AS / A LEVEL CHEMISTRY

Measuring enthalpy

1. Calculating enthalpy
2. What is calorimetry?
   a) Coffee cup calorimeter
   b) Spirit burner calorimeter
3. Errors and assumptions
4. Exam style questions
5. Summary

CALCULATING ENTHALPY

$$Q=mc\Delta T$$

Q

- Heat exchanged with the surroundings
- Unit: Joule (J)

m

- Mass of the substance heated/cooled
- Unit: Grams (g)

C

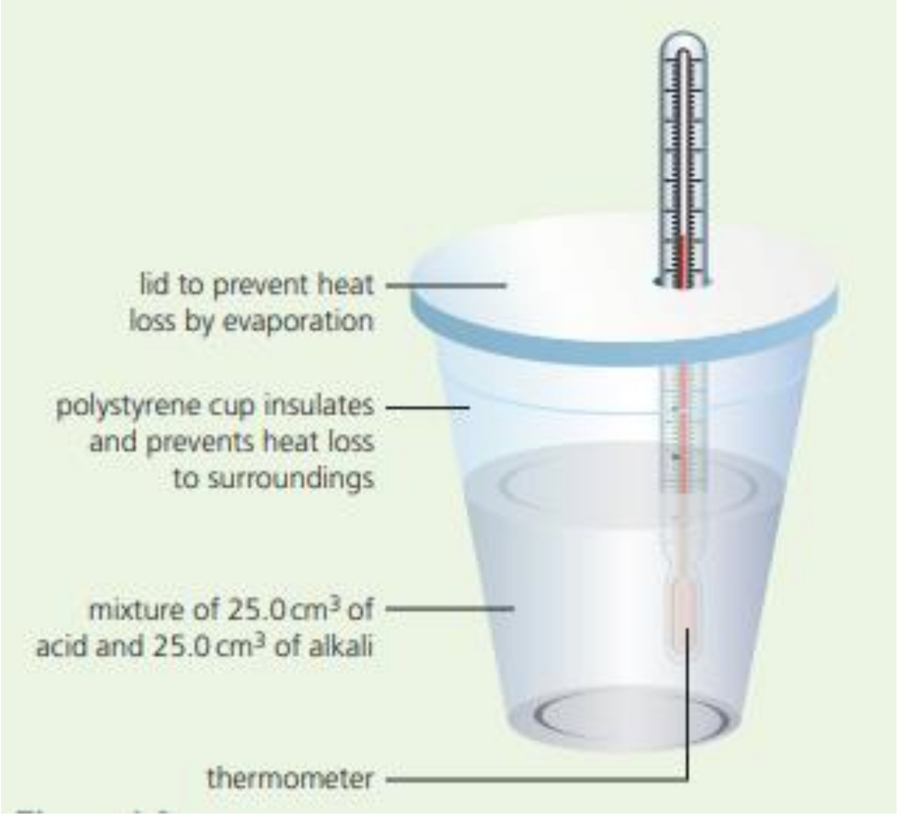
- Specific heat capacity
- Energy required to raise the temperature of 1g of the substance by 1K
- Unit: $J*g^{-1}K^{-1}$

