# Chemistry PAG 6: Titration

# Suggested Activity 1: Titration of sodium hydroxide with hydrochloric acid

## Instructions and answers for teachers and technicians

These instructions cover the learner activity section which can be found on [page 13](#_Learner_Activity). This Practical activity supports OCR GCSE Chemistry.

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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). |

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| Royal Society of Chemistry | This resource is adapted from the Practical Chemistry project, developed by the Nuffield Foundation and the Royal Society of Chemistry – <http://www.rsc.org/learn-chemistry/collections/experimentation/practical-chemistry> specifically the practical ‘Titrating sodium hydroxide with hydrochloric acid’ <http://www.rsc.org/learn-chemistry/resource/res00000697/titrating-sodium-hydroxide-with-hydrochloric-acid>. |
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**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

In this activity, learners will practice their titration technique by titrating acid against alkali of known concentration, then against a sample of alkali of unknown concentration.

It is suggested that prior technique practice with the glassware is carried out using distilled water before titration with acids/alkalis are carried out.

Additionally, the suggested activity PAG7.1 The Vinegar Dilemma could be used to introduce the ideas behind titration before tackling volumetric titration here.

### 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: **iv** [*vi*]) volume of liquids

**3** [*8*]: Use of appropriate apparatus and techniques for: 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

**8**: Use of appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including; iv) the determination of concentrations of strong acids and strong alkalis

### Aims

To determine the concentration of a sample of sodium hydroxide

### Intended class time

45-60 minutes

### Links to Specifications:

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

C3.3e recognise that aqueous neutralisation reactions can be generalised to hydrogen ions reacting with hydroxide ions to form water

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

C5.1b 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 reacts completely together

CM5.1ii provide answers to an appropriate number of significant figures

CM5.1iii covert units where appropriate particularly from mass to moles

CM5.1iv arithmetic computation, ratio, percentage and multistep calculations permeates quantitative chemistry

CM5.1vi change the subject of a mathematical equation

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

WS1.3c carrying out and representing mathematical and statistical analysis

WS1.3e interpreting observations and other data

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

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

WS1.4e interconvert units

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

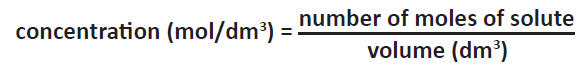
WS2a carry out experiments

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)

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.

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

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

IaS2.11. 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

### Mathematical Skills covered

M1a Recognise and use expressions in decimal form

M1c Use ratios, fractions and percentages

M2a Use an appropriate number of significant figures

M2b Find arithmetic means

M2f Understand the terms mean, mode and median

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

M3d Solve simple algebraic equations

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Technical Requirements – PER GROUPChemicals (per group)  | **Identity** | **Approximate quantity required or produced PER GROUP** | **Hazard information** | | | **Risk information** | | --- | --- | --- | --- | --- | --- | | 0.400 mol dm–3 aqueous hydrochloric acid, HC*l*(aq) | c. 300 cm3 | Currently not classified as hazardous at this concentration | | |  | | 0.400 mol dm−3aqueous sodium hydroxide, NaOH(aq) | c. 100 cm3 | HSE warning symbol | | WARNING  Causes skin irritation and serious eye irritation |  | | 0.300 mol dm−3aqueous sodium hydroxide, NaOH(aq)  Label as:  Sample **A** (PAG 6.1) | c. 100 cm3 | HSE warning symbol | WARNING  Causes skin irritation and serious eye irritation | |  |  Equipment (per group) – either all larger volume apparatus or all smaller volume apparatus  * burette (25 or 50 cm3) * pipette (10 or 25 cm3) and filler * conical flask (100 or 250 cm3) * beaker × 5 (100 cm3) * small (filter) funnel (about 4 cm diameter) * white tile or a piece of white paper * stand * burette clamp * methyl orange indicator solution (dropper bottle) (DANGER: Toxic) * phenolphthalein indicator solution (dropper bottle) (WARNING: Flammable) |

### Health and Safety

Eye protection should be worn at all times.

Burettes and pipettes are fragile glassware – inexperienced and rough handing can lead to very sharp broken glassware and potential for injury. Ensure learners are well trained and supervised.

### Method

Learners will practice their titration technique by titrating 0.400 mol/dm3 hydrochloric acid against 0.400 mol/dm3 sodium hydroxide, with the expectation that their mean titre value is very close to the volume of sodium hydroxide used.

They will then carry out titration of 0.300 mol/dm3 sodium hydroxide as a solution of unknown concentration, to give them real data to process.

This method could be extended to include other strong acids or alkalis such as sulfuric acid or potassium hydroxide.

