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 = 6.02×10^{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:**

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

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?

3. For $2A + B \rightarrow C$, initial rate law data are:

Exp.	[A]	[B]	Rate
#1	0.10	0.10	2.0×10^{-3}
#2	0.30	0.10	18.0×10^{-3}
#3	0.20	0.30	24.0×10^{-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 $2A + B \rightarrow C$ 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. 1.6×10^{-9}
b. 7.0×10^{-44}
(2) c. 2.6×10^{-22}
d. 4.2×10^{17}
e. 2.4×10^{-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. 4.1×10^{-8}
b. 1.4×10^{-10}
(2) c. 2.1×10^{-4}
d. 2.8×10^{-7}
e. 2.4×10^{-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 $HCHO_2$) = 1.8×10^{-4}.
a. 2.91
b. 4.57
(2) c. 4.77
d. 9.43
e. 11.09

22. Which of the following would <u>NOT</u> 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 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) = 1.8×10^{-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 pK_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 <u>smallest</u> 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, ΔS is positive.
(2) Entropy is a thermodynamic property related to the degree of disorder.
(2) (3) As temperature in a gas decreases, ΔS 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 ΔG 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. 1.7×10^{25}
b. 3.0×10^{50}
(2) c. 5.4×10^{59}
d. 3.4×10^{-51}
e. 1.8×10^{-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 ε_{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 1.42×10^{-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 ΔH°_{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