A-level Chemistry exemplar for required practical 2

Measurement of an enthalpy change:

To determine an enthalpy change which cannot be measured directly. The reaction involves the conversion of anhydrous copper(II) sulfate into hydrated copper(II) sulfate.

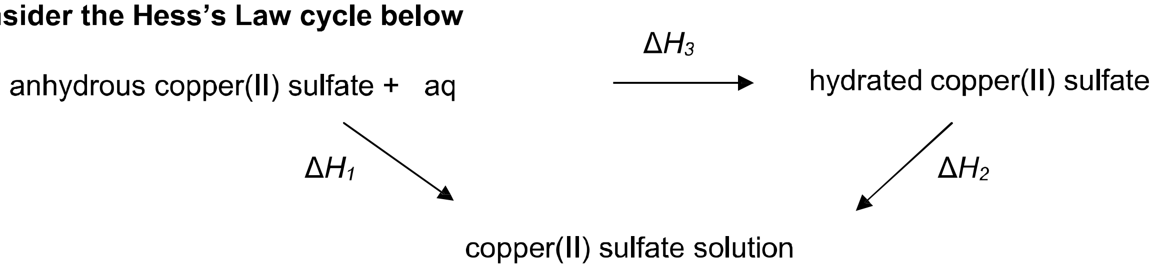
Student sheet

Requirements

You are provided with the following:

- hydrated copper(II) sulfate crystals
- anhydrous copper(II) sulfate powder
- polystyrene cups with lids
- 250 cm^3 or 400^3 cm beaker (as appropriate for holding the cup)
- stand and clamp
- 0 °C to 50 °C glass or digital thermometer
- two 25 cm^3 measuring cylinders
- two weighing bottles
- stopwatch
- graph paper
- stirrer
- deionised or distilled water
- access to a digital mass balance (measuring to 2 decimal places).

Consider the Hess's Law cycle below



We can measure accurately by experiment both the values ΔH_1 and ΔH_2

By applying Hess's Law, we can calculate the value for ΔH_3, since the two routes from anhydrous copper(II) sulfate to copper(II) sulfate solution have the same overall enthalpy change.

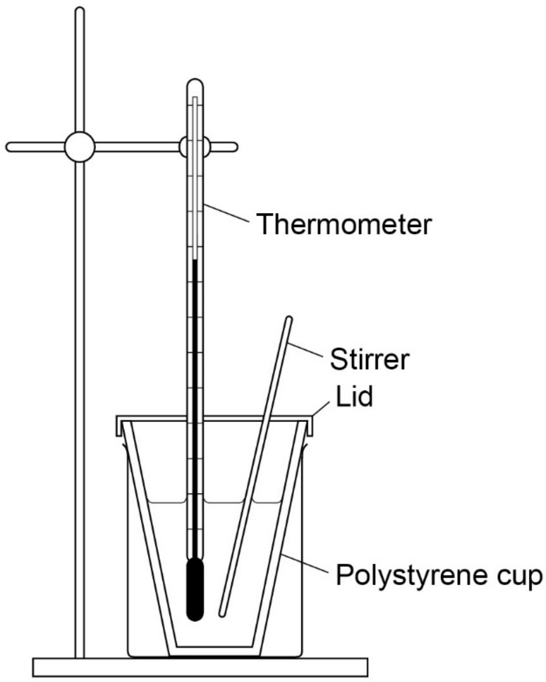
ie $\quad \Delta H_1 = \Delta H_2 + \Delta H_3$

therefore $\quad \Delta H_3 = \Delta H_1 - \Delta H_2$

Suggested method

Experiment 1 - Collecting data for the determination of ΔH_1

a) Weigh out between 3.90 g and 4.10 g of anhydrous copper(II) sulfate in a dry stoppered weighing bottle, keeping the stock of solid in a closed container during weighing. **Take care to avoid skin contact.** The precise mass should be recorded.
b) Construct a suitable table of results to allow you to record temperatures at minute intervals up to 15 minutes.
c) Using a measuring cylinder, place 25 cm^3 of deionised water into a polystyrene cup and record its temperature at the beginning (t=0), start the timer and then record the temperature again every minute, stirring the liquid continuously.



d) At the fourth minute, add the powdered anhydrous copper(II) sulfate **rapidly** to the water in the polystyrene cup and continue to stir, but **do not** record the temperature. At the fifth minute and for every minute up to 15 minutes, stir and record the temperature of the solution in the polystyrene cup.
e) Plot a graph of temperature (on the *y*-axis) against time. Draw two separate best fit lines; one, which joins the points before the addition, and one, which joins the points after the addition, extrapolating both lines to the fourth minute.
f) Use your graph to determine the temperature change at the fourth minute, which theoretically should have occurred immediately on addition of the solid.

Experiment 2 - Collecting data for the determination of ΔH_2

a) Weigh out between 6.20 g and 6.30 g of hydrated copper(II) sulfate in a dry stoppered weighing bottle. The precise mass should be recorded.
b) Construct a suitable table of results to allow you to record temperatures at minute intervals up to 15 minutes as you did for Experiment 1.
c) Using a measuring cylinder, place 24 cm^3 of deionised water into a polystyrene cup. Since the hydrated crystals contain water, the total amount of water will be approximately the same as in Experiment 1.
d) Repeat the procedure adopted in Experiment 1. Add the copper(II) sulfate crystals to the water in the polystyrene cup and obtain temperature data for 15 minutes.
e) Plot a graph similar to that in Experiment 1 and determine the temperature change in this experiment.

Analysing the data and calculating ΔH_3

You should be familiar with the expression

Heat change = mass × specific heat capacity × temperature change

Heat change = m c ΔT

In this experiment, we will ignore heat loss to the surroundings.

The specific heat capacity of the polystyrene cup is negligible when compared to the mass of water and the aqueous solutions can be considered to have the same specific heat capacity as water.

(For many aqueous chemical reactions, it can be assumed that the only substance heated is water).

In each of Experiment 1 and Experiment 2 you need the **mass of water, m (in g),** which has changed in temperature. As the density of water can be assumed to be 1 g cm^{-3} the mass can be directly taken from the volume of water ie 25 g in each case. Do **not** add on the mass of the solid used.

You will also need the **temperature change, ΔT (in K)**, from your graph in order to be able to calculate the heat change.

For water, the specific heat capacity, **c = 4.18 J K^{-1} g^{-1}** and, so, the value that you obtain for the heat change in each experiment will be in **joules**. You can convert this value into kilojoules by dividing it by 1000.

You can then calculate the enthalpy changes, ΔH_1 and ΔH_2 , in **kJ mol^{-1},** using the masses of the solids used in each experiment.

You need to use the values that you have obtained for ΔH_1 and ΔH_2 and apply Hess's

Law to calculate ΔH_3 in **kJ mol^{-1}** for the hydration of copper(II) sulfate.

$$CuSO_4(s) + aq \rightarrow CuSO_4.5H_2O(s)$$