

AS and A Level

Practical skills handbook

CHEMISTRY A CHEMISTRY B (SALTERS)

H032/H432

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For first teaching in 2015

OCR Advanced Subsidiary and Advanced GCE in Chemistry

Version 2.0

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Version 2.0 (January 2024)

Changes to wording to improve accessibility and clarity. Minor changes to the guidance for practical skills 1.2.1(d), (e) and (f) to better support teacher assessment.

Version 1.6 (May 2018)

One change of note made between Version 1.5 and Version 1.6:

1. Guidance on Appendix 4: Measurements - Uncertainties

Version 1.5 (October 2017)

Minor changes made between Version 1.4 and Version 1.5:

1. Editing/removal of external web links in Resources section.

Version 1.4 (August 2017)

One change of note made between Version 1.3 and Version 1.4:

1. Guidance on arrangements of visits and standardisation.

Version 1.3 (January 2016)

One change of note made between Version 1.2 and Version 1.3:

1. Guidance on uncertainties in use of digital apparatus amended in Appendix 4, page 38, to achieve consistency in approach across all A Level sciences. We strongly recommend reading this revised guidance as it is relevant to both internal and external assessments.

Version 1.2 (October 2015)

One change of note made between Version 1.1 and Version 1.2:

1. Guidance on recording mean titres clarified in Appendix 4.

Version 1.1 (September 2015)

Changes of note made between Version 1.0 and 1.1 are:

1. Confirmation of the titles of the practical activities for PAGs 7–12 in Section 4, Table 2.
2. Clarification of regulations relating to monitoring arrangements, assessment of the Practical Endorsement, and Access arrangements, in Section 4.
3. Addition of potential lab book suppliers in Appendix 2.
4. Addition of a number of terms and definitions relating to the language of measurement in Appendix 4.
5. Modifications to wording on Anomalous readings in Appendix 4.
6. Addition of guidance on tables in Appendix 6.

Additional small textual corrections have been made to clarify meaning. These have not affected the content of this Handbook.

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1 Introduction

During their study of Chemistry, students are expected to acquire experience of planning, implementation, use of apparatus and techniques, analysis and evaluation. These skills will be indirectly assessed in the written examinations at both AS and A Level. In addition, certain planning and implementation skills will be directly assessed at A Level only, through the Practical Endorsement.

This Handbook offers guidance on the skills required for both assessments, clarifies the arrangements for the Practical Endorsement, and gives suggestions towards planning a practical scheme of work that will cover all requirements.

The specification is the document on which assessment is based and this Handbook is intended to elaborate on the content of the specification to clarify how skills are assessed and what practical experience is necessary to support an assessment. The Practical Skills Handbook should therefore be read in conjunction with the specification.

How to use this handbook

Sections 2–4 of this handbook describe the assessment of practical skills in the AS and A Level qualifications. These sections elaborate on the information provided in the specification. Teachers are particularly advised to carefully read **Section 4**, which sets out the requirements for the Practical Endorsement – the direct assessment of practical skills in the A Level qualifications.

Section 5 provides guidance on planning the practical scheme of work, bringing together the various aspects that should be taken into account. The guidance in this section is intended to be supportive rather than prescriptive.

Section 6 gives some further guidance on the practical skills set out in specification Section 1.2.1, which are covered in the Practical Endorsement. This section is intended to support centres in planning how they will develop these skills.

The **Appendices** provide reference information on various topics.

- **Appendices 1 and 2** provide information on health and safety and apparatus requirements, and may be useful to share with technicians.
- **Appendices 3–6** give additional information on skills related to recording and presenting experimental data, covering measurements, units, graphs and referencing respectively. This content could be shared with students to help them develop an appropriate level of skill.
- **Appendix 7** lists a number of useful resources, including additional resources and support provided by OCR.

2 Overview of practical skills requirements

Summary of the assessment model

The practical skills assessment consists of a theoretical and a practical component.

- The 'theoretical' component is an **indirect** assessment of practical skills through the written examinations taken at the end of the course.
- The 'practical' component is a **direct** assessment of practical skills displayed by students as they are performing practical work. This is assessed by the teacher across the whole of the course.

The indirect, written assessment is a component of both AS and A Level Chemistry. The direct assessment, known as the Practical Endorsement, is a component of A Level Chemistry only.

The skills required for the practical skills assessments are set out in Module 1: Development of practical skills in chemistry. Module 1 is divided into two sections:

- **Section 1.1** of the specification covers skills that are assessed indirectly in a written examination. These skills may be assessed in any of the written papers that constitute the written assessment, at both AS and A Level. Assessment of practical skills forms a minimum of 15% of the written assessment at both AS and A Level.
- **Section 1.2** of the specification covers skills that are assessed directly through the Practical Endorsement. Student performance is teacher-assessed against the Common Practical Assessment Criteria (CPAC).

The Practical Endorsement is a component of the assessment at A Level only. There is no direct assessment of practical skills at AS Level.

Performance in the Practical Endorsement is reported separately to the performance in the A Level as measured through the externally assessed components.

Summary of the practical skills required

Skills assessed in the written examinations

The skills assessed in the written examination cover the following areas:

- Planning
- Implementing
- Analysis
- Evaluation

Questions assessing these practical skills will be embedded in contexts relating to the content of the specification.

Skills assessed through the Practical Endorsement

The skills assessed through the Practical Endorsement cover the areas of Planning and Implementing, specifically the following:

- Independent thinking
- Use and application of scientific methods and practices
- Research and referencing
- Instruments and equipment

Students must exemplify their skill in these areas through use of the apparatus and techniques listed in the specification, Section 1.2.2.

Centres can assess a wide range of practical activities for the Practical Endorsement, which may include our suggested practicals, centre-developed practicals, or practicals from other publishers, as long as these are appropriately mapped to the CPAC.

AS Level students and the Practical Endorsement

There is no direct assessment of practical skills within the AS Level qualification. However, AS Level students will benefit from completing the type of practical activities recommended within the Practical Endorsement, as well as others, for the following reasons:

- completing practical activities will help to develop the practical skills that are assessed in the written examination
- completing practical activities will support understanding of the content of the specification
- students who decide to continue to take the A Level qualification after completing AS Level will be able to use their performance on Practical Endorsement activities completed in their first year towards the Practical Endorsement, as long as appropriate records have been kept.

3 Practical skills assessed in a written examination

Planning

Specification Section 1.1.1.

Learners should be able to demonstrate and apply their knowledge and understanding of:

- experimental design, including to solve problems set in a practical context
- identification of variables that must be controlled, where appropriate
- evaluation that an experimental method is appropriate to meet the expected outcomes.

Experimental design should include selection of suitable apparatus, equipment and techniques for the proposed experiment.

Students will benefit from having been given the opportunity to design simple experiments and receiving feedback on their plans. Additionally, they should routinely be asked to consider why experiments are performed in the way they are, and how the experimental set-up contributes to being able to achieve the expected outcome. Students could be asked what might be the effect of changing aspects of the method.

Implementing

Specification Section 1.1.2.

Learners should be able to demonstrate and apply their knowledge and understanding of:

- how to use a wide range of practical apparatus and techniques correctly
- appropriate units for measurements
- presenting observations and data in an appropriate format.

The practical apparatus and techniques that may be assessed are those outlined in the specification statements related to practical techniques and procedures and, for A Level only, those covered in the Practical Endorsement

Students will be expected to understand the units used for measurements taken using common laboratory apparatus. See Appendix 4 for units commonly used in practical work in chemistry.

Appropriate presentation of data includes use of correct units and correct number of decimal places for quantitative data. This skill also includes appropriate use of tables and graphs for presentation of data.

Further information on recording measurements and the use of graphs is given in Appendices 3 and 5, respectively.

Analysis

Specification Section 1.1.3.

Learners should be able to demonstrate and apply their knowledge and understanding of:

- processing, analysing and interpreting qualitative and quantitative experimental results
- use of appropriate mathematical skills for analysis of quantitative data
- appropriate use of significant figures
- plotting and interpreting suitable graphs from experimental results, including:
 - (i) selection and labelling of axes with appropriate scales, quantities and units
 - (ii) measurement of gradients and intercepts.

Students will benefit from having practised these skills in a range of practical contexts. Many of the skills and techniques that form part of the Practical Endorsement will also be suitable for practising these skills.

Appendix 3 gives further information about the use of significant figures. Appendix 4 gives further information about the plotting of graphs. See also the [Mathematical Skills Handbook](#) for further guidance on the mathematical skills required in analysing experimental results, and in other areas of quantitative chemistry.

Evaluation

Specification Section 1.1.4.

Learners should be able to demonstrate and apply their knowledge and understanding of:

- how to evaluate results and draw conclusions
- the identification of anomalies in experimental measurements
- the limitations in experimental procedures
- precision and accuracy of measurements and data, including margins of error, percentage errors and uncertainties in apparatus
- refining experimental design by suggestion of improvements to the procedures and apparatus.

Students will benefit from having practised these skills in a range of practical contexts. As a matter of course, students should be encouraged to think carefully about the procedure they are performing and how it relates to the content of the specification; this will better place them to draw appropriate conclusions, identify anomalous and unexpected results, and identify limitations in procedures. Many activities included in the Practical Endorsement, as well as others, can be extended to allow students to consider errors and uncertainties, and suggest improvements to procedures.

Appendix 3 provides further information on precision, accuracy and errors, as well as identifying anomalous results.

4 Practical skills assessed in the Practical Endorsement

Introduction to the OCR Practical Endorsement

In order to pass the Practical Endorsement, students must demonstrate by the end of the two-year A Level course that they consistently and routinely exhibit the competencies described in the Common Practical Assessment Criteria (CPAC), listed in Section 5 of the specification. These competencies must be developed through a practical programme that encompasses the skills, apparatus and techniques listed in section 1.2 of the specification and must comprise a minimum of 12 practical activities.

In our specifications, 12 Practical Activity Groups (PAGs) are presented, which provide opportunities for demonstrating competency in all required apparatus and techniques. Additionally, all of the required skills can be developed through the individual practical activities. Some of the required skills are explicitly included in the requirements for individual practical activities, while others can be developed across the full range of activities.

The PAGs have been designed so that activities can be chosen that directly support the specification content. PAG1–5 support concepts that are likely to be taught in the first year of A Level, while PAG6–9 support concepts from the second year of A Level. PAG10 and PAG11 are less scaffolded activities, designed for development of the investigative skills covered in Module 1.2.1, and can be used to bring together knowledge from across the course. Finally, PAG12 allows students to demonstrate research skills and apply investigative approaches and may link in with any content from the course or beyond.

Planning activities to cover the Endorsement requirements

The Practical Activity Groups

Table 1 on the next page lists the 12 Practical Activity Groups (PAGs) with the minimum of skills and use of apparatus and techniques to be covered in each. We have designed the groups to include the types of activities that will support the requirements of the Practical Endorsement, as well as the assessment of practical skills within the written examinations.

You can use Table 1 to construct a practical scheme of work that covers all requirements. Centres are not required to stick rigidly to this table, as long as overall all the requirements are covered. For example, the skills included in PAG12 could be covered as part of an activity described for another PAG, rather than as a separate activity. That is fine, as long as at least 12 activities are completed overall.

