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A LEVEL

CHEMISTRY A
CHEMISTRY B

H432, H433

For first teaching in 2015

Practical Activities Support Guide

Version 2

www.ocr.org.uk/chemistry

Contents

Introduction

This Practical Activities Support Guide is designed to provide support specifically around how our Practical Activity Group (PAG) suggested activities can be adjusted by centres and revision support for our specification's learning outcomes in 1.1 (Practical skills assessed in a written examination). This guide supplements our existing resources regarding the Practical Endorsement, including:

- Positive about Practical
    - This page features videos outlining our PAG approach to the Practical Endorsement. It also contains links to cross-board communications relating to the Practical Endorsement and monitoring.
- Practical Endorsement FAQs
- Practical Skills Handbook
    - This is a comprehensive handbook which describes the assessment of practical skills in the AS and A Level specifications, including the requirements of the Practical Endorsement and guidance on planning a practical scheme of work.
- OCR Science Practical Endorsement Training Site
    - Lead teachers are required to have undertaken this free online training and should ensure all other teachers are familiar with the requirements. We recommend that, for the purpose of standardisation within your centre, all teachers who assess the Practical Endorsement undertake the training.
- PAG teacher and student sheets
- Science Coordinator Materials
    - This is where secure documents are held including answers for the questions in the PAG student sheets and the PAG trackers.
- Specifications (Chemistry A and Chemistry B)
    - Most notably this includes:
        - Module 1.1 Practical skills assessed in a written examination
        - Module 1.2 Practical skills assessed in the practical endorsement
        - Section 5 Practical Endorsement appendix
- PAG Practice question sets

For entries into the Summer 2021 series only

- The Practical Endorsement monitoring process 2019-2021
- Additional Practical Endorsement guidance – 2020-2021
- Practical Endorsement guidance for remote monitoring

The Practical Endorsement

Extract from the Practical Skills Handbook:

The Practical Endorsement is directly assessed by teachers and is a mandatory part of the A Level qualification. The assessment is certificated as Pass or Not-classified. As part of the Head of Centre declaration that centres must submit every year, any centre offering A Level Chemistry must declare that they have provided students with the opportunity to complete practical work towards the Practical Endorsement.

In order to achieve a Pass, candidates will need to have met 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.

Learners 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 candidate consistently and routinely exhibits the required competencies before completion of the A Level course.

The PAG Approach

Candidates can demonstrate these competencies in any practical activity undertaken throughout the course of study. The 12 OCR Practical Activity Groups (PAGs) described in the specification provide opportunities for demonstrating competence in all required skills, together with the use of apparatus and practical techniques for each subject.

Using our suggested practical activities is **not** mandatory. You can use the suggested practical activities from the Practical Activity Groups (PAGs), your own activities, or activities from other publishers to assess student practical skills. If you use activities other than our suggested practical activities, you need to ensure that you have mapped these activities to the relevant 1.2.1 and 1.2.2 criteria and the CPAC so you can track student progress in these. You are free to make changes to our suggested activities, but if these changes change which parts of 1.2.1, 1.2.2 and the CPAC you are assessing you will need to make sure this is reflected in your tracking of student progress.

In the OCR specifications, 12 PAGs are presented. Within each PAG are 3-4 suggested activities. None of these activities are explicitly required. Instead, the PAG approach gives some possible routes for students to learn the practical skills in the AS and A Level specifications and to achieve the Practical Endorsement.

At least 15% of the marks in examinations will assess practical skills. Examinations will not assume candidates have carried out all of these activities. However, they **will** assume that students are familiar with specific practical aspects mentioned in modules 2-6 (Chemistry A) and section 2d (Chemistry B), as well as those from the 1.2.2 criteria which students will have covered during the course of the Practical Endorsement. Questions may test the application of practical skills in novel and familiar contexts.

Health and safety

For additional health and safety guidance, please refer to CLEAPPS.

The CPAC and our specifications

The CPAC criteria is very closely linked to our specification learning outcomes in 1.2.1 Practical skills. Below, we have mapped out how these learning outcomes map to the CPAC criteria as well as our PAG activities.

In addition, we have also mapped out how our PAG activities relate to our specification's 1.2.2 Use of apparatus and techniques learning outcomes.

PAG vs CPAC and 1.2.1

This table shows how our suggested practical activities in the PAGs relate to both the CPAC and our specification's 1.2.1 Practical skills learning outcomes.

PAG	CPAC 1: Follows written procedures	CPAC 2: Applies investigative approaches and methods when using instruments and equipment		CPAC 3: Safely uses a range of practical equipment and materials		CPAC 4: Makes and records observations			CPAC 5: Researches, references and reports		
1.2.1	**c)** follow written instructions	**a)** apply investigating approaches to practical work	**g)** use appropriate software and tools to process data, carry out research and report findings	**b)** safely use a range of practical equipment & materials	**j)** use a wide range of experimental and practical instruments, equipment and techniques	**d)** make and record observations/ measurements	**e)** keep appropriate records of experimental activities	**f)** present information and data in a scientific way	**g)** use appropriate software and tools to process data, carry out research and report findings	**h)** use online and offline research skills including websites, textbooks and other printed scientific sources of information	**i)** correctly cite sources of information
1.1	✓			✓	✓	✓	✓	✓			
1.2	✓			✓	✓	✓	✓	✓			
1.3	✓			✓	✓	✓	✓	✓			
2.1	✓			✓	✓	✓	✓	✓			
2.2	✓			✓	✓	✓	✓	✓			
2.3	✓			✓	✓	✓	✓	✓			
3.1	✓			✓	✓	✓	✓	✓			
3.2	✓			✓	✓	✓	✓	✓			
3.3	✓			✓	✓	✓	✓	✓			
4.1	✓			✓	✓	✓	✓	✓			
4.2		✓		✓	✓	✓	✓	✓			
4.3		✓		✓	✓	✓	✓	✓			
5.1	✓			✓	✓	✓	✓	✓		✓	✓
5.2	✓			✓	✓	✓	✓	✓		✓	✓
5.3	✓			✓	✓	✓	✓	✓		✓	✓
5.4	✓			✓	✓			✓		✓	✓
6.1	✓			✓	✓	✓	✓	✓		✓	✓
6.2	✓			✓	✓	✓	✓	✓		✓	✓

PAG	CPAC 1: Follows written procedures	CPAC 2: Applies investigative approaches and methods when using instruments and equipment		CPAC 3: Safely uses a range of practical equipment and materials		CPAC 4: Makes and records observations			CPAC 5: Researches, references and reports		
1.2.1	**c)** follow written instructions	**a)** apply investigating approaches to practical work	**g)** use appropriate software and tools to process data, carry out research and report findings	**b)** safely use a range of practical equipment & materials	**j)** use a wide range of experimental and practical instruments, equipment and techniques	**d)** make and record observations/ measurements	**e)** keep appropriate records of experimental activities	**f)** present information and data in a scientific way	**g)** use appropriate software and tools to process data, carry out research and report findings	**h)** use online and offline research skills including websites, textbooks and other printed scientific sources of information	**i)** correctly cite sources of information
6.3	✓			✓	✓	✓	✓	✓		✓	✓
7.1	✓			✓	✓	✓	✓	✓			
7.2	✓			✓	✓	✓	✓	✓			
7.3	✓	✓		✓	✓	✓	✓	✓			
8.1	✓			✓	✓	✓	✓	✓			
8.2	✓			✓	✓	✓	✓	✓			
8.3	✓			✓	✓	✓	✓	✓			
9.1	✓	✓	✓	✓	✓	✓	✓	✓	✓		
9.2	✓		✓	✓	✓	✓	✓	✓	✓		
9.3	✓		✓	✓	✓	✓	✓	✓	✓		
10.1	✓	✓	✓	✓	✓	✓	✓	✓	✓		
10.2	✓	✓	✓	✓	✓	✓	✓	✓	✓		
10.3	✓	✓	✓	✓	✓	✓	✓	✓	✓		
11.1		✓		✓	✓	✓	✓	✓			
11.2		✓		✓	✓	✓	✓	✓			
11.3	✓	✓		✓	✓	✓	✓	✓			
12.1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12.2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12.3		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

PAG vs 1.2.2

This table shows how our suggested practical activities in the PAGs relate to our specification's 1.2.2 Use of apparatus and techniques learning outcomes.

