**KWANTLEN UNIVERSITY COLLEGE**

**DEPARTMENT OF CHEMISTRY**

**CHEM 1210 FINAL EXAMINATION** **TOTAL = 105 MARKS**
**April 17,2002**
Time: 3 hours

NAME:_____

**INSTRUCTIONS:**

1. Read all questions thoroughly and answer each question completely. **ALL WORK MUST BE SHOWN IN ORDER TO RECEIVE ANY CREDIT.**

2. You will be allowed to use only the given sheet of thermodynamic equations.

3. Ensure that this exam paper has **58** questions**.**

**ADDITIONAL INFORMATION:**

Avogadro's number = $6.02 \times 10^{23}$
Faraday = 96485 Coulombs
R = 0.08206 L-atm/mol-K = 8.314 J/mol-K

**Arrhenius equation:** $k = Ae^{-Ea/RT}$

**Nernst equation:** $\varepsilon = \varepsilon^\circ - (0.05916/n)\log Q$ (at 25°C)

**First order kinetics:** $\ln(A_o/A) = kt$

**Second order kinetics:** $[1/A] - [1/A_o] = kt$

**Freezing point depression and boiling point elevation:** $\Delta T = iKm$

1. **(5 Marks)** Balance the following oxidation-reduction reaction in **basic solution:**

$$MO_2^{+} + YO_2^{1-} \rightarrow Y_2 + Y_3O_5 + MO$$

**Balance the three half-reactions:**

**$H_2O + 3e^- + MO_2^{+} \rightarrow MO + 2\ OH^-$**
**$4H_2O + 6e^- + 2YO_2^{1-} \rightarrow Y_2 + 8\ OH^-$**
**$(H_2O + 3YO_2^{1-} \rightarrow Y_3O_5 + e^- + 2\ OH^-)$**

**The easiest combination is to multiply the third half-reaction by nine and then add them together. Resulting in the following answer:**

**$14H_2O + MO_2^{+} + 29\ YO_2^{1-} \rightarrow MO + Y_2 + 9\ Y_3O_5 + 28\ OH^-$**

**This is only one of many possible answers although this is the easiest combination to come up with.**

2. **(2 Marks)** Under certain conditions oxidation of sodium azide ($NaN_3$, molar mass = 65.01) results in the production of $NO_2$(g). What is the equivalent mass of sodium azide under these conditions?

**$13e^- + N_3^- \rightarrow 3NO_2$**
**therefore equivalent Mass = 65.01/13 = 5.00 g/equiv**

3. For 2A + B → C, initial rate law data are:

| Exp. | [A] | [B] | Rate |
|---|---|---|---|
| #1 | 0.10 | 0.10 | $2.0 \times 10^{-3}$ |
| #2 | 0.30 | 0.10 | $18.0 \times 10^{-3}$ |
| #3 | 0.20 | 0.30 | $24.0 \times 10^{-3}$ |

**(2)**

The rate law is Rate = $k[A]^x[B]^y$
a. x = 1 and y = 2
**b. x = 2 and y = 1**
c. x = 1 and y = 1
d. x = 2 and y = 2
e. x = 0 and y = 2

4. What are the units for the rate constant for the rate law = $k$[A][B][C]?
a. $M^{-2}$-sec
b. $M^{-1}$-$sec^{-1}$
**(1)** c. $M^{2}$-$sec^{-1}$
**d. $M^{-2}$-$sec^{-1}$**
e. $M^{-3}$-$sec^{-1}$

5. If the half-life of a reaction is found to be directly proportional to the concentration of a reactant, the reaction order is

**a. zero**

b. first

**(1)** c. second

d. third

e. none of these

6. If a catalyst is added to a reaction

(1) the value of *k* is increased.

(2) the value of *k* is decreased.

**(1)** (3) the rate is increased.

(4) the rate is decreased.

(5) neither rate nor the rate constant are changed, only the order.

a. 1 and 4 b. 2 and 4 c. 2 and 3 **d. 1 and 3** e. only 5

7. Substance A decomposes by a first-order reaction. If $[A]_o$ = 2.00 *M* and after 150 minutes [A] = 0.25 *M*, then its half life is:

a. 300 minutes

**(2)** b. 150 minutes

c. 75 minutes

**d. 50 minutes**

e. 37.5 minutes

8. Which of the following statements is TRUE about the reaction 2A + B → C which is first order in A and first order overall

a. The rate of the reaction will decrease at higher concentrations of B

b. The time required for one half of A to react is directly proportional to the quantity of A present.

