Calorimetry

A calorimeter is a devise used for determining the heat of reaction. The simple "Styrofoam coffee-cup calorimeter" is often used in laboratories to measure the heat of reaction in aqueous solution, which occurs at constant pressure. This type of calorimeter measures the enthalpy change (ΔH) of a reaction. The heat produced by the reaction is absorbed by the solution (the reaction's surrounding), which can be calculated from the mass, its specific heat capacity, and the temperature change of the solution using the expression: $q_{soln} = m \times s \times \Delta t$

For example, suppose we mix 50.0 mL of 1.0 M HCl and 50.0 mL of 1.0 M NaOH in a coffee-cup calorimeter and both solution were initially at 22.0 ^oC. After mixing, the temperature of the solution rises to 29.0 ^oC. Assuming the density of the solution as 1.0 g/mL and the specific heat of the solution as 4.02 J/g.^oC, the amount of heat absorbed by the solution is calculated as follows:

$$q_{soln} = 100.0 \text{ g} \times (4.02 \text{ J/g.}^oC) \times 7.0\ ^oC = 2814 \text{ J} = 2.8 \times 10^3 \text{ J}$$

If the heat capacity of the calorimeter is known, let say C_{cal} = 10.J/^oC, we can also calculate the heat absorbed by the calorimeter, which is,

$$q_{cal} = (10. \text{ J}/^oC) \times 7.0\ ^oC = 70. \text{ J}$$

The total heat produced by the reaction (q_{rxn}) is equal to the sum of the above heat absorbed by the solution and calorimeter:

$$q_{rxn} = -(q_{soln} + q_{cal}) = -(2814 \text{ J} + 70 \text{ J}) = -2884 \text{ J} = -2.9 \text{ kJ}$$

The reaction is: $HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$,

and the ionic equation is: $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$

The number of mole of H^+ reacted = 0.0500 L x 1.0 mol/L = 0.0500 mol

That is, 2.9 kJ of heat is produced when 0.0500 mol H^+ ions is reacted. The molar enthalpy for the reaction is -2.9 kJ/(0.0500 mol) = -58 kJ/mol

A "*bomb-calorimeter*" is a type of calorimeter used to measure the amount of heat produced in a combustion reaction. It measures the heat of reaction carried out at constant volume. The amount of heat produced is calculated by measuring the heat absorbed by the calorimeter, which is

$q_{comb.} = -\ q_{cal}$; and $q_{cal.} = C_{cal} \times \Delta t$; ($C_{cal}$ = heat capacity of the calorimeter)

Exercise-4:

1. 0.255 g of magnesium strip is added to 100.0 mL of 1.00 M HCl at 22.0 ^oC in a coffee-cup calorimeter. When the reaction is completed, the temperature of the solution is found to increase to 33.7 ^oC. Assuming that the density of the solution is 1.00 g/mL and its specific heat is 4.02 J/g.^oC, and the heat capacity of the calorimeter is 12 J/^oC. (a) Calculate the total quantity of heat absorbed by the solution and calorimeter, respectively. (b) Calculate the enthalpy change (ΔH_{rxn}) for the reaction:

$$Mg_{(s)} + 2\ HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

2. Burning 1.00 g of sucrose ($C_{12}H_{22}O_{11}$) is found to raise the temperature of the calorimeter by 2.35 ^{o}C. If the overall heat capacity of the calorimeter is 7.12 kJ/^{o}C, calculate the molar enthalpy of combustion for sucrose.

$$C_{12}H_{22}O_{11(s)} + 12\ O_{2(g)} \rightarrow 12CO_{2(g)} + 11H_2O_{(g)}$$