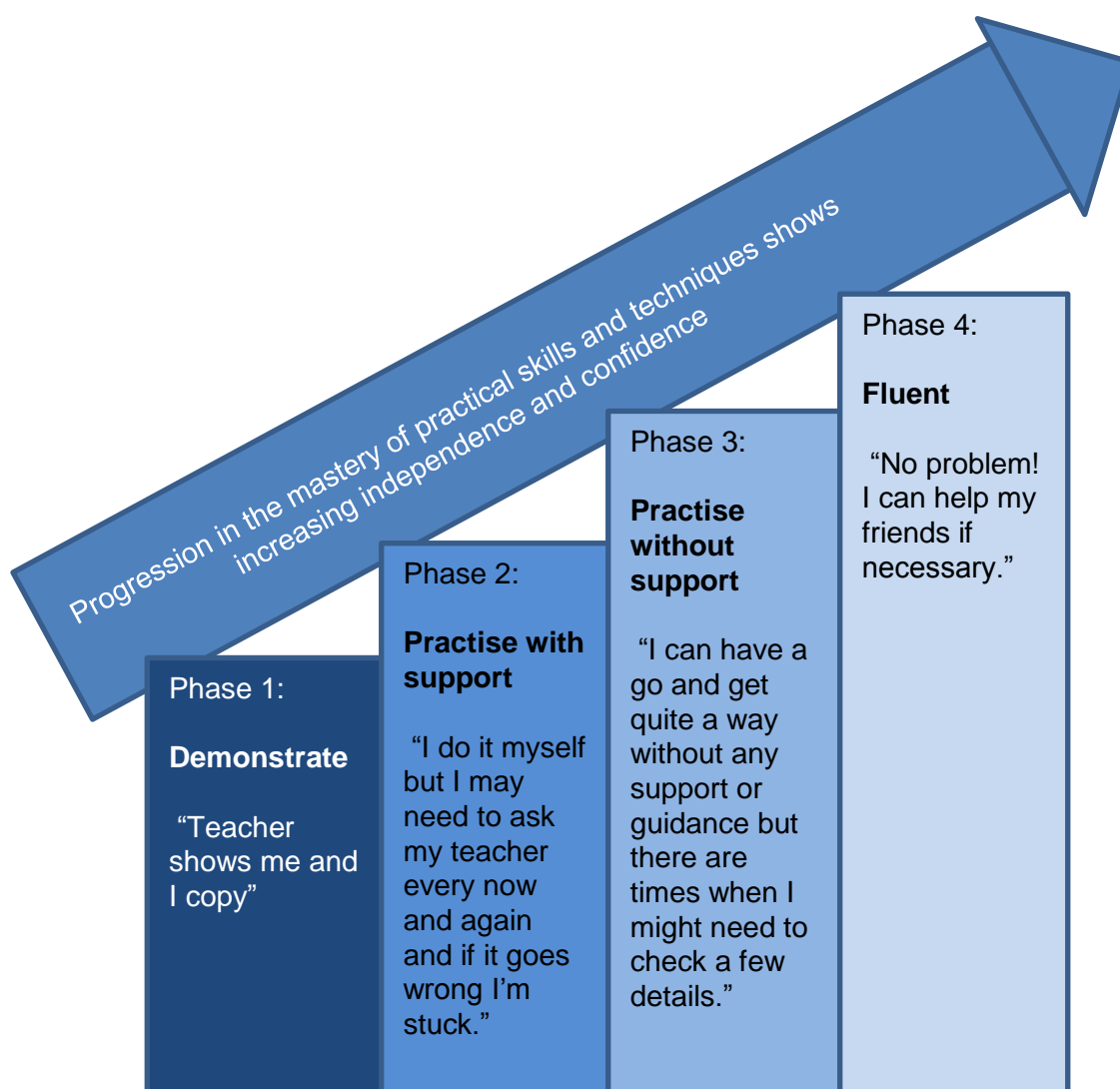
1. To support and consolidate **scientific concepts** (knowledge and understanding).
This is done by applying and developing what is known and understood of abstract ideas and models. Through practical work we are able to make sense of new information and observations, and provide insights into the development of scientific thinking.
2. To develop **investigative skills**. These transferable skills include:
 - a. devising and investigating testable questions
 - b. identifying and controlling variables
 - c. analysing, interpreting and evaluating data.
3. To build and master **practical skills** such as:
 - a. using specialist equipment to take measurements
 - b. handling and manipulating equipment with confidence and fluency
 - c. recognising hazards and planning how to minimise risk.

By focusing on the reasons for carrying out a particular practical, teachers will help their students understand the subject better, to develop the skills of a scientist and to master the manipulative skills required for further study or jobs in STEM subjects.

The reformed A-levels in Biology, Chemistry and Physics separate the ways in which practical work is assessed. This is discussed in the next section.

Fluency in science practical work

At the beginning of a year 12 course, students will need support and guidance to build their confidence. This could involve, for example, breaking down practicals into discrete sections or being more explicit in instructions. Alternatively, a demonstration of a key technique followed by students copying, may support students' development. This could be a better starting point than 'setting students loose' to do it for themselves.



B. Practical work in reformed A-level Biology, Chemistry and Physics

Statement on practical work by Glenys Stacey, Chief Regulator at Ofqual, April 2014

Practical work and experimentation is at the heart of science. It matters to science students, their teachers and their future universities and employers. But A-level students do not always have the chance to do enough of it.

Practical work counts for up to 30 per cent of the final grades and the vast majority of students get excellent marks for it, but still many enter university without good practical skills. It is possible to do well in science A-levels without doing sufficient or stretching hands-on science, and other pressures on schools can make it difficult for science teachers to carve out enough time and resource to do it if students can get good A-level grades in any event. That is not right – so why is it so?

Students are assessed and marked on their performance in set tasks, but these are generally experiments that are relatively easy to administer and not particularly stretching. It has proved extremely difficult to get sufficient variety and challenge in these experiments, and so students do well even if they have not had the opportunity to do enough varied and stretching experimentation, and learn and demonstrate a variety of lab skills. What to do? In future, science A-level exams will test students' understanding of experimentation more so than now. Those who have not had the chance to design, conduct and evaluate the results from a good range of experiments will struggle to get top grades in those exams. They will also be required to carry out a minimum of twelve practical activities across the two year course – practical activities specific to their particular science, and that are particularly valued in higher education. Students will receive a separate grade for their practical skills (a pass/fail grade).

These reforms should place experimentation and practical skills at the heart of science teaching, where they should be, and students going to university to study a science are more likely to go well prepared. They will also change the game for science teachers, enabling them to teach science in a more integrated and stimulating way with more hands on science and to say with justification that without sufficient time and effort put into lab work, their students will struggle to get the grades they deserve.

Glenys Stacey, Chief Regulator

The reformed AS and A-level specifications will have **no** direct assessment of practical work that contributes to the AS or A-level grades.

There are **two** elements to the practical work that students must carry out in their study of A-level Biology, Chemistry and Physics:

Apparatus and techniques (see section I)

These have been agreed by all exam boards, so all students will have experienced similar practical work after following a science A-level course.

All

Examples

Use of a light microscope at high power and low power, including use of a graticule.
Purify a solid product by recrystallisation.
Use laser or light source to investigate characteristics of light.

12 required practical activities (see section I)

These have been specified by AQA. They cover the apparatus and techniques for each subject – so teachers do not have to worry about whether they are all covered.

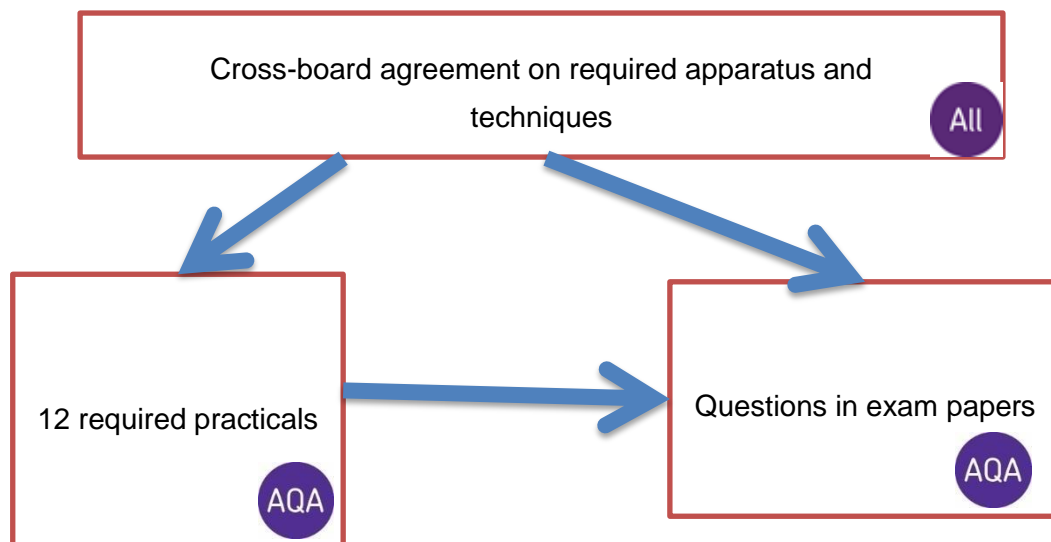
AQA

Examples

Use of aseptic techniques to investigate the effect of antimicrobial substances on microbial growth.
Carry out simple test-tube reactions to identify cations and anions in aqueous solution.
Determination of g by a free-fall method.

These will be assessed in two ways:

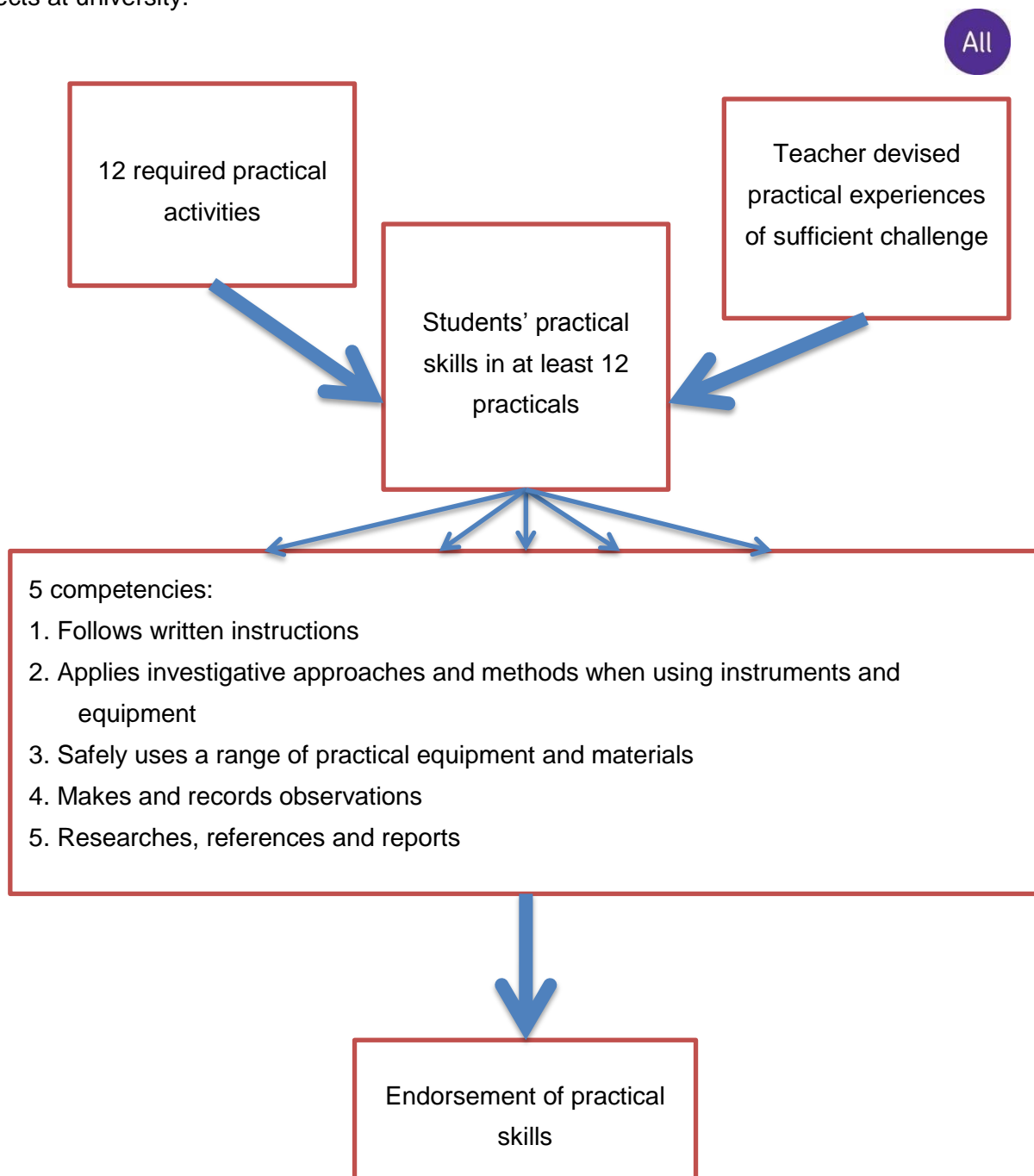
1. Questions in the written papers, assessed by AQA (see section C)



2. The practical endorsement, directly assessed by teachers (see section F)

Teachers will assess their students' competence at carrying out practical work. They will assess each student on at least 12 different occasions. This could be whilst teaching the 12 required practicals, or could be during other practical work of sufficient challenge.

At the end of the course, teachers will decide whether or not to award a pass in the endorsement of practical skills. The teacher must be confident that the student has shown a level of mastery of practical work good enough for the student to go on to study science subjects at university.



Students who miss a required practical activity

1. Written exam papers

The required practical activities are part of the specification. As such, exam papers could contain questions about the activities and assume that students understand those activities. A student who misses a particular practical activity may be at a disadvantage when answering questions in the exams.

It will often be difficult to set up a practical a second time for students to catch up although if at all possible an attempt should be made. Teachers will need to decide on a case by case basis whether they feel it is important for the student to carry out that particular practical. This is no different from when teachers make decisions about whether to re-teach a particular topic if a student is away from class when it is first taught.

2. Endorsement

To fulfil the requirements of the endorsement, every student must carry out a minimum of 12 practicals. A student who misses one of the required practicals must carry out another practical to be able to gain the endorsement.

In most cases, this can be any experiment of A-level standard. However, students must have experienced use of each of the apparatus and techniques. In some cases, a particular apparatus and technique is only covered in one required practical activity. If a student misses that activity, the teacher will need to provide an opportunity for the student to carry out a practical that includes that activity. The list below shows the apparatus and techniques that are covered by one activity only and alternatives to the required practical.

Note: there is a possibility that the student could be asked questions about the required activity in written papers that would not be fully understood by carrying out the alternative. This should be considered when deciding whether to repeat the required activity.

Chemistry



If a student misses this required practical activity...	...they won't have covered this apparatus and technique.	Other practicals within an A-level Chemistry course involving this skill
1. Make up a volumetric solution and carry out a simple acid-base titration.	<p>e. use volumetric flask, including accurate technique for making up a standard solution.</p> <p>f. use acid-base indicators in titrations of weak/strong acids with weak/strong alkalis.</p>	<p>Make up a standard solution for any other volumetric exercise.</p> <p>There are many practical opportunities throughout the course to use acid–base indicators in titrations weak/strong acids with weak/strong alkalis.</p>
7. Measure the rate of reaction: <ul style="list-style-type: none"> by an initial rate method by a continuous monitoring method. 	<p>l. measure rates of reaction by at least two different methods, for example:</p> <ul style="list-style-type: none"> an initial rate method such as a clock reaction a continuous monitoring method. 	<p>eg iodine clock or thiosulfate/ acid</p> <p>eg gas syringe, collection of gas over water, decrease in mass on top pan balance and colorimetrically.</p>
8. Measuring the EMF of an electrochemical cell	j. set up electrochemical cells and measuring voltages.	(No obvious alternative)
9. Investigate how pH changes when a weak acid reacts with a strong base and when a strong acid reacts with a weak base	c. measure pH using pH charts, or pH meter, or pH probe on a data logger.	One of these methods for measuring pH is required. (No obvious alternative).
10. Preparation of: <ul style="list-style-type: none"> a pure organic solid and test of its purity a pure organic liquid. 	<p>g. purify:</p> <ul style="list-style-type: none"> a solid product by recrystallisation a liquid product, including use of separating funnel. <p>h. use melting point apparatus.</p>	Preparation of a different solid and liquid from those that the rest of the class prepared.
12. Separation of species by thin-layer chromatography.	i. use thin-layer or paper chromatography.	Use thin-layer chromatography for separation of a different species.

C. Practical skills assessment in question papers

The AS and A-level papers will contain the following types of questions which relate to practical work:

1. Questions set in a practical context, where the question centres on the science, not the practical work.

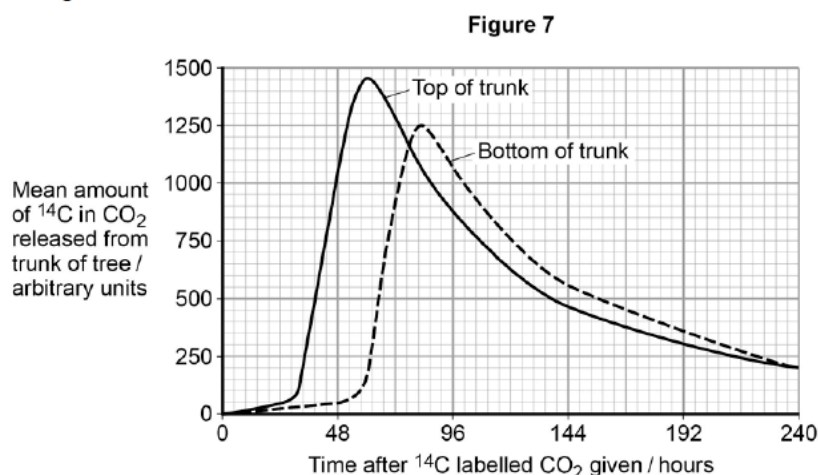
Example (A-level Biology Specimen Paper 1)

Scientists measured translocation in the phloem of trees. They used carbon dioxide labelled with radioactive ^{14}C .

They put a large, clear plastic bag over the leaves and branches of each tree and added $^{14}\text{CO}_2$. The main trunk of the tree was not in the plastic bag.

At regular intervals after adding the $^{14}\text{CO}_2$ to the bag, the scientists measured the amount of $^{14}\text{CO}_2$ released from the top and bottom of the main trunk of the tree. On the surface of the trunk of these trees, there are pores for gas exchange.

Figure 7 shows the scientists' results.



- 0 9 . 2 Name the process that produced the $^{14}\text{CO}_2$ released from the trunk. [1 mark]

- 0 9 . 3 How long did it take the ^{14}C label to get from the top of the trunk to the bottom of the trunk? Explain how you reached your answer. [2 marks]

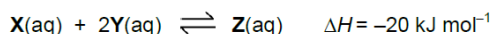
- 0 9 . 4 What other information is required in order to calculate the mean rate of movement of the ^{14}C down the trunk? [1 mark]

These questions are set in the context of practical work that has been carried out.

However, the questions relate more to the basic Biology behind the situation, or mathematical skills.

Example (AS Chemistry Specimen Paper 1)

- 4 Colourless solutions of $X(aq)$ and $Y(aq)$ react to form an orange solution of $Z(aq)$ according to the following equation.



A student added a solution containing 0.50 mol of $X(aq)$ to a solution containing 0.50 mol of $Y(aq)$ and shook the mixture.
After 30 seconds, there was no further change in colour.
The amount of $Z(aq)$ at equilibrium was 0.20 mol.

- 0 4 . 1 Deduce the amounts of $X(aq)$ and $Y(aq)$ at equilibrium.

[2 marks]

Amount of $X(aq)$ = _____ mol Amount of $Y(aq)$ = _____ mol

This question requires an understanding of the underlying chemistry, not the practical procedure undertaken.

Example (A-level Physics Specimen Paper 3)

- 0 2 . 6 The experiment is performed with a capacitor of nominal value $680 \mu\text{F}$ and a manufacturing tolerance of $\pm 5\%$. In this experiment the charging current is maintained at $65 \mu\text{A}$. The data from the experiment produces a straight-line graph for the variation of pd with time. This shows that the pd across the capacitor increases at a rate of 98 mV s^{-1} .

Calculate the capacitance of the capacitor.

[2 marks]

capacitance = _____ μF

This question is set in a practical context, and particular readings need to be used to calculate the answer, but the specific practical set-up is not important.

2. Questions that require specific aspects of a practical procedure to be understood in order to answer a question about the underlying science.

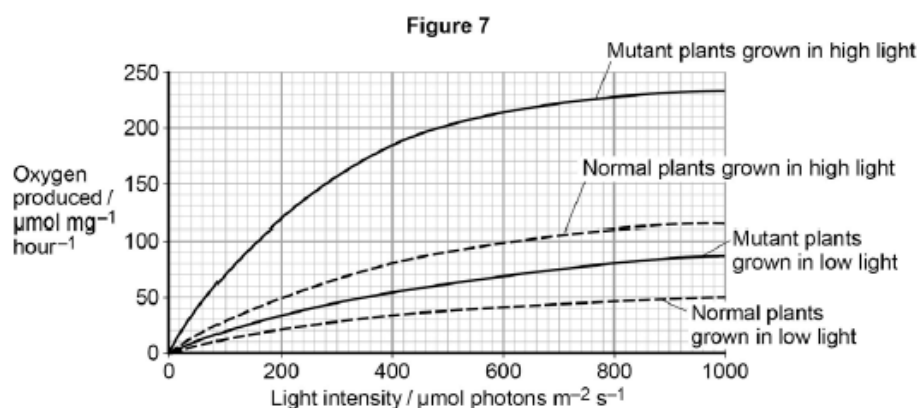
Example (A-level Biology Specimen Paper 2)

8 Chloroplasts contain chlorophyll a and chlorophyll b. Scientists found tobacco plants with a mutation that caused them to make more chlorophyll b than normal tobacco plants. They investigated the effect of this mutation on the rate of photosynthesis.

The scientists carried out the following investigation.

- They grew normal and mutant tobacco plants. They grew some of each in low light intensity and grew others in high light intensity.
- They isolated samples of chloroplasts from mature plants of both types.
- Finally, they measured oxygen production by the chloroplasts they had isolated from the plants.

Figure 7 shows the scientists' results.



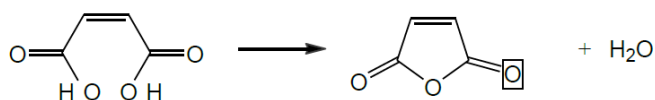
0 8 . 1 Explain why the scientists measured the rate of production of oxygen in this investigation.

[2 marks]

This question requires the students to understand how oxygen production can be used as a proxy measure for photosynthesis, but no other details of the practical procedure are important.

Example (AS Chemistry Specimen Paper 2)

0 1 . 4 The effect of gentle heat on maleic acid is shown below.



A student predicted that the yield of this reaction would be greater than 80%.

In an experiment, 10.0 g of maleic acid were heated and 6.53 g of organic product were obtained.

Is the student correct? Justify your answer with a calculation using these data.

[2 marks]

To answer this question, the student must understand the process of yield calculation (which will have been gained through practical work), but again the details of the practical procedure are unimportant.

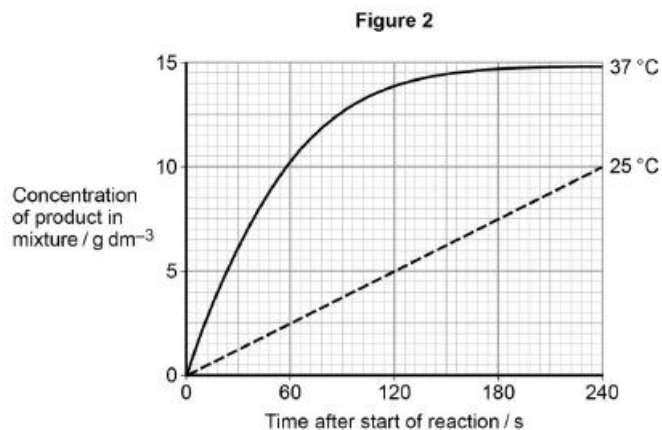
3. Questions directly on the required practical procedures.

Example (AS Biology Specimen Paper 1)

2

A technician investigated the effect of temperature on the rate of an enzyme-controlled reaction. At each temperature, he started the reaction using the same volume of substrate solution and the same volume of enzyme solution.

Figure 2 shows his results.



0 2 . 1 Give one other factor the technician would have controlled.

[1 mark]

0 2 . 2 Calculate the rate of reaction at 25 °C.

[2 marks]

Similarly, in this example, the students should have done a very similar experiment.

The first question is simple recall of the factors involved in the rate of enzyme controlled reactions.

The second requires the calculation of a gradient, which is a skill students will have learned through their practical and other work.

Example (A-level Chemistry Specimen Paper 3)

3 A peptide is hydrolysed to form a solution containing a mixture of amino acids. This mixture is then analysed by silica gel thin-layer chromatography (TLC) using a toxic solvent. The individual amino acids are identified from their R_f values.

Part of the practical procedure is given below.

1. **Wearing plastic gloves to hold a TLC plate**, draw a pencil line 1.5 cm from the bottom of the plate.
2. Use a capillary tube to apply a very small drop of the solution of amino acids to the mid-point of the pencil line.
3. Allow the spot to dry completely.
4. In the developing tank, add the developing solvent to **a depth of not more than 1 cm**.
5. Place your TLC plate in the developing tank.
6. Allow the developing solvent to rise up the plate **to the top**.
7. Remove the plate and quickly mark the position of the solvent front with a pencil.
8. Allow the plate to dry **in a fume cupboard**.

0 3 . 1 Parts of the procedure are in bold text.

For each of these parts, consider whether it is essential and justify your answer. [4 marks]

Students who have completed the related required practical will have a greater understanding of each of the steps in the procedure and will be able to explain each in turn.

This type of question is likely to be fairly rare, to avoid predictable assessments.

4. Questions applying the skills from the required practical procedures and the apparatus and techniques list.

Example (A-level Chemistry Specimen Paper 3)

0 1 . 3 The boiling points of the organic compounds in a reaction mixture are shown in Table 1.

Table 1

Compound	ethanol	ethanal	ethanoic acid
Boiling point / °C	78	21	118

Use these data to describe how you would obtain a sample of ethanal from a mixture of these three compounds. Include in your answer a description of the apparatus you would use and how you would minimise the loss of ethanal. Your description of the apparatus can be either a description in words or a labelled sketch. [5 marks]

This question expects students to understand distillation which is one of the required practicals. It is not necessary for students to have carried out this precise experiment to understand the requirements.

Example (AS Physics Specimen Paper 2)

0 2

Data analysis question

Capillary action can cause a liquid to rise up a hollow tube. Figure 3 shows water that has risen to a height h in a narrow glass tube because of capillary action.

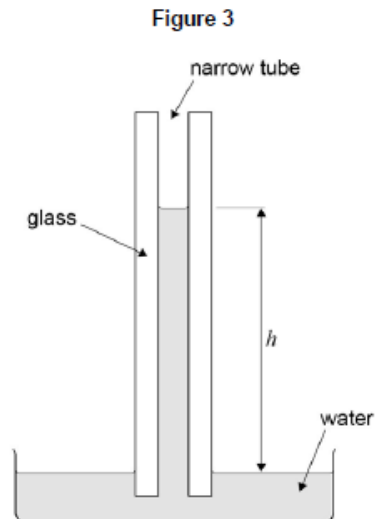
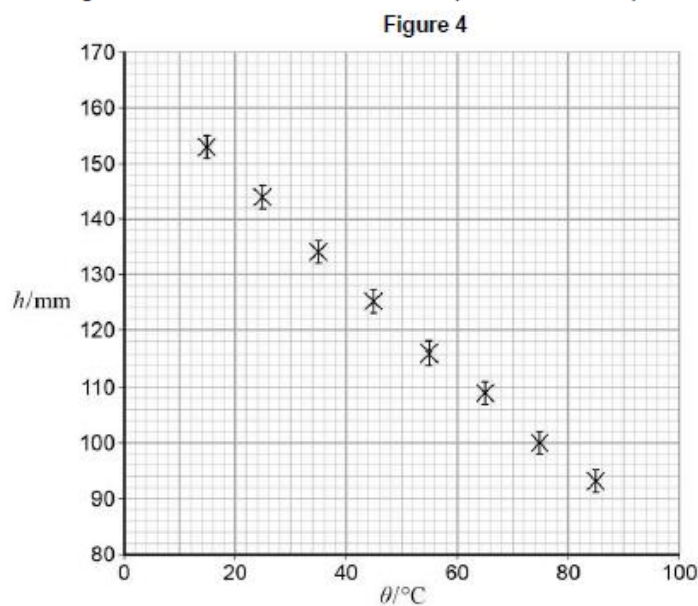


Figure 4 shows the variation of h with temperature θ for this particular tube.



The uncertainty in the measurement of h is shown by the error bars. Uncertainties in the measurements of temperature are negligible.

0 2

1 Draw a best-fit straight line for these data (Figure 4).

[1 mark]

0 2

2 It is suggested that the relationship between h and θ is

$$h = h_0 - (h_0 k) \theta$$

where h_0 and k are constants.

Determine h_0 .

[1 mark]

This question requires students to apply the skills of data analysis that they will have gained through their practical work in the required practicals and apply it to an unusual situation.

D. Guidelines for supporting students in practical work

Developed in collaboration with NFER and CLEAPSS

Clarify the importance of keeping a lab book or other records of practical work

Explain that students need a record of their achievements to guide their learning. Lab books also can be an opportunity to develop a skill used both by scientists and in business. They allow students to accurately and clearly record information, ideas and thoughts for future reference which is a very useful life skill.

Warn students against plagiarism and copying

Explain the meaning of the term plagiarism and that the use of acknowledged sources is an encouraged and acceptable practice, but trying to pass off other people's work as their own is not, and will not help them learn. Show students how sources should be cited.

Explain the learning criteria for each skill

This will help students learn and allow them to know when they have met the criteria. The student lab book contains the criteria, but they own the process and have the responsibility for collecting appropriate evidence of success.

Use clearly defined learning outcomes

For example, if you are running a practical session to teach students how to use a microscope and staining techniques safely and efficiently, then make sure they know why they are learning this. This will also make it much easier for them to know when they have met the criteria.

Start with simple tasks initially

Students need to become confident with the apparatus and concepts of practical work before they can proceed to more complicated experiments. It may be more effective to start with simple manipulation skills and progress to the higher order skills.

Teach practical work in your preferred order

Teach the skills as you see fit and suit your circumstances – the assessment process is designed to be flexible and help you teach practical work, not to dictate how it should be done.

Use feedback

Research shows that feedback is the best tool for learning in practical skills. Students who normally only receive numerical marks as feedback for work will need to be trained in both giving and receiving comment-based feedback. Provided it is objective, focused on the task and meets learning outcomes, students will quickly value this feedback.

Feedback is essential to help students develop skills effectively. Allowing self and peer review will allow time for quality feedback as well as provide powerful learning tools. However, this is a decision for teachers. The scheme is designed to be flexible while promoting best practice.

Don't give marks

We have deliberately moved away from banded criteria and marks to concentrate on the mastery of key practical competencies. The purpose of marking should be changed to emphasise learning. Students should find it easier to understand and track their progress, and focus their work. We would expect most students, with practice and the explicit teaching of skills and techniques, to succeed in most competencies by the end of the course.

Give feedback promptly

Feedback does not need to be lengthy, but it does need to be done while the task is fresh in the students' mind. Not everything needs written feedback but could be discussed with students, either individually or as a class. For example, if a teacher finds that many students cannot calculate percentage change, the start of the next lesson could be used for a group discussion about this.

Use peer assessment

The direct assessment of practical work is designed to allow teachers to integrate student-centred learning (including peer review), into day-to-day teaching and learning. This encourages critical skills. Research indicates these are powerful tools for learning. For example, teachers could ask students to evaluate each other's data objectively. The students could identify why some data may be useful and some not. This can be a very good way of getting students to understand why some conventions are used, and what improves the quality of results. This also frees up marking time to concentrate on teaching.

Use group work

This is a very useful skill, allowing students to build on each other's ideas. For example, planning an experiment can be done as a class discussion. Alternatively, techniques such as snowballing can be used, in which students produce their own plan then sit down in a small group to discuss which are the best collective ideas. From this, they revise their plan which is then discussed to produce a new 'best' plan.

E. Use of lab books

Students do **not** need to write up every practical that they do in detail. However, it is good practice to have a record of all they do. A lab book could contain this record. It is a student's personal book and may contain a range of notes, tables, jottings, reminders of what went wrong, errors identified and other findings. It is a live document that can function as a learning journal.

Lab books are **not** a requirement of the CPAC endorsement or the AQA AS and A-level specifications in Biology, Chemistry or Physics. They are highly valued by colleagues in higher education and are an easy way for students to demonstrate their mastery of Competence 5 "Researches, references and reports".

Each institution has its own rules on lab book usage. The following guidelines are an amalgam of guidelines from a selection of companies and universities that use lab books. They are designed to help students and teachers in preparing to use lab books for university but do not represent the only way that books could be used for A-level sciences. Teachers will wish to vary or ignore the following points to suit their purposes.

The purpose of a lab book

A lab book is a complete record of everything that has been done in the laboratory. As such, it becomes important both to track progress of experiments, but also, in industry and universities, to prove who developed an idea or discovered something first.

A lab book is a:

- source of data that can be used later by the experimenter or others
- complete record of what has been done so that experiments could be understood or repeated by a competent scientist at some point in the future
- tool that supports sound thinking and helps experimenters to question their results to ensure that their interpretation is the same one that others would come to
- record of why experiments were done.

Type of book

A lab book is often a hard-backed book with bound pages. Spiral bound notebooks are not recommended as it is too easy to rip a page out and start again. It is generally advisable that a lab book has a cover that won't disintegrate the moment it gets slightly wet.

Style

Notes should be recorded as experiments are taking place. They should not be a "neat" record written at a later date from scraps of paper. However, they should be written clearly, in legible writing and in language which can be understood by others.

Many lab books are used in industry as a source of data, and so should be written in indelible ink.

To ensure that an observer can be confident that all data are included when a lab book is examined, there should be no blank spaces. Mistakes should be crossed out and re-written. Numbers should not be overwritten, erased, nor should Tippex be used. Pencil should not be used for anything other than graphs and diagrams.