ΔT

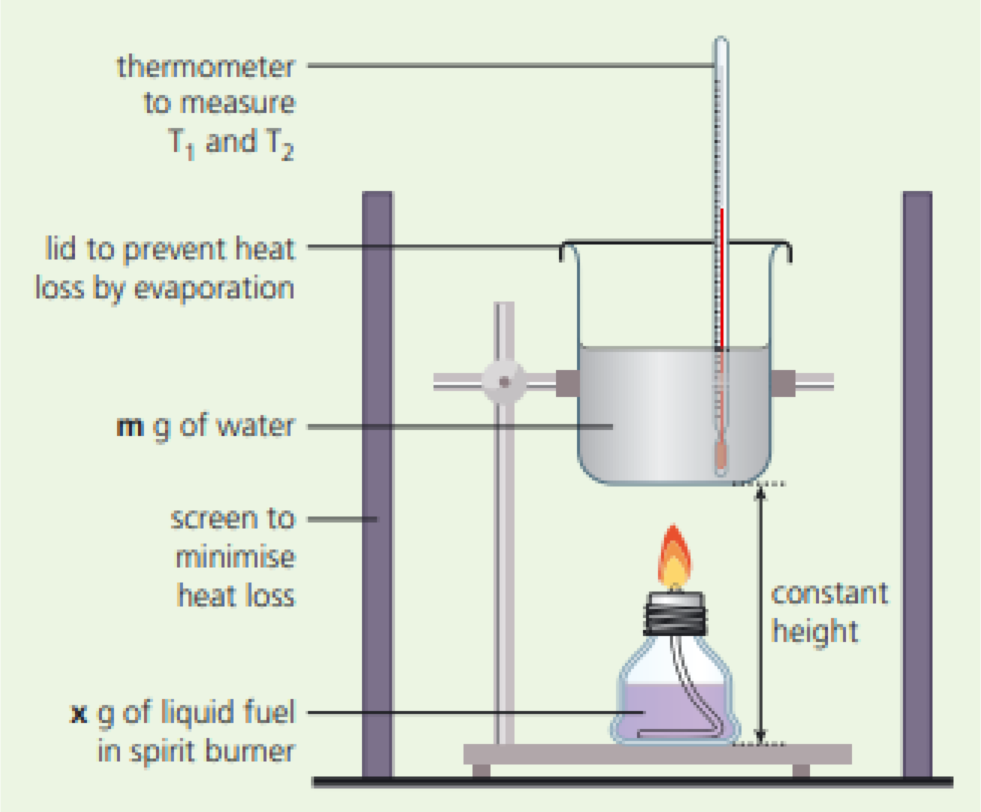
- Change in temperature
- Unit: Kelvin (K)

WHAT IS CALORIMETRY?

- Quantitative study of chemical energy in a chemical reaction.
- We can measure the enthalpy change of some reactions by a technique called calorimetry. The apparatus used is called a calorimeter.
  - **Simple calorimeter (Coffee cup calorimeter)**

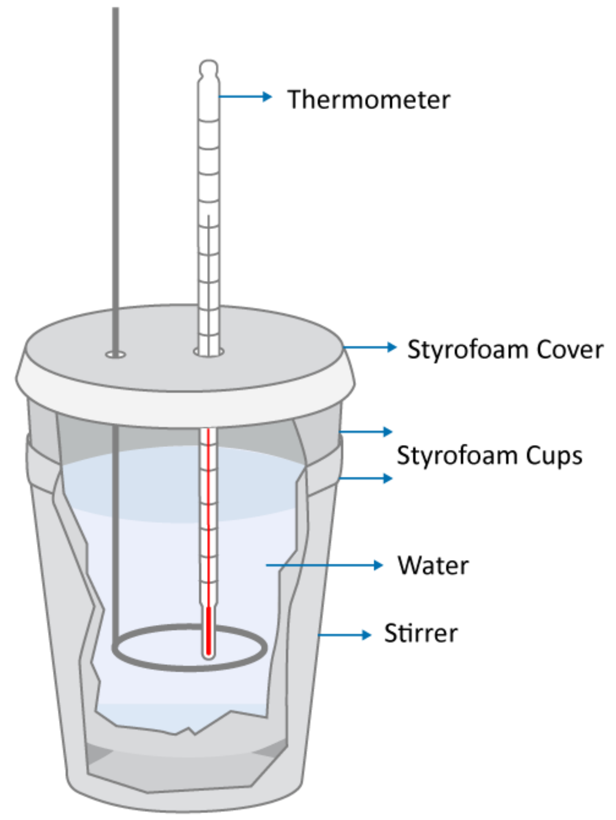


  - **Spirit burner calorimeter**



WHAT IS CALORIMETRY?

- **Simple calorimeter (Coffee cup calorimeter)**

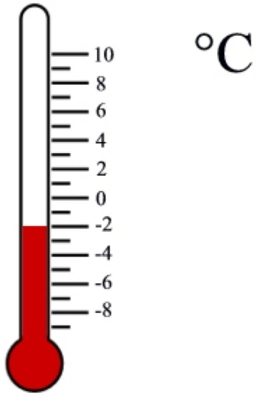


COFFEE CUP CALORIMETER EXAMPLE

- The setup:

Polystyrene lid

Thermometer



- **Styrofoam cup**
  - This could be held:
  - In another Styrofoam cup
  - In a beaker

WHAT IS CALORIMETRY?

