Gibbs Free Energy Problems

From the web and edited by S.L. Shultz

1. Calculate ΔH° and ΔS° for the following reaction and decide in which direction each of these factors will drive the reaction.

(HINT: Use Hess's Law: ΔH°_{f}, or S°_{f}, or $G^{\circ}_{f} = \Sigma$H, or S, or G (products) - Σ H,S,G (reactants))

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g)$$

Use these following formation values at standard temperatures:

Compound	**ΔH°_{f} (kJ/mol)**	**S° (J/mol-K)**
$N_2(g)$	**0**	**191.61**
$H_2(g)$	**0**	**130.68**
$NH_3(g)$	**-46.11**	**192.45**

2a. Calculate ΔH° and ΔS° for the following reaction:

$$NH_4NO_{3(s)} + H_2O_{(l)} \rightarrow NH_4^+{}_{(aq)} + NO_3^-{}_{(aq)}$$

Compound	ΔH°_{f} (kJ/mol)	S° (J/mol-K)
$NH_4NO_{3(s)}$	-365.56	151.08
$NH_4^+{}_{(aq)}$	-132.51	113.4
$NO_3^-{}_{(aq)}$	-205.0	146.4

2b. Use the results of this calculation to determine the value of ΔG° for this reaction at 25°C, and explain why NH_4NO_3 spontaneously dissolves in water at room temperature.

3. Use the following values of ΔH° and ΔS to predict whether the following reaction is spontaneous at 25°C:

ΔH° = -92.22 kJ (favorable)

ΔS° = -198.75 J/K (unfavorable)

$$N_{2(g)} + 3\,H_{2(g)} \rightleftharpoons 2\,NH_{3(g)}$$

4. Predict whether the following reaction is still spontaneous at 500°C:

$$N2(g) + 3\,H2(g) \rightleftharpoons 2\,NH3(g)$$

Assume that the values of ΔH° and ΔS° used in Problem 3 are still valid at this temperature.

5. Which of the following processes will lead to an increase in the entropy of the system?

(a) $N_2(g) + 3H_2(g) \rightleftharpoons 2\,NH_3(g)$

(b) $H_2O(l) \rightleftharpoons H_2O(g)$

(c) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

(d) $NH_4NO_3(s) + H_2O(l) \rightarrow NH_4^+(aq) + NO_3^-(aq)$

6. Use ΔG°=32.96 kJ to calculate the equilibrium constant for the following at 25°C, where R is the universal Gas Law Constant which is R= 8.314 J/K•mol. Make sure you convert to J or kJ depending on your preference in the units in the problem.

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g)$$