Each page should be dated

Worksheets, graphs, printed information, photographs and even flat “data” such as chromatograms or TLC plates can all be stuck into a lab book. They should not cover up any information so that photocopying the page shows all information in one go. Anything glued in should lie flat and not be folded.

Content

Generally, lab books will contain:

- title and date of experiment
- notes on the objectives of the experiment (eg apparatus and techniques covered or CPAC assessed)
- notes on the method, including all details (eg temperatures, volumes, settings of pieces of equipment) with justification where necessary
- estimates of the uncertainty of measurements
- sketches of how equipment has been set up can be helpful. Photographs pasted in are also acceptable
- data and observations input to tables (or similar) while carrying out the experiment
- calculations – annotated to show thinking
- graphs and charts
- summary, discussions and conclusions
- cross-references to earlier data and references to external information.

This list and its order are not prescriptive. Many experiments change as they are set up and trials run. Often a method will be given, then some data, then a brief mention of changes that were necessary, then more data and so on.

F. Cross-board statement on CPAC

Common Practical Assessment Criteria (CPAC)

The assessment of practical skills is a compulsory requirement of the course of study for A-level qualifications in biology, chemistry and physics. It will appear on all students' certificates as a separately reported result, alongside the overall grade for the qualification. The arrangements for the assessment of practical skills are common to all awarding organisations. These arrangements include:

- A minimum of 12 practical activities to be carried out by each student which, together, meet the requirements of Appendices 5b (Practical skills identified for direct assessment and developed through teaching and learning) and 5c (Use of apparatus and techniques) from the prescribed subject content, published by the Department for Education. The required practical activities will be defined by each awarding organisation in their specification;
- Teachers will assess students using Common Practical Assessment Criteria (CPAC) issued jointly by the awarding organisations. The CPAC are based on the requirements of Appendices 5b and 5c of the subject content requirements published by the Department for Education, and define the minimum standard required for the achievement of a pass;
- Each student will keep an appropriate record of their practical work, including their assessed practical activities;
- Students who demonstrate the required standard across all the requirements of the CPAC will receive a 'pass' grade;
- There will be no separate assessment of practical skills for AS qualifications;
- Students will answer questions in the AS and A level examination papers that assess the requirements of Appendix 5a (Practical skills identified for indirect assessment and developed through teaching and learning) from the prescribed subject content, published by the Department for Education. These questions may draw on, or range beyond, the practical activities included in the specification.

Competency	Practical mastery
	<p>To be awarded a Pass a student must, by the end of the practical science assessment, consistently and routinely meet the criteria in respect of each competency listed below. A student may demonstrate the competencies in any practical activity undertaken as part of that assessment throughout the course of study.</p> <p>Student may undertake practical activities in groups. However, the evidence generated by each student must demonstrate that he or she independently meets the criteria outlined below in respect of each competency. Such evidence:</p> <ul style="list-style-type: none"> a. will comprise both the student's performance during each practical activity and his or her contemporaneous record of the work that he or she has undertaken during that activity, and b. must include evidence of independent application of investigative approaches and methods to practical work.
1. Follows written procedures	a. Correctly follows written instructions to carry out experimental techniques or procedures.
2. Applies investigative approaches and methods when using instruments and equipment	<ul style="list-style-type: none"> a. Correctly uses appropriate instrumentation, apparatus and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting. b. Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and making adjustments when necessary. c. Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled. d. Selects appropriate equipment and measurement strategies in order to ensure suitably accurate results.
3. Safely uses a range of practical equipment and materials	<ul style="list-style-type: none"> a. Identifies hazards and assesses risks associated with these hazards, making safety adjustments as necessary, when carrying out experimental techniques and procedures in the lab or field. b. Uses appropriate safety equipment and approaches to minimise risks with minimal prompting.

4. Makes and records observations	a. Makes accurate observations relevant to the experimental or investigative procedure. b. Obtains accurate, precise and sufficient data for experimental and investigative procedures and records this methodically using appropriate units and conventions.
5. Researches, references and reports	a. Uses appropriate software and/or tools to process data, carry out research and report findings. b. Cites sources of information demonstrating that research has taken place, supporting planning and conclusions.

Extra information on the endorsement

The information below is based on the cross-board agreements, but is not a cross-board agreed wording.

‘Consistently and routinely’

Teachers should be confident that their students can demonstrate a particular competence going forwards. This means that demonstrating a competence once to the expected standard is unlikely to be enough, but there is no stipulated number of times that each competence must be demonstrated. The teacher should use professional judgement when holistically assessing their students at the end of the course.

Observing differences in standard over time

There is an expectation that students will improve in their skills and abilities in practical work throughout a two-year course. An adviser attending a school in the earlier part of the course would expect to see students working at a lower level than the same students would be working at by the end of the course.

There are many different ways of tracking students’ skills development towards competence. Advisers will not expect to see any particular method of tracking or showing this development during visits. Advisers will discuss tracking with teachers in order to become confident that the teachers understand the standard expected at the end of the course and that their planning supports students’ skills progression.

Demonstrations

Demonstrations cannot be substituted for any of the required practical activities. Teachers can demonstrate experiments when teaching new techniques, before students carry out the experiment in subsequent lessons. However, if CPAC 1 is being assessed, the instructions must not simply repeat what was shown in the demonstration.

The link between the apparatus and techniques and CPAC

All students should have experienced use of each of the apparatus and techniques. Their competence in practical work will be developed through the use of these apparatus and techniques. However, students are not being assessed on their abilities to use a particular piece of equipment, but on their general level of practical competence.

Simulations

Simulations are not acceptable for use in the place of the apparatus and techniques.

Helping students during practical work

Teachers can help students during practical work, but the amount of guidance will be dependent on the criteria being assessed. For example, if a student was being assessed on CPAC 3, and needed to be reminded on the basics of safety, they could not be assessed as passing.

It may be appropriate to help students if the equipment or the technique is new or unusual through spot demonstrations.

The amount of help would depend on when in the course the practical work was taking place. For example, at the beginning of year 12 the teacher would be likely to be giving a lot of guidance, and tasks would include a lot of scaffolding. By the end of year 13, there is likely to be minor prompting to help students as they become more confident and competent.

Language used by students

In written exams, students are expected to use scientific language that corresponds to the glossary of terms in this handbook. Whilst doing practical work, students should be encouraged to use the correct terms (such as discussing if results are 'accurate', 'precise', 'repeatable' etc), but should not be penalised for using incorrect vocabulary verbally. This is because the assessment is about the students' abilities in practical work, not their use of terms.

Certificates

Students will either have 'Pass' or 'Not classified' recorded on their certificate for the endorsement.

Carry forward and retakes

Students may carry forward the outcome of practical assessments if they resit the qualification. This also applies if students decide to complete the qualification again with a different exam board. They cannot retake the practical science assessment without retaking exams. This is because practical skills should be developed as part of teaching and learning of the whole subject and the assessment is designed to assess students demonstrating the skills over a period, not just as a one-off.

Reasonable adjustments

The JCQ document Access Arrangements and Reasonable Adjustments sets out arrangements for access arrangements for all assessments.

The arrangements applicable to the endorsement must not compromise the objectives of the assessment. So, for example, it is likely to be reasonable for a student to have a reader or extra time while being assessed against CPAC 1. Students would be demonstrating their ability to follow instructions in the form the students were used to receiving them in.

CPAC 2 and 3 make reference to the use of instruments, equipment and materials. The use of a practical assistant for a student with very poor motor coordination or a severe visual impairment could potentially compromise the purpose of the assessment (to develop manipulative skills).

Teachers should work with the special educational needs coordinator to determine which arrangements are appropriate and reasonable.

The AQA website will be updated as further guidance becomes available.

Monitoring visits

AQA are committed to making the monitoring process a supportive one. One teacher from the cross board trial stated: “I felt like I should have felt a bit more nervous... but I realised it wasn’t an Ofsted. It was an opportunity for my students to show off their learning and the teachers to show their teaching. It wasn’t a big stick. It could be positive and be helpful for the teachers in putting pressure on their SLTs to make resources available.”

All schools will be monitored for one subject by one of the boards in the first two years of the course. For example, if a school is taking Biology with AQA, while Chemistry and Physics with other boards, AQA would only visit the Biology department, or another board may visit Chemistry or Physics. Larger schools and colleges (who tend to have separate departments) will be visited three times, one visit to each department. AQA’s first visits took place between January and April 2016. Remaining first visits will take place between September 2016 and January 2017, leaving enough time for repeat visits if there is an issue identified.

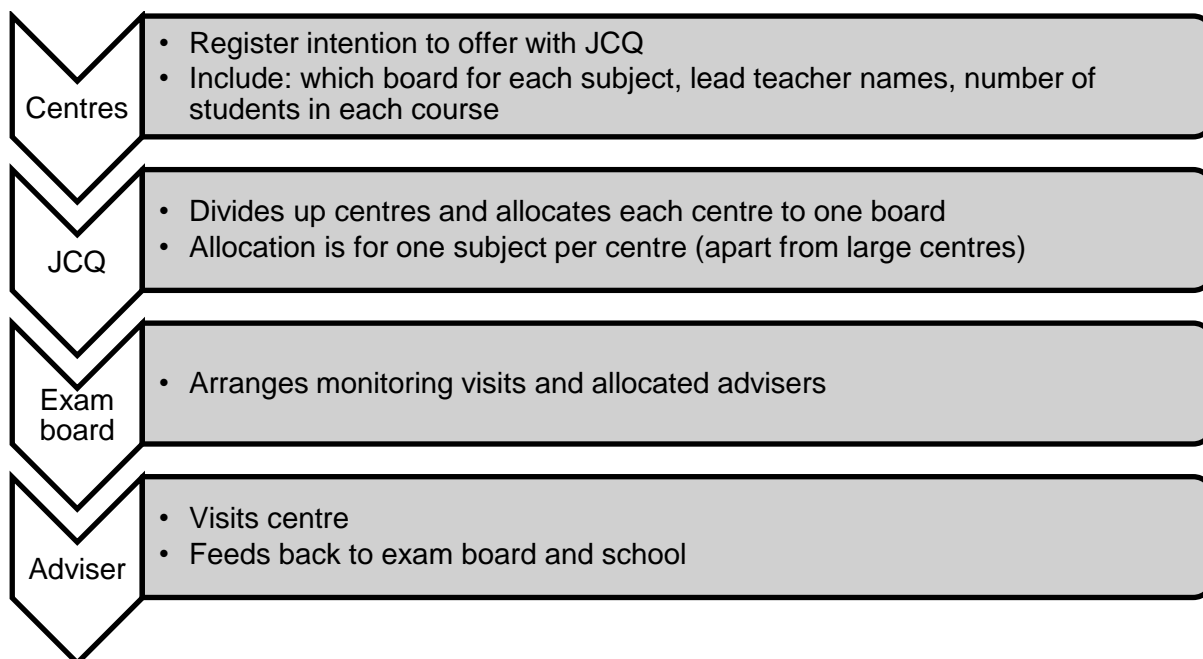
In order to emphasise the supportive nature of the process, we refer to our monitors as advisers.

Advisers will be looking to confirm two things:

- that schools are **compliant** with the **rules**
- that teachers are **assessing** students at the correct **standard**.

Cross-board agreed process and code of conduct

Process



Training

Training on the standard is free and available online on our website. The Lead teacher must undertake this compulsory training and disseminate information as directed by their exam board.

Notice of monitoring

Each exam board is expected to give centres at least 2 weeks' notice of monitoring visits. Where possible, exam boards may take into account centres' timetables, but on most occasions it will be necessary for centres to make arrangements to allow the adviser to observe a practical lesson.

Materials required by the monitor on the day of the visit:

1. Documented plans to carry out sufficient practical activities which meet the requirements of CPAC, incorporating skills and techniques detailed in appendix 5, over the course of the A-level.
2. A record of each practical activity undertaken and the date when this was completed.
3. A record of the criteria being assessed in that practical activity.
4. A record of student attendance.
5. A record of which student met the criteria and which did not.
6. Student work showing evidence required for the particular task with date.
7. Any associated materials provided for the practical activity eg written instructions given.

A timetable for the day and lists of people who the adviser will meet will also be required.

Notes on evidence

Evidence 1: Although there is an expectation that planning to cover the full requirements of the endorsement should take place, plans may be in outline form if seen in the first year of the course. Evidence 2–6: Will only be available after particular activities have taken place. The adviser should take a proportionate view on whether sufficient practical activities have taken place by the time of the visit.

Evidence 7: A similarly proportionate view should be taken on this requirement.

Before the day of monitoring

Exam board/adviser will communicate expectations with the centre, explaining the process, evidence required, the staff and students who will be observed or spoken to, and making arrangements for the day.

On the day of monitoring

The timings of the monitoring visit will be discussed with the centre and will be dependent on the number of students.

Advisers will be expected to:

- meet the Lead teacher for the endorsement of practical work for the subject being visited
- observe a lesson including a practical activity (which may or may not be one of the required practicals) during which students are assessed against the competencies
- discuss the teacher's assessment of the students in the class
- meet students and discuss the practical work that students have been doing (this may take place during the lesson if appropriate)
- view the work of students from the lesson and other classes, as per cross-board agreement
- view teachers' records of assessment of practical work
- follow all rules and procedures as required by the school.

Advisers may undertake formal or informal monitoring for an additional A-level subject when in a school or college where teachers are using the adviser's exam board and have requested or agreed to such monitoring.

Advisers will under no circumstances:

- attempt to persuade teachers who are not currently teaching for the advisers' exam board to change exam boards
- attempt to persuade teachers to change exam boards for GCSE or other courses
- collect information about teachers' names and exam boards for subjects not taking exams with the adviser's board
- meet teachers for A-level subjects where the board used is not the adviser's board except where training is on another qualification where the teacher uses the adviser's board (for example, when a teacher uses different boards for GCSE and A-level)
- accept any sort of gifts from the school or teachers
- make notes that could be constituted as a "lesson observation", or feedback any judgement on teaching and learning to the teacher or school
- make audio, video or photographic records of students without prior explicit permission being granted by the senior leadership of the school and the parents of the students involved
- remove any original students' work from the centre at the end of the visit
- expect teachers to be using a particular method of planning, teaching or assessment.

Feedback

The adviser will not give a formal judgement during the visit. Feedback will be received by the centre following review by the exam board's Lead adviser within 2 weeks of the visit.

Follow up actions

On occasion, the adviser may require supplementary evidence. These will generally be any actions that can take place remotely (for example, emailing or sending evidence or documents to the adviser).

Non-compliant centres

Centres that have not met the required standard will be reported to JCQ for follow up, which may include a follow up visit for the subject and/or monitoring for the other subjects.

Safety

At all times the adviser should comply with health and safety regulations and the instructions of the teacher unless they would put the adviser at risk. The safety of students is the responsibility of the teacher. In particular, advisers should not be left alone with classes, especially where practical work is taking place. Advisers should be chaperoned at all times.

Quality of teaching

The adviser is **not** monitoring the quality of teaching.

Working with students

Advisers must be accompanied at all times whilst in schools and working with students.

Is the adviser role for you?

All of our advisers are practising teachers with a passion for practical work teaching. If you are interested in becoming one of our advisers, please look for our regular advert on our website.

G. Evidence for the endorsement

Centres will be visited by a monitor who will agree with teachers a date for their visit. They are likely to watch practical work taking place, and discuss with the teacher present their views of the competencies exhibited by the students. There should be no need to coach students for this visit, as it is the teachers' abilities to assess practical work that are being monitored, not the students' performance.

The following minimum documentation requirements have been agreed by the awarding bodies, and would be expected to be available to the monitor to view. There is currently no requirement for any of the following to be sent into the exam board.

1. Documented plans to carry out sufficient practical activities which meet the requirements of CPAC, incorporating skills and techniques detailed in appendix 5, over the course of the A-level.
2. A record of each practical activity undertaken and the date when this was completed.
3. A record of the criteria being assessed in that practical activity.
4. A record of student attendance.
5. A record of which student met the criteria and which did not.
6. Student work showing evidence required for the particular task with date.
7. Any associated materials provided for the practical activity eg written instructions given.

There are many ways of fulfilling these requirements. AQA believes that teachers should have the ability to choose the methods they use to collect this documentation. Different schools and colleges will find different ways to track this information depending on local needs. AQA will be providing exemplar methods of tracking this information, but will not be requiring teachers to use specific forms. Advisers will be trained by AQA and will accept the following methods, or alternatives which contain the required information.

1. Documented plans to carry out sufficient practical activities which meet the requirements of CPAC, incorporating skills and techniques detailed in appendix 5, over the course of the A-level.

Note: Appendix 5 here refers to the DfE subject criteria. The apparatus and techniques are listed in sections 7 and 8 of the combined specifications on the AQA website, and the next section in this handbook.

Teachers may wish to keep this information in the following ways:

- Long-term schemes of work which include the required practicals (and any other practicals where teachers will be assessing students' competencies)
- Timetables or lists of dates of each of the practicals
- Sheets stuck in the front of students' lab books.

2. A record of each practical activity undertaken and the date when this was completed.
3. A record of the criteria being assessed in that practical activity.

These records could be kept:

- in a long-term scheme of work, there may be bullet points after each practical identifying the competencies to be completed
- on student sheets, the competences that the teacher will be assessing could be detailed
- on tracking spreadsheets.

4. A record of student attendance.

This could be done via normal school systems if teachers feel that cross-referencing between SIMS or similar and their schemes of work allow them to be confident that all students have done each experiment.

Alternative methods could include:

- tracking spreadsheets
- teacher mark books
- on sheets stuck at the front of students' lab books.

5. A record of which student met the criteria and which did not.

Examples of how this could be recorded:

- tracking spreadsheets
- on individual pieces of work/lab book pages
- an overview page per student at the front of lab books.

6. Student work showing evidence required for the particular task with date.

Teachers must be confident that they are able to assess the quality of students' work in accordance with the relevant CPAC criteria. For example:

- in lab books (allowing all practical work to be kept in one place)
- in students' folders, interspersed with their theory work (allowing the link between practical and theory to be highlighted)
- in computer-based systems
- on individual sheets collected at the end of practical sessions
- in pre-printed workbooks.

In each case, teachers must be able to locate students' work if an adviser visits the centre and asks to see the work.

7. Any associated materials provided for the practical activity, eg written instructions given.

This could include:

- notes in lesson plans or schemes of work
- worksheets or workbooks
- notes made on tracking sheets.

These materials should allow an adviser to understand how much guidance students were given. For example, they could show that teachers gave students full details of an experiment, which would limit the ability of the students to demonstrate the ability to apply investigative approaches.

H. Questions from teachers following the first year of the practical endorsement

The following questions were received during our end-of-year practical webinar that took place in July 2016. The answers were provided by Catherine Witter, AQA's Lead Practical Adviser.

CPAC 1

1. Can you test a large group of students by getting them to do written answers to questions for CPAC 1? Some pupils are expressing concern quietly that they feel like they are being continuously assessed because of the directed questioning - do you have any advice as to how to get around this?

These two questions go together well. To pass CPAC 1, students need to follow the written instructions in the order written, be able to explain the reasons for doing each step and to collect a set of data that would be expected. If they complete some questions that secure independent access to the pass that would be a good alternative to questioning them during the lesson.

2. Do you have to have an accompanying checklist for CPAC 1, or is it enough to record what a student did incorrectly?

When assessing students against CPAC 1, they need to be correctly carrying out the method steps in the right order. They also need to be able to explain why they are doing each step and to get a set of data that you would expect. Lots of teachers are choosing to keep a checklist to secure robust evidence against these assessment criteria but we will not ask to see it. Teachers can make records in whatever form they would like to, to allow them to make an accurate assessment.

3. Is it wrong to do a dry demo of a titration and then next lesson students carry out the titration. You go round and ask question and award CPAC 1?

Teaching the general titration technique before expecting students to do it is good teaching, and this is the case before any assessment of CPAC is carried out. Dry demonstrating the practical method steps the lesson before they follow the written instructions is far less acceptable as the students need to independently show you that they can meet the pass standard in CPAC 1.

Circulating the laboratory and asking questions as they carry out the practical following a written method steps provided will allow you to assess whether they can justify the reasons for carrying out each step. This is one of the assessment criteria for a pass in CPAC 1 and so would be good practice.

4. Do students have to complete all CPAC 1 for all 12 practicals?

To be endorsed for CPAC 1, your students will have to have consistently and routinely met the pass standard in CPAC 1. This may take 3 attempts; it may take all 12 attempts or more if you invite them to be assessed on your own level 3 challenge practical work. When you feel strongly, without question, that your students could follow a set of written instructions, justify the reasons for carrying out each step and collect a set of expected data totally independently of you – and when at university in their first year – then you are less likely to want to assess them on CPAC 1. They must be in this position at the end of the course and so only assessing CPAC 1 to this point in year 12, for example, before stopping would not be recommended.

CPAC 2

1. You mentioned that writing a method showed mastery of CPAC 1. I thought writing up a method was CPAC 2 not CPAC 1?

To demonstrate the pass standard for CPAC 2c, students must be able to write a method and determine which variables to change, control and measure.

To demonstrate the pass standard in CPAC 1, students must follow a written set of instructions provided, be able to explain why they are carrying out each step and collect expected data.

If students followed their own written method steps, providing that they have been carefully checked for both safety and to ensure they will generate expected data, that is a greater step towards total independence and hence a mastery of CPAC 1 is being developed.

Many teachers ask us “Is it okay if students plan a method but then I give them one to follow?”. Often the technician has not got the capacity (or sometimes the apparatus) to support several different methods being followed each time. Of course, we could support that and students would have access to the pass standard for CPAC 1 and 2c if given this task.

2. If a student is supposed to write their own method, why are they published by AQA in a handbook?

Writing a method is a skill that students need to develop. Our exemplar practical work will give students access to the apparatus and techniques that they will be examined on. There are a multitude of practical experiments that you could ask your students to write a set of method steps for, to allow them to access this CPAC 2c strand.

3. Can we assess some CPAC areas for a plan of an investigation (not a required practical) even if the students don't carry out the practical itself?

Absolutely, yes. Aspects of CPAC 2 require students to be able to plan an investigation and if they do this successfully they would reach the pass standard in CPAC 2c. This can be set as a discrete task, you don't have to assess any other CPAC against the work they have done unless you choose to.

CPAC 3

1. For CPAC 3, if a student has broken glassware and not attempted to clean it up, does that mean they have failed for that time?

It is not as clear cut as that. For CPAC 3, students need to be able to identify major hazards, associated risks and control measures. During the practical lesson, they need to be observing the non-negotiable, practical specific safety measures.

Leaving broken glass on the desk or floor without dealing with it will certainly mean that the student has not reached pass standard on that occasion but will hopefully have partially met it. We would also like to think that teachers would report progress to students as them ‘not having shown evidence towards the pass on this occasion’ rather than the much stronger, negative word fail.

2. Is it Physics' fault if students complete CPAC 3 on a simple and safe experiment - they can still carry out a full risk assessment sheet - it may just be limited?

Some practicals are much better vehicles to assess CPAC 3 as they present a greater challenge to students when identifying the major hazards, associated risks and control measures. There are practicals in physics that are therefore more suitable including required practicals 1, 2, 5 and 12 amongst others. All CPAC do not have to be assessed during every practical.

3. With CPAC 3, is 3a about the planning and identifying the hazards and risks (in the way shown in the table on your slides) and then 3b about them actually doing it? I know that may be a simplification but I'm just trying to differentiate between them.

Yes, you have interpreted the information from the webinar correctly.

4. I showed my class a video for the required practical where they make cyclohexene as we do not have enough fume cupboards. I assessed them based on their risk assessment and planning, is this ok despite them not carrying it out themselves?

Assessing CPAC 3a in this way is absolutely fine for this practical although your students do need to have access to doing a practical involving simple distillation. The cyclohexene preparation is a very routine example of how this technique can be used and refers to some important theory which is why we have chosen it but there are others. Please note that Required practicals 5a or 5b can be used as alternatives as they both involve the use of simple distillation.

CPAC 4

1. When assessing CPAC 4, you've said "full headings" are required - is it sufficient to write eg "T / s" in physics as a heading for time period measured in seconds? This was always the preferred method for the old ISAs when standard symbols were used. Would abbreviations include V in place of voltage etc?

There is a section in our practical handbooks to support teachers and their students to keep a record of data whilst carrying out practical work. In the physics handbook this can be found in Section J, page 50.

2. Is biological drawings CPAC 4?

Yes, this is a way of recording qualitative data. Please see one of the downloadable attachments that I used during the webinar on 6th July for support from CLEAPSS if that would be helpful in your own teaching.

3. We couldn't get good results for Physics practical 4 (Young modulus) despite ordering 2 new sets of apparatus. Is it okay for pupils to have poor results and assess that data and still get credit?

Some of the Biology practicals have not worked through no fault of the students. Can we still assess them on a practical that did not give the expected results?

To meet the pass standard for CPAC 4, students need to be able to design a suitable data table and record their data on collection. If the data was poor but is what you as their teacher would expect (as you also collected similar data) the students should not be penalised. If they then go on to process that data to formulate a conclusion, it would be a good exercise to then do some research and

evaluate their data against a secondary source. This would open access to CPAC 5 in a very meaningful way.

4. Students had previously carried out individual test-tubes reactions on individual chemicals and were asked to record observations on an unknown but they could not record all observations and they could not identify the unknown. Can I award CPAC4?

From the information that you have provided we would suggest that they have not met the pass standard in CPAC 4 on this occasion. However, if they have carried out the chemical tests correctly after following a set of written instructions to get a set of data that you would expect, even if they could not independently record it, you may wish to give them credit for meeting the pass standard in CPAC 1 through this practical experience.

5. Is it still acceptable for students to record data in tables CPAC 4b to same number of decimal places or do they have to record to same number of significant figures?

When recording data, students should record data to the correct resolution of the apparatus that they have used to collect that data. For example, a titration would be expected to be collected to 2 decimal places.

6. We were informed by AQA that practicals involving fume hoods could include demonstrations by the teacher (rather than having each pupil in a class taking a turn at a fume hood). If the pupils record observations, is this correct?

Further to my question about fume hoods - could the pupils use their research to inform how the teacher should best carry out the demonstration etc. Would this pass the CPAC?

If you are only assessing CPAC 4 then this approach would be fine. If you had chosen to assess CPAC 1, demonstrations would clearly not be acceptable in the same lesson unless the student was struggling to meet the pass standard and you wanted to use demonstration at the time to improve their technique.

For the second part of your question I recommend using this research towards evidencing CPAC 3 and 5. Students could identify major hazards and associated risks to inform you how to carry out a safe demonstration. Their research could then be referenced fully.

7. Is it appropriate (due to lack of equipment) for individual or pairs of students to make one measurement (eg count rate at one distance) and then combine all results to get class set? (We only have one GM tube and gamma source).

If you can extend that to allow each individual to make a set of repeats of the same measurement, to allow them to independently collect and record a set of data that would more in keeping with the expected pass standard.

CPAC 5

1. CPAC 5 "sources of information are cited demonstrating that research has taken place supporting planning and conclusions". This seemed to imply it will inform the practical they are doing rather than "inform further practical work". Is it the latter now?

The research element of CPAC 5 is to enable students to inform their past, current or future practical work. Whether it is to support method planning, the apparatus to use, to compare the data collected

to a secondary source or to support a conclusion or practical evaluation, the potential for research use is large.

Students should be taught how to research most effectively and how to reference their sources to enable the source to be found again. Students should also have an understanding of the reliability of that resource of course as has been standard at GCSE level.

2. Do students need to use a system for referencing? Our school asks for Harvard system across the board. If pupils reference but not use Harvard what would I mark them as?

The cross board produced pen portrait documents on our website and our Lead teacher online training demonstrate that the successful use of the Harvard system for example would demonstrate mastery in this element of CPAC 5. If they did not do this but referenced the sources well to allow them to be found again they would be meeting the pass standard.

3. If they research a method and it is not feasible to do (ie not the one they would use in class) would they still pass that CPAC?

Do they have to carry out their plan or can they be given a pre-prepared plan AFTER the research phase and still get a positive assessment?

Successful research to inform current or future practical work or to support evaluation of practical work has been done, if referenced correctly, can be used for the assessment of CPAC 5. It is, however, likely that teachers will give them a written method of their own to follow for CPAC 1. This is absolutely fine as it is very likely that students will have chosen to use apparatus that may not be available in a routine school laboratory.

4. I marked a titration practical and gave feedback. Referencing was not as good as I wanted. They asked if they could redo the write up after feedback. Can I still award CPAC 5 for the second draft or is it only the first draft that counts?

Students will have plenty opportunity to access a pass on each of the CPAC areas as they go through the course. The first draft will count, the students concerned will have partially met CPAC 5, but they will have also understood what you require for referencing when they next meet some research work.

To meet the pass standard, students must independently meet the pass standard consistently and routinely across all five competency areas by the end of the course. A second draft as described would mean that they hadn't independently achieved the CPAC 5b pass standard.

5. On CPAC 5 it says 'Uses appropriate software and/or tools to process data & report findings'.

Must they use software to pass this, or would drawing graphs by hand, using calculators to perform calculations suffice?

A calculator is a tool and so to gain evidence towards the pass for CPAC 5 this would suffice. However all the apparatus and techniques in the specification must be covered to ensure that your students have full access to the examination questions and so if data can be collected and processed using dataloggers or Excel for example, that will be a good experience for your students to have.

6. For the award of CPAC 5, is it okay for students to write up instructions for testing for ions after having carried out the experiments?

If you are assessing CPAC 2, planning a method, then the way that you have described has not given them independent access to the task in hand as they have simply copied out the instructions given. They would not pass CPAC 5 on this occasion.

CPAC 5, Researches, references and reports involves data processing and referencing in addition to providing a structured report of what a student has done.

General queries

1. What level of detail is required in terms of marking the key practical assessments to show evidence that students have met the required competency standards?

Visiting advisers do not expect to see feedback given in any particular way. The majority of teachers are however using written feedback to communicate to their students how they might improve against the pass assessment criteria for any particular CPAC.

The adviser will be quality assuring teacher assessment of CPAC during their visit. If there is no feedback in student lab book records it will be necessary for the adviser to question the subject teachers at length to ensure they can indeed assess student work correctly.

2. Have schools used a standard proforma for marking and assessment of student practical work?

No. We will not be providing one either as the lead teacher online training clearly outlines what the pass standard looks like for all five CPAC areas. If you look on the website you will find a teacher checklist that we have written, to crystallise the assessment criteria for pass. Teachers will then use those as guidance to think through in advance how the practical they are delivering will allow student access to those criteria.

We have provided an exemplar set of 12 required practicals that together will ensure that students access all the apparatus and techniques they will need to be able to answer the practical questions in the written exams. Providing common proformas that all teachers mark to will, in effect, mean that we have gone backwards as teachers will then see them as 12 controlled assessments.

Teachers have the flexibility to assess CPAC as often as they want to, through any practical work of appropriate challenge they wish to. When teachers have fully grasped the key messages from the online training they will be in a position to assess CPAC accurately without the need for prescriptive mark schemes.

3. When two worksheets are given in the practical handbook for a required practical, for example 5a and 5b in chemistry, do we need to do both, or is only one is enough? With my group, I only did 5b which had more skills involved in compared to 5a.

In this case, 5a or 5b are optional, you were right to choose only one as they both gave the students the opportunity to experience simple distillation. You do however need to ensure that you have covered the theory associated with both practical schedules.

However, required practicals 7 and 10 in Chemistry also each contain parts a and b. In the case of required practicals 7 and 10, these are not optional as they cover different apparatus and techniques and so students must complete practical work that covers those apparatus and techniques.

4. Will we have to send off the practical books to the exam board?

Your monitoring visit is to quality assure teacher assessment of CPAC. Once we are confident that you can apply the assessment criteria accurately you can endorse your students at the end of Year 13 without AQA requiring any further evidence from you. You will therefore not be required to send us any examples of marked student lab books or teacher records.

5. What are the most common reasons why schools have not been endorsed?

Approximately 10% of schools and colleges who have already had their first monitoring visit require a second visit. Most commonly that is because subject teachers have not completed the necessary training to be able to apply the CPAC assessment criteria accurately. Tracking progress inaccurately is also a common reason.

Teachers are currently working very hard during the planning stage to enable students to access CPAC assessment regularly to enable students to eventually be able to 'consistently and routinely' meet the pass standard. Therefore if the planning documentation for the opportunities for CPAC assessment is not in place, more correspondence between the adviser and lead teacher will be required before the written report is finalised.

6. Do we notify AQA via e-AQA of the pass/not classified?

Yes, cross-board discussion currently is about how we will ask you to communicate your students' practical skills endorsement pass/not classified to us.

The final date for reporting this to AQA is 15 May 2017.

7. Can students pass the A-level if they are 'not classified' in the practical skills endorsement in May 2017?

Students will get a certificate in the A-level if they achieve a grade E or above overall. If they pass the practical skills endorsement and fail to achieve a grade, they will not receive a certificate. Students can therefore pass the A-level grades A*–E if they are given a non-classified report in their practical skills.

8. What is the consequence for getting a "not classified"? SLT has asked what are consequences of failing our AQA practical audit for pupils?

Higher Education admissions tutors were a strong voice heard in A-level reform. Over time, AQA expects the practical endorsement reported to be a significant part of the student offer as universities get to grips with the changes to practical work in the new specifications. We do feel strongly that upwards of 95% of all students taking A-level sciences should be able to reach the pass standard and so pass the practical skills endorsement. Good science teachers will give their students many opportunities to hone their skills to ensure they can demonstrate them routinely and consistently.

Ofqual also plans to do some research. They will then be able to measure the impact of the changes to practical work assessment in the reformed specifications.

9. May the requirement of CPAC grades be classified in Distinction, Merit, Pass or Fail?

The only two ways of reporting the practical skills endorsement are pass or non-classified. Most teachers will encourage their students to demonstrate a mastery of the five CPAC however.

10. One of my students has missed their Biology TLC practical. We are also doing TLC in Chemistry - can they use evidence from the Chemistry practical for the Biology endorsement?

We agree that the TLC technique is the same regardless of subject. Please be aware, however, that students often find applying their knowledge difficult and so if you can encourage a catch up opportunity, as is the standard expectation when students are absent, that would be the best scenario for the student in our opinion.

11. What is the best support we can give to our technician (Chemistry) who will have to do all practicals for A-levels and has no experience of A-level Biology or Physics?

We have recently surveyed a large number of science technicians who support teachers delivering A-level science. We are currently thinking about how we might be able to support them but in the meantime we suggest that you give them a copy of the practical handbook for each subject where they will find technician notes to help them to help you.