1.2.2	**a)** use of appropriate apparatus to record a range of measurements (to include mass, time, volume of liquids and gases, temperature)	**b)** use of a water bath or electric heater or sand bath for heating	**c)** measurement of pH using pH charts, or pH meter, or pH probe on a data logger	**d)(i)** use of laboratory apparatus for titration, using a burette and pipette	**d)(ii)** use of laboratory apparatus for distillation and heating under reflux, including setting up glassware using retort stand and clamps	**d)(iii)** use of laboratory apparatus for qualitative tests for ions and organic functional groups	**d)(iv)** use of laboratory apparatus for filtration, including use of fluted filter paper, or filtration under reduced pressure	**e)** use of a volumetric flask, including accurate technique for making up a standard solution	**f)** use of acid–base indicators in titrations of weak/strong acids with weak/strong alkalis	**g)(i)** purification of a solid product by recrystallisation	**g)(ii)** purification of a liquid product, including use of a separating funnel.	**h)** use of melting point apparatus	**i)** use of thin layer or paper chromatography	**j)** setting up of electrochemical cells and measuring voltages	**k)** safely and carefully handling solids and liquids, including corrosive, irritant, flammable and toxic substances	**l)(i)** measurement of rates of reaction by an initial rate method such as a clock reaction	**l)(ii)** measurement of rates of reaction by a continuous monitoring method
1.1	✓														✓		
1.2	✓														✓		
1.3	✓																
2.1	✓			✓				✓	✓								
2.2	✓			✓				✓	✓						✓		
2.3	✓			✓				✓	✓						✓		
3.1	✓														✓		
3.2	✓														✓		
3.3	✓														✓		
4.1						✓									✓		
4.2			✓			✓									✓		
4.3			✓			✓									✓		
5.1	✓				✓						✓				✓		
5.2	✓	✓			✓	✓					✓				✓		
5.3	✓	✓			✓	✓									✓		
5.4	✓										✓				✓		
6.1	✓	✓			✓		✓			✓		✓	✓		✓		
6.2	✓	✓			✓		✓			✓		✓	✓		✓		
6.3	✓	✓					✓			✓		✓	✓		✓		
7.1		✓				✓									✓		
7.2		✓	✓			✓									✓		
7.3		✓	✓			✓							✓		✓		

1.2.2	**a)** use of appropriate apparatus to record a range of measurements (to include mass, time, volume of liquids and gases, temperature)	**b)** use of a water bath or electric heater or sand bath for heating	**c)** measurement of pH using pH charts, or pH meter, or pH probe on a data logger	**d)(i)** use of laboratory apparatus for titration, using a burette and pipette	**d)(ii)** use of laboratory apparatus for distillation and heating under reflux, including setting up glassware using retort stand and clamps	**d)(iii)** use of laboratory apparatus for qualitative tests for ions and organic functional groups	**d)(iv)** use of laboratory apparatus for filtration, including use of fluted filter paper, or filtration under reduced pressure	**e)** use of a volumetric flask, including accurate technique for making up a standard solution	**f)** use of acid–base indicators in titrations of weak/strong acids with weak/strong alkalis	**g)(i)** purification of a solid product by recrystallisation	**g)(ii)** purification of a liquid product, including use of a separating funnel.	**h)** use of melting point apparatus	**i)** use of thin layer or paper chromatography	**j)** setting up of electrochemical cells and measuring voltages	**k)** safely and carefully handling solids and liquids, including corrosive, irritant, flammable and toxic substances	**l)(i)** measurement of rates of reaction by an initial rate method such as a clock reaction	**l)(ii)** measurement of rates of reaction by a continuous monitoring method
8.1	✓													✓	✓		
8.2	✓													✓	✓		
8.3														✓	✓		
9.1	✓																✓
9.2	✓																✓
9.3	✓																✓
10.1	✓														✓	✓	
10.2	✓															✓	
10.3	✓	✓													✓	✓	
11.1	✓		✓												✓		
11.2	✓		✓	✓													
11.3	✓		✓												✓		
12.1	✓			✓				✓							✓		
12.2	✓			✓				✓									
12.3	✓														✓	✓	

PAG 1: Moles determination

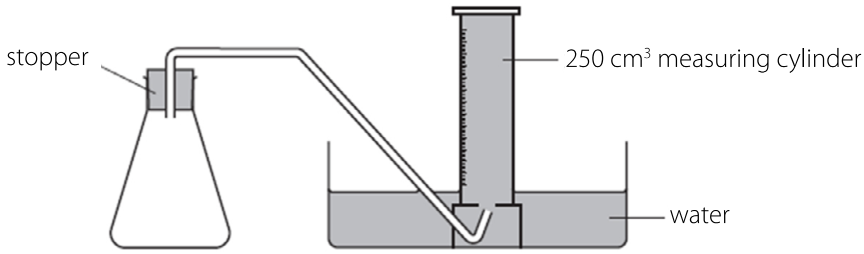
Suggested activities	1.2.1 practical skills covered	1.2.2 apparatus and techniques covered
1.1: Determination of the composition of copper(II) carbonate basic	b, c, d, e, f, j	a, k
1.2: Determination of the relative atomic mass of magnesium		
1.3: Determination of the formula for magnesium oxide		a

Overview

Techniques/skills covered in this practical activity group (minimum):

- use of appropriate apparatus to record measurements of mass and volume of a gas, 1.2.2(a)

In **PAG 1.1**, students react a known mass of copper(II) carbonate basic with an excess of sulfuric acid, collecting the carbon dioxide gas that is produced. They then measure the volume of the carbon dioxide and use this to determine the percentage by mass of copper(II) carbonate in copper(II) carbonate basic. The apparatus used in this practical activity is shown below:



During this procedure, some gas produced will be lost as the stopper is replaced after adding reagents. Additionally, some of the carbon dioxide will dissolve in the water, so the volume of carbon dioxide collected will be less than expected. Both of these factors lead to the calculated percentage by mass of copper(II) carbonate being smaller than would otherwise be expected.

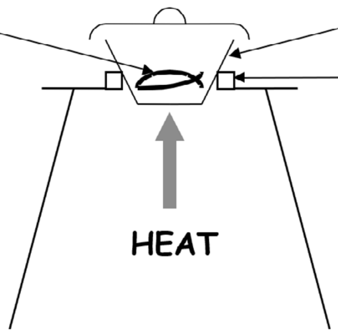
There are some alternatives to the equipment shown above. A Buchner flask may be used instead of a conical flask, with a rubber tube in place of the glass delivery tube. This is easier to handle and less likely to fall over. Additionally, instead of collection of the gas produced over water, a gas syringe may be used. As most gas syringes measure up to 100 cm^3, the masses used in the practical may need to be adjusted accordingly.

A similar set-up is used for **PAG 1.2**. In this practical activity, students determine the relative atomic mass of magnesium by reacting a measured mass of magnesium with aqueous sulfuric acid, collecting and measuring the volume of the evolved hydrogen gas.

The same equipment alternatives as for PAG 1.1 apply here. As with PAG 1.1, it's important to insert the stopper as quickly as possible once the reagents have been added. Otherwise, a lower total volume of hydrogen gas produced will be recorded, leading to a lower result for the relative atomic mass of magnesium than expected.

An alternative method for determining the relative atomic mass of magnesium involves reacting magnesium oxide with sulfuric acid, evaporating the resulting solution to obtain magnesium sulfate, and using the mass of the product to calculate the value for magnesium's relative atomic mass.

In **PAG 1.3**, students determine the empirical formula for magnesium oxide by accurate measurements of the mass of a sample of magnesium, heating in air to form magnesium oxide, and then accurately measuring the mass of the product. The apparatus used for this practical are shown below:



Note that, unlike PAGs 1.1 and 1.2, this activity does not cover measurement of the volumes of gas (1.2.2k).

The lift of the crucible must be briefly lifted at intervals during the procedure to allow sufficient oxygen to enter and react with the magnesium. Incomplete reaction of the magnesium leads to a lower than expected value for oxygen in the empirical formula deduced.

Possible adjustments

A CLEAPSS alternative to PAG 1.3 is provided by OCR and is also available here: http://science.cleapss.org.uk/Resource-Info/PP063-Finding-the-Formula-of-Magnesium-Oxide.aspx. This microscale alternative uses metal bottle caps tied together with nichrome wire, within which the magnesium is placed. The gaps between the bottle caps allow entry of oxygen without the loss of reaction material, giving a more accurate result.

1.2.1(h) (using online and offline research skills) and 1.2.1(i) (correctly citing sources of information) could be met by adding a research element to this practical. This could involve researching alternative methods.

