

## 1021SCG Chemistry 1A – Module 3: Physicochemical Concepts Week 7

References and resources: Blackman, Bottle, Schmid, Mocerino and Wille, 3<sup>rd</sup> Edn., Chapter 8, Sections 8.1 – 8.4

### Learning Objectives

You should be able to:

- Describe energy in its various forms and its transformations.
- Define the first law of thermodynamics in words and by an equation.
- Describe how changes in internal energy ( $\Delta U$ ) of a system is related to the transfer of energy as heat ( $\Delta Q$ ) and work ( $\Delta W$ ) between the system and its surroundings.
- Define heat capacity ( $C$ ) and specific heat ( $c$ ) and calculate any one of the following given the other three quantities: heat, quantity of material, specific heat and temperature change.
- Define state functions.
- Define enthalpy ( $H$ ) and relate the enthalpy change ( $\Delta H$ ) of a process occurring at constant pressure to the heat absorbed by the system (endothermic) or lost by the system (exothermic).
- Associate the sign (+ or -) of  $\Delta H$  for a process as being endothermic (+) or exothermic (-).
- State Hess's Law and be able to apply it to determine the enthalpy change in a process.
- Define the terms standard state.
- Use the equation  $\Delta_r H^\ominus = [\sum n \cdot \Delta_f H(\text{products})] - [\sum m \cdot \Delta_f H(\text{reactants})]$  to calculate the enthalpy change in a reaction occurring at constant pressure given the standard enthalpies of formation of each reactant and product [where  $\Sigma$  (sigma) means "the sum of", and  $n$  and  $m$  are the stoichiometric coefficients of the chemical reaction].

### Workshop and Study Questions

#### 1. Thermodynamic functions

- (a) What is energy?
- (b) What are the two main forms of energy and how do they differ?
- (c) What is meant by the terms system, surroundings and universe in thermodynamics?
- (d) What are the two ways in which energy can be transferred into and out of a system?
- (e) What is internal energy and state the first law of thermodynamics in terms of the internal energy of a system?
- (f) What are state functions?  
Are temperature, pressure, and volume state functions? Why or why not?  
Are work and heat state functions? Why or why not?

2. For each of the following processes, calculate the change in internal energy ( $\Delta U$ ) of the system, and indicate whether the process is endothermic or exothermic [Hint: is each form of energy transferred from the system to the surroundings (negative) or transferred from the surroundings to the system (positive)].

- (a) A balloon is heated by adding 900 J of heat ( $\Delta Q$ ). It expands, doing 422 J of work ( $\Delta W$ ) on the atmosphere.
- (b) A 50 g sample of water is cooled from 30°C to 15°C, thereby losing approximately 3149 J of heat.
- (c) A chemical reaction releases 8.65 kJ of heat and does no work on the surroundings.

### 3. Enthalpy

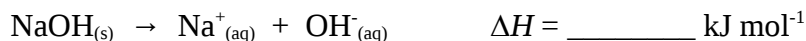
- What is the definition of Enthalpy ( $H$ )?
- Under what conditions will the enthalpy change of a process equal the amount of heat
- transferred into or out of a system ( $\Delta H = \Delta Q_p$ )
- What is the sign of  $\Delta H$  for an endothermic and endothermic change?

### 4. Consider the following reaction:



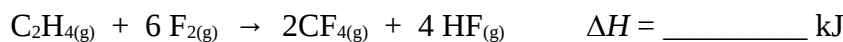
- Is the reaction exothermic or endothermic?
- What is the enthalpy change for the reverse reaction?
- What is the enthalpy change for 1 mol of  $\text{Mg}_{(s)}$ ?
- Calculate the amount of heat transferred when 2.4 g of  $\text{Mg}_{(s)}$  reacts at constant pressure [Hint: from (c), what is  $\Delta H$  per mol of  $\text{Mg}_{(s)}$ ? Determine the molar amount of Mg in 2.4 g of  $\text{Mg}_{(s)}$  and then find  $\Delta H$ ]
- Which mass (in grams) of MgO are produced during an enthalpy change of 96.0 kJ?
- How much heat (in kilojoules) is absorbed when 7.50 g of  $\text{MgO}_{(s)}$  are decomposed into  $\text{Mg}_{(s)}$  (i.e. the reverse of the above reaction) at constant pressure? [Hint: think how you derived your answers for (b) and (d)]

5. When a 9.55 g sample of solid sodium hydroxide dissolves in 100.0 g of water in a calorimeter, the temperature rises from 23.6°C to 47.4°C. Assuming the specific heat of the solution is the same as that for water ( $c = 4.184 \text{ J g}^{-1} \text{ K}^{-1}$ ), calculate  $\Delta H$  (in  $\text{kJ mol}^{-1}$  of NaOH) for the dissolution process:

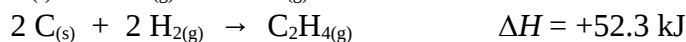


### 6. Hess's Law

- State Hess's Law.
- Why is Hess's Law important to thermochemistry?
- Use Hess's Law to calculate the enthalpy change ( $\Delta H$ ) for the reaction of ethylene ( $\text{C}_2\text{H}_4$ ) with fluorine gas ( $\text{F}_2$ ):



given the following reactions:

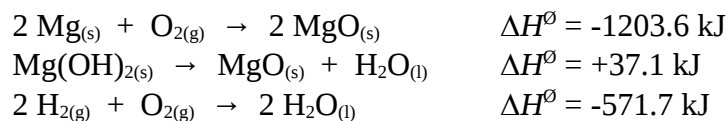


[Hint: manipulate the above given reactions so that when added together "unwanted" substances will be cancelled from the reactants and products to give the desired target equation  $\text{C}_2\text{H}_{4(g)} + 6 \text{F}_{2(g)} \rightarrow 2\text{CF}_{4(g)} + 4 \text{HF}_{(g)}$ . Remember to adjust the sign and magnitude of  $\Delta H$  for each manipulation]

### 7.

- What is meant by the term standard condition, with reference to enthalpy changes?
- What is meant by the term enthalpy of formation?

- (c) What is meant by the term standard enthalpy of formation?  
(d) Using Hess's Law calculate the standard enthalpy of formation ( $\Delta_f H^\ominus$ ) of solid  $\text{Mg(OH)}_2$  given the following data:



[Hint: manipulate the above given reactions so that when added together "unwanted" substances will be cancelled from the reactants and products to give the expression for the formation of solid  $\text{Mg(OH)}_2$ . Remember to adjust the sign and magnitude of  $\Delta H^\ominus$  for each manipulation]

### 8. Enthalpy of formation

Using values of  $\Delta_f H^\ominus$  (contained, for example, within Appendix A of the text book- Thermodynamic data for selected elements, compounds and ions), calculate the standard enthalpy change for each of the following reactions:

- (a)  $2 \text{SO}_{2(g)} + \text{O}_{2(g)} \rightarrow 2 \text{SO}_{3(g)}$   
(b)  $\text{Mg(OH)}_{2(s)} \rightarrow \text{MgO}_{(s)} + \text{H}_2\text{O}_{(l)}$   
(c)  $4 \text{FeO}_{(s)} + \text{O}_{2(g)} \rightarrow 2 \text{Fe}_2\text{O}_{3(s)}$   
(d)  $\text{SiCl}_{4(l)} + 2 \text{H}_2\text{O}_{(l)} \rightarrow \text{SiO}_{2(s)} + 4 \text{HCl}_{(g)}$