If they are not already a member of a technician forum, that might be something to consider. Many technicians tap into a support network every day to share best practice.

12. If we are only assessing 6–8 students in a lesson and only assessing one or two CPACs at a time and only tracking progress of the required practicals, there is a worry that we will not be able to get through all students and all CPACs isn't there?

Yes. For schools and colleges who plan only to deliver the minimum number of required practicals, detailed in our practical handbooks, this is a risk if the approach in the question is taken. Assessment of CPAC needs to be robust however and manageable in the practical lesson time should teachers be assessing CPAC 1,2a, 2b, 2d, 3b and 4.

Teachers who adopt this approach are therefore utilising homework and testing well to enable CPAC assessment. Many teachers are recycling legacy ISA and EMPA questions that fit with CPAC assessment and using those.

13. I thought the Verbal Feedback Stamp was now already out of date and frowned upon by many. Verbal feedback is usually always given. Surely a stamp does not confirm this? This seems to be here to tick certain boxes for School Marking Policy.

It is not for AQA to comment upon the different Teaching and Learning policies that each school adopt. We chose to share that during our webinar as it was working well for the school using it. Teachers are often concerned about the amount of written feedback expected in lab books and so this is one alternative to reassure teachers that AQA will not be expecting to see feedback in any one specific form. Feedback can be given to students in many ways and teachers will take the approach no doubt that is most beneficial to their own students and the progress they make against the CPAC.

14. Are we okay with students annotating their instruction sheets?

Often this is a good way of assessing CPAC 2b. When students are carrying out their written instructions they may identify ways to adjust the method slightly to enable more accurate data to be collected. If CPAC 1 is the focus of assessment then students can only access the pass standard if they have followed the written instructions independently and so annotation reflecting whole class support prior to the start of the practical would clearly not be conducive to that.

15. Can't we assess the 5 CPACs in each practical? Do you think an average student can meet all the CPAC standards in just the required practical work?

If teacher plans reflect a rigorous assessment of each CPAC area before the end of the course then we would support that completing the minimum 12 required practicals would allow students to reach a pass in the endorsement.

All five CPAC can be assessed in a single practical experience yes but it is unlikely that it would be possible in the practical lesson time alone, even for a handful of students. Using homework and test questions and time maybe a lesson before and/or after the practical lesson itself would allow teachers to plan specific activities through which all five competencies could be assessed.

16. When will the new tracker be available?

Our new trackers are available on our website now. There will also be a small selection of trackers that colleagues from schools and colleges have shared with us during our monitoring visits so that teachers can see how others are approaching the tracking requirement.

17. We have had an email saying an adviser is coming for our Biology A-level but have not had communication regarding Chemistry. Will this be done on the same visit?

If we have already had a monitoring visit, would we get another one this year?

JCQ have allocated a biology monitoring visit for your school and so we will not require any documentation from the chemistry department on this occasion. Small centres, where each subject has fewer than 140 entries, have one visit to one subject for each examination series.

If successful, all three subjects at the school or college can endorse their students for the first time by 15 May 2017.

18. How will you manage the monitoring visits to overseas schools such as ours?

If your school has been allocated to AQA by JCQ we will be in touch with you shortly to arrange your monitoring visit in the autumn term or just after. All other international schools and colleges who offer our qualifications worldwide will be contacted to see how monitoring of their lesson, teacher records and student records may be best quality assured. This may include the use of modern technology and postal sampling although we will aim to carry out the full monitoring experience in person if appropriate.

19. Is a Physics exemplar lab book on the AQA website? Is there anywhere centrally we can access each practical proformas already planned out like the one in worksheet 1? To save us all doing these?

A lab book is a collection of student practical work. This is not something that we plan to put onto the website as a document but there are several examples of resources that show student work in

photographic form. On the practical website page you will find the webinar recording and slides, a number of presentations etc.

The required practicals in our specifications are suggested practicals that incorporate the apparatus and techniques that students will be examined on. We aim to keep practical work at A-level very open and so will not be creating or sharing a set of materials bespoke to each of the 12 practicals. We feel this will dampen teacher planning and enthusiasm to try new practical methods with their students.

20. Do you have additional support for teachers outside subject specialism? Do we have dates for the courses yet? Where can we find them?

We have run a number of very successful courses in Leicester, Leeds, Manchester and London during the summer term after two initial pilot courses earlier in the year. These courses are aimed at offering teachers the opportunity to carry out the 12 required practicals for themselves with guidance about how to integrate CPAC assessment.

Dates for the autumn term are currently being decided. You will find details in the science section of the CPD area on the AQA website.

21. Are you allowed to discuss which CPACs students need to work on more over the 2 year course?

Many teachers are sharing the tracking documentation with their students to inform them about which CPAC need more work if they are to reach the pass standard and their practical skills be endorsed at the end of year 13. I have seen many students tracking their own progress, interacting with teacher written feedback after practical work has taken place.

22. How do we do the distillation of ethanal practical due to the recent safety concerns? We only have 3 fume cupboards.

Our required practicals are only suggestions. We have worked hard to incorporate the apparatus and techniques for teachers but recognise that teachers may wish to choose an alternative practical that incorporates simple distillation if they wish to. Practical 5a or 5b are alternatives as they both include simple distillation and so only one needs to be completed. However, these are not the only options.

23. During the monitoring visit, do we have to show an endorsed practical?

During the visit, your adviser (monitor) will need to see students doing some practical work. It can be any practical work of level 3 challenge; it does not need to be one of our 12 required practicals. The purpose of the visit is to quality assure teacher assessment and so it might be helpful to assess some of the CPAC criteria whilst teaching the lesson although this is not compulsory.

24. Please could you advise how I can access the Compulsory Lead teacher online training? Do all teachers have to do the CPAC training and get their own certificate?

The practical page of our website will signpost all the help that you will need to deliver the A-level practical work and endorsement of your students. Our compulsory lead teacher training is only compulsory for the lead teacher as indicated but in our experience all teachers who deliver our new specifications in many schools and colleges that we have visited are completing it. Many technicians are also completing it.

25. Do students need to write a full write up for each 6 practicals?

That is entirely up to you and what you require them to learn from the exercise. You may have assessed one of the competency areas and just need evidence for that perhaps?
All the required practicals, however, can be assessed through terminal examination and so they should be written up in a form that students can revise from.

26. If a student drops physics, ie not studying year 13, do we need their documents for any reason?

The CPAC are generic across all three sciences and so if this applies we would recommend passing their work across to their other science teachers to provide extra evidence.
You will no longer need to keep your own records of the CPAC progress in physics if they are not likely to take it any further or move to another establishment to study it.

27. Will the AQA examiner be looking at OCR courses at the centre? For example my Physics course is AQA, but Chemistry and Biology are OCR.

The AQA adviser, if allocated an AQA subject visit by JCQ, will only monitor the work done by teachers and students in that specific subject. If we have contacted you, the visit will be for Physics only for example.

28. Do you have any tips to improve consistency of approach across the department?

There are many subject teams that have a large number of teachers and there are strategies they are using to secure, strong quality assurance. We would advise discussing the practical work first as a team, deciding which CPAC might be more suitable to assess in each one before collectively deciding on the assessment criteria that you would be looking for uniformly across all teachers and classes of students.

Lots of teachers are using checklists to help them to do this but we would not be asking to see them during a monitoring visit if this was the case.

29. CPAC5a and CPAC5b could be assessed in different experiments. How would that be recorded in the tracker?

Our trackers have a tab for each of the required practicals and there are also tabs to record teacher assessments after other practical work has been completed.

Holistically, as long as the pass standard has been met in CPAC 5 consistently and routinely, the student can be endorsed in CPAC 5.

30. With Physics there are some practicals that require equipment we cannot afford to buy as class sets such as the one where Hall probes/an oscilloscope are used to investigate magnetic fields. How can we assess pupils for the CPACs for this?

We understand that equipment, particularly in Physics, can be costly. Students must be able to demonstrate the five competencies independently to be endorsed and many schools and colleges are using a carousel in practical Physics lessons for example to ensure this can happen with limited apparatus.

31. One of our students has transferred to us from another college, he has done AQA at his old college too. What do we do about his progress against CPACs?

As the second centre, you have full responsibility for the assessment of CPAC and the endorsement of this student's practical skills. They must be assessed at pass standard consistently and routinely across all five CPAC areas and so in year 13 it is important that he or she has many opportunities to demonstrate this to you.

I recognise that this is difficult and potentially very time consuming and so I recommend contacting the previous college and asking for any related documentation to be passed across to you. The student file with their AS work will also be a useful starting point for evidence of CPAC 4 and 5 for example.

32. I am wondering about what you said in terms of many schools are doing more than 12 minimum practicals. I am struggling a little to fit in the 'official' practicals (recommended ones) but can I also include any other practicals I do?

Absolutely. The CPAC can be assessed through any level 3 challenge practical work as well as through the minimum 12 required practicals. Many schools and colleges are doing more to allow the teaching of a practical technique, access to new apparatus for example before assessing students on the use of them.

It is also likely that some of your students will need a few more attempts at demonstrating a competency area to you before they are routinely and consistently reaching the expected pass standard.

33. For our visit next year, would you expect to see the work of students who are not continuing onto the full A-level?

The endorsement of practical skills happens at the end of year 13 and so we would not need to see the work of any students who have chosen not to continue with the subject. During your visit a sample of work will be chosen from all students who are in Year 12 or 13. Your adviser will explain how we do this when they make contact with you.

34. We have class sizes of around 22. I would be interested in any strategies to carrying out the necessary discussions with students during lesson time

Perhaps consider only assessing one student in each pair, for example, during the lesson or if your lesson time is short, only a third of the class on any one occasion. This will depend of how many practicals that you plan to do over the duration of the course.

Students need to be able to explain the reasons for carrying out each step as they do a practical if you are assessing CPAC 1. Using an associated homework or test question to allow them to do this may also be a valuable way of assessing numbers of students at any one time and I understand that this may be your preference.

35. If a student has achieved a CPAC during that particular practical, but not often enough for it to be 'consistently and routinely' - would this appear as green or amber on the endorsement tracker you've provided?

There is a practical tab for each of the required practicals in our tracker. If you are using these over time you might expect the student to meet the pass standard in each CPAC more regularly. In other

words, moving through the tabs if the colour green is seen for CPAC 1 more often than not, the students is consistently and routinely meeting the pass standard.

If you are using just one sheet to record all progress made towards the pass standard in CPAC 1 you will be moving from red to amber through to green as you assess students are meeting the pass standard more and more over time. Through your records I expect that you are making a note of how many times that you have given them access to each competency.

36. Can I tell students exactly what I will be looking for in order for them to pass a criterion before the practical?

It is becoming common practice for teachers to tell their students what CPAC(s) they will be assessing in particular practicals. It is perfectly acceptable to scaffold their task to allow them to access the assessment criteria for pass that you have learned about when completing the online training materials. Over time, the withdrawal of that scaffolding will allow students to become more and more independent, indicative of a mastery of the competency area.

37. I was wondering, if a student doesn't meet the criteria for a particular part of a given CPAC, does this mean they fail their AS/A-level? Also, if they do not meet the criteria for a given CPAC, are they allowed to repeat the practical?

Each student must meet the pass standard in all parts of all five CPAC, consistently and routinely, before the end of the course in order for you to endorse their practical skills.

Repeating a practical will not stretch or challenge a student but, if students are struggling to meet the pass in CPAC 1 for example, giving them access to another practical of level 3 challenge, to allow them to demonstrate their ability to follow a set of written instructions, would be the next step.

38. Will centres have the checklist that monitors have for their visit?

All our advisers at AQA that carry out the monitoring visits in schools and colleges have had an extra full training day, over and above the completion of a pre-training day assessment that is a larger version of the online training test. All the paperwork that they use to support them doing the monitoring visit can be found on our practicals page on our website, most of which is also emailed out to the lead teacher when the adviser makes first contact.

39. I visited a school last week who said they had a record of the practicals and just ticks in the books. They were told more feedback was needed from the teachers. I'm feeling confused with the level of feedback you want us to give.

It is hard to comment on this occasion as I have not seen the lab books that you refer to. The adviser who carries out your visit will look at a sample of student lab book records and will be able to see if the pass standard has been reached across the CPAC areas. Admittedly this is more difficult for the quality assurance of CPAC 1, 2a, 2b, 2d, 3b without teacher feedback as they are competencies that are assessed during a lesson as students manipulate apparatus, work safely etc.

Feedback can be given in many forms and is essentially for the student to allow them to make progress. If the adviser finds their quality assurance exercise difficult, with the absence of feedback to students, they will ask a number of questions to ascertain teachers thorough understanding of the assessment criteria. We will support you as much or as little as you need to become fully fluent with all the CPAC assessment criteria both through our online training and other associated resources that you will find on our practical page of the website.

40. We were told that a hard back lab book was most appropriate during our monitoring visit. Can we continue to use exercise books or should buy new ones?

Across the country, teachers are using many different approaches to supply students with lab records, namely their practical work being kept together. We have seen exercise books as you have described, loose leaf wallets, arch lever folders, hard backed lab books etc. Essentially, I would suggest using the approach that is best for your students. If they are not very organised and likely to lose sheets if they are kept in loose leaf form, then a book of some sort is best. Hard backed books are more resilient to everyday use and are most portable over time but not the only way to correctly house practical work.

41. If a student completes a practical but does an incorrect calculation can they still be awarded a CPAC? Also, if students are given an opportunity to correct the calculation is that work no longer acceptable for CPAC?

This depends on what you have chosen to assess as only CPAC 5 involves calculation work and data processing. CPAC 1, for example, assesses a student's ability to follow a set of written instructions and so in this case your student could still access a pass if they collected a set of data that you would expect.

If your students were given help after their first attempt at a calculation that you regard as too much help for them to independently correct the calculation then I would assess it as a partial pass on this occasion if most but not all of the calculation steps were carried out correctly.

42. Please could you advise how I can access the compulsory lead teacher online training?

The online training can be found on our practicals webpage which is accessible through the Biology, Chemistry and Physics pages.

43. For A-level Physics practical 12 (inverse square law for gamma radiation). Can I use UV Photo diode instead of gamma. A class set is cheaper to get than gamma. It works really well.

In order for a student to be awarded the practical endorsement, he or she must gain experience in all of the apparatus and techniques specified on pages 80 and 83 of the specification. This is a compulsory part of the full A-level course. AT I demands the use of ionising radiation, including detectors. It is therefore a requirement for the full A-level. Additionally one of the required practicals for the AQA award at full A-level is an Investigation of the inverse-square law for gamma radiation, so we would expect students to be familiar with that particular experiment and its underlying principles.

Using a UV photodiode or an LDR would reinforce general skills in the inverse square law, but by itself, it is not a suitable replacement for AT I or Practical 12 as students are not gaining experience of using a source of ionising radiation.

It is clear that students must have, either individually or in a group, hands-on experience of the use of ionising radiation including the use of detectors. This can be achieved using simple domestic equipment that emits ionising radiation. Such equipment could consist of thorium-coated gas mantles or commercial smoke detectors of the type that include an alpha emitter.

In terms of a follow-up investigation, this could include a practical simulation involving radiation from the electromagnetic spectrum other than gamma radiation. It could also include spreadsheet analysis of raw data obtained from a gamma experiment but which had not necessarily been obtained within the centre itself.

I. Cross-board apparatus and techniques and AQA required practical activities

The apparatus and techniques lists for Biology, Chemistry and Physics are common to all boards. Students taking any specification in these subjects are expected to have had opportunities to use the apparatus and develop and demonstrate the techniques.

The required practical activities in each subject are specific to AQA. We have written our specifications so that AS is co-teachable with the A-level specification. Therefore the first six required practicals are included in both specifications and the second six are A-level only.

Carrying out the 12 required practicals in the full A-level will mean that students will have experienced the use of each of the expected apparatus and techniques. Teachers are encouraged to develop students' abilities by inclusion of other opportunities for skills development, as exemplified in the right-hand column of the content section of the specification.

Teachers are encouraged to vary their approach to the required practical activities. Some are more suitable for highly structured approaches that develop key techniques. Others allow opportunities for students to develop investigative approaches.

This list is not designed to limit the practical activities carried out by students. A rich practical experience for students will include more than the 12 required practical activities. The explicit teaching of practical skills builds students' competence. Many teachers will also use practical approaches to the introduction of content knowledge in the course of their normal teaching. Students' work in these activities can also contribute towards the endorsement of practical skills.

For the endorsement all students must have experienced use of one of the alternatives in the apparatus and techniques list. So, for example, in chemistry, students can pass the **endorsement** if they have measured pH using pH charts or a pH meter or a pH probe on a data logger.

However, to best prepare students for **exams**, teachers should ensure that all students understand each of the alternatives so they can answer questions on practical work that involve any of these. **Therefore, all "or" statements in the apparatus and techniques list should be viewed as "and" statements for the written exams.**

Chemistry apparatus and techniques



Apparatus and techniques	
AT a	Use appropriate apparatus to record a range of measurements (to include mass, time, volume of liquids and gases, temperature)
AT b	Use water bath or electric heater or sand bath for heating
AT c	Measure pH using pH charts, or pH meter, or pH probe on a data logger
AT d	Use laboratory apparatus for a variety of experimental techniques including: <ul style="list-style-type: none">• titration, using burette and pipette• distillation and heating under reflux, including setting up glassware using retort stand and clamps• qualitative tests for ions and organic functional groups• filtration, including use of fluted filter paper, or filtration under reduced pressure
AT e	Use volumetric flask, including accurate technique for making up a standard solution
AT f	Use acid–base indicators in titrations of weak/strong acids with weak/strong alkalis
AT g	Purify: <ul style="list-style-type: none">• a solid product by recrystallisation• a liquid product, including use of separating funnel
AT h	Use melting point apparatus
AT i	Use thin-layer or paper chromatography
AT j	Set up electrochemical cells and measuring voltages
AT k	Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances
AT l	Measure rates of reaction by at least two different methods, for example: <ul style="list-style-type: none">• an initial rate method such as a clock reaction• a continuous monitoring method

Chemistry required activities (1-6 AS), (1-12 A-level)



Required activity	Apparatus and technique reference
1. Make up a volumetric solution and carry out a simple acid–base titration	a, d, e, f, k
2. Measurement of an enthalpy change	a, d, k
3. Investigation of how the rate of a reaction changes with temperature	a, b, k
4. Carry out simple test-tube reactions to identify: <ul style="list-style-type: none"> • cations – Group 2, NH_4^+ • anions – Group 7 (halide ions), OH^-, CO_3^{2-}, SO_4^{2-} 	d, k
5. Distillation of a product from a reaction	b, d, k
6. Tests for alcohol, aldehyde, alkene and carboxylic acid	b, d, k
7. Measuring the rate of reaction: <ul style="list-style-type: none"> • by an initial rate method • by a continuous monitoring method 	a, k, l a, k, l
8. Measuring the EMF of an electrochemical cell	j, k
9. Investigate how pH changes when a weak acid reacts with a strong base and when a strong acid reacts with a weak base	a, c, d, k
10. Preparation of: <ul style="list-style-type: none"> • a pure organic solid and test of its purity • a pure organic liquid 	a, b, d, g, h, k b, d, g, k
11. Carry out simple test-tube reactions to identify transition metal ions in aqueous solution	b, d, k
12. Separation of species by thin-layer chromatography	i, k

J. Tabulating data

It is important to keep a record of data whilst carrying out practical work. Tables should have clear headings with units indicated using a forward slash (solidus) before the unit.

Time / min	Temperature / °C
0	14.8
1	14.7
2	14.6

Although using a forward slash (solidus) is the standard format, other formats are generally acceptable. For example:

Volume in cm ³	Time taken in s
15	23
25	45
35	56

Concentration (mol dm ⁻³)	Time (s)
1.0	152
1.5	93
2.0	54

It is good practice to draw a table before an experiment commences and then enter data straight into the table. This can sometimes lead to data points being in the wrong order. For example, when investigating the pH change in an acid-base titration, a student may do a number of pH measurements at 10, 20, 25, 30 and 35 cm³ of reagent added, and then investigate the range between 20 and 30 further by adding readings at 22, 24, 24.5, 25, 25.5, 26, 28. Whilst this is perfectly acceptable, it is generally a good idea to make a fair copy of the table in ascending order of temperature to enable patterns to be spotted more easily. Reordered tables should follow the original data if using a lab book, data should not be noted down in rough before it is written up.

It is also expected that the independent variable is the left hand column in a table, with the following columns showing the dependent variables. These should be headed in similar ways to measured variables. The body of the table should not contain units.

Tabulating logarithmic values

When the logarithm is taken of a physical quantity, the resulting value has no unit. However, it is important to be clear about which unit the quantity had to start with. The logarithm of a time in seconds will be very different from the logarithm of the same time in minutes.

These should be included in tables in the following way:

Reading number	time / s	log (time / s)
1	2.3	0.36
2	3.5	0.54
3	5.6	0.75

K. Significant figures

Data should be written in tables to the same number of significant figures. This number should be determined by the resolution of the device being used to measure the data or the uncertainty in measurement. For example, a sample labelled as “1 mol dm⁻³ acid” should not be recorded in a table of results as 1.0 mol dm⁻³.

There is sometimes confusion over the number of significant figures when readings cross multiples of 10. Changing the number of decimal places across a power of ten retains the number of significant figures **but changes the accuracy**. The same number of decimal places should therefore generally be used, as illustrated below.

0.97	99.7
0.98	99.8
0.99	99.9
1.00	100.0
1.10	101.0

It is good practice to write down all digits showing on a digital meter.

Calculated quantities should be shown to the number of significant figures of the data with the least number of significant figures.

Example:

Calculate the concentration, in mol dm⁻³, of a solution of sodium hydroxide that contains 0.28 mol of NaOH in 465 cm³ of water.

$$\text{Concentration} = \frac{0.28}{465} \times 1000 = 0.59$$

Note that the concentration can only be quoted to two significant figures as the number of moles is only quoted to two significant figures.

Equipment measuring to half a unit (eg a thermometer measuring to 0.5 °C) should have measurements recorded to one decimal place (eg 1.0 °C, 2.5 °C). The uncertainty in these measurements would be ±0.25, but this would be rounded to the same number of decimal places (giving measurements quoted with uncertainty of (1.0 ± 0.3) °C etc).

L. Uncertainties

Sources of uncertainties

Students should know that every measurement has some inherent uncertainty.

The important question to ask is whether an experimenter can be confident that the true value lies in the range that is predicted by the uncertainty that is quoted. Good experimental design will attempt to reduce the uncertainty in the outcome of an experiment. The experimenter will design experiments and procedures that produce the least uncertainty and to provide a realistic uncertainty for the outcome.

In assessing uncertainty, there are a number of issues that have to be considered. These include:

- the resolution of the instrument used
- the manufacturer's tolerance on instruments
- the judgments that are made by the experimenter
- the procedures adopted (eg repeated readings)
- the size of increments available (eg the size of drops from a pipette).

Numerical questions will look at a number of these factors. Often, the resolution will be the guiding factor in assessing a numerical uncertainty. There may be further questions that would require candidate to evaluate arrangements and procedures. Students could be asked how particular procedures would affect uncertainties and how they could be reduced by different apparatus design or procedure

A combination of the above factors means that there can be no hard and fast rules about the actual uncertainty in a measurement. What we can assess from an instrument's resolution is the **minimum** possible uncertainty. Only the experimenter can assess the other factors based on the arrangement and use of the apparatus and a rigorous experimenter would draw attention to these factors and take them into account.

Readings and measurements

It is useful, when discussing uncertainties, to separate measurements into two forms:

Readings
the values found from a single judgement when using a piece of equipment

Measurements
the values taken as the difference between the judgements of two values.

Examples

When using a thermometer, a student only needs to make one judgement (the height of the liquid). This is a reading. It can be assumed that the zero value has been correctly set.

For burettes and rulers, both the starting point and the end point of the measurement must be judged, leading to two uncertainties.

The following list is not exhaustive, and the way that the instrument is used will determine whether the student is taking a reading or a measurement.

Reading (one judgement only)	Measurement (two judgements required)
thermometer	ruler
pH meter	stopwatch
top pan balance	analogue meter
measuring cylinder	burette
volumetric flask	

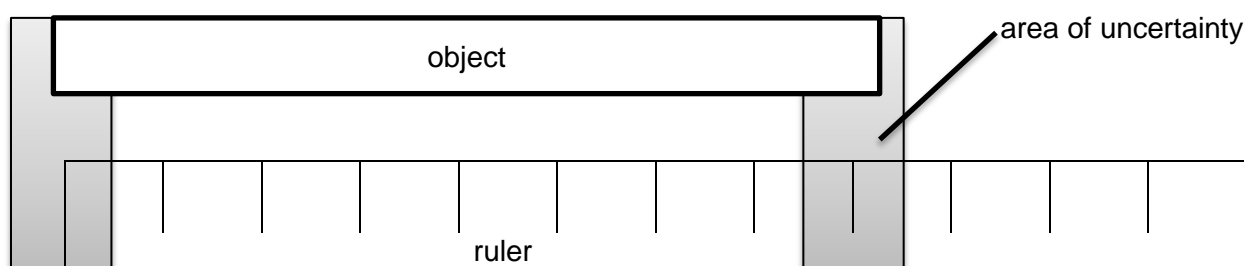
The uncertainty in a **reading** when using a particular instrument is **no smaller** than plus or minus half of the smallest division or greater. For example, a temperature measured with a thermometer is likely to have an uncertainty of ± 0.5 °C if the graduations are 1 °C apart.

Students should be aware that readings are often written with the uncertainty. An example of this would be to write a voltage as (2.40 ± 0.01) V. It is usual for the uncertainty quoted to be the same number of significant figures as the value. Unless there are good reasons otherwise (eg an advanced statistical analysis), students at this level should quote the uncertainty in a measurement to the same number of decimal places as the value.

Measurement example: length

When measuring length, **two** uncertainties must be included: the uncertainty of the placement of the zero of the ruler and the uncertainty of the point the measurement is taken from.

As both ends of the ruler have a ± 0.5 scale division uncertainty, the measurement will have an uncertainty of ± 1 division.



For most rulers, this will mean that the uncertainty in a measurement of length will be ± 1 mm.

This “initial value uncertainty” will apply to any instrument where the user can set the zero (incorrectly), but would not apply to equipment such as balances or thermometers where the zero is set at the point of manufacture.

In summary

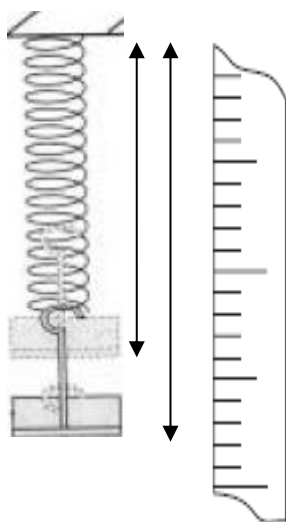
- The uncertainty of a reading (one judgement) is at least ± 0.5 of the smallest scale reading.
- The uncertainty of a measurement (two judgements) is at least ± 1 of the smallest scale reading.

The way measurements are taken can also affect the uncertainty.

Measurement example: the extension of a spring

Measuring the extension of a spring using a metre ruler can be achieved in two ways.

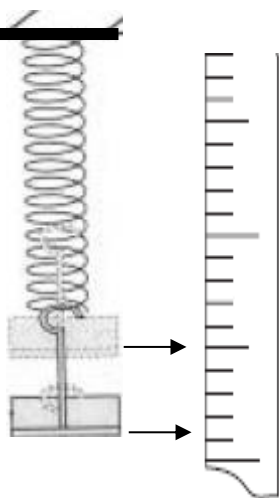
1. Measuring the total length unloaded and then loaded.



Four readings must be taken for this: The start and end point of the unloaded spring's length and the start and end point of the loaded spring's length.

The minimum uncertainty in each measured length is ± 1 mm using a meter ruler with 1 mm divisions (the actual uncertainty is likely to be larger due to parallax in this instance). The extension would be the difference between the two readings so the minimum uncertainty would be ± 2 mm.

2. Fixing one end and taking a scale reading of the lower end.



Two readings must be taken for this: the end point of the unloaded spring's length and the end point of the loaded spring's length. The start point is assumed to have zero uncertainty as it is fixed.

The minimum uncertainty in each reading would be ± 0.5 mm, so the minimum extension uncertainty would be ± 1 mm.

Even with other practical uncertainties this second approach would be better.

Realistically, the uncertainty would be larger than this and an uncertainty in each reading of 1 mm or would be more sensible. This depends on factors such as how close the ruler can be mounted to the point as at which the reading is to be taken.

Other factors

There are some occasions where the resolution of the instrument is not the limiting factor in the uncertainty in a measurement.

Best practice is to write down the full reading and then to write to fewer significant figures when the uncertainty has been estimated.

Examples

A stopwatch has a resolution of hundredths of a second, but the uncertainty in the measurement is more likely to be due to the reaction time of the experimenter. Here, the student should write the full reading on the stopwatch (eg 12.20 s), carry the significant figures through for all repeats, and reduce this to a more appropriate number of significant figures after an averaging process later.

If a student measures the length of a piece of wire, it is very difficult to hold the wire completely straight against the ruler. The uncertainty in the measurement is likely to be higher than the ± 1 mm uncertainty of the ruler. Depending on the number of “kinks” in the wire, the uncertainty could be reasonably judged to be nearer ± 2 or 3 mm.

The uncertainty of the reading from digital meters depends on the electronics and is not strictly the last figure in the readout. Manufacturers usually quote the percentage uncertainties for the different ranges. Unless otherwise stated it may be assumed that ± 0.5 in the least significant digit is to be the uncertainty in the measurement. This would generally be rounded up to ± 1 of the least significant digit when quoting the value and the uncertainty together. For example (5.21 ± 0.01) V. If the reading fluctuates, then it may be necessary to take a number of readings and do a mean and range calculation.

Uncertainties in given values

In written exams, students can assume the uncertainty to be ± 1 in the last significant digit. For example, if a boiling point is quoted as being 78°C , the uncertainty could be assumed to be $\pm 1^\circ\text{C}$. The uncertainty may be lower than this but without knowing the details of the experiment and procedure that lead to this value there is no evidence to assume otherwise.

Repeated measurements

Repeating a measurement is a method for reducing the uncertainty.

With many readings one can also identify those that are exceptional (that are far away from a significant number of other measurements). Sometimes it will be appropriate to remove outliers from measurements before calculating a mean. On other occasions, particularly in Biology, outliers are important to include. For example, it is important to know that a particular drug produces side effects in one person in a thousand.

If measurements are repeated, the uncertainty can be calculated by finding half the range of the measured values.

For example:

Repeat	1	2	3	4
Distance / m	1.23	1.32	1.27	1.22

$1.32 - 1.22 = 0.10$ therefore
Mean distance: (1.26 ± 0.05) m

Percentage uncertainties

The percentage uncertainty in a measurement can be calculated using:

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{value}} \times 100\%$$

The percentage uncertainty in a repeated measurement can also be calculated using:

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{mean value}} \times 100\%$$

Further examples:

Example 1. Some values for diameter of a wire

Repeat	1	2	3	4
Diameter / mm	0.35	0.37	0.36	0.34

The exact values for the mean is 0.355 mm and for the uncertainty is 0.015 mm

This could be quoted as such or recorded as 0.36 ± 0.02 mm given that there is a wide range and only 4 readings. Given the simplistic nature of the analysis then giving the percentage uncertainty as 5% or 6% would be acceptable.

Example 2. Different values for the diameter of a wire

Repeat	1	2	3
Diameter / mm	0.35	0.36	0.35

The mean here is 0.3533 mm with uncertainty of 0.005 mm

The percentage uncertainty is 1.41% so may be quoted as 1% but really it would be better to obtain further data.

Titration

Titration is a special case where a number of factors are involved in the uncertainties in the measurement.

Students should carry out a rough titration to determine the amount of titrant needed. This is to speed up the process of carrying out multiple samples. The value of this titre should be ignored in subsequent calculations.

In titrations one single titre is never sufficient. The experiment is usually done until there are at least two titres that are concordant ie within a certain allowable range, often 0.10 cm^3 . These values are then averaged.

For example:

Titration	Rough	1	2	3
Final reading	24.20	47.40	24.10	47.35
Initial reading	0.35	24.20	0.65	24.10
Titre / cm^3	23.85	23.20	23.45	23.25

Here, titres 1 and 3 are within the allowable range of 0.10 cm^3 so are averaged to 23.23 cm^3 .

Unlike in some Biology experiments (where anomalous results are always included unless there is good reason not to), in Chemistry it is assumed that repeats in a titration should be concordant. If they are not then there is likely to have been some experimental error. For example, the wrong volume of solution added from the burette, the wrong amount of solution measuring the pipette or the end point might have been misjudged.

The total error in a titre is caused by three factors:

Error	Uncertainty
Reading the burette at the start of the titration	Half a division = $\pm 0.05 \text{ cm}^3$
Reading the burette at the end of the titration	Half a division = $\pm 0.05 \text{ cm}^3$
Judging the end point to within one drop	Volume of a drop = $\pm 0.05 \text{ cm}^3$
Total	$\pm 0.15 \text{ cm}^3$

This will, of course, depend on the glassware used, as some burettes are calibrated to a higher accuracy than others.

Uncertainties in exams

Wherever possible, questions in exams will be clear on whether students are being asked to calculate the uncertainty of a reading, a measurement, or given data.

Where there is ambiguity, mark schemes will allow alternative sensible answers and credit clear thinking.

It is important that teachers read the Reports on the examination following each series to understand common mistakes to help their students improve in subsequent years.

Uncertainties in practical work

Students are expected to develop an understanding of uncertainties in measurements through their practical work. Teachers may use students' assessments of uncertainties in measurements, and their recording, as evidence towards several of the endorsement criteria. Teachers will decide on each occasion what acceptable uncertainty values are, and the ways in which they expect students to record these.

Examples

CPAC 2: Students should be attempting to reduce the uncertainties in experiments. This could be by choosing appropriate equipment (CPAC 2d), or by choosing procedures such as repeating readings that reduce overall uncertainties (CPAC 2c).

CPAC 4: Students' records should take into account uncertainties. For example, students should be making sensible decisions about the number of significant figures to include, particularly in calculated values.

CPAC 5: Students could comment on the uncertainties in their measurements. For example, students could comment on whether the true value (eg for a concentration, or the acceleration due to gravity) lies within their calculated range of uncertainty. With some measurements, students may compare their value with those from secondary sources, contributing evidence for CPAC 5b.