Centres are not required to cover the skills and techniques for each PAG in a single activity. Some PAGs cover a range of skills, and centres may prefer to split these out. For example, PAG6 could be covered through a series of stand-alone activities, focusing on synthesis and filtration, recrystallisation, melting point determination and TLC as stand-alone practicals. Risk assessments could be completed for any or all of these.

The Common Practical Assessment Criteria (CPAC) can be applied to student performance across all practical work performed throughout the A Level course. It is not the intention that assessment of the Practical Endorsement should only be based on performance in 12 activities, one from each PAG. For example, if you run multiple titration activities, you can take into account students' performance across all these activities, not just their performance in an activity selected explicitly to cover PAG2.

Table 1 Practical activity requirements for the OCR Chemistry Practical Endorsement.

Practical activity group (PAG)	Techniques/skills covered (minimum)
1 Moles determination	<ul style="list-style-type: none">• use of appropriate apparatus to record measurements of mass and volume of a gas, 1.2.2(a)
2 Acid–base titration	<ul style="list-style-type: none">• measurement of volume of a liquid, 1.2.2(a)• use of volumetric flask, including accurate technique for making up a standard solution, 1.2.2(e)• use of laboratory apparatus for titration, using burette and pipette, 1.2.2(d)(i)• use of acid–base indicators in titrations of weak/strong acids with weak/strong alkalis, 1.2.2(f)
3 Enthalpy determination	<ul style="list-style-type: none">• use of appropriate apparatus to record measurements of temperature, 1.2.2(a)
4 Qualitative analysis of ions	<ul style="list-style-type: none">• use of laboratory apparatus for qualitative tests for ions, 1.2.2(d)(iii)• make and record qualitative observations, 1.2.1(d)
5 Synthesis of an organic liquid	<ul style="list-style-type: none">• use of laboratory apparatus for heating under reflux, 1.2.2(d)(ii)¹• purification of a liquid product, including use of a separating funnel, 1.2.2(g)(ii)• use of laboratory apparatus for distillation, 1.2.2(d)(ii)• identification of potential hazards (risk assessment), CPAC3
6 Synthesis of an organic solid	<ul style="list-style-type: none">• use of laboratory apparatus for heating under reflux, 1.2.2(d)(ii)¹• use of laboratory apparatus for filtration, including use of fluted filter paper, or filtration under reduced pressure, 1.2.2(d)(iv)• purification of a solid product by recrystallisation, 1.2.2(g)(i)• use of melting point apparatus, 1.2.2(h)• use of thin layer or paper chromatography, 1.2.2(i)• identification of potential hazards (risk assessment), CPAC3
7 Qualitative analysis of organic functional groups	<ul style="list-style-type: none">• use of laboratory apparatus for qualitative tests for organic functional groups, 1.2.2(d)(iii)• use of a water bath or electric heater or sand bath for heating, 1.2.2(b)• make and record qualitative observations, 1.2.1(d)
8 Electrochemical cells	<ul style="list-style-type: none">• setting up of electrochemical cells and measuring voltages, 1.2.2(j)
9 Rates of reaction – continuous monitoring method	<ul style="list-style-type: none">• measurement of rate of reaction by a continuous monitoring method, 1.2.2(l)(ii)• use of appropriate apparatus to record measurements of time, 1.2.2(a)• use appropriate software to process data, 1.2.1(g)²
10 Rates of reaction – initial rates method	<ul style="list-style-type: none">• measurement of rate of reaction by an initial rate method such as a clock reaction, 1.2.2(l)(i)• identify and control variables, CPAC2• use appropriate software to process data, 1.2.1(g)²
11 pH measurement	<ul style="list-style-type: none">• measurement of pH using pH charts, or pH meter, or pH probe on a data logger, 1.2.2(c)
12 Research skills	<ul style="list-style-type: none">• apply investigative approaches and methods to practical work, 1.2.1(a)• use online and offline research skills, including websites, textbooks and other printed scientific sources of information, 1.2.1(h)• correctly cite sources of information, 1.2.1(j)

^{1,2} These techniques/skills may be covered in *either* of the groups indicated.

Table 1 refers mainly to learning outcomes in Section 1.2 of the specification. In a few instances, references are included to the Common Practical Assessment Criteria (CPAC), to ensure coverage of criteria that are not explicitly stated in the learning outcomes.

Some of the learning outcomes in Section 1.2 are generic and they could be covered in many different activities. These have not been explicitly included in Table 1.

The learning outcome 'Safely and correctly handling solids and liquids, including corrosive, irritant, flammable and toxic substances', 1.2.2(k), needs to be covered across the selection of activities.

It is expected that there will be ample opportunities to develop and demonstrate the following skills across the whole practical course, regardless of the exact selection of activities:

- safely and correctly use a range of practical equipment and materials, 1.2.1(b) (though note identifying hazards has been explicitly included in PAG5 and PAG6)
- follow written instructions, 1.2.1(c)
- make and record observations/measurements, 1.2.1(d) (though note *qualitative* observations are explicitly included in PAG4 and PAG7)
- keep appropriate records of experimental activities, 1.2.1(e)
- present information and data in a scientific way, 1.2.1(f)
- use appropriate tools to process data, carry out research and report findings, 1.2.1(g)
- use a wide range of experimental and practical instruments, equipment and techniques, 1.2.1(j).

Practical Activity Support

We do not require specific activities to be completed for the Practical Endorsement. Centres may select activities of their own, or provided by third parties, and map these against the requirements.

You can contact us at science@ocr.org.uk with any queries regarding selection of activities for the Practical Endorsement.

Our activities

We have produced three suggested activities for each PAG, comprising student sheets and teacher/technician guidance. You may use these directly, adapt them to your requirements, or merely use them as reference for the types of activity that would satisfy the criteria for each PAG and the Endorsement as a whole.

The suggested activities are available on Teach Cambridge.

Table 2 lists the activity titles of the OCR suggested activities for A Level Chemistry. Our [Practical Activities Support Guide](#) provides more detailed guidance these suggested activities and how you may adapt them

Table 2 Our PAG activities

PAG1	PAG7
1.1 Determination of the composition of copper(II) carbonate basic 1.2 Determination of the relative atomic mass of magnesium 1.3 Determination of the formula for magnesium oxide	7.1 Identifying organic unknowns 1 7.2 Identifying organic unknowns 2 7.3 Identifying organic unknowns 3
PAG2	PAG8
2.1 Determination of the concentration of hydrochloric acid 2.2 Determination of the molar mass of an acid 2.3 Identification of an unknown carbonate	8.1 Electrochemical cells 1 8.2 Electrochemical cells 2 8.3 Electrochemical cells 3
PAG3	PAG9
3.1 Determination of the enthalpy change of neutralisation 3.2 Determination of an enthalpy change of reaction by Hess' Law 3.3 Determination of enthalpy changes of combustion	9.1 The rate of decomposition of hydrogen peroxide 9.2 The rate of reaction of calcium carbonate and hydrochloric acid 9.3 The rate of reaction of magnesium and hydrochloric acid
PAG4	PAG10
4.1 Identifying unknowns 1 4.2 Identifying unknowns 2 4.3 Identifying unknowns 3	10.1 Rates – iodine clock 10.2 Rates – thiosulfate and acid 10.3 Rates – activation energy
PAG5	PAG11
5.1 Synthesis of a haloalkane 5.2 Preparation of cyclohexene 5.3 Oxidation of ethanol	11.1 pH – problem solving 11.2 pH – titration curves 11.3 pH – acids and buffers
PAG6	PAG12
6.1 Synthesis of aspirin 6.2 Preparation of benzoic acid 6.3 Preparation of methyl 3-nitrobenzoate	12.1 Investigating iron tablets 12.2 Investigating the copper content of brass screws 12.3 Investigating the reaction between potassium manganate(VII) and ethanedioic acid

Tracking achievement

You need to keep the following records:

1. Plans to cover all practical requirements, such as a scheme of work to show how sufficient practical activities will be carried out to meet the requirements of the CPAC, incorporating all the skills and techniques required over the course of the A Level.
2. A record of each practical activity that is carried out and the date it was done.
3. A record of the criteria assessed in each practical activity.
4. A record of student attendance.
5. A record of which students met which criteria and which did not.
6. Evidence of students' work associated with particular activities.
7. Any associated materials provided e.g. written instructions.

You are free to choose the format in which students record evidence of their work that best suits them. Possible suitable methods include the use of a lab book, a folder of relevant sheets or a collection of digital files.

Our PAG trackers

We have developed spreadsheets that can be used to track the progress of a class through the Practical Endorsement. These trackers and guides to using them can be found on Teach Cambridge.

You can use our trackers as evidence for items 2–5 of the list of record keeping requirements above. By using a tracker, along with a scheme of work, any student sheets used and the students' evidence, the internal monitoring of the Practical Endorsement should be very easy to administer.

Monitoring arrangements

Monitoring visits

Monitoring runs in two-year cycles, with large centres (more than 140 students in any science subject) receiving visits for each science subject in each cycle. Other centres receive a visit for a single science subject in each monitoring cycle.

The purpose of the monitoring process is to ensure that centres are planning and delivering appropriate practical work and making and recording judgements on student competences to meet the required standards.

On the day of the visit the monitor will:

- observe practical activity
- review the records kept by the centre and by students (see Tracking achievement above)
- talk with staff and students.

Following the visit, the monitor will complete a record of the visit, which will be copied to the centre. The record will state whether the monitor is satisfied that the centre is meeting the requirements for the Practical Endorsement. The report may additionally offer guidance on improvements that could be made by the centre.

Should a centre dispute the outcome of a monitoring visit, a repeat visit by an alternative monitor may be requested.

Arrangement of visits

Awarding Organisations (AOs) use information from centre entries for A levels in Biology, Chemistry and Physics in the previous summer examination series to jointly plan monitoring visits.

Centres will be monitored for a different science than that which was monitored in the previous monitoring cycle. The first contact with a centre will be from the AO with which the science to be monitored was previously entered. This first contact will be with the exams officer (or other nominated school contact) before arranging a mutually convenient time for the monitoring visit to take place with the lead teacher for that subject.

AOs publish cross-board messaging at the beginning of each two-year monitoring cycle. The latest cross-board messaging can be found on Teach Cambridge.

Standardisation

Lead teachers must complete the free on-line training provided (available and accessible to all teachers at: <https://practicalendorsement.ocr.org.uk>) on the implementation of the Practical Endorsement. They should also ensure that all other teachers of that science within the centre are familiar with the requirements so that:

- all students are given an adequate opportunity to fulfil the requirements of the Practical Endorsement
- standards are applied appropriately across the range of students within the centre.

Assessing the Practical Endorsement

The Practical Endorsement is directly assessed by teachers. The assessment is certificated as Pass or Not-classified.

To achieve a **Pass**, students need to meet the expectations set out in the Common Practical Assessment Criteria (CPAC) (see Table 2 in the specification, Appendix 5) including demonstrating competence in all the skills, apparatus and techniques in sections 1.2.1 and 1.2.2 of each specification. Students can demonstrate these competencies in any practical activity undertaken throughout the course of study.

Students may work in groups but must be able to demonstrate and record independent evidence of their competency. This must include evidence of independent application of investigative approaches and methods to practical work.

Teachers who award a Pass need to be confident that the student consistently and routinely exhibits the required competencies before completion of the A Level course.

Access arrangements

There are no formal access arrangements for the Practical Endorsement. The approach for reasonable adjustments for the Practical Endorsement is described in [this JCQ document](#).