### Images from the trial

|  |  |
| --- | --- |
| The experimental setup | The experimental setup |
| Taking readings from the burette | Taking readings from the burette Taking readings from the burette |
| Phenolphtalein indicator in alkali, at the end point and in acidic solutions. | Phenolphtalein indicator in alkali, at equivalence point and in acidic solutions. |
| Methyl orange indicator in alkali, at the end point and in acidic solutions | Methyl orange indicator in alkali, at equivalence point and in acidic solutions |

# Analysis of results – Trial results

**Stage 2**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Titre** | ***Example*** | **Rough** | **1** | **2** | **3** | **4** |
| final volume (cm3) | *24.50* | 26.30 | 25.10 | 25.65 | 25.20 |  |
| initial volume (cm3) | *1.55* | 0.10 | 0.10 | 0.15 | 0.10 |  |
| titre (cm3) | *22.95* | 26.20 | 25.00 | 25.50 | 25.10 |  |
| use in mean titre (✓/ X) | *X* | *X* | ✓ | X | ✓ |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **1.** | Calculate the mean titre from your concordant titres. **[2 marks]** | |  |
|  |  | Mean titre = *V*(HC*l*) = ✓= 25.05 cm3 ✓ (correct answer given to 2 decimal places) | |
|  |  | |  |
| **2.** | Calculate the number of moles of hydrochloric acid used in your titration. **[2 marks]** | |  |
|  |  | number of moles = concentration × titre =  *n*(HC*l*) = *c*(HC*l*) × *V*(HC*l*) = 0.400 ×  ✓ = 0.0100 mol ✓ (correct answer given to 3 significant figures) | |
|  |  | |  |
| **3.** | Calculate the number of moles of sodium hydroxide in your sample. **[1 mark]** | |  |
|  |  | As one mole of HC*l* reacts with one mole of NaOH, *n*(NaOH) = 0.0100 mol ✓ | |
|  |  | |  |
| **4.** | Calculate the concentration of the sodium hydroxide. **[2 marks]** | |  |
|  |  | *c*(NaOH) = ==✓ = 0.400 mol/dm3 ✓ | |

**Stage 3**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Titre** | ***Example*** | **Rough** | **1** | **2** | **3** | **4** |
| final volume (cm3) | *24.50* | 20.20 | 18.95 | 37.75 | 19.05 |  |
| initial volume (cm3) | *1.55* | 0.15 | 0.20 | 18.95 | 0.10 |  |
| titre (cm3) | *22.95* | 20.05 | 18.75 | 18.80 | 18.95 |  |
| use in mean titre (✓/ X) | *X* | X | ✓ | ✓ | X |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **1.** | Calculate the mean titre from your concordant titres. **[2 marks]** | |  |
|  |  | Mean titre = *V*(HC*l*) = ✓= 18.78 cm3 ✓ (correct answer given to 2 decimal places) | |
|  |  | |  |
| **2.** | Calculate the number of moles of hydrochloric acid used in your titration. **[2 marks]** | |  |
|  |  | number of moles = concentration × titre =  *n*(HC*l*) = *c*(HC*l*) × *V*(HC*l*) = 0.400 ×  ✓ = 0.00751 mol ✓ (correct answer given to 3 significant figures) | |
|  |  | |  |
| **3.** | Calculate the number of moles of sodium hydroxide in your sample. **[1 mark]** | |  |
|  |  | As one mole of HC*l* reacts with one mole of NaOH, *n*(NaOH) = 0.00751 mol ✓ | |
|  |  | |  |
| **4.** | Calculate the concentration of the sodium hydroxide. **[2 marks]** | |  |
|  |  | *c*(NaOH) = ==✓ = 0.300 mol/dm3 ✓ | |

### Extension opportunities

|  |  |  |  |
| --- | --- | --- | --- |
| **1.** | Write word, symbol and ionic equations for the reaction between hydrochloric acid and sodium hydroxide. **[3 marks]** | |  |
|  |  | Word hydrochloric acid + sodium hydroxide → sodium chloride + water  Symbol HC*l* (aq) + NaOH(aq) → NaC*l*(aq) + H2O(l)  Ionic H+(aq) + OH–(aq) → H2O(l) | |

|  |  |  |  |
| --- | --- | --- | --- |
| **2.** | Describe how replacing hydrochloric acid with sulfuric acid (H2SO4) of the same concentration would affect your results. **[2 marks]** | |  |
|  |  | Sulfuric acid produces two moles of hydrogen ions per mole compared to one mole of hydrogen ions per mole for hydrochloric acid ✓ therefore sulfuric acid titres would be half those of hydrochloric acid ✓. | |
| **3.** | Explain why you carry out a rough titration. **[2 marks]** | |  |
|  |  | A rough titration allows you to quickly check that you can carry out the titration (i.e. reach the end-point) with the concentrations and volumes of solutions chosen ✓ and prevents the need to add the total volume of the acid drop-by-drop ✓. | |
| **4.** | Explain the purpose of carrying out repeated titrations until you obtain concordant results. **[3 marks]** | |  |
|  |  | Concordant results are needed to ensure that an accurate ✓mean final titre volume can be calculated ✓ which minimises the effect of random errors ✓. | |