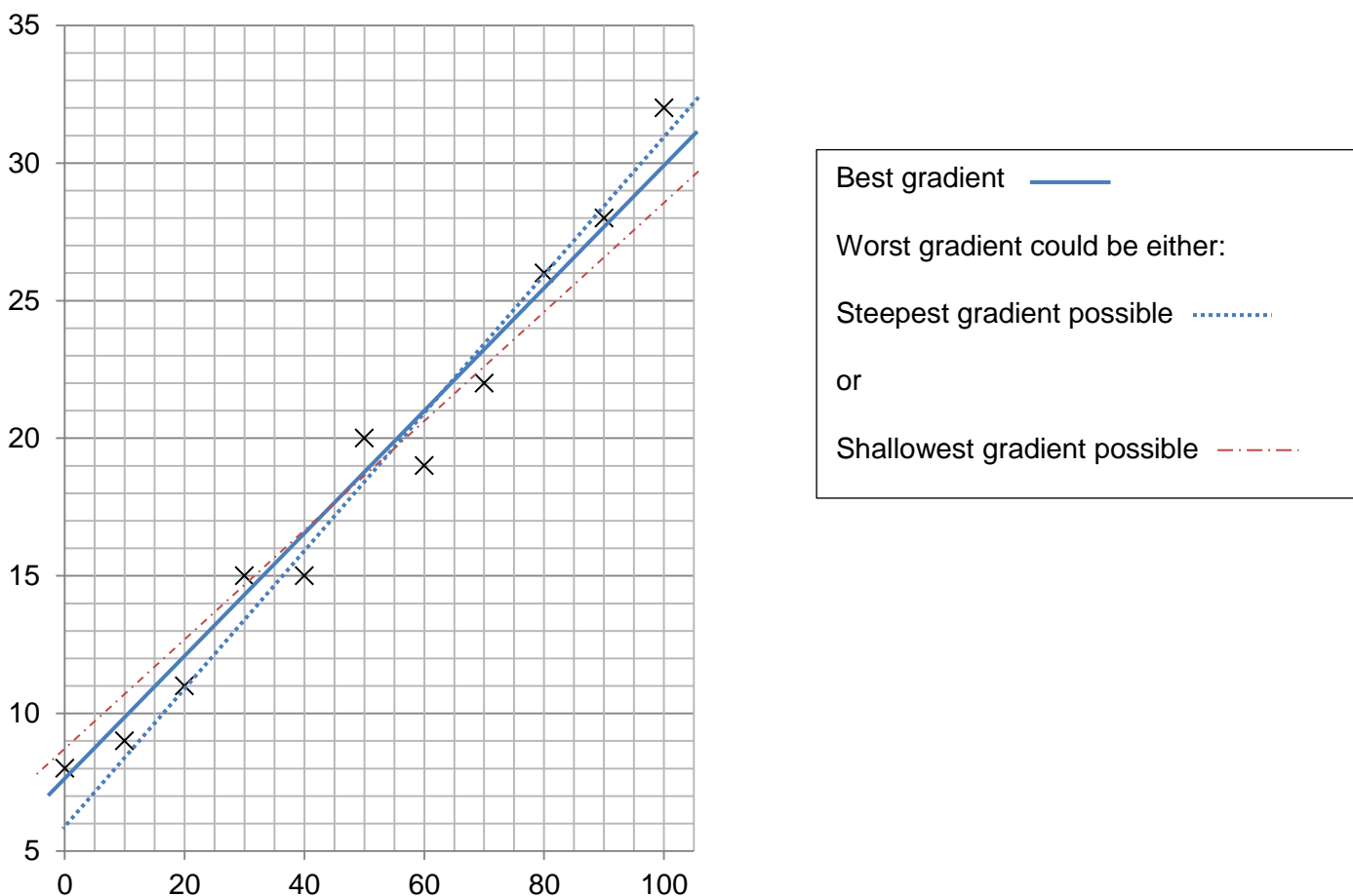
Uncertainties from gradients

To find the uncertainty in a gradient, two lines should be drawn on the graph. One should be the “best” line of best fit. The second line should be the steepest or shallowest gradient line of best fit possible from the data. The gradient of each line should then be found.

The uncertainty in the gradient is found by:

$$\text{percentage uncertainty} = \frac{|\text{best gradient} - \text{worst gradient}|}{\text{best gradient}} \times 100\%$$

Note the modulus bars meaning that this percentage will always be positive.



In the same way, the percentage uncertainty in the y-intercept can be found:

$$\text{percentage uncertainty} = \frac{|\text{best } y \text{ intercept} - \text{worst } y \text{ intercept}|}{\text{best } y \text{ intercept}} \times 100\%$$

Combining uncertainties

Percentage uncertainties should be combined using the following rules:

Combination	Operation	Example
Adding or subtracting values $a = b + c$	Add the absolute uncertainties $\Delta a = \Delta b + \Delta c$	Initial volume in burette = $3.40 \pm 0.05 \text{ cm}^3$ Final volume in burette = $28.50 \pm 0.05 \text{ cm}^3$ Titre = $25.10 \pm 0.10 \text{ cm}^3$
Multiplying values $a = b \times c$	Add the percentage uncertainties $\epsilon a = \epsilon b + \epsilon c$	Mass = $50.0 \pm 0.1 \text{ g}$ Temperature rise (T) = $10.9 \pm 0.1 \text{ }^\circ\text{C}$ Percentage uncertainty in mass = 0.20% Percentage uncertainty in T = 0.92% Heat change = 2278 J Percentage uncertainty in heat change = 1.12% Absolute uncertainty in heat change = $\pm 26 \text{ J}$ (Note – the uncertainty in specific heat is taken to be zero)
Dividing values $a = \frac{b}{c}$	Add the percentage uncertainties $\epsilon a = \epsilon b + \epsilon c$	Mass of salt in solution = $100 \pm 0.1 \text{ g}$ Volume of solution = $250 \pm 0.5 \text{ cm}^3$ Percentage uncertainty in mass = 0.1% Percentage uncertainty in volume = 0.2% Concentration of solution = 0.400 g cm^{-3} Percentage uncertainty of concentration = 0.3% Absolute uncertainty of concentration = $\pm 0.0012 \text{ g cm}^{-3}$
Power rules $a = b^c$	Multiply the percentage uncertainty by the power $\epsilon a = c \times \epsilon b$	Concentration of H^+ ions = $0.150 \pm 0.001 \text{ mol dm}^{-3}$ rate of reaction = $k[\text{H}^+]^2 = 0.207 \text{ mol dm}^{-3} \text{ s}^{-1}$ (Note – the uncertainty in k is taken as zero and its value in this reaction is $0.920 \text{ dm}^6 \text{ mol}^{-2} \text{ s}^{-1}$) Percentage uncertainty in concentration = 0.67% Percentage uncertainty in rate = 1.33% Absolute uncertainty in rate = $\pm 0.003 \text{ mol dm}^{-3} \text{ s}^{-1}$

Note: Absolute uncertainties (denoted by Δ) have the same units as the quantity.

Percentage uncertainties (denoted by ϵ) have no units.

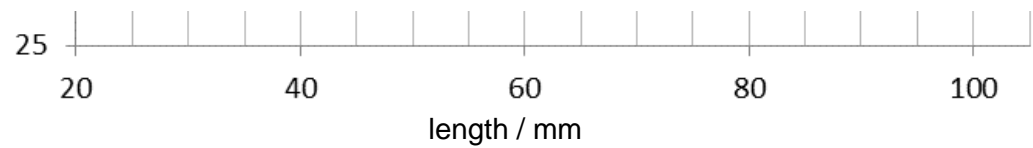
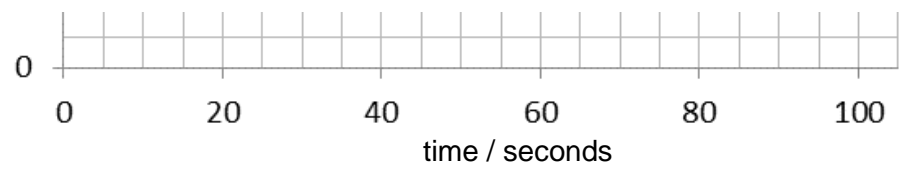
Uncertainties in trigonometric and logarithmic functions will not be tested in A-level exams.

M. Graphing

Graphing skills can be assessed both in written papers for the A-level grade and by the teacher during the assessment of the endorsement. Students should recognise that the type of graph that they draw should be based on an understanding of the type of data they are using and the intended analysis of the data. The rules below are guidelines which will vary according to the specific circumstances.

Labelling axes

Axes should always be labelled with the quantity being measured and the units. These should be separated with a forward slash (solidus):



Axes should not be labelled with the units on each scale marking.

Data points

Data points should be marked with a cross. Both \times and $+$ marks are acceptable, but care should be taken that data points can be seen against the grid.

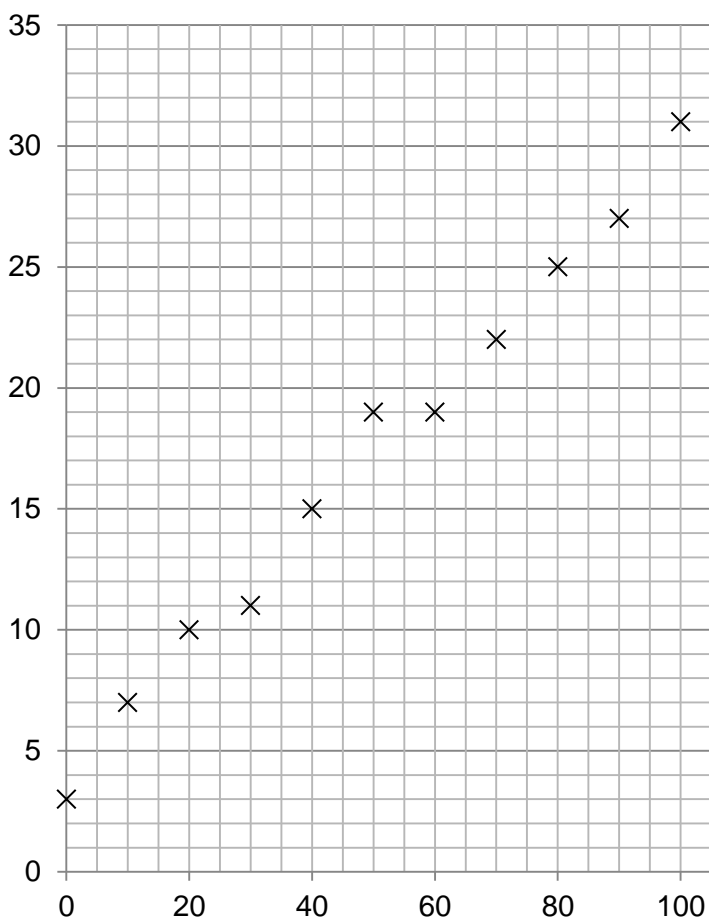
Error bars can take the place of data points where appropriate.

Scales and origins

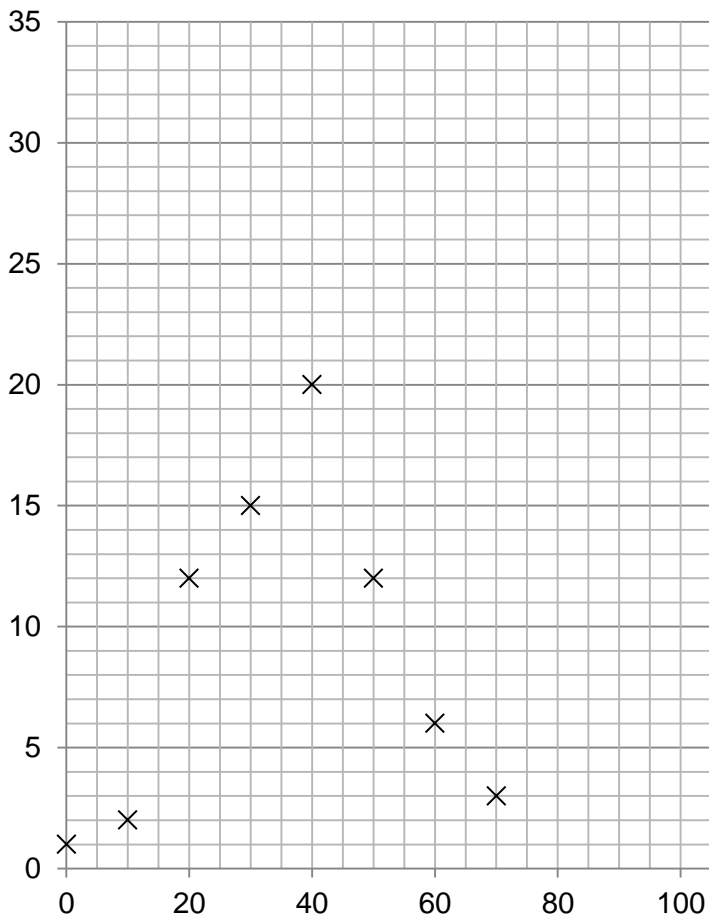
Students should attempt to spread the data points on a graph as far as possible without resorting to scales that are difficult to deal with. Students should consider:

- the maximum and minimum values of each variable
- the size of the graph paper
- whether 0.0 should be included as a data point
- how to draw the axes without using difficult scale markings (eg multiples of 3, 7, 11 etc)
- In exams, the plots should cover **at least half** of the grid supplied for the graph.

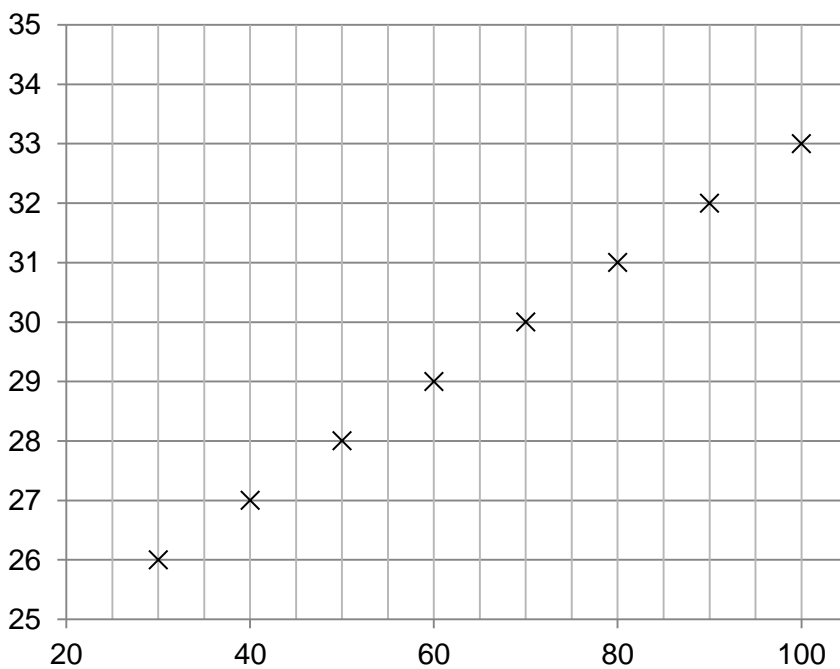
Please note that in section M, many generic graphs are used to illustrate the points made. For example, the following three graphs are intended to illustrate the information above relating to the spread of data points on a graph. Students producing such graphs on the basis of real practical work or in examination questions would be expected to add in axes labels and units.



This graph has well-spaced marking points and the data fills the paper. Each point is marked with a cross (so points can be seen even when a line of best fit is drawn).



This graph is on the limit of acceptability. The points do not quite fill the page, but to spread them further would result in the use of awkward scales.



At first glance, this graph is well drawn and has spread the data out sensibly. However, if the graph were to later be used to calculate the equation of the line, the lack of a y-intercept could cause problems. Increasing the axes to ensure all points are spread out but the y-intercept is also included is a skill that requires practice and may take a couple of attempts.

Lines of best fit

Lines of best fit should be drawn when appropriate. Students should consider the following when deciding where to draw a line of best fit:

- Are the data likely to be following an underlying equation (for example, a relationship governed by a physical law)? This will help decide if the line should be straight or curved.
- Are there any anomalous results?

There is no definitive way of determining where a line of best fit should be drawn. A good rule of thumb is to make sure that there are as many points on one side of the line as the other. Often the line should pass through, or very close to, the majority of plotted points. Graphing programs can sometimes help, but tend to use algorithms that make assumptions about the data that may not be appropriate.

Lines of best fit should be continuous and drawn as a thin pencil line that does not obscure the points below and does not add uncertainty to the measurement of gradient of the line.

Not all lines of best fit go through the origin. Students should ask themselves whether a 0 in the independent variable is likely to produce a 0 in the dependent variable. This can provide an extra and more certain point through which a line must pass. A line of best fit that is expected to pass through (0,0), but does not, would imply some systematic error in the experiment. This would be a good source of discussion in an evaluation.

Dealing with anomalous results

At GCSE, students are often taught to automatically ignore anomalous results. At A-level, students should think carefully about what could have caused the unexpected result and therefore whether it is anomalous. A student might be able to identify a reason for the unexpected result and so validly regard it as an anomaly. For example, an anomalous result might be explained by a different experimenter making the measurement, a different solution or a different measuring device being used. In the case where the reason for an anomalous result occurring can be identified, the result should be recorded and plotted but may then be ignored.

Anomalous results should also be ignored where results are expected to be the same (for example, in a titration in chemistry).

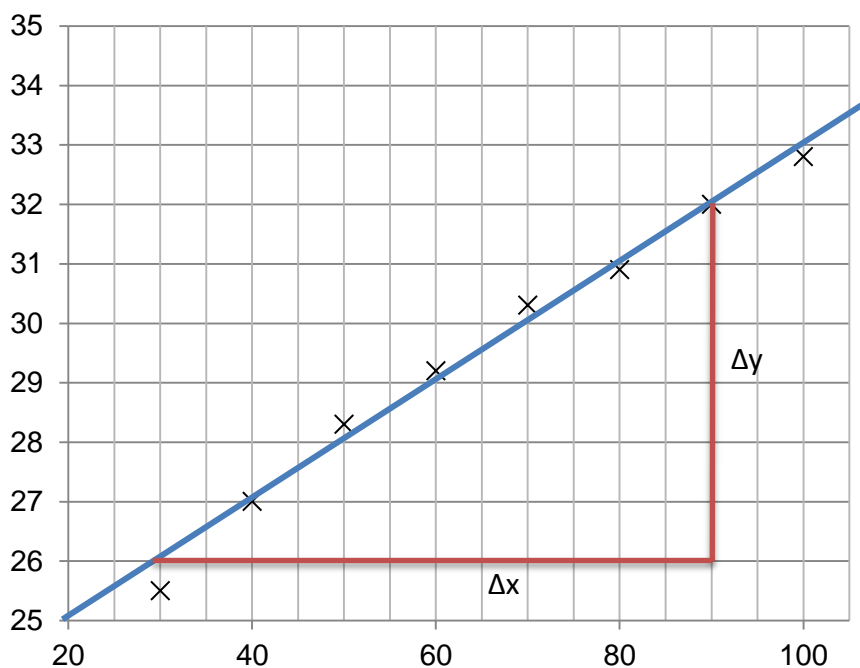
Where there is no obvious error and no expectation that results should be the same, anomalous results should be included. This will reduce the possibility that a key point is being overlooked.

Please note: when recording results it is important that all data are included. Anomalous results should only be ignored at the data analysis stage.

It is best practice whenever an anomalous result is identified for the experiment to be repeated. This highlights the need to tabulate and even graph results as an experiment is carried out.

Measuring gradients

When finding the gradient of a line of best fit, students should show their working by drawing a triangle on the line. The hypotenuse of the triangle should be at least half as big as the line of best fit.



The line of best fit here has an equal number of points on both sides. It is not too wide so points can be seen under it. The gradient triangle has been drawn so the hypotenuse includes more than half of the line. In addition, it starts and ends on points where the line of best fit crosses grid lines so the points can be read easily (this is not always possible).

$$\text{gradient} = \frac{\Delta y}{\Delta x}$$

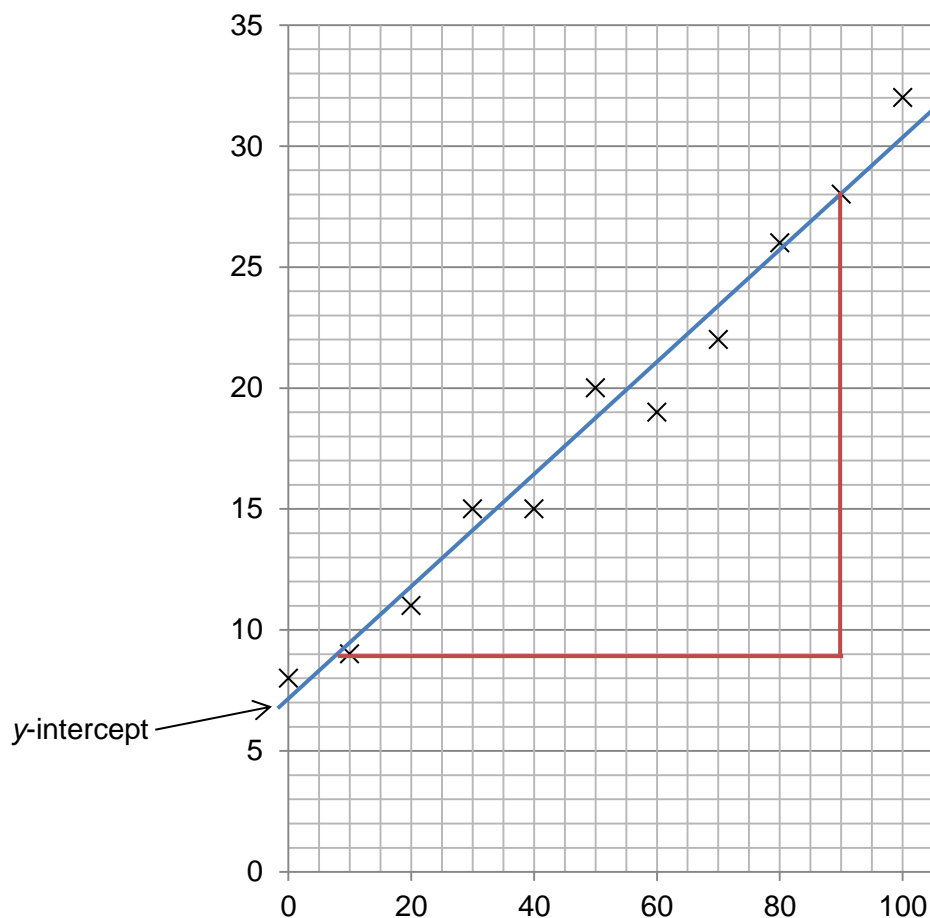
When finding the gradient of a curve, eg, the rate of reaction at a time that was not sampled, students should draw a tangent to the curve at the relevant value of the independent variable (x-axis). Use of a set square to draw a triangle over this point on the curve can be helpful in drawing an appropriate tangent.

The equation of a straight line

Students should understand that the following equation represents a linear relationship.

$$y = mx + c$$

Where y is the dependent variable, m is the gradient, x is the independent variable and c is the y -intercept.



$$\Delta y = 28 - 9 = 19$$

$$\Delta x = 90 - 10 = 80$$

$$\text{gradient} = 19 / 80 = 0.24 \text{ (2 sf)}$$

$$\text{y-intercept} = 7.0$$

equation of line:

$$y = 0.24x + 7.0$$

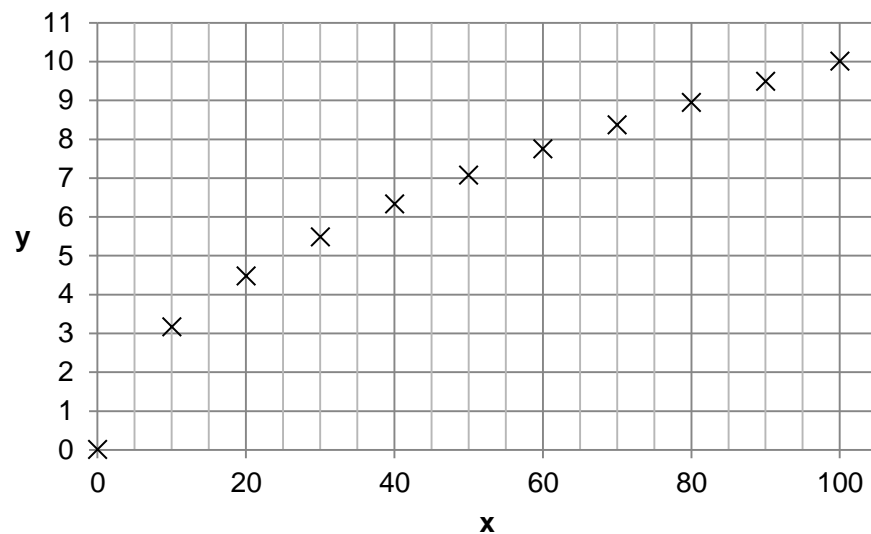
Testing relationships

Sometimes it is not clear what the relationship between two variables is. A quick way to find a possible relationship is to manipulate the data to form a straight line graph from the data by changing the variable plotted on each axis.

For example:

- **Raw data and graph**

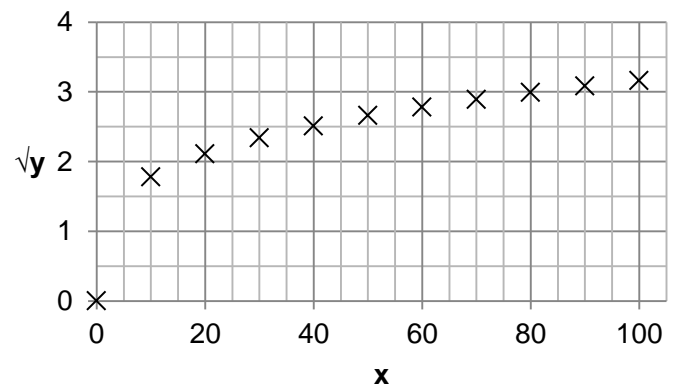
x	y
0	0.00
10	3.16
20	4.47
30	5.48
40	6.32
50	7.07
60	7.75
70	8.37
80	8.94
90	9.49
100	10.00

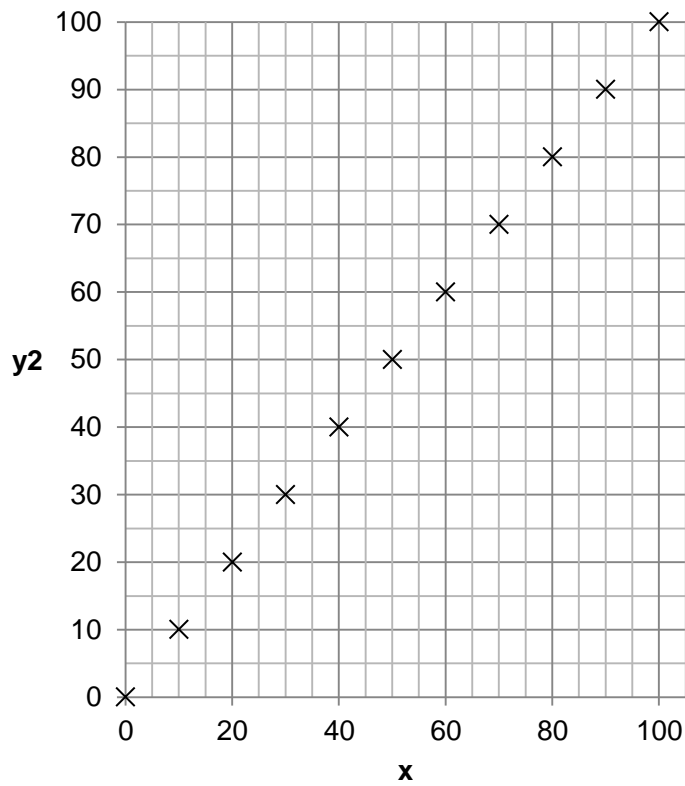


This is clearly not a straight line graph. The relationship between x and y is not clear.

A series of different graphs can be drawn from these data. The one that is closest to a straight line is a good candidate for the relationship between x and y .

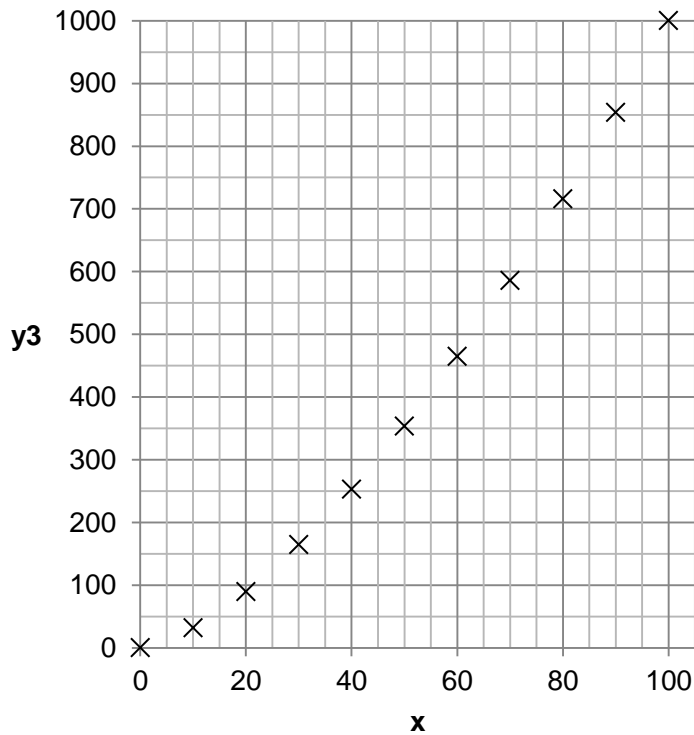
x	y	\sqrt{y}	y^2	y^3
0	0.00	0.00	0.00	0.00
10	3.16	1.78	10.00	32
20	4.47	2.11	20.00	89
30	5.48	2.34	30.00	160
40	6.32	2.51	40.00	250
50	7.07	2.66	50.00	350
60	7.75	2.78	60.00	470
70	8.37	2.89	70.00	590
80	8.94	2.99	80.00	720
90	9.49	3.08	90.00	850
100	10.00	3.16	100.00	1000





This is an idealised set of data to illustrate the point.

The straightest graph is y^2 against x , suggesting that the relationship between x and y is

$$y^2 \propto x$$


More complex relationships

Graphs can be used to analyse more complex relationships by rearranging the equation into a form similar to $y=mx+c$.

Example one: testing power laws

A relationship is known to be of the form $y=Ax^n$, but n is unknown.

Measurements of y and x are taken.

A graph is plotted with $\log(y)$ plotted against $\log(x)$.

The gradient of this graph will be n , with the y intercept $\log(A)$, as $\log(y) = n(\log(x)) + \log(A)$

Example two

The equation that relates the rate constant of a reaction to temperature is

$$k = Ae^{-\frac{E_a}{RT}}$$

This can be rearranged into

$$\ln(k) = -\frac{E_a}{R}\left(\frac{1}{T}\right) + \ln A$$

So a graph of $\ln(k)$ against $\left(\frac{1}{T}\right)$ should be a straight line, with a gradient of $-\frac{E_a}{R}$ and a y -intercept of $\ln A$

N. Glossary of terms

The following subject specific vocabulary provides definitions of key terms used in AQA's AS and A-level Biology, Chemistry and Physics specifications.

Accuracy

A measurement result is considered accurate if it is judged to be close to the true value.

Calibration

Marking a scale on a measuring instrument.

This involves establishing the relationship between indications of a measuring instrument and standard or reference quantity values, which must be applied.

For example, placing a thermometer in melting ice to see whether it reads 0 °C, in order to check if it has been calibrated correctly.

Data

Information, either qualitative or quantitative, that has been collected.

Errors

See also uncertainties.

measurement error

The difference between a measured value and the true value.

anomalies

These are values in a set of results which are judged not to be part of the variation caused by random uncertainty.

random error

These cause readings to be spread about the true value, due to results varying in an unpredictable way from one measurement to the next.

Random errors are present when any measurement is made, and cannot be corrected. The effect of random errors can be reduced by making more measurements and calculating a new mean.

systematic error

These cause readings to differ from the true value by a consistent amount each time a measurement is made.

Sources of systematic error can include the environment, methods of observation or instruments used.

Systematic errors cannot be dealt with by simple repeats. If a systematic error is suspected, the data collection should be repeated using a different technique or a different set of equipment, and the results compared.

zero error

Any indication that a measuring system gives a false reading when the true value of a measured quantity is zero, eg the needle on an ammeter failing to return to zero when no current flows.

A zero error may result in a systematic uncertainty.

Evidence

Data that have been shown to be valid.

Fair test

A fair test is one in which only the independent variable has been allowed to affect the dependent variable.

Hypothesis

A proposal intended to explain certain facts or observations.

Interval

The quantity between readings eg a set of 11 readings equally spaced over a distance of 1 metre would give an interval of 10 centimetres.

Precision

Precise measurements are ones in which there is very little spread about the mean value.

Precision depends only on the extent of random errors – it gives no indication of how close results are to the true value.

Prediction

A prediction is a statement suggesting what will happen in the future, based on observation, experience or a hypothesis.

Range

The maximum and minimum values of the independent or dependent variables.

For example, a range of distances may be quoted as either:

'from 10 cm to 50 cm' or

'from 50 cm to 10 cm'.

Repeatable

A measurement is repeatable if the original experimenter repeats the investigation using same method and equipment and obtains the same results.

Reproducible

A measurement is reproducible if the investigation is repeated by another person, or by using different equipment or techniques, and the same results are obtained.

Resolution

This is the smallest change in the quantity being measured (input) of a measuring instrument that gives a perceptible change in the reading.

Sketch graph

A line graph, not necessarily on a grid, that shows the general shape of the relationship between two variables. It will not have any points plotted and although the axes should be labelled they may not be scaled.

True value

This is the value that would be obtained in an ideal measurement.

Uncertainty

The interval within which the true value can be expected to lie, with a given level of confidence or probability eg "the temperature is $20\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$, at a level of confidence of 95%".

Validity

Suitability of the investigative procedure to answer the question being asked. For example, an investigation to find out if the rate of a chemical reaction depended upon the concentration of one of the reactants would not be a valid procedure if the temperature of the reactants was not controlled.

Valid conclusion

A conclusion supported by valid data, obtained from an appropriate experimental design and based on sound reasoning.