Centres may make reasonable adjustments to their planned practical activities to allow students with disabilities to participate in practical work. Where such adjustments allow these students to independently demonstrate the competencies and technical skills required, without giving these students an unfair assessment advantage, centres may award a Pass for the Practical Endorsement.

For example, students who are colour blind can use colour charts to help them identify colour changes. Alternatively, practical activities can be selected that involve changes that such students are able to observe without such assistance.

A student whose impairment restricts their ability to perform some or all of the required practical work independently cannot achieve a Pass in the Practical Endorsement. However, they can access all the marks within the written examinations and will benefit from having been given the opportunity to experience all practical work, perhaps with the help of a practical assistant. An application for Special Consideration for such students should be made in the standard way. Details of the application process can be found [in this JCQ document](#).

More information about possible reasonable adjustments is available in [our blog](#).

5 Planning your practical scheme of work

In planning the practical scheme of work, you need to ensure sufficient opportunities are provided to support students' development of understanding and skill in the following areas:

- practical skills assessed in the written examinations (identified in specification Section 1.1)
- practical techniques and procedures assessed in the written examinations (identified throughout the content modules of the specifications)
- practical skills assessed through the Practical Endorsement (identified in specification Section 1.2, for A Level only)
- conceptual understanding which can be supported through practical work.

This section presents an approach to planning a practical scheme of work that takes into account all of the above. The information in this section is presented for guidance only; there is no prescribed approach.

A possible approach to planning

1. Identify the learning outcomes within the specification that relate to knowledge and understanding of practical techniques and procedures.
2. Identify which of these learning outcomes relate to Practical Activity Groups, so that carrying out practical work in support of these learning outcomes will also meet certain requirements within the Practical Endorsement. For both GCE Chemistry specifications, PAGs 1–11 relate to activity types that will also directly support learning outcomes assessed in the written examinations.
3. Select practical activities that will adequately cover the requirements identified so far.
4. Consider how to incorporate coverage of PAG12. The research, citation and investigative skills covered in PAG12 may be developed in the context of any topic in the specification (or beyond). You may elect to:
 - a. develop these skills in an area not already included in the PAGs (e.g. equilibrium investigations or redox titrations)
 - b. use this type of activity to give additional support in an area of practical activity already covered
 - c. run this type of activity as a 'mini-investigation', giving students some freedom of choice of topic.
5. Identify how the chosen practical activities can be used to support development of the practical skills assessed in the written examinations. Modify the choice of activities, or add activities, if more support is required.
6. Identify how the chosen practical activities can be used to support other learning outcomes within the specification. Again, if insufficient opportunities have been identified, consider modifying the choice of activities or adding additional activities.

Note that a much wider range of practical work can be carried out than is suggested by the learning outcomes specifically related to practical techniques and procedures.

The learning outcomes related to techniques and procedures form just one potential starting point for planning the practical scheme of work. It is equally possible to begin by considering the work you wish to carry out to support conceptual understanding, and then checking that other requirements have been covered. Alternatively, you could begin by planning sufficient work to cover the requirements of the Practical Endorsement.

6 Guidance on practical skills

Section 1.2.1 of the specification covers the general practical skills which student should develop and practice during their course. This appendix includes suggestions about how this process of skills development can be managed.

This section provides guidance which teachers can use to assist how they teach the required skills, as well as things to look out for in assessing whether students are performing the skills competently. This section is not intended as a 'mark scheme', or statement of the minimum standard required for a pass in individual activities.

Practical skills (specification Section 1.2.1)

1.2.1(a) apply investigative approaches and methods to practical work

Students are expected to be able to think independently about solving problems in a practical context. This means that students should develop their own ideas about how to approach a task, before perhaps discussing them with other students and joining together as a group to put an agreed plan into effect.

Demonstrating investigative approaches could include:

- choosing the materials, or amounts of materials, to use
- choosing which variables to measure and which to control
- deciding what measurements or observations to make and when to make them
- choosing apparatus and devising a procedure that is safe and appropriate.

Applying investigative approaches should include completing tasks that do not include complete step by step instructions. However, activities may still be structured in some form. For example:

- providing a basic method, with students asked to modify this to measure the effect of changing a certain variable
- providing a limited range of equipment, with students asked to think about how they can use what they have been given to solve a practical problem
- providing a certain amount of information, allowing students to consider how to use familiar techniques or procedures to investigate and solve a problem.

1.2.1(b) safely and correctly use a range of practical equipment and materials

Students should be shown how to use practical equipment when it is first met, through a demonstration by the teacher or technician. Good quality videos of many techniques are available online which could be used to complement such a demonstration. Teacher demonstration should also include the safe disposal of materials at the end of the laboratory session.

Hazards, and the ways in which risks should be minimised, should be explicitly explained to students whenever equipment is used for the first time, and on subsequent occasions as required. Students should also be shown how to handle materials safely so they adopt a standard routine whenever they need to use any materials. Some materials are associated with particular hazards and students should be clearly shown how they need to be handled to minimise the risk involved. In some cases, the hazards may be such that it is good practice for students to use the materials under the direct supervision of the teacher.

Increasingly, students should be able to use chemicals and common laboratory equipment safely with minimal prompting. They should be doing this routinely and consistently by the end of the course.

Students will be expected to be able to identify hazards and understand how to minimise risk. This skill can be developed by asking them to devise their own risk assessments. The risk assessment should identify the hazards associated with materials and techniques that students will be using, and describe the steps that they will take to minimise the risks involved. In some cases it may also be appropriate for them to describe how they will safely dispose of materials at the end of the laboratory session. Teachers should always check risk assessments and make sure students are aware of any errors or omissions before they begin the practical activity.

Risk assessments have been included in the OCR Practical Endorsement structure as part of PAG5 and PAG6, as organic preparations frequently offer a number of different types of hazard to consider. However, students could demonstrate this skill in the context of any type of activity. Performing a risk assessment also gives the opportunity to demonstrate research and citation skills.

More detail about the safe use of equipment and materials is given in Appendix 1: Health and safety.

1.2.1(c) follow written instructions

In many activities students will be asked to follow written instructions. It is helpful if they are first given the aims of the activity so they are clear what is expected of them and what they should expect to learn from the activity. An introduction is also a good idea so that students can fit what they are doing into a bigger picture.

It is quite common for students to be given too much information and be asked to do too many things at the same time. Research suggests that when many students follow complex instructions they are not able to think about the theoretical implications and explanations of their task at the same time. It is probably better to focus on these issues before and after the practical task itself. Providing students with instructions to look through before the practical session allows them to think about what is needed and to visualise what they will do in advance of the practical session.

1.2.1(d) make and record observations and measurements

Each student must individually make measurements for each of the activities and retain a contemporaneous record of these. Appropriate scientific vocabulary should be used when recording qualitative data.

Units and format of recording quantitative and qualitative data are not assessed under this skill.

Students need to be able to make measurements using a range of equipment. See Appendix 3: Measurements and Appendix 4: Units for more detail about how to record measurements appropriately.

Observations should be recorded using appropriate scientific vocabulary and should be precise. Examples of ambiguous or incorrect language include:

- mentioning colours, but not associating this with a substance or state (e.g. 'it went brown' rather than 'the solution went brown' or 'a brown precipitate formed')
- giving an accurate observation of the state of a solution or mixture, but not indicating that nothing has changed (e.g. 'blue solution' rather than 'solution remains blue' or 'no change')
- using 'clear' instead of 'colourless'.

1.2.1(e) keep appropriate records of experimental activities

Each student should have a permanent record of each activity they have completed, and where appropriate with suitable tables and graphs and/or calculated results. These records should be made during the laboratory session and are the primary evidence of the outcomes of experiments. Some errors/inconsistencies in the presentation of data are acceptable.

Where experimental procedures have been provided they do not need to be written out again, but they should be kept as part of the record.

Where the activities are 'investigations' there should be a suitable description of the manner in which these were carried out and why - citing which variables were dependent and which independent, whether or not ranges were adjusted to produce suitable results and how.

There should be enough detail to interpret the results produced.

The record may also show how the student has processed raw data, perhaps by using graphs or calculations, and the conclusions they have drawn. In some cases, students may also evaluate their practical activity by calculating errors and/or commenting on the limitations of experimental procedures. These skills are not assessed in the Practical Endorsement but are valuable in understanding the purpose of a practical activity, and will be assessed in the written examinations.

Records may be kept in a laboratory notebook, in a loose-leaf file or electronically. Students should record measurements and observations during laboratory sessions immediately, but these could be transferred to the permanent record later; for example, if there is no means of entering data into an electronic record in the lab.

1.2.1(f) present information and data in a scientific way

Students should present information and data in ways that are appropriate for that information or data. In many cases this will involve the use of tables. These should include an explanatory title, clear headings for columns and relevant units for measurements (see Appendix 3: Measurement and Appendix 4: Units for further details).

Graphs should be of an appropriate type for the information or data involved. Further detail about drawing and using graphs is given in Appendix 5: Graphical skills.

Some information is best presented by using clear, well labelled diagrams or potentially using annotated photographs.

1.2.1(g) use appropriate software and tools to process data, carry out research and report findings

The most obvious tools and software used for processing data are calculators and spreadsheets. Spreadsheets provide a very effective way of processing data, particularly when the amount of data is large. They can be used to sort data, carry out calculations and generate graphs. Graphs drawn using spreadsheets should not be too small, should have a clear title and the axes should be clearly labelled. Where more than one graph is drawn using the same axes it should be clear what each graph refers to.

If records are kept electronically, students will routinely make use of a word processing package to report their findings. Short video clips can be used to show changes over time. Digital images, podcasts and PowerPoint® presentations also provide creative ways in which students can personalise their individual record of practical activities.

Rates experiments and pH titrations lend themselves to use of a data logger, particularly when very short or very long timescales of data collection are involved. Students need training in how to use both the hardware and associated software to collect data, particularly if choices need to be made about measurement scales or when a trigger is used to start data collection. It is usually better to present collected data graphically rather than recording a large amount of raw data.

1.2.1(h) use online and offline research skills including websites, textbooks and other printed scientific sources of information

Students should be given opportunities to use both online and offline research skills in the context of practical activities. A useful starting point might be finding reliable information to devise a risk assessment for an experiment. Safety data sheets, such as the CLEAPSS® Student Safety Sheets (accessible without a login) are a good place to start. More detail about sources of information is given in Appendix 1: Health and safety.

In other situations students might consult websites, textbooks or scientific journals to clarify or suggest experimental techniques and/or to provide supporting background theory to practical activities.

1.2.1(i) correctly cite sources of information

Where a student records information that they have looked up they should provide an accurate reference so that readers can find the information. Examples of how to do this are given in Appendix 6: Referencing.

1.2.1(j) use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification

It is expected that students will carry out practical work throughout their course and will therefore use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification. The minimum of apparatus and techniques that each student must use is listed in specification Section 1.2.2. Suggested apparatus for use during the course is also provided in Appendix 2: Apparatus list.

Appendix 1: Health and safety

This appendix provides information on handling Health and safety issues while carrying out practical experiments.












Before carrying out any experiment or demonstration based on this guidance, it is the responsibility of teachers to ensure that they have undertaken a risk assessment in accordance with their employer's requirements, making use of up-to-date information and taking account of their own particular circumstances. Any local rules or restrictions issued by the employer must always be followed.

