1021SCG Chemistry 1A – Module 3: Physicochemical Concepts
Week 8

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

Learning Objectives
You should be able to:

- Define enthalpy and entropy.
- Determine whether enthalpy and entropy is increasing or decreasing in a reaction.
- Predict what will happen when two substances are mixed, based on enthalpy and entropy considerations.

Workshop and Study Questions

1. Define and explain enthalpy and enthalpy change.

2. Calculate the maximum non-$p{\cdot}V$ work available from the oxidation of 1 mol of octane (C_8H_{18}) by oxygen at 25°C and standard pressure.

Substance	$\Delta_f G^{\varnothing}$ (kJ mol^{-1})
$C_8H_{18(l)}$	+17.3
$CO_{2(g)}$	-394.4
$H_2O_{(l)}$	-237.2
$O_{2(g)}$	0

3. In the following examples, is the enthalpy increasing or decreasing? Are the reactions endothermic or exothermic?

(a) A + B → C + D ΔH = -24 kJ
(b) X + Y → Z ΔH = 87 kJ
(c) E + D → F + 45 kJ
(d) G + J + 36 kJ → L + M

4. Tell whether each of the following is endothermic or exothermic and state which has minimum enthalpy, the reactants or the products:

(a) $PCl_{5(g)} \rightarrow Cl_{2(g)} + PCl_{3(g)}$ ΔH = 92.5 kJ
_____thermic and the _____ have minimum enthalpy.

(b) $2\ NH_{3(g)} + 92.4\ kJ \rightarrow N_{2(g)} + 3\ H_{2(g)}$
_____thermic and the _____ have minimum enthalpy.

(c) $CO_{(g)} + 3\ H_{2(g)} \rightarrow CH_{4(g)} + H_2O_{(g)} + 49.3\ kJ$
_____thermic and the _____ have minimum enthalpy.

(d) $Cl_{2(g)} \rightarrow Cl_{2(aq)}$ ΔH = -25 kJ
_____thermic and the _____ have minimum enthalpy.

5. When no other factors are considered, a reaction will move in such a way (left or right) in order to achieve a state of _____ enthalpy.

6. Given the equation: $2\ NH_{3(g)} + 92.4\ kJ \rightarrow N_{2(g)} + 3\ H_{2(g)}$
if only the enthalpy is considered, the _____ (reactant / products) will be favoured.

7. Given the equation: $Cl_{2(aq)} \rightarrow Cl_{2(g)}$ ΔH = 25 kJ
if only the enthalpy is considered, the _____ (reactant / product) will be favoured.

8. If the reaction: $CO_{(g)} + 3\ H_{2(g)} \rightarrow CH_{4(g)} + H_2O_{(g)} + 49.3\ kJ$
was proceeding to the right, the enthalpy would be _____ing. Is this a favourable change? _____.

9. If the reaction: $PCl_{5(g)} \rightarrow Cl_{2(g)} + PCl_{3(g)}$ ΔH = 92.5 kJ
was proceeding to the right, the enthalpy would be _____ing. Is this a favourable change? _____.

10. If the reaction: $Cl_{2(g)} \rightarrow Cl_{2(aq)}$ ΔH = -25 kJ
was proceeding to the right, the enthalpy would be _____ing. Is this a favourable change? _____.

11. If the reaction: $2\ NH_{3(g)} + 92.4\ kJ \rightarrow N_{2(g)} + 3\ H_{2(g)}$
was proceeding to the right, the enthalpy would be _____ing. Is this a favourable change? _____.

12. For each of the following, decide whether the reactants or the products have greater entropy:

(a) $I_{2(s)} \rightarrow I_{2(aq)}$
The _____ have greater entropy.

(b) $2\ NH_{3(g)} \rightarrow N_{2(g)} + 3\ H_{2(g)}$
The _____ have greater entropy.

(c) $NH_{3(g)} \rightarrow NH_{3(aq)}$
The _____ have greater entropy.

(d) $CO_{(g)} + Cl_{2(g)} \rightarrow COCl_{2(g)}$
The _____ have greater entropy.

(e) $MgCO_{3(s)} + 2\ HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$
The _____ have greater entropy.

A chemical reaction will favour the side with maximum entropy, if no other factors are considered. Also, a chemical reaction will tend toward a state of minimum enthalpy, if sufficient activation energy is available and no other factors are considered. Therefore, there is a tendency in nature towards minimum enthalpy and maximum entropy. If the two tendencies in a process oppose each other, the process will reach a state of equilibrium.

13. For each of the following reactions, decide which has minimum enthalpy (reactants or products), which has maximum entropy (reactants or products), and if the reactants are mixed, what will happen? (go to completion / reach a state of equilibrium / not occur at all).

(a) $PCl_{3(g)} + Cl_{2(g)} \rightarrow PCl_{5(g)}$ ΔH = -92.5 kJ
The _____ has/have minimum enthalpy.
The _____ has/have maximum entropy.
If PCl_3 and Cl_2 are put together, the reaction _____.

(b) $2\ NO_{2(g)} \rightarrow N_2O_{4(g)}$ + energy
The _____ has/have minimum enthalpy.
The _____ has/have maximum entropy.
If NO_2 was put in a flask, the reaction _____.

(c) $P_{4(s)} + 6\ H_{2(g)}$ + 37 kJ $\rightarrow 4\ PH_{3(g)}$
The _____ has/have minimum enthalpy.
The _____ has/have maximum entropy.
If $P_{4(s)}$ and $H_{2(g)}$ was put in a flask, the reaction _____.

(d) $2\ PbO_{(s)} + 4\ NO_{2(g)} + O_{2(g)} \rightarrow 2\ Pb(NO_3)_{2(s)}$ ΔH = - 597 kJ
The _____ has/have minimum enthalpy.
The _____ has/have maximum entropy.
If $PbO_{(s)}$ and $NO_{2(g)}$ were put in a flask, the reaction _____.