1. Consider the Gibbs free energy relationship

$$\Delta G = \Delta H - T\Delta S$$

Circle the temperatures at which the following reactions would be spontaneous:

Reaction	ΔS	ΔH	Spontaneous ($\Delta G < 0$) at …			
(A)	positive	negative	all Temps	high Temps	low Temps	no Temps
(B)	positive	positive	all Temps	high Temps	low Temps	no Temps
(C)	negative	positive	all Temps	high Temps	low Temps	no Temps
(D)	negative	negative	all Temps	high Temps	low Temps	no Temps

2. Ammonia (NH_3) is a weak base in water with a $K_b = 1.8 \times 10^{-5}$.

A) Calculate the standard Gibbs free energy change ($\Delta G°$) for the dissociation of ammonia in water using the following table of thermodynamic properties at 298.15 K.

	NH_3 (aq)	NH_4^+ (aq)	H_2O (l)	OH^- (aq)
$\Delta H° \left(\frac{\text{kJ}}{\text{mol}}\right)$	−80.3	−132.5	−285.8	−230.0
$\Delta S° \left(\frac{\text{J}}{\text{mol} \cdot \text{K}}\right)$	111.3	113.4	69.9	−10.8

B) Calculate the equilibrium constant (K_b) for NH_3 based on its $\Delta G°$ from part A.

$$\Delta G° = -RT \ln K \quad K = e^{-\Delta G°/RT} \quad R = 8.314 \frac{\text{J}}{\text{mol} \cdot \text{K}}$$

C) What are standard conditions? This is what the "°" symbol denotes in $\Delta G°$. Is the dissociation of ammonia spontaneous under standard conditions?

D) Do you think typical aqueous solutions of weak acids/bases are at standard conditions? The answer is no! Why?

Now calculate the Gibbs free energy change (ΔG) when $[NH_3]$ = 0.60 M and $[NH_4^+] = [OH^-]$ = 0.0010 M at 298.15 K. Is this process spontaneous now?

$$\Delta G = \Delta G° + RT \ln Q$$

3. For each reaction, predict the sign of the entropy change.

A) $Ag^+ (aq) + Cl^- (aq) \rightarrow AgCl (s)$

B) $2\ C_6H_6 (l) + 15\ O_2 (g) \rightarrow 6\ CO_2 (g) + 3\ H_2O (l)$

4. What is the free energy change (ΔG) for the process shown under the specified conditions?

$$2\ NH_3 (g) \rightleftharpoons N_2 (g) + 3\ H_2 (g) \qquad \Delta G° = 33.0\ \text{kJ/mol}$$

$T = 25\ °C$ $P_{NH_3} = 12.9\ \text{atm}$ $P_{N_2} = 0.870\ \text{atm}$ $P_{H_2} = 0.250\ \text{atm}$