- **Process:**
  a. **Add a measured mass of the first reactant**
     i. **Take temperature**
     ii. **Repeat every minute until the temperature is stable**
  a. **Add second reactant**
     i. **You do not need to measure the temperature the minute this is added**
  b. **Monitor the temperature**
     i. **Do this every minute for 5 minutes**

- When carrying out experiments in calorimeters we use known amounts of reactants and known volumes of liquids.
- We also measure the temperature change of the liquid in the calorimeter as the reaction occurs.
- The thermometer should be accurate to 0.1 or 0.2°C. Calorimetry relies on the fact that it takes 4.18 J of energy to increase the temperature of 1g of water by 1 °C.
- The energy required to raise the temperature of 1g of a liquid by 1°C is called the specific heat capacity, c, of the liquid.
- So, the specific heat capacity of water is 4.18 Jg–1 °C–1. The energy transferred as heat (the enthalpy change) is given by the relationship:

$\Delta H = -mc\Delta T$ where: ΔH is the enthalpy change, in J m is the mass of water, in g c is the specific heat capacity, in J g–1 °C–1 ΔT is the temperature change, in °C

With solutions we make the assumptions that:

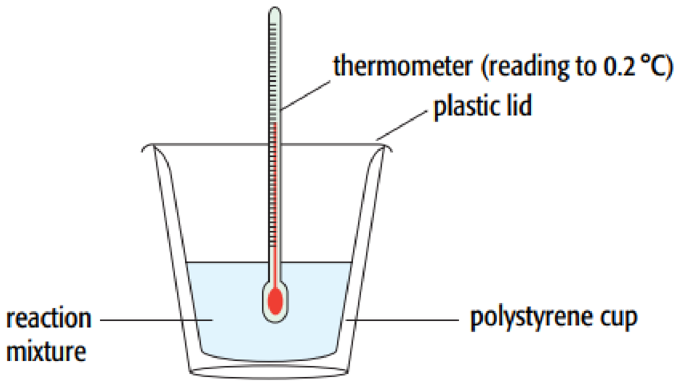
■■ 1cm3 of solution has a mass of 1g

■■ the solution has the same specific heat capacity as water.

THE ENTHALPY CHANGE OF NEUTRALISATION BY EXPERIMENT

The procedure is:

1. Place 50 cm3 of 1.0moldm–3 hydrochloric acid in the cup and record its temperature.
2. Add 50 cm3 of 1.0moldm–3 sodium hydroxide (at the same temperature) to the acid in the cup.
3. Stir the reaction mixture with the thermometer and record the highest temperature.



Results and calculation

mass of solution = 100g (50cm3 of acid plus 50cm3 of alkali and assuming that 1.0cm3 of solution has a mass of 1.0g)

specific heat capacity = 4.18Jg–1 °C–1 (assuming that the heat capacity of the solution is the same as the heat capacity of water)

starting temperature of = 21.3 °C

reactant solutions final temperature of = 27.8 °C

product solution temperature rise = +6.5 °C

ENTHALPY CHANGE OF SOLUTION BY EXPERIMENT

The procedure is:

1 Weigh an empty polystyrene cup.

2 Pour 100cm3 of water into the cup and weigh the cup and water.

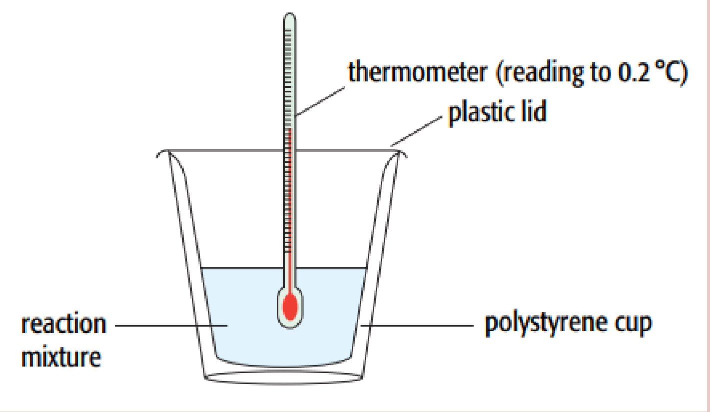
3 Record the steady temperature of the water with a thermometer reading to at least the nearest 0.2 °C.