Variables

These are physical, chemical or biological quantities or characteristics.

categoric variables

Categoric variables have values that are labels eg names of plants or types of material or reading at week 1, reading at week 2 etc.

continuous variables

Continuous variables can have values (called a quantity) that can be given a magnitude either by counting (as in the case of the number of shrimp) or by measurement (eg light intensity, flow rate etc).

control variables

A control variable is one which may, in addition to the independent variable, affect the outcome of the investigation and therefore has to be kept constant or at least monitored.

dependent variables

The dependent variable is the variable of which the value is measured for each and every change in the independent variable.

independent variables

The independent variable is the variable for which values are changed or selected by the investigator.

nominal variables

A nominal variable is a type of categoric variable where there is no ordering of categories (eg red flowers, pink flowers, blue flowers)

O. Practical ladders and exemplar experiments: Chemistry

During the development of our A-levels in Biology, Chemistry and Physics, we spoke to hundreds of teachers. Teachers helped us to develop every part of the specification and assessments including the content and layout of the specification, what is examined on which paper, and question types. Teachers also helped us to decide which practical activities to include in our 12 required practicals for each subject.

Both in development, and in our launch meetings, teachers asked us for full, comprehensive instructions on how to carry out each of the 12 required practicals. In response, we have included a **sample** method for each practical on the next few pages. These have been prepared so that a reasonably equipped school or college can cover the required activity with their students. It gives **one possible version** of the experiment that teachers could use. They will help inform planning the time required and ensuring schools and colleges have the right equipment. Many are based on existing ISA and EMPA tasks as we know that they worked well and schools and colleges have been using them for a number of years in the current specifications.

This document should **only** be seen as a starting point. We do not intend to stifle innovation and would encourage teachers to try different methods. Students will not be examined on the specific practical work exemplified within this section but on the skills and understanding they build up through their practical work. It is, therefore, important that students are able to apply these skills and this understanding to novel contexts in written examinations. Teachers can vary all experiments to suit their and their students' needs.

Using set methods to assess students' competence for the endorsement

Students who are given a method that is fully developed, with full, clear instructions, will be able to demonstrate some competencies (eg following written instructions), but not others (eg researching and reporting).

We have developed 'ladders' which will help you to modify each of the given practicals to allow your students greater freedom to develop and demonstrate these wider practical skills. Each ladder identifies how slight modifications to the way the experiment is presented can change the focus of the experiment and allow students to demonstrate more independence. In turn they will allow you to be more confident in your judgement of the students' abilities for the endorsement of practical skills.

Investigation

Students do **not** need to carry out a full investigation. To achieve the endorsement, teachers must be confident that students can carry out practicals using 'investigative approaches'. In some practicals, teachers will wish to give full instructions for every stage in the activity. In other activities, teachers will give students some choice over how they carry out the activity, for example choosing the apparatus or the conditions for the experiment. On other occasions, teachers will wish to give students choice over how they analyse the data, including the choice of an appropriate statistical test.

This approach means that students will be able to demonstrate all aspects of investigation over the A-level course without the practical problems associated with a full investigation.

Safety

At all times, the teacher is responsible for safety in the classroom. Teachers should intervene whenever they see unsafe working. Risk assessments should be carried out before working, and advice from CLEAPSS and other organisations should be followed.

It is appropriate to give students at A-level more independence when making decisions about safety. They should be taught how to assess risks and how to write risk assessments when appropriate. They should also understand the appropriate use of safety equipment and how to put measures in place to reduce the risks.

To support teachers further, Mary Philpott, Biology Adviser, CLEAPSS outlines the difference between identification of major hazards, associated risk and control measures and a full risk assessment.

The risk assessment should always be complete, as it is this that prevents injury or ill-health.

The risk assessment is fundamentally the **thinking** that has taken place before and during an activity, so that any foreseeable risk is reduced to a minimum. A written record is necessary only to show that the thinking has taken place.

We tend to get caught up in the paperwork that provides evidence for the risk assessment, but the guidance from the Health and Safety Executive is that the written record should be on a **Point-of-use document** and there is no particular form etc. that needs to be filled in. The tables/forms etc. that many schools use are simply planning documents that the teachers use to provide the point of use risk assessment for each of their lessons. Incidentally, CLEAPSS members must refer to our current advice when preparing their point-of-use documents.

The student is **not responsible** for their risk assessment. In a large part, therefore, the student's risk assessment will be that they carry through the safety measures that the teacher has put in place. It is therefore fine if the student makes a note on their point-of-use document that shows they have thought about how to behave safely, and carried it through. The teacher will also be able to record what they have seen in a practical that shows that the student's risk assessment is effective.

For example, the student's written risk assessment could be as simple as making notes on a method sheet about where they will put on eye protection or how they will arrange any heating equipment so that there is a minimum risk of scalding or burning themselves or the person next to them.

The teacher's observation notes will refer to whether they have carried out their written plans. It might help the students to think safely if the teacher gives them a little time at the start of each practical to highlight or make notes about the safety aspects, and a class discussion about safety could show up any safety aspects that perhaps the teacher had not considered.

The students may also note where they have reminded other students about any safety issues.

The teacher should pass the student's CPAC when the students are seen to carry out the safety measures that they have written on their point of use document.

If the students are planning their own practical activities, they could use the safety advice given in the [CLEAPSS Student Safety Sheets](#)

In this case, they could identify hazards, risks and control measures.

In this case, they would make their own point of use document, with the control measures clearly identified.

The teacher would need to check that the risk assessment is adequate before they let the students proceed with the activity.

Chemistry practicals

These are examples of 12 experiments that can be done as part of the AS/A-level Chemistry course. The methods are written using commonly used reagents and techniques, although teachers can modify the methods and reagents as desired.

Trialling

All practicals should be trialled before use with students.

Risk assessment and risk management

Risk assessment and risk management are the responsibility of the centre.

Safety is the responsibility of the teacher and the centre. It is important that students are taught to act safely in the laboratory at all times, including the wearing of goggles at all times and the use of additional safety equipment where appropriate.

Notes from CLEAPSS

Technicians/teachers should follow CLEAPSS guidance, particularly that found on Hazcards and recipe sheets. The worldwide regulations covering the labelling of reagents by suppliers are currently being changed. Details about these changes can be found in leaflet GL101, which is available on the CLEAPSS Website. You will need to have a CLEAPSS login.

Practical 1

Required practical	Make up a volumetric solution and carry out a simple acid-base titration			
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT a. use appropriate apparatus to record a range of measurements AT d. use laboratory apparatus for a variety of experimental techniques AT e. use volumetric flask, including accurate technique for making up a standard solution AT f. use acid-base indicators in titrations of weak/strong acids with weak/strong alkalis AT k. safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances			
Indicative apparatus	Basic laboratory glassware, volumetric flask, burette, volumetric pipette and filler, and protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions for how to produce a standard solution. Teacher gives students a full method for how to carry out a simple titration.	Teacher gives students an outline for the procedure but allows choices at different steps. Teacher gives students an outline for the procedure to carry out a simple titration, but with some choices in technique, equipment or indicators.	Teacher specifies the compound and concentration of solution. Students research the method to carry out for the preparation of the standard solution. Students research methods to carry out a simple titration using the equipment provided.	Students research methods for making a standard solution and choose the chemical and concentration to be made. Students research methods for carrying out a simple titration and choose the method, chemicals and equipment to use.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method, making individual choices in technique or equipment.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.

Applies investigative approaches and methods when using instruments and equipment	✓ Students must correctly use the appropriate equipment. Procedure should be followed methodically and appropriate variables measured or controlled.	✓ Students must correctly use the appropriate equipment. Procedure should be followed methodically and suitable variables identified, measured and controlled.	✓✓ Students must correctly select and use the appropriate equipment. Procedural steps should be well sequenced and adjusted where necessary. Suitable variables identified, measured and controlled.	✓✓✓ Student must choose an appropriate methodical approach, equipment and techniques. Procedural steps should be well sequenced and adjusted where necessary. Suitable variables should be identified for measurement and control. Where variables cannot be readily controlled, approaches should be planned to take account of this.
Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✓ Students record data in specified ways.	✓ Students record accurate data in specified ways.	✓✓ Students record precise and accurate data, methodically using appropriate units, in specified ways.	✓✓✓ Students must choose the most effective way of recording precise and accurate data methodically using appropriate units.
Researches, references and reports	✓ Data is reported and conclusions drawn.	✓ Data is reported and conclusions drawn. Students compare results and identify reasons for differences.	✓✓✓ Students must research methods available. They compare results and report on differences. Appropriate software is used to process data and report findings.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results. Appropriate software and/or tools are used to process data and report findings.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity ✕: No opportunity

A-level Chemistry exemplar for required practical No. 1 part a

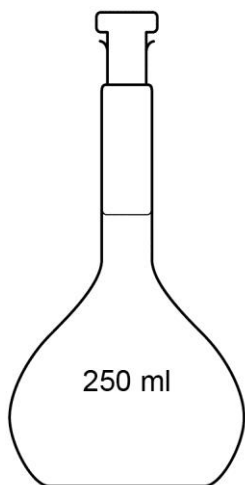
**Make up a volumetric solution and carry out a simple acid-base titration:
To prepare a solution of sodium hydrogensulfate that has a known concentration**

Student sheet

Requirements

You are provided with the following:

- weighing bottle or boat
- 250 cm³ volumetric (graduated) flask
- sodium hydrogensulfate solid
- filter funnel
- spatula
- deionised or distilled water in a wash bottle
- 250 cm³ beaker
- glass rod
- digital mass balance (reading to 2 or 3 decimal places).



Volumetric flask



Weighing bottle



Weighing boat



Wash bottle

Suggested method

The task is to prepare 250 cm³ of a solution of sodium hydrogensulfate with a known concentration in the range 0.090 to 0.110 mol dm⁻³

The procedure is as follows:

- a) Calculate the mass of sodium hydrogensulfate solid needed to produce 250 cm³ of a 0.100 mol dm⁻³ solution. Show your working. If you are using the anhydrous solid, the mass to weigh out will be between 2.7 and 3.3 g, and if you are using the monohydrate, the mass to weigh out should be between 3.1 and 3.8 g
- b) Weigh a clean dry weighing bottle (or weighing boat).
- c) Place the weighing bottle on the pan of a digital balance and, using a spatula, place into the bottle **approximately** the mass of sodium hydrogensulfate that you have calculated to be necessary.
- d) Weigh the weighing bottle and its contents accurately and record the **precise** mass.
- e) Pour the contents of the weighing bottle into a beaker and re-weigh the weighing bottle (which may still contain traces of sodium hydrogensulfate).
- f) Calculate the mass of sodium hydrogensulfate that you have transferred. Remember to record all weighings to the resolution of the balance that you have used.
- g) Add approximately 100 cm³ of deionised (or distilled) water to the beaker containing the solid and use a glass rod to stir the contents of the beaker until all of the sodium hydrogensulfate dissolves.
- h) Using a funnel, pour the contents of the beaker into a 250 cm³ volumetric (graduated) flask and then using the wash bottle rinse the beaker and funnel into the same volumetric flask. Rinse the glass rod into these washings.
- i) Make the volumetric flask up to the graduated mark by carefully adding deionised water from the wash bottle. You will need to be careful so that you do not over-shoot the mark.
- j) Stopper the volumetric flask and shake it thoroughly to mix the contents of the flask.
- k) Calculate the exact concentration in mol dm⁻³ of your solution quoting the value to the appropriate precision. Show all of your working.

A-level Chemistry exemplar for required practical No. 1 part a

**Make up a volumetric solution and carry out a simple acid-base titration:
To prepare a solution of sodium hydrogensulfate that has a known concentration**

Teachers' notes

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

In addition to general laboratory apparatus, each student needs:

- weighing bottle or boat
- 250 cm³ volumetric (graduated) flask
- sodium hydrogensulfate solid (see below)
- filter funnel
- spatula
- deionised or distilled water in a wash bottle
- 250 cm³ beaker
- glass rod
- digital mass balance (reading to 2 or 3 decimal places).

The composition of the **sodium hydrogensulfate** should be known; either anhydrous (and the purest available) or the monohydrate. Students need to be advised which they are using. Suppliers can also call this reagent sodium bisulfate.

If using anhydrous, make sure it is not too old as it will have picked up water and therefore not be as accurate a mass.

In trials, 3.5 g of anhydrous and 4.0 g of the monohydrate were used.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

A-level Chemistry exemplar for required practical No. 1 part b

**Make up a volumetric solution and carry out a simple acid-base titration:
To determine the concentration of a solution of sodium hydroxide by titration using a sodium hydrogensulfate solution that has a known concentration**

Student sheet

Requirements

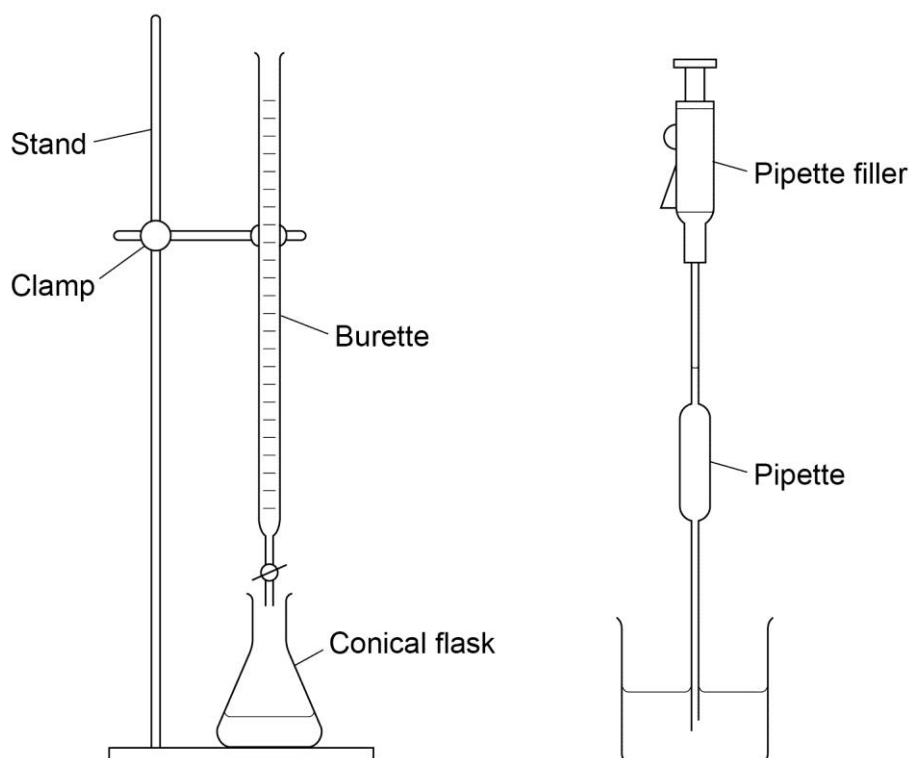
You are provided with the following:

- burette
- stand and clamp
- 25 cm³ pipette
- pipette filler
- two 250 cm³ conical flasks
- two 250 cm³ beakers
- funnel
- wash bottle
- phenolphthalein indicator
- sodium hydrogensulfate solution
- sodium hydroxide solution.

The sodium hydrogensulfate solution may be the solution which you prepared in part a of this experiment or it could be a solution provided to you by your teacher.

Suggested method

- Pour approximately 100 cm^3 of the sodium hydrogensulfate solution into a clean, dry beaker that is labelled 'sodium hydrogensulfate'. Use a small volume of this solution to rinse the burette before filling it with the sodium hydrogensulfate solution.
- Pour approximately 100 cm^3 of the sodium hydroxide solution into a second clean, dry beaker labelled 'sodium hydroxide'.
- Rinse a 25 cm^3 pipette with the sodium hydroxide solution provided and then, using a pipette filler, pipette exactly 25.0 cm^3 of sodium hydroxide solution into a 250 cm^3 conical flask (which has been rinsed with deionised water).
- Add **two to three drops** of phenolphthalein indicator to the solution in the conical flask and note the colour of the indicator in alkali.
- Before you start** to titrate, construct a table ready to record your results.
- Record the initial burette reading. Make sure that all your burette readings are to the appropriate precision.
- Titrate the contents of the conical flask by adding sodium hydrogensulfate solution to it from the burette. Add the sodium hydrogensulfate solution slowly, swirling the flask gently to mix the solution. Add the sodium hydrogensulfate solution dropwise near the end-point until the indicator undergoes a definite colour change; this is the end-point of the titration. Record the colour change in your results. Record the final burette reading in your table of results.



- Calculate and record in your table of results the volume of sodium hydrogensulfate solution used.
- Repeat the titration until you obtain two results which are concordant. You should normally carry out at least three titrations. Record all of the results that you obtain.
- Calculate and record the mean volume of sodium hydrogensulfate solution used in the titration. Show your working.
- Use your results to calculate the concentration of the sodium hydroxide. Show your working.

A-level Chemistry exemplar for required practical No. 1 part b

**Make up a volumetric solution and carry out a simple acid-base titration:
To determine the concentration of a solution of sodium hydroxide by titration using a sodium hydrogensulfate solution that has a known concentration**

Teachers' notes

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

In addition to general laboratory apparatus, each student needs:

- burette
- stand and clamp
- 25 cm³ pipette
- pipette filler
- two 250 cm³ conical flasks
- two 250 cm³ beakers
- funnel
- wash bottle
- phenolphthalein indicator
- standard sodium hydrogensulfate solution (150 cm³)
- sodium hydroxide solution (150 cm³) labelled as "Sodium hydroxide solution of unknown concentration".

The sodium hydrogensulfate solution needs to be a **solution** with an accurately known concentration between 0.090 and 0.100 mol dm⁻³ or could be the solution which the student prepared as part a of this required practical.

Students should use a sodium hydroxide solution with an accurately known concentration between 0.090 and 0.100 mol dm⁻³ but labelled as "Sodium hydroxide solution of unknown concentration".

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Sample masses per dm³, for example:

$$3.6 \text{ g} > 1 \text{ dm}^3 = 0.090 \text{ mol dm}^{-3}$$

$$3.8 \text{ g} > 1 \text{ dm}^3 = 0.095 \text{ mol dm}^{-3}$$

$$4.0 \text{ g} > 1 \text{ dm}^3 = 0.100 \text{ mol dm}^{-3}$$

Sample results

The following table is a sample results table using results from the trial of this experiment.

	Titre 1 / cm ³	Titre 2 / cm ³	Titre 3 / cm ³
Initial reading	0.10	0.00	0.10
Final reading	24.95	25.10	25.10
Titre	24.85	25.10	25.00
		✓	✓

All titre readings to 2 decimal places.

Concordant results should be within 0.10 cm³ of each other. In this case, titre 2 and titre 3 are concordant.

The average titre is 25.05 cm³

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Practical 2

Required practical	Measurement of an enthalpy change			
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT a. use appropriate apparatus to record a range of measurements AT d. use laboratory apparatus for a variety of experimental techniques AT k. safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances			
Indicative apparatus	This depends on the reaction being studied and the type of practical carried out, but will likely include basic laboratory glassware, insulated cup or metal calorimeter/can, thermometer and protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions for how to measure the enthalpy change in a given reaction. Analysis is very structured for students, outlining how to carry out each stage and calculation.	Teacher gives students instructions for the apparatus and general method to be used, but allows for choices in several steps. Analysis is structured in the form of questions with limited guidance.	Teacher chooses the reaction to be measured but does not specify method. Students research methods available and choose which to carry out with the resources available. Students research how to analyse the data from their reaction and carry out an analysis, with some guidance, to determine the enthalpy change for their experiment.	Students research methods for measuring enthalpy changes and decide which reaction to use. Students choose a method to use, given the resources available. Students research how to analyse the data from their reaction and independently carry out an analysis to determine the enthalpy change for their experiment.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.

Applies investigative approaches and methods when using instruments and equipment	✓ Students must correctly use the appropriate equipment. Procedure should be followed methodically and appropriate variables measured or controlled.	✓ Students must correctly use the appropriate equipment. Procedure should be followed methodically and suitable variables identified, measured and controlled.	✓✓ Students must correctly select and use the appropriate equipment. Procedural steps should be well sequenced and adjusted where necessary. Suitable variables identified, measured and controlled.	✓✓✓ Student must choose an appropriate methodical approach, equipment and techniques. Procedural steps should be well sequenced and adjusted where necessary. Suitable variables should be identified for measurement and control. Where variables cannot be readily controlled, approaches should be planned to take account of this.
Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✓ Students record data in specified ways.	✓ Students record accurate data in specified ways.	✓✓ Students record precise and accurate data, methodically using appropriate units, in specified ways.	✓✓✓ Students must choose the most effective way of recording precise and accurate data methodically using appropriate units.
Researches, references and reports	✓ Data is reported and conclusions drawn.	✓ Data is reported and conclusions drawn. Students compare results and identify reasons for differences.	✓✓✓ Students must research methods available. They compare results and report on differences. Appropriate software is used to process data and report findings.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results. Appropriate software and/or tools are used to process data and report findings.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity ✕: No opportunity

A-level Chemistry exemplar for required practical No. 2

Measurement of an enthalpy change:

To determine an enthalpy change which cannot be measured directly. The reaction involves the conversion of anhydrous copper(II) sulfate into hydrated copper(II) sulfate.

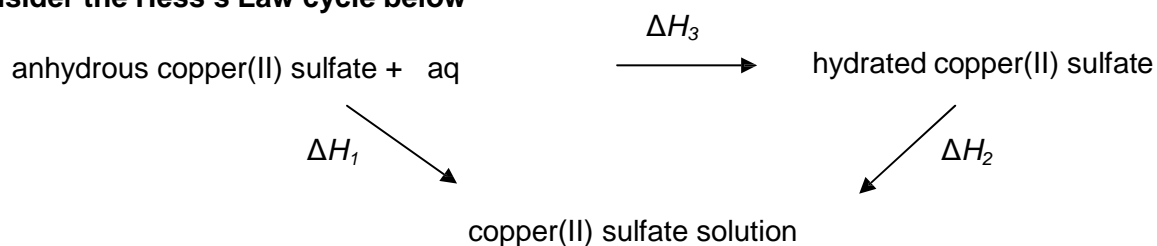
Student sheet

Requirements

You are provided with the following:

- hydrated copper(II) sulfate crystals
- anhydrous copper(II) sulfate powder
- polystyrene cups with lids
- 250 cm³ or 400³ cm beaker (as appropriate for holding the cup)
- stand and clamp
- 0 °C to 50 °C glass or digital thermometer
- two 25 cm³ measuring cylinders
- two weighing bottles
- stopwatch
- graph paper
- stirrer
- deionised or distilled water
- access to a digital mass balance (measuring to 2 decimal places).

Consider the Hess's Law cycle below



We can measure accurately by experiment both the values ΔH_1 and ΔH_2

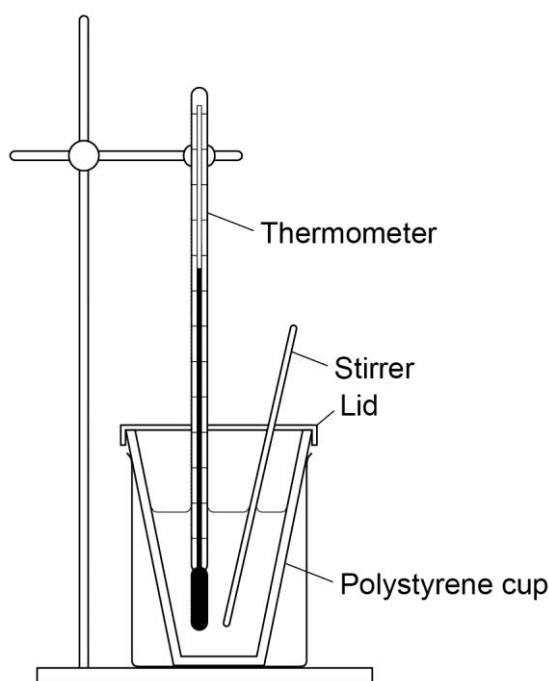
By applying Hess's Law, we can calculate the value for ΔH_3 , since the two routes from anhydrous copper(II) sulfate to copper(II) sulfate solution have the same overall enthalpy change.

$$\begin{array}{l} \text{ie} \qquad \qquad \Delta H_1 = \qquad \Delta H_2 \quad + \quad \Delta H_3 \\ \text{therefore} \qquad \Delta H_3 = \qquad \Delta H_1 \quad - \quad \Delta H_2 \end{array}$$

Suggested method

Experiment 1 - Collecting data for the determination of ΔH_f

- Weigh out between 3.90 g and 4.10 g of anhydrous copper(II) sulfate in a dry stoppered weighing bottle, keeping the stock of solid in a closed container during weighing.
Take care to avoid skin contact. The precise mass should be recorded.
- Construct a suitable table of results to allow you to record temperatures at minute intervals up to 15 minutes.
- Using a measuring cylinder, place 25 cm³ of deionised water into a polystyrene cup and record its temperature at the beginning ($t=0$), start the timer and then record the temperature again every minute, stirring the liquid continuously.



- At the fourth minute, add the powdered anhydrous copper(II) sulfate **rapidly** to the water in the polystyrene cup and continue to stir, but **do not** record the temperature. At the fifth minute and for every minute up to 15 minutes, stir and record the temperature of the solution in the polystyrene cup.
- Plot a graph of temperature (on the y -axis) against time. Draw two separate best fit lines; one, which joins the points before the addition, and one, which joins the points after the addition, extrapolating both lines to the fourth minute.
- Use your graph to determine the temperature change at the fourth minute, which theoretically should have occurred immediately on addition of the solid.

Experiment 2 - Collecting data for the determination of ΔH_2

- Weigh out between 6.20 g and 6.30 g of hydrated copper(II) sulfate in a dry stoppered weighing bottle. The precise mass should be recorded.
- Construct a suitable table of results to allow you to record temperatures at minute intervals up to 15 minutes as you did for Experiment 1.
- Using a measuring cylinder, place 24 cm³ of deionised water into a polystyrene cup. Since the hydrated crystals contain water, the total amount of water will be approximately the same as in Experiment 1.
- Repeat the procedure adopted in Experiment 1. Add the copper(II) sulfate crystals to the water in the polystyrene cup and obtain temperature data for 15 minutes.
- Plot a graph similar to that in Experiment 1 and determine the temperature change in this experiment.

Analysing the data and calculating ΔH_3

You should be familiar with the expression

Heat change = mass \times specific heat capacity \times temperature change

Heat change = $m c \Delta T$

In this experiment, we will ignore heat loss to the surroundings.

The specific heat capacity of the polystyrene cup is negligible when compared to the mass of water and the aqueous solutions can be considered to have the same specific heat capacity as water.

(For many aqueous chemical reactions, it can be assumed that the only substance heated is water).

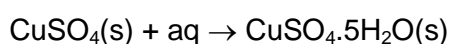
In each of Experiment 1 and Experiment 2 you need the **mass of water, m (in g)**, which has changed in temperature. As the density of water can be assumed to be 1 g cm⁻³ the mass can be directly taken from the volume of water ie 25 g in each case. Do **not** add on the mass of the solid used.

You will also need the **temperature change, ΔT (in K)**, from your graph in order to be able to calculate the heat change.

For water, the specific heat capacity, **$c = 4.18 \text{ J K}^{-1} \text{ g}^{-1}$** and, so, the value that you obtain for the heat change in each experiment will be in **joules**. You can convert this value into kilojoules by dividing it by 1000.

You can then calculate the enthalpy changes, ΔH_1 and ΔH_2 , in **kJ mol^{-1}** , using the masses of the solids used in each experiment.

You need to use the values that you have obtained for ΔH_1 and ΔH_2 and apply Hess's Law to calculate ΔH_3 in **kJ mol^{-1}** for the hydration of copper(II) sulfate.



A-level Chemistry exemplar for required practical No. 2

Measurement of an enthalpy change:

To determine an enthalpy change which cannot be measured directly. The reaction involves the conversion of anhydrous copper(II) sulfate into hydrated copper(II) sulfate.

Teachers' notes

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

In addition to general laboratory apparatus, each student needs:

- hydrated copper(II) sulfate (small) crystals (~ 6.20–6.30 g)
- anhydrous copper(II) sulfate powder (~ 3.90–4.10 g)
- polystyrene cups (as a calorimeters) with lids
- 250 cm³ or 400³ cm beaker (as appropriate for holding the cup)
- stand and clamp
- 0 °C to 50 °C glass or digital thermometer (0.1 °C or 0.2 °C divisions are desirable but not essential)
- two 25 cm³ measuring cylinders
- two weighing bottles
- stopwatch
- graph paper
- stirrer
- deionised or distilled water
- access to a digital mass balance (measuring to 2 decimal places).

The calorimeter is a polystyrene cup (an ordinary coffee cup) fitted into the beaker which will provide some insulation, and also act as a support.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Additional notes

If the stock of anhydrous copper(II) sulfate powder is not white, place in an evaporation dish in an oven at a low temperature or heat gently over a Bunsen burner before storing in a desiccator.

Results obtained could vary considerably depending on the type of cup used, whether or not a lid was used or if there is a high temperature in the laboratory on the day. Lids on the polystyrene cups help to minimise heat loss and maximise change in temperature.

If weighing bottles are not available, a weighing boat can be used if students work quickly.

Safety

Each student will use a fairly large amount of copper sulfate(VI) and it has an environmental warning. Waste will be an issue so solutions should be collected, filtered and allowed to evaporate so that copper sulfate(VI) can be recycled.

Sample results

The following table is a sample results table using results from the trial of this experiment.

Temperature / °C	Experiment 1	Experiment 2
0	19.8	19.8
1	19.6	19.8
2	19.6	19.8
3	19.6	19.8
4		
5	27.4	18.2
6	27.2	18.2
7	26.8	18.2
8	26.6	18.2
9	26.4	18.2
10	26.2	18.2
11	26.2	18.2
12	26.2	18.2
13	26.2	18.2
14	26.2	18.2
15	26.2	18.2

4.94 g anhydrous copper(II) sulfate and 7.72 g hydrated copper(II) sulfate were used.

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Practical 3

Required practical	Investigation of how the rate of a reaction changes with temperature			
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT a. use appropriate apparatus to record a range of measurements AT b. use water bath or electric heater or sand bath for heating AT k. safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances			
Indicative apparatus	This depends on the reaction being studied, but will likely include basic laboratory glassware, heating equipment (water bath or Bunsen burner), timer, and protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions for how to measure the rate of a given reaction and which temperatures to be used.	Teacher gives students a method with choices at different steps, including which temperatures to be used. Students could compare the rate of their reaction with regard to the choices of temperature made.	Teacher chooses the reaction to be studied, but does not specify the method or temperatures. Students research the methods available and choose which to carry out. Students could compare the rate of their reactions with regard to the choices of temperature and method made.	Students research methods to measure variation of the rate of reaction with temperature and decide which method, temperature, and which reaction to study.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.
Applies investigative approaches and methods	✓ Students must correctly use the appropriate equipment.	✓ Students must correctly use the appropriate equipment.	✓✓ Students must correctly select and use the appropriate equipment.	✓✓✓ Students must choose an appropriate methodical approach,

when using instruments and equipment	Procedure should be followed methodically and appropriate variables measured or controlled.	Procedure should be followed methodically and suitable variables identified, measured and controlled.	Procedural steps should be well sequenced and adjusted where necessary. Suitable variables identified, measured and controlled.	equipment and techniques. Procedural steps should be well sequenced and adjusted where necessary. Suitable variables should be identified for measurement and control. Where variables cannot be readily controlled, approaches should be planned to take account of this.
Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✓ Students record data in specified ways.	✓ Students record accurate data in specified ways.	✓✓ Students record precise and accurate data, methodically using appropriate units, in specified ways.	✓✓✓ Students must choose the most effective way of recording precise and accurate data methodically using appropriate units.
Researches, references and reports	✓ Data is reported and conclusions drawn.	✓ Data is reported and conclusions drawn. Students compare results and identify reasons for differences.	✓✓✓ Students must research methods available. They compare results and report on differences. Appropriate software is used to process data and report findings.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results. Appropriate software and/or tools are used to process data and report findings.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity ✗: No opportunity

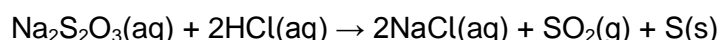
A-level Chemistry exemplar for required practical No. 3

Investigation of how the rate of a reaction changes with temperature:

To investigate how the rate of the reaction of sodium thiosulfate with hydrochloric acid changes as the temperature of the reaction is changed

Student sheet

Sodium thiosulfate reacts with hydrochloric acid according to the equation



The reaction produces a precipitate of sulfur. The rate of this reaction can be monitored by measuring the time taken for a fixed amount of sulfur to be produced. An easy method to do this is by timing how long it takes for a cross, marked under the bottom of the reaction vessel, to disappear as it is obscured by the sulfur precipitate.

Dilute hydrochloric acid will be added to sodium thiosulfate solution at different temperatures in a series of experiments.

This table shows the approximate temperatures for five experiments.

Experiment	1	2	3	4	5
Approximate temperature / °C	room*	~25	~35	~45	~55**

[* The temperature of the room is likely to be 15 to 18 °C]

[** The temperature must **not** exceed 55 °C]

It is not necessary for these exact temperatures to be used although the temperature used must **not** exceed 55 °C. However, the actual temperature at which each experiment is carried out must be known as accurately as possible. One way that this can be achieved is to measure both the initial temperature and the final temperature and then use a mean temperature when plotting your graph.

Requirements

You are provided with the following:

- thermometer
- 400 cm³ beaker (for use as a water bath)
- plastic container with lid
- 2 glass tubes to hold 12–14 cm³ of liquid
- 0.05 mol dm⁻³ sodium thiosulfate solution
- 1.0 mol dm⁻³ hydrochloric acid (or 0.5 mol dm⁻³ sulfuric acid)
- 10 cm³ measuring cylinder
- plastic graduated pipette
- stopwatch
- graph paper.

Suggested method

- Add about 10 cm³ of 1 mol dm⁻³ hydrochloric acid (or 0.5 mol dm⁻³ sulfuric(VI) acid) to the 'acid' tube. Place this tube into the correct hole in the plastic container (ie the one without the cross under it).
- Use a measuring cylinder to add 10.0 cm³ of 0.05 mol dm⁻³ sodium thiosulfate solution to the second tube. Place this tube into the correct hole in the plastic container (ie the one with the cross under it) and carefully place a thermometer in this tube.
- Note the start temperature and then add 1 cm³ of the acid to the thiosulfate solution and start timing.
- Look down through the tube from above and record the time for the cross to disappear from view.
- Record the temperature of the reaction mixture. Pour the cloudy contents of the vial into the sodium carbonate solution (the 'stop bath').
- Now add water from a very hot water tap (or kettle) to the plastic container. The water should be no hotter than 55 °C. Add cold water if necessary.
- Measure another 10.0 cm³ of 0.05 mol dm⁻³ sodium thiosulfate solution into a clean tube. Insert this tube into the correct hole in the plastic container (ie the one with the cross under it).
- Leave the tube to warm up for about 3 minutes.
- Repeat steps (c) to (e) above.
- Repeat to obtain results for at least 5 different temperatures in total.

