Chemistry 223 Exam I Cover Sheet

Spring XXXX

Name: _____

This exam consists of twenty-five (25) multiple-choice questions and four (4) short answer questions with five points of extra credit.

A periodic table and scratch paper are available for you to use on this exam.

Before you start:

- Write your first and last name in the space above
- Sign the integrity statement below. **Failing to sign the integrity statement on this exam imparts an immediate grade of zero.**
- For multiple choice questions: clearly enter your letter answer in the appropriate location. **Circle** the letter which corresponds to your answer.
- For short answer questions: clearly **circle** your final answer, showing all work.

Point values and your exam score will be summarized on the final page.

Integrity statement:

I have neither given nor received aid on this exam.

_____

Your signature

1. A statement of the second law of thermodynamics is that

   a. spontaneous reactions are always exothermic.
   b. energy is conserved in a chemical reaction.
   c. the Gibbs free energy is a function of both enthalpy and entropy.
   d. $\Delta S = - \Delta H$ for any chemical reaction.
   e. in a spontaneous process, the entropy of the universe increases.

Letter answer to question #1: _____

2. As defined by Ludwig Boltzmann, the third law of thermodynamics states that

   a. in a spontaneous process, the entropy of the universe increases.
   b. there is no disorder in a perfect crystal at 0 K.
   c. the total entropy of the universe is always increasing.
   d. the total energy of the universe is constant.
   e. mass and energy are conserved in all chemical reactions.

Letter answer to question #2: _____

3. Which of the following processes involves a decrease in entropy?

   a. the decomposition of $NH_3(g)$ into $H_2(g)$ and $N_2(g)$ gas
   b. the dissolution of NaCl in water
   c. the condensation of steam to liquid water
   d. the evaporation of ethanol
   e. the sublimation of dry ice (i.e., $CO_2(s)$)

Letter answer to question #3: _____

4. Calculate the standard entropy change for the following reaction,

   $$2\ HgO(s) \rightleftharpoons 2\ Hg(l) + O_2(g)$$

   given $S°[HgO] = 70.3$ J/K·mol, $S°[Hg(l)] = 76.0$ J/K·mol, and $S°[O_2(g)] = 205.1$ J/K·mol.

   a. -216.5 J/K
   b. +210.8 J/K
   c. +216.5 J/K
   d. +351.4 J/K
   e. +497.7 J/K

Letter answer to question #4: _____

5. Predict the signs of ΔH, ΔS, and ΔG for the evaporation of water 25 °C.

   a. $\Delta H > 0, \Delta S < 0, \Delta G < 0$
   b. $\Delta H > 0, \Delta S > 0, \Delta G > 0$
   c. $\Delta H < 0, \Delta S > 0, \Delta G < 0$
   d. $\Delta H < 0, \Delta S > 0, \Delta G > 0$
   e. $\Delta H < 0, \Delta S < 0, \Delta G < 0$

Letter answer to question #5: _____

6. The dissolution of ammonium nitrate occurs spontaneously in water at 25 °C. As NH_4NO_3 dissolves, the temperature of the water decreases. What are the signs of ΔH, ΔS, and ΔG for this process?

   a. $\Delta H > 0, \Delta S < 0, \Delta G > 0$
   b. $\Delta H > 0, \Delta S > 0, \Delta G > 0$
   c. $\Delta H > 0, \Delta S > 0, \Delta G < 0$
   d. $\Delta H < 0, \Delta S < 0, \Delta G < 0$
   e. $\Delta H < 0, \Delta S > 0, \Delta G > 0$

Letter answer to question #6: _____

7. At what temperatures will a reaction be spontaneous if $\Delta H = -76.0$ kJ and $\Delta S = +231$ J/K?

   a. All temperatures below 329 K
   b. Temperatures between 0 K and 231 K
   c. All temperatures above 329 K
   d. The reaction will be spontaneous at any temperature.
   e. The reaction will never be spontaneous.