An alternative method for determining the relative atomic mass of magnesium (PAG 1.2) involves reacting magnesium oxide with sulfuric acid, evaporating the resulting solution to obtain magnesium sulfate, and using the mass of the product to calculate the value for magnesium's relative atomic mass. 1.2.2(g)(i) (purification of a solid product by recrystallisation) could be met using this method, as the magnesium sulfate would need to be recrystallised.

1.2.2(l)(ii) (measuring rate of reaction by a continuous monitoring method) could be met as part of PAG 1.1 or 1.2 by continuous monitoring of the evolution of gas during the reaction to determine the rate.

1.2.2(a) (use of appropriate apparatus to record measurements of mass and volume of a gas) can also be met in a number of our other suggested practical activities (for example, in PAG 9).

Support resources

The following resources may be useful as revision aids for your students to remind them of the practical procedures used in this PAG.

- **VIDEO: Dept. of Chemistry & Biochemistry, San Diego State University: Practical procedure for PAG 1.3**:

  https://www.youtube.com/watch?v=OuFqtxZJRvM

  This video shows the procedure provided in PAG 1.3. It also includes an additional step of adding a small amount of water once the reaction is complete and then continuing to heat the crucible. This ensures a more complete reaction and also removes any magnesium nitride that may have formed by converting it to ammonia, allowing the magnesium to react with oxygen. This gives a more accurate result.

- **VIDEO: MaChemGuy: Questions relating PAG 1**:

  https://www.youtube.com/watch?v=4eTbOod4tcY

  This video examines example questions relating to the practical activities in PAG 1, discusses methods and provides worked answers.

- **VIDEO: David Read, University of Southampton: Using a gas syringe to measure volumes of gases:**

  https://www.youtube.com/watch?v=lC0LNR37THs

  This video uses the example of the reaction of marble chips with hydrochloric acid to show how a gas syringe can be used to measure the volume of gas produced by a reaction.

- **VIDEO: David Read, University of Southampton: Collecting gases produced in chemical reactions:**

  https://www.youtube.com/watch?v=nOcuplk-mnY

  A quick video which demonstrates how to collect a gas from a reaction using the collection over water method.

- **ALTERNATIVE PRACTICAL: Education in Chemistry: Finding the formula of copper(II) oxide:**

  https://edu.rsc.org/resources/finding-the-formula-of-copperii-oxide/727.article

  This activity involves heating copper(II) oxide in a glass tube while passing methane over it. The copper(II) oxide is reduced to copper and by weighing the reactants and the products students can deduce the formula of copper(II) oxide.

- **ALTERNATIVE PRACTICAL: Education in Chemistry: Finding the formula of hydrated copper(II) sulfate:**

  https://edu.rsc.org/experiments/finding-the-formula-of-hydrated-copperii-sulfate/436.article

  In this activity a known mass of hydrated copper(II) sulfate is heated to remove the water of crystallisation and various mass readings allow the formula to be determined.

PAG 2: Acid-base titration

Suggested activities	1.2.1 practical skills covered	1.2.2 apparatus and techniques covered
2.1: Determination of concentration of hydrochloric acid	b, c, d, e, f, j	a, d(i), e, f
2.2: Determination of the molar mass of an acid		a, d(i), e, f, k
2.3: Identification of an unknown carbonate		

Overview

Techniques/skills covered in this practical activity group (minimum):

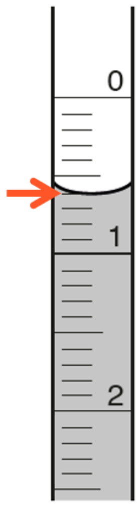
- measurement of volume of a liquid, 1.2.2(a)
- use of volumetric flask, including accurate technique for making up a standard solution, 1.2.2(e)
- use of laboratory apparatus for titration, using burette and pipette, 1.2.2(d)(i)
- use of acid–base indicators in titrations of weak/strong acids with weak/strong alkalis, 1.2.2(f)

In **PAG 2.1**, students make up a standard solution of sodium hydrogencarbonate and then titrate this against a solution of hydrochloric acid in order to work out the concentration of the acid.

In **PAG 2.2**, students make up a solution of an unknown hydrated acid (citric acid monohydrate), then titrate against sodium hydroxide solution of known concentration. From their results, they determine the molar mass of the acid, and with additional information, the formula of the acid.

In **PAG 2.3**, students make up a solution of an unknown Group 1 carbonate, and then titrate this solution against hydrochloric acid. From their results they determine the molar mass of the carbonate and hence the identity of the metal.

There are numerous opportunities throughout these practical activities to calculate the uncertainty in readings from apparatus. Full guidance on calculating uncertainties is available in the Practical Skills Handbook (p39-41). Questions to allow students to practice these are provided in the student sheets to accompany the practical activities, with trial results and worked answers provided in the teacher and technician sheets.



Volumetric pipettes are used to transfer solutions when carrying out a titration. These have a smaller associated uncertainty, leading to more accurate results.

When taking burette readings, the reading should be taken from the bottom of the meniscus, as shown in the diagram to the left. When filling volumetric pipettes, they should be filled so that the bottom of the meniscus sits on the line which indicates where it should be filled to.

Burettes are rinsed with the substance they will be filled with prior to filling them. Otherwise, residual substances may lower the concentration of the substance the burette is being filled with. This would lead to a larger titre being recorded, reducing accuracy.

The burette's tap space should also be filled before the titration starts. Failure to do this means a larger titre will be recorded as this space will fill first before the solution comes out of the burette.

An indicator is commonly used to show when a titration is completed. Only a few drops should be added, as otherwise the indicator can affect the titre values recorded (this is because they are usually weak acids or bases).

Titrations should be repeated until concordant results are obtained (titres within 0.1 cm3 of each other). The mean titre should be calculated from concordant results only and trial results should not be included.

Possible adjustments

All of these suggested practical activities could be truncated to simply involve the making up of a standard solution, 1.2.2(e), if additional opportunities to practise this specific skill are needed. Similarly, for a shorter practical activity which offers additional practice of titration techniques, 1.2.2(d)(i), the making up of a standard solution could be omitted (though it would still need to be covered elsewhere).

1.2.1(h) (using online and offline research skills) and 1.2.1(i) (correctly citing sources of information) could be met by adding a research element to this practical. This could involve researching methods prior to carrying out practical work.

CLEAPSS offer an alternative practical activity involving the microscale titration of vinegar. This activity may be useful if you have limited titration equipment or if you have need for a practical activity which can be conducted outside a laboratory setting. While 1.2.2(d)(i) (use of laboratory apparatus for titration) could not be met using this procedure, it would still allow for students to meet 1.2.2(a) (measurement of volume of a liquid) and 1.2.2(f) (use of acid–base indicators). They would also still be able to meet the 1.2.1 criteria that our own suggested practical activities map to.

Support resources

The following resources may be useful as revision aids for your students to remind them of the practical procedures used in this PAG.

- **RESOURCED LESSON OUTLINE: Cambridge International Resource Plus: An acid-base volumetric titration:**

  https://learning.cambridgeinternational.org/classroom/course/view.php?id=3630

  This resourced lesson outline includes a video and teacher walkthrough of the techniques, a teaching pack of resources, and an associated quiz.

- **SIMULATION: Royal Society of Chemistry: Titration screen experiment:**

  https://edu.rsc.org/resources/titration-screen-experiment/2077.article

  This interactive resource allows students to simulate a titration procedure. This includes both acid-base and redox titration examples. Teacher notes are included.

- **VIDEOS: MaChemGuy: How to do an acid-base titration:**

  Part 1: https://www.youtube.com/watch?v=jnG9Ut--yUA

  Part 2: https://www.youtube.com/watch?v=UAkibS8DOqY

  These videos walk through the process for carrying out a titration, including worked examples of the subsequent calculations.

- **INFOGRAPHIC: Compound Interest: Chemistry techniques: titration:**

  https://www.compoundchem.com/2016/07/14/titration/

  This infographic gives a quick overview of the apparatus and procedures used during a titration.

- **VIDEO: David Read, University of Southampton: Carrying out a titration:**

  https://www.youtube.com/watch?v=Y-5QJIr7Xm4

  An additional video illustrating the techniques required when carrying out a titration.

- **ALTERNATIVE PRACTICAL: Education in Chemistry: Thermometric titration:**

  https://edu.rsc.org/resources/a-thermometric-titration/429.article

  This activity requires students to measure the maximum temperature reached in the reaction between hydrochloric acid and sodium hydroxide in order to determine the end point of the titration. There are also potential links here to PAG 3 (enthalpy determination), as this method could also be used to calculate the enthalpy of neutralisation.

