# Chemistry PAG 6: Titration

# Suggested Activity 2: The vinegar dilemma

## Instructions and answers for teachers & technicians

These instructions cover the learner activity section which can be found on [page 14](#_Learner_Activity). This Practical activity supports OCR GCSE Chemistry and Combined Science.

**When distributing the activity section to the learners, either as a printed copy or as a Word file, you will need to remove the teacher instructions section.**

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| This is a **suggested** practical activity that can be used as part of teaching the GCSE (9-1) Gateway Science (A) and Twenty First Century Science (B) specifications.  These are **not controlled assessment tasks**, and there is **no requirement to use these particular activities**.  You may modify these activities to suit your learners and centre. Alternative activities are available from, for example, [Royal Society of Biology](https://www.rsb.org.uk/education/teaching-resources/secondary-schools), [Royal Society of Chemistry](http://www.rsc.org/learn-chemistry), [Institute of Physics](http://www.iop.org/education/teacher/resources/index.html), [CLEAPSS](http://science.cleapss.org.uk/) and [publishing companies](https://global.oup.com/education/content/secondary/key-issues/gcse_science_2016/?region=uk), or of your own devising.  Further details are available in the [specifications](http://www.ocr.org.uk/science) (Practical Skills Topics), and in these [videos](https://www.youtube.com/playlist?list=PLBD9B84FF4BD54AA4). |

**OCR recommendations:**

**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.**

**CLEAPSS resources are useful for carrying out risk-assessments: (**<http://science.cleapss.org.uk>**).**

**Centres should trial experiments in advance of giving them to learners. Centres may choose to make adaptations to this practical activity, but should be aware that this may affect the Apparatus and Techniques covered by the learner.**

### Introduction

Learning the techniques and procedures of titration can be complex for leaners as there are a wide range of conceptual and practical aspects to be mastered. This activity can be used as part of a staged introduction to titration, by not requiring the use of burettes and volumetric pipettes, and simplifying the resultant calculations.

**After this activity, learners can then progress to learning to use the more accurate volumetric apparatus, and then the more involved resultant calculations, for example with a standard hydrochloric acid – sodium hydroxide titration (see** [**OCR PAG Titration, Suggested activity 1**](http://www.ocr.org.uk/Images/351861-pag-activity-chemistry-titration-suggestion-1.docx)**, or RSC:** [**http://www.rsc.org/learn-chemistry/resource/res00000536/a-microscale-acid-base-titration**](http://www.rsc.org/learn-chemistry/resource/res00000536/a-microscale-acid-base-titration)**).**

This method is based on the CLEAPSS activity PP019: <http://science.cleapss.org.uk/Resource-Info/PP019-Analysis-of-vinegar-small-scale.aspx>.

Further thoughts on developing titration practical work can be found at: <http://www.ocr.org.uk/qualifications/by-subject/science/science-news/practical-work-and-cognitive-load/>

### DfE Apparatus and Techniques covered

The codes used below match the OCR Practical Activity Learner Record Sheet ([**Chemistry**](http://www.ocr.org.uk/Images/295630-gcse-chemistry-learner-record-sheet.doc) / [*Combined Science*](http://www.ocr.org.uk/Images/304431-gcse-combined-science-learner-record-sheet.doc)) and Trackers ([**Chemistry**](http://www.ocr.org.uk/Images/323481-gcse-chemistry-practical-tracker.zip) / [*Combined Science*](http://www.ocr.org.uk/Images/323483-gcse-combined-science-practical-tracker.zip)) available online. **There is no requirement to use these resources.**

By doing this experiment, learners have an opportunity to develop the following skills:

**1** [*1*]: Use of appropriate apparatus to make and record a range of measurements accurately, including: **i** [*iii*]) mass

**3** [*8*]: Use of appropriate apparatus and techniques for: i) conducting and monitoring chemical reactions; ii) conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations

**6** [*11*]: Safe use and careful handling of gases, liquids and solids, including: i) careful mixing of reagents under controlled conditions; ii) using appropriate apparatus to explore chemical changes and/or products

**NOTE**: This practical does **not** cover ‘**8:** The determination of concentrations of strong acids and strong alkalis”.