Analysing the data

In these experiments at different temperatures, the concentrations of all the reactants are the same. You are investigating the time taken to produce the same amount of sulfur at different temperatures. If you were to plot a graph of the amount of sulfur produced against time, it would initially be a straight line because the reaction has only just started. Therefore,

$$\text{the initial rate of reaction} = (\text{amount of sulfur})/\text{time}$$

so the initial rate of reaction is proportional to 1/time ($\frac{1}{t}$).

AS analysis

- calculate the mean temperature of each reaction mixture
- for each of the five temperatures, calculate $\frac{1}{t}$ to 3 significant figures, where t is the time taken for the cross to be obscured
- plot a graph of $\frac{1}{t}$ on the y-axis against average temperature
- the plotting of the points may be more straightforward if you multiply all of the values for $\frac{1}{t}$ by a common factor (eg 10⁴).

A-level analysis

The rate constant for a reaction varies with temperature according to the following equation, where T is the temperature in **kelvins**:

$$k = Ae^{-E_a/RT}$$

taking natural logarithms

$$\ln k = -\frac{E_a}{R}\left(\frac{1}{T}\right) + \ln A$$

In this experiment, the rate constant is directly proportional to $\frac{1}{t}$. Therefore

$$\ln \frac{1}{t} = -\frac{E_a}{R}\left(\frac{1}{T}\right) + \text{constant}$$

- plot a graph of $\ln \frac{1}{t}$ on the y-axis against $\frac{1}{T}$
- the graph should be a straight line with gradient $-\frac{E_a}{R}$ so measure the gradient
- calculate a value for the activation energy and express your answer in kJ mol^{-1}
- $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

A-level Chemistry exemplar for required practical No. 3

Investigation of how the rate of a reaction changes with temperature:

To investigate how the rate of the reaction of sodium thiosulfate with hydrochloric acid changes as the temperature of the reaction is changed

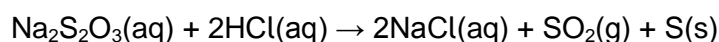
Teachers' notes

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Introduction

Sodium thiosulfate reacts with hydrochloric acid according to the equation



The reaction produces a precipitate of sulfur. The rate of this reaction can be monitored by measuring the time taken for a fixed amount of sulfur to be produced. An easy method to do this is by timing how long it takes for a cross, marked on the bottom of the reaction vessel, to disappear as it is obscured by the sulfur precipitate.

Dilute hydrochloric acid will be added to sodium thiosulfate solution at different temperatures in a series of experiments.

This table shows the approximate temperatures for five experiments.

Experiment	1	2	3	4	5
Approximate temperature / °C	room*	~25	~35	~45	~55**

[* The temperature of the room is likely to be 15 to 18 °C]

[** The temperature must **not** exceed 55 °C]

It is not necessary for these exact temperatures to be used although the temperature used must **not** exceed 55 °C. However, the actual temperature at which each experiment is carried out must be known as accurately as possible. One way that this can be achieved is to measure both the initial temperature and the final temperature and then use a mean temperature when plotting your graph.

Requirements

In addition to general laboratory apparatus, each student needs:

- thermometer ($-10\text{ }^{\circ}\text{C}$ to $110\text{ }^{\circ}\text{C}$)
- 400 cm^3 beaker (for use as a water bath)
- plastic container with lid
- 2 glass tubes to hold $12\text{--}14\text{ cm}^3$ of liquid
- 0.05 mol dm^{-3} (or 40 g dm^{-3}) sodium thiosulfate solution
- 1.0 mol dm^{-3} hydrochloric acid (or 0.5 mol dm^{-3} sulfuric acid)
- 10 cm^3 measuring cylinder
- plastic graduated pipette
- stopwatch
- graph paper.

A lid is advised in this experiment. Two holes should be made in the lid using a hot wide cork borer. These holes should securely hold the glass tubes and vertically in the plastic container. A cross should be marked on the inside base of the plastic container below one of the larger holes using a **permanent** black marker pen.

Alternatives include using clear A4 plastic wallets to use as a lid over the plastic container. Also, rather than marking the bottom of the plastic container directly, a laminated sheet marked with a black cross could be used

Caution: the CLEAPSS Hazcard states 'sulfur dioxide is produced in this reaction' and 'known sufferers of asthma should be closely monitored'.

Centres are advised to ensure that the investigation is carried out in a well-ventilated room and that appropriate measures are taken to dispose of waste solutions.

Stop baths – containers of sodium carbonate solution and phenolphthalein should be available to students so that the acid and sulfur dioxide can be neutralised (immediately, if required, during the practical and) after the experiment has finished. Once the colour of the solution in the stop bath changes, the sodium carbonate has been used up and the stop bath will need to be replenished. The stop bath should be placed in a fume cupboard, if available.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Analysing the data

In these experiments at different temperatures, the concentrations of all the reactants are the same. You are investigating the time taken to produce the same amount of sulfur at different temperatures. If you were to plot a graph of the amount of sulfur produced against time, it would initially be a straight line because the reaction has only just started. Therefore,

$$\text{the initial rate of reaction} = (\text{amount of sulfur})/\text{time}$$

so the initial rate of reaction is proportional to $1/\text{time}$ ($\frac{1}{t}$).

AS analysis

- calculate the mean temperature of each reaction mixture
- for each of the five temperatures, calculate $\frac{1}{t}$ to 3 significant figures, where t is the time taken for the cross to be obscured
- plot a graph of $\frac{1}{t}$ on the y -axis against average temperature
- the plotting of the points may be more straightforward if you multiply all of the values for $\frac{1}{t}$ by a common factor (eg 10^4).

A-level analysis

The rate constant for a reaction varies with temperature according to the following equation, where T is the temperature in **kelvins**:

$$k = Ae^{-E_a/RT}$$

taking natural logarithms

$$\ln k = -\frac{E_a}{R} \left(\frac{1}{T}\right) + \ln A$$

In this experiment, the rate constant is directly proportional to $\frac{1}{t}$. Therefore

$$\ln \frac{1}{t} = -\frac{E_a}{R} \left(\frac{1}{T}\right) + \text{constant}$$

- plot a graph of $\ln \frac{1}{t}$ on the y -axis against $\frac{1}{T}$
- the graph should be a straight line with gradient $-\frac{E_a}{R}$ so measure the gradient
- calculate a value for the activation energy and express your answer in kJ mol^{-1}
- $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

Practical 4

Required practical	Carry out simple test-tube reactions to identify cations and anions in aqueous solution			
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT d. use laboratory apparatus for a variety of experimental techniques AT k. safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances			
Indicative apparatus	Basic laboratory glassware and protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions for how to test a range of labelled compounds.	Teacher gives students a full method with clear instructions for how to test a range of unidentified compounds.	Students research methods to test for a number of identified anions and cations. They then use these methods to test a range of unidentified aqueous solutions.	Students research methods to test for a range of cations and anions. They apply these methods to test a range of unidentified aqueous solutions. Students could compare their identities for each solution based on the methods they used.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.
Applies investigative approaches and methods when using instruments and equipment	✓ Students must correctly use the appropriate equipment.	✓ Students must correctly use the appropriate equipment.	✓✓ Students must correctly use the appropriate equipment.	✓✓✓ Students must choose an appropriate approach, equipment and techniques. They must identify correct variables for measurement and control.

Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✗	✓ Students record observations in specified ways.	✓ Students record observations in specified ways.	✓✓✓ Students must choose the most effective way of recording observations.
Researches, references and reports	✗	✓ Students compare results and identify reasons for differences.	✓✓ Students must research methods available. They compare results and report on differences.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity ✗: No opportunity

A-level Chemistry exemplar for required practical No. 4

**Carry out simple test-tube reactions to identify cations and anions in aqueous solution:
To carry out tests for the presence of cations and anions and to make accurate observations**

Student sheet

These tests may be split over several lessons.

Requirements

You are provided with the following:

General

- test tubes and stoppers
- test-tube racks
- plastic graduated dropping pipettes
- deionised or distilled water
- forceps.

Test 1

- 0.1 mol dm⁻³ barium chloride solution
- 0.6 mol dm⁻³ sodium hydroxide solution
- 0.1 mol dm⁻³ calcium bromide solution (or calcium nitrate/potassium bromide)
- 0.1 mol dm⁻³ magnesium chloride solution
- 0.1 mol dm⁻³ strontium chloride solution.

Test 2

- 0.1 mol dm⁻³ barium chloride solution
- 1.0 mol dm⁻³ sulfuric acid
- 0.1 mol dm⁻³ calcium bromide solution (or calcium nitrate/potassium bromide)
- 0.1 mol dm⁻³ magnesium chloride solution
- 0.1 mol dm⁻³ strontium chloride solution.

Test 3

- 0.1 mol dm⁻³ ammonium chloride
- 0.4 mol dm⁻³ sodium hydroxide solution
- red litmus paper
- kettle
- water bath.

Test 4

- 0.4 mol dm⁻³ sodium hydroxide solution
- red litmus paper (or universal indicator paper)
- 1.0 mol dm⁻³ ammonia solution
- petri dish with lid.

Test 5

- 0.5 mol dm⁻³ sodium carbonate solution
- 0.5 mol dm⁻³ hydrochloric acid
- 0.02 mol dm⁻³ calcium hydroxide solution (limewater).

Test 6

- 0.1 mol dm⁻³ barium chloride solution
- 0.1 mol dm⁻³ magnesium sulfate solution.

Test 7

- 0.1 mol dm⁻³ potassium chloride solution
- 0.1 mol dm⁻³ potassium bromide solution
- 0.1 mol dm⁻³ potassium iodide solution
- 0.1 mol dm⁻³ nitric acid
- 0.05 mol dm⁻³ silver nitrate solution
- concentrated ammonia solution
- 2.0 mol dm⁻³ ammonia solution

Test 8

- potassium chloride solid
- potassium bromide solid
- potassium iodide solid
- 0.1 mol dm⁻³ lead nitrate solution (or lead ethanoate solution)
- blue litmus paper
- filter paper
- small spatula.
- concentrated sulfuric acid in dropping bottles
- 0.5 mol dm⁻³ acidified potassium dichromate(VI) solution

Suggested method

In every case, you should present all of your observations in a neat table. The presentation of a clearly organised record of your observations is an important skill which you will be expected to demonstrate.

Tests 1 and 2: Testing for Group 2 metal cations

Test 1 – dilute sodium hydroxide

- Place about 10 drops of 0.1 mol dm⁻³ barium chloride in a clean test tube. Add about 10 drops of 0.6 mol dm⁻³ sodium hydroxide solution, mixing well.
- Now continue to add this sodium hydroxide solution, dropwise with gentle shaking, until in excess.

The test tube should **not** be more than half full. Once completed, dispose of the contents by placing the test tube in a bowl of water.

- Repeat this test with the calcium bromide, magnesium chloride and strontium chloride.

Test 2 – dilute sulfuric acid

- Place about 10 drops of 0.1 mol dm^{-3} barium chloride in a clean test tube. Add about 10 drops of 1.0 mol dm^{-3} sulfuric acid, mixing well.
- Now continue to add this dilute sulfuric acid, dropwise with gentle shaking, until in excess.
The test tube should **not** be more than half full. Once completed, dispose of the contents by placing the test tube in a bowl of water.
- Repeat this test with the calcium bromide, magnesium chloride and strontium chloride.

Test 3: Testing for ammonium ions

- Place about 10 drops of 0.1 mol dm^{-3} ammonium chloride in a clean test tube. Add about 10 drops of 0.4 mol dm^{-3} sodium hydroxide solution. Shake the mixture.
- Warm the mixture in the test tube gently using a water bath.
- Test the fumes released from the mixture by using forceps to hold a piece of damp red litmus paper in the mouth of the test tube.
- Dispose of the contents by using the previous method.

Tests 4, 5, and 7: Tests for anions in aqueous solution

Test 4: Test for hydroxide ions in aqueous solution

- Test about 1 cm^3 of 0.4 mol dm^{-3} sodium hydroxide solution in a test tube with red litmus paper or universal indicator paper.
- Record your observations. Dispose of the test tube contents.
This approach can also be used to test for the alkaline gas, ammonia, which forms hydroxide ions when it comes into contact with water.
- Take 5 drops of 1 mol dm^{-3} ammonia solution and place on a filter paper and place inside a petri dish with lid. Dampen a piece of red litmus paper with deionised water and place on the other side of the petri dish. Replace the lid and observe over a few minutes.
- Record your observations.

Test 5: Test for carbonate ions in aqueous solution

- a) Have about 2 cm³ of calcium hydroxide (limewater) ready in a test tube.
- b) To about 3 cm³ of 0.5 mol dm⁻³ sodium carbonate solution in a test tube, add an equal volume of 1.0 mol dm⁻³ dilute hydrochloric acid.
- c) Immediately put in delivery tube with open end into the limewater test tube. Make sure that the end of the tube is below the level of the liquid.
- d) Record your observations. Dispose of the test tube contents.

Test 6: Test for sulfate ions in aqueous solution

- a) To about 1 cm³ of 0.1 mol dm⁻³ magnesium sulfate solution in a test tube, add an equal volume of dilute hydrochloric acid followed by an equal volume of 0.1 mol dm⁻³ barium chloride solution.
- b) Record your observations. Dispose of the test tube contents.

Test 7: Test for halide ions in aqueous solution

Test for chloride, bromide and iodide ions in aqueous solution

- a) Place about 10 drops of 0.1 mol dm⁻³ potassium chloride in a clean test tube. Add about 5 drops of dilute nitric acid. Shake well.
- b) To the solution add another 10 drops of 0.05 mol dm⁻³ silver nitrate solution.
- c) Then add an excess of 2 mol dm⁻³ ammonia solution and shake to mix thoroughly. Dispose of the tube contents
- d) Repeat steps a) and b), but this time add an excess of concentrated ammonia solution, working in a fume cupboard. Dispose of the tube contents
- e) Repeat steps a) to d) but using potassium bromide and then potassium iodide instead of potassium chloride.

Test 8: Test for halide ions in solid salts using concentrated sulfuric acid

Test for chloride, bromide and iodide ions in solid potassium halides

Note: Gloves **must** be worn for this procedure

These experiments must be done in a fume hood

- a) Place a small spatula of solid potassium chloride in a clean dry test tube.
- b) Slowly add a few (2 to 5) drops of concentrated sulfuric acid.
- c) Record what happens.
- d) Test the gas evolved with moist blue litmus paper, taking care that the paper does not touch the sides of the test tube.
- e) Repeat this experiment with solid potassium bromide, but this time test the gas produced using a narrow strip of filter paper that has been dipped in acidified potassium dichromate solution.
- f) Repeat this experiment with potassium iodide, but this time test the gas produced using a narrow strip of filter paper that has been dipped in lead nitrate solution.

A-level Chemistry exemplar for required practical No. 4

**Carry out simple test-tube reactions to identify cations and anions in aqueous solution:
To carry out tests for the presence of cations and anions and to make accurate observations**

Teachers' notes

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

It is advisable to split the content of this practical over a number of sessions so that the material is carefully completed.

Requirements

General

- test tubes and stoppers
- test-tube racks
- plastic graduated dropping pipettes
- deionised or distilled water
- forceps.

In addition to general laboratory apparatus, each student needs the following for each test:

Test 1

- 0.1 mol dm⁻³ barium chloride solution
- 0.6 mol dm⁻³ sodium hydroxide solution
- 0.1 mol dm⁻³ calcium bromide solution (or calcium nitrate/potassium bromide)
- 0.1 mol dm⁻³ magnesium chloride solution
- 0.1 mol dm⁻³ strontium chloride solution.

Test 2

- 0.1 mol dm⁻³ barium chloride solution
- 1.0 mol dm⁻³ sulfuric acid
- 0.1 mol dm⁻³ calcium bromide solution (or calcium nitrate/potassium bromide)
- 0.1 mol dm⁻³ magnesium chloride solution
- 0.1 mol dm⁻³ strontium chloride solution.

Test 3

- 0.1 mol dm⁻³ ammonium chloride
- 0.4 mol dm⁻³ sodium hydroxide solution
- red litmus paper
- kettle
- water bath.

Test 4

- 0.4 mol dm⁻³ sodium hydroxide solution
- red litmus paper (or universal indicator paper)
- 1.0 mol dm⁻³ ammonia solution (freshly prepared)
- petri dish with lid.

Test 5

- 0.5 mol dm⁻³ sodium carbonate solution
- 0.5 mol dm⁻³ hydrochloric acid
- 0.02 mol dm⁻³ calcium hydroxide solution (limewater).

Test 6

- 0.1 mol dm⁻³ barium chloride solution
- 0.1 mol dm⁻³ magnesium sulfate solution.

Test 7

- 0.1 mol dm⁻³ potassium chloride solution
- 0.1 mol dm⁻³ potassium bromide solution
- 0.1 mol dm⁻³ potassium iodide solution
- 0.1 mol dm⁻³ nitric acid
- 0.05 mol dm⁻³ silver nitrate solution
- concentrated ammonia solution (in a fume cupboard)
- 2.0 mol dm⁻³ ammonia solution (in a fume cupboard, freshly prepared and labelled 'ammonia solution').

Test 8

- potassium chloride solid
- potassium bromide solid
- potassium iodide solid
- 0.1 mol dm⁻³ lead nitrate solution (or lead ethanoate solution)
- blue litmus paper
- filter paper
- small spatula.
- concentrated sulfuric acid in dropping bottles (in a fume cupboard)
- 0.5 mol dm⁻³ acidified potassium dichromate(VI) solution (in a fume cupboard, see below)

The acidified potassium dichromate(VI) solution should be made by dissolving 3 g of potassium dichromate in 100 cm³ of 1.0 mol dm⁻³ sulfuric acid.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Additional notes

In test 3, step (b) will work slowly at room temperature or use water from a recently boiled kettle poured into a beaker.

In test 8, step (b), only 2 to 5 drops of concentrated sulfuric acid should be added and this should be done slowly.

Sample results

Test 1

	Barium chloride	Calcium bromide	Magnesium chloride	Strontium chloride
Initial	colourless solution	colourless solution	colourless solution	colourless solution
10 drops of 0.6 mol dm⁻³ NaOH	colourless solution	slight white precipitate	slight white precipitate	slight white precipitate
Excess NaOH	colourless solution	slight white precipitate	white precipitate	slight white precipitate

Test 2

	Barium chloride	Calcium bromide	Magnesium chloride	Strontium chloride
10 drops of 1.0 mol dm⁻³ H₂SO₄	white precipitate	slight white precipitate	slight white precipitate	white precipitate
Excess H₂SO₄	white precipitate	slight white precipitate	colourless solution	white precipitate

Test 3

Ammonium chloride + sodium hydroxide – Damp red litmus paper = blue

Test 4

Sodium hydroxide – Damp red litmus paper = blue

Ammonia solution – Damp red litmus paper = blue

Test 5

Limewater - colourless solution to cloudy

Test 6

Test of sulfate ions – white precipitate forms

Test 7

	+ HNO₃	+ 2 M NH₃	+ concentrated NH₃
Potassium chloride	white precipitate	colourless solution	colourless solution
Potassium bromide	cream precipitate	cream precipitate	colourless solution
Potassium iodide	yellow precipitate	yellow precipitate	yellow precipitate

Test 8

	Concentrated sulfuric acid	Result of paper test
Potassium chloride	effervescence	red
Potassium bromide	effervescence brown gas produced solution turns deep brown/red	
Potassium iodide	solution goes red/brown immediately brown gas produced	turns black/grey

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Practical 5

Required practical	Distillation of a product from a reaction			
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT b. use water bath or electric heater or sand bath for heating AT d. use laboratory apparatus for a variety of experimental techniques AT k. safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances			
Indicative apparatus	This will depend on the liquid to be distilled, but will likely include basic laboratory glassware, washer bottles, distillation apparatus, heating equipment and protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions on how to distil a named product from a reaction.	Teacher gives students a method with choices at different steps. Students could compare the volume of product they distilled with regard to the choices made.	Teacher chooses the product to be distilled and the equipment to be used, but does not specify the method. Students research methods available and choose which to carry out with the resources available.	Students research techniques to distil a product from a reaction and decide which reaction, and so which product to distil and which method to use, given the resources available.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.
Applies investigative approaches and methods when using instruments and equipment	✓ Students must correctly use the appropriate equipment.	✓ Students must correctly use the appropriate equipment.	✓✓ Students must correctly use the appropriate equipment.	✓✓✓ Students must choose an appropriate approach, equipment and techniques. They must identify correct variables for measurement and control.

Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✗	✓ Students record observations in specified ways.	✓ Students record observations in specified ways.	✓✓✓ Students must choose the most effective way of recording observations.
Researches, references and reports	✗	✓ Students compare results and identify reasons for differences.	✓✓ Students must research methods available. They compare results and report on differences.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity ✗: No opportunity

A-level Chemistry exemplar for required practical No. 5 – alternative a

Distillation of a product from a reaction:

To prepare cyclohexene by the dehydration of cyclohexanol and to distil the cyclohexene from the reaction mixture

Student sheet

Requirements

You are provided with the following:

- semi-micro distillation apparatus OR Quickfit apparatus fitted with a thermometer and collection vessel
- concentrated phosphoric acid
- cyclohexanol
- protective gloves
- stand and clamp
- micro-burner
- 10 cm³ measuring cylinder
- 25 cm³ measuring cylinder
- anti-bumping granules
- separating funnel
- 250 cm³ beaker
- 100 cm³ conical flask fitted with a stopper
- saturated sodium chloride solution
- anhydrous calcium chloride (or molecular sieves)
- plastic graduated dropping pipette
- acidified potassium manganate(VII) solution
- sample container
- access to a digital mass balance (reading to ± 0.1 g).

Suggested method

The dehydration of cyclohexanol to form cyclohexene

This experiment must be carried out in a fume cupboard.

- a) Pour about 20 cm³ of cyclohexanol into a weighed 50 cm³ pear-shaped flask. Reweigh the flask and record the mass of cyclohexanol.
- b) Using a plastic graduated dropping pipette, carefully **and with frequent shaking**, add to the flask approximately 8 cm³ of concentrated phosphoric acid.
- c) Add a few anti-bumping granules to the flask and assemble the semi-micro distillation apparatus, so that the contents of the flask may be distilled. Heat the flask **gently**, distilling over any liquid which boils below 100 °C.
- d) Pour the distillate into a separating funnel and add 50 cm³ of saturated sodium chloride solution. Shake the mixture and allow the two layers to separate.

-
- e) Carefully run off the lower layer into a beaker (for later disposal) and then transfer the upper layer, which contains the crude cyclohexene, into a small conical flask.
 - f) Add a few lumps of anhydrous calcium chloride or anhydrous sodium sulfate(VI) or anhydrous magnesium sulfate (or use molecular sieves (4A), if available) to the crude cyclohexene to remove water. Stopper the flask, shake the contents and allow this to stand until the liquid becomes clear.
 - g) Decant the liquid into a clean, dry, weighed sample container.
 - h) Reweigh the container, calculate the mass of dry cyclohexene produced and determine the percentage yield of your product. You should assume that the whole of the dry distillate is cyclohexene.
 - i) Test the distillate as described below, to confirm that it contains an alkene.

A test on the product to confirm the formation of an alkene

- a) To approximately 1 cm^3 of the distillate in a test tube, add an equal volume of acidified potassium manganate(VII) solution. Shake the contents of the test tube well.
- b) Record your observations.

A-level Chemistry exemplar for required practical No. 5 – alternative a

Distillation of a product from a reaction:

To prepare cyclohexene by the dehydration of cyclohexanol and to distil the cyclohexene from the reaction mixture

Teachers' notes

This experiment must be carried out in a fume cupboard only.

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

In addition to general laboratory apparatus, each student needs the following:

- semi-micro distillation apparatus OR Quickfit apparatus fitted with a thermometer ($-10\text{ }^{\circ}\text{C}$ to $110\text{ }^{\circ}\text{C}$) and collection vessel
- concentrated phosphoric acid ($\sim 8\text{ cm}^3$)
- cyclohexanol ($\sim 20\text{ cm}^3$)
- protective gloves
- stand and clamp
- micro-burner
- 10 cm^3 measuring cylinder
- 25 cm^3 measuring cylinder
- anti-bumping granules
- separating funnel
- 250 cm^3 beaker
- 100 cm^3 conical flask fitted with a stopper
- saturated sodium chloride solution ($\sim 20\text{ cm}^3$)
- anhydrous calcium chloride (or molecular sieves)
- plastic graduated dropping pipette
- acidified potassium manganate(VII) solution (see below)
- sample container
- digital mass balance (reading to $\pm 0.1\text{ g}$).

This requires the use of semi-micro distillation apparatus. Students will need guidance in how to set this up. Students will also need guidance in the correct use of a separating funnel.

The acidified potassium manganate(VII) solution should be made by taking a solution of potassium manganate(VII) of the usual concentration in use in laboratories and then acidifying it with an equal volume of dilute sulfuric acid. Each student requires approximately 1 cm^3 .

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

A-level Chemistry exemplar for required practical No. 5 – alternative b

Distillation of a product from a reaction:

To prepare ethanal by the oxidation of ethanol and to distil the ethanal from the reaction mixture

Student sheet

Requirements

You are provided with the following:

- simple distillation apparatus OR Quickfit apparatus
- acidified sodium dichromate(VI)
- protective gloves
- stand and clamp
- 10 cm³ measuring cylinder
- 25 cm³ measuring cylinder
- anti-bumping granules
- test tube
- thermometer
- two 250 cm³ beakers
- ethanol
- teat pipette
- 0.05 mol dm⁻³ silver nitrate solution
- 2 mol dm⁻³ dilute ammonia solution
- 2 mol dm⁻³ sodium hydroxide solution
- 1 mol dm⁻³ dilute sulfuric acid.

Suggested method

The oxidation of ethanol to ethanal

- a) Using a 25 cm³ measuring cylinder, carefully measure out 12 cm³ of the solution of acidified sodium dichromate(VI). Pour this oxidising agent into a boiling tube. You should wear protective gloves when handling the corrosive oxidising agent.
- b) Cool the boiling tube in cold water in a beaker.
- c) Using a 10 cm³ measuring cylinder, carefully measure out 2 cm³ of ethanol.
- d) Using a teat pipette, **slowly** add the 2 cm³ of ethanol **dropwise**, to the oxidising agent in the **cooled boiling tube** (immersed in cold water in a beaker), shaking the tube gently to mix the contents.
- e) After the addition of ethanol, add a few anti-bumping granules to the boiling tube and attach to it a bung fitted with a right-angled glass delivery tube.
- f) Clamp the boiling tube at about 45° in a beaker of water. Heat this beaker of water gently and **slowly** distil off approximately 5 cm³ of liquid distillate into a test tube **which is immersed in cold water in a beaker**. Keep the test tube cool to avoid loss of the volatile ethanal.
- g) Carry out the test described below on the distillate to confirm that ethanal has been formed in this reaction.

Test on the distillate to confirm the formation of ethanal

Tollens' silver mirror test:

- a) Prepare a sample of Tollens' reagent by adding 5 drops of sodium hydroxide solution to 2 cm³ of silver nitrate solution in a test tube.
- b) To this test tube add **just enough** dilute ammonia solution to dissolve the brown precipitate completely.
- c) Using a beaker of hot water (50–60 °C), **gently warm** approximately 5 cm³ of this test reagent in a test tube.
- d) Add 10 drops of the distillate containing ethanal to the warmed Tollens' reagent in the test tube. Wait a few minutes and note what happens. You should have produced a silver mirror on the walls of the tube.

Make sure that you dispose of the Tollens' reagent thoroughly by rinsing it away with plenty of water and then rinsing any glassware that has contained the reagent with a little dilute sulfuric acid when you are finished.

A-level Chemistry exemplar for required practical No. 5 – alternative b

Distillation of a product from a reaction:

To prepare ethanal by the oxidation of ethanol and to distil the ethanal from the reaction mixture

Teachers' notes

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

In addition to general laboratory apparatus, each student needs the following:

- simple distillation apparatus OR Quickfit apparatus
- acidified potassium dichromate(VI) (see below)
- protective gloves
- stand and clamp
- 10 cm³ measuring cylinder
- 25 cm³ measuring cylinder
- anti-bumping granules
- test tube
- thermometer (–10 °C to 110 °C)
- two 250 cm³ beakers
- ethanol
- teat pipette
- 0.05 mol dm⁻³ silver nitrate solution
- 2 mol dm⁻³ dilute ammonia solution
- 2 mol dm⁻³ sodium hydroxide solution
- 1 mol dm⁻³ dilute sulfuric acid.

The student sheet assumes that **simple distillation apparatus** will be used and this can be made by using a boiling tube fitted with a bung with a right-angled glass delivery tube. The delivery tube needs to be long enough to go into a test tube immersed in cold water in a beaker. A 400 cm³ beaker can be used for the water bath as this will be big enough to immerse the test tube. Ideally, a lab jack should be available for the beaker to collect the product in. If not available, several heat proof mats or an inverted trough with a mat on top will work.

The alternative is for the centre to provide Quickfit apparatus and guidance to students in its assembly. This apparatus will lead to a more ethanal being collected because it is condensed more efficiently using a water-cooled condenser.

The **oxidising agent** can be made for the class by dissolving potassium dichromate(VI) in dilute sulfuric acid. The concentration of the potassium dichromate(VI) should be approximately 1 g in every 10 cm³ of this dilute acid.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Practical 6

Required practical	Tests for alcohol, aldehyde, alkene and carboxylic acid			
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT b. use water bath or electric heater or sand bath for heating AT d. use laboratory apparatus for a variety of experimental techniques AT k. safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances			
Indicative apparatus	Basic laboratory glassware, pH probe or meter or indicator, heating equipment and protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions for how to test a range of labelled compounds.	Teacher gives students a full method with clear instructions, including some choices, for how to test a range of unidentified compounds.	Students research methods to test for the given compounds. They then use these methods to test a range of unidentified solutions.	Students research methods to test for a range of organic compounds. They then apply these methods to test a range of unidentified solutions, using the equipment provided. Students could compare their identities for each solution based on the methods they used.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.
Applies investigative approaches and methods when using instruments and equipment	✓ Students must correctly use the appropriate equipment.	✓ Students must correctly use the appropriate equipment.	✓✓ Students must correctly use the appropriate equipment.	✓✓✓ Students must choose an appropriate approach, equipment and techniques. They must identify correct variables for measurement and control.

Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✗	✓ Students record observations in specified ways.	✓ Students record observations in specified ways.	✓✓✓ Students must choose the most effective way of recording observations.
Researches, references and reports	✗	✓ Students compare results and identify reasons for differences.	✓✓ Students must research methods available. They compare results and report on differences.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity ✗: No opportunity

A-level Chemistry exemplar for required practical No. 6

Tests for alcohol, aldehyde, alkene and carboxylic acid:

To carry out tests for the presence of organic functional groups and to make accurate observations

Student sheet

Requirements

You are provided with the following:

- ethanol
- ethanal or propanal
- cyclohexene
- 1-bromobutane
- dilute ethanoic acid
- small pieces of metallic sodium under petroleum ether (a beaker of ethanol should be available for safe disposal of any excess sodium)
- Fehling's solution A
- Fehling's solution B
- bromine water
- sodium carbonate solution
- sodium hydrogencarbonate solid
- sodium hydroxide solution
- silver nitrate solution (0.05 mol dm^{-3})
- dilute nitric acid
- 250 cm^3 beaker
- anti-bumping granules
- test tubes, boiling tubes and a test-tube holder
- thermometer
- plastic graduated dropping pipettes.

Suggested method

This experiment is divided into five parts.

In every case, you should present all of your observations in a neat table. The presentation of a clearly organised record of your observations is an important skill which you will be expected to demonstrate as part of this assessment.

Part 1 – A test for an alcohol

- To about 1 cm^3 of ethanol in a **dry** test tube, add a small piece of metallic sodium.
- Record your observations.
- Make sure that you dispose safely of any excess sodium using the beaker of ethanol provided.

Part 2 – A test for an aldehyde using Fehling's solution.

- a) In a clean test tube mix together equal volumes of Fehling's solution A and Fehling's solution B. The resultant Fehling's test reagent should be a clear dark blue solution.
- b) Add 5 drops of this test reagent to about 1 cm³ of sodium carbonate solution in a test tube containing a few anti-bumping granules and then add about 1 cm³ of ethanal (or propanal) to this same test tube.
- c) Warm the test tube gently for approximately 2 minutes in a beaker half-filled with hot water and then gradually bring the beaker of water to boiling and maintain this temperature for a few minutes.
- d) Using the test tube holder, carefully lift the test tube out of the boiling water and allow its contents to stand for several minutes. Record your observations.

Part 3 – A test for an alkene (a test for unsaturation)

- a) To about 2 drops of cyclohexene in a test tube, add about 1 cm³ of bromine water and shake the contents of the tube vigorously from side to side.
- b) Record your observations.

Part 4 – A test for a carboxylic acid

- a) Place one small spatula measure of solid sodium hydrogencarbonate in a boiling tube and add to it about 2 cm³ of dilute ethanoic acid.
- b) Record your observations.

Part 5 – A test for a halogenoalkane

- a) Using a test pipette, add 5 drops of 1-bromobutane to about 1 cm³ of sodium hydroxide solution in a test tube. Warm the contents of the test tube for a few minutes, by placing it into a beaker filled with hot water at approximately 60 °C.
- b) Acidify the contents of the test tube by adding 2 cm³ of dilute nitric acid and then add about 1 cm³ of silver nitrate solution.
- c) Record your observations.

A-level Chemistry exemplar for required practical No. 6

Tests for alcohol, aldehyde, alkene and carboxylic acid:

To carry out tests for the presence of organic functional groups and to make accurate observations

Teachers' notes

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

In addition to general laboratory apparatus, each student needs the following:

- ethanol
- ethanal or propanal
- cyclohexene
- 1-bromobutane
- dilute ethanoic acid
- small pieces of metallic sodium under petroleum ether *
(a beaker of ethanol should be available for safe disposal of any excess sodium)
- Fehling's solution A
- Fehling's solution B
- bromine water
- sodium carbonate solution
- sodium hydrogencarbonate solid
- sodium hydroxide solution
- silver nitrate solution (0.05 mol dm^{-3})
- dilute nitric acid
- 250 cm^3 beaker
- anti-bumping granules
- test tubes, boiling tubes and a test-tube holder
- thermometer ($-10 \text{ }^\circ\text{C}$ to $110 \text{ }^\circ\text{C}$)
- plastic graduated dropping pipettes.