Useful information can be found at www.cleapss.org.uk (available to CLEAPSS® members only).

Hazard labelling systems

The CLP regulations were launched in 2010, and fully implemented across the EU in 2015. The 'CHIP' system is no longer in active use, but some older containers may still carry the CHIP symbols, and students may come across them in older reference works. It is important that students are taught to use both systems, particularly if centres are still using chemicals carrying CHIP hazard symbols.

OCR recognises the CLP system as the default system in current use. OCR resources indicate hazards using the CLP system.

	Oxidising		Toxic	CLP pictograms are also accompanied by a 'signal word' to indicate the severity of the hazard. 'DANGER' for more severe; 'WARNING' for less severe.
	Highly flammable		Indicates that the chemical could cause serious <i>long term</i> health effects.	
	Corrosive		Indicates less serious health hazards (e.g. skin irritants).	
	Oxidising		Toxic	'CHIP' system (being phased out)
	Highly Flammable		Harmful or Irritant	
	Corrosive			

Risk assessments

In UK law, health and safety is the responsibility of the employer. Employees, i.e. teachers, lecturers and technicians, have a duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 2002 and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful micro-organisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found at

<http://www.ase.org.uk/resources/health-and-safety-resources>

For members, the CLEAPSS® guide, *Managing Risk Assessment in Science** offers detailed advice. Most education employers have adopted a range of nationally available publications as the basis for their Model Risk Assessments. Those commonly used include:

- *Safety in Science Education*, DfEE, 1996, HMSO, ISBN 0 11 270915 X.

Now out of print but sections are available at

<http://www.ase.org.uk/resources/health-and-safety-resources>;

- *Topics in Safety*, 3rd edition, 2001, ASE ISBN 0 86357 316 9;
- *Safeguards in the School Laboratory*, 11th edition, 2006, ASE ISBN 978 0 86357 408 5;
- CLEAPSS® *Hazcards*.*

CLEAPSS® are in the process of updating the *Hazcards*, the latest edition being the CLP Edition, 2014. At present, CLP Hazcards have only been published for some chemicals. For other chemicals, the CHIP Hazcard is referenced and should be consulted.

- CLEAPSS® *Laboratory Handbook**;
- *Hazardous Chemicals*, A Manual for Science Education, 1997, SSERC Limited ISBN 0 9531776 0 2.

Where an employer has adopted these or other publications as the basis of their model risk assessments, the teacher or lecturer responsible for overseeing the activity in the school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment.

Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision is inadequate or the skills of the students are insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, for example on schemes of work, published teachers' guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed, although a few employers require this.

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or microorganisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting CLEAPSS® (or, in Scotland, SSERC).

*These, and other CLEAPSS® publications, are on the CLEAPSS website. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS - go to www.cleapss.org.uk. In Scotland, SSERC (www.sserc.org.uk) has a similar role to CLEAPSS®.

Appendix 2: Apparatus list

This appendix lists the apparatus likely to be required in order to complete a practical scheme of work that covers all requirements of the qualification. Teachers and technicians should bear in mind that activities that would support the qualification may require additional apparatus not on this list. Resources provided by OCR detail the apparatus needed for individual activities.

Apparatus likely to be required

The following apparatus is likely to be required to complete activities covering all techniques required by the Practical Endorsement in GCE Chemistry (Section 1.2.2 of the specification).

- Balance reading to at least two decimal places
- Stop clocks/watches reading to 1 s or better.
- Beakers (400 cm³, 250 cm³, 100 cm³)
- Pipettes (25 cm³, 10 cm³)
- Pipette fillers
- Burettes (50 cm³)
- Measuring cylinders (250 cm³, 50 cm³, 25 cm³, 10 cm³)
- Gas syringes (100 cm³) (can be replaced by inverted burettes, measuring cylinders)
- Thermometers (–10 to 110 °C or equivalent, accurate to 0.5 °C)
- Heating apparatus: water baths, or electric heaters, or sand baths

A water bath could consist of a beaker of water on a tripod and gauze over a Bunsen flame.

- pH indicator paper, or pH meter, or pH probe
- Quickfit (or microscale) apparatus to carry out distillation and reflux

Note that the requirements for the Practical Endorsement require use of 'laboratory apparatus' for distillation and reflux, not specifically Quickfit.

Experience of using Quickfit apparatus may be beneficial as preparation for the written assessments.

- Retort stands and clamps
- Test tubes and boiling tubes
- Test-tube holders
- Stoppers
- Dropping pipettes
- Filter funnels, or apparatus to carry out filtration under reduced pressure: Buchner flask and Buchner funnel or boiling tube with side-arm and Hirsch funnel
- Filter paper
- Volumetric flasks (250 cm³ or 100 cm³)
- Conical flasks (250 cm³, 100 cm³)
- Watchglasses

- Separating funnels
- Melting point apparatus or oil bath/Thiele tubes
- Melting point tubes (capillary tubes)
- Chromatography paper or thin layer chromatography plates
- Voltmeter (or multimeter)
- Apparatus for setting up electrochemical cells
- Wash bottles with distilled water

Apparatus potentially required

The following laboratory equipment may additionally be required to support further practical work towards the Endorsement as well as to support teaching of the specification and preparation for the written examinations.

- Plastic/styrofoam cups for use as a calorimeter
- Pipeclay triangles
- Porcelain crucibles + lid
- Bunsen burners
- Glass rods
- Heat proof mats
- Tripods and gauze
- Colorimeter
- Data loggers

Additional requirements

In order to fulfil the requirements of the skills set out in Section 1.2.1 of the specification, students will require access to the following.

- Chemical data or hazard sheets
- Graph plotting and data analysis software (e.g. Microsoft Excel)
- Textbooks, websites and other sources of scientific information
- A means of recording practical activity undertaken towards the Practical Endorsement, for example a logbook, binder to collect loose sheets, or means to create and store digital files.

Lab Books

Students can keep their records in any appropriate form including the use of a ring binder or other folder. Should your centre wish to purchase lab books there are educational suppliers who stock a wide variety of these.

Some publishers offer lab book resources which include practical activities and space for students to record results. Take care if using these resources as they are not endorsed and in some cases the level of scaffolding provided for the recording of results could prevent students from being able to independently demonstrate some 1.2.1 skills. You should check the mapping of these activities to the 1.2.1 and 1.2.2 practical skills as in some cases the publisher's mapping is not accurate.

Appendix 3: Measurements

This appendix provides background information on terms used in measurement, and conventions for recording and processing experimental measurements. This information relates to skills assessed both in the written examinations and in the Practical Endorsement, notably 1.1.2(c), 1.1.3(c), 1.1.4(b), 1.1.4(d), 1.2.1(d), 1.2.1(f).

Further guidance on the language of measurement is also provided by our language of measurement in context resource, [available on Teach Cambridge](#).

Useful terms

Accuracy is a measure of the closeness of agreement between an individual test result and the **true** value. If a test result is **accurate**, it is in close agreement with the true value. An accepted reference value may be used as the true value, though in practice the true value is usually not known.

Anomaly (outlier) is a value in a set of results that is judged not to be part of the inherent variation.

Confidence is a qualitative judgement expressing the extent to which a conclusion is justified by the quality of the evidence.

Error (of measurement) is the difference between an individual measurement and the **true** value (or accepted reference value) of the quantity being measured.

Precision is the closeness of agreement between independent measurements obtained under the same conditions. It depends only on the distribution of random errors (*i.e.* the spread of measurements) and does not relate to the true value.

Repeatability is the precision obtained when measurement results are produced over a short timescale by one person (or the same group) using the same equipment in the same place.

Reproducibility is the precision obtained when measurement results are produced over a wider timescale by different people using equivalent equipment in different (but equivalent) places.

Resolution is the smallest change in the quantity being measured that can be detected by an instrument.

Uncertainty is an estimate attached to a measurement which characterises the range of values within which the true value is asserted to lie. This is normally expressed as a range of values such as 44.0 ± 0.4 .

Validity can apply to an individual measurement or a whole investigation. A measurement is valid if it measures what it is supposed to be measuring. An investigative procedure is valid if it is suitable to answer the question being asked. Validity will be reduced, for example, if no negative control is included in an investigation into the efficacy of a therapeutic drug.

The ASE booklet *The Language of Measurement* (Campbell 2010) provides information on these and other terms along with examples of their use. In particular please note that **reliability** will no longer be used. As the authors of the booklet said:

“The word ‘reliability’ has posed particular difficulties because it has an everyday usage and had been used in school science to describe raw data, data patterns and conclusions, as well as information sources. On the strong advice of the UK metrology institutes, we avoid using the word ‘reliability’ because of its ambiguity. For data the terms ‘repeatable’ and ‘reproducible’ are clear and therefore better. For conclusions from an experiment, evaluative statements can mention ‘confidence’ in the quality of the evidence.”

Uncertainties

Whenever a measurement is made, there will always be some doubt about the result that has been obtained. An uncertainty in a measurement is an interval that indicates a range within which we are reasonably confident that the true value lies.

Uncertainties technically depend on a range of factors related to measurements, including both systematic and random errors. Determining uncertainties based on the spread of data obtained is not required within the context of AS and A Level Chemistry. Rather, an estimation of uncertainty is made based on the characteristics of the equipment used.

Uncertainties in apparatus and equipment

When using any apparatus, students should check whether the apparatus itself is marked with the uncertainty. This is, for example, generally the case in for volumetric glassware used to measure specific volumes of liquid, such as volumetric flasks and pipettes frequently used in A Level Chemistry. The degree of uncertainty in these cases depends on the class of apparatus.

For example, a 100 cm³ measuring cylinder is graduated in divisions every 1 cm³.

- A Class A measuring cylinder has an uncertainty of half a division or 0.5 cm³ in each measurement
- A Class B measuring cylinder has an uncertainty of a whole division or 1 cm³ in each measurement.

In the absence of information provided on the equipment, the following assumptions are made regarding the uncertainty in each measurement:

- When using apparatus with an analogue graduated scale, the uncertainty is assumed to be \pm half the smallest graduation.

For example, a 30 cm rule has divisions of 1 mm and an uncertainty of half a division, or 0.5 mm. When measuring a distance the uncertainty has to be taken into account twice and it is overall 1 mm.

An analogue meter with scale markings each 0.2 V has an uncertainty of 0.1 V.

- When using digital apparatus, the uncertainty is presumed to be \pm the resolution of the apparatus in each measurement.

For example, a two-decimal place balance has an uncertainty of ± 0.01 g in each measurement and a voltmeter with three significant figures which has an uncertainty of ± 0.1 V in the 0-20 V range will have an uncertainty of ± 1 V in the 0-100 V range.

The basis of the assumption for electronic apparatus is that the electronic circuit is designed to avoid “hunting” which is the rapid cycling from one figure to another in the final digit. This is achieved by programming the equipment to go up to the next value at a level greater than 0.5, and to go to the lower value at a level below 0.5; this could be going up at 0.7 and down at 0.3. As we are not aware of that value we can only assume ± 1 digit in the final digit.

Students should be able to calculate a percentage uncertainty for a measurement from the absolute uncertainty for the apparatus used. See worked examples on the next page.

Because of the variability in uncertainties associated with equipment, assessments will frequently state the absolute uncertainty in any measurement given to allow students to calculate the percentage uncertainty. If no information is given, the uncertainty in each reading is derived from the resolution of the apparatus used as explained above.