### Aims

To experimentally determine the concentration of ethanoic acid in a range of vinegar samples.

### Intended class time

30-40 minutes

### Links to Specifications:

### Gateway Science (Suite A) – including Working Scientifically (WS)

C3.3g use and explain the terms dilute and concentrated (amount of substance) and weak and strong (degree of ionisation) in relation to acids [to include ratio of amount of acid to volume of solution]

C3.3h recall that relative acidity and alkalinity are measured by pH

C3.3i describe neutrality and relative acidity and alkalinity in terms of the effect of the concentration of hydrogen ions on the numerical value of pH (whole numbers only)

C3.3j recall that as hydrogen ion concentration increases by a factor of ten the pH value of a solution decreases by a factor of one.

C3.3k describe techniques and apparatus used to measure pH

C5.1a explain how the concentration of a solution in mol/dm3 is related to the mass of the solute and the volume of the solution

C5.1b describe the technique of titration

C5.1c explain the relationship between the volume of a solution of known concentration of a substance and the volume or concentration of another substance that react completely together

C5.1f explain how the mass of a solute and the volume of the solution is related to the concentration of the solution

WS1.2d recognise when to apply knowledge of sampling techniques to ensure any samples collected are representative

WS1.2e evaluate methods and suggest possible improvements and further investigations

WS1.3a presenting observations and other data using appropriate methods

WS1.3e interpreting observations and other data

WS1.3f presenting reasoned explanations relating data to hypotheses

WS1.3g evaluating data in terms of accuracy, precision, repeatability and reproducibility

WS1.3h identifying potential sources of random and systematic error

WS1.3i communicating the scientific rationale for investigations, methods used, findings and reasoned conclusions

WS1.4a use scientific vocabulary, terminology and definitions

WS1.4b recognise the importance of scientific quantities and understand how they are determined

WS1.4c use SI units and IUPAC chemical nomenclature unless inappropriate

WS1.4d use prefixes and powers of ten for orders of magnitude

WS1.4e interconvert units

WS1.4f use an appropriate number of significant figures in calculation

WS2a carry out experiments

WS2b make and record observations and measurements using a range of apparatus and methods

WS2c presenting observations using appropriate methods to include descriptive, tabular diagrammatic and graphically

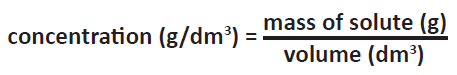
### Twenty First Century Science (Suite B) – including Ideas about Science (IaS)

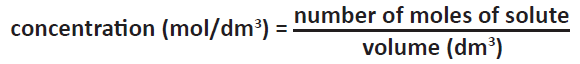
C6.1.4 recall that relative acidity and alkalinity are measured by pH including the use of universal indicator and pH meters

C6.1.5 use and explain the terms dilute and concentrated (amount of substance) and weak and strong (degree of ionisation) in relation to acids including differences in reactivity with metals and carbonates

C6.1.6 use the idea that as hydrogen ion concentration increases by a factor of ten the pH value of a solution decreases by one

C6.1.7 describe neutrality and relative acidity and alkalinity in terms of the effect of the concentration of hydrogen ions on the numerical value of pH (whole numbers only)

C5.4.2 explain how the mass of a solute and the volume of the solution are related to the concentration of the solution and calculate concentration using the formula: 

C5.4.3 explain how the concentration of a solution in mol/dm3 is related to the mass of the solute and the volume of the solution and calculate the molar concentration using the formula 

C5.4.4 describe neutralisation as acid reacting with alkali to form a salt plus water including the common laboratory acids hydrochloric acid, nitric acid and sulfuric acid and the common alkalis, the hydroxides of sodium, potassium and calcium

C5.4.5 recall that acids form hydrogen ions when they dissolve in water and solutions of alkalis contain hydroxide ions

