1. [10 points] Predict the sign of the molar Gibbs free energy for the process $\text{H}_2\text{O}(s) \rightarrow \text{H}_2\text{O}(l)$ at 1 atm and 1°C, 0°C, and –1°C, respectively.
   A) +, 0, and –
   B) –, 0, and +
   C) +, +, and –
   D) –, –, and +
   E) +, 0, and +

2. [10 points] The vapor pressure of water above 40 mL of water in a 100 mL container is 23.8 Torr at 25°C. What is the vapor pressure of the water if the volume of the container is changed to 50 mL?
   A) about 25 Torr
   B) about 20 Torr
   C) 23.8 Torr
   D) 47.6 Torr
   E) 11.9 Torr

3. [25 points] Estimate the enthalpy of vaporization of CCl₄ given that at 25°C and 58°C its vapor pressure is 107 and 405 Torr, respectively. Assume that the enthalpy of vaporization is independent of the temperature.
   A) 486 J·mol⁻¹
   B) 48.6 kJ·mol⁻¹
   C) 142 kJ·mol⁻¹
   D) 3.98 kJ·mol⁻¹
   E) 33.1 kJ·mol⁻¹
4. [15 points] The phase diagram for a pure substance is given below. What is the critical temperature?

![Phase Diagram]

A) 0 K  
B) 250 K  
C) 300 K  
D) 400 K  
E) 200 K

5. [25 points] Consider the reaction

$$2\text{Fe}_2\text{O}_3(s) + 3\text{C}(s) \rightarrow 4\text{Fe}(s) + 3\text{CO}_2(g)$$

$$\Delta H^\circ = 462 \text{ kJ}, \Delta S^\circ = 558 \text{ J-K}^{-1}$$

Calculate the equilibrium constant for this reaction at 525°C.

A) $3.04 \times 10^{-3}$  
B) $8.07 \times 10^{-2}$  
C) $5.20 \times 10^{-7}$  
D) $1.9 \times 10^{6}$  
E) $2.18 \times 10^{-2}$

6. [15 points] Consider the reaction

$$2\text{SO}_2(g) + \text{O}_2(g) \leftrightarrow 2\text{SO}_3(g)$$

At equilibrium at a certain temperature, the partial pressures of SO$_2$(g), O$_2$(g), and SO$_3$(g) are 0.0012, 0.18, and 2.2 bar, respectively. Argon is introduced into the reaction vessel until the partial pressure of argon is 5.0 bar. Predict the final partial pressures of the reactants and products.
7. [25 points] The equilibrium constant for the reaction
\[ \text{HNO}_2(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{NO}_2^-(aq) + \text{H}_3\text{O}^+(aq) \]
is \(4.3 \times 10^{-4}\) at 25°C. Will nitrous acid spontaneously dissociate when
\([\text{HNO}_2(aq)] = 1.0 \text{ M}\) and \([\text{NO}_2^-(aq)] = [\text{H}_3\text{O}^+(aq)] = 1.0 \times 10^{-5} \text{ M}\)?
Show your calculations.

8. [15 points] Lake Mälaren was allegedly created by the famous Norse goddess Gefjun and is located in central Sweden, with the city of Stockholm abutting its eastern end. Mälaren drains into the Baltic Sea near Stockholm through a few canals. Interestingly, in the winter, Mälaren freezes before the Baltic waters which seem to freeze first near Mälaren. Explain.

9. [25 points] In an admittedly extraordinary turns of events, Gefjun has teleported you onto the middle of frozen Mälaren in the dead of winter. She needs your chemistry expertise to improvise up some antifreeze for her vehicle, such that it has a freezing point of -1.0 °C. Gefjun waves her hand and melts some snow which gets you 1000 mL of pure liquid water in a bucket. She also supplies some Absolut vodka which can be crudely described as 40% of ethanol by weight in water. Thankfully, since you have been studying for the general chemistry test, you remember that the freezing point constant for water is 1.86 K×kg/mol. How much Absolut do you need to add to your bucket of water to get the desired antifreeze?

10. [15 points] Trickstress Gefjun offers to teleport you back to College Station, but, oddly enough, only if you inform her of what the total vapor pressure of antifreeze (from question 9) would be in College Station (where it is +25 °C). You of course recall that the vapor pressures of pure ethanol and pure water at this temperature are 59.0 and 23.8 Torr, respectively. Assuming ideal behavior, what answer will set you free?
Answer Key

1. B
2. C
3. E
4. D
5. B
6. They all stay the same.
7. Yes
8.
9.
10.