Measurement of time

Whilst a stopwatch measures time with a resolution of say 0.001 s, the operator reaction time is significantly longer, increasing the total uncertainty in the measurement, in which case a reasonable estimate for the uncertainty would be the reaction time of the operator.

A light gate measures time with the same resolution of 0.001 s, but has a significantly lower total uncertainty as it eliminates the reaction time of the operator.

Examples of uncertainties

Some examples are shown below. Note that the actual uncertainty on a particular item of glassware may differ from the values given below.

Volumetric or standard flask (Class B)

- A 250 cm³ volumetric flask has an uncertainty of ± 0.2 cm³ or 0.08%.

Pipette (Class B)

- A 25 cm³ pipette has an uncertainty of ± 0.06 cm³ or 0.24%.

Worked examples

The significance of the uncertainty in a measurement depends upon how large a quantity is being measured. It is useful to quantify this uncertainty as a percentage uncertainty.

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

For example, a measurement of 2.56 g is taken using a two-decimal place balance with an uncertainty of ± 0.01 g.

- percentage uncertainty = $\frac{0.01}{2.56} \times 100\% = 0.39\%$

For a mass measurement of 0.12 g, the percentage uncertainty is much greater:

- percentage uncertainty = $\frac{0.01}{0.12} \times 100\% = 8.3\%$

For individual mass measurements, it is assumed there is no uncertainty in the tare of the balance.

Multiple measurements

Where quantities are measured by difference, there will be an uncertainty in each measurement, which must be combined to give the uncertainty in the final value. The principle of the following example for a mass measurement can be applied to other quantities measured by difference, such as temperature difference and titre.

For two mass measurements that give a resultant mass by difference, there are two uncertainties. These uncertainties are combined to give the uncertainty in the resultant mass. The formula for the percentage uncertainty is then:

$$\text{percentage uncertainty} = \frac{2 \times \text{uncertainty in each measurement}}{\text{quantity measured}} \times 100\%$$

For example, using the same two-decimal place balance as above:

Mass of crucible + crystals before heat = 23.45 g uncertainty = 0.01 g

Mass of crucible + crystals after heat = 23.21 g uncertainty = 0.01 g

Mass lost = 0.23 g overall uncertainty = 2×0.01 g

There is a negligible percentage uncertainty in each mass measurement, but the overall percentage uncertainty in the mass loss is much greater:

$$\text{percentage uncertainty in mass loss} = \frac{2 \times 0.01}{0.23} \times 100\% = 8.7\%$$

Notes

We are aware that some textbooks available do not give a consistent message regarding the treatment of uncertainties. In OCR Chemistry A and B we will therefore allow both half the smallest division as the absolute uncertainty for a measuring instrument and the smallest division itself as the absolute uncertainty. This will ensure that we do not penalise students in any examination - since this ambiguity is not their fault.

The guidance on electronic instruments differs from guidance previously provided by OCR and other sources which state that the uncertainty for digital apparatus is half the resolution, e.g. ± 0.005 g for a two-decimal place balance. The guidance here has been updated for consistency across the OCR suite of A level sciences. For assessment purposes, approaches correctly using either the resolution or half the resolution as the uncertainty will be considered acceptable.

Recording measurements

When using a digital measuring device (such as a modern top pan balance or ammeter),

- record *all* the digits shown. (Note, when using a digital timer such as a stopwatch, do not record to more than two decimal places.)

When using a non-digital device (such as a ruler or a burette),

- record all the figures that are known for certain plus one that is estimated.

Reading burettes

A burette is graduated in divisions every 0.1 cm^3 . A burette is a non-digital device, so we record all figures that are known for certain plus one that is estimated.

Using the half-division rule, the estimation is one of 0.05 cm^3 . We therefore record burette measurements to two decimal places with the last figure either '0' or '5'.

The uncertainty in each measurement = 0.05 cm^3 . The overall uncertainty in any volume measured always comes from two measurements, so the overall uncertainty = $2 \times 0.05 \text{ cm}^3 = 0.1 \text{ cm}^3$.

In a titration, a burette will typically deliver about 25 cm^3 so the percentage uncertainty is small.

$$\text{percentage uncertainty} = \frac{0.1}{25} \times 100\% = 0.4\%$$

For small volumes, the percentage uncertainty becomes more significant. For delivery of 2.50 cm^3 :

$$\text{percentage uncertainty} = \frac{0.1}{2.50} \times 100\% = 4\%$$

Recording volumes during titrations

As shown above, each burette measurements should be recorded to two decimal places with the last figure either '0' or '5'.

During a titration, it is expected that students will record both initial and final burette readings from which a titre is calculated by difference. It is usual practice to record titration results in a table of the type shown below.

	Trial	1	2	3
Final burette reading / cm ³				
Initial burette reading / cm ³				
Titre / cm ³				
Mean titre / cm ³				

When recording the titre, it is normal practice to use two decimal places.

Mean titres

When recording a mean titre, it is usual practice to take the mean of the concordant titres, i.e. those that agree to within 0.1 cm³. Where this is not possible, the two titres that have the closest agreement should be used. Trial titres should not be used to calculate mean titres.

For example, three recorded titres are 25.80 cm³, 25.30 cm³ and 25.20 cm³. The mean titre is the mean of the 2nd and 3rd titres, as they agree to within 0.1 cm³.

$$\text{mean titre} = \frac{25.30 + 25.20}{2} = 25.25 \text{ cm}^3$$

Mean titres may be reported to either 2 or 3 decimal places. When using titre values in further calculations, it is appropriate to use the **unrounded** value (see Significant figures below).

Presentation of results

Table headings

It is expected that **all** table column (or row) headings will consist of a quantity **and** a unit.

The quantity may be represented by a symbol or written in words. There must be some kind of distinguishing notation between the quantity and the unit. Students should be encouraged to use solidus notation, but a variety of other notations are accepted. For example:

$$T / ^\circ\text{C} \quad T(^{\circ}\text{C}) \quad T \text{ in } ^\circ\text{C} \quad \frac{T}{^{\circ}\text{C}}$$

are all **acceptable** as column headings.

Students should avoid notations that do not distinguish between the quantity and the unit, such as

$$T \text{ cm} \quad T_{\text{cm}} \quad \text{just 'cm'}$$

The logarithm of a quantity has no units. Therefore, the heading for e.g. pH measurements can be written simply as 'pH'.

Consistency of presentation of raw data

All raw readings of a particular quantity should be recorded to the same number of decimal places. These should be consistent with the apparatus used to make the measurement (see above).

Significant figures

How many significant figures should be used?

The result of a calculation that involves measured quantities cannot be more certain than the *least* certain of the information that is used. So the result should contain the same number of significant figures as the measurement that has the *smallest* number of significant figures.

A common mistake by students is to simply copy down the final answer from the display of a calculator. This often has far more significant figures than the measurements justify.

Rounding off

When rounding off a number that has more significant figures than are justified (as in the example above), if the last figure is between 5 and 9 inclusive round up; if it is between 0 and 4 inclusive round down.

For example, the number 3.5099 rounded to:

4 sig. figs. is 3.510

3 sig. figs. is 3.51

2 sig. figs. is 3.5

1 sig. fig. is 4

Notice that when rounding you only look at the one figure beyond the number of figures to which you are rounding, *i.e.* to round to three sig. fig. you only look at the fourth figure.

How do we know the number of significant figures?

If the number 450.13 is rounded to 2 sig. figs. the result is 450.

However, if seen in isolation, it would be impossible to know whether the final zero in 450 is significant (and the value to 3 sig. figs.) or insignificant (and the value to 2 sig. figs.).

In such cases, standard form should be used and is unambiguous:

- 4.5×10^2 is to 2 sig. figs.
- 4.50×10^2 is to 3 sig. figs.

When to round off

It is important to be careful when rounding off in a calculation with two or more steps.

- Rounding off should be left until the very end of the calculation.
- Rounding off after each step, and using this rounded figure as the starting figure for the next step, is likely to make a difference to the final answer. This introduces a **rounding error**.

Students often introduce rounding errors in multi-step calculations.

Example

When 6.074 g of a carbonate is reacted with 50.0 cm³ of 2.0 mol dm⁻³ HCl(aq) (which is an excess), a temperature rise of 5.5 °C is obtained. The specific heat capacity of the solution is 4.18 J g⁻¹ K⁻¹,

The energy transferred = 50.0 × 4.18 × 5.5 for which a calculator gives 1149.5 J = 1.1495 kJ

Since the least certain measurement (the temperature rise) is only to 2 significant figures, the answer should also be quoted to 2 significant figures.

Therefore, the heat produced = 1.1 kJ

*It should be noted however, that if this figure is to be used subsequently to calculate the enthalpy change per mole then the rounding off should **not** be applied until the final answer has been obtained.*

For example, if the carbonate has a molar mass of 84.3 g mol⁻¹, the enthalpy change per mole of carbonate can be calculated from the value above.

Using the calculator value of 1.1495 kJ for the energy transferred,

- enthalpy per mole = -15.95371255 kJ mol⁻¹.
- rounding to 2 sig figs gives -16 kJ mol⁻¹

Using the rounded value of 1.1 kJ for the energy transferred,

- enthalpy per mole = $-15.26671057 \text{ kJ mol}^{-1}$.
- rounding to 2 sig figs gives -15 kJ mol^{-1} and we have a 'rounding error'.

Errors in procedure

The accuracy of a final result also depends on the procedure used. For example, in an enthalpy experiment, the measurement of a temperature change may be precise but there may be large heat losses to the surroundings which affect the accuracy of overall result.

Anomalous readings

Anomalies (outliers) are values in a set of results that are judged not to be part of the inherent variation. If a piece of data was produced due to a failure in the experimental procedure, or by human error, it would be justifiable to remove it before analysing the data. For example, if a titre is clearly different to the other readings taken for that particular data point, it might be judged as being an outlier and could be ignored when the mean titre is calculated. However, data must never be discarded simply because it does not correspond with expectation.

References

The Royal Society of Chemistry has produced several very helpful documents on measurements and errors, see:

<http://www.rsc.org/learn-chemistry/resource/res00001274/measurement-accuracy-and-precision?cmpid=CMP00002674>

The ASE booklet *The Language of Measurement* (ISBN 9780863574245) provides additional guidance on many of the matters discussed in this section.

Appendix 4: Units

Students are expected to use the following units for measurements made and in associated calculations during the course of the practical work carried out to support the GCE Chemistry qualifications. Records of measurements should always include the relevant units.

amount of substance	mol
concentration	mol dm ⁻³ or g dm ⁻³ <i>OCR specifications do not support the use of M (molar)</i>
energy	J
enthalpy	kJ mol ⁻¹
mass	g
pH	no units
rate of reaction	mol dm ⁻³ s ⁻¹ <i>These units are the standard in the context of reactions occurring in solution, where the rate is measured in terms of the rate at which the concentration of one of the reactants falls</i>
temperature	°C or K <i>Standard thermometers measure temperature in °C. In certain practical contexts conversion to K is not required; for example in enthalpy determinations, the measured temperature difference is equivalent to the difference in K. However, some practical contexts may require students to convert units, for example for calculations using the ideal gas equation and when using the Arrhenius equation.</i>
time	s
potential difference	V
volume	cm ³ or dm ³ <i>Measurements using laboratory apparatus will commonly be in cm³, while concentrations are expressed in terms of dm³. ml and l are not official SI units and their use is not supported in OCR specifications</i>

Appendix 5: Tables and graphs

Tables

The following guidelines should be followed when presenting results in tables.