C5.4.6 recognise that aqueous neutralisation reactions can be generalised to hydrogen ions reacting with hydroxide ions to form water

C5.4.7 describe and explain the procedure for a titration to give precise, accurate, valid and repeatable results

C5.4.8 evaluate the quality of data from titrations

C5.4.9 explain the relationship between the volume of a solution of known concentration of a substance and the volume or concentration of another substance that react completely together (separate science only)

IaS1.3 recognise the importance of scientific quantities and understand how they are determined

IaS1.8 use appropriate scientific vocabulary, terminology and definitions to communicate the rationale for an investigation and the methods used using diagrammatic, graphical, numerical and symbolic forms

IaS2.1 present observations and other data using appropriate formats

IaS2.2 when processing data use SI units where appropriate (e.g. kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate

IaS2.3 when processing data use prefixes (e.g. tera, giga, mega, kilo, centi, milli, micro and nano) and powers of ten for orders of magnitude

IaS2.5 when processing data interconvert units

IaS2.6 when processing data use an appropriate number of significant figures

IaS2.8 when analysing data identify patterns/trends, use statistics (range and mean) and obtain values from a line on a graph (including gradient, interpolation and extrapolation),

IaS2.9 in a given context evaluate data in terms of accuracy, precision, repeatability and reproducibility, identify potential sources of random and systematic error, and discuss the decision to discard or retain an outlier

IaS2.10 evaluate an experimental strategy, suggest improvements and explain why they would increase the quality (accuracy, precision, repeatability and reproducibility) of the data collected, and suggest further investigations

IaS2.11 in a given context interpret observations and other data (presented in diagrammatic, graphical, symbolic or numerical form) to make inferences and to draw reasoned conclusions, using appropriate scientific vocabulary and terminology to communicate the scientific rationale for findings and conclusions

IaS2.12 explain the extent to which data increase or decrease confidence in a prediction or hypothesis

### Mathematical Skills covered

M1a recognise and use expressions in decimal form

M1b recognise and use expressions in standard form

M1c use ratios, fractions and percentages

M2a use an appropriate number of significant figures

M2f understand the terms mean

M3a understand and use the symbols: =, <, ≪, ≫, >, ∝, ~

M3b change the subject of an equation

M3c substitute numerical values into algebraic equations using appropriate units for physical quantities

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| Technical Requirements – PER GROUPChemicals  | **Identity** | **Approximate quantity required or produced PER GROUP** | **Hazard information** | | **Risk information** | | --- | --- | --- | --- | --- | | labelled vinegar samples (see Notes) | c. 1 cm3 each (see notes) | Currently not classified as hazardous at this concentration | |  | | 0.2 mol dm–3 sodium hydroxide solution | c. 10 cm3 | HSE warning symbol | WARNING  Causes skin and serious eye irritation | Ensure learners are wearing eye protection and all spills are promptly cleared up. | | 0.1% phenolphthalein solution | a few drops | Highly flammable | WARNING  Highly flammable  See CLEAPSS Recipe Book 46 | Ensure learners are wearing eye protection and all spills are promptly cleared up. |  Equipment  * retort stand, boss and clamp * 1 × pastettes (extended fine tip pastettes / fine tipped plastic Pasteur pipettes) * dropping pipette with volume markings **OR** measuring cylinder (10 cm3) and pipette * white tile * small beaker or small glass vial (c. 14 cm3), e.g. Timstar VI16982 (162 reusable vials for about £40) * access to a 2 decimal place mass balance – if you only have access to a 3 d.p. balance, place masking tape over the last decimal place. |

### Notes

Shop-brought vinegar samples can be used in this practical, and will need diluting down 1:4, e.g. 25 cm3 vinegar made up to 100 cm3 with deionised water.