Letter answer to question #7: _____

8. Calculate $\Delta G°_{rxn}$ for the reaction below at 25.0 °C

   $CO(g) + H_2O(l) \rightarrow H_2(g) + CO_2(g)$

   given $\Delta G°_f [CO(g)] = -137.2$ kJ/mol, $\Delta G°_f [H_2O(l)] = -237.2$ kJ/mol and $\Delta G°_f [CO_2(g)] = -394.4$ kJ/mol.

   a. -768.8 kJ
   b. -294.4 kJ
   c. -20.0 kJ
   d. +20.0 kJ
   e. +768.8 kJ

Letter answer to question #8: _____

9. Write the expression for K for the reaction: $Al_2S_3(s) \rightleftharpoons 2\ Al^{3+}(aq) + 3\ S^{2-}(aq)$

   a. $K = [Al^{3+}]^2[S^{2-}]^3$
   b. $K = [Al^{3+}][S^{2-}]$
   c. $K = [2\ Al^{3+}][3\ S^{2-}]$
   d. $K = \dfrac{[Al_2S_3]}{[Al^{3+}]^2[S^{2-}]^3}$
   e. $K = \dfrac{[Al^{3+}]^2[S^{2-}]^3}{[Al_2S_3]}$

Letter answer to question #9: _____

10. Write the expression for K_p for the reaction: **$2\ HBr(g) \rightleftharpoons H_2(g) + Br_2(l)$**

a. $K_p = \dfrac{P_{HBr}^2}{P_{Br_2} P_{H_2}}$

b. $K_p = \dfrac{P_{H_2}}{P_{HBr}^2}$

c. $K_p = P_{HBr}^2$

d. $K_p = \dfrac{P_{HBr}^2}{P_{H_2}}$

e. $K_p = \dfrac{P_{H_2} P_{Br_2}}{P_{HBr}^2}$

Letter answer to question #10: _____

11. A 4.00 L flask is filled with 0.75 mol SO_3, 2.50 mol SO_2, and 1.30 mol O_2, and allowed to reach equilibrium. Predict the effect on the concentrations of SO_3 as equilibrium is achieved by using Q, the reaction quotient. Assume the temperature of the mixture is chosen so that $K_c = 12$. $2\ SO_3(g) \rightleftharpoons 2\ SO_2(g) + O_2(g)$

a. $[SO_3]$ will decrease because Q > K.
b. $[SO_3]$ will decrease because Q < K.
c. $[SO_3]$ will increase because Q < K.
d. $[SO_3]$ will increase because Q > K.
e. $[SO_3]$ will remain the same because Q = K.

Letter answer to question #11: _____

12. This reaction below is studied at a high temperature. **$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$** At equilibrium, the partial pressures of the gases are as follows: $PCl_5 = 1.8 \times 10^{-2}$ atm, $PCl_3 = 5.6 \times 10^{-2}$ atm, and $Cl_2 = 3.8 \times 10^{-4}$ atm. What is the value of K_p for the reaction?

a. 3.8×10^{-7}
b. 1.2×10^{-3}
c. 3.1
d. 8.5×10^{2}
e. 2.6×10^{6}

Letter answer to question #12: _____

13. A sealed tube is prepared with 1.07 atm PCl_5 at 500 K. The PCl_5 decomposes until equilibrium is established; 1.54 atm is the equilibrium pressure of the tube. Calculate K_p using the equation: **$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$**

a. 0.052
b. 0.20
c. 0.27
d. 0.37
e. 2.2

Letter answer to question #13: _____

14. Hydrogen monoiodide can decompose into hydrogen and iodine gases: **$2\ HI(g) \rightleftharpoons H_2(g) + I_2(g)$ $K_p = 0.016$** at -17 °C. If 0.820 atm of HI(g) is sealed in a flask at -17 °C, what is the pressure of each gas when equilibrium is established?