4 Add a few pellets of sodium hydroxide (corrosive!) which have been stored under dry conditions.

5 Keep the mixture stirred continuously with a thermometer and record the temperature at fixed intervals, e.g. every 20 seconds.

6 Keep recording the temperature for 5 minutes after the maximum temperature has been reached. Measuring enthalpy changes (continued)

7 Weigh the cup and its contents to calculate the mass of sodium hydroxide which dissolved.



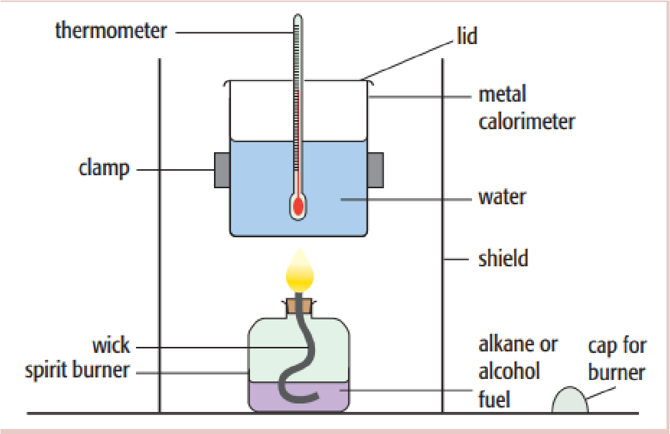
Results and calculations

mass of polystyrene cup =
mass of polystyrene cup + water =
mass of water =
mass of cup + water + sodium hydroxide =
mass of sodium hydroxide that dissolved =
initial temperature of water =
final temperature of water =
temperature rise =

FINDING THE ENTHALPY CHANGE OF COMBUSTION

The procedure is:

1. Weigh the spirit burner containing propan-1-ol. The cap on the burner must be kept on when the burner is not lit to avoid evaporation of the fuel.
2. Pour 100 cm3 (100g) of water into the calorimeter. For greater accuracy this should be weighed out.
3. Stir the water and record its temperature with a thermometer reading to at least the nearest 0.1 °C.
4. Place the spirit burner beneath the calorimeter, remove the cap and light the wick. The length of the wick should have been previously adjusted so that the material of the wick does not burn and the flame just touches the bottom of the calorimeter.
5. Keep stirring the water with the thermometer until there is a temperature rise of about 10 °C. Record this temperature. Measuring enthalpy changes (continued)
6. Remove the spirit burner, place the cap on it and reweigh it.



Results and calculations

mass of water in calorimeter =
mass of spirit burner and propan-1-ol at start =
mass of spirit burner and propan-1-ol at end =
mass of propan-1-ol burnt =
initial temperature of water =
final temperature of water =
temperature change of the water=

EXAM STYLE QUESTION

1. A student added 50cm3 of sodium hydroxide to 50cm3 of hydrochloric acid. Both solutions were at 18°C to start with. When the solutions were mixed a reaction occurred. The temperature rose to 33°C. Calculate the energy released in this reaction.

EXAM STYLE QUESTION

25.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid were placed in a polystyrene cup and the initial temperature recorded as 22.7 °C. 25.0 cm^3 of 1.00 mol dm^{-3} sodium hydroxide solution were added.

The highest temperature recorded was 29.3 °C. Assume the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1} and the density of the solution is 1.00 g cm^{-3}. Calculate a value for the enthalpy change when one mole of water is formed, to 3 significant figures.

EXAM STYLE QUESTION

2. A student calculated the standard enthalpy change of combustion of ethanol ΔH —O c [C2 H5OH] by calorimetry as –870kJmol–1. The data book value is –1367kJmol–1. Explain the difference between these values.