**(2)** c. The rate of formation of C is twice the rate of reaction of A.

d. The rate of reaction of B is the same as the rate of reaction of A.

**e. None of these.**

9. The half-life for a first order reaction is 12 hours at 35°C and 2.5 hours at 100°C. What is the activation energy for this reaction?

**(2)** a. 31.6 kJ/mol

b. 27.4 kJ/mol

**c. 23.1 kJ/mol**

d. 10.0 kJ/mol

e. -27.4 kJ/mol

10. Consider the following hypothetical equilibrium:

$$B_2(g) + A_2(g) \rightleftarrows 2AB(g) \text{ where } K_c = 4$$

What is the value of $K_c$ for the equilibrium:

$$4AB(g) \rightleftarrows 2B_2(g) + 2A_2(g)$$

a. 0.5

b. 0.25

**(2)** c. 2

**d. 0.0625**

e. 16

11. Given the following equilibria:

$$2A(g) + B(g) \rightleftarrows 3C(g) \quad K_c = 1.7 \times 10^{-13}$$
$$2D(g) + 2B(g) \rightleftarrows 3C(g) \quad K_c = 4.1 \times 10^{-31}$$

Find the equilibrium constant for the following equilibrium: $2D(g) + B(g) \rightleftarrows 2A(g)$

a. $1.6 \times 10^{-9}$
b. $7.0 \times 10^{-44}$
**(2)** c. $2.6 \times 10^{-22}$
d. $4.2 \times 10^{17}$
**e. $2.4 \times 10^{-18}$**

12. For the reaction: $POCl_3(g) \rightleftarrows POCl(g) + Cl_2(g)$, $K_c = 0.450$
A sample of pure $POCl_3(g)$ was placed in a container and allowed dissociate according to the above reaction. At equilibrium, the concentration of $POCl(g)$ was found to be 0.150 *M*. What was the initial concentration of $POCl_3(g)$?

a. 0.225 *M*
**b. 0.200 *M***
**(2)** c. 0.633 *M*
d. 0.483 *M*
e. 0.350 *M*

13. For the following chemical reaction at equilibrium:

$$2Cl_2(g) + 2H_2O(g) \rightleftarrows 4HCl(g) + O_2(g)$$

a. $K_p = K_c$
**(2)** b. **$K_p = K_c(RT)$**
c. $K_p = K_c(RT)^{-1}$
d. $K_p = K_c(RT)^{-3}$
e. $K_p = K_c(RT)^3$

14. Calculate the ratio ($K_p/K_c$) for the following chemical reaction at equilibrium at 25°C:

$$2Cl_2(g) + 2H_2O(g) \rightleftarrows 4HCl(g) + O_2(g)$$

a. 1
**(1)** **b. 24.5**
c. 2.05
d. 0.0408
e. 2477

15. Consider the equilibrium:

$$2SO_2(g) + O_2(g) \rightleftarrows 2SO_3(g), \Delta H° = -196.6 \text{ kJ}$$

The equilibrium is shifted to the left if:

a. some sulfur trioxide is removed.
**b. the temperature is raised.**
**(2)** c. a catalyst is added.
d. the pressure is raised.
e. none of these answers.

16. All of the following may shift the position of a reaction at equilibrium **EXCEPT**:

a. temperature change
b. concentration change
**(1)** c. volume change
d. pressure change
**e. catalyst**

17. For the reaction: $N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$
In a closed 3.0 liter container are placed 0.75 mol of $N_2$ and 1.20 mol of $H_2$. When the reaction reaches equilibrium, $[H_2] = 0.100\ M$. Which of the following is TRUE?
a. $[NH_3] = 0.150\ M$
**(2)** **b. $[NH_3] = 0.200\ M$**
c. $[N_2] = 0.650\ M$
d. $[N_2] = 0.250\ M$
e. none of these

