1. Entropy questions: PICK TWO
(6 each)

1.00 mole of water freezes at 0.00°C and 1 atm, releasing 6.01 kJ of heat. Calculate the change in entropy and free energy for the process.

Calculate the entropy change when a 10-molecule crystal changes from having all 10 molecules lines up identically in a perfect crystal to having one of the ten molecules rotated by 180°.
1. Entropy questions, continued: PICK TWO

Determine the change in entropy when a 1.043 kg iron vessel containing 1.107 kg of water is heated from 296.5 K to 307.2 K. Assume that any heat capacities you might need are independent of temperature, over this range.
2. Consider the reaction of hypochlorite ion and sulfite ion, as seen in the demonstration done in class.

\[
\text{SO}_3^{2-} (\text{aq}) + \text{OCl}^- (\text{aq}) \rightarrow \text{SO}_4^{2-} (\text{aq}) + \text{Cl}^- (\text{aq})
\]

(5) Use the information at the front of the exam to calculate the value of \(\Delta H\) for this reaction.

(5) The reaction is performed in an adiabatic calorimeter at constant pressure, by combining 50.0 mL of bleach with 50.0 mL of 0.80 M sodium sulfite. The heat capacity of the calorimeter and solution is 419 J/K. A temperature rise of 19.74°C is observed. What is the enthalpy change, for the amounts used in this reaction.
2. Continued…

(6) Assuming the hypochlorite ion of the Chlorox is the limiting reagent of the reaction, what is the concentration of hypochlorite ion in the bleach, in moles per liter?
3. Multiple Choice. Circle the correct responses for each question. There may be MORE THAN ONE correct answer. You will receive a point for each letter that is correctly circled and for each that is correctly left uncircled. It is not in your best interest to guess!

(4) Consider the weak acid, HA with a $K_a$ of $10^{-5}$. Which response is the most accurate picture of a 1 M aqueous solution of HA on a molecular level?

A. Less $A^-$ and $H_3O^+$ compared to HA than shown in A.
B. More $A^-$ and $H_3O^+$ compared to HA than shown in B.

(4) The reaction of $O_2(g)$ and $N_2(g)$ to form $N_2O(g)$ is an endothermic process. The reaction of $N_2(g)$ and $H_2(g)$ to form $NH_3(g)$ is an exothermic process. Which substance has the LOWEST value of $\Delta H^\circ_f$?

A. $O_2$ (g)
B. $N_2O$ (g)
C. $NH_3$ (g)
D. $H_2$ (g)

(4) For acetic acid, $CH_3COOH$, the $pK_a$ is 5. What would happen if you added concentrated HCl to a 1 M solution of acetic acid?

A. The pH would increase.
B. The pH would decrease.
C. The concentration of $CH_3COO^-$ would increase.
D. The concentration of $CH_3COOH$ would increase.

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3. Multiple Choice, continued.

(4) The formation of ozone from oxygen is an endothermic reaction, with $\Delta H = 85$ kJ/mol.

$$3 \text{O}_2 (g) \rightarrow 2 \text{O}_3 (g)$$

If the partial pressure of O$_3$ and O$_2$ are both 1 atm, at what relative temperature would you expect this reaction to be spontaneous?

A. At low temperature.
B. At high temperature.
C. At all temperatures.
D. At no temperature.

(4) For the following reaction, which statements are true?

$$\text{HPO}_4^{2-} + \text{NH}_4^+ \rightleftharpoons \text{H}_2\text{PO}_4^- + \text{NH}_3$$

A. NH$_4^+$ is acting as an acid and HPO$_4^{2-}$ is acting as a base.
B. The conjugate acid of NH$_4^+$ is NH$_3$.
C. The conjugate base of NH$_4^+$ is NH$_3$.
D. HPO$_4^{2-}$ is acting as an acid and NH$_4^+$ is acting as a base.

(4) For a reaction with a $\Delta G^\circ$ less than zero

A. The formation of products is spontaneous, under standard state conditions.
B. The reaction goes to completion.
C. The products are thermodynamically more stable than the reactants.
D. The reaction is exothermic.

(4) A 1.0 g block of aluminum (C = 0.9 J/g K) at 100°C and a 1.0 g block of iron (C = 0.4 J/g K) at 0°C are both placed in a beaker containing 10.0 mL of water (C = 4.2 J/g K) at 50°C. What will be the final temperature of the water?

A. 50°C
B. <50°C
C. >50°C
D. insufficient information to tell the final temperature
3. Multiple Choice, continued.

(4) For the reaction shown in the following graph of Gibbs free energy vs. extent of reaction, which statements are true?

\[
\text{extent of reaction}
\]

A. At equilibrium, products are favored over reactants.
B. \( \Delta G^\circ \) for the reaction is negative.
C. If pure products are placed in a reaction vessel, reactants will spontaneously form.
D. Reactants are thermodynamically more stable than products.

(4) Consider a 100 mL sample of 0.5 M HCl solution. Which of the following statements is true of this solution?

A. pH is less than 0.
B. More 0.5 M NaOH would be required to neutralize the solution than for the same volume and concentration of a weaker acid.
C. The pK\(_a\) is a really small number.
D. The K\(_a\) is a really small number.
3. Multiple Choice, continued.

Consider the following two titration curves.

Which of the following statements are true:

A. A is a weaker acid than B.
B. A and B could be the same weak acid, but more experiments would be required to confirm this.
C. A and B could be different weak acids, with the same concentration and sample volume, titrated with the same concentration of base.
D. A and B could be the same weak acid with the same concentration and sample volume, titrated with different concentrations of base.
4. Choose THREE of the solutions below and calculate the pH
(5 each)
0.130 M ammonium chloride
0.243 M benzoic acid
4. Continued (CHOOSE THREE, 5 points each)

0.050 M sodium formate

0.163 M ammonia
5. Consider the following chemical reaction:

\[ \text{H}_2 (g) + \text{Cl}_2 (g) \rightleftharpoons 2 \text{HCl} (g) \]

\[ K_c = 4 \times 10^{31} \text{ at } 300 \text{ K} \]
\[ K_c = 4 \times 10^{18} \text{ at } 500 \text{ K} \]

(9) Circle all the words or equations below that correctly describe this process.

- Exothermic
- Endothermic
- \( \Delta G^\circ < 0 \text{ at both temperatures} \)
- \( \Delta H = \Delta H^\circ \text{ f of HCl} \)
- \( \Delta H = \text{bond enthalpy of H-Cl bond} \)
- \( \Delta S > 0 \)
- favors products at equilibrium
- favors reactants at equilibrium
- \( K_p > K_c \)

(8) If 1.0 M of HCl is placed in a sealed 5.00 L vessel and heated to 500 K, what will be the concentration of each species at equilibrium? Show clear, complete calculations and words describing any assumptions made. Show evidence for the validity of any approximation you make.

\[ [\text{HCl}] = \]

\[ [\text{H}_2] = \]

\[ [\text{Cl}_2] = \]