Alternatively, sample vinegars can be made up at different concentrations, with appropriate labels. The vinegars used in the trial were made up as follows:

|  |  |
| --- | --- |
| **Vinegar sample** | **Volume of 1 mol/dm3 ethanoic acid solution required / cm3** |
| Trading standards stock vinegar | 21 |
| Supermarket vinegar | 20 |
| Farm shop vinegar | 26 |
| Fred's Chip Shop vinegar | 14 |

Make up these volumes of ethanoic acid separately to 100 cm3 with deionised water.

### Health and Safety

Eye protection should be worn at all times.

### Method

As the method of titration here is simplified, learners can focus on developing their observational skills to accurately identify the end-point of the titration. The method also minimises the use of reagents and allows rapid collection of quality data.

### Images from trials

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| Images from the trial  Images from the trial |

Figure 1 – Images from the trial

# Analysis of results – Trial results

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| --- | --- | --- | --- | --- | --- |
| Data and calculations | *Example data* | Trading standards stock vinegar | Supermarket vinegar | Farm shop vinegar | Fred’s Chip Shop vinegar |
| ***M1*** / g | *10.40* | *10.10* | *10.41* | *10.30* | *10.36* |
| ***M2*** / g | *11.51* | *10.97* | *11.51* | *11.59* | *11.05* |
| ***M3*** / g | *12.80* | *11.88* | *12.64* | *13.28* | *11.56* |
| percentage concentration / %  *=* | *5.6* | *5.0* | *4.9* | *6.3* | *3.5* |

The questions you set your learners will depend on the focus of the experiment.

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| **1.** | Based on your results, write a short report to Trading Standards on whether further investigation is required. **[3 marks]** |  |
|  | *The percentage concentration of Fred’s Chip shop vinegar is 3.5% and therefore less than the required 5.0%.*  *✓*  *As only one sample and one repeat was used, a firm conclusion cannot be made.*  *✓*  *Therefore, further investigation should be carried out.* *✓* |  |

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| **2.** | Discuss ways to improve the design of the analysis to give you more confidence in your data: | |  |
|  | **(a)** | Repeatability **[3 marks]** |  |
|  |  | *At least three repeats should be carried out*  *✓*  *A mean average of the results can then be calculated,*  *✓*  *which minimises random errors/increases accuracy.* *✓* |  |
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|  | **(b)** | Reproducibility **[1 mark]** |  |
|  |  | *Either:*  *Another scientist should carry out the analysis using the same method.* *✓*  *or*  *The same scientist should carry out the analysis using a different method.* *✓* |  |

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|  | **(c)** | Sampling **[2 marks]** |  |
|  |  | *Samples should be taken from several bottles of vinegar from Fred’s Chip Shop and analysed.* *✓*  *This will help to decide whether there was just one bad bottle of vinegar, or whether there is a wider problem.* *✓* |  |

### Extension opportunities

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| **1.** | A chemist works in the quality assurance laboratory of a vinegar manufacturer.  Her job is to check that all the vinegar is at least 5.0% (w/v) acidity.  She tests 10 cm3 samples with 0.40 mol/dm3 potassium hydroxide and phenolphthalein indicator. | |  |
|  | **(a)** | Calculate the minimum mass of ethanoic acid that must be in a 10 cm3 sample: **[2 marks]** |  |
|  |  | *(mass = volume × percentage concentration)*  *10 x (5.0 / 100) ✓ =*  *0.50 g ✓* |  |

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| --- | --- | --- | --- |
|  | **(b)** | Therefore calculate the minimum amount (in moles) of ethanoic acid in the 10 cm3 sample.  Relative molecular mass of ethanoic acid is *60.0 g/mol*. **[2 marks]** |  |
|  |  | *(amount = mass / relative molecular mass)*  *0.5 / 60.0 ✓ =*  *8.333 × 10–3 mol ✓* |  |
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|  | **(c)** | Therefore, calculate the minimum volume (in cm3) of 0.40 mol/dm3 potassium hydroxide that will need to be added to the sample to neutralise it.  Ethanoic acid and potassium hydroxide react in a 1:1 ratio. **[3 marks]** |  |
|  |  | *(volume = amount / concentration)*  *8.333 × 10–3 mol / 0.40 mol/dm3✓ =*  *0.02083 dm3 ✓*  *21 cm3 (to 2 sig fig) ✓* |  |