18. In the equilibrium system: $PO_4^{3-}(aq) + H_2O(l) \rightleftarrows HPO_4^{2-}(aq) + OH^-(aq)$
Brønsted-Lowry theory would designate:
a. $PO_4^{3-}$ and $H_2O$ as the bases
b. **$HPO_4^{2-}$ and $PO_4^{3-}$ as a conjugate pair**
**(1)** c. $HPO_4^{2-}$ as a base
d. $HPO_4^{2-}$ and $H_2O$ as a conjugate pair
e. $PO_4^{3-}$ as amphiprotic

19. Which species in the following reaction acts as the Lewis acid?

$$Co^{2+}(aq) + 4Cl^-(aq) \rightleftarrows CoCl_4^{2-}(aq)$$

a. $CoCl_4^{2-}$
b. $Cl^-$
**(1)** **c. $Co^{2+}$**
d. none are acids

20. 0.272 g of a monoprotic acid (Molar mass = 189 g/mol) is dissolved in water to produce 25.0 mL of a solution with pH = 4.93. Calculate the disociation constant of the acid.
a. $4.1 \times 10^{-8}$
b. $1.4 \times 10^{-10}$
**(2)** c. $2.1 \times 10^{-4}$
d. $2.8 \times 10^{-7}$
**e. $2.4 \times 10^{-9}$**

21. Determine the pH of the solution prepared by mixing equal amounts of 0.210 *M* HCl and 1.63 *M* $NaCHO_2$. $K_a$(for $HCHO_2$) = $1.8 \times 10^{-4}$.
a. 2.91
**b. 4.57**
**(2)** c. 4.77
d. 9.43
e. 11.09

22. Which of the following would NOT be considered a buffer solution?
a. 0.1 *M* $HC_2H_3O_2$ and 0.1 *M* $NaC_2H_3O_2$
b. 0.1 *M* $NH_3$ and 0.1 *M* $NH_4NO_3$
**(1)** c. 0.1 *M* $NaHSO_3$ and 0.1 *M* $H_2SO_3$
**d. 0.1 *M* HI and 0.1 *M* NaI**
e. 0.1 *M* $Na_2HPO_4$ and 0.1 *M* $NaH_2PO_4$

23. In the titration of 20.0 mL of a 0.100 *M* $H_2A$ acid ($pK_{a1}$ = 4.00 and $pK_{a2}$ = 6.00) with 0.200 *M* NaOH. Which of the following is FALSE?
a. 20.0 mL of NaOH solution are needed to reach the second equivalence point.
b. the pH at the first equivalence point is 5.00
**(4)** c. the pH at the second equivalence point is greater than 7.0
**d. when 10.0 mL of NaOH have been added the $[H_2A] = [HA^-]$**
e. At the start before any base has been added the pH = 2.50

24. What is the pH after addition of 10.0 mL of 1.0 *M* HCl to 90.0 mL of a buffer consisting of 1.0 *M* $NH_3$ and 1.0 *M* $NH_4Cl$?
$K_b$(for ammonia) = $1.8 \times 10^{-5}$
a. 4.74
**b. 9.16**
**(2)** c. 9.26
d. 9.36
e. 11.58

25. A certain acid has a $K_a = 6.80 \times 10^{-6}$. What is the pH of a 0.247 *M* solution of the acid's potassium salt?
a. 4.72
**b. 9.28**
**(2)** c. 9.11
d. 9.44
e. 9.89

26. For aqueous $NH_4NO_3$, predict whether the solution is acidic, basic or neutral and why.
a. acidic because it is a strong acid.
b. basic because it is a weak base.
**(1)** c. neutral because there is no hydrolysis.
d. acidic because it is the salt of a strong acid.
**e. acidic because it is the salt of a weak base.**

27. Phenol red indicator changes from yellow to red in the pH range 6.6 to 8.0. What color will the indicator show in a 0.10 M NaCN solution?
**a. red**
b. yellow
**(1)** c. red-yellow mixture
d. the indicator is its original color
e. there is not enough information to answer this question.

