Chem12 Entropy : Notes/W.S.-20

The **entropy** of a system (symbol S) is a measure of the degree of disorder or randomness of that system.

The change in entropy is given by ΔS. ΔS = S(products) - S(reactants).

Important : **A natural tendency in nature is for matter to achieve a high entropy and low enthalpy**.

The following situations represent an increase (ΔS= +) in **entropy** :

a) an ionic solid is dissolved in water
b) a liquid becomes a gas
c) a solid becomes a liquid
d) few molecules become more molecules
e) there is an increase in the temperature

Exercise 1 : Predict whether ΔS is + or -.

a) $N_2O_4(g) \rightarrow 2NO_2(g)$
b) water freezes
c) $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$
d) $4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(g)$
e) $Zn(s) + 2H^+(aq) \rightarrow H_2(g) + Zn^{2+}(aq)$
f) $C_{14}H_{28}(s) + H_2(g) \rightarrow C_{14}H_{30}(s)$
g) $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$
h) $PCl_3(l) + Cl_2(g) \rightarrow PCl_5(s)$
i) $H_2O(g) \rightarrow H_2(g) + (1/2)O_2(g)$
j) $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$
k) $C_2H_2(g) + 2Cl_2(g) \rightarrow C_2H_2Cl_4(l)$
l) $H_2(g) + Br_2(l) \rightarrow 2HBr(g)$
m) $2HgO(s) \rightarrow 2Hg(l) + O_2(g)$
n) $2Al(s) + 3Br_2(l) \rightarrow Al_2Br_6(s)$
o) $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$
p) $PCl_3(l) + Cl_2(g) \rightarrow PCl_5(s)$
q) A quantity of gas is heated.

Entropy (continued)

In the Haber process, ammonia is made from $N_2(g)$ and $H_2(g)$ according to the **reversible** reaction :

$N_2(g) + 3H_2(g) <-> 2NH_3(g) + heat$ ($\Delta H = -92.6kJ$)

The double arrow means that the reaction is **reversible** and the system is said to be at **<u>equilibrium</u>**. Both the **forward** and **reverse** reactions occur at the same time. This reaction requires high temperature, high pressure and a **catalyst**.

This is an example of the two competing factors which drive a reaction. **S increases** (reverse reaction in this case) and **H decreases** (forward reaction in this case)

These two factors can be combined in the Gibbs equation :

$G = H - TS$ (T is the Kelvin temperature)

We can also write :

$\Delta G = \Delta H - T\Delta S$ (T constant)

If ΔG is -, the forward reaction is favored (**spontaneous**). If ΔG is +, the reverse reaction is favored. If $\Delta G = 0$, the system is at equilibrium. G is the Gibbs free energy. It is the maximum amount of energy available to do work.

ΔH	ΔS	
-	+	products favored (spontaneous)
+	-	reactants favored (not spon)
-	-	equilibrium (depends on T)
+	+	equilibrium (depends on T)

Exercise 2 : Determine what happens in the following reactions. It will go to completion (products favored), or it will not occur (reactants favored), or, it will reach equilibrium)

a) $2H_2(g) + O_2(g) \rightarrow 2H_2O(g) + 483kJ$
b) $C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -394kJ$
c) $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$ $\Delta H = +68kJ$
d) $N_2O_4(g) + 52kJ \rightarrow 2NO_2(g)$
e) $S(s) + O_2(g) \rightarrow SO_2(g)$ $\Delta H = -297kJ$
f) $A(g) + B(g) \rightarrow C(s)$ $\Delta H = -100kJ$
g) $XY(g) \rightarrow X(g) + Y(g) + heat$
h) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + heat$

i) $2H_2O(l)$ +energy -> $2H_2(g)$ +$O_2(g)$
j) $C_{12}H_{22}O_{11}(s)$ + $12O_2(g)$ -> $12CO_2(g)$ + $11H_2O(l)$ +heat

Answers : 1)a) +, b) -, c) +, d) +, e) +, f) -, g) -, h) -, i) +, j) -, k) -, l) +, m) +, n) -, o) -, p) -, q) +. 2)a) eq, b) pf, c) rf, d) eq, e) pf, f) eq, g) pf, h) eq, i) eq, j) pf.