# Chemistry PAG 8: Measuring rates of reaction

# Combined Science PAG C5: Measuring rates of reaction

# Suggested Activity 4: Heat of a displacement reaction

## Instructions and answers for teachers and technicians

These instructions cover the learner activity section which can be found on [page 11](#_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

In this activity, learners will investigate the relationship between the concentration of a salt solution and the temperature rise of a displacement reaction. This activity allows this common experiment to be carried out at a reduced scale, minimising the cost and disposal issues with copper sulfate solutions.

This resource is adapted from the CLEAPSS experiment ‘Heat of reaction: the zinc / copper(II) sulfate(VI) reaction’ – <http://science.cleapss.org.uk/Resource-Info/TL003-Heat-of-reaction-of-zinc-with-copper-II-sulfate-VI.aspx>

### DfE Apparatus and Techniques covered

The codes used below match the OCR Practical Activity Learner Record Sheet ([**Chemistry**](https://www.ocr.org.uk/Images/295630-gcse-chemistry-student-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; **iii** [*v*]) temperature; **iv** [*vi*]) volume of liquids

**3** [*8*]: Use of appropriate apparatus and techniques for: i) conducting and monitoring chemical reactions

**5** [*10*]: Making and recording of appropriate observations during chemical reactions including: i) changes in temperature

**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

### Aims

To determine the relationship between the concentration of copper sulfate and the temperature change when reacted with zinc.

### Intended class time

30−40 minutes

### Links to Specifications:

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

C3.2a distinguished between endothermic and exothermic reactions on the basis of the temperature change of the surroundings

C3.2b draw and label a reaction profile for an exothermic and an endothermic reaction [to include: activation energy, energy change, reactants and products]

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

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

WS1.3b translating data from one form to another

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

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

WS1.4a use scientific vocabulary, terminology and definitions

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

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)

C1.2.1 distinguish between endothermic and exothermic reactions on the basis of the temperature change of the surroundings

C1.2.2 draw and label a reaction profile for an exothermic and an endothermic reaction, identifying activation energy

IaS2.4. be able to translate data from one form to another

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

IaS2.7. when displaying data graphically select an appropriate graphical form, use appropriate axes and scales, plot data points correctly, draw an appropriate line of best fit, and indicate uncertainty (e.g. range bars)

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

IaS3.4. use a variety of models (including representational, spatial, descriptive, computational and mathematical models) to: i) solve problems, ii) make predictions, iii) develop scientific explanations and understanding, iv) identify limitations of models

### Mathematical Skills covered

M1a Recognise and use expressions in decimal form

M1c Use ratios, fractions and percentages

M4a Translate information between graphical and numeric form

M4c Plot two variables from experimental or other data

M4d Determine the slope and intercept of a linear graph

### Image from trials

|  |
| --- |
| Image from trialThe experimental setup. |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Technical Requirements – PER GROUPChemicals

| **Identity** | **Approximate quantity required or produced PER GROUP** | **Hazard information** | **Risk information** |
| --- | --- | --- | --- |
| 1.0 mol/dm3 copper sulfate(VI) solution | 40 cm3 | HSE warning symbol | WARNINGHarmful if swallowed. Causes skin irritation. Causes serious eye irritation. | Brief students about disposal method before carrying out reaction. |
| zinc powder | 4 g | Hazard warning image**Hazard warning image** | DANGERVery toxic to aquatic life with long lasting effects. In contact with water releases flammable gases which ignite spontaneously. Catches fire spontaneously if exposed to air. | Ensure no naked flames in the laboratory. |

Equipment* beaker, glass or plastic (100 cm3)
* glass vials (c. 12-14 cm3) × 5– if unavailable, boiling tubes can be substituted
* weighing boats × 5
* dropping pipette with volume markings
* spatula
* thermometer (–10−110°C)
* cotton wool
* deionised water
* access to waste beaker/bucket
* access to accurate mass balance (2 decimal places)
 |

*Note: glass vials are available from e****.****g****.*** *TIMSTAR (VI6982) and SCICHEM (TVL060030)*

### Health and Safety

Eye protection should be worn at all times.