**Document updates**

v1.1 January 2017 Original - published on qualification page

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# Chemistry PAG 6: Titration

# Suggested Activity 1: Titration of sodium hydroxide with hydrochloric acid

## Learner Activity

### Introduction

Titration is a quantitative analytical technique that allows you to accurately determine the concentration of an acidic or alkaline solution. For example, acid of known concentration is added to a known volume of alkali (of unknown concentration) until an acid-base indicator changes colour. With the volume and concentration of the acid now known, and the volume of the alkali known, the concentration of the alkali can be worked out mathematically.

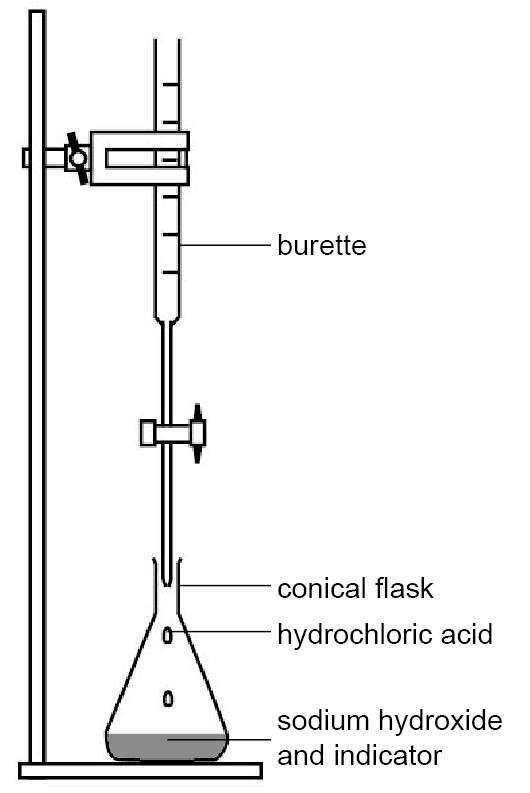
In this activity you will first practice your titration technique by confirming the concentration of a sample of 0.400 mol/dm3 sodium hydroxide using 0.400 mol/dm3 hydrochloric acid, using one of two acid-base indicators (methyl orange or phenolphthalein). You will then determine the concentration of another sample of sodium hydroxide. An extension activity is available to determine the concentration of a solution of sulfuric acid.

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| Royal Society of Chemistry | This resource is adapted from the Practical Chemistry project, developed by the Nuffield Foundation and the Royal Society of Chemistry – <http://www.rsc.org/learn-chemistry/collections/experimentation/practical-chemistry> specifically the practical ‘Titrating sodium hydroxide with hydrochloric acid’ <http://www.rsc.org/learn-chemistry/resource/res00000697/titrating-sodium-hydroxide-with-hydrochloric-acid>. |
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### Aims

### To practice titration technique and to determine the concentration of a sample of sodium hydroxide

### Equipment set-up

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|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Phenolphthalein** | | |  | **Methyl orange** | | |
| alkali | end point | acid |  | alkali | end point | acid |
| pink | just colourless | colourless |  | yellow | orange | red |

*(Note, if titrating from acid to alkali with phenolphthalein, the end-point is usually taken as the first permanent faint pink colouration, i.e. lasting at least 10 seconds.)*

### Intended class time

45-60 minutes

### Chemicals and equipment (per group)

* burette (25 or 50 cm3)
* pipette (10 or 25 cm3) and filler
* conical flask (100 or 250 cm3)
* beaker × 5 (100 cm3)
* small (filter) funnel (about 4 cm diameter)
* white tile or a piece of white paper
* stand
* burette clamp
* methyl orange indicator solution (dropper bottle) (DANGER: Toxic)
* phenolphthalein indicator solution (dropper bottle) (WARNING: Flammable)
* 0.400 mol dm–3 hydrochloric acid
* 0.400 mol dm–3 sodium hydroxide solution (WARNING: Causes skin and eye irritation)
* sample **A** (sodium hydroxide solution of unknown concentration) (WARNING: Causes skin and eye irritation)

### Health and Safety

* Eye protection should be worn at all times.
* Ensure the funnel is below eye level when filling the burette and the tap is closed
* Take particular care when handling the burette and pipette – these are fragile glassware and can make very sharp fragments if broken.
* Ensure you hold the pipette close to the end when twisting into the filler.

