Kwantlen Polytechnic University
Department of Chemistry
Chemistry 1210 Final Examination
Saturday, December 13, 2014

Name: ___________________________ Student #: _________________________________

Instructions:

- You have **three hours** to complete this exam.
- This exam consists of **eighteen** pages: This cover page and seventeen pages of questions. You should also have a formula sheet and a periodic table. Please ensure you have a complete paper, and obtain one **immediately** if you do not.
- There are **93** marks available in **30** questions. Plan your time appropriately.
- You are to work independently. Any sharing of any information of any kind in any way with anyone is strictly prohibited.
- Good luck!

Page	Mark	Max
2		5
3		2
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17		6
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Total		93

1) **[5 marks total]** One potential mechanism for the reaction of chlorine gas with hydrogen gas:

$$Cl_2 \underset{k_2}{\overset{k_1}{\rightleftharpoons}} 2Cl\cdot \qquad \text{(fast)}$$

$$Cl\cdot + H_2 \xrightarrow{k_3} HCl + H\cdot \qquad \text{(slow)}$$

$$H\cdot + Cl\cdot \xrightarrow{k_4} HCl \qquad \text{(fast)}$$

a) **[1 mark]** What is the overall reaction?

b) **[0.5 marks]** Are there any reactive intermediates? If so, what are they?

c) **[0.5 marks]** Are there any catalysts? If so, what are they?

d) **[3 marks]** What rate law is predicted by the mechanism above?

2) **[2 marks]** Polonium-210 has a half-life of 138.38 days. It is found in tobacco leaves, where (when you smoke) it is inhaled into the lungs. There, it decays into lead. How long will it take for 99 percent of the polonium from a single cigarette to decay to lead in the lungs?

3) **[6 marks total]** Given the following unbalanced redox reaction, occurring in **basic** solution:

$S_2O_3^{2-} + ClO_3^{-} \longrightarrow SO_3^{2-} + ClO^{-}$

a) **[4 marks]** Balance the reaction.

b) **[0.5 marks]** How many electrons are transferred in the overall reaction?

c) **[0.5 marks]** What is the oxidizing agent?

d) **[1 mark]** What is the normality of a 0.10 M solution of $Na_2S_2O_3$?

4) **[7 marks total]** A battery is constructed using the two half-reactions:

$Fe^{3+}(aq) + e^{-} \longrightarrow Fe^{2+}(aq)$
$Co^{2+}(aq) + 2e^{-} \longrightarrow Co(s)$

The overall reaction occurring in the battery is:

$2Fe^{3+}(aq) + Co(s) \rightleftharpoons 2Fe^{2+}(aq) + Co^{2+}(aq)$

The battery produces 1.051 V when run under standard conditions at 25°C. Two litres of solution are used in each half-cell.

a) **[1 mark]** Give the (shorthand) cell notation for the battery.

b) **[2 marks]** Calculate the voltage that the battery will produce at 25°C if the $[Fe^{3+}] = 2.0 \times 10^{-4}$ M, the $[Fe^{2+}] = 5.0$ M, and the $[Co^{2+}] = 0.80$ M.

c) **[1 mark]** Over time, the voltage the battery will produce will:

i) Increase, because the concentration of reactants should increase
ii) Increase, because the concentration of products should increase
iii) Decrease, because the concentration of the reactants should increase
iv) Decrease, because the concentration of the products should increase
v) None of these

d) **[2 marks]** The battery is constructed using the conditions described above and a current of 5 x 10^{-4} A is drawn from it for 321 minutes and 37 seconds. What will be the concentration of Fe^{3+} after that time?

e) **[1 mark]** The battery described in this problem may be recharged successfully. This means that which of the following statements is or are true for the battery? (Circle any and all that apply.)

i) The reduction potential of water is more positive than that of Co^{2+}
ii) The reduction potential of water is more negative than that of Co^{2+}
iii) The oxidation potential of water is more positive than that of Co^{2+}
iv) The oxidation potential of water is more negative than that of Co^{2+}

5) **[3 marks]** A concentration cell is set up according to the following half-reactions:

Half-cell 1: $2H^{+}(aq, X\ M) + 2e^{-} \rightleftharpoons H_2(g, 1\ bar)$
Half-cell 2: $2H^{+}(aq, Y\ M) + 2e^{-} \rightleftharpoons H_2(g, 1\ bar)$

The first half-cell uses a 2.0 M solution of a weak acid with a K_a = 5.0 x 10^{-5}. The second half-cell uses a 0.010 M solution of $HClO_4$. Calculate the voltage produced by the cell at 25°C.

6) **[5 marks total]** $H_3PO_4(aq)$ is a weak polyprotic acid, with $K_{a1} = 6.9 \times 10^{-3}$; $K_{a2} = 6.3 \times 10^{-8}$; $K_{a3} = 4.8 \times 10^{-13}$.

