

Chem 260 – First Exam

On the following pages are six problems covering material in thermodynamics. Read each problem carefully and think about how best to approach the problem before you begin work. If you aren't sure how to begin a problem, then move on; working on a new problem may stimulate an idea that helps you solve the more troublesome one. For problems requiring a written response, be sure that your answer directly and clearly answers the question. No brain dumps allowed! Generous partial credit is available, but only if you include sufficient work for evaluation.

Problem 1 ____/14

Problem 4 ____/19

Problem 2 ____/19

Problem 5 ____/14

Problem 3 ____/19

Problem 6 ____/15

Total_____

A few constants and thermodynamics values are given here:

$$d_{\text{H}_2\text{O}} = 1.00 \text{ g/mL}$$

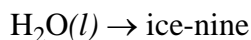
$$S_{\text{H}_2\text{O}} = 4.184 \text{ J/g}\cdot^\circ\text{C}$$

$$R = 8.314 \text{ J/mol}_{\text{rxn}}\cdot\text{K}$$

$$F = 96,485 \text{ J/V}\cdot\text{mol } e^-$$

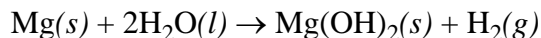
species	ΔH_f° (kJ/mol _{rxn})	ΔG_f° (kJ/mol _{rxn})	S° (J/mol _{rxn} ·K)
C(s, <i>graphite</i>)	0	0	5.7
CO(g)	-110.5	-137.2	197.7
CO ₂ (g)	-393.5	-394.4	213.7
Fe(s)	0	0	27.3
FeO(s)	-272.0	-255.0	61.0
Fe ₂ O ₃ (s)	-842.2	-742.2	87.4
Fe ₃ O ₄ (s)	-1118.4	-1015.4	146.4
H ₂ (g)	0	0	130.7
H ₂ O(g)	-241.8	-228.6	188.2
H ₂ O(l)	-285.8	-237.1	69.9
Mg(s)	0	0	32.7
Mg(OH) ₂ (s)	-924.5	-833.6	63.2

Problem 1. In Kurt Vonnegut's novel *Cat's Cradle*, a hypothetical substance known as ice-nine destroys the world. Ice-nine is described as a crystalline compound consisting of water molecules arranged differently than those in normal ice. This alternative arrangement of water molecules gives ice-nine its unique properties, one of which is that its melting point is 45.8°C. When a seed crystal of ice-nine is introduced into the ocean, the water in the ocean instantly solidifies. Based on this description, what can you say about the sign of ΔH° for the reaction



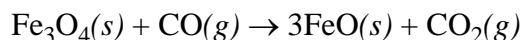
at room temperature. The possible answers are ΔH° is negative, ΔH° is positive, ΔH° is zero or there is insufficient information to determine the value of ΔH° . Clearly justify your choice in two to three sentences.

Problem 2. Several companies market prepared foods that are packaged in self-heating containers. One such product consists of a pouch containing the food, which sits on top of a Styrofoam tray. On the bottom of the tray is a mesh bag containing magnesium metal. To use the device the food pouch is removed, a packet containing salt water is opened and added to the tray, and the food pouch replaced. The reaction



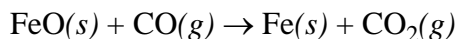
liberates heat, which raises the temperature of the salt water, heating the food. Suppose that a typical package contains 2.00 g of Mg and a packet containing 0.125 L of salt water with a density of 1.07 g/mL. If the initial temperature of the water is 25.0°C, what is its final temperature? You may assume that the specific heat of salt water is the same as that for deionized water.

Problem 3. Over three thousand years ago ancient metal workers first developed the technique of smelting iron ore in the presence of charcoal to obtain metallic iron. The same general process continues to find use in the modern blast furnace. The chemistry of the process is relatively simple, consisting of a series of steps in which iron ore, Fe_2O_3 , is reduced first to Fe_3O_4 , then to FeO and, finally, to Fe . The second step in the process is



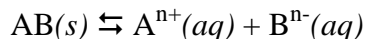
Is this reaction favorable at the typical blast furnace temperature of 1000 K to 2000 K assuming standard state conditions?

Problem 4. The final step in the process of smelting iron is



This reaction is unfavorable under standard state conditions at a blast furnace's operating temperatures. Nevertheless, the reaction is favorable and does occur. Knowing that K_{eq} for this reaction is $P_{\text{CO}_2}/P_{\text{CO}}$, that ΔH° is $-11.0 \text{ kJ/mol}_{\text{rxn}}$ and that ΔS° is $-17.7 \text{ J/mol}_{\text{rxn}} \cdot \text{K}$, what must be true about the value of Q at 1300 K?

Problem 5. Consider the following generic reaction for the solubility of a sparingly soluble ionic salt

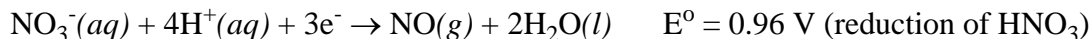
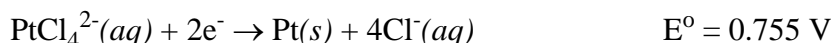


for which the equilibrium constant is

$$K = [A^{n+}][B^{n-}]$$

Most sparingly soluble ionic salts are more soluble at higher temperatures, but in a few cases solubility decreases at higher temperatures. In two to four sentences, offer a valid thermodynamic explanation for this difference in the effect of temperature on solubility.

Problem 6. In 800 AD the Islamic alchemist Jabir Ibn Hayyan discovered that metals, such as gold, that could not be dissolved in HCl or HNO₃ could sometimes be dissolved in a mixture of the two acids. This mixture eventually was called *aqua regia* or “royal water.” Given the following standard-state reduction potentials:



explain why Pt can be dissolved in *aqua regia* but not in HCl or in HNO₃. Be sure your answer is clear and easy to follow! Support your answer with relevant calculations. Assume that standard state conditions apply.