The concentrations of the aqueous solutions in these experiments need to be sufficient to ensure that obvious reactions take place. In practice, this is likely to mean **2 mol dm⁻³** for most solutions.

* The small pieces of metallic sodium should be approximately the size of a grain of rice.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Practical 7

Required practical	Measuring the rate of reaction by an initial rate method			
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT a. Use appropriate apparatus to record a range of measurements AT k. Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances AT l. Measure rates of reaction by an initial rate method			
Indicative apparatus	This depends on the reaction being studied, but will likely contain basic laboratory glassware, timer, and protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions for how to measure the rate of a given reaction. Clear instructions are provided for how to determine the rate of reaction.	Teacher gives students a method with choices at different steps. Students could compare the rate of their reaction with regard to the choices made. Instructions are given, in the form of questions, for how to determine the rate of reaction.	Teacher chooses the reaction to be studied, but does not specify the method. Students research the methods available and choose which to carry out. Students research how to analyse their data in order to determine the rate of reaction.	Students research methods to measure the rate of reaction and decide which method and which reaction to study. Students research how to analyse their data in order to determine the rate of reaction.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.
Applies investigative approaches and methods when using instruments and	✓ Students must correctly use the appropriate equipment. Procedure should be followed	✓ Students must correctly use the appropriate equipment. Procedure should be followed	✓✓ Students must correctly select and use the appropriate equipment. Procedural steps should be well	✓✓✓ Students must choose an appropriate methodical approach, equipment and techniques. Procedural steps

equipment	methodically and appropriate variables measured or controlled.	methodically and suitable variables identified, measured and controlled.	sequenced and adjusted where necessary. Suitable variables identified, measured and controlled.	should be well sequenced and adjusted where necessary. Suitable variables should be identified for measurement and control. Where variables cannot be readily controlled, approaches should be planned to take account of this.
Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✓ Students record data in specified ways.	✓ Students record accurate data in specified ways.	✓✓ Students record precise and accurate data, methodically using appropriate units, in specified ways.	✓✓✓ Students must choose the most effective way of recording precise and accurate data methodically using appropriate units.
Researches, references and reports	✓ Data is reported and conclusions drawn.	✓ Data is reported and conclusions drawn. Students compare results and identify reasons for differences.	✓✓✓ Students must research methods available. They compare results and report on differences. Appropriate software is used to process data and report findings.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results. Appropriate software and/or tools are used to process data and report findings.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity ✗: No opportunity

A-level Chemistry exemplar for required practical No. 7 – part a

Measuring the rate of reaction by an initial rate method:

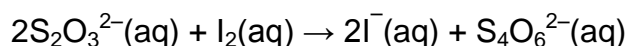
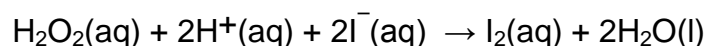
An 'Iodine Clock' experiment: To investigate the reaction of iodide(V) ions with hydrogen peroxide in acidic solution and to determine the order of the reaction with respect to iodide ions.

Student sheet

The 'Iodine Clock' experiment can be used to determine the effect of a change in concentration of iodide ions on the reaction between hydrogen peroxide and iodide ions.

Introduction

Hydrogen peroxide reacts with iodide ions to form iodine and the thiosulfate ion immediately reacts with iodine as shown below.



When the I_2 produced has reacted with all of the limited amount of thiosulfate ions present, excess I_2 remains in solution. Reaction with the starch then forms a dark blue-black colour.

By varying the concentration of I^- , you can determine the order of reaction with respect to I^- ions.

Requirements

You are provided with the following:

- 0.25 mol dm⁻³ dilute sulfuric acid
- 0.10 mol dm⁻³ potassium iodide solution
- 0.05 mol dm⁻³ sodium thiosulfate solution (in a shared burette)
- 0.10 mol dm⁻³ hydrogen peroxide solution (in a shared burette)
- starch solution
- 50 cm³ burette
- funnel suitable for filling a burette
- stand and clamp
- white tile
- plastic dropping pipette
- 25 cm³ measuring cylinder
- 50 cm³ measuring cylinder
- 100 cm³ beaker
- 250 cm³ beaker
- stirrer
- stopwatch
- paper towels to dry beakers
- plentiful supply of distilled or deionised water.

Suggested method

Experiment 1

- Rinse a 50 cm³ burette with potassium iodide solution. Fill the burette with potassium iodide solution.
- Transfer 10.0 cm³ of hydrogen peroxide solution from the shared burette provided to a clean, dry **100 cm³** beaker. You will use this in step (h).
- Use a 50 cm³ measuring cylinder to add 25 cm³ of sulfuric acid to a clean, dry **250 cm³** beaker.
- Use a 25 cm³ measuring cylinder to add 20 cm³ of distilled or deionised water into the 250 cm³ beaker.
- Use a plastic dropping pipette to add about 1 cm³ of starch solution to this beaker.
- Use your burette to add 5.0 cm³ of potassium iodide solution to the mixture in the 250 cm³ beaker.
- Finally, add 5.0 cm³ of sodium thiosulfate solution from the shared burette provided to the mixture in the 250 cm³ beaker. Make sure this sodium thiosulfate solution is added last.
- Stir the mixture in the 250 cm³ beaker. Pour the hydrogen peroxide solution from the 100 cm³ beaker into the 250 cm³ beaker and **immediately** start the timer. Stir the mixture.
- Stop the timer when the mixture in the 250 cm³ beaker turns blue-black. Record the time to an appropriate precision in a table of your own design. This experiment could take several minutes.
- Rinse the 250 cm³ beaker with distilled or deionised water and dry it with a paper towel.

Experiments 2–5

- Repeat steps (b) to (j) in four further experiments using the volumes shown in the following table.

Volumes of solutions added to 250 cm³ beaker

Experiment	Sulfuric acid 0.25 M / cm ³	Starch / cm ³	Water / cm ³	Potassium iodide 0.10 M / cm ³	Sodium thiosulfate 0.05 M / cm ³
1	25	1	20	5.0	5.0
2	25	1	15	10.0	5.0
3	25	1	10	15.0	5.0
4	25	1	5	20.0	5.0
5	25	1	0	25.0	5.0

Volume in 100 cm³ beaker

Hydrogen peroxide 0.10 M / cm ³
10.0
10.0
10.0
10.0
10.0

A-level Chemistry exemplar for required practical No. 7 – part a

Measuring the rate of reaction by an initial rate method:

An 'Iodine Clock' experiment: To investigate the reaction of iodide(V) ions with hydrogen peroxide in acidic solution and to determine the order of the reaction with respect to iodide ions.

Teachers' notes

This practical covers Apparatus and technique reference AT I. This requires students to measure rates of reaction by at least two different methods. This worksheet provides a method with which students can measure the rate of reaction using one method. Students will also have to complete a further practical activity and measure the rate of reaction using another method. This could be based on our exemplar practical in worksheet 7b or any alternative practical work that fulfils the requirement to cover Apparatus and technique AT I.

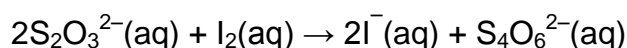
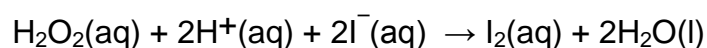
Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Introduction

The 'Iodine Clock' experiment can be used to determine the effect of a change in concentration of iodide ions on the reaction between hydrogen peroxide and iodide ions.

Hydrogen peroxide reacts with iodide ions to form iodine and the thiosulfate ion immediately reacts with iodine as shown below.



When the I_2 produced has reacted with all of the limited amount of thiosulfate ions present, excess I_2 remains in solution. Reaction with the starch then forms a dark blue-black colour.

By varying the concentration of I^- , you can determine the order of reaction with respect to I^- ions.

Requirements

In addition to general laboratory apparatus, each student needs the following:

- 125 cm³ of 0.25 mol dm⁻³ dilute sulfuric acid
- 100 cm³ of 0.10 mol dm⁻³ potassium iodide solution
- 25 cm³ of 0.05 mol dm⁻³ sodium thiosulfate solution
- 50 cm³ of 0.10 mol dm⁻³ hydrogen peroxide solution (freshly prepared)
- 5 cm³ of 1% starch solution (freshly prepared)
- 50 cm³ burette
- funnel suitable for filling a burette
- stand and clamp
- white tile
- plastic dropping pipette (or starch solution provided in a dropping bottle)
- 25 cm³ measuring cylinder
- 50 cm³ measuring cylinder
- 100 cm³ beaker
- 250 cm³ beaker
- stirrer
- stopwatch
- paper towels to dry beakers
- plentiful supply of distilled or deionised water.

The exemplar method provided is based on each student having access to communal burettes (approximately one set for every five students) containing hydrogen peroxide and sodium thiosulfate solutions. Teachers are advised that frequent refilling of these burettes will be required.

The hydrogen peroxide solution must be freshly prepared on the day of the practical from a recently purchased, more concentrated solution.

The 1% starch solution must be freshly prepared on the day of the practical.

The hydrogen peroxide is the reagent controlling the time of the reaction and the concentration stated above can be varied as required.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Practical 7b

Required practical	Measuring the rate of reaction by a continuous monitoring method			
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT a. use appropriate apparatus to record a range of measurements AT k. safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances AT l. measure rates of reaction by a continuous monitoring method			
Indicative apparatus	This depends on the reaction being studied, but will likely contain basic laboratory glassware, timer, and protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions for how to measure the rate of a given reaction. Clear instructions are provided for how to determine the rate of reaction.	Teacher gives students a method with choices at different steps. Students could compare the rate of their reaction with regard to the choices made. Instructions are given, in the form of questions, for how to determine the rate of reaction.	Teacher chooses the reaction to be studied, but does not specify the method. Students research the methods available and choose which to carry out. Students research how to analyse their data in order to determine the rate of reaction.	Students research methods to measure the rate of reaction and decide which method and which reaction to study. Students research how to analyse their data in order to determine the rate of reaction.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.
Applies investigative approaches and methods when using instruments	✓ Students must correctly use the appropriate equipment. Procedure should be	✓ Students must correctly use the appropriate equipment. Procedure should be	✓✓ Students must correctly select and use the appropriate equipment. Procedural steps should	✓✓✓ Students must choose an appropriate methodical approach, equipment and techniques.

and equipment	followed methodically and appropriate variables measured or controlled.	followed methodically and suitable variables identified, measured and controlled.	be well sequenced and adjusted where necessary. Suitable variables identified, measured and controlled.	Procedural steps should be well sequenced and adjusted where necessary. Suitable variables should be identified for measurement and control. Where variables cannot be readily controlled, approaches should be planned to take account of this.
Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✓ Students record data in specified ways.	✓ Students record accurate data in specified ways.	✓✓ Students record precise and accurate data, methodically using appropriate units, in specified ways.	✓✓✓ Students must choose the most effective way of recording precise and accurate data methodically using appropriate units.
Researches, references and reports	✓ Data is reported and conclusions drawn.	✓ Data is reported and conclusions drawn. Students compare results and identify reasons for differences.	✓✓✓ Students must research methods available. They compare results and report on differences. Appropriate software is used to process data and report findings.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results. Appropriate software and/or tools are used to process data and report findings.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity ✕: No opportunity

A-level Chemistry exemplar for required practical No. 7 – part b

Measuring the rate of reaction by a continuous monitoring method: The reaction between magnesium and hydrochloric acid

Student sheet

Requirements

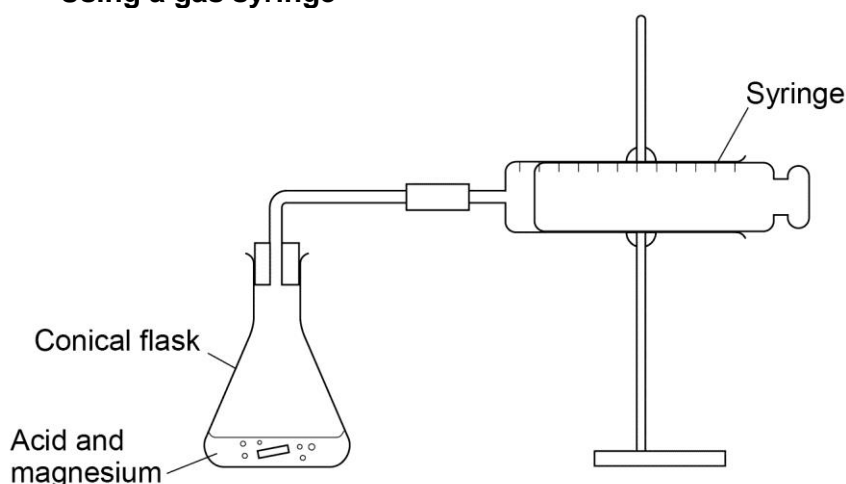
You are provided with the following:

- magnesium ribbon
- 0.8 mol dm^{-3} hydrochloric acid
- 50 cm^3 measuring cylinder
- 100 cm^3 conical flask
- rubber bung and delivery tube to fit conical flask
- 100 cm^3 gas syringe OR trough/plastic container with 100 cm^3 measuring cylinder
- stand, boss and clamp
- stopwatch or timer
- distilled or deionised water.

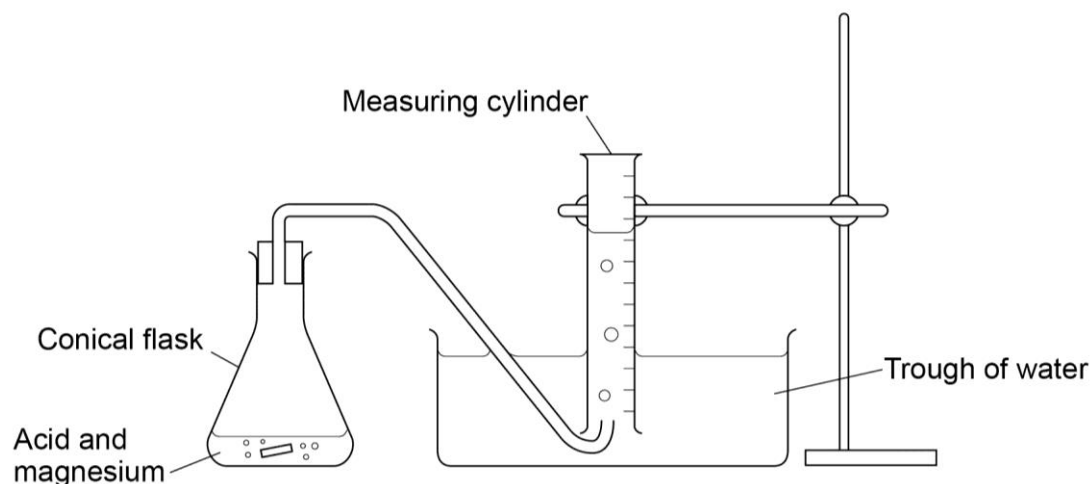
Suggested method

- Measure 50 cm^3 of the 0.8 mol dm^{-3} hydrochloric acid and add to conical flask.
- Set up the gas syringe in the stand (or alternative gas collection method as shown by your teacher).

Using a gas syringe



Using a trough



- Add one 6 cm strip of magnesium ribbon to the conical flask, place the bung firmly into the top of the flask and start the timer.
- Record the volume of hydrogen gas collected every 15 seconds for 2.5 minutes.

Repeat steps (a) to (d) using 0.4 mol dm^{-3} hydrochloric acid, made by mixing 25 cm^3 of the 0.8 mol dm^{-3} hydrochloric acid with 25 cm^3 of distilled or deionised water.

Analysis

- Plot a graph of volume of hydrogen produced on the y -axis against time in seconds for each hydrochloric acid concentration. Draw a line of best fit.
- Draw a tangent to each line of best fit at time, $t = 0 \text{ s}$
- Calculate the gradient of each tangent in order to deduce the rate of each reaction.
- Compare the two rate values obtained.

A-level Chemistry exemplar for required practical No. 7 – part b

Measuring the rate of reaction by a continuous monitoring method: The reaction between magnesium and hydrochloric acid

Teachers' notes

This practical covers Apparatus and technique reference AT I. This requires students to measure rates of reaction by at least two different methods. This worksheet provides a method with which students can measure the rate of reaction using one method. Students will also have to complete a further practical activity and measure the rate of reaction using another method. This could be our exemplar practical in worksheet 7a or any alternative practical work that fulfils the requirement to cover Apparatus and technique AT I.

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

In addition to general laboratory apparatus, each student needs the following:

- 6 cm strips of magnesium ribbon
- 75 cm³ of 0.8 mol dm⁻³ hydrochloric acid
- 50 cm³ measuring cylinder
- 100 cm³ conical flask
- rubber bung and delivery tube to fit conical flask
- 100 cm³ gas syringe OR trough/plastic container with 100 cm³ measuring cylinder
- stand, boss and clamp
- stopwatch or timer
- distilled or deionised water.

In the suggested method, the magnesium ribbon is provided as 6 cm strips, pre-cut by the technician.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

From trials, a 100 cm³ gas syringe was suitable for the volume of gas produced in 2.5 minutes. However, you can replace this with a 250 cm³ gas syringe based on your own trial results.

Sample results

The following table is a sample results table using results from the trial of this experiment.

Time / s	Volume of gas collected / cm ³	
	0.4 mol dm ⁻³ hydrochloric acid	0.8 mol dm ⁻³ hydrochloric acid
0	0.0	0.0
15	4.0	15.0
30	6.0	29.0
45	9.0	43.0
60	17.0	54.0
75	20.0	66.0
90	22.0	75.0
105	24.0	84.0
120	27.0	91.0
135	30.0	95.0
150	32.0	96.0

These were obtained using 0.8 mol dm⁻³ hydrochloric acid and 0.4 mol dm⁻³ hydrochloric acid with 6 cm strips of magnesium ribbon.

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Practical 8

Required practical	Measuring the EMF of an electrochemical cell			
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT j. set up electrochemical cells and measure voltages AT k. safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances			
Indicative apparatus	Basic laboratory glassware, protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions, including a diagram, for how to set up an electrochemical cell. Students are given full instructions for how to measure the EMF of their electrochemical cell.	Teacher gives students a method for how to set up an electrochemical cell, but allows for choices of equipment. Students are given instructions, with some choices, for how to measure the EMF of their electrochemical cell.	Students research electrochemical cells and choose a method to set an electrochemical cell using the equipment provided. Students research how to measure the EMF of the electrochemical cell they have been instructed to make.	Students research electrochemical cells and choose a method and equipment to set an electrochemical cell. Students research how to measure the EMF of the electrochemical cell they have chosen to make.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.
Applies investigative approaches and methods when using instruments and equipment	✓ Students must correctly use the appropriate equipment. Procedure should be followed methodically and appropriate	✓ Students must correctly use the appropriate equipment. Procedure should be followed methodically and suitable	✓✓ Students must correctly select and use the appropriate equipment. Procedural steps should be well sequenced and adjusted where	✓✓✓ Students must choose an appropriate methodical approach, equipment and techniques. Procedural steps should be well sequenced and

	variables measured or controlled.	variables identified, measured and controlled.	necessary. Suitable variables identified, measured and controlled.	adjusted where necessary. Suitable variables should be identified for measurement and control. Where variables cannot be readily controlled, approaches should be planned to take account of this.
Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✓ Students record data in specified ways.	✓ Students record accurate data in specified ways.	✓✓ Students record precise and accurate data, methodically using appropriate units, in specified ways.	✓✓✓ Students must choose the most effective way of recording precise and accurate data methodically using appropriate units.
Researches, references and reports	✓ Data is reported and conclusions drawn.	✓ Data is reported and conclusions drawn. Students compare results and identify reasons for differences.	✓✓✓ Students must research methods available. They compare results and report on differences. Appropriate software is used to process data and report findings.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results. Appropriate software and/or tools are used to process data and report findings.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity ✗: No opportunity

A-level Chemistry exemplar for required practical No. 8

Measuring the EMF of an electrochemical cell

Student sheet

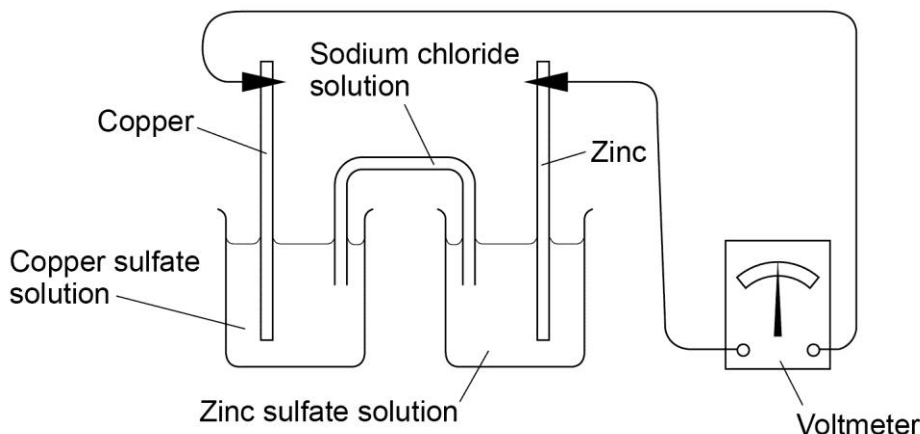
Requirements

You are provided with the following:

- pieces of copper and zinc foil (about 2 cm × 5 cm)
- propanone
- 2.0 mol dm⁻³ NaCl solution
- 1.0 mol dm⁻³ CuSO₄ solution
- 1.0 mol dm⁻³ ZnSO₄ solution
- emery paper or fine grade sandpaper
- two 100 cm³ beakers
- plastic or glass U-tube
- cotton wool soaked in sodium chloride solution
- voltmeter (digital or high impedance)
- two electrical leads with connectors for the voltmeter at one end and crocodile clips at the other end
- samples of metals.

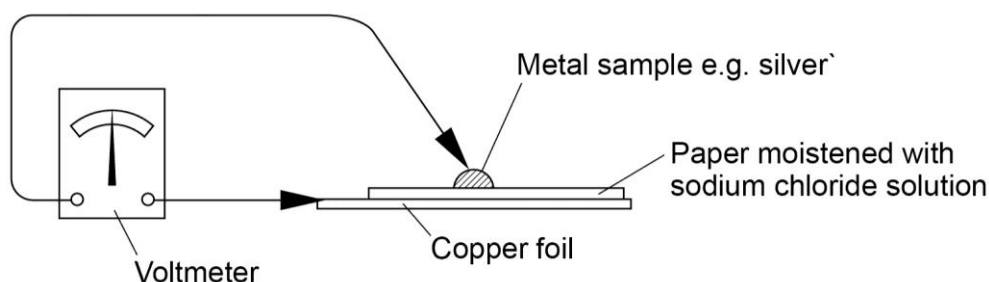
Suggested method for setting up a standard cell

- Clean a piece of copper and a piece of zinc using emery paper or fine grade sandpaper.
- Degrease the metal using some cotton wool and propanone.
- Place the copper into a 100 cm³ beaker with about 50 cm³ of 1 mol dm⁻³ CuSO₄ solution.
- Place the zinc into a 100 cm³ beaker with about 50 cm³ of 1 mol dm⁻³ ZnSO₄ solution.
- Lightly plug one end of the plastic tube with cotton wool and fill the tube with the solution of 2 mol dm⁻³ NaCl provided.
- Plug the free end of the tube with cotton wool which has been soaked in sodium chloride. Join the two beakers with the inverted U-tube so that the plugged ends are in the separate beakers.
- Connect the Cu(s)|Cu²⁺(aq) and Zn(s)|Zn²⁺(aq) half-cells by connecting the metals (using the crocodile clips and leads provided) provided to the voltmeter and read off the voltage.



Suggested method for measuring comparative electrode potentials of different metals

- Clean a piece of copper using emery paper or fine grade sandpaper.
- Connect the positive terminal of the voltmeter to the copper using a crocodile clip and one of the leads.
- Cut a piece of filter paper to about the same area as the copper, moisten the filter paper with the sodium chloride solution and place on top of the copper.
- Connect the second lead to the voltmeter and use the crocodile clip on the other end of the lead to grip a piece of another metal.
- Hold the metal against the filter paper and note the voltage reading and sign.



- Repeat steps (d) and (e) with different metals and record your results in a table.
- Write the conventional representation for each of the cells that you have constructed
- Suggest how you could construct the cell with the largest EMF from the metals provided.

A-level Chemistry exemplar for required practical No. 8

Measuring the EMF of an electrochemical cell

Teachers' notes

Requirements

In addition to general laboratory apparatus, each student needs the following:

- pieces of copper and zinc foil (about 2 cm × 5 cm)
- propanone
- 2.0 mol dm⁻³ NaCl solution
- 1.0 mol dm⁻³ CuSO₄ solution
- 1.0 mol dm⁻³ ZnSO₄ solution
- emery paper or fine grade sandpaper
- two 100 cm³ beakers
- plastic or glass U-tube
- cotton wool or a strip of filter paper (soaked in sodium chloride solution)
- voltmeter (digital or high impedance)
- two electrical leads with connectors for the voltmeter at one end and crocodile clips at the other end
- samples of metals, which could include titanium, iron, calcium, silver.

In the second part of the practical, magnesium can be used as the standard instead of copper.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Practical 9

Required practical	Investigate how pH changes when a weak acid reacts with a strong base and when a strong acid reacts with a weak base			
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT a. use appropriate apparatus to record a range of measurements AT c. measure pH using pH charts, or pH meter, or pH probe on a data logger AT d. use laboratory apparatus for a variety of experimental techniques AT k. safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances			
Indicative apparatus	Basic laboratory glassware, burette, volumetric pipette and filler, pH meter or probe, and protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method, with clear instructions, for how to carry out simple titrations using given chemicals and equipment. Students monitor the pH using equipment provided and following given instructions.	Teacher gives students an outline for the procedure to carry out simple titrations, but with some choices in technique, equipment and chemicals. Students monitor the pH using their choice of equipment provided and following given instructions.	Students research the methods to carry out simple titrations using the equipment and chemicals provided. Students monitor the pH using their choice of equipment provided and following instructions they have researched.	Students research methods for carrying out simple titrations and choose the method, chemicals and equipment to use. Students monitor the pH using their choice of equipment provided and following instructions they have researched.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.
Applies investigative approaches and methods	✓ Students must correctly use the appropriate equipment.	✓ Students must correctly use the appropriate equipment.	✓✓ Students must correctly select and use the appropriate equipment.	✓✓✓ Students must choose an appropriate methodical approach,

when using instruments and equipment	Procedure should be followed methodically and appropriate variables measured or controlled.	Procedure should be followed methodically and suitable variables identified, measured and controlled.	Procedural steps should be well sequenced and adjusted where necessary. Suitable variables identified, measured and controlled.	equipment and techniques. Procedural steps should be well sequenced and adjusted where necessary. Suitable variables should be identified for measurement and control. Where variables cannot be readily controlled, approaches should be planned to take account of this.
Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✓ Students record data in specified ways.	✓ Students record accurate data in specified ways.	✓✓ Students record precise and accurate data, methodically using appropriate units, in specified ways.	✓✓✓ Students must choose the most effective way of recording precise and accurate data methodically using appropriate units.
Researches, references and reports	✓ Data is reported and conclusions drawn.	✓ Data is reported and conclusions drawn. Students compare results and identify reasons for differences.	✓✓✓ Students must research methods available. They compare results and report on differences. Appropriate software is used to process data and report findings.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results. Appropriate software and/or tools are used to process data and report findings.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity *: No opportunity

A-level Chemistry exemplar for required practical No. 9

**To investigate how pH changes when a weak acid reacts with a strong base:
Investigation of how the pH of a solution of ethanoic acid changes as sodium hydroxide solution is added.**

Student sheet

This experiment investigates how the pH of a solution of ethanoic acid changes as sodium hydroxide solution is added.

The results are plotted in a graph which shows the general pattern of how the pH changes when a weak acid reacts with a strong base.

It is necessary initially to calibrate a pH meter so as to give accurate pH values for each pH reading.

Requirements

You are provided with the following:

- two 50 cm³ burettes
- two funnels
- 100 cm³ beaker
- deionised (or distilled) water in a wash bottle
- stand and clamp
- pH meter/probe
- 0.100 mol dm⁻³ sodium hydroxide solution
- 0.100 mol dm⁻³ ethanoic acid solution
- standard pH buffer solutions at pH 4.00, 7.00 and 9.20
- stirring rod
- graph paper.

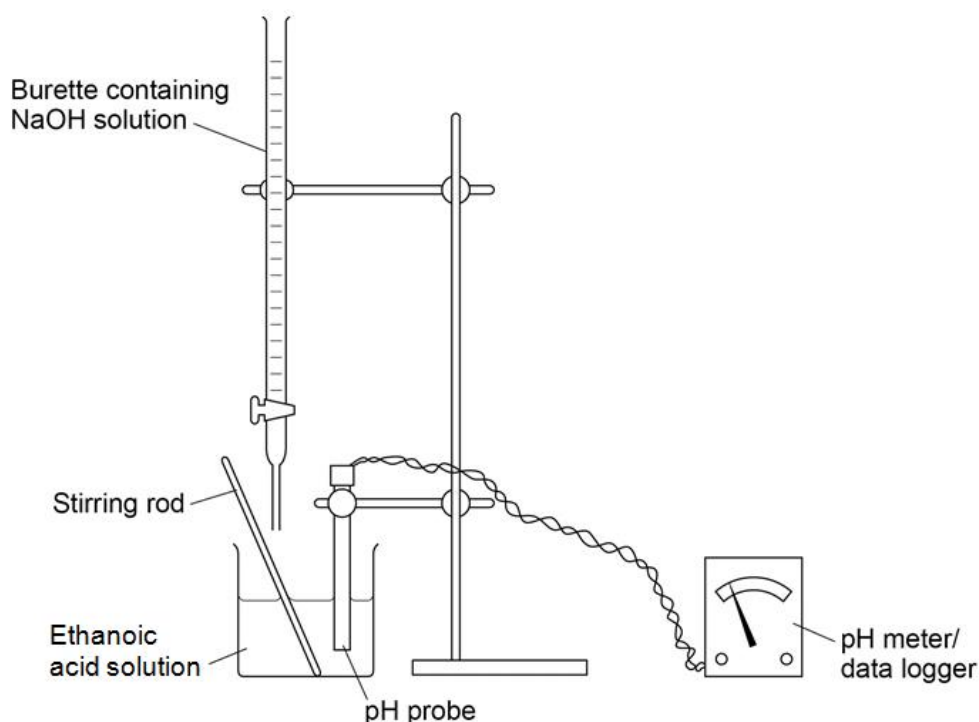
Suggested method

Part 1 Calibrate the pH meter

- a) Rinse the pH probe thoroughly with deionised water, and shake it gently to remove excess water. Place the probe in the standard pH 7.00 buffer solution provided, ensuring that the bulb is fully immersed. Record the pH reading in a suitable table.
- b) Repeat this process using the standard pH 4.00 and 9.20 buffer solutions. Rinse the pH probe thoroughly with deionised water before taking each reading. Record the pH readings in your table.
- c) Plot a graph of your recorded pH reading (x-axis) against the pH of the buffer solution. Your graph may be a straight line or a curve. This calibration graph will be used in the next part of the experiment to convert pH readings into more accurate pH values.

Part 2 The measurement of the pH of the mixture of acid and alkali

- Rinse a burette with the $0.100 \text{ mol dm}^{-3}$ solution of ethanoic acid provided and then fill the burette with this solution, ensuring that it is filled below the tap. Label this burette so that you do not confuse it with the second burette.
- Use the burette to transfer exactly 20.0 cm^3 of ethanoic acid to a clean 100 cm^3 beaker.
- Rinse a second burette with the $0.100 \text{ mol dm}^{-3}$ NaOH solution provided and then fill this second burette with this solution, ensuring that it is filled below the tap.
- Rinse the pH probe with distilled or deionised water and clamp it so that its bulb is fully immersed in the ethanoic acid solution in the beaker. Use a rod to stir the solution gently and record the pH reading in a suitable table.



- Using the second burette, add exactly 2.0 cm^3 of the NaOH solution to the beaker containing the ethanoic acid. Stir the mixture gently with the glass rod and measure the pH of the mixture. Record the pH reading.
Add the NaOH solution in 2.0 cm^3 portions from the second burette to the ethanoic acid in the beaker until 18 cm^3 of the NaOH solution have been added. Take a pH reading after each addition of NaOH solution, and in each case record the pH reading in your table.
Then add the NaOH solution in 0.20 cm^3 portions until 22.0 cm^3 is reached.
Then add the NaOH solution in 2.0 cm^3 portions again until 40 cm^3 have been added.
- Rinse the pH probe with distilled or deionised water when you have taken all of your readings.

Analysing the data

- a) Use your calibration graph from Part 1 to adjust, as appropriate, the pH readings obtained in your experiment in Part 2. These corrected pH values should be entered into a new column in your table of results.
- b) Plot a graph of the corrected pH values from Part 2 (y -axis) against volume of sodium hydroxide solution added.
- c) Join the points in the most appropriate way.
- d) Comment on the shape of the curve.

A-level Chemistry exemplar for required practical No. 9

**To investigate how pH changes when a weak acid reacts with a strong base:
Investigation of how the pH of a solution of ethanoic acid changes as sodium hydroxide solution is added.**

Teachers' notes

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

In addition to general laboratory apparatus, each student needs the following:

- two 50 cm³ burettes
- two funnels
- 100 cm³ beaker
- deionised (or distilled) water in a wash bottle
- stand and clamp
- pH meter/probe
- 0.100 mol dm⁻³ sodium hydroxide solution
- 0.100 mol dm⁻³ ethanoic acid solution
- standard pH buffer solutions at pH 4.00, 7.00 and 9.20
- stirring rod
- graph paper.

Teachers may choose to use other weak acid/strong base combinations or strong acid/weak base combinations.