Consider 40.00 mL of a 5.0 M solution of H_3PO_4

a) **[2 marks]** Determine the pH of this solution

b) **[3 marks]** Determine the pH after adding 20.00 mL of 5.0 M NaOH to the $H_3PO_4(aq)$ solution.

7) **[3 marks]** Determine the pOH of a 0.45 M solution of HCl at 50.0°C. $K_w = 1.0 \times 10^{-14}$ at 25°C, and the autohydrolysis of water reaction has ΔH° = 55.8 kJ/mol.

8) **[5 marks total]** A lab technician is trying to prepare a saturated solution of Copper(II) hydroxide. $Cu(OH)_2(s)$ has a $K_{sp} = 4 \times 10^{-15}$. To do this, they add some $Cu(OH)_2$ (97.57 g/mol) into a 1.500 L volumetric flask and stir.

   a) **[3 marks]** Determine the amount of $Cu(OH)_2(s)$ in grams that will dissolve.

   b) **[2 marks]** Determine the pH of the prepared solution

9) **[2 marks]** For the reaction:

$A + 3B \longrightarrow 2C + 5D$

the (experimental) rate law has been found to be rate = k[A][B]

From the information above, it can be deduced that:

a) The rate of disappearance of A is three times that of B.
b) The rate of appearance of C is 40 percent of that of D.
c) C and D must never appear in the reaction mechanism.
d) There must be a catalyst present in order for the reaction to proceed.
e) None of these

10) **[5 marks]** Given the following data for the mythical reaction $2A + 3B \longrightarrow C + 6D$

Run	[A]	[B]	$-\frac{\Delta[A]}{\Delta t}\ (\frac{M}{s})$
1	1.0	1.0	4.0
2	2.0	1.0	16.0
3	3.0	2.0	36.0

a) **[2 marks]** The values of x and y in the rate law rate = $k[A]^x[B]^y$ are:

i) x =1 and y = 0
ii) x = 1 and y = 1
iii) x = 1 and y = 2
iv) x = 2 and y = 0
v) x = 2 and y = 1
vi) x = 2 and y = 2

b) **[2 marks]** The value of the rate constant (without units) is:

i) 2.0
ii) 4.0
iii) 6.0
iv) 8.0
v) None of these

c) **[1 mark]** What will be the rate of disappearance of compound B in run 3?

11) **[2 marks]** The rate of a certain reaction triples when the temperature is increased from 25°C to 50°C. The molar energy of activation for the reaction is:

a) 4.6 J
b) 35.2 kJ
c) 352 J
d) 457 J
e) None of these

12) **[2 marks]** Consider the following reaction:

$CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$

When 1.00 mol of CO(g) is mixed with 3.00 mol of $H_2(g)$ in a 2.0 L vessel at 250°C and the reaction is allowed to reach equilibrium, it is determined that 0.500 mol of $H_2O(g)$ are present at equilibrium. Determine K_c at 250°C.

a) 9.3×10^{-3}
b) 3.7×10^{-2}
c) 0.13
d) 0.15
e) 0.59

13) **[1 mark]** Consider the following reaction:

$CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$ $\Delta H° = -20.0$ kJ

If the system is at equilibrium, which of the following changes will push the equilibrium towards the reactants?

a) Increasing the volume
b) Adding a catalyst
c) Condensing water to remove it from the equilibrium
d) Increasing the pressure
e) Decreasing the temperature

14) **[2 marks]** The following equilibrium constants have been determined for oxalic acid ($H_2C_2O_4$) at 25°C:

$H_2C_2O_4(aq) \rightleftharpoons H^+(aq) + HC_2O_4^-(aq)$ $K_{a1} = 6.5 \times 10^{-2}$

$2HC_2O_4^-(aq) \rightleftharpoons 2H^+(aq) + 2C_2O_4^{2-}(aq)$ $K_{a2} = 3.7 \times 10^{-9}$

Calculate the equilibrium constant for the following reaction at the same temperature:

$H_2C_2O_4(aq) \rightleftharpoons 2H^+(aq) + C_2O_4^{2-}(aq)$

a) 2.4×10^{-10}
b) 4.0×10^{-6}
c) 1.6×10^{-5}
d) 6.5×10^{-2}
e) 1.8×10^{7}

15) **[2 marks]** Consider the following equilibrium:

$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$ $K_c = 4.6 \times 10^{-3}$ at 800 K

If a sample of 15.0 g of $COCl_2(g)$ (98.9 g/mol) is placed in a 1.0 L flask at 800 K, the equilibrium concentration of $COCl_2(g)$ will be:

a) 0.0240 M
b) 0.0260 M
c) 0.126 M
d) 0.128 M
e) 0.152 M

16) **[2 marks]** Consider the following equilibrium:

$2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$ $K_p = 4.6 \times 10^{-3}$ at 800 K, $\Delta H° = -40.5$ kJ

Determine K_p at 400 K

a) 3.7×10^{-9}
b) 1.0×10^{-5}
c) 4.6×10^{-3}
d) 2.0×10^{0}
e) 5.6×10^{3}

17) **[5 marks total]** Given the half-reactions:

$H_3IO_6(aq) + 3H^+(aq) + 4e^- \longrightarrow IO_3^-(aq) + 3H_2O(l)$ ε° = 1.6 V
$IO_3^-(aq) + 5H^+(aq) + 4e^- \longrightarrow HIO(aq) + 2H_2O$ ε° = 1.13 V

a) **[2 marks]** ε° for the disproportionation of the IO_3^- ion will be:

i) -2.73 V
ii) -1.365 V
iii) -0.47 V
iv) 0.47 V
v) 1.365 V
vi) 2.73 V

b) **[2 marks]** ε° for the half-reaction

$H_3IO_6 + 8H^+ + 8e^- \longrightarrow HIO + 5H_2O$

will be:

i) -2.73 V
ii) -1.365 V
iii) -0.47 V
iv) 0.47 V
v) 1.365 V
vi) 2.73 V

c) **[1 mark]** A battery is constructed using the two half-reactions above. The anode half-reaction will be:

i) $H_3IO_6(aq) + 3H^+(aq) + 4e^- \longrightarrow IO_3^-(aq) + 3H_2O(l)$
ii) $IO_3^-(aq) + 5H^+(aq) + 4e^- \longrightarrow HIO(aq) + 2H_2O$
iii) $IO_3^-(aq) + 3H_2O(l) \longrightarrow H_3IO_6(aq) + 3H^+(aq) + 4e^-$
iv) $HIO(aq) + 2H_2O \longrightarrow IO_3^-(aq) + 5H^+(aq) + 4e^-$

18) **[2 marks]** What mass of potassium benzoate ($KC_7H_5O_2$: 160.15 g/mol) does one need to add to 255 mL of 0.15 M benzoic acid ($HC_7H_5O_2$), $K_a = 6.5 \times 10^{-5}$, to prepare a solution with pH = 4.50? Assume no volume change when solid potassium benzoate is added.

a) 3.21 g
b) 12.6 g
c) 49.3 g
d) 50.1 g
e) 132 g

19) **[2 marks]** Which solution, from the list below, would have the highest pH at 25°C?

a) 1.00×10^{-1} M HCl
b) 1.00×10^{-1} M HNO_2 ($K_a = 4.5 \times 10^{-4}$)
c) 1.00×10^{-1} M $NaNO_2$ (K_a (HNO_2) = 4.5×10^{-4})
d) 1.00×10^{-5} M NaOH
e) 1.00×10^{-5} M HCl

20) **[2 marks]** Which of the following acids would have the highest percent ionization:

a) 1.00×10^{-2} M HF ($K_a = 6.3 \times 10^{-4}$)
b) 1.00×10^{-3} M HF
c) 1.00×10^{-4} M HF
d) 1.00×10^{-2} M HNO_2 ($K_a = 4.5 \times 10^{-4}$)
e) 1.00×10^{-3} M HNO_2

21) **[2 marks]** Which of the following salts would have the highest molar solubility:

a) $Fe(OH)_3$ $K_{sp} = 2.5 \times 10^{-39}$
b) $Ca_3(PO_4)_2$ $K_{sp} = 1.0 \times 10^{-26}$
c) NiS $K_{sp} = 3.0 \times 10^{-19}$
d) AgI $K_{sp} = 8.3 \times 10^{-17}$
e) $Zn(OH)_2$ $K_{sp} = 2.1 \times 10^{-16}$

22) **[2 marks]** Determine the molar solubility of $Mg(OH)_2$ ($K_{sp} = 1.8 \times 10^{-11}$) in a solution that has a pH of 11.14.

a) 6.5×10^{-9} M
b) 9.4×10^{-6} M
c) 1.65×10^{-4} M
d) 6.9×10^{-4} M
e) 1.4×10^{-3} M

23) **[2 marks]** When 0.608 grams of KNO_3 (101.1 g/mol) is dissolved in 100.0 mL of water (D = 1.00 g/mL, S = 4.184 J/g·°C), the temperature of the resulting solution falls from 25.000°C to 24.500°C. Given this information, ΔH° for the reaction

$$KNO_3(s) \longrightarrow KNO_3(aq)$$

should be:

a) -210 J
b) -35 kJ
c) 35 kJ
d) 210 J
e) None of these

24) **[2 marks]** Given the reaction:

$$2NaOH(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l) \qquad \Delta H° = -160 \text{ kJ}$$