a. HI = 0.576 atm, H_2 = 0.096 atm, I_2 = 0.096 atm
b. HI = 0.654 atm, H_2 = 0.083 atm, I_2 = 0.083 atm
c. HI = 0.728 atm, H_2 = 0.092 atm, I_2 = 0.092 atm
d. HI = 0.737 atm, H_2 = 0.083 atm, I_2 = 0.083 atm
e. HI = 0.768 atm, H_2 = 0.111 atm, I_2 = 0.111 atm

Letter answer to question #14: _____

15. Using the chemical reactions below, determine the equilibrium constant for the following reaction:
$Ca^{2+}(aq) + 2\ H_2O(l) \rightleftharpoons Ca(OH)_2(s) + 2\ H^+(aq)$

$Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2\ OH^-(aq)$ $\quad K = 6.5 \times 10^{-6}$
$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$ $\quad K = 1.0 \times 10^{-14}$

a. 1.5×10^{-23}
b. 6.5×10^{-20}
c. 1.3×10^{-19}
d. 1.5×10^{-9}
e. 1.5×10^{19}

Letter answer to question #15: _____

16. Hydrogen and iodine react to form hydrogen monoiodide according to: **$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$ $K_c = 0.504$** at 25 °C. If initial concentrations of 0.170 M H_2 and 0.170 M I_2 are allowed to equilibrate, what is the equilibrium concentration of HI?

a. 0.0445 M
b. 0.0891 M
c. 0.0684 M
d. 0.0706 M
e. 0.0129 M

Letter answer to question #16: _____

17. Which of the following is never a Brønsted-Lowry acid in an aqueous solution?

a. hydrogen monochloride, HCl(g)
b. dihydrogen monosulfide, $H_2S(g)$
c. ammonium chloride, $NH_4Cl(s)$
d. hydrogen monofluoride, HF(g)
e. sodium perchlorate, $NaClO_4(s)$

Letter answer to question #17: _____

18. At 25 °C, what is the H_3O^+ concentration in 0.044 M NaOH(aq)?

a. 4.4×10^{-16} M
b. 2.3×10^{-13} M
c. 4.4×10^{-7} M
d. 1.36 M
e. 12.6 M

Letter answer to question #18: _____

19. Assuming equal initial concentrations of the given species, which of the following weak acids has the strongest conjugate base in an aqueous solution?

    a. acetic acid, $K_a = 1.8 \times 10^{-5}$
    b. formic acid, $K_a = 1.8 \times 10^{-4}$
    c. hydrogen sulfite ion, $K_a = 6.2 \times 10^{-8}$
    d. nitrous acid, $K_a = 4.5 \times 10^{-4}$
    e. phosphoric acid, $K_a = 7.5 \times 10^{-3}$

Letter answer to question #19: _____

20. What is the pH of 5.0×10^{-3} M HF? The K_a for hydrofluoric acid is 7.2×10^{-4}. *Hint: is 100*K_a < C_a?*

    a. 2.72
    b. 2.80
    c. 4.60
    d. 5.44
    e. 6.12

Letter answer to question #20: _____

21. A solution is made by diluting 0.50 mol NaClO to a volume of 3.0 L with water. What is the pH of the solution? (K_b of ClO^{-1} = 2.9×10^{-7})

    a. 3.66
    b. 7.46
    c. 10.34
    d. 10.58
    e. 13.22

Letter answer to question #21: _____

22. What is the effect of adding 10 mL of 0.1 M NaOH(aq) to 100 mL of 0.2 M NH_4^+(aq)?

    1. The pH will decrease.
    2. The concentration of NH_3 will increase.
    3. The concentration of NH_4^+ will decrease.