PAG 3: Enthalpy determination

Suggested activities	1.2.1 practical skills covered	1.2.2 apparatus and techniques covered
3.1: Determination of the enthalpy change of neutralisation	b, c, d, e, f, j	a, k
3.2: Determination of an enthalpy change of reaction by Hess' law		
3.3: Determination of enthalpy changes of combustion		

Overview

Techniques/skills covered in this practical activity group (minimum):

- use of appropriate apparatus to record measurements of temperature, 1.2.2(a)

In **PAG 3.1**, students use calorimetry to measure the temperature change when hydrochloric acid and sodium hydroxide solution are mixed. From their results they calculate the enthalpy change of neutralisation.

In **PAG 3.2**, students determine the enthalpy change of reaction by Hess' Law using experimental evidence. This involves measuring the temperature changes in the reactions of both K2CO3 and KHCO3 with hydrochloric acid and applying knowledge of Hess' Law to calculate the enthalpy change of thermal decomposition of KHCO3.

In **PAG 3.3**, students determine the enthalpy change of combustion of alcohols. This involves measuring the mass of the alcohol combusted, the mass of the water heated and the temperature change.

These suggested practical activities all offer ample opportunities for the discussion of how experimental limitations can affect results. These can include, but are not limited to:

- Energy losses from containers used to carry out reactions
- Incomplete combustion (in PAG 3.3)
- Variations in the value of specific heat capacity (the specific heat capacity for water is used generally, but the true value may differ slightly in the case of solutions) and in the density of solutions from that of pure water
- Deviation from standard conditions

Students could be expected to suggest improvements which would mitigate the effects of some of these limitations, where appropriate.

When calculating the enthalpy change for a reaction where a solid is added to a solution, the masses of the solid and the solution should be summed if the solid subsequently forms part of the solution (that is, if it fully dissolves or reacts). This is the approach used in the written examinations unless a question states otherwise.

Possible adjustments

In **PAG 3.3**, students do not have to carry out the activity for a range of alcohols if this is not practical – they can still meet the criteria assessed in this activity by carrying it out with a single alcohol. This may help if you need to carry out this activity in a shorter time period or with limited equipment.

For **PAG 3.1** and **3.3**, the opportunity to process the data gained on the enthalpy changes of could also be provided. This would allow coverage of 1.2.1(g) (use appropriate software and tools to process data).

1.2.1(h) (using online and offline research skills) and 1.2.1(i) (correctly citing sources of information) could be met by adding a research element to this practical. This could involve researching methods prior to carrying out practical work, or looking up and appropriately referencing literature enthalpy values.

Support resources

The following resources may be useful as revision aids for your students to remind them of the practical procedures used in this PAG.

- **RESOURCED LESSON OUTLINE: Cambridge International Resource Plus: Determining the enthalpy for the thermal decomposition of potassium hydrogen carbonate**:

  https://learning.cambridgeinternational.org/classroom/course/view.php?id=3635

  This resource links closely to PAG 1.2 and includes a video walkthrough, teacher outline, worked examples of relevant calculations, and accompanying resources.

- **VIDEO: MaChemGuy: Quick revision of enthalpy change of neutralisation:**

  https://www.youtube.com/watch?v=VmvhhZYAXN4

  This video covers the theory behind enthalpy change of neutralisation, the practical procedure used to determine it, and the associated calculations.

- **ALTERNATIVE PRACTICAL: Education in Chemistry: Microscale chemistry: energy changes in neutralisation:**

  https://edu.rsc.org/resources/energy-changes-in-neutralisation/525.article

  A microscale alternative practical that involves carrying out a reaction on thermochromic strips to determine the temperature change. As this practical activity can be carried out at microscale, there is potential for it to be used outside the laboratory, though a risk assessment should be carried out beforehand. The ability to discern high quality quantitative data from the results of this activity may be limited, so you should keep this in mind if you decide to use it with your students.

- **TEACHING TIPS: Education in Chemistry: Measuring enthalpy changes: Teaching tips for your classroom:**

  https://edu.rsc.org/resources/measure-enthalpy-changes/2395.article

  Some useful practical tips on carrying out enthalpy change practicals. Also includes an alternative microscale method which could be used for **PAG 3.1**.

PAG 4: Qualitative analysis of ions

Suggested activities	1.2.1 practical skills covered	1.2.2 apparatus and techniques covered
4.1: Identifying unknowns 1	b, c, d, e, f, j	d(iii), k
4.2: Identifying unknowns 2	a, b, d, e, f, j	c, d(iii), k
4.3: Identifying unknowns 3		

Overview

Techniques/skills covered in this practical activity group (minimum):

- use of laboratory apparatus for qualitative tests for ions, 1.2.2(d)(iii)
- make and record qualitative observations, 1.2.1(d)

In **PAG 4.1**, students identify the negative and positive ions present in a mixture of Group 2 salts.

In **PAG 4.2 & 4.3**, students identify a range of unknown compounds, with the opportunity to decide which tests they should carry out.

Tests that students need to know the equations and observations for are identified in the specification. They will be expected to explain how these tests are carried out, observations made and inferences from these observations.

Possible adjustments

Students don't need to cover every single qualitative test they need to know from the specification in these practical activities in order to meet the Practical Endorsement criteria. However, it is useful for students to observe the results of these tests themselves. If there are any tests that they don't carry out themselves, they'll still need to know about how these are carried out and the expected observations in order to answer questions about them in the examinations.

To reduce the quantities of reagents required, qualitative tests which only require the reagents to be mixed could be carried out on a microscale basis using dimple trays or even used tablet blister packs. A microscale method carrying out reactions on a sheet covered with a plastic wallet can also be used, as shown in this video from CLEAPSS.

1.2.1(h) (using online and offline research skills) and 1.2.1(i) (correctly citing sources of information) could be met by adding a research element to this practical. This could involve researching testing methods prior to carrying out practical work, or looking up and appropriately referencing expected results of the tests.

Support resources

The following resources may be useful as revision aids for your students to remind them of the practical procedures used in this PAG.

- **ALTERNATIVE PRACTICAL: Education in Chemistry: Microscale reactions of positive ions with sodium hydroxide:**

  https://edu.rsc.org/resources/microscale-reactions-of-positive-ions-with-sodium-hydroxide/757.article

  This alternative practical uses a microscale method to carry out the reaction of various positive ions with sodium hydroxide. This can help reduce the quantities of both chemicals and equipment used during practical work. As the practical only involves the mixing of solutions, it could be carried out in a non-laboratory classroom if an appropriate risk assessment is carried out. The microscale method could be extended to some of the other qualitative tests in this PAG.

- **VIDEOS: Education in Chemistry: Qualitative tests for anions and cations:**

  https://edu.rsc.org/resources/qualitative-tests-for-anions-and-cations-practical-videos-16-18-students/4012298.article

  This collection of videos covers all of the relevant ion tests at A Level, and also includes some teaching tips.

- **VIDEO AND WORKED QUESTION: MaChemGuy: PAG4:**

  https://www.youtube.com/watch?v=h_txyV-PCII&feature=emb_title

  Video outlining equations and a worked example of a question relating to this PAG.

PAG 5: Synthesis of an organic liquid

Suggested activities	1.2.1 practical skills covered	1.2.2 apparatus and techniques covered
5.1: Synthesis of a haloalkane	b, c, d, e, f, h, i, j	a, d(ii), g(ii), k
5.2: Preparation of cyclohexene		a, b, d(ii), d(iii), g(ii), k
5.3: Oxidation of ethanol		a, b, d(ii), d(iii), k
5.4: Hydration of hex-1-ene	b, c, f, h, i, j	a, g(ii), k

Overview

Techniques/skills covered in this practical activity group (minimum):

- use of laboratory apparatus for heating under reflux, 1.2.2(d)(ii) (can also be covered in PAG 6)
- 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 (links to 1.2.1(b))

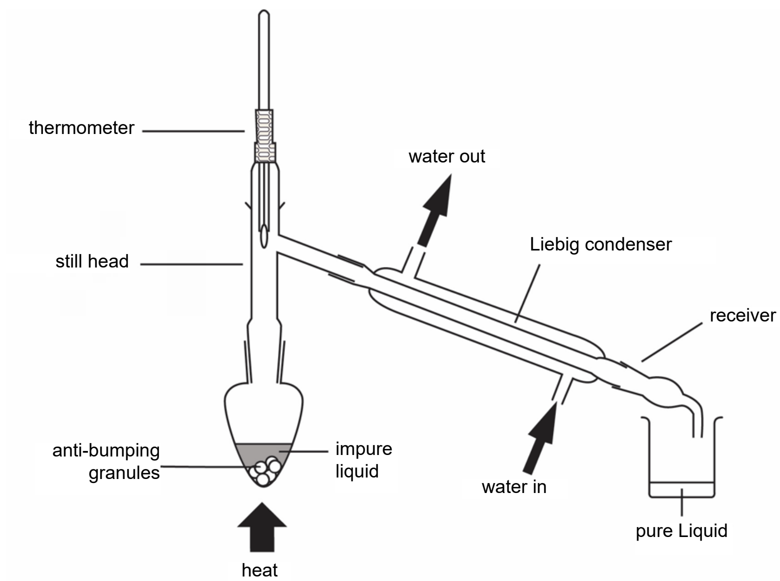
In **PAG 5.1**, students carry out the synthesis of a haloalkane by reacting an alcohol with concentrated hydrochloric acid. The product is purified first using a separating funnel and then by distillation.

