

## Measuring enthalpy changes

This lesson plan accompanies the article **How to teach enthalpy cycles post-16** in *Education in Chemistry* which includes more guidance and teaching strategies, including common misconceptions, and can be viewed at: [rsc.li/3ADkpGa](https://rsc.li/3ADkpGa)

### Resource components

<p><b>Student sheet:</b> includes instructions for the practical activities, questions and write-up.</p>	<p><b>Presentation:</b> slides include key points, questions and instructions for practical activities.</p>	<p><b>Technician notes:</b> full set up and safety information for the practical activities.</p>

In this lesson, ask learners to carry out two practical activities to observe what happens when water is added to anhydrous copper(II) sulfate and when hydrated copper(II) sulfate is dissolved in water. This will introduce them to Hess's law and its application.

### Learning objectives

- 1 Recognise that some enthalpy changes can't be measured directly.
- 2 Know that Hess's law shows that whichever route is taken to a product, the overall enthalpy change is the same.

### Teaching sequence

#### Introduction (slide 2)

1. Introduce the activity by saying that although we can measure the enthalpy change of combustion for fuels, other enthalpy changes cannot be measured directly.
2. Ask learners for examples, e.g. the energy released when we eat food.
3. Mention other reactions where chemists cannot control the bond-breaking, bond-making process.

#### Activity: what happens when water is added to anhydrous copper(II) sulfate?

4. Organise learners into pairs or small groups.

5. Get learners to complete activity 1 (slide 3)
6. Check learners have observed that heat is released.
7. Pose questions to develop ideas (slide 4), such as:
  - Is the enthalpy change for this reaction exothermic or endothermic?
  - What sign should the enthalpy change have?
  - What is the equation for this reaction?
  - What bonds are being broken and formed in this reaction?
  - Why is it difficult to measure this enthalpy change directly?
  - What is this enthalpy change called?
8. Share the learning objectives (slide 5).

### Key points

9. Explain the following points (slide 6):
  - It is difficult to measure the enthalpy change of hydration accurately in a direct way because the hydration process can't be controlled directly.
  - Instead, anhydrous and hydrated copper(II) sulfate can be dissolved in water.
  - These enthalpy changes can be measured easily.
  - Each 'route' produces a solution of hydrated copper(II) sulfate.
  - Hydrated copper(II) sulfate has some water in the structure already. By dissolving the two salts and determining the enthalpy changes, we can work out the enthalpy change of hydration.

### Experiment: an enthalpy change you cannot measure directly

Support and supervise as learners:

10. Complete the experiment.
11. Collect data according to the worksheet.
12. Calculate the enthalpy changes.
13. Apply Hess's law to find the overall enthalpy change of copper(II) sulfate solution.

### Plenary

14. In a plenary, use questions to develop thinking:
  - What is the equation for the enthalpy change we want to measure?
  - What are the enthalpy changes for the two reactions we have measured?
  - How can we make a triangle between these reactions?
  - Why do both routes to the copper(II) sulfate solution involve the same amount of energy?
  - Why is it useful to be able to measure enthalpy changes?

### Feedback

15. Take in the accounts of the experiment and, if possible, give written feedback (guidance for reviewing learner answers is given below.)

## Practical activities

The equipment list, preparation, safety information and disposal instructions for the practical activities are included in the technician notes. The student sheet provides step-by-step instructions for each activity, from [rsc.li/3T9sEQD](https://rsc.li/3T9sEQD)

Read our standard health and safety guidance ([rsc.li/3zyJLkx](https://rsc.li/3zyJLkx)) and carry out a risk assessment before running any live practical.

### Learners must:

- Wear safety glasses throughout.
- Avoid skin contact with the solids or solutions.
- Not exceed the amounts stated.

## Commentary

Asking lots of questions provides a structured approach to revealing what your learners understand of the topic. The experimental work grounds the questions in reality, giving the opportunity to consolidate learning from the preliminary test, but questions are important to gauge understanding.

Written feedback will confirm correct ideas and will indicate whether learners need any additional support.

## Answers for writing a summary

When evaluating learners' summaries, pay particular attention to:

- Understanding why the enthalpy change cannot be measured directly.
- Understanding the idea of the two routes to the same substance.
- The application of Hess's law to find the enthalpy change of hydration.

Points to look for:

- The enthalpy change is the 'enthalpy change of hydration'.
- It can't be measured directly as we cannot physically measure how much energy is released when five moles of water react with one mole of copper(II) sulfate.
- Both routes end up with a solution of copper(II) sulfate. The difference between the two routes is the enthalpy change of hydration.
- A typical value for the enthalpy change is of the order of  $-5 \text{ kJ mol}^{-1}$ .