How do we measure enthalpy changes?

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.

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

Try this test.

Equipment

- Safety glasses
- Test tube
- Test tube rack
- Spatula
- Pipette
- Small beaker containing water
- Anhydrous copper(II) sulfate powder

(DANGER: corrosive, irritant, environmental hazard)

Method

1. Wear eye protection.
2. Use a spatula to put a small amount (thumbnail covering) of anhydrous copper(II) sulfate into a test tube.
3. Add water drop by drop.
4. Carefully touch the outside of the test tube. What do you notice? What happens to the copper(II) sulfate?

Some enthalpy changes are easy to measure – you can measure enthalpy changes of combustion, for example, by completely burning the substance in oxygen and measuring the amount of energy produced. Others are difficult because chemists cannot easily control the bond-breaking and bond-making processes.
The experiment below introduces a law, Hess's law, to help.

Hess's law says that the enthalpy change for a reaction will be the same regardless of the route taken. Imagine a chemical journey from A → B; the enthalpy change will be the same even if you were to get there going through C, D and/or E!

This means that by breaking a 'non-measurable' enthalpy change into measurable steps that give two different routes, we can measure the change.

Experiment: an enthalpy change you cannot measure directly

Equipment

- Eye protection
- Anhydrous copper(II) sulfate powder (DANGER: corrosive, irritant, environmental hazard)
- Hydrated copper(II) sulfate crystals (DANGER: corrosive, irritant, environmental hazard)
- Spatula
- Weighing boat (or similar)
- Insulated cup
- Beaker
- Thermometer reading 0–110°C in 0.1°C increments
- Water
- 50 cm^3 pipette or measuring cylinder
- Access to a mass balance

Method

1. Wear eye protection.
2. Calculate the mass of 0.025 moles of anhydrous copper(II) sulfate.
3. Use a spatula to measure out this mass into a weighing boat.
4. Stand the cup in the beaker. Measure out 50 cm^3 of water into the cup.
5. Record the temperature of the water in the cup.
6. Add the anhydrous copper(II) sulfate to the water and stir.
7. Record the highest temperature reached.
8. Repeat these steps with hydrated copper(II) sulfate.

Working out the enthalpy changes

1. Calculate the energy released.
   $E_h = mc\Delta T$
   Heat energy change (Joules) = 50 x 4.2 x temperature change

2. Divide the energy figure by the number of moles.
3. Write equations with state symbols for the enthalpy changes you have measured. Write their enthalpy changes alongside them.

Write a summary

Write a summary of the experiment.
Make sure you explain:

- ☐ the name of the enthalpy change you are trying to measure,
- ☐ why this enthalpy change can't be measured directly,
- ☐ why the two routes have the same enthalpy change,
- ☐ what the value of the enthalpy change is from your measurements.