Learners should have access to a large beaker/bucket for disposal of their reactions mixture which should then be treated as follows:

* Wear eye protection. Use a fume cupboard in case a spray is produced.
* Take the disposal bucket containing the waste chemicals - add more water if necessary and stir the mixture to ensure all remaining copper sulfate has reacted with the zinc and the liquid is clear and colourless.
* Add 2 mol/dm3 sulfuric(VI) acid in 10 to 20 cm3 portions until there is no more fizzing (the acid reacts with any remaining zinc).
* Filter the mixture.
* Pour the filtrate (acidic zinc sulfate solution) into a bucket of water. Dispose of down the foul water drain.
* The metallic copper left on the filter paper appears quite black because (i) it is finely divided and (ii) some of it is air-oxidised.
* Once dry, the copper can be roasted in a metal crucible for 15 minutes. After cooling, the copper can be added to 1.5 M sulfuric(VI) acid, heated to boiling and then cooled. Pour the solution into a shallow tray for crystals of copper(II) sulfate(VI) to form (these can be used for other experiments).

### Method

Learners will collect temperature data from the reaction between zinc and copper sulfate solution at various concentrations.

This activity provides a good opportunity to develop learners’ organisational skills and initial analysis. They should be encouraged to split the activity into i) set-up, ii) data collection and initial analysis, iii) clear-up and iv) data analysis and interpretation, and ensuring they carry out each step fully before moving to the next. This will give them opportunity to focus on the task at hand, minimising the likelihood of steps being missed and maximising their learning.

### Analysis of results – Trial results

|  |  |  |  |
| --- | --- | --- | --- |
| **volume of 1 mol/dm3 copper sulfate solution / cm3** | **initial temperature / °C** | **final temperature / °C** | **temperature difference / °C** |
| 2 | 26.0 | 35.0 | 9.0 |
| 4 | 25.0 | 43.0 | 18.0 |
| 6 | 24.5 | 49.0 | 24.0 |
| 8 | 25.0 | 55.5 | 30.5 |
| 10 | 24.5 | 61.0 | 36.5 |

(original data from CLEAPSS)

|  |  |  |
| --- | --- | --- |
| **1.** | Calculate the temperature difference for each of the reactions **[2 marks]** |  |
|  | 1 mark for correct calculations ✓1 mark for all temperature differences to one decimal place ✓ |  |
|  |  |  |
| **2.** | Plot a graph of volume of copper sulfate against temperature difference **[4 marks]**. |  |
|  | 1 mark for correct y–axis ✓1 mark for accurate plotting (correct to within one small square on 2 mm graph paper) ✓1 mark for appropriate line of best fit✓ |  |
|  | **The change in temperature on addition of an excess of zinc powder to variable concentrations of copper(II) sulphate**Graph to show the change in temperature |  |
|  |  |  |

|  |  |  |
| --- | --- | --- |
| **3.** | From your line of best fit, calculate the temperature change per cm3 of copper sulfate **[3 marks]** |  |
|  | gradient = = 3.4 °C/cm31 mark for accurate reading from the graph ✓1 mark for correct calculation ✓1 mark for correct units ✓ |  |
|  |  |  |

**Extension Opportunities**

|  |  |  |
| --- | --- | --- |
| **1.** | Based on your results, would you classify the reaction between zinc and copper sulfate solution as endothermic or exothermic? What evidence supports this classification? **[2 marks]** |  |
|  |  |  |
|  | Exothermic ✓The change in temperature is positive, indicating that the reaction produces heat. ✓ |  |
|  |  |
| **2.** |  The energy change of this reaction can be calculated using: energy change = temperature difference x -42. The accepted value is -217kJ/mol. Comment on how close your calculated value is to the accepted value. **[2 marks]** |  |
|  |  |  |
|  | *Calculation based on trial data.*Energy change = -42 x 3.4 = -140kJ/mol ✓This change is lower than the expected value possibly due to heat loss to the atmosphere.(*accept any suitable comment*) ✓ |  |
|  |  |
| **3.** | Describe how you would modify the experimental method to increase the accuracy of your results. **[2 marks]** |  |
|  |  |  |
|  | Carry out three repeats of each reaction ✓ and calculate a mean average temperature increase for each reaction ✓. |  |
|  |  |
| **4.** | Describe one potential source of random error and one of systematic error and how you would modify the experimental method to minimise these errors. **[4 marks]** |  |
|  |  |  |
|  | Allow any suitable source of error and related modification (1 mark each).For example:random error: inaccuracy in measuring volumes with a pipette ✓; use a measuring cylinder for measuring volumes ✓.systematic error: concentration of the stock copper sulfate solution is higher than expected, leading to greater temperature increases ✓ make up fresh stock solution from a solid sample of the salt ✓ |  |

**Document updates**

 v1 November 2016 Published on qualification page

 v1.1 January 2017 Consolidated labelling and formatting of activities

 v1.2 June 2021 Updated to meet digital accessibility standards



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# Chemistry PAG 8: Measuring rates of reaction

# Combined Science PAG C5: Measuring rates of reaction

# Suggested Activity 4: Heat of a displacement reaction

# *Learner Activity*

### Introduction

Measuring the temperature change during a reaction provides useful insight into the energetics of the reaction. You will likely have carried out this reaction at Key Stage 3, where you noted whether reactions got hotter (exothermic) or cooler (endothermic). In this activity, you will collect quantitative data on the reaction between zinc and copper sulfate.