In **PAG 5.2**, students carry out the preparation of cyclohexene from cyclohexanol in an elimination reaction. The reaction mixture is heated by reflux and then distilled. The product is purified using a separating funnel. Students then identify the organic functional group in the product.

In **PAG 5.3**, students carry out the synthesis and purification of ethanal and ethanoic acid by the oxidation of ethanol.

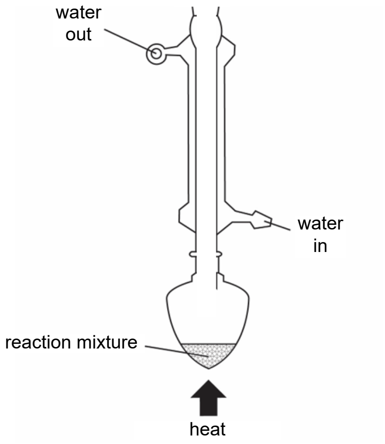
In **PAG 5.4**, students synthesise hexan-2-ol by the hydration of hex-1-ene with cold moderately concentrated sulfuric acid. The product can be partially purified using a separating funnel. Further purification can be carried out if required by drying with anhydrous sodium carbonate and distillation.

In the examinations, students will be expected to be able to draw labelled diagrams depicting distillation and heating under reflux and explain aspects of the procedures.



In both distillation and heating under reflux, anti-bumping granules are added to the reaction mixture. These act as nucleation sites for bubbles, ensuring that the liquid boils smoothly.

Water is introduced at the bottom of the condenser for both distillation and heating under reflux. This ensures that the condenser is completely filled with cold water so that cooling is efficient.



When drawing diagrams of apparatus for distillation and heating under reflux, it's important to ensure that closed lines are not drawn between the pear-shaped flask and the condenser. For reflux apparatus, the top of the condenser should not be shown as sealed, as this would lead to a dangerous build-up of pressure. A thermometer should not be placed in the top of the condenser for the same reason; there is also no need for a thermometer in this set up, anyway. The vapour should not be reaching the top of the condenser so a thermometer wouldn't be measuring the temperature of anything meaningful.

Possible adjustments

If you need pupils to cover specific skills from these suggested activities, you can also carry these out as short practicals in their own right. For example, if you want to give your students an additional opportunity to practise using a separating funnel (1.2.2(g)(ii)), you could carry this out as a separate activity. The same goes for the other apparatus and techniques covered in this PAG.

For **PAG 5.3**, make sure you've read the CLEAPPS guidance on the safe preparation and use of dichromate solutions. Note that 1.2.2(g) (safely and carefully handling solids and liquids, including corrosive, irritant, flammable and toxic substances) does not specifically require for students to use dichromate solutions as part of practical work. However, they will be expected to know about dichromate's use as an oxidising agent for the examinations.

Note that the Practical Endorsement requires use of 'laboratory apparatus' for distillation and reflux, not specifically Quickfit. However, experience of using Quickfit apparatus may be beneficial as preparation for the written assessments, considering that diagrams usually depict this apparatus.

Support resources

The following resources may be useful as revision aids for your students to remind them of the practical procedures used in this PAG.

- **SIMULATION AND VIDEO: Education in Chemistry: The interactive lab primer - heating under reflux:**
  https://edu.rsc.org/resources/heating-under-reflux/1075.article?adredir=1
  This resource contains a video which outlines the principles and procedure of heating under reflux, as well as an animated simulation of the process.

- **VIDEO: Royal Society of Chemistry: Synthesising an organic liquid:**
  Part 1 (reflux): https://www.youtube.com/watch?v=RRZrjgGms6o
  Part 2 (separating funnel): https://www.youtube.com/watch?v=M0N_uo4THYk
  Part 3 (distillation): https://www.youtube.com/watch?v=n_ahNYiL93I
  This 3-part video series looks at the techniques involved in synthesising an organic liquid, in this case butyl ethanoate. The set-up and procedure for heating under reflux, using a separating funnel and distillation are all covered.

- **VIDEO & WORKED QUESTION: MaChemGuy: PAG5:**
  https://www.youtube.com/watch?v=Ro48moEjskQ&feature=emb_title
  Video outlining methods and a worked example of a question relating to this PAG.

- **ALTERNATIVE PRACTICAL: CLEAPSS: Distillation of copper(II) sulfate:**
  http://science.cleapss.org.uk/Resource-Info/PP067-Distillation-of-copper-II-sulfate.aspx
  A simple additional practical which could be used to cover 1.2.2(d)(ii) (use of laboratory apparatus for distillation). This avoids the use of Quickfit apparatus but still meets the requirements as outlined in the specification. If you do opt to use activities that do not use Quickfit apparatus, bear in mind that students may still be expected to draw diagrams of set-ups using Quickfit apparatus in the examinations, so will still need to be taught about them.

- **ALTERNATIVE PRACTICAL: CLEAPSS: Extracting limonene from orange peel:**
  http://science.cleapss.org.uk/Resource-Info/TL004-Extracting-limonene.aspx
  This practical involves a small scale distillation followed by reflux then distillation using Quickfit apparatus, meeting the requirements of 1.2.2(d)(ii) (use of laboratory apparatus for reflux and distillation). A separation funnel could also be used to separate the limonene at the end of the practical activity, allowing 1.2.2(g)(ii) (use of a separating funnel) to be met

PAG 6: Synthesis of an organic solid

Suggested activities	1.2.1 practical skills covered	1.2.2 apparatus and techniques covered
6.1: Synthesis of aspirin	b, c, d, e, f, h, i, j	a, b, d(ii), d(iv), g(i), h, i, k
6.2: Preparation of benzoic acid		
6.3: Preparation of methyl 3-nitrobenzoate		a, b, d(iv), g(i), h, i, k

Overview

Techniques/skills covered in this practical activity group (minimum):

- use of laboratory apparatus for heating under reflux, 1.2.2(d)(ii) (can also be covered in PAG 5)
- 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 (links to 1.2.1(b))

In **PAG 6.1**, students carry out the synthesis of aspirin, an organic solid, using a two-stage process starting from oil of wintergreen. In the first stage, oil of wintergreen, which contains methyl 2-hydroxybenzoate, is hydrolysed by heating under reflux with sodium hydroxide solution to produce 2-hydroxybenzoic acid (salicylic acid). In the second stage, the 2-hydroxybenzoic acid is esterified using ethanoic anhydride to form aspirin (2-ethanoyloxybenzoic acid, or acetyl salicylic acid). The aspirin is recrystallised and analysed by thin layer chromatography and by melting temperature.

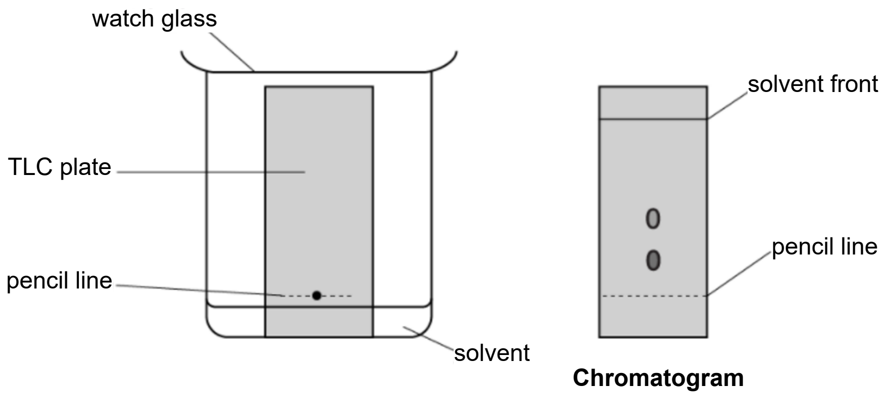
In **PAG 6.2**, students prepare benzoic acid, C_6H_5COOH, by alkaline hydrolysis of an ester, followed by acidification.