- All raw data in a single table with ruled lines and border.
- Independent variable (IV) in the first column; dependent variable (DV) in columns to the right (for quantitative observations) OR descriptive comments in columns to the right (for qualitative observations).
- Processed data (e.g. means, rates) in columns to the far right.
- No calculations in the table, only calculated values.
- Each column headed with informative description (for qualitative data) or physical quantity **and** correct units (for qualitative data); units separated from physical quantity using either brackets or a solidus (slash).
- No units in the body of the table, only in the column headings.
- Raw data recorded to a number of decimal places appropriate to the resolution of the measuring equipment.
- All raw data of the same type recorded to the same number of decimal places.
- Processed data recorded to up to one significant figure more than the raw data.

Graphs

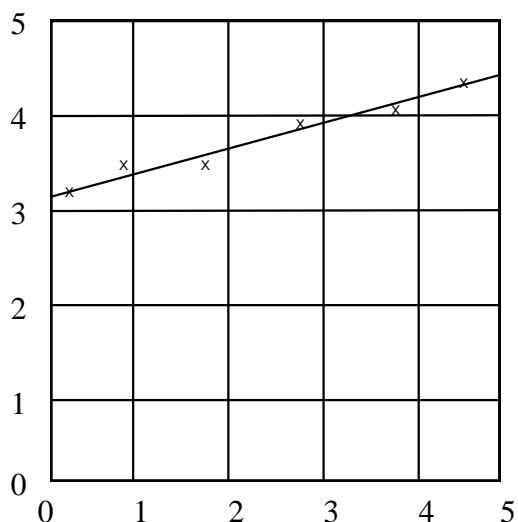
This appendix provides background information on the following graphical skills:

- choice of scale
- plotting of points
- line of best fit
- calculation of gradient
- determination of the y-intercept.

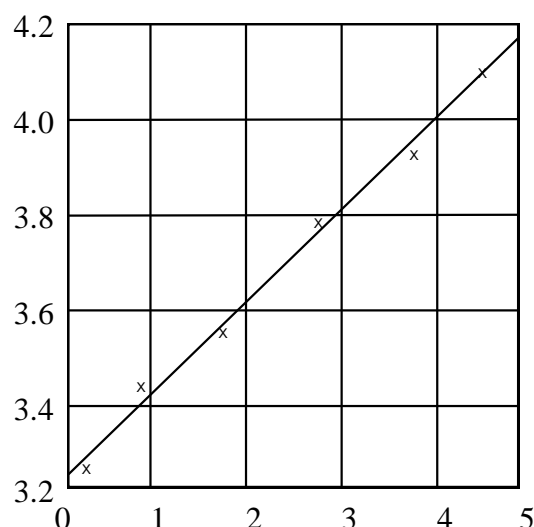
This information relates to skills assessed both in the written examinations and in the Practical Endorsement, notably 1.1.3(d) and 1.2.1(f).

Choice of scales

Scales should be chosen so that the plotted points occupy at least half the graph grid in both the x and y directions.



Not acceptable - scale in the y-direction is compressed



Acceptable - points fill more than half the graph grid in both the x and y directions

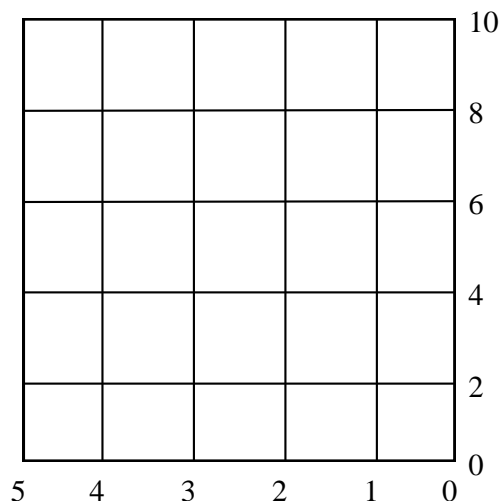
It is expected that each axis will be labelled with the quantity (including unit) which is being plotted. The quantity may be represented by a symbol or written in words. There must be some kind of distinguishing notation between the quantity and the unit. Students should be encouraged to use solidus notation, but a variety of other notations are accepted. For example:

$$T / ^\circ\text{C} \quad T (^{\circ}\text{C}) \quad T \text{ in } ^\circ\text{C} \quad \frac{T}{^{\circ}\text{C}}$$

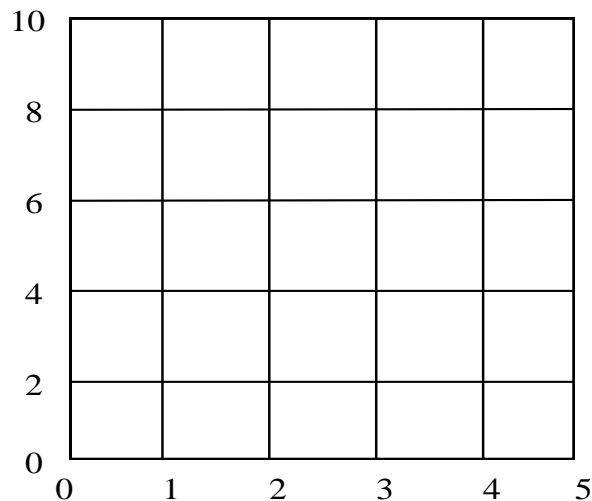
are all **acceptable** as axis labels.

The logarithm of a quantity has no units. Therefore, the axis label for e.g. pH measurements can be written simply as 'pH'.

The scale direction must be conventional (i.e. increasing from left to right).



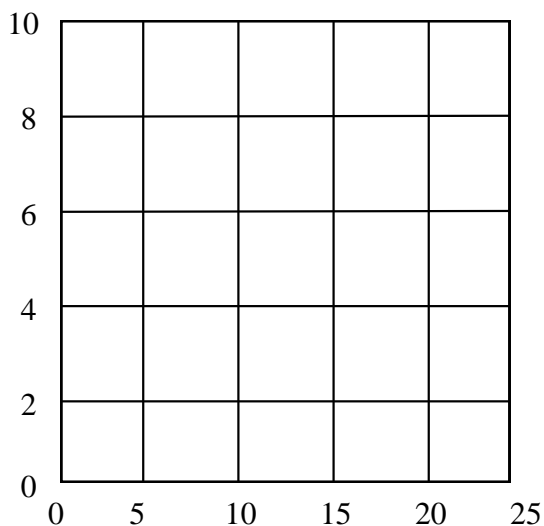
Not acceptable - unconventional scale direction



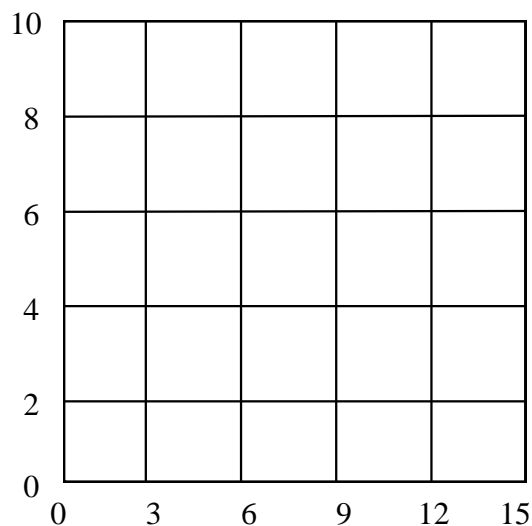
Acceptable - conventional scale direction

This problem often occurs when scales are used with negative numbers.

Students should be encouraged to choose scales that are easy to work with.



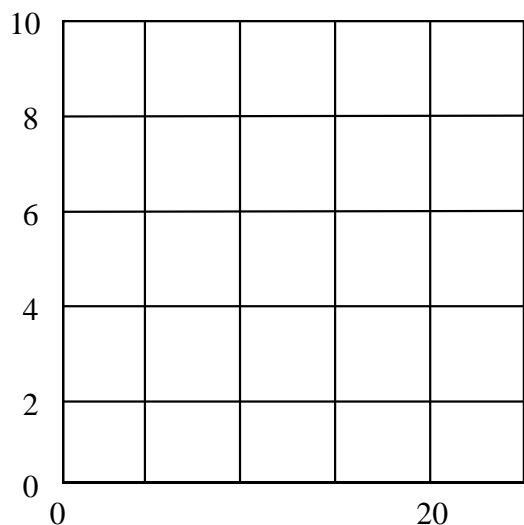
Acceptable scale divisions.



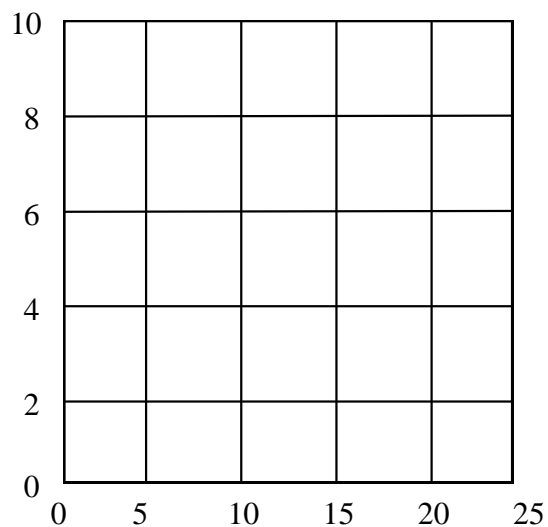
Not acceptable - awkward scale on the x-axis.

Students who choose awkward scales in examinations often lose marks for plotting points (as they cannot read the scales correctly) and calculation of gradient (Δx and Δy often misread – again because of poor choice of scale).

Scales should be labelled reasonably frequently (i.e. there should not be more than three large squares between each scale label on either axis).

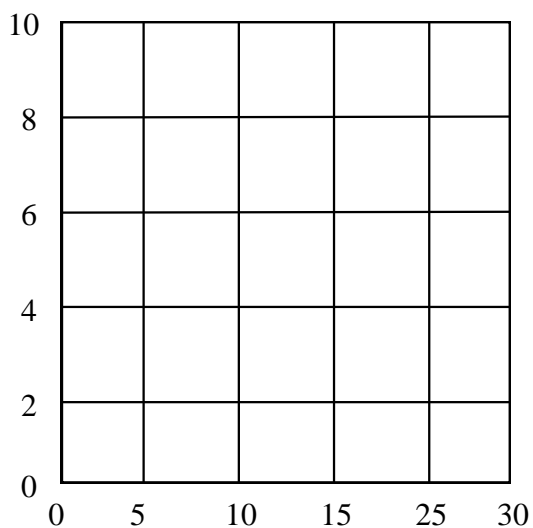


Not acceptable - too many large squares with no label

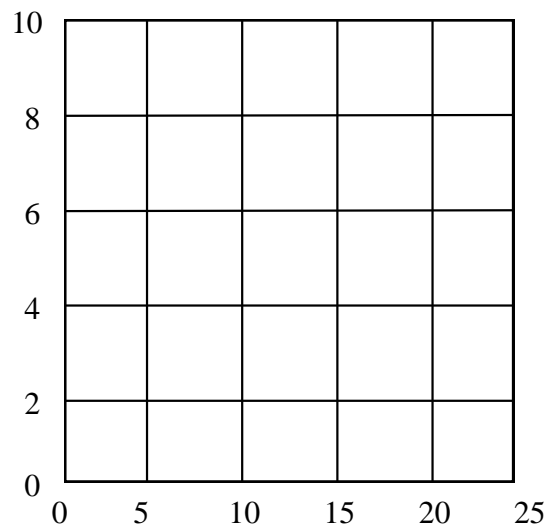


Acceptable - scales have regular labels

There should be no 'holes' in the scale.