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| **2.** | Describe the similarities and differences between the acidic nature of a hydrochloric acid and ethanoic acid. **[6 marks]** | |  |
|  |  | *Both substances are acidic because they contain hydrogen, ✓*  *and dissociate in water to produce hydrogen ions (H+).✓*  *Hydrochloric acid is a strong acid ✓ as it fully ionises in solution.✓*  *Ethanoic acid is a weak acid ✓ as it partially ionises in solution. ✓* |  |

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| **3.** | Find out about phenolphthalein in a book or through an internet search. Discuss why it is a better indicator than universal indicator for titration of vinegar with a strong base such as potassium hydroxide. **[4 marks]** | |  |
|  |  | *Phenolphthalein is an acid-base indicator which is colourless in acidic solutions ✓*  *and pink in alkali solutions. ✓*  *This gives a clear colour change when the solution is neutralised, ✓*  *unlike universal indicator where a subjective judgement needs to be made about which colour indicates the solution is neutralised. ✓* |  |

### Document updates

v1 August 2016 Published on qualification pages

v1.1 January 2017 Consolidated labelling and formatting of activities; removed ‘accurate measurement of volume’ from Apparatus and Techniques list.

v1.2 July 2017 Details of making up sample vinegars added. Updated equipment list.

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# Chemistry PAG 6: Titration

# Suggested Activity 2: The vinegar dilemma

## Learner Activity

### Introduction

A new local fish-and-chip shop has been accused of watering down its vinegar. Your task is to provide preliminary evidence to trading standards to help them decide whether to investigate further.

Vinegar should have an ethanoic acid concentration of at least 5.0% (w/v) − this means for every 100 cm3 of vinegar there should be at least 5.0 g of ethanoic acid present (w/v means weight per volume).

You will be provided with a sample of stock vinegar from the Trading Standards laboratory, and two other well established sources, along with the vinegar from Fred’s Chip Shop.

This method is based on the CLEAPSS activity PP019: <http://science.cleapss.org.uk/Resource-Info/PP019-Analysis-of-vinegar-small-scale.aspx>.

### Aims

To experimentally determine the concentration of ethanoic acid in a range on vinegar samples.

### Intended class time

30-40 minutes

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| Experiment setup  glass vial  vinegar and phenolphthalein  clamp  sodium hydroxide  pipette  mass balance |

Figure 1 – The experimental setup

### Chemicals and equipment (per group)

* 0.2 mol dm–3 sodium hydroxide solution (WARNING: Irritant)
* four vinegar samples labelled
  + Trading standards stock vinegar
  + Supermarket vinegar
  + Farm shop vinegar
  + Fred’s Chip Shop vinegar
* fine-tipped dropping pipette
* dropping pipette with volume markings **OR** measuring cylinder (10 cm3) and pipette
* phenolphthalein solution
* white tile
* small beaker or small glass vial (c. 14 cm3)
* retort stand, boss and clamp
* access to a 2 decimal place mass balance

### Health and Safety

* Eye protection should be worn at all times.

### Method

*STAGE 1: Preparing your titration setup*

1. Squeeze the pipette bulb of the fine–tipped dropping pipette as tightly as possible, and suck up as much 0.2 mol dm–3 sodium hydroxide as possible.
2. Carefully clamp the bulb of the pipette in clamp, attached to a retort stand with a boss.
3. Add one drop of phenolphthalein indicator to a clean glass vial (or small beaker). Weigh and record the mass of the vial and its contents (this mass is called **M1**).
4. Add about 1 cm3 of the vinegar sample to the vial. Reweigh and record the mass of the vial and its contents (**M2**)

👓 *The solution should be colourless at this stage.*

*STAGE 2: Carrying out the titration*

1. Place the vial under the end of the sodium hydroxide pipette.
2. Slowly turn the clamp screw to add a drop of sodium hydroxide to the vial. Agitate/swirl the vial to ensure thorough mixing.