In PAG 6.3, students prepare methyl 3-nitrobenzoate, purify it by recrystallisation, and use melting point analysis and/or chromatography to identify it. This activity doesn't include the opportunity to carry out heating under reflux, so this opportunity will need to be provided in another activity if this is the sole suggested practical used in this group.

The same points as previously raised regarding reflux apparatus for PAG 5 also apply here. Students should be able to draw a diagram of this apparatus and explain how it works.

Melting point analysis (1.2.2(h)) can be carried out using an electronic melting point machine or apparatus known as a Thiele tube. Pure substances have a sharp melting point; impurities will slightly lower the melting point and cause it to be seen over a range rather than at a specific temperature.

For thin layer or paper chromatography (1.2.2(i)), tiny drops of the sample should be used to prevent different spots merging. The solvent level should not be above the pencil line the sample is dotted on. A pencil line is used as the pencil does not dissolve in the solvent, while a watch glass is placed over the beaker to prevent evaporation of the solvent. When measuring the distance spots have moved, measurements should be made to the middle of the spots. This is also the approach taken in examination questions.



Possible adjustments

As with PAG 5, if you need pupils to cover specific skills from these suggested activities, you can also carry these out as short practicals in their own right. Melting point analysis (1.2.2(h)), thin layer or paper chromatography (1.2.2(i)) and recrystallisation (1.2.2(g)(i)) could all be carried out as individual activities if required.

Similarly, the aspirin synthesis practical, notorious for requiring extended laboratory time to complete, could be shortened to students carrying out one of the stages, depending on which practical skills you wish to focus on covering. You could simply carry out the first stage if your focus is on use of reflux apparatus, while just stages 2 and 3 could be used if your focus is on recrystallisation. If you do make these adjustments, be sure to adjust the mapping in the tracker for this activity accordingly.

Support resources

The following resources may be useful for teachers when planning/adjusting activities or as revision aids for your students to remind them of the practical procedures used in this PAG.

- **VIDEOS: Education in Chemistry: Synthesis of an organic liquid or solid:**

  https://edu.rsc.org/resources/synthesis-of-an-organic-solid-or-liquid-practical-videos-16-18-students/4012313.article

  This page collates a number of videos on the techniques used in the synthesis of organic liquids and solids, accompanied with teacher guidance.

- **VIDEOS: Education in Chemistry: Thin-layer chromatography:**

  https://edu.rsc.org/4012270.article

  A series of videos and teacher guidance on the use of thin-layer chromatography.

- **ALTERNATIVE PRACTICAL: Royal Society of Chemistry: Paracetamol – a curriculum resource:**

  https://edu.rsc.org/download?ac=11243

  This resource includes a number of free-standing activities relating to paracetamol which you could use with your students as part of this PAG. In particular, the preparation of paracetamol could be used as an alternative activity to the synthesis of aspirin. A TLC activity is also included which could be used in full if you carry out the full synthesis, or adapted if you only carry out particular steps.

- **SIMULATION: Royal Society of Chemistry: Aspirin screen experiment:**

  https://edu.rsc.org/resources/aspirin-screen-experiment/1644.article

  A resource which allows students to run their own virtual synthesis of aspirin. While simulations cannot be counted towards competence in the Practical Endorsement, it could be useful to familiarise students with the procedure before carrying it out, or to introduce them to the whole procedure if you only plan to carry out parts of it.

- **VIDEO AND WORKED QUESTION: MaChemGuy: PAG6:**

  https://www.youtube.com/watch?v=YzXj_gx7xrl&t=16s

  Video outlining methods and a worked example of a question relating to this PAG.

- **ALTERNATIVE PRACTICAL: CLEAPSS: Paper chromatography of amino acids:**

  http://science.cleapss.org.uk/Resource-Info/PP062-Paper-chromatography-of-amino-acids.aspx

  This short practical activity could provide students with a useful additional opportunity to cover 1.2.2(h) (use of thin-layer or paper chromatography).

- **ALTERNATIVE PRACTICAL: CLEAPSS: Thin-layer chromatography of plant pigments:**

  http://science.cleapss.org.uk/Resource-Info/PP056-Thin-layer-chromatography-of-plant-pigments.aspx

  Another practical activity which can provide an additional opportunity to cover 1.2.2(h) (use of thin-layer or paper chromatography).

PAG 7: Qualitative analysis of organic functional groups

Suggested activities	1.2.1 practical skills covered	1.2.2 apparatus and techniques covered
7.1: Identifying organic unknowns 1	b, c, d, e, f, j	b, d(iii), k
7.2: Identifying organic unknowns 2		b, c, d(iii), k
7.3: Identifying organic unknowns 3	a, b, c, d, e, f, j	b, c, d(iii), i, k

Overview

Techniques/skills covered in this practical activity group (minimum):

- 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)

In **PAG 7.1**, students carry out qualitative tests for a number of organic functional groups, specifically alkenes and haloalkanes, identifying the expected observations.

In **PAG 7.2**, students carry out qualitative tests for a number of organic functional groups, specifically alcohols, aldehydes and carboxylic acids, identifying the expected observations.

In **PAG 7.3**, students attempt to confirm the presence of functional groups in six naturally occurring organic compounds by carrying out test-tube tests.

The qualitative functional group tests that students are expected to know for the examinations are identified in the specification. They will be expected to explain how these tests are carried out, observations made and inferences from these observations.

Possible adjustments

Students don't need to cover every single qualitative test they need to know from the specification in these practical activities in order to meet the Practical Endorsement criteria. However, it is useful for students to observe the results of these tests themselves. If there are any tests that they don't carry out themselves, they'll still need to know about how these are carried out and the expected observations in order to answer questions about them in the examinations.

To reduce the quantities of reagents required, qualitative tests which only require the reagents to be mixed could be carried out on a microscale basis using dimple trays or even used tablet blister packs. A microscale method carrying out reactions on a sheet covered with a plastic wallet can also be used, as shown in this video from CLEAPSS.

Support resources

The following resources may be useful as revision aids for your students to remind them of the practical procedures used in this PAG.

- **RESOURCED LESSON OUTLINE: Cambridge International Resource Plus: Identifying alkenes, alcohols and haloalkanes:**

  https://learning.cambridgeinternational.org/classroom/course/view.php?id=3633

  This resource includes a video outlining the procedures for carrying out these tests and the expected observations and inferences. It also includes a teaching pack and quiz for students.

- **RESOURCED LESSON OUTLINE: Cambridge International Resource Plus: Identifying aldehydes and ketones:**

  https://learning.cambridgeinternational.org/classroom/course/view.php?id=3632

  This resource includes a video outlining the procedures for carrying out these tests and the expected observations and inferences. It also includes a teaching pack and quiz for students.

- **VIDEOS: Education in Chemistry: Qualitative tests for organic functional groups:**

  https://edu.rsc.org/resources/qualitative-tests-for-organic-functional-groups-practical-videos-16-18-students/4012307.article

  This resource collates a series of videos on the various qualitative organic functional group tests. It also includes links to additional microscale practical work.

- **VIDEO AND WORKED QUESTION: MaChemGuy: PAG7:**

  https://www.youtube.com/watch?v=3E8ISqIMd9o

  Video outlining methods and a worked example of a question relating to this PAG.

