SCH4U1 Name:
ER02 Date:

Calorimetry

Calorimetry is the measurement of energy changes in chemical reactions, and is based on two fundamental laws:

1. The First Law of Thermodynamics (The Law of Conservation of Energy): the energy of an isolated system is constant; the energy can be transformed into different forms, but cannot be created or destroyed.
2. Hess's Law of Constant Heat Summation (ER03): regardless of the multiple stages or steps of a reaction, the total enthalpy change for the reaction is the sum of all changes.

To carry out calorimetry, we must assume:

1. No heat is transferred to or from the surroundings (a closed system).
2. No heat is absorbed or released from the equipment used.
3. The density & heat capacity of any aqueous solution is equal to that of pure water (D = 1.00 g/mL and c = 4.184 J/g·°C)

Note: these are simplifying assumptions.

A calorimeter is an instrument designed for these experiments. A simple calorimeter allows a reaction to be carried out in an aqueous solution without the loss of heat (Figure 1). A bomb calorimeter (Figure 2) allows a reaction to be carried out in a separate chamber and the heat produced is measured by the temperature change in the water jacket.

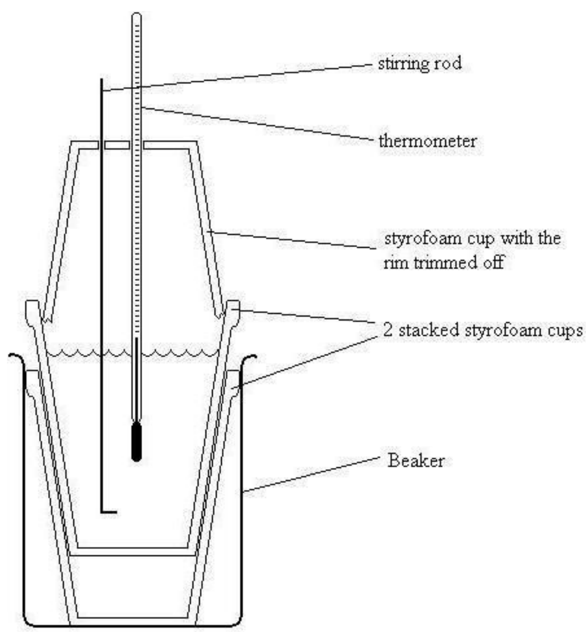

Figure 1: A Simple Calorimeter

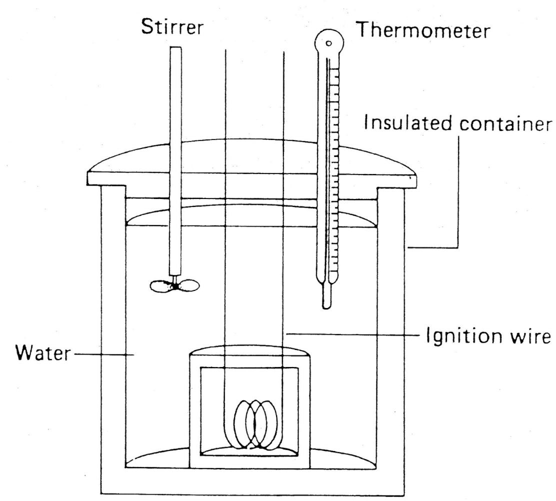

Figure 2: A Bomb Calorimeter

To investigate an energy change, we use the law of conservation of energy that tells us the change in energy of a chemical system is the same as the change in energy of the surroundings:

$$\Delta H_{sys} = \pm\, |\, q_{surroundings} |$$

If $q_{surroundings}$ is **positive** then the change is exothermic **(- Δ*H*)**.

If $q_{surroundings}$ is **negative** then the change is endothermic **(+ Δ*H*)**.

Calculating Heat of Reaction using Calorimetry

As energy is added or removed from a substance, the temperature of a substance changes.

- amount of energy (***q*** in Joules)
- amount of material (***m*** or mass in grams)
- type of material (***c***, the specific heat capacity in J/g·°C)
- temperature change ($\Delta T = T_f - T_i$)

$$q = mc\Delta T$$

In calorimetry, the energy change is usually calculated by the change in temperature of a known quantity of water inside the calorimeter.

Therefore the molar enthalpy (heat of reaction) can be found:

$$\Delta H° = \frac{q_{rxn}}{n}$$

e.g.1 If 5.2 g of sodium hydroxide undergoes a reaction that results in the temperature of 250 mL of water to increase from 21.0°C to 28.0°C, calculate the molar enthalpy of reaction ($\Delta H°_r$), in kJ per mole, of sodium hydroxide.

e.g.2 What would be the final temperature in a calorimeter containing 250 mL of water at 22.4°C if 10.0 g of ammonium nitrate is completely dissolved?

NH_4NO_3 (s) $\longrightarrow$ NH_4NO_3 (aq) $\Delta H°_{sol}$ = +26.2 kJ/mol