    a. 1 only
    b. 2 only
    c. 3 only
    d. 2 and 3
    e. 1, 2, and 3

Letter answer to question #22: _____

23. What is the pH of an aqueous solution of 0.30 M HF and 0.15 M F^-? (K_a of HF = 7.2×10^{-4})

    a. 1.83
    b. 2.84
    c. 3.14
    d. 3.44
    e. 10.86

Letter answer to question #23: _____

24. Which of the following combinations would be best to buffer an aqueous solution at a pH of 2.0?

a. H_3PO_4 and $H_2PO_4^-$, $K_{a1} = 7.5 \times 10^{-3}$
b. HNO_2 and NO_2^{-1}, $K_a = 4.5 \times 10^{-4}$
c. CH_3CO_2H and CH_3COO^{-1}, $K_a = 1.8 \times 10^{-5}$
d. $H_2PO_4^{-1}$ and HPO_4^{2-}, $K_{a2} = 6.2 \times 10^{-8}$
e. NH_4^+ and NH_3, $K_a = 5.7 \times 10^{-10}$

Letter answer to question #24: _____

25. The K_a of hypochlorous acid, HClO, is 3.5×10^{-8}. What $[ClO^-]/[HClO]$ ratio is necessary to make a buffer with a pH of 7.71?

a. 2.0×10^{-8}
b. 0.25
c. 0.56
d. 1.8
e. 3.9

Letter answer to question #25: _____

Part II: Short Answer / Calculation, 40 points total. *Show all work!*

1. Consider a 1.00 L solution which is 0.700 M CH_3CO_2H and 0.600 M $NaCH_3CO_2$. $K_a = 1.8*10^{-5}$ (10 points)

a. What is the pH of the initial solution?

b. Calculate the pH upon adding 10.00 mL of 1.00 M HCl to the solution from part a.

c. Calculate the pH upon adding 15.00 mL of 2.10 M NaOH to the solution from part a.

2. Consider the reaction: $\mathbf{B_2H_6(g) \rightleftharpoons 2\ BH_3(g)}$, $\mathbf{\Delta H = +112\ kJ}$ Use Le Chatelier's principle to predict the effect of the following changes on this reaction at equilibrium. Write **RIGHT**, **LEFT** or **NO CHANGE** to indicate the effect observed. (10 points)

	Effect
Addition of B_2H_6:	_____
Addition of a catalyst:	_____
Increasing the pressure:	_____
Removal of BH_3:	_____
Increasing temperature:	_____

3. Calculate $\Delta G°$ for the reaction below at 25.0 °C. (10 points)

$$P_4(s) + 6\ H_2O(l) \rightarrow 4\ H_3PO_4(l)$$

Species	$\Delta H°_f$ (kJ/mol)	$S°_f$ (J/K·mol)
$P_4(s)$	0	22.80
$H_2O(l)$	-285.8	69.95
$H_3PO_4(l)$	-1279.0	110.5

4. a. Problem: write your name on the front of this exam (5 points)

b. List the five strong acids. (5 points)

c. List the three strong bases (5 points)

CH 223 Exam I Point Distribution Sheet

*Avoid a point penalty - do **not** write on this page!*

Multiple choice questions:

_____ X *4 points per question* **=** _____ points

number of multiple choice questions correct

Short answer questions:

_____ points

Total points on this exam: _____ points

Grade	***Percentage***	***Points on This Exam***
A	90% - 100%	126 - 140
B	80% - 89%	112 - 125
C	70% - 79%	98 - 111
D	60% - 69%	84 - 97
F	0% - 59%	0 - 83

Part I: Multiple Choice Questions

1. E
2. B
3. C
4. C
5. B

6. C
7. D
8. C
9. A

10. B
11. B
12. B
13. D

14. B
15. A
16. B
17. E
18. B

19. C
20. B
21. C
22. D
23. B

24. A
25. D

Part II: Short Answer / Calculation.

1. Buffer question:
    a. 4.67
    b. 4.66
    c. 4.72
2. Le Chatelier's Principle question:
    a. right
    b. no change
    c. left
    d. right
    e. right
3. -3401 kJ
4. Questions
    a. :)
    b. HCl, HBr, HI, HNO_3, $HClO_4$
    c. NaOH, KOH, LiOH