CHAPTER 8: THERMOCHEMISTRY

Concept of Enthalpy

1 Hydrogen gas burns in air to form water:

$$2H_2\,(g) \;+\; O_2\,(g) \;\rightarrow\; 2\,H_2O\,(l) \qquad \Delta H = -\,572\text{ kJ}$$

How much heat energy is given off if 10.0 kg of hydrogen gas is burnt in excess oxygen?

2 Ammonium nitrate ,NH_4NO_3 decomposes by the following reaction:

$$2\,NH_4NO_3\,(g) \;\rightarrow\; 2\,N_2O\,(g) \;+\; 4\,H_2O\,(g) \qquad \Delta H^{\circ} = -\,74.8\text{ kJ}$$

If 74.0 g of H_2O are formed from the reaction, how much heat was released?

Calorimetry

1 When 18.70 g sodium chloride was dissolved in 400 cm^3 distilled water, the temperature of the solution decreased by 1.0 °C.
[*Specific heat capacity of solution = 4.20 $Jg^{-1}\,°K^{-1}$, density of solution = 1.0 g cm^{-3}*]
a) Calculate the heat of solution of sodium chloride.
b) Determine the enthalpy of solution of sodium chloride.

2 A sample of 0.02 mol octane, C_8H_{18} (*l*) was burnt in a bomb calorimeter, the temperature of 1000 cm^3 water increased by 24.2 °C.
[*Specific heat capacity of solution = 4.20 $Jg^{-1}\,°C^{-1}$, density of solution = 1.0 g cm^{-3}*]
a) What is the enthalpy of combustion of octane?
b) Write the thermochemical equation for the combustion of octane.

3 When 1.00 g of calcium chloride, $CaCl_2$, is added to 60.0 g of water in a coffee cup calorimeter, it dissolves:

$$CaCl_2\,(s) \;\rightarrow\; Ca^{2+}\,(aq) \;+\; 2Cl^{-}\,(aq)$$

The temperature rises from 20.00^0C to 23.51^0C. Assuming that all the heat given off by the reaction is transferred to the water, calculate the heat for the reaction.

4 An amount of 120.0 mL of coffee in a well-insulated cup at 82.0 °C is too hot to drink. What volume of cold fresh milk at 15.0 °C need to be added to the coffee in order to achieve a temperature of 65.0 °C? Assume specific heat capacities and densities of coffee and milk are the same as water.

5 100.00 cm^3 of 2.0 mol dm^{-3} hydrochloric acid was added to excess 100.00 cm^3 of 3.0 mol dm^{-3} potassium hydroxide solution. Both solutions are at initial temperature of 30.0 °C are mixed in a calorimeter. The maximum temperature of the solution is 41.0 °C.
[*Specific heat capacity of solution = 4.20 $Jg^{-1}\,°C^{-1}$*]
a) Determine the limiting reagent.
b) Calculate the enthalpy of neutralization for the reaction.
c) Write the thermochemical equation between hydrochloric acid and potassium hydroxide solution.

6 150 cm^3 of potassium hydroxide solution of concentration 2.0 M and 250 cm^3 of 1.5 M hydroiodic acid were mixed in a calorimeter. If the temperature rise is 10.2 °C, calculate heat evolved from the reaction.

$$KOH\ (aq) + HI\ (aq) \rightarrow KI\ (aq) + H_2O\ (aq)$$

[*Specific heat capacity solution = 4.2* $Jg^{-1o}C^{-1}$; *density of solution = 1.0 g* cm^{-3}]

7 The enthalpy of combustion of benzoic acid is – 3226.8 kJ mol^{-1}. When 3.2 g benzoic acid, C_6H_5COOH is completely combusted in a bomb calorimeter containing 2.0 kg of water, the temperature of the water increased by 3.8 °C.

a) Write the thermochemical equation for the combustion of benzoic acid.

b) Calculate the heat capacity of the calorimeter.

8 3.00 g of carbon was burned in a bomb calorimeter containing 2000 g of water at an initial temperature 20 ^oC. The maximum temperature recorded was 31.3 ^oC and the enthalpy of combustion of carbon is 402 kJ/mol. Calculate the heat capacity of bomb calorimeter. The specific heat for water is 4.184 J/g$^{\circ}$C.

Hess's Law

1 Standard enthalpy of formation of CO_2 (*g*), H_2O (*l*) and C_5H_{12} (*g*) are – 394 kJ mol^{-1}, – 286 kJ mol^{-1} and – 173 kJ mol^{-1} respectively. Determine the heat of combustion of pentane, C_5H_{12} using standard enthalpies of formation given.

2 Calculate the heat of combustion of methane using standard heats of formation below:

ΔH_f CO_2 (*g*) = – 394 kJ mol^{-1}
ΔH_f H_2O (*l*) = – 286 kJ mol^{-1}
ΔH_f CH_4 (*g*) = – 75 kJ mol^{-1}

3 Determine the enthalpy of formation of hydrogen peroxide (H_2O_2) by using the data below.

	ΔH° (kJ/mol)
$H_2\ (g) + \frac{1}{2} O_2\ (g) \rightarrow H_2O\ (g)$	– 241.82
$2\ H\ (g) + O\ (g) \rightarrow H_2O\ (g)$	– 926.92
$2\ H\ (g) + 2\ O\ (g) \rightarrow H_2O_2\ (g)$	– 1070.62
$2\ O\ (g) \rightarrow O_2\ (g)$	– 498.34
$H_2O_2\ (l) \rightarrow H_2O_2\ (g)$	+ 51.46

4 Draw the Born-Haber cycle for the formation of magnesium chloride, $MgCl_2$ from magnesium metal and chlorine gas. Calculate the enthalpy of formation of $MgCl_2$.
Given:

Heat of sublimation of magnesium, ΔH_1 = + 149 kJ mol^{-1}
First ionization energy of magnesium, ΔH_2 = + 740 kJ mol^{-1}
Second ionization energy of magnesium, ΔH_3 = + 1456 kJ mol^{-1}
Heat of atomization of chlorine, ΔH_4 = + 240 kJ mol^{-1}
Electron affinity of chlorine, ΔH_5 = – 369 kJ mol^{-1}
Lattice energy of $MgCl_2$, ΔH_6 = – 3933 kJ mol^{-1}

SPONGE BOB: MAINTAIN EXCELLENT BUT NOT OVER CONFIDENT