28. What is the concentration of $SO_4^{2-}$ ion in a 3.6 *M* $H_2SO_4$ solution?
$K_{a2} = 1.1 \times 10^{-2}$.
**a. 0.011 *M***
b. 0.040 *M*
**(2)** c. 0.20 *M*
d. 0.60 *M*
e. 1.8 *M*

29. Ten mL of 0.10 *M* $NH_3(aq)$ ($K_b$ = 1.8 x $10^{-5}$) is mixed with ten mL of 0.10 *M* $NH_4Cl$, the resulting solution:
a. has a pH = 4.74
**(2)** b. has a $[H^+]$ of about 1 x $10^{-3}$ *M*
c. is acidic
**d. has an $[OH^-]$ of about 1.8 x $10^{-5}$ *M***
e. has an $[NH_4^+]$ greater than that of the $NH_4Cl(aq)$

30. The p$K_b$ for methylamine is 3.38. What is the pH of an aqueous solution for which the label reads 0.042 *M* $CH_3NH_2$?

a. 2.4
b. 4.8
**(2)** c. 9.2
**d. 11.6**
e. 12.3

31. Which of the following has the smallest molar solubility in pure water?
**a. CuS ($K_{sp}$ = 8 x $10^{-37}$)**
b. $Bi_2S_3$ ($K_{sp}$ = 1 x $10^{-70}$)
**(3)** c. $Ag_2S$ ($K_{sp}$ = 6 x $10^{-51}$)
d. MnS ($K_{sp}$ = 7 x $10^{-16}$)
e. PbS ($K_{sp}$ = 3 x $10^{-28}$)

32. Calculate the molar solubility of silver chromate in a 0.010 *M* $Na_2CrO_4$ solution. $K_{sp}$ of $Ag_2CrO_4$ = 9.0 x $10^{-12}$.
a. 9.0 x $10^{-10}$ *M*
b. 4.5 x $10^{-10}$*M*
**(2)** c. 6.0 x $10^{-5}$*M*
d. 3.0 x $10^{-5}$*M*
**e. 1.5 x $10^{-5}$*M***

33. The solubility product of silver sulfate is 1.6 x $10^{-5}$. What is the molar solubility of this compound in pure water?
a. $8^{\frac{1}{2}}$ x $10^{-2}$ *M*
**(2)** **b. $4^{\frac{1}{3}}$ x $10^{-2}$ *M***
c. $16^{\frac{1}{2}}$ x $10^{-3}$ *M*
d. 1.6 x $10^{-5}$ *M*
e. none of these *M*

34. The heat of combustion, $\Delta H°_{comb}$, for one mole of benzene($C_6H_6$) is -3267.4 kJ. Given the $\Delta H°_f(CO_2(g))$ = -393.5 kJ/mol and $\Delta H°_f(H_2O(l))$ = -285.8 kJ/mol.

$$C_6H_6(l) + 15/2\ O_2(g) \rightarrow 6CO_2(g) + 3H_2O(l)$$

Calculate the $\Delta H°_f$ of benzene.
a. +2588.1 kJ/mol
**(2)** b. -49.0 kJ/mol
c. -808.4 kJ/mol
**d. +49.0 kJ/mol**
e. +808.4 kJ/mol

35. For the reaction $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ $\Delta H° = -483.6$ kJ
What mass of $H_2$(g) is required to liberate 1000 kJ of heat?
a. 66.2 g
**(2)** b. 2.05 g
c. 4.17 g
**d. 8.34 g**
e. 16.7 g

36. Choose the correct statements concerning entropy.
(1) As two gases mix, $\Delta S$ is positive.
(2) Entropy is a thermodynamic property related to the degree of disorder.
**(2)** (3) As temperature in a gas decreases, $\Delta S$ is positive.
(4) Molecules in the liquid state have higher entropy than molecules in the gaseous state.

a. 1 and 3 b. 1,2 and 3 **c. 1 and 2** d. 1,2 and 4 e. 2 and 3

37. Which of the following combinations of signs for $\Delta H°$ and $\Delta S°$ will **always** result in a reaction being spontaneous?
a. $\Delta H°$(+) and $\Delta S°$(+)
b. $\Delta H°$(+) and $\Delta S°$(-)
**(1)** **c. $\Delta H°$(-) and $\Delta S°$(+)**
d. $\Delta H°$(-) and $\Delta S°$(-)
e. cannot determine without the temperature

