

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
- spontaneous reactions are always exothermic.
 - energy is conserved in a chemical reaction.
 - the Gibbs free energy is a function of both enthalpy and entropy.
 - $\Delta S = -\Delta H$ for any chemical reaction.
 - 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
- in a spontaneous process, the entropy of the universe increases.
 - there is no disorder in a perfect crystal at 0 K.
 - the total entropy of the universe is always increasing.
 - the total energy of the universe is constant.
 - 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?
- the decomposition of $\text{NH}_3(\text{g})$ into $\text{H}_2(\text{g})$ and $\text{N}_2(\text{g})$ gas
 - the dissolution of NaCl in water
 - the condensation of steam to liquid water
 - the evaporation of ethanol
 - the sublimation of dry ice (i.e., $\text{CO}_2(\text{s})$)

Letter answer to question #3: _____

4. Calculate the standard entropy change for the following reaction,
$$2 \text{HgO}(\text{s}) \rightleftharpoons 2 \text{Hg}(\text{l}) + \text{O}_2(\text{g})$$

given $S^\circ[\text{HgO}] = 70.3 \text{ J/K}\cdot\text{mol}$, $S^\circ[\text{Hg}(\text{l})] = 76.0 \text{ J/K}\cdot\text{mol}$, and $S^\circ[\text{O}_2(\text{g})] = 205.1 \text{ J/K}\cdot\text{mol}$.
- 216.5 J/K
 - +210.8 J/K
 - +216.5 J/K
 - +351.4 J/K
 - +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.
- $\Delta H > 0$, $\Delta S < 0$, $\Delta G < 0$
 - $\Delta H > 0$, $\Delta S > 0$, $\Delta G > 0$
 - $\Delta H < 0$, $\Delta S > 0$, $\Delta G < 0$
 - $\Delta H < 0$, $\Delta S > 0$, $\Delta G > 0$
 - $\Delta H < 0$, $\Delta S < 0$, $\Delta G < 0$

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?
- $\Delta H > 0, \Delta S < 0, \Delta G > 0$
 - $\Delta H > 0, \Delta S > 0, \Delta G > 0$
 - $\Delta H > 0, \Delta S > 0, \Delta G < 0$
 - $\Delta H < 0, \Delta S < 0, \Delta G < 0$
 - $\Delta H < 0, \Delta S > 0, \Delta G > 0$

Letter answer to question #6: _____

7. At what temperatures will a reaction be spontaneous if $\Delta H = -76.0 \text{ kJ}$ and $\Delta S = +231 \text{ J/K}$?
- All temperatures below 329 K
 - Temperatures between 0 K and 231 K
 - All temperatures above 329 K
 - The reaction will be spontaneous at any temperature.
 - The reaction will never be spontaneous.

Letter answer to question #7: _____

8. Calculate $\Delta G^\circ_{\text{rxn}}$ for the reaction below at 25.0 °C
 $\text{CO(g)} + \text{H}_2\text{O(l)} \rightarrow \text{H}_2\text{(g)} + \text{CO}_2\text{(g)}$
 given $\Delta G^\circ_f[\text{CO(g)}] = -137.2 \text{ kJ/mol}$, $\Delta G^\circ_f[\text{H}_2\text{O(l)}] = -237.2 \text{ kJ/mol}$ and $\Delta G^\circ_f[\text{CO}_2\text{(g)}] = -394.4 \text{ kJ/mol}$.
- 768.8 kJ
 - 294.4 kJ
 - 20.0 kJ
 - +20.0 kJ
 - +768.8 kJ

Letter answer to question #8: _____

9. Write the expression for K for the reaction: $\text{Al}_2\text{S}_3\text{(s)} \rightleftharpoons 2 \text{Al}^{3+}\text{(aq)} + 3 \text{S}^{2-}\text{(aq)}$
- $K = [\text{Al}^{3+}]^2[\text{S}^{2-}]^3$
 - $K = [\text{Al}^{3+}][\text{S}^{2-}]$
 - $K = [2 \text{Al}^{3+}][3 \text{S}^{2-}]$
 - $K = \frac{[\text{Al}_2\text{S}_3]}{[\text{Al}^{3+}]^2[\text{S}^{2-}]^3}$
 - $K = \frac{[\text{Al}^{3+}]^2[\text{S}^{2-}]^3}{[\text{Al}_2\text{S}_3]}$

Letter answer to question #9: _____

10. Write the expression for K_p for the reaction: $2 \text{HBr(g)} \rightleftharpoons \text{H}_2\text{(g)} + \text{Br}_2\text{(l)}$

a.
$$K_p = \frac{P_{\text{HBr}}^2}{P_{\text{Br}_2} P_{\text{H}_2}}$$

b.
$$K_p = \frac{P_{\text{H}_2}}{P_{\text{HBr}}^2}$$

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

d.
$$K_p = \frac{P_{\text{HBr}}^2}{P_{\text{H}_2}}$$

e.
$$K_p = \frac{P_{\text{H}_2} P_{\text{Br}_2}}{P_{\text{HBr}}^2}$$

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 $K_c = 12$. $2 \text{SO}_3\text{(g)} \rightleftharpoons 2 \text{SO}_2\text{(g)} + \text{O}_2\text{(g)}$

- a. $[\text{SO}_3]$ will decrease because $Q > K$.
- b. $[\text{SO}_3]$ will decrease because $Q < K$.
- c. $[\text{SO}_3]$ will increase because $Q < K$.
- d. $[\text{SO}_3]$ will increase because $Q > K$.
- e. $[\text{SO}_3]$ will remain the same because $Q = K$.

