Gibbs Free Energy

This worksheet will cover the topic of gibbs free energy as it pertains to thermodynamics. Gibbs free energy (also simply known as free energy or $\Delta G°$) is the amount of energy available to perform work during chemical processes. This worksheet will discuss Gibbs free energy conceptually, as well as mathematically. It will also relate the concept of formation energy to other thermodynamic values, and the rate constant K, allowing you to make predictions about the spontaneity of a reaction.
Note Prior conceptual knowledge on ΔH, ΔS, and K_{eq} concepts is required to complete worksheet*

1. The reaction $H_{2\,(g)} + F_{2\,(g)} \rightarrow 2\,HF_{(g)}$ has a standard enthalpy ($\Delta H°$) of -546.6 kJ/mol, and a standard entropy ($\Delta S°$) of 160.3 J/mol*K. Calculate the $\Delta G°$ for the reaction at 298 K

    a. Is the reaction spontaneous? Why or why not?

2. Calculate $\Delta G°$ in kJ for the following reactions, using the thermodynamic data provided in the table.

    (Hint : $\boldsymbol{\Delta} G° \;=\; \sum \boldsymbol{\Delta} G°\, products \;-\; \sum \boldsymbol{\Delta} G°\, reactants$)

    a. $SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(l)}$

    b. $2\,NH_4Cl_{(s)} + CaO_{(s)} \rightarrow CaCl_{2(s)} + H_2O_{(l)} + 2\,NH_{3(g)}$

    c. $CaSO_{4(s)} + 2\,HCl_{(g)} \rightarrow CaCl_{2(s)} + H_2SO_{4(l)}$

Compound	$\Delta G°$ (kJ/mol)
$H_2SO_{4(l)}$	-696.07
$NH_4Cl_{(s)}$	-202.97
$H_2O_{(l)}$	-237
$SO_{3(g)}$	-371.08
$CaSO_{4(s)}$	-1321.85
$HCl_{(g)}$	-95.31
$CaCl_{2(s)}$	-750.2
$NH_{3(g)}$	-16.45
$CaO_{(s)}$	-604.54

3. When solid KI is dissolved in water, a cooling mixture occurs because the solution process is endothermic. Explain, in terms of what happens to the molecules and ions, why this mixing occurs spontaneously?

4. The value of ΔG° for the following reaction is negative at low temperatures but positive at high temperatures. Explain.

   $N_{2(g)} + 3\ H_{2(g)} \rightarrow 2\ NH_{3(g)}$ $\Delta H° = -92.2$ kJ/mol

5. The formation of methane gas, represented by the equation $CO_{(g)} + 3\ H_{2(g)} \rightarrow CH_{4(g)} + H_2O_{(g)}$, has a equilibrium constant of 1.4×10^3 at 303 K.

   a. Without a calculation, predict the algebraic sign of ΔG°.

   b. Using the equation $\Delta G° = -RTln(K)$, solve for ΔG°.