The pH buffer solutions can be bought in ready-made or as tablets which can then be made up.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Practical 10a

Required practical	Preparation of an organic solid and a test of its purity			
Apparatus and techniques covered (Not full statements)	AT a. use appropriate apparatus to record a range of measurements AT b. use water bath or electric heater or sand bath for heating AT d. use laboratory apparatus for a variety of experimental techniques AT g. purify a solid product by recrystallisation AT h. use melting point apparatus AT k. safely and carefully handle solids and liquids			
Indicative apparatus	This will depend on the solid to be produced, but will likely include basic laboratory glassware, washer bottles, crystallisation dishes, Buchner funnels and pumps, heating equipment and protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions for how to produce a given solid and then to purify it.	Teacher gives students a method with choices at different steps. Students could compare the purity of their product with regard to the choices made.	Teacher chooses the compound to be made but doesn't specify the method. Students research methods available and choose which to carry out.	Students research organic pathways and solids and decide which solid to produce and which method to use, given the resources available.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.
Applies investigative approaches and methods when using instruments and equipment	✓ Students must correctly use the appropriate equipment.	✓ Students must correctly use the appropriate equipment.	✓✓ Students must correctly use the appropriate equipment.	✓✓✓ Students must choose an appropriate approach, equipment and techniques and identify correct variables for measurement and control.

Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✗	✓ Students record observations in specified ways.	✓ Students record observations in specified ways.	✓✓✓ Students must choose the most effective way of recording observations.
Researches, references and reports	✗	✓ Students compare results and identify reasons for differences.	✓✓ Students must research methods available. They compare results and report on differences.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity ✗: No opportunity

A-level Chemistry exemplar for required practical No. 10 – part a

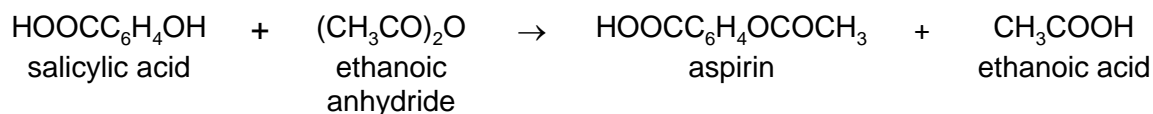
Preparation of an organic solid and a test of its purity:

To prepare a sample of aspirin

Student sheet

Aspirin is prepared by the acylation of salicylic acid (2-hydroxybenzenecarboxylic acid) using ethanoic anhydride as the acylating agent.

The reaction can be represented as follows.



Aspirin (2-ethanoylhydroxybenzenecarboxylic acid) is an antipyretic drug (reduces fever by lowering body temperature) and an analgesic (relieves pain).

Aspirin does not react in the acidic conditions in the stomach, but is hydrolysed in the alkaline conditions found in the intestines to produce ethanoate ions and salicylate (2-hydroxybenzenecarboxylate) ions. Salicylates lower the body temperature of feverish patients and have a mild analgesic effect relieving headaches and other pain. The toxic dose is relatively high, but symptoms of poisoning can occur with quite small quantities.

Requirements

You are provided with the following:

Part 1

- salicylic (2-hydroxybenzenecarboxylic) acid
- 100 cm³ conical flask
- 10 cm³ measuring cylinder
- ethanoic anhydride
- concentrated sulfuric acid in a dropping bottle
- 400 cm³ beaker
- tripod, gauze and Bunsen burner
- thermometer
- 250 cm³ beaker
- reduced pressure filtration apparatus
- filter paper
- stirring rod
- deionised or distilled water in a wash bottle
- spatula.

Part 2

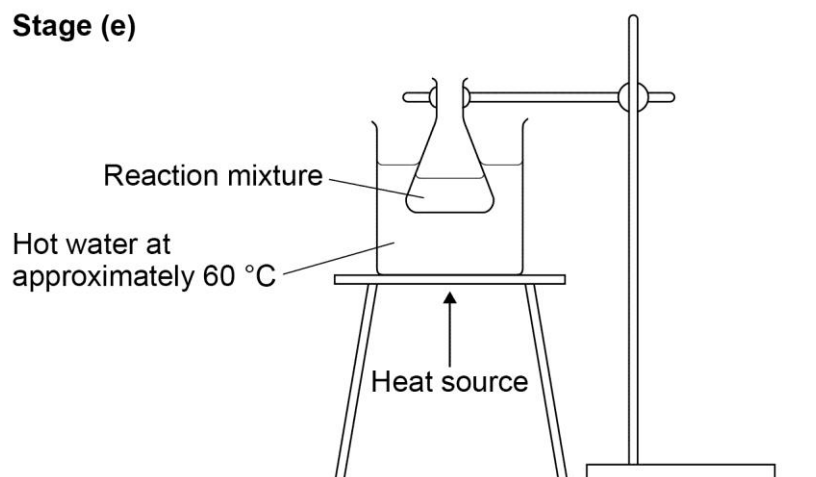
- 25 cm³ measuring cylinder
- boiling tube
- ethanol
- thermometer
- deionised or distilled water in a wash bottle
- 250 cm³ beaker
- 100 cm³ conical flask
- stirring rod
- kettle
- access to a digital mass balance (reading to 2 decimal places).

Suggested method

Part 1 Preparation

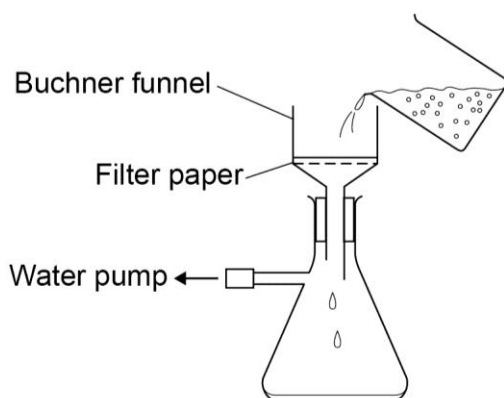
- Weigh out approximately 6.00 g of salicylic acid directly into a 100 cm³ conical flask.
- Record the mass of salicylic acid used.
- Using a 10 cm³ measuring cylinder, add 10 cm³ of ethanoic anhydride to the flask and swirl the contents.
- Add 5 drops of concentrated sulfuric acid to the flask and swirl the mixture in the flask for a few minutes to ensure thorough mixing.
- Warm the flask for about 20 minutes in a 400 cm³ beaker of hot water at approximately 60 °C. The temperature in the flask should **not** be allowed to rise above 65 °C.

Stage (e)



- Allow the flask to cool and pour its contents into 75 cm³ of water in a beaker, stirring well to precipitate the solid.
- Filter off the aspirin under reduced pressure, avoiding skin contact.

Stage (g)



- h) Collect the crude aspirin on a double thickness of filter paper and allow it to dry

Part 2 Purification

- Using a 25 cm³ measuring cylinder, measure out 15 cm³ of ethanol into a boiling tube.
- Prepare a beaker half-filled with hot water at a temperature of approximately 75 °C. The safest way to do this is to use a kettle of boiling water and add water from the kettle to cold water in the beaker until the temperature is at approximately 75 °C.
NB The boiling point of ethanol is 78 °C and the temperature of the water in the beaker should **not** be allowed to go above this.
- Use a spatula to add the crude aspirin to the boiling tube and place the tube in the beaker of hot water. **Do not scrape the filter paper.**
- Stir the contents of the boiling tube until all of the aspirin dissolves into the ethanol.
- Pour the hot solution containing dissolved aspirin into approximately 40 cm³ of water in a 100 cm³ conical flask. If a solid separates at this stage, gently warm the contents of the flask in the water bath until solution is complete. You should avoid prolonged heating, since this will decompose the aspirin.
- Allow the conical flask to cool slowly and white needles of aspirin should separate.
- If no crystals have formed after the solution has cooled to room temperature, you may need to scratch the insides of the flask with a glass stirring rod to obtain crystals. Cool the whole mixture in an ice bath.
- Filter off the purified solid under reduced pressure and allow it to dry on filter paper.
- Record the mass of the dry purified solid.

Analysing the effectiveness of this method of preparation of aspirin

- Calculate the theoretical yield of aspirin which should be formed from 6.00 g of salicylic acid.
- Calculate the percentage yield of aspirin from your experiment and comment on the reasons for the losses that have occurred during the preparation and the purification of the solid.
- Calculate the atom economy for the preparation of aspirin by this method.
- Consider the reasons why the alternative preparative method which uses ethanoyl chloride rather than ethanoic anhydride, is not favoured by industry even though this alternative method has a higher atom economy.

To test the purity of an organic solid by measuring its melting point

The purity of an organic solid can be determined in part by measuring its melting point and comparing the value with the known Data Book value of the melting point for that compound. A pure dry solid will melt at a precise temperature whereas an impure solid will melt over a **range** of temperatures which are **lower** than the melting point of the pure solid.

Melting point apparatus varies in type from the most simple using an oil bath to the more sophisticated electrothermal devices. In every case, the same general principle applies that the heating of a small quantity of the solid in a thin-walled melting point tube should be undertaken slowly and with care. When melting occurs, the solid should collapse into a liquid without any change in temperature and the way in which this occurs can give a clue to the purity of the solid. Repeat measurements should be taken with further samples of the organic solid to verify the reliability of the value obtained.

The method will not work if the solid decomposes on heating.

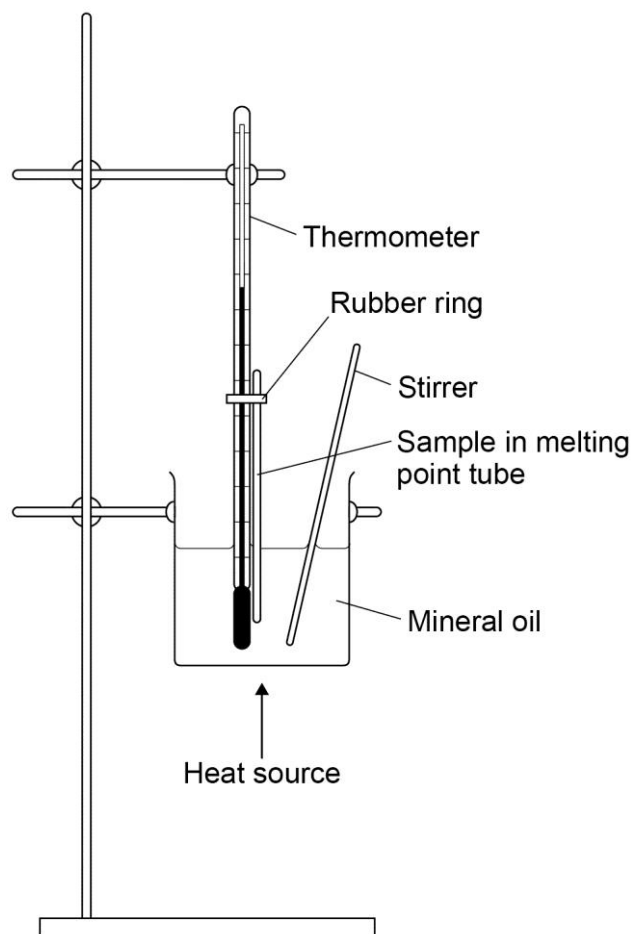
Requirements

You are provided with the following:

- pure benzenecarboxylic acid
- other pure organic solids as desired by the centre
- thermometer (0 °C to 250 °C range)
- melting point apparatus to include either:
an electrothermal melting point apparatus **or** oil bath (Thiele tube or small beaker half-filled with mineral oil)
- tripod, gauze and Bunsen burner
- rubber ring to attach melting point tube to thermometer (if needed)
- melting point tubes
- watch glass
- spatula.

Suggested method

- Powder a sample of the organic solid by crushing it gently with a spatula onto the surface of a filter paper.
- Fill three melting point tubes with the organic solid to a depth of approximately 0.5 cm.
- Set up the melting point apparatus provided and mount one of the melting point tubes ready for taking a measurement.



- Heat the apparatus gently and observe the temperature at which the solid collapses into a liquid. The melting point will be in the range 100 °C to 200 °C.
- Allow the melting point apparatus to cool and repeat the measurement of the melting point of the solid with the other two samples. If the first reading is taken as an approximate value, then the subsequent heating of the other two samples can be done much more slowly as this approximate value is approached.
- On the basis of the three measurements that you have taken, record the melting point of the organic solid.
- Ask your teacher for the Data Book value of the melting point for the solid that you have tested and compare this value with your own.

A-level Chemistry exemplar for required practical No. 10 – part a

Preparation of an organic solid and a test of its purity:

To prepare a sample of aspirin

Teachers' notes

This practical covers Apparatus and technique reference AT g. This worksheet provides a method with which students purify a solid product by recrystallisation. Students will also have to complete a further practical activity to purify a liquid product. This could be based on our exemplar practical in worksheet 10b or any alternative practical work that fulfils the requirement to cover Apparatus and technique AT g.

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

This practical is likely to require at least two practical sessions.

Requirements

In addition to general laboratory apparatus, each student needs the following:

Part 1

- salicylic (2-hydroxybenzenecarboxylic) acid (~ 6.0 g)
- 100 cm³ conical flask
- 10 cm³ measuring cylinder
- ethanoic anhydride (~ 10 cm³)
- concentrated sulfuric acid in a dropping bottle
- 400 cm³ beaker
- tripod, gauze and Bunsen burner
- thermometer (–10 °C to 110 °C)
- 250 cm³ beaker
- reduced pressure filtration apparatus
- filter paper
- stirring rod
- deionised or distilled water in a wash bottle
- spatula.

Additional notes

For the preparation in part 1, 2 g of salicylic acid and 4 cm³ of ethanoic anhydride could be used. The concentrated sulfuric acid could also be replaced by 5 drops of phosphoric acid. These quantities fit in a pear-shaped flask and give a good yield.

Relatively new ethanoic anhydride should be used to ensure a good yield.

Part 2

- 25 cm³ measuring cylinder
- boiling tube
- ethanol (~ 15 cm³)
- thermometer (-10 °C to 110 °C)
- deionised or distilled water in a wash bottle
- 250 cm³ beaker
- 100 cm³ conical flask
- stirring rod
- kettle
- digital mass balance (reading to 2 decimal places).

Salicylic acid is unpleasant to work with as there is a hazard associated with skin contact, which should be avoided. Consider the use of protective gloves.

To test the purity of an organic solid by measuring its melting point

Requirements

In addition to general laboratory apparatus, each student needs the following:

- pure benzenecarboxylic acid
- other pure organic solids as desired by the centre
- thermometer (0 °C to 250 °C range)
- melting point apparatus to include either:
an electrothermal melting point apparatus **or** oil bath (Thiele tube or small beaker half-filled with mineral oil)
- tripod, gauze and Bunsen burner
- rubber ring to attach melting point tube to thermometer (if needed – can be cut from rubber tubing)
- melting point tubes (if open ended, these will need sealing at one end by the technician)
- watch glass
- spatula.

You can choose to use a range of organic solids, but the target should be to ensure that:

- the solid does **not** decompose on heating
- the melting point of each solid is in the range 100 °C to 200 °C
- the solid gives a precise and sharp melting point temperature.

Providing a range of thermometers at the melting point stage is a good way to assess correct equipment as students will have to pick the one with the correct scale and range required.

As an extension to this practical, thin-layer chromatography can be used to examine the product at the beginning, the crude product and the purified product.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Practical 10b

Required practical	Preparation of a pure organic liquid			
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT b. use water bath or electric heater or sand bath for heating AT d. use laboratory apparatus for a variety of experimental techniques AT g. purify a liquid product, including use of a separating funnel AT k. safely and carefully handle solids and liquids			
Indicative apparatus	This will depend on the liquid to be produced, but will likely include basic laboratory glassware, separating funnel, washer bottles, distillation apparatus, heating equipment and protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions for how to produce and purify a given liquid.	Teacher gives students a method to produce and purify a given organic liquid, with choices at different steps. Students could compare the purity of their product with regard to the choices made.	Teacher chooses the liquid to be made but doesn't specify the method. Students research methods available and choose which to carry out in order to produce and purify a given liquid.	Students research organic pathways and liquids and decide which liquid to produce and which method to use to produce and purify an organic liquid of their choice, given the resources available.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.
Applies investigative approaches and methods when using instruments and equipment	✓ Students must correctly use the appropriate equipment.	✓ Students must correctly use the appropriate equipment.	✓✓ Students must correctly use the appropriate equipment.	✓✓✓ Students must choose an appropriate approach, equipment and techniques and identify correct variables for measurement and control.

Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✗	✓ Students record observations in specified ways.	✓ Students record observations in specified ways.	✓✓✓ Students must choose the most effective way of recording observations.
Researches, references and reports	✗	✓ Students compare results and identify reasons for differences.	✓✓ Students must research methods available. They compare results and report on differences.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity ✗: No opportunity

A-level Chemistry exemplar for required practical No. 10 – part b

Preparation of a pure organic liquid: The preparation of ethyl ethanoate

Student sheet

An ester is a chemical compound that is formed when an organic acid reacts with an alcohol. Esters frequently have distinctive odours and are naturally occurring flavour and fragrance chemicals in many fruits and plants. In this practical, the ester ethyl ethanoate is prepared and purified by distillation.

Requirements

Stage 1: Preparation of ethyl ethanoate

- 12 cm³ glacial ethanoic acid
- 10 cm³ ethanol
- 15 drops concentrated sulfuric acid
- anti-bumping granules
- disposable dropping pipette
- 10 cm³ measuring cylinder
- 25 cm³ measuring cylinder
- 250 cm³ beaker
- 50 cm³ pear-shaped flask
- condenser (with rubber tubing)
- clamp stand
- clamps and bosses
- heatproof mat
- Bunsen burner
- tripod and gauze.

Stage 2: Isolation of ethyl ethanoate

- 4.5 g sodium carbonate
- 15 cm³ distilled or deionised water
- 100 cm³ beaker
- 50 cm³ beaker
- separating funnel and stopper
- anhydrous sodium sulfate
- boiling tube
- 50 cm³ pear-shaped flask.

Stage 3: Purification of the ethyl ethanoate

- thermometer (0–100 °C) and adapter
- three-way adapter
- condenser (with rubber tubing)
- receiver adapter
- anti-bumping granules
- joint clips
- 250 cm³ beaker
- clamp stand
- clamps and bosses
- heatproof mat
- Bunsen burner
- tripod and gauze
- access to a balance.

Suggested method

Stage 1: Preparation of ethyl ethanoate

- a) Put a few anti-bumping granules in a 50 cm³ pear-shaped flask.
- b) In a fume-cupboard, add 10 cm³ ethanol, 12 cm³ glacial ethanoic acid and 15 drops of concentrated sulfuric acid to the flask.
- c) Place a 250 cm³ beaker containing some water on a tripod and gauze over a Bunsen burner.
- d) Clamp the pear-shaped flask in the beaker of water so that the reaction mixture is below the water line.
- e) Add a condenser so that it is set up for heating with reflux. Clamp the condenser. Do **not** insert a stopper.
- f) Light the Bunsen burner to heat the hot water bath. Raise the temperature of the hot water until the mixture in the flask is gently boiling. Continue the gentle boil of the reaction mixture for about 15 minutes. Turn off the Bunsen burner and cool the mixture by removing the hot water bath.

Stage 2: Isolation of ethyl ethanoate

- g) Prepare a saturated solution of sodium carbonate by combining 4.5 g of sodium carbonate with 15 cm³ of distilled water in a 100 cm³ beaker.
- h) In a fume cupboard, transfer the reaction mixture from the pear-shaped flask to the beaker and stir.
- i) Transfer the mixture to a separating funnel. Stopper it and turn it upside down gently and then open the stopcock to vent the system. Invert at least 15–20 times, opening the stopcock each time.
- j) Allow the two layers to separate. Ethyl ethanoate is less dense than water, therefore the top layer is ethyl ethanoate.
- k) Remove the stopper, open the stopcock and slowly drain off the waste aqueous layer into a 50 cm³ waste beaker, then close the stopcock.
- l) Transfer the remaining ethyl ethanoate into a dry boiling tube containing about 1 g of anhydrous sodium sulfate. Agitate the tube so that any water is absorbed into the anhydrous solid.
- m) Decant the ethyl ethanoate into a clean, dry 50 cm³ pear-shaped flask.

Stage 3: Purification of the ethyl ethanoate

- n) Add a few anti-bumping granules to the pear-shaped flask.
- o) Set up the apparatus for distillation.
- p) Place the flask in the 250 cm³ beaker and clamp it so the crude ethyl ethanoate is below the water line.
- q) Weigh a clean, dry 100 cm³ conical flask on an analytical balance. Record the mass in your Data Table.
- r) Place the conical flask under the receiver.
- s) Light the Bunsen burner and heat the flask in the hot water bath. Heat until the ethyl ethanoate is gently boiling.
- t) As the ethyl ethanoate vapours start to carry over and condense, record the temperature of the vapours in a suitable table. Record this temperature at the beginning and end of the distillation.
- u) Distil the ethyl ethanoate until no more distillate comes over. There should be some liquid remaining in the round-bottom flask. Never distil to dryness.
- v) Turn off the Bunsen burner.
- w) Reweigh the conical flask with the distilled ethyl ethanoate.

Stage 4: Yield calculation

Which is the limiting reagent - ethanoic acid or ethanol?

What is the percentage yield from the limiting reagent?

A-level Chemistry exemplar for required practical No. 10 – part b

Preparation of a pure organic liquid: The preparation of ethyl ethanoate

Teachers' notes

This practical covers Apparatus and technique reference AT g. This worksheet provides a method with which students prepare a pure organic liquid. Students will also have to complete a further practical activity to purify a solid product by recrystallisation. This could be based on our exemplar practical in worksheet 10a or any alternative practical work that fulfils the requirement to cover Apparatus and technique AT g.

Whenever possible, students should work individually. If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

In addition to general laboratory apparatus, each student needs the following:

Stage 1: Preparation of ethyl ethanoate

- 12 cm³ glacial ethanoic acid
- 10 cm³ ethanol
- 15 drops concentrated sulfuric acid
- anti-bumping granules
- disposable dropping pipette
- 10 cm³ measuring cylinder
- 25 cm³ measuring cylinder
- 250 cm³ beaker
- 50 cm³ pear-shaped flask
- condenser (with rubber tubing)
- clamp stand
- clamps and bosses
- heatproof mat
- Bunsen burner
- tripod and gauze.

Stage 2: Isolation of ethyl ethanoate

- 4.5 g sodium carbonate
- 15 cm³ distilled or deionised water
- 100 cm³ beaker
- 50 cm³ beaker
- separating funnel and stopper
- anhydrous sodium sulfate
- boiling tube
- 50 cm³ pear-shaped flask.

Stage 3: Purification of the ethyl ethanoate

- thermometer (0–100 °C) and adapter
- three-way adapter
- condenser (with rubber tubing)
- receiver adapter
- anti-bumping granules
- joint clips
- 250 cm³ beaker
- clamp stand
- clamps and bosses
- heatproof mat
- Bunsen burner
- tripod and gauze
- access to a balance.

A 250 cm³ beaker is used for the water bath in order to use less hot water. This can be substituted with a 400 cm³ flask if the design of your flasks means that they do not fit.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Practical 11

Required practical	Carry out simple test-tube reactions to identify transition metal ions in aqueous solution			
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT b. use water bath or electric heater or sand bath for heating AT d. use laboratory apparatus for a variety of experimental techniques AT k. safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances			
Indicative apparatus	Basic laboratory glassware and protective equipment such as goggles.			
	Amount of choice			
	Increasing independence			
	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions for how to test a range of labelled transition metal solutions.	Teacher gives students a full method with clear instructions for how to test a range of unidentified transition metal solutions.	Students research methods to test for a number of identified transition metal ions. They then use these methods to test a range of unidentified transition metal solutions.	Students research methods to test for a range of transition metal ions. They apply these methods to test a range of unidentified transition metal solutions. Students could compare their identities for each solution based on the methods they used.
Opportunities for observation and assessment of competencies				
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.
Applies investigative approaches and methods when using instruments and equipment	✓ Students must correctly use the appropriate equipment.	✓ Students must correctly use the appropriate equipment.	✓✓ Students must correctly use the appropriate equipment.	✓✓✓ Students must choose an appropriate approach, equipment and techniques and identify correct variables for measurement and control.

Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	x	✓ Students record observations in specified ways.	✓ Students record observations in specified ways.	✓✓✓ Students must choose the most effective way of recording observations.
Researches, references and reports	x	✓ Students compare results and identify reasons for differences.	✓✓ Students must research methods available. They compare results and report on differences.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity x: No opportunity

A-level Chemistry exemplar for required practical No. 11

Carry out simple test-tube reactions to identify transition metal ions in aqueous solution: An investigation of some transition metal compounds

Student sheet

Most transition metal compounds are coloured. Some of them are used as dyes and pigments. A dye is a soluble coloured compound. A pigment is an insoluble coloured compound. Both dyes and pigments have to be resistant to chemical change.

Four solutions, labelled **P**, **Q**, **R** and **S**, have been provided by a supplier as possible dyes.

- You will carry out tests on these solutions.
- You will record what you **observe** for each test.
- You should ensure that you record observations on dropwise addition, on addition to excess and on standing.
- Where no visible change is observed, write 'no visible change'.

In this task, you are **not** required to identify any of the solutions or any of the reaction products.

Requirements

You are provided with the following:

- four solutions – labelled 'Solution **P**', 'Solution **Q**', 'Solution **R**' and 'Solution **S**'
- sodium hydroxide solution
- sodium carbonate solution
- silver nitrate solution
- 12 test tubes
- 7 dropping pipettes
- test-tube rack
- 250 cm³ beaker
- access to hot water
- plentiful supply of distilled or deionised water.

Suggested method

Test 1(a)

- a) Place about 10 drops of solution **P** in a test tube.
- b) Add sodium hydroxide solution, dropwise with gentle shaking, until in excess.
- c) **Do not discard this mixture.**
- d) Repeat this test with solution **Q** and then solution **R** and then solution **S**.

Test 1(b)

- a) Half fill a 250 cm³ beaker with the freshly boiled water provided.
- b) Allow the four test tubes containing the mixtures from **Test 1(a)** to stand in the beaker of hot water for about 10 minutes.
- c) While you are waiting, begin **Test 2**.

Test 2

- a) Place about 10 drops of sodium carbonate solution in a test tube.
- b) Add about 10 drops of solution **P** and shake the mixture gently.
- c) Repeat this procedure with solution **Q** and then with solution **R** and then solution **S**.

Test 3

- a) Place about 10 drops of solution **P** in a test tube.
- b) Add about 10 drops of silver nitrate solution and shake the mixture gently.
- c) Repeat this procedure with solution **Q** and then with solution **R** and then solution **S**.
- d) Allow the four test tubes to stand for about 10 minutes.

A-level Chemistry exemplar for required practical No. 11

Carry out simple test-tube reactions to identify transition metal ions in aqueous solution: An investigation of some transition metal compounds

Teachers' notes

An investigation of some transition metal compounds

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

In addition to general laboratory apparatus, each student needs the following:

- chromium(III) sulfate solution – labelled 'Solution P'
- iron(III) nitrate solution – labelled 'Solution Q'
- copper(II) chloride solution – labelled 'Solution R'
- ammonium iron(II) sulfate solution – labelled 'Solution S'
- sodium hydroxide solution
- sodium carbonate solution
- silver nitrate solution
- 12 test tubes
- 7 dropping pipettes
- test-tube rack
- 250 cm³ beaker
- access to hot water
- plentiful supply of distilled or deionised water.

The following concentrations were used to produce the sample results on the next page:

- 0.05 mol dm⁻³ chromium(III) sulfate solution
- 0.2 mol dm⁻³ iron(III) nitrate solution
- 0.2 mol dm⁻³ copper(II) chloride solution
- 0.5 mol dm⁻³ ammonium iron(II) sulfate solution
- 1.0 mol dm⁻³ sodium hydroxide solution
- 1.0 mol dm⁻³ sodium carbonate solution
- 0.05 mol dm⁻³ silver nitrate solution.

Additional guidance in previous practical assessments has included the advice to make up the solutions of chromium(III) sulfate and ammonium iron(II) sulfate in water, no more than one day before the practical. If any solution forms a precipitate, just sufficient drops of dilute sulfuric acid should be added to produce a clear solution.

Potassium chromium(III) sulfate (chrome alum), of the same concentration, can be used in place of chromium(III) sulfate.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Sample results

Test 1(a) and (b)

	P	Q	R	S
Initial	blue solution	yellow solution	light blue solution	pale green solution
Add NaOH	white precipitate	orange/brown precipitate	deep blue precipitate	grey/green precipitate
On standing in hot water	green solution	no visible change	no visible change	no visible change

Test 2

	P	Q	R	S
Addition of sodium carbonate	grey precipitate	orange/brown precipitate and effervescence	blue/green precipitate	grey/green precipitate

Test 3

	P	Q	R	S
Addition of silver nitrate	no visible change	white precipitate	white precipitate	light brown precipitate

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)

Practical 12

Required practical	Separation of species by thin-layer chromatography				
Apparatus and techniques covered (Relevant apparatus only, not full statements)	AT i. use thin-layer or paper chromatography AT k. safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances				
Indicative apparatus	This will depend on the liquid to be produced, but will likely include basic laboratory glassware, washer bottles, distillation apparatus, heating equipment and protective equipment such as goggles.				
	Amount of choice				
	Increasing independence	Least choice	Some choice	Many choices	Full investigation
	Teacher gives students a full method with clear instructions for how to carry out a thin-layer or paper chromatography separation of a known mixture.	Teacher gives students a full method with clear instructions for how to carry out a thin-layer or paper chromatography separation of an unknown mixture.	Students research methods for separating a known mixture by chromatography. They then use these methods to carry out a separation on a known mixture.	Students research methods for separating a mixture by chromatography. They apply these methods to separate an unknown mixture. Students could compare the results of separation based on the methods they used.	
Opportunities for observation and assessment of competencies					
Follow written procedures	✓✓✓ Students follow written method.	✓✓✓ Students follow written method.	✓✓✓ Students follow a method they have researched.	✓✓✓ Students follow a method they have researched.	
Applies investigative approaches and methods when using instruments and equipment	✓ Students must correctly use the appropriate equipment.	✓ Students must correctly use the appropriate equipment.	✓✓ Students must correctly use the appropriate equipment.	✓✓✓ Students must choose an appropriate approach, equipment and techniques and identify correct variables for measurement and control.	

Safely uses a range of practical equipment and materials	✓ Students must safely use the equipment.	✓ Students must safely use the equipment.	✓✓ Students minimise risks with minimal prompting.	✓✓✓ Students must carry out a full risk assessment and minimise risks.
Makes and records observations	✗	✓ Students record observations in specified ways.	✓ Students record observations in specified ways.	✓✓✓ Students must choose the most effective way of recording observations.
Researches, references and reports	✗	✓ Students compare results and identify reasons for differences.	✓✓ Students must research methods available. They compare results and report on differences.	✓✓✓ Students must research alternatives in order to plan their work. Reporting covers the planning, carrying out and an analysis of their results.

✓✓✓: Very good opportunity ✓✓: Good opportunity ✓: Slight opportunity ✗: No opportunity

A-level Chemistry exemplar for required practical No. 12

Separation of species by thin-layer chromatography: Analysis of the composition of some common medicines

Student sheet

Requirements

You are provided with the following:

- ethanol or other solvent
- ethyl acetate
- ibuprofen tablet
- paracetamol tablet
- caffeine tablet
- aspirin tablet
- Anadin Extra tablet (or equivalent containing aspirin, paracetamol and caffeine)
- pestle and mortar
- weighing boat or bottle
- TLC plate
- capillary tubes
- developing chamber (or suitable container with lid)
- access to UV lamp.

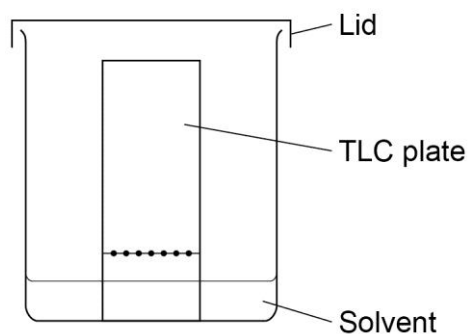
Suggested method

Preparation of samples

- Use a pestle and mortar to crush the aspirin tablet and transfer to a weighing boat or bottle.
- Dissolve approximately 0.1 g of the powdered tablet in 0.5 cm³ of ethanol.
- Repeat steps (a) and (b) with the ibuprofen tablet and the paracetamol tablet.
- Use a pestle and mortar to crush the caffeine tablet and transfer to a weighing boat or bottle.
- Dissolve approximately 0.1 g of the powdered tablet in 7.0 cm³ of ethanol.
- Repeat steps (d) and (e) with the Anadin Extra tablet.

Thin-layer chromatography

- Carefully use a pencil to draw a **faint** line 1 cm above the bottom of a TLC plate and mark five spots, equally spaced along this line.
- Use a capillary tube to apply a tiny drop of each solution to a different origin spot and allow the plate to air dry.
- Add approximately 10 cm³ of ethyl acetate to a development chamber (or suitable container with a lid)
- Place the TLC plate into the developing chamber, making sure that the level of the solvent is below the spotting line. Replace the lid and make sure it is a tight seal.



- e) When the level of the solvent reaches about 1 cm from the top of the plate, remove the plate and mark the solvent front with a pencil. Allow the plate to dry in the fume cupboard.
- f) Place the plate under a UV lamp in order to visualise the spots. Draw around them lightly in pencil.
- g) Calculate the R_f values of the observed spots.

A-level Chemistry exemplar for required practical No. 12

Separation of species by thin-layer chromatography: Analysis of the composition of some common medicines

Teachers' notes

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

In addition to general laboratory apparatus, each student needs the following:

- ethanol (or other solvent*)
- ethyl acetate
- ibuprofen tablet
- paracetamol tablet
- caffeine tablet
- aspirin tablet
- Anadin Extra tablet (or equivalent containing aspirin, paracetamol and caffeine)
- pestle and mortar
- weighing boat or bottle
- TLC plate
- capillary tubes
- developing chamber (or suitable container with lid, such as a beaker with a watch glass)
- access to UV lamp.

* In the suggested method, ethanol is used as the solvent based on the solubility in ethanol of the following:

Aspirin: 1 g in 5 cm³
Caffeine: 1 g in 66 cm³
Ibuprofen: very soluble
Paracetamol: freely soluble

Methanol could also be used as a possible solvent. As could an acetone/methanol mix in a 1:1 ratio.

Very fine paint brushes can be used to apply the drops on the TLC plates instead of capillary tubes.

Suppliers offer a range of TLC plates. Typically, 50 aluminium or plastic TLC plates (20 cm × 20 cm) can be purchased for approximately £160 whilst 50 smaller plates (8 cm × 4 cm) cost approximately £50. All of these plates can be cut into smaller sizes, if required. The more samples being run on a plate, the wider it needs to be. If cutting is required, the TLC plates should be handled carefully to avoid the coating of adsorbent being disturbed and to avoid getting the plates dirty.

Spare supplies of all reagents specified in these notes should be available for student use (if needed).

Photographs of an exemplar set-up of this practical can be found in our mini-guide for each practical, which are available on our [practical resources page](#)