### Method

NOTE: The instructions below are based on a 50 cm3 burette, 25 cm3 pipette and 250 cm3 conical flask. If you are using the smaller volume apparatus, use the volumes indicated in (brackets).

### STAGE 1: Preparation

1. Label your beakers ‘waste’, ‘0.400M HC*l*’, ‘0.400M NaOH’, ‘unknown NaOH’. Use these to collect samples from the relevant stock bottles.
2. Place your waste beaker under your clamped burette and ensure the tap is closed.
3. Using the funnel, pour about 10 cm3 0.400 mol/dm3 hydrochloric acid into the burette.
4. Open the tap and allow the acid to flow into the waste beaker until the tip is full – if an air bubble remains, speak to your teacher.
5. Close the tap then fill the burette with the acid above the 0 cm3 mark.
6. Slowly open the tap until the meniscus sits close to but below the 0 cm3 mark.

### STAGE 2: Practice of titration technique

1. Add 25 cm3 (10 cm3) 0.400 mol dm–3 sodium hydroxide to the 250 cm3 (100 cm3) conical flask.
2. Add 2–3 drops of your chosen indicator.
3. Make a note of your initial burette volume reading to two decimal places.
4. Carry out a rough titration by adding 1-2 cm3 of the acid from the burette at a time to the conical flask with swirling.
5. When you have reached the end-point (the indicator has changed colour), make a note of the final burette volume reading.
6. Carefully rinse your conical flask and refill your burette if required.
7. Add alkali and indicator to your conical flask (as in Steps 1 and 2).
8. Carry out accurate titrations until you have concordant results (titres within 0.1 cm3) as follows:
   1. Add acid to within 3-4 cm3 of your rough titre (e.g. if your rough titre was 23.50 cm3, about 20.00 cm3).
   2. Add acid drop-by-drop (1 drop per second) with swirling until you reach the end-point.
   3. Make a note of the final volume reading.

**STAGE 3: Determining the concentration of alkali of unknown concentration**

1. Repeat Stage 2, using the sodium hydroxide of unknown concentration (sample A) in place of the 0.400 mol/dm3 sodium hydroxide.

### Analysis of results

You will need one table for each set of titrations you carry out (i.e. one for Stage 2 and one for Stage 3). You can draw your own table, or use the one below:

**STAGE 2**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Titre** | ***Example*** | **Rough** | **1** | **2** | **3** | **4** |
| final volume (cm3) | *24.50* |  |  |  |  |  |
| initial volume (cm3) | *1.55* |  |  |  |  |  |
| titre (cm3) | *22.95* |  |  |  |  |  |
| use in mean titre (✓/ X) | *X* |  |  |  |  |  |

**STAGE 3**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Titre** | ***Example*** | **Rough** | **1** | **2** | **3** | **4** |
| final volume (cm3) | *24.50* |  |  |  |  |  |
| initial volume (cm3) | *1.55* |  |  |  |  |  |
| titre (cm3) | *22.95* |  |  |  |  |  |
| use in mean titre (✓/ X) | *X* |  |  |  |  |  |

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

|  |  |  |  |
| --- | --- | --- | --- |
| **1.** | Calculate the mean titre from your concordant titres. **[2 marks per stage]** | |  |
|  | **STAGE 2** | **STAGE 3** | |
|  |  | |  |
| **2.** | Calculate the number of moles of hydrochloric acid used in your titration. **[2 marks per stage]** | |  |
|  | **STAGE 2** | **STAGE 3** | |
|  |  | |  |
| **3.** | Calculate the number of moles of sodium hydroxide in your sample. **[1 mark per stage]** | |  |
|  | **STAGE 2** | **STAGE 3** | |
|  |  | |  |
| **4.** | Calculate the concentration of the sodium hydroxide. **[2 marks per stage]** | |  |
|  | **STAGE 2** | **STAGE 3** | |

### Extension opportunities

|  |  |  |  |
| --- | --- | --- | --- |
| **1.** | Write word, symbol and ionic equations for the reaction between hydrochloric acid and sodium hydroxide. **[3 marks]** | |  |
|  |  |  | |

|  |  |  |  |
| --- | --- | --- | --- |
| **2.** | Describe how replacing hydrochloric acid with sulfuric acid (H2SO4) of the same concentration would affect your results. **[2 marks]** | |  |
|  |  |  | |
| **3.** | Explain why you carry out a rough titration. **[2 marks]** | |  |
|  |  |  | |
| **4.** | Explain the purpose of carrying out repeated titrations until you obtain concordant results. **[3 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-iv | 3-ii | 6-i | 6-ii |  | *1-vi* | *8-ii* | *11-i* | *11-ii* |
| 8-iv |  |  |  |  |  |  |  |  |