👓 *The pink indicator colour may appear then disappear on mixing.*

1. Continue to add drops with mixing **until the pink colour remains throughout the liquid for at least 10 seconds**.
2. Reweigh and record the mass of the vial and its contents (**M3**)
3. Calculate the percentage composition (weight by volume) of ethanoic acid in each vinegar using the equation in the last row of the results table.

*STAGE 3: Clearing up*

1. Rinse all solutions down the sink with plenty of water.

### Analysis of results

Use the table below to collect your data:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Data and calculations | *Example data* | Trading standards stock vinegar | Supermarket vinegar | Farm shop vinegar | Fred’s Chip Shop vinegar |
| ***M1*** / g | *10.40* |  |  |  |  |
| ***M2*** / g | *11.51* |  |  |  |  |
| ***M3*** / g | *12.80* |  |  |  |  |
| percentage concentration / %  *=* | *5.6* |  |  |  |  |

*Take care with your BIDMAS in the last row – ((M3 – M2) × 4.8) ÷ (M2 – M1) – check you get 5.6% with the example data before analysing your results.*

Your ability to analyse your observations may depend on how much of the GCSE Chemistry/Combined Science course you have studied. Your teacher will let you know which questions you should focus on:

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| --- | --- | --- |
| **1.** | Based on your results, write a short report to Trading Standards on whether further investigation is required. **[3 marks]** |  |
|  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **2.** | Discuss ways of improving the design of the analysis to give you more confidence in your data: | |  |
|  | **(a)** | Repeatability **[3 marks]** |  |
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|  | **(b)** | Reproducibility **[1 mark]** |  |
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| --- | --- | --- | --- |
|  | **(c)** | Sampling **[2 marks]** |  |
|  |  |  |  |

### Extension opportunities

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| --- | --- | --- | --- |
| **1.** | A chemist works in the quality assurance laboratory of a vinegar manufacturer.  Her job is to check that all the vinegar is at least 5.0% (w/v) acidity.  She tests 10 cm3 samples with 0.40 mol/dm3 potassium hydroxide and phenolphthalein indicator. | |  |
|  | **(a)** | Calculate the minimum mass of ethanoic acid that must be in a 10 cm3 sample: **[2 marks]** |  |
|  |  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
|  | **(b)** | Therefore calculate the minimum amount (in moles) of ethanoic acid in the 10 cm3 sample. Relative molecular mass of ethanoic acid is 60.0 g/mol. **[2 marks]** |  |
|  |  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
|  | **(c)** | Therefore, calculate the minimum volume (in cm3) of 0.40 mol/dm3 potassium hydroxide that will need to be added to the sample to neutralise it. Vinegar and potassium hydroxide react in a 1:1 ratio. **[3 marks]** |  |
|  |  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **2.** | Describe the similarities and differences between the acidic nature of a hydrochloric acid and ethanoic acid. **[6 marks]** | |  |
|  |  |  |  |
|  |  |  |  |
| **3.** | Find out about phenolphthalein in a book or through an internet search. Discuss why it is a better indicator than universal indicator for titration of vinegar with a strong base such as potassium hydroxide. **[4 marks]** | |  |
|  |  |  |  |

### DfE Apparatus and Techniques covered

If you are using the OCR Practical Activity Learner Record Sheet ([**Chemistry**](http://www.ocr.org.uk/Images/295630-gcse-chemistry-learner-record-sheet.doc) / [*Combined Science*](http://www.ocr.org.uk/Images/304431-gcse-combined-science-learner-record-sheet.doc)) you may be able to tick off the following skills:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Chemistry** | | | |  | ***Combined Science*** | | | |
| 1-i | 3-i | 3-ii | 6-i |  | *1-iii* | *8-i* | *8-ii* | *11-i* |
| 6-ii |  |  |  |  | *11-ii* |  |  |  |