PAG 8: Electrochemical cells

Suggested activities	1.2.1 practical skills covered	1.2.2 apparatus and techniques covered
8.1: Electrochemical cells 1	b, c, d, e, f, j	a, j, k
8.2: Electrochemical cells 2		
8.3: Electrochemical cells 3 (microscale)		j, k

Overview

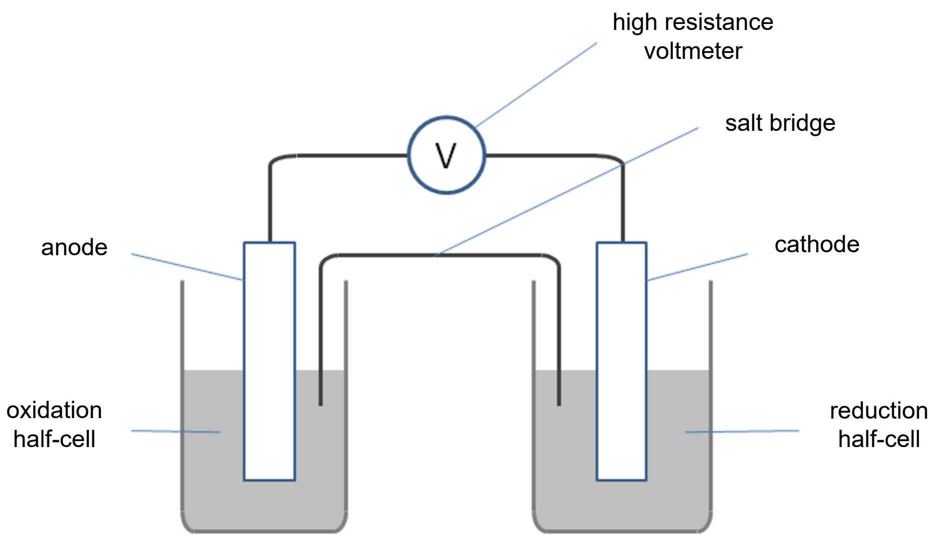
Techniques/skills covered in this practical activity group (minimum):

- setting up of electrochemical cells and measuring voltages, 1.2.2(j)

In **PAG 8.1**, students set-up a simple electrochemical cell using two types of half-cell. The copper half-cell uses copper solution, and a piece copper metal as both the electrode and source of copper atoms in the subsequent redox reaction. The iron half-cell uses a graphite electrode, as both iron species involved in the redox reaction are ionic and in solution.

In **PAG 8.2**, students set up different electrochemical cells and measure the cell potential. From these data they construct a table of electrode potentials and identify weakest and strongest oxidising agents.

In **PAG 8.3** is a microscale experiment, in which the whole cell is made up on one piece of filter paper. Multiple cells can be constructed in one petri dish, making investigation and data collection efficient.



A diagram of a typical electrochemical cell is shown above. The direction of electron flow in the diagram is from the anode to the cathode.

The purpose of the salt bridge is to complete the electrical circuit of the electrochemical cell. It's often made from filter paper soaked in a saturated salt solution. It's important that this salt solution isn't one which can react with either the electrodes or solutions – potassium nitrate is commonly used.

Possible adjustments

To simplify **PAG 8.1**, if a shorter activity is required, the investigative aspects relating to equilibrium could be removed, and students could simply be tasked with the part of the activity which involves setting up the electrochemical cells and comparing them. This would also reduce the quantities of reagents required.

PAG 8.3 is a good alternative option if you are short on equipment for all of your students to carry out **PAG 8.1** or **8.2**. It's important, if you're using this activity exclusively for this PAG, to make clear how the microscale set-up relates to the traditional electrochemical cell, and which parts of each cell correspond to one another.

Support resources

The following resources may be useful as revision aids for your students to remind them of the practical procedures used in this PAG.

- **RESOURCED LESSON OUTLINE: Cambridge International Resource Plus: Constructing electrochemical cells and measuring electrode potentials:**

  https://learning.cambridgeinternational.org/classroom/course/view.php?id=3634

  This resource includes a video demonstrating how to set up an electrochemical cell. It also includes additional resources and a student quiz.

- **VIDEOS: Education in Chemistry: Electrochemistry:**

  https://edu.rsc.org/resources/electrochemistry-practical-videos-16-18-students/4012295.article

  This set of collated videos cover setting up electrochemical cells, and also includes teaching guidance and additional useful links.

- **VIDEO AND WORKED QUESTION: MaChemGuy: PAG8:**

  https://www.youtube.com/watch?v=xlvdnYoE58A

  Video outlining methods and a worked example of a question relating to this PAG.

PAG 9: Rates of reaction – continuous monitoring method

Suggested activities	1.2.1 practical skills covered	1.2.2 apparatus and techniques covered
9.1: Rate of decomposition of hydrogen peroxide	a, b, c, d, e, f, g, j	a, l(ii)
9.2: The rate of reaction of calcium carbonate and hydrochloric acid	b, c, d, e, f, g, j	
9.3: The rate of reaction of magnesium and hydrochloric acid		

Overview

Techniques/skills covered in this practical activity group (minimum):

- 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) (can also be covered in PAG 10)

In **PAG 9.1**, students investigate the rate of the decomposition of H2O2 catalysed by MnO_2. They follow the progress of the reaction by measuring the volume of oxygen produced over time.

In **PAG 9.2**, students investigate the rate of the reaction between calcium carbonate and hydrochloric acid. They do this by carrying out two different methods: measuring mass lost and recording volume of gas released over time.

In **PAG 9.3**, students investigate the rate of the reaction between magnesium and different concentrations of hydrochloric acid. They follow the progress of the reaction by measuring the volume of hydrogen produced over time.

Where rate of gas production is being measured over time, this will gradually slow to a stop towards the end of the experiment as the reaction reaches completion. Gas syringes usually only measure a small amount of gas, so the quantities of reagents used need to be judged accordingly, otherwise more gas than the syringe can contain will be produced.

Possible adjustments

If you do not have a sufficient supply of gas syringes for this PAG, collection over water can be used instead, as in PAG 9.1. This PAG uses an upturned burette, but if you do not have a sufficient supply of burettes for this then measuring cylinders can be used instead.

The 'software to process data' required by 1.2.1(g) can simply be any software that allows students to record and manipulate data in a spreadsheet, and for this PAG, subsequently produce relevant graphs. Similarly to how 1.2.1(h) (using online and offline research skills) and 1.2.1(i) (correctly citing sources of information) can be completed outside of the classroom, work towards 1.2.1(g) could be completed by students independently, with the outcomes of their data processing serving of evidence of competence.

Support resources

The following resources may be useful as revision aids for your students to remind them of the practical procedures used in this PAG.

- **VIDEOS: Education in Chemistry: Rates of reaction:**

  https://edu.rsc.org/resources/rates-of-reaction-practical-videos-16-18-students/4012309.article

  A set of collated videos covering both PAG 9 and PAG 10 content. Also includes teacher guidance and links to additional useful content.

- **VIDEO AND WORKED QUESTION: MaChemGuy: PAG9:**

  https://www.youtube.com/watch?v=0X_ptI2P7b8

  Video outlining methods and a worked example of a question relating to this PAG.

- **ALTERNATIVE PRACTICAL: Education in Chemistry: Rates and rhubarb:**

  https://edu.rsc.org/resources/rates-and-rhubarb/745.article

  This activity uses rhubarb sticks, which contain oxalic acid, to reduce and decolourise potassium manganate(VII) solution. The activity can be used to show how the rate of reaction is affected by surface area or concentration.

- **ALTERNATIVE PRACTICAL: Education in Chemistry: Catalysis of the reaction between zinc and sulfuric acid:**

  https://edu.rsc.org/experiments/catalysis-of-the-reaction-between-zinc-and-sulfuric-acid/1713.article

  In this activity students compare the rate of reaction of zinc with sulfuric acid with an without a copper catalyst. The method described at the link merely describes monitoring the rate of production of bubbles, but this could be modified to collect the gas and record the gas produced over time.

PAG 10: Rates of reaction – initial rates method

Suggested activities	1.2.1 practical skills covered	1.2.2 apparatus and techniques covered
10.1: Rates – iodine clock	a, b, c, d, e, f, g, j	a, k, l(i)
10.2: Rates – thiosulfate and acid		a, l(i)
10.3: Rates – activation energy		a, b, k, l(i)

Overview

Techniques/skills covered in this practical activity group (minimum):

- 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) (can also be covered in PAG 9)

In **PAG 10.1**, students carry out an iodine clock reaction, timing how long it takes from the start of each experiment for the blue colour to appear. The initial rate of disappearance of I^-(aq) can be determined from this time. Students use the results to find the order of this reaction with respect to I^- and also to find the rate constant for the reaction.

In **PAG 10.2**, students investigate the reaction between aqueous thiosulfate ions, $S_2O_3^{2-}$(aq), and aqueous acid, H^+(aq). The rate of this reaction can be followed by observing the precipitation of sulfur. Using an initial rates method, students investigate the effect on the rate of this reaction of changing the concentration of thiosulfate ions, [$S_2O_3^{2-}$(aq)], and hydrochloric acid, [HCl(aq)].