When 2.00 g of NaOH (40.0 g/mol) is added to 100.0 mL of .400 M H_2SO_4 (S = 4.184 J/g·°C, D = 1.00 g/mL), the amount of heat liberated should be:

a) 4 kJ
b) 6.4 kJ
c) 8 kJ
d) 10.4 kJ
e) 163 kJ

25) **[2 marks]** Given the reaction

$2C_4H_{10}(g) + 13O_2(g) \longrightarrow 8CO_2(g) + 10H_2O(l)$ $\Delta H° = -5756$ kJ

and that the molar enthalpies of formation of $CO_2(g)$ and $H_2O(l)$ are -393.5 kJ and -285.8 kJ, respectively, the molar enthalpy of formation of $C_4H_{10}(g)$ should be:

a) -2878 kJ
b) -250 kJ
c) -125 kJ
d) 125 kJ
e) 250 kJ
f) 2878 kJ

26) **[3 marks]** At 78.37°C, the vapour pressure of ethanol (C_2H_5OH) is 1 atm. Complete the table below with **only the sign** of the indicated thermodynamic quantity for the reaction

$C_2H_5OH(g, 1\ atm) \rightleftharpoons C_2H_5OH(l)$

Use either + (greater than zero), - (less than zero), or 0 (zero).

T (°C)	ΔG°	ΔH°	ΔS°
50			
75			
100			

27) **[10 marks total]** The reaction

$$2A(g) + B(s) \rightleftharpoons 3C(l) + D(g)$$

has $K_p = 2.07 \times 10^{-23}$ at 26°C, and 7.23×10^{-21} at 77°C.

a) **[2 marks]** ΔH° for the reaction is:

   i) -1911 J/mol
   ii) -1000 J/mol
   iii) -100 kJ/mol
   iv) 100 kJ/mol
   v) 1000 J/mol
   vi) 1911 J/mol

b) **[2 marks]** Four electrons are transferred during the reaction. At 26°C, ε° for the reaction will be:

   i) -0.337 V
   ii) -0.029 V
   iii) -0.003 V
   iv) 0.003 V
   v) 0.029 V
   vi) 0.337 V

c) **[2 marks]** If the pressure of A(g) is set to 1000 bar, and the pressure of D(g) is set to 1×10^{-20} bar, then at 77°C, the reaction will be:

   i) Spontaneous, because $\Delta S°_{univ} < 0$
   ii) Spontaneous, because Q < K
   iii) Spontaneous, because ΔG° > 0
   iv) Non-spontaneous, because $\Delta S°_{univ} < 0$
   v) Non-spontaneous, because Q < K
   vi) Non-spontaneous, because ΔG° > 0

d) **[1 mark]** ΔS° for the reaction above is -100 J/K. Is that value about what you would expect it to be? How do you know? (No marks for guessing. ☺)

e) **[2 marks]** ΔG° for the reaction at 125°C is 139.815 kJ. K_p for the reaction at 125°C is:

i) 5.70×10^{-1835}
ii) 3.76×10^{-59}
iii) 4.55×10^{-19}
iv) 2.20×10^{18}
v) 2.66×10^{58}
vi) 1.76×10^{1834}

f) **[1 mark]** At 25°C, ΔE° - ΔH° for the reaction should be:

i) -208 J
ii) -25 J
iii) -2.5 kJ
iv) 2.5 kJ
v) 25 J
vi) 208 J

28) **[1 mark]** What happens when a substance is heated and pressurized beyond its critical point?

a) All three phases coexist
b) A plasma is generated and this phase is unstable
c) The substance is entirely in the gas phase
d) The substance exists in a phase that has properties of both liquids and gases
e) It is impossible to reach such temperatures and pressures under experimental conditions

29) **[2 marks]** A liquid solution consists of 0.30 mole fraction of ethylene dibromide, $C_2H_4Br_2$, and 0.70 mole fraction of propylene dibromide, $C_3H_6Br_2$. Both ethylene dibromide and propylene dibromide are volatile liquids, and their vapour pressures at some temperature are 173 mmHg and 127 mmHg respectively. The vapour pressure of the mixture was determined to be 140.8 mmHg. From this information, which of the following is true:

a) The mixture is ideal and follows Raoult's law
b) The mixture is non-ideal and shows negative deviation from Raoult's law
c) The mixture is non-ideal and shows positive deviation from Raoult's law
d) The mixture contains about the same mass of ethylene dibromide and propylene dibromide
e) none of the above

30) **[2 marks]** Ammonia has a normal boiling point of -33.4°C. Determine the boiling point of ammonia in a pressurized flask at 3.00 atm taking into account $\Delta H^{\circ}_{vap}(NH_3)$= 23.4 kJ/mol.

a) -270°C
b) -53.8°C
c) -8.65°C
d) 33.8°C
e) 75.1°C