Honors Chemistry Hour\_\_\_\_\_ Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Dr. Wexler  
Lab: Energy Changes in Chemical and Physical Processes (HS-PS1-4)  
Date\_\_\_\_\_  
  
**Background:**   
When a chemical or physical process occurs, heat (enthalpy) may be absorbed or released by the system, and the entropy, or disorder, of the system may increase or decrease.

Whether a process is spontaneous or not depends upon whether the change in enthalpy of the system and the change in entropy of the system are positive or negative. A process is always spontaneous if ∆Hsystem is negative and ∆Ssystem is positive, whereas a process is never spontaneous if the deltas are reversed.

If both deltas are positive or negative, the temperature determines whether or not the process will be spontaneous (High T if both positive, Low T if both negative). For a positive ∆H, when ΔS is positive, at high enough T the value of TΔS will be larger than ΔH, meaning the value for ΔG (free energy change) is negative according to the equation   
∆G = ∆H - T∆S. Therefore, ΔS must be positive and T relatively large for an endothermic reaction to be spontaneous (∆G is negative).

**Objectives:**Measure the temperature of four systems before and after a chemical or physical process.  
Calculate the change in temperature of each system during the process.  
Observe physical changes that occur during each process.  
Deduce whether each process is spontaneous.

**Special Materials:**NH4Cl (s)  
NaHCO3 (s)  
6M HCl  
24-well microplate  
Small scoops  
Thermometer  
Toothpicks  
Scissors  
Distilled water

**Pre-Lab:**1. How are exothermic and endothermic reactions/processes different?

2. Is ∆Hsystem positive or negative in an exothermic process? In an endothermic process?

3. What usually happens to the entropy of a system when a solid or liquid dissolves to form a solution?  
4. What is the equation that relates free energy change, enthalpy change, entropy change, and temperature?

5. Is a process spontaneous when free energy change is positive or negative?

**Procedure:**  
1. Measure and record the air temperature. Assume all stock solutions are at air temperature.  
2. Place a small amount of ammonium chloride in wells A1 and B1 on the microplate.  
3. Place a small amount of sodium bicarbonate in wells A2 and B2 on the microplate.  
4. Add 0.5ml distilled water to well A1. Stir with a toothpick. Measure and record the temperature and any physical changes you observe.  
5. Add 0.5ml distilled water to well A2. Stir, measure, record as before.  
6. Repeat with wells B1 and B2, using 6M HCl.

**Results:**Your data table should look like this:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Well | Contents | Temperature (°C) | | Temperature change (°C) | Observations |
| Before mixing | After mixing |
| A1 | NH4Cl + H2O |  |  |  |  |
| A2 | NaHCO3 + H2O |  |  |  |  |
| B1 | NH4Cl + HCl |  |  |  |  |
| B2 | NaHCO3 + HCl |  |  |  |  |

**Conclusions:**1. Classify the process that occurred in each well as endothermic or exothermic.  
2. Is ∆H for each process positive or negative?  
3. Is ∆S for each process positive or negative? (Hint: think about the physical change that occurred in each process)  
4. Under what conditions will each process occur spontaneously?

**Questions:**1. Diamonds are highly valued as gems for jewelry and are also used in industry to make abrasives and cutting tools. Both diamond and graphite (pencil lead) are made of pure carbon. Under what conditions, if any, is the conversion of graphite to diamond spontaneous (∆Hsystem = +1.90 kJ)? Explain.  
(Note: the entropy (S) of diamond is +2.4 J/°K and the entropy (S) of graphite is +5.7 J/°K)

2. Benzene can be added to gasoline to make an alternative fuel. Is the combustion of benzene spontaneous at 25°C? (Note: In the combustion reaction, ∆Hsystem = -6535kJ and ∆Ssystem = -439.1 J/K)

3. Ammonia (NH3) is used as a refrigerant and as a starting material in the manufacture of fertilizer and explosives. Under the right conditions, solid NH4Cl decomposes into NH3 and HCl. In this reaction, ∆Hsystem = +176kJ and ∆Ssystem = +285 J/K. What is the lowest temperature at which the reaction will occur spontaneously?  
(Note: Assume ∆Gsystem = -0.1 kJ at that temperature)