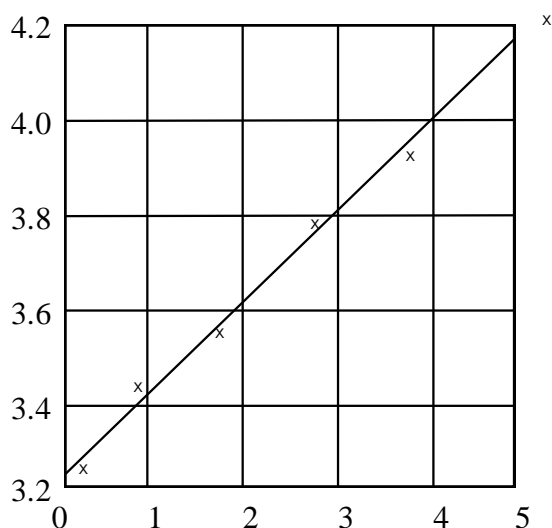
Not acceptable - non-linear scale on the x-axis



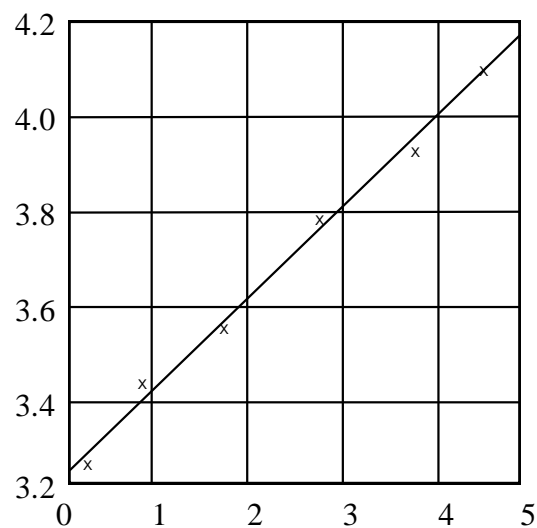
Acceptable - scale labelling is regular

Plotting of points

Plots in the margin area are not allowed and will be ignored in examinations. Sometimes students (realising they have made a poor choice of scale) will attempt to draw a series of lines in the margin area so that they can plot the 'extra' point in the margin area. This is considered to be bad practice and would not be credited.



Not acceptable - the last point has been plotted in the margin area



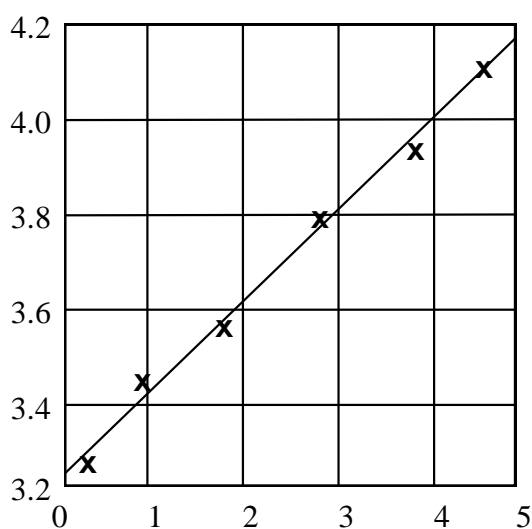
Acceptable - all plotted points are on the graph grid

It is expected that all observations will be plotted (e.g. if six observations have been made then it is expected that there will be six plots).

Plotted points must be accurate to half a small square.

Plots must be clear (and not obscured by the line of best fit or other working).

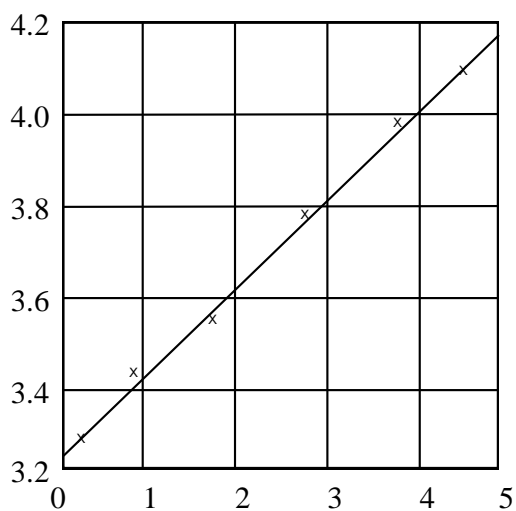
Thick plots are not acceptable. If it cannot be judged whether a plot is accurate to half a small square (because the plot is too thick) then the plotting mark will not be awarded.



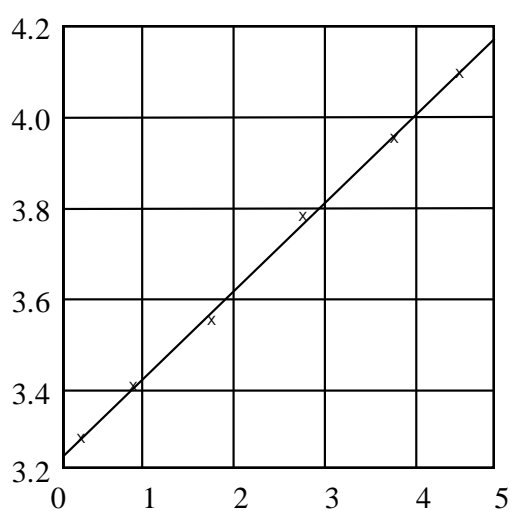
Thick plots not acceptable

Line (or curve) of best fit

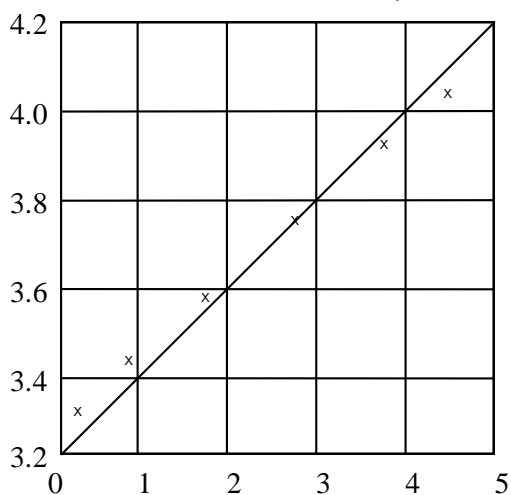
There must be a reasonable balance of points about the line. Students should use a clear plastic rule so that points can be seen which are on both sides of the line as it is being drawn.



Not acceptable - too many points above the line

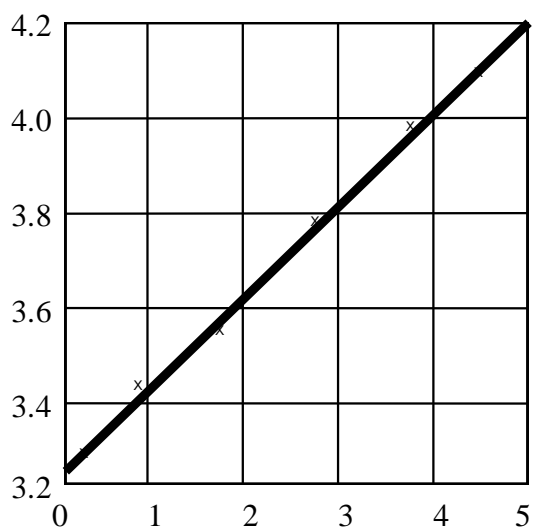


Acceptable balance of points about the line

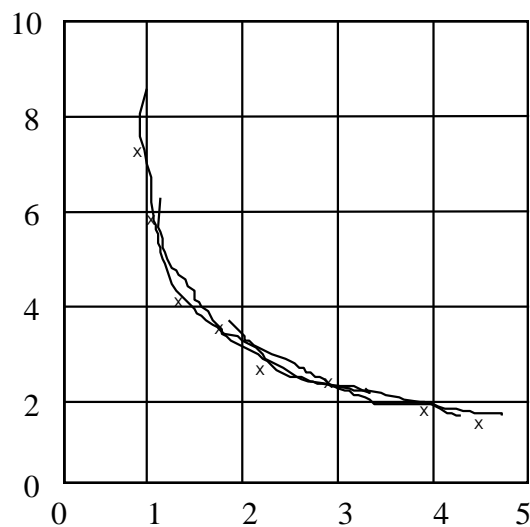


Not acceptable - forced line through the origin (not appropriate in this instance)

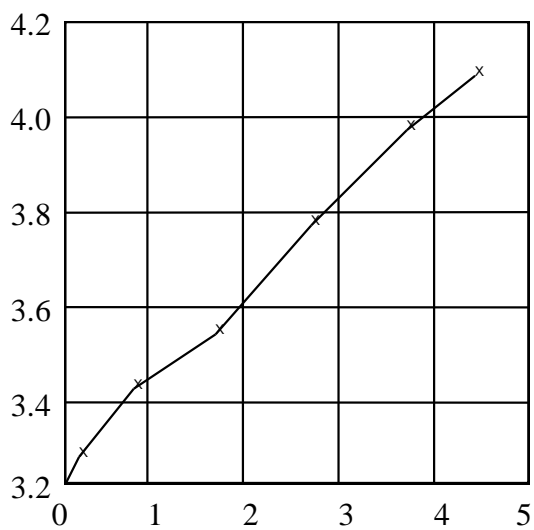
The line must be thin and clear. Thick/hairy/point-to-point/kinked lines are not credited.



Not acceptable - thick line



Not acceptable - 'hairy' curve

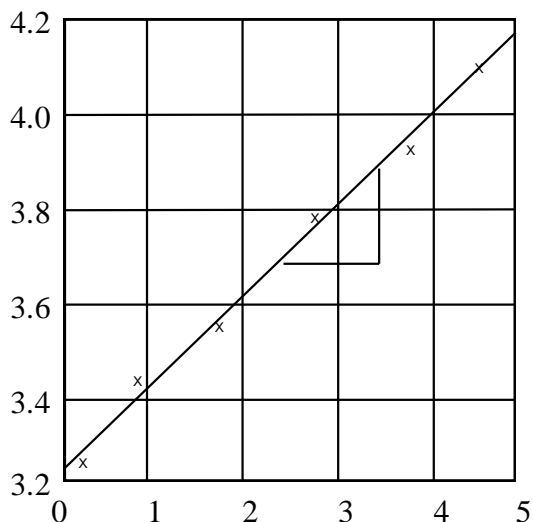


Not acceptable – joining point-to-point

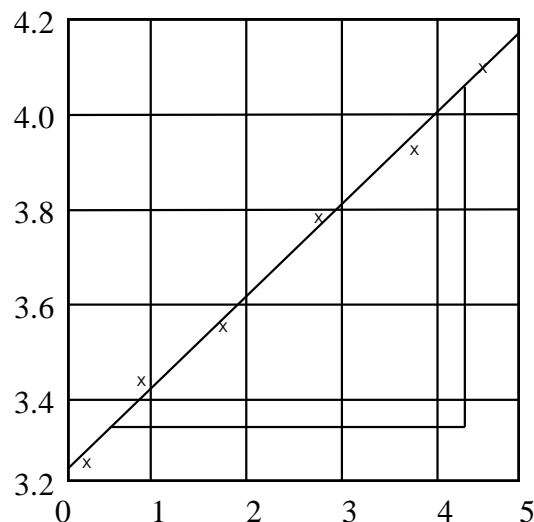
Determining gradients

All the working must be shown. A 'bald' value for the gradient may not be credited. It is helpful to both students and examiners if the triangle used to find the gradient is drawn on the graph grid and the co-ordinates of the vertices clearly labelled.