38. Calculate the entropy change for methanol at its normal boiling point of 64.5°C. The molar enthalpy of vaporization of methanol is 38.0 kJ/mol.
a. must know $\Delta G$ to calculate
b. 112 kJ/mol-K
**(1)** c. 589 kJ/mol-K
d. 0.589 kJ/mol-K
**e. 0.112 kJ/mol-K**

39. For a particular reaction $K_p = 0.377$ at 25°C. What is $\Delta G°$ for this reaction?
a. 88.02 J/mol
b. 202.7 J/mol
**(1)** c. 1049 J/mol
**d. 2420 J/mol**
e. -1049 J/mol

40. For the reaction: $2O_3(g) \rightarrow 3O_2(g)$. What is $\Delta S°$ for the system?
a. +605 J/K
**(2)** **b. +137 J/K**
c. +12 J/K
d. -39 J/K
e. -183 J/K

41. For the reaction: $2O_3(g) \rightarrow 3O_2(g)$ at 298 K. Which of the following statements is TRUE?
**a. $\Delta S_{universe} > 0$ and $\Delta G° < 0$**
**(2)** b. $\Delta S_{universe} < 0$ and $\Delta G° > 0$
c. $\Delta S_{universe} = 0$ and $\Delta G° = 0$
d. $\Delta S_{universe} > 0$ and $\Delta S_{surroundings} = 0$
e. $\Delta S_{universe} < 0$ and $\Delta S_{system} > 0$

42. For the reaction $Cl_2(g) + 3F_2(g) \rightleftarrows 2ClF_3(g)$ $K_p = 4.1 \times 10^{34}$ at 77°C and $K_p = 1.3 \times 10^{43}$ at 25°C. What is the value of $\Delta H°$?
a. +157 kJ
**(2)** b. -157 kJ
c. -6.0 kJ
d. -142 kJ
**e. -326 kJ**

43. Consider the reaction:

| | $CO(g)$ | + $2H_2(g)$ | $\rightleftarrows$ $CH_3OH(g)$ |
|---|---|---|---|
| $\Delta H°_{f,298}$(kJ/mol) | -110.5 | 0 | -200.7 |
| $S°$(J/mol-K) | 197.6 | 130.6 | 239.7 |

What is $\Delta G°$ for this reaction at 300°C? Is the reaction spontaneous at 300°C?
a. -35.3 kJ, YES
**b. +35.3 kJ, NO**
**(2)** c. +35.3 kJ, YES
d. -24.5 kJ, NO
e. -24.5 kJ, YES

44. Determine the equilibrium constant ($K_c$) for the following reaction at 298 K:
$$Sn^{2+}(aq) + Ti(s) \rightarrow Sn(s) + Ti^{2+}(aq)$$
Given the standard reduction potentials: $Ti^{2+}/Ti = -1.630$ *V* and for $Sn^{2+}/Sn = -0.137$ *V*
a. $1.7 \times 10^{25}$
**b. $3.0 \times 10^{50}$**
**(2)** c. $5.4 \times 10^{59}$
d. $3.4 \times 10^{-51}$
e. $1.8 \times 10^{-60}$

45. Will magnesium metal react with $Al^{3+}$ ion from an aqueous solution?
The standard reduction potentials: $Mg^{2+}/Mg = -2.36$ *V* and for $Al^{3+}/Al = -1.68$ *V*
a. no, since the cell voltage is negative
b. yes, since $\Delta G°$ is positive
**(2)** c. yes, because the system is at equilibrium
**d. yes, since $\Delta S_{universe} > 0$**
e. no, because the reverse reaction is spontaneous

46. Choose the INCORRECT statement:
a. An electrode is often a strip of metal.
b. An electrode in a solution of its ions is a half cell.
**(1)** **c. An electrochemical cell is a half-cell**.
d. The electromotive force (emf) is the cell potential.
e. The cell potential is the potential difference between the half-cells.

47. A copper electrode weighs 23.07 g before the electrolysis of a $CuSO_4$ solution and 24.34 g after the electrolysis has run using a current of 193 ampere. What was the time for this electrolysis?
a. 10 seconds
**(2)** **b. 20 seconds**
c. 40 seconds
d. 60 seconds
e. 80 seconds

48. Choose the FALSE statement:
a. Only spontaneous processes occur naturally.
b. The entropy of vaporization is always positive.
**(2)** c. The combustion of any hydrocarbon is exothermic.
**d. $\Delta G°$ is always equal to zero at equilibrium**.
e. The greater the degree of randomness in a system, the greater the entropy of the system.

