# Temperature changes in reactions

Answers, marking points and revision notes | AQA Combined Science 8464 and AQA GCSE Chemistry 8462

**GCSE science required practicals**

This practical online

## Answers

**1** Name the independent variable and the dependent variable in Zara's investigation. (2 marks)

Independent: the volume of sodium hydroxide added. Dependent: the temperature rise.

**Marking points**

- Independent: volume of sodium hydroxide
- Dependent: temperature rise / highest temperature

**2** Give one control variable and explain why it must be kept the same. (2 marks)

The volume of hydrochloric acid must be 25 $cm^3$ each time. A different volume of acid would change how much reaction happens and how much liquid is heated, which would change the temperature rise.

**Marking points**

- Valid control: volume or concentration of acid, concentration of alkali, cup type
- Reason: it would also affect the temperature rise, so the test would not be fair

**3** Explain why the reaction is done in a polystyrene cup with a lid instead of a glass beaker. (2 marks)

Polystyrene is a good thermal insulator and the lid stops warm air escaping, so less energy is lost to the surroundings. This means the temperature rise measured is closer to the true value.

**Marking points**

- Polystyrene / lid reduce energy (heat) loss to the surroundings
- So the measured temperature rise is more accurate / larger

**4** Give one hazard in this practical and a way of reducing the risk. (2 marks)

Sodium hydroxide is an irritant and can damage the eyes if it splashes. Wear safety goggles and wash any spills off skin with plenty of water.

**Marking points**

- Hazard: sodium hydroxide / acid irritant or corrosive, or glass thermometer breaking
- Matching control: goggles, wash off, stir with a rod not the thermometer

**5** Calculate the missing temperature rise for 20 $cm^3$ of sodium hydroxide. (1 mark)

11.4 °C

Temperature rise = highest temperature - starting temperature

Temperature rise = 31.3 - 19.9 = 11.4 °C

**Marking points**

- 11.4 °C


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**6** Is the reaction between hydrochloric acid and sodium hydroxide exothermic or endothermic? Explain how the table shows this. (2 marks)

Exothermic. The temperature of the mixture went up every time, which shows the reaction transferred energy to the surroundings (the solution and the thermometer).

**Marking points**

- Exothermic
- Temperature rises, so energy is transferred to the surroundings

**7** Identify the anomalous result and explain how you can tell. (2 marks)

The 15 $cm^3$ result (6.9 °C). The temperature rise goes up steadily from 5 to 25 $cm^3$, so it should be about 9 to 10 °C, but it is lower than the result for 10 $cm^3$.

**Marking points**

- 15 $cm^3$ / 6.9 °C
- Does not fit the pattern: lower than the 10 $cm^3$ result when it should be between 7.3 and 11.4

**8** Describe the pattern in the temperature rise as more sodium hydroxide is added, and explain why it changes after 25 $cm^3$. (3 marks)

The temperature rise increases from 5 $cm^3$ to a maximum at 25 $cm^3$, then decreases. Up to 25 $cm^3$, more alkali means more acid reacts so more energy is released. At 25 $cm^3$ all the acid has been neutralised, so extra sodium hydroxide does not react and just adds cooler liquid that has to be warmed, so the rise gets smaller.

**Marking points**

- Rise increases to a peak at 25 $cm^3$, then decreases
- Before the peak, more acid reacts so more energy is released
- After the peak, acid is used up; extra alkali does not react and absorbs energy / dilutes, so the rise falls

**9** Zara repeated the 25 $cm^3$ experiment twice more and got temperature rises of 12.9 °C and 12.4 °C. Calculate the mean temperature rise for 25 $cm^3$, using all three results. Give your answer to 1 decimal place. Show your working. (3 marks)

12.6 °C

Total = 12.6 + 12.9 + 12.4 = 37.9 °C

Mean = 37.9 / 3 = 12.63...

Mean = 12.6 °C (1 decimal place)

**Marking points**

- Adds all three: 12.6 + 12.9 + 12.4 = 37.9
- Divides by 3
- 12.6 °C


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**10** **Higher tier**

The reaction between hydrochloric acid and sodium hydroxide is exothermic. Explain why, in terms of the energy needed to break bonds and the energy released when bonds are made. (3 marks)

Energy has to be taken in to break the bonds in the reactants, and energy is given out when the new bonds in the products are made. In this reaction more energy is released making the new bonds than is needed to break the old ones, so overall energy is transferred to the surroundings and the temperature rises.

**Marking points**

- Breaking bonds takes in energy (endothermic)
- Making bonds releases energy (exothermic)
- More energy is released making bonds than is taken in breaking them, so the reaction is exothermic overall

**11** **Higher tier**

Zara's results go up in steps of 5 $cm^3$, so she cannot be sure that the peak is exactly at 25 $cm^3$. Suggest how she could find the volume for the maximum temperature rise more precisely. (2 marks)

Do extra experiments with smaller steps close to the peak, such as 22, 23, 24, 26, 27 and 28 $cm^3$. She could also plot two lines of best fit, one through the rising points and one through the falling points, and read off where they cross.

