Teacher Resource Bank

GCE Chemistry

PSA4: AS Physical Chemistry

- Measure an Enthalpy Change

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AS Physical Chemistry

PSA4   Measure an enthalpy change

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Technical Sheet

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.

Whenever possible, students should work individually.
If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

<u>Requirements</u>

- hydrated copper(II) sulfate (small) crystals
- anhydrous copper(II) sulfate powder
- polystyrene cup (as a calorimeter)
- 250 cm^3 or 400 cm^3 beaker
- stand and clamp
- 0 ^{o}C to 50 ^{o}C thermometer (0.1 ^{o}C or 0.2 ^{o}C divisions)
- Two 25 cm^3 measuring cylinders
- Two weighing bottles
- stopwatch
- graph paper
- stirrer

The calorimeter is a polystyrene cup (an ordinary coffee cup) fitted into the beaker which will provide some insulation, and also act as a support.

Centres are expected to carry out and be responsible for their own safety risk assessments.

Student Sheet

It is the responsibility of the student to carry out and be responsible for their own safety risk assessment before carrying out this experiment. Wear safety glasses at all times. Assume that all of the reagents and liquids are toxic, corrosive and flammable.

Consider the Hess's Law cycle below

ΔH_3

| anhydrous copper(II) sulfate   +   (aq) | $\longrightarrow$ | hydrated copper(II) sulfate |

ΔH_1

ΔH_2

| copper(II) sulfate solution |
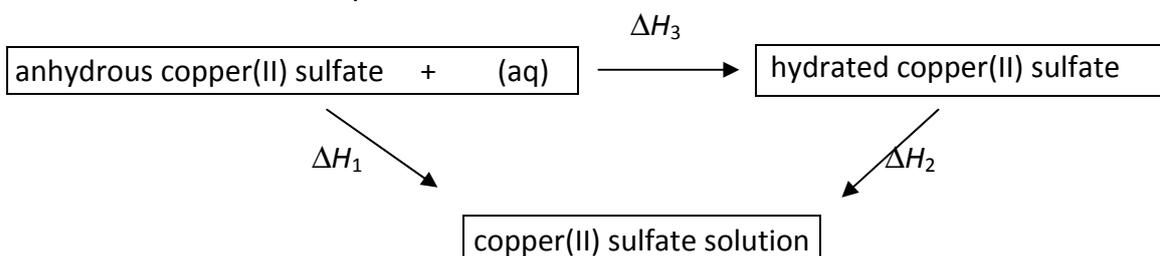
We can measure accurately by experiment both the values ΔH_1 and ΔH_2
By applying Hess's Law, we can calculate the value for ΔH_3, since the two routes from anhydrous copper(II) sulfate to copper(II) sulfate solution have the same overall enthalpy change.

i.e. ΔH_1 = ΔH_2 + ΔH_3

therefore ΔH_3 = ΔH_1 - ΔH_2

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 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 fifteen 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, which would 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 and record its temperature every minute stirring continuously. 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 fifteen 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

The ability to calculate values for ΔH_1, ΔH_2 and ΔH_3 is NOT part of the PSA but this is a useful task to complete.
        Your teacher can help you with this part of the work.

You should be familiar with the expression

        Heat Change = Mass x Specific Heat Capacity x 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 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 (quoted in g),** which has changed in temperature, in addition to the **temperature change, ΔT (quoted in Kelvin),** in order to be able to calculate the change in enthalpy.

For water the specific heat capacity, **c = 4.18 J K^{-1} g^{-1}** and 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 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}** of copper(II) sulfate.

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Teacher Notes and Marking Guidance

The specific marking guidance in the specification is as follows

2 marks: All areas of the task are carried out competently.
Masses and volumes are measured precisely and within the required range.
Initial/final temperatures are measured precisely and mixing is complete.
The results lead to an enthalpy change which is within the expected range.

1 mark: One of the areas of the task is performed poorly.
Masses or volumes are measured imprecisely or not in the required range **OR**
Temperatures are measured imprecisely or mixing is incomplete **OR**
The results lead to an enthalpy change which is outside the expected range.

0 marks: At least two of the areas of the task are performed poorly.
Masses or volumes are measured imprecisely or not in the required range.
Temperatures are measured imprecisely or mixing is incomplete.
The results lead to an enthalpy change which is outside the expected range.

Guidance for Teachers and Students

Teachers are expected to exercise professional judgement in assessing the competence of their candidates in following the instructions.

Candidates should have been given guidance in the correct use of equipment and this guidance **can continue during the practical session** for which this PSA forms a part.

If, however, the guidance required is fundamental or frequent, then the student should **not** be awarded 2 marks.

Judgement of 2 marks, 1 mark or 0 marks will depend on whether the candidate has carried out the activity safely, particularly with regard to measuring out and transferring solids and water to the calorimeter and to recording weighings and temperatures to an appropriate precision.

The value for ΔH_1 is exothermic and that for ΔH_2 is slightly endothermic. In the latter case, the temperature may fall by only 0.5 ^{o}C

Students should not be judged on their ability to apply Hess's Law nor on their ability to calculate values for enthalpy changes. They should be judged on their ability to follow the instructions and to carry out the practical task which leads to the production of a valid set of results.

The expected range may best be judged by the teacher calculating a class average for ΔH_1 which excludes significant anomalies. Variation of more than $\pm$ 20 % from this class average may be judged to be outside the expected range.

It is important to remember when marking these practical exercises that PSA is about student competence and that for a student to score full marks on this exercise **perfection is neither expected nor required**.