Letter answer to question #11: _____

12. This reaction below is studied at a high temperature. $\text{PCl}_5\text{(g)} \rightleftharpoons \text{PCl}_3\text{(g)} + \text{Cl}_2\text{(g)}$ At equilibrium, the partial pressures of the gases are as follows: $\text{PCl}_5 = 1.8 \times 10^{-2}$ atm, $\text{PCl}_3 = 5.6 \times 10^{-2}$ atm, and $\text{Cl}_2 = 3.8 \times 10^{-4}$ 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: $\text{PCl}_5\text{(g)} \rightleftharpoons \text{PCl}_3\text{(g)} + \text{Cl}_2\text{(g)}$

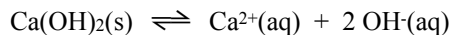
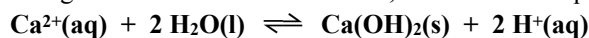
- a. 0.052
- b. 0.20
- c. 0.27
- d. 0.37
- e. 2.2

Letter answer to question #13: _____

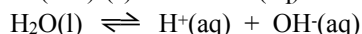
14. Hydrogen monoiodide can decompose into hydrogen and iodine gases: $2 \text{HI(g)} \rightleftharpoons \text{H}_2\text{(g)} + \text{I}_2\text{(g)}$ $K_p = 0.016$ at -17°C . If 0.820 atm of HI(g) is sealed in a flask at -17°C , what is the pressure of each gas when equilibrium is established?
- HI = 0.576 atm, H_2 = 0.096 atm, I_2 = 0.096 atm
 - HI = 0.654 atm, H_2 = 0.083 atm, I_2 = 0.083 atm
 - HI = 0.728 atm, H_2 = 0.092 atm, I_2 = 0.092 atm
 - HI = 0.737 atm, H_2 = 0.083 atm, I_2 = 0.083 atm
 - 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:



$$K = 6.5 \times 10^{-6}$$



$$K = 1.0 \times 10^{-14}$$

- 1.5×10^{-23}
- 6.5×10^{-20}
- 1.3×10^{-19}
- 1.5×10^{-9}
- 1.5×10^{19}

Letter answer to question #15: _____

16. Hydrogen and iodine react to form hydrogen monoiodide according to: $\text{H}_2\text{(g)} + \text{I}_2\text{(g)} \rightleftharpoons 2 \text{HI(g)}$ $K_c = 0.504$ 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?

- 0.0445 M
- 0.0891 M
- 0.0684 M
- 0.0706 M
- 0.0129 M

Letter answer to question #16: _____

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

- hydrogen monochloride, HCl(g)
- dihydrogen monosulfide, $\text{H}_2\text{S(g)}$
- ammonium chloride, $\text{NH}_4\text{Cl(s)}$
- hydrogen monofluoride, HF(g)
- sodium perchlorate, $\text{NaClO}_4\text{(s)}$

Letter answer to question #17: _____

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

- 4.4×10^{-16} M
- 2.3×10^{-13} M
- 4.4×10^{-7} M
- 1.36 M
- 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?
- acetic acid, $K_a = 1.8 \times 10^{-5}$
 - formic acid, $K_a = 1.8 \times 10^{-4}$
 - hydrogen sulfite ion, $K_a = 6.2 \times 10^{-8}$
 - nitrous acid, $K_a = 4.5 \times 10^{-4}$
 - 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 $100 \cdot K_a < C_a$?*

- 2.72
- 2.80
- 4.60
- 5.44
- 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 $\text{ClO}^- = 2.9 \times 10^{-7}$)

- 3.66
- 7.46
- 10.34
- 10.58
- 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)?

- The pH will decrease.
- The concentration of NH_3 will increase.
- The concentration of NH_4^+ will decrease.

- 1 only
- 2 only
- 3 only
- 2 and 3
- 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})

- 1.83
- 2.84
- 3.14
- 3.44
- 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^- , $K_a = 4.5 \times 10^{-4}$
- c. $\text{CH}_3\text{CO}_2\text{H}$ and CH_3COO^- , $K_a = 1.8 \times 10^{-5}$
- d. H_2PO_4^- 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 $[\text{ClO}^-]/[\text{HClO}]$ 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 $\text{CH}_3\text{CO}_2\text{H}$ and 0.600 M NaCH_3CO_2 . $K_a = 1.8 \times 10^{-5}$ (10 points)

- a. What is the pH of the initial solution?

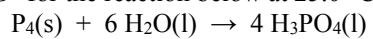
- b. Calculate the pH upon adding 10.00 mL of 1.00 M HCl to the solution from part a.

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

2. Consider the reaction: $\text{B}_2\text{H}_6(\text{g}) \rightleftharpoons 2 \text{BH}_3(\text{g})$, $\Delta H = +112 \text{ kJ}$ 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)

	<u>Effect</u>
Addition of B_2H_6 :	_____
Addition of a catalyst:	_____
Increasing the pressure:	_____
Removal of BH_3 :	_____
Increasing temperature:	_____

3. Calculate ΔG° for the reaction below at 25.0 °C. (10 points)



Species	ΔH_f° (kJ/mol)	S_f° (J/K·mol)
P ₄ (s)	0	22.80
H ₂ O(l)	-285.8	69.95
H ₃ PO 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

<i>Grade</i>	<i>Percentage</i>	<i>Points on This Exam</i>
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, HNO₃, HClO₄
 - c. NaOH, KOH, LiOH