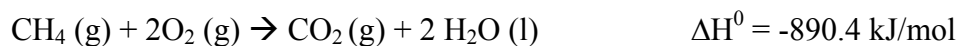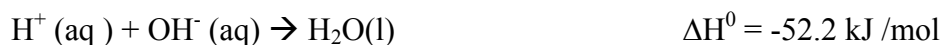**Spontaneous Processes**

There are two kinds of processes, spontaneous and non-spontaneous. A **spontaneous process** is the process that occurs under the given the set of conditions. Keep in mind that, it does not mean instantaneous process. A **non-spontaneous process** is the process that does not occur under the specified set of conditions. We encounter spontaneous processes every day, but we never realize that they are spontaneous. Here are few examples:
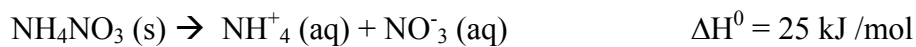
- Water freezes spontaneously below 0^0 C, and ice melts spontaneously above 0^0 C at 1 atm pressure (you see frost on your windshield on a cold night)

- Heat flows spontaneously from hotter object to colder object, but not other way around (that is how your room gets heated in the winter time)

- A water fall (Niagara Falls or dams) runs spontaneously downhill, but never uphill

- When you put a sugar in a cup of coffee, it dissolves spontaneously but it does not reappear in its original form

- Rusting of iron nail when it exposed to moisture and oxygen is spontaneous. So is tarnishing of the silverwares.

These few examples certainly indicate that spontaneous processes occur in one direction but not the other direction.

Now we would like to know why the processes (chemical reactions) are spontaneous in one direction. One would think that the energy might be playing the role. If that is the case, exothermic reactions - the decrease in energy going from reactants to products takes place – must be spontaneous. It is indeed the case with some reactions, like acid-base neutralization reactions and combustion of cooking gas (methane gas), which are respectively shown below:

$$H^+ (aq) + OH^- (aq) \rightarrow H_2O(l) \qquad\qquad \Delta H^0 = -52.2 \text{ kJ /mol}$$

$$CH_4 (g) + 2O_2 (g) \rightarrow CO_2 (g) + 2 H_2O (l) \qquad\qquad \Delta H^0 = -890.4 \text{ kJ/mol}$$

But there are some endothermic reactions that are spontaneous too. Like melting of ice and dissolution of ammonium nitrate:

$$H_2O (s) \rightarrow H_2O (l) \qquad\qquad \Delta H^0 = 6.01 \text{ kJ /mol}$$

$$NH_4NO_3 (s) \rightarrow NH^+_4 (aq) + NO^-_3 (aq) \qquad\qquad \Delta H^0 = 25 \text{ kJ /mol}$$

From these examples, it is clear that exothermicity favors spontaneity but does not guarantee the spontaneity because some endothermic reactions also have spontaneity. Therefore, the energy may not be the only the factor that involving in predicting the spontaneity, there must be some other factor that must be involved. That factor is known as entropy that is discussed in the following section.