**Marking points**

- More volumes with smaller intervals around 25 $cm^3$
- Or draw two lines of best fit and find where they intersect

**12** Zara's thermometer has 0.1 °C divisions. Kai repeated the investigation with a thermometer that has only 1 °C divisions. Explain why Zara's results are better for comparing temperature rises, and give one further advantage of using a temperature probe and data logger. (3 marks)

Zara's thermometer has a higher resolution (0.1 °C instead of 1 °C), so she can measure small differences between results, such as her repeat rises of 12.4 °C and 12.9 °C, which Kai could not tell apart. A temperature probe and data logger records the temperature continuously, so the highest temperature is not missed while she is reading the scale.

**Marking points**

- Zara's thermometer has the higher resolution (0.1 °C rather than 1 °C)
- So small differences between temperature rises can be measured (more precise)
- A probe and data logger records continuously, so the highest temperature is not missed

**13** Zara's results are lower than the true values because some energy is always lost through the open top of the cup. Is this a random or a systematic error? Explain your answer. (2 marks)

It is a systematic error, because energy is lost in every experiment, so every temperature rise is too low in the same direction.

**Marking points**

- Systematic error
- It makes every result too low in the same way


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**14** When magnesium powder is added to copper(II) sulfate solution, the temperature rises. Plan an investigation to find out how the mass of magnesium powder affects the temperature rise. (6 marks)

Wear goggles. Stand a polystyrene cup in a beaker and add 25 $cm^3$ of copper(II) sulfate solution, measured with a measuring cylinder. Put a thermometer through the lid and record the starting temperature. Weigh 0.10 g of magnesium powder on a balance, tip it into the cup, put the lid on and stir. Record the highest temperature reached and work out the rise. Rinse the cup and repeat with 0.20, 0.30, 0.40 and 0.50 g of magnesium, each time with fresh copper sulfate solution. Keep the volume and concentration of the solution and the type of cup the same, and start at room temperature. Repeat each mass three times and find the mean temperature rise, then plot a graph of mean temperature rise against mass of magnesium. Keep the magnesium away from flames as it is flammable.

**Marking points (any 6, with the method in a logical order)**

- Fixed volume of copper(II) sulfate in a polystyrene cup with lid
- Measure the starting temperature
- Weigh a mass of magnesium on a balance
- Add, stir and record the highest temperature
- Temperature rise = highest - start
- Repeat with at least 5 different masses
- Control: volume and concentration of solution, cup, starting temperature
- Repeat each mass and calculate a mean
- Safety: goggles, magnesium powder kept away from flames

**How it is marked**

- 5-6 marks: a detailed, logical plan with insulated cup, start and highest temperature, a range of weighed masses, control variables and repeats that could give valid results.
- 3-4 marks: a reasonable plan covering measuring the temperature and changing the mass, but with missing detail such as no control variables or no repeats.
- 1-2 marks: some relevant points, such as adding magnesium and measuring temperature, but not organised into a method.

## Revision notes: the method

**Aim:** To find out how the volume of sodium hydroxide solution added to hydrochloric acid affects the temperature change of the neutralisation reaction.

**Equipment**

- polystyrene cup with a lid that has a hole for the thermometer
- 250 $cm^3$ beaker to hold the cup steady
- thermometer (-10 to 50 °C, 0.1 °C divisions) or temperature probe
- two 50 $cm^3$ measuring cylinders
- dilute hydrochloric acid
- sodium hydroxide solution
- glass stirring rod
- safety goggles

**Method**


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1. Stand a polystyrene cup inside a beaker so it cannot tip over.
2. Use a measuring cylinder to add 25 $cm^3$ of dilute hydrochloric acid to the cup.
3. Put the thermometer through the lid into the acid and record the starting temperature.
4. Measure 5 $cm^3$ of sodium hydroxide solution in a second measuring cylinder.
5. Add the sodium hydroxide to the cup, put the lid on and stir.
6. Watch the thermometer and record the highest temperature reached.
7. Work out the temperature rise: highest temperature minus starting temperature.
8. Rinse and dry the cup, then repeat with 10, 15, 20, 25, 30, 35 and 40 $cm^3$ of sodium hydroxide, each time with a fresh 25 $cm^3$ of acid.
9. Repeat the whole set and calculate a mean temperature rise for each volume.

### Variables

- **Independent:** The volume of sodium hydroxide solution added.
- **Dependent:** The temperature rise (highest temperature minus starting temperature), measured with a thermometer.
- **Control:** Volume of hydrochloric acid (25 $cm^3$); Concentration of the acid and of the alkali; Type of cup, with a lid, each time; Starting temperature of the solutions (room temperature)

### Hazards

| Hazard | What could happen | How to reduce the risk |
|---|---|---|
| Sodium hydroxide solution | Irritant or corrosive to eyes and skin | Wear safety goggles; wash splashes off immediately with water |
| Dilute hydrochloric acid | Irritates eyes and cuts in the skin | Wear goggles and handle with care |
| Glass thermometer | Can break and cut the hand if used to stir | Stir with a glass rod, not the thermometer, and keep the cup inside a beaker so it does not tip |

### Key points

- Record the highest temperature reached, not the temperature after a fixed time.
- Temperature rise = highest temperature - starting temperature; this allows for different starting temperatures.
- A polystyrene cup with a lid reduces energy lost to the surroundings, because polystyrene is a good insulator.
- A temperature rise means an exothermic reaction; a fall means endothermic.
- The biggest rise is when the acid and alkali exactly neutralise; adding more alkali after that just cools the mixture down.
- Stir so that the whole mixture reaches the same temperature.


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