In **PAG 10.3**, students investigate the reaction between potassium manganate(VII), $KMnO_4$(aq), and ethanedioc acid, $H_2C_2O_4$(aq), timing how long it takes for the brown colour to appear. The initial rate of the reaction can be determined from this time. Students measure the initial rate at different temperatures, and use the Arrhenius equation to determine the activation energy, E_a, for the reaction.

Possible adjustments

As with PAG 9, work towards 1.2.1(g) could be completed by students independently, with the outcomes of their data processing serving of evidence of competence.

1.2.1(h) (using online and offline research skills) and 1.2.1(i) (correctly citing sources of information) could be met by adding a research element to this practical. This could involve researching methods prior to carrying out practical work, or the chemical details for the particular reactions being studied.

To save on reagent and equipment quantities required, adapted microscale versions of these practicals could be used. One such example of a microscale version of the iodine clock practical is provided here: https://cd1.edb.hkedcity.net/cd/science/chemistry/s67chem/pdf/sMC_1_iodine_clock.pdf.

A similar microscale method for the acid thiosulfate reaction is provided as part of this article on microscale chemistry from *Education in Chemistry:* https://edu.rsc.org/feature/microscale-chemistry/2020192.article.

Support resources

The following resources may be useful as revision aids for your students to remind them of the practical procedures used in this PAG.

- **VIDEOS: Education in Chemistry: Rates of reaction:**

  https://edu.rsc.org/resources/rates-of-reaction-practical-videos-16-18-students/4012309.article

  A set of collated videos covering both PAG 9 and PAG 10 content. Also includes teacher guidance and links to additional useful content.

- **VIDEO AND WORKED QUESTION: MaChemGuy: PAG10:**

  https://www.youtube.com/watch?v=ZiQrBIjYBJk

  Video outlining methods and a worked example of a question relating to this PAG.

- **ALTERNATIVE TECHNIQUE: CLEAPSS: Small-scale Andrew's apparatus for estimating rate of gas produced by a reaction:**

  http://science.cleapss.org.uk/Resource-Info/TL014-Small-scale-Andrew-s-apparatus-for-estimating-rate-of-gas-produced-by-a-reaction.aspx

  This apparatus could be used in a practical activity to determine the initial rate of a catalysed reaction. It produces results very quickly so has the advantage of making a number of repeats quick and easy to carry out.

- **ALTERNATIVE PRACTICAL: Education in Chemistry: The hydrolysis of 2-bromo-2-methyl propane:**

  https://edu.rsc.org/feature/the-hydrolysis-of-2-bromo-2-methylpropane/2020254.article

  This activity uses an initial rates method to determine the order of reaction with respect to hydroxide ions, allowing students to meet 1.2.2(l)(i) (measurement of rates by an initial rates method). It would also be easy to meet 1.2.1(g) (use appropriate software and tools to process data) using this activity.

PAG 11: pH measurement

Suggested activities	1.2.1 practical skills covered	1.2.2 apparatus and techniques covered
11.1: pH – problem solving	a, b, d, e, f, j	a, c, k
11.2: pH – titration curves		a, c, d(i)
11.3: pH – acids and buffers	a, b, c, d, e, f, j	a, c, k

Overview

Techniques/skills covered in this practical activity group (minimum):

- measurement of pH using pH charts, or pH meter, or pH probe on a data logger, 1.2.2(c)

In **PAG 11.1**, students are given a number of colourless solutions of acids and/or alkalis. They must plan and implement a practical procedure to work out the identity of each solution.

In **PAG 11.2**, students follow the pH during acid–base reactions. They plot pH titration curves for different combinations of strong and weak acids and bases. They measure the pH using appropriate apparatus. They plot the pH titration curves by hand, using software, or automatically as they record results, depending on the software available.

In **PAG 11.3**, students prepare hydrochloric acid solutions of a range of concentrations by dilution and measure their pH values. Then, they will prepare a range of buffer solutions and measure their pH values. For both types of solutions, they will investigate how the pH changes on addition of sodium hydroxide solution.

It's important that students don't confuse the terms 'end point' and 'equivalence point', which t they will come across during these suggested practical activities. The end point is the point at which the indicator being used for a titration changes colour. The equivalence point is the point at which stoichiometric amounts of acid and alkali have been added, and is found at the midpoint of the vertical section of a pH curve. For an accurate titration, an indicator with an end point with a value the same as that of the equivalence point should be chosen.

Possible adjustments

For each of these suggested practicals shortened versions of the activities can be used if required and these will still allow students to meet the criteria. So, for **PAG 11.1**, a subset of the solutions suggested in the instructions could be used, for **PAG 11.2** a single reaction could be investigated, or for **PAG 11.3** a smaller number of solutions could be prepared.

As the criteria suggest, there is no requirement to use a particular type of pH measurement. So pH meter, pH probe with datalogger or narrow range pH paper can all be used, depending on availability.

1.2.1(h) (using online and offline research skills) and 1.2.1(i) (correctly citing sources of information) could be met by adding a research element to this practical. This could involve researching methods prior to carrying out practical work, or looking up details on various indicators which could be used.

Support resources

The following resources may be useful as revision aids for your students to remind them of the practical procedures used in this PAG.

- **VIDEO: MaChemGuy: pH curves (strong acid-strong base):**

  https://www.youtube.com/watch?v=FPkI3f4lpJ0

  This video shows the practical method for plotting a pH curve for a strong acid-strong base, and includes discussion of the pH curve produced.

- **VIDEO AND WORKED QUESTION: MaChemGuy: PAG11:**

  https://www.youtube.com/watch?v=G8S16KODt3Y

  Video outlining methods and a worked example of a question relating to this PAG.

- **SUMMARY NOTES: ChemGuide: pH (titration) curves:**

  https://www.chemguide.co.uk/physical/acidbaseeqia/phcurves.html

  Summary notes explaining the theory behind pH curves and what they can tell us.

- **SIMULATION: pH APP:**

  https://ph.lattelog.com/titrage

  This simulation allows the plotting of pH curves to be simulated for a range of different acids and alkalis.

- **SIMULATION: Education in Chemistry: Titration curves and indicators animation:**

  https://edu.rsc.org/resources/titration/2258.article

  The linked article focuses more generally on titration, but includes a downloadable simulator for pH curves. It's less customisable but more intuitive than the previous simulation, and includes indicators.

PAG 12: Research skills

Suggested activities	1.2.1 practical skills covered	1.2.2 apparatus and techniques covered
12.1: Investigating iron tablets	a, b, d, e, f, g, h, i, j	a, d(i), e, k
12.2: Investigating the copper content of brass screws		a, d(i), e
12.3: Investigating the reaction between potassium manganate(VII) and ethanedioic acid	a, b, c, d, e, f, g, h, i, j	a, k, l(i)

Overview

Techniques/skills covered in this practical activity group (minimum):

- 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)

In **PAG 12.1**, students carry out an investigation to determine the mass of iron in a commercial iron tablet. They will have to conduct research to find information about a given titration method in order to plan their investigation, prior to carrying it out.

In **PAG 12.2**, students carry out an investigation to determine the copper content in a sample of brass. They will have to conduct research to find information about a given titration method in order to plan their investigation, prior to carrying it out.

In **PAG 12.3**, students carry out an investigation into the effect of acidic conditions on the reaction between potassium manganate(VII) and ethanedioic acid. They will use research skills to inform planning, and to find out about the theory behind the reaction.

Possible adjustments

The primary skills covered by these suggested practical activities are those relating to investigative approaches, research and citation. The suggested practicals in this PAG are not mandatory and, if you have covered the relevant skills during other practical work you have carried out with students, you may choose not to use any of these practical activities in your teaching. If this is the case, bear in mind that your students still need to have completed a minimum of 12 practical activities to meet the usual requirements of the Practical Endorsement.

Support resources

The following resources may be useful as revision aids for your students to assist them with the skills covered in this PAG.

- **SKILLS GUIDE: OCR: The OCR guide to referencing:**

  https://www.ocr.org.uk/Images/570838-guide-to-referencing.pdf

  This guide contains general advice on referencing which will help students meet the requirements of 1.2.1(i) (correctly cite sources of information). Further guidance on referencing is provided in the Practical Skills Handbook on p56-57. While it doesn't matter which referencing system students use, references should be complete and consistent.

- **VIDEOS: Education in Chemistry: Redox:**

  https://edu.rsc.org/resources/redox-practical-videos-16-18-students/4012311.article

  This set of collated videos cover some of the content our suggested activities for this PAG cover, so may be useful if you use these activities with your students.

Need to get in touch?

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