The length of the hypotenuse of the triangle should be greater than half the length of the line which has been drawn.



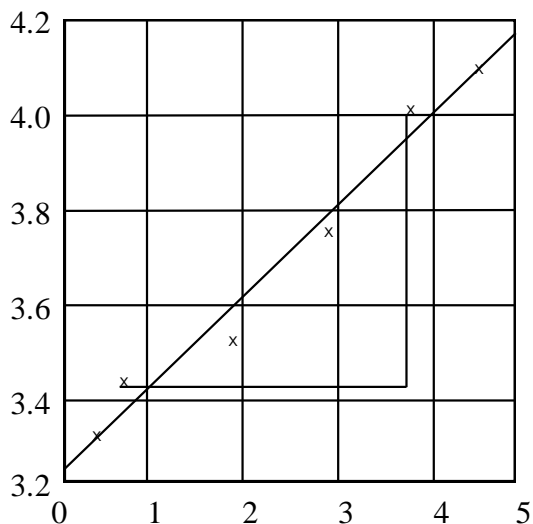
Not acceptable - the 'triangle' used is too small



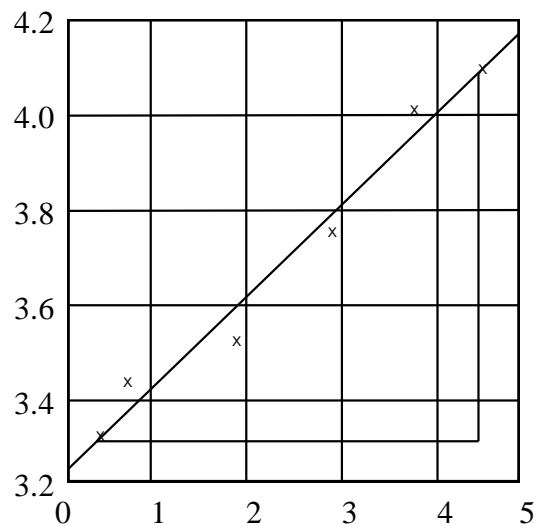
Acceptable – a large 'triangle' used

The values of Δx and Δy must be given to an accuracy of at least one small square (i.e. the 'read-off' values must be accurate to half a small square).

If plots are used which have been taken from the table of results then they must lie on the line of best fit (to within half a small square).



Not acceptable - the data points used which do not lie on the line of best fit

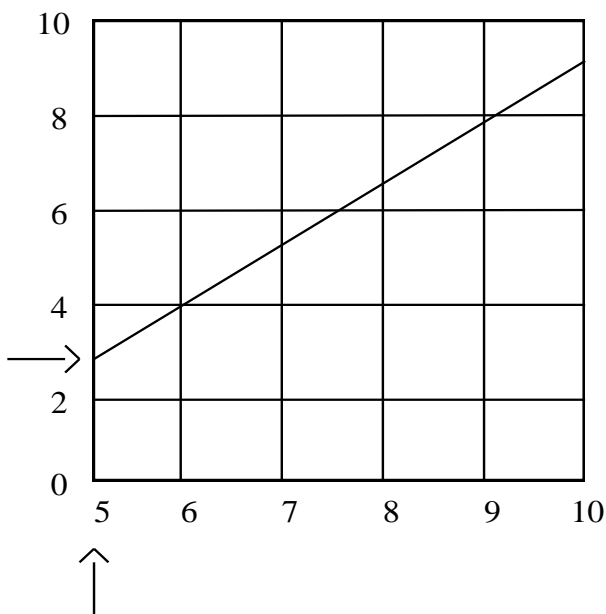


Acceptable - plots on line

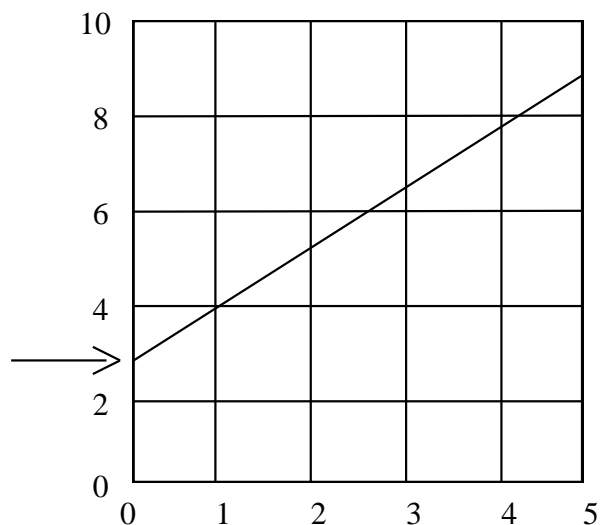
Students should remember to use appropriate units when reporting gradient values.

Intercept

The y -intercept must be read from an axis where $x = 0$. It is often the case that students will choose scales so that the plotted points fill the graph grid (as they should do) but then go on to read the y -intercept from a line other than $x = 0$.



Not acceptable – the y -intercept is found from the line $x = 5$



Acceptable – the value taken from the line $x = 0$

Alternatively, the intercept value can be calculated, recognising that a straight-line graph has the basic formula $y = mx + c$. Substituting the gradient value and a set of coordinates on the line of best fit and solving the equation will give the intercept.

Appendix 6: Referencing

One of the requirements of the Practical Endorsement is that students demonstrate that they can appropriately cite sources of information. The point of referencing is to provide the sources of information that have been used to produce the document, and to enable readers to find that information. There are many different systems of reference in use; the most important thing for students to appreciate at this level is that they should be consistent in how they reference, and that they provide sufficient information for the reader to find the source.

Use of a specific referencing system for the Practical Endorsement is not expected. However, students' referencing should be complete and consistent and allow you to accurately find the original source. If students are already using a particular referencing system in another area of study, for example for an Extended Project qualification, it would make sense if they use the same system within their Chemistry studies.

Systems of citation

Wherever a piece of information that has been retrieved from a source is provided in a text, an in-text citation should be included that links to the full original source in the reference list.

There are two main systems of in-text citation: the Vancouver system, which uses numerical citations, and the parenthetical system (of which the Harvard system is the best-known version), in which limited reference information is given in brackets in the text.

Students are likely to find the Harvard system easier to handle. However, students should be aware of the Vancouver system as they may come across this system in their secondary research.

Vancouver system

The Vancouver system looks like this:

Titration using potassium manganate(VII) can be used to determine the concentration of a solution of Fe^{2+} ions.¹

The full references are given in a numbered list at the end of the document, with each number linked to the appropriate reference, e.g.:

1. Bloggs, J. (2011) *Manganate(VII) titrations*, 2nd ed., Cambridge, Practical Chemistry Publications

The references are ordered in the sequence in which they are first cited in the text. The numbers are repeated in the in-text citations as required, so the same number is always used to cite a given reference.

Parenthetical (Harvard) system

The parenthetical system looks like this:

Titration using potassium manganate(VII) can be used to determine the concentration of a solution of Fe^{2+} ions (Bloggs, 2011).

The author(s) and date of the work are included in brackets at the appropriate point in the text. In this case, the list of full references at the end of the document is ordered alphabetically, and the references are not numbered.

For multi-author works, the full list of names is usually not given in in-text references. Rather, the first name is given followed by 'et al.'. This is commonly done for works with more than three authors.

References

While different referencing systems have minor variations in how they present complete references, the basic information provided is always very similar, and based on the principle of providing sufficient information so that the reader can find the information source.

An overview is given below of standard referencing formats for the types of sources that students are likely to cite.

Books

General reference format:

Authors (year), *Title*, edition (if relevant), publisher's location, publisher

For example:

Atkins, P.W. (1986), *Physical Chemistry*, 3rd ed., Oxford, Oxford University Press

For books that have an editor or editors, include (ed.) or (eds) after the names.

If a book does not have named authors or editors, the reference begins with the title, e.g.:

CLEAPSS Laboratory Handbook (2001), Uxbridge, CLEAPSS School Science Service

Journal articles

General reference format:

Authors (year), 'Article title', *Journal title*, vol. no, issue no, pp. xxx–xxx

For example:

Asakai, T., Hioki, A. (2011), 'Investigation of iodine liberation process in redox titration of potassium iodate with sodium thiosulfate', *Analytica Chimica Acta*, vol. 689, no 1, pp. 34–38

Websites

General reference format:

Authors (year), *Title*. [online] Last accessed date: URL

For example:

Clark, J. (2002), *Some beryllium chemistry untypical of Group 2*. [online] Last accessed 3 February 2015: <http://www.chemguide.co.uk/inorganic/group2/beryllium.html#top>

Webpages and online resources frequently do not have individual authors. In that case, the name of the organisation is given.

Similarly, it is often not possible to find the year in which online material or documents were produced. In that case, use the year in which the information was sourced.

Royal Society of Chemistry (2015), *Weightlifting: Teacher handout*. [online] Last accessed 3 February 2015: <http://www.rsc.org/learn-chemistry/resource/res00000858/chemistry-and-sport-weightlifting>

If no author or organisation can be found, reference the website by title. However, in that case due consideration should be given as to whether the website is a trustworthy source!

Appendix 7: Resources

General resources

There are many resources available to help teachers provide support to students. These include both books and websites.

Useful websites are:

- CLEAPSS at www.cleapss.org.uk
- the Royal Society of Chemistry at www.rsc.org
- Royal Society of Chemistry Practical chemistry resources: <https://edu.rsc.org/resources/practical/>
- the ASE at www.schoolscience.co.uk
- ChemGuide at www.chemguide.co.uk
- www.periodicvideos.com

Professional Development

OCR runs Professional Development courses every year, and these include sessions to support the Practical Endorsement. More details about Professional Development provision are available on [Teach Cambridge](#).

Subject Advisor support

OCR Subject Advisors are available to offer support and guidance on all aspects of the Practical Endorsement. Direct queries regarding the Practical Endorsement to the OCR Science Team through: science@ocr.org.uk.

Need to get in touch?

If you ever have any questions about OCR qualifications or services (including administration, logistics and teaching) please feel free to get in touch with our customer support centre.

Call us on
01223 553998

Alternatively, you can email us on
support@ocr.org.uk


For more information visit

 **ocr.org.uk/qualifications/resource-finder**

 **ocr.org.uk**

 **facebook.com/ocrexams**

 **twitter.com/ocrexams**

 **instagram.com/ocrexaminations**

 **linkedin.com/company/ocr**

 **youtube.com/ocrexams**

We really value your feedback

Click to send us an autogenerated email about this resource. Add comments if you want to. Let us know how we can improve this resource or what else you need. Your email address will not be used or shared for any marketing purposes.



I like this



I dislike this

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