### Aims

To determine the relationship between concentration of copper sulfate and temperature change when reacted with zinc

### Intended class time

30−40 minutes



### Chemicals and equipment (per group)

* beaker, glass or plastic (100 cm3)
* glass vials × 5
* weighing boats × 5
* dropping pipette with volume markings
* spatula
* thermometer (–10−110 °C)
* cotton wool
* deionised water
* access to waste beaker/bucket
* access to accurate mass balance (2 decimal places)
* 1 mol/dm3 copper sulfate(VI) solution (c. 40 cm3)
* zinc powder (c. 4 g)

### Health and Safety

Eye protection should be worn at all times.

**DO NOT tip the mixtures down the sink.** Dispose of mixtures in the waste container as directed by your teacher.

### Method

1. Prepare an insulating reaction container by putting cotton wool into a 100 cm3 beaker, then make a vial-sized space in the middle – see Figure 1.
2. Line up five vials (labelled **2, 4, 6, 8, 10**)
3. Use a 3 cm3 plastic pipette to add, respectively, 8, 6, 4, 2, and 0 cm3 of water to the vials.
4. Using the same pipette, add, respectively, **2, 4, 6, 8 and 10 cm3** of 1 mol/dm3 copper sulfate solution to the vials.
5. Weigh out separately in five weighing boats 0.65-0.75 g zinc power (the zinc is in excess).
6. Place vial **2** in the insulated container, then measure and record the temperature of the solution to the nearest 0.5°C.
7. Add a sample of zinc powder to the vial, hold the container with one hand, then carefully stir the mixture with the thermometer.
8. Measure and record the highest temperature. Then rinse the thermometer.
9. Repeat Steps 6-8 with the remaining vials.
10. Place all waste mixtures in the waste container.

### Analysis of results

You can draw your own table, or use the one below:

|  |  |  |  |
| --- | --- | --- | --- |
| **volume of 1 mol/dm3 copper sulfate solution / cm3** | **initial temperature / °C** | **final temperature / °C** | **temperature difference / °C** |
| 2 |  |  |  |
| 4 |  |  |  |
| 6 |  |  |  |
| 8 |  |  |  |
| 10 |  |  |  |

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:

|  |  |  |
| --- | --- | --- |
| **1.** | Calculate the temperature difference for each of the reactions **[2 marks]** |  |
| **2.** | Plot a graph of volume of copper sulfate against temperature difference **[4 marks]**. |  |
| **3.** | From your line of best fit, calculate the temperature change per cm3 of copper sulfate **[3 marks]** |  |
|  |  |  |

### Extension opportunities

|  |  |  |
| --- | --- | --- |
| **1.** | Based on your results, would you classify the reaction between zinc and copper sulfate solution as endothermic or exothermic? What evidence supports this classification? **[2 marks]** |  |
|  |  |  |
|  |  |  |
|  |  |

|  |  |  |
| --- | --- | --- |
| **2.** | The energy change of this reaction can be calculated using: energy change = temperature difference x -42. The accepted value is -217kJ/mol. Comment on how close your calculated value is to the accepted value. **[2 marks]** |  |
|  |  |  |
|  |  |  |
|  |  |
| **3.** | Explain how you would modify the experimental method to increase the accuracy of your results. **[2 marks]** |  |
|  |  |  |
|  |  |  |
|  |  |
| **4.** | Describe one potential source of random error and one of systematic error and explain how you would modify the experimental method to minimise these errors. **[4 marks]** |  |
|  |  |  |
|  |  |  |
|  |  |

### DfE Apparatus and Techniques covered

If you are using the OCR Practical Activity Learner Record Sheet ([**Chemistry**](https://www.ocr.org.uk/Images/295630-gcse-chemistry-student-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 | 1-iii | 1-iv | 3-i |  | *1-iii* | *1-v* | *1-vi* | *8-i* |
| 5-i | 6-i | 6-ii |  |  | *10-i* | *11-i* | *11-ii* |  |