49. Calculate $\varepsilon_{cell}$ for the following voltaic cell at 298 K:

$$Ni(s)|\ Ni^{2+}(aq)[\text{saturated } NiCO_3(s)]||Ni^{2+}(0.010\ M)|Ni(s)$$

The $K_{sp}$ for $NiCO_3$ is $1.42 \times 10^{-7}$ and the standard reduction potential for $Ni^{2+}/\ Ni = -0.257\ V$.
a. +0.257 *V*
**(2)** b. -0.0422 *V*
c. 0.000 *V*
d. +0.0844 *V*
**e. +0.0422 *V***

50. What is $\varepsilon°$ for the reaction: $CH_3OH(l) + 3/2\ O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ if the $\Delta G° = -702.5$ kJ?
a. +0.91 *V*
**b. +1.21 *V***
**(2)** c. +1.82 *V*
d. +3.64 *V*
e. -1.82 *V*

51. Which probably has the highest boiling point at 1.00 atm pressure?
a. $CH_3NH_2$
**b. $CH_3CH_2CH_2OH$**
**(1)** c. $CH_3OH$
d. $(CH_3)_2N(CHF_2)$
e. $C_4H_{10}$

52. If a substance has a heat of vaporization of 3.46 kJ/g and a heat of sublimation of 4.60 kJ/g, what is its heat of fusion?
**a. 1.14 kJ/g**
b. 8.06 kJ/g
**(1)** c. -1.14 kJ/g
d. -8.06 kJ/g
e. none of these

53. The triple point of water is at 4.58 mm Hg and +0.01°C. Some $H_2O$ at -50°C is heated to 120°C at a constant pressure of 2.05 mm Hg. The changes of state(s) occuring in this process are:

**a. solid to gas**

b. solid to liquid to gas

**(1)** c. liquid to gas

d. solid to liquid

e. no change in state occurs at constant pressure

54. The normal boiling point of ethanol is 78.3°C and $\Delta H^\circ_{vap}$ = 39.3 kJ/mol. What is the vapor pressure of ethanol at 50.0°C?

a. 118 mm Hg

**b. 234 mm Hg**

**(2)** c. 354 mm Hg

d. 485 mm Hg

e. 670 mm Hg

55. The vapor pressure of pure hexane at 25°C is 151.4 mm Hg and for hepane it is 45.6 mm Hg. A solution contains 0.800 mol fraction hexane. What is the composition of the vapor in equilibrium with this solution at 25°C?

a. 80.0% hexane and 20.0% heptane

**(2)** b. 50.0% hexane and 50.0% heptane

c. 77.0% hexane and 23.0% heptane

d. 45.0% hexane and 55.0% heptane

**e. 93.0% hexane and 7.0% heptane**

56. A solution composed of 5 mol acetone ($CH_3COCH_3$, $P^o$ = 324 mm Hg) and 5 moles of chloroform ($CHCl_3$, $P^o$ = 274 mm Hg) has a vapor pressure of 236 mm Hg. Which one of the following statements is completely true about this solution?

a. The solution obey's Raoult's Law.

b. The solution shows a positive deviation from Raoult's Law.

**(2)** c. The solution shows a negative deviation from Raoult's Law and possesses a minimum boiling point azeotrope.

**d. The solution shows a negative deviation from Raoult's Law and possesses a maximum boiling point azeorope.**

e. The solution process is exothermic because the forces between unlike molecules are weaker than those between like molecules.

57. An aqueous NaCl solution freezes at -1.13°C. Calculate the approximate NaCl concentration of this solution in % by mass. $K_f$ for water is 1.86 °C-$m^{-1}$.

a. 3.55%

**b. 1.78%**

**(2)** c. 0.870%

d. 17.8%

e. 8.90%

58. Solutions are made that contain 0.10 mol of each of the following compounds below in 100 g of water. Choose the compound whose solution will have the lowest freezing point.

**(2)** **a. $BaBr_2$** b. KCl c. $CH_3OH$ d. $NiSO_4$ e. $H_2SO_4$