Kwantlen Polytechnic University
Department of Chemistry
Chemistry 1154 Final Examination
Saturday, December 13, 2014

Name: ___________________________ Student #: ________________________________

Instructions:

- You have **three hours** to complete this exam.

- This exam consists of **sixteen** pages: This cover page and 15 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 **86** marks available in **29** 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
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3		4
4		5
5		6
6		5
7		5
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11		7
12		9
13		6
14		7
15		6
16		6
Total		86

1) **[4 marks]** A forensic scientist is given a sample of LSD ($C_{24}H_{30}N_3O$, molar mass 376.52 g) which is cut with sugar ($C_{12}H_{22}O_{11}$, molar mass 342.3 g). When 1.00 mg of the mixture is combusted, 2.00 mg of CO_2 is formed. What is the mass percentage of LSD in the mixture?

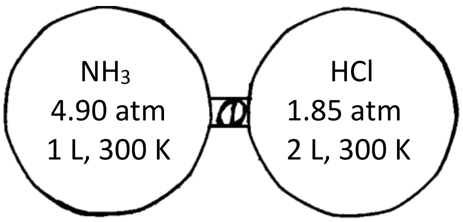
2) **[4 marks total]** A solid sample with mass 0.950 g contained strontium chloride ($SrCl_2$, molar mass 158.5 g) and inert impurities. The solid was dissolved in water and 25.00 mL of 0.2241 M $AgNO_3$(aq) was added. Solid AgCl precipitated. The excess Ag^+ ions were titrated with 15.48 mL of 0.09845 M NH4SCN(aq) according to the equation:

$$Ag^+(aq) + NH_4SCN(aq) \longrightarrow AgSCN(s) + NH_4^+(aq)$$

a) **[3 marks]** Determine the percent strontium chloride in the original sample.

b) **[1 mark]** What other method could be used to determine the percent strontium chloride?

3) **[5 marks total]** Two glass bulbs are filled with NH_3 and HCl gases as illustrated below:



When the bulbs are connected the gases mix and solid NH_4Cl is formed according to the reaction:

$$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$$

If the initial pressure of NH_3 is 4.90 atm and the initial pressure of HCl is 1.85 atm, both at 300 K, determine the following:

a) **[2 marks]** The mass of NH_4Cl (53.5 g/mol) that should be produced

b) **[2 marks]** The final pressure in the system after the reaction is complete.

c) **[1 mark]** The percent yield of the reaction is only 6.50 g of NH_4Cl is obtained.

4) **[1 mark]** The molar mass of the sex pheromone of the European elm bark beetle was determined by effusion. A sample of the pheromone for the US pine beetle (molar mass 142 g) took 43.7 seconds to effuse. Under the same conditions it took 47.8 seconds for a similar sample of the European elm bark beetle pheromone to effuse. Determine the molar mass of the European elm bark beetle pheromone.

5) **[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 mass of $Cu(OH)_2(s)$ in grams that will dissolve.

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

6) **[5 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.

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) **[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+}

7) **[5 marks total]** A certain compound has a normal melting point of 41°C and a normal boiling point of 123°C. The triple point is at 39°C and 85 mmHg.

a) **[3 marks]** Sketch the phase diagram for this substance. Label all regions, lines and points appropriately.

b) **[1 mark]** Does the solid phase of this substance have a density greater or less than that of the liquid phase? How do you know? (No marks for guessing. ☺)

c) **[1 mark]** Describe what happens when a sample of this substance at 2 atm and a temperature of 20°C is heated at constant pressure to a temperature of 50°C, pressure is decreased at constant temperature to 84 mmHg, and then cooled at constant pressure to 30°C.

8) **[3 marks]** The primary constituent of lemon oil is the hydrocarbon limonene. Limonene is 88.16% C and 11.84% H. A solution of 4.181 g of limonene in 50.00 g of benzene boils at 83.28°C. The benzene used to prepare the solution boils at 80.15°C. The boiling point elevation constant for benzene is 5.12°C·kg/mol. Determine the molecular formula of limonene.

9) **[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

10) **[1 mark]** Consider the following reaction:

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

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

11) **[2 marks]** The following equilibrium constants have been determined for oxalic acid ($H_2C_2O_4$) at 25°C:

$H_2C_2O_4(aq) \rightleftharpoons H^+(aq) + HC_2O_4^-(aq) \quad K_{a1} = 6.5 \times 10^{-2}$
$2HC_2O_4^-(aq) \rightleftharpoons 2H^+(aq) + 2C_2O_4^{2-}(aq) \quad K_{a2} = 3.7 \times 10^{-9}$

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}

12) **[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

13) **[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}

14) **[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) $Zn(OH)_2$ $K_{sp} = 2.1 \times 10^{-16}$

15) **[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

16) **[3 marks]** An indicator ($pK_a = 8.0$) was used in a titration. The indicator appears yellow when $[Hind]/[Ind^{1-}] = 25$ and blue when $[Hind]/[Ind^{1-}] = 0.25$. Calculate the pH range over which this indicator changes colour and place those pH values in the appropriate blanks below.

pH range: ______(yellow) to ______(blue)

Would this be a suitable indicator to use for the titration of NH_3 with HCl?

Yes No

17) **[1 mark]** For the equilibrium system

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_2^{1-} + H_3O^+(aq)$

circle the true statement:

a) NH_3 and H_2O are acting as Bronsted-Lowry bases.
b) H_2O and H_3O^+ are a conjugate pair.
c) NH_2^{1-} and OH^{1-} are acting as Bronsted-Lowry acids.
d) NH_2^{1-} and H_2O are a conjugate pair.
e) NH_3 is acting as an Arrhenius base.

18) **[3 marks]** A solution of an unknown acid has a pH = 2.95. Reaction of 20.0 mL of this acid solution required 24.62 mL of 0.1025 M sodium hydroxide for complete neutralization. Assuming that the acid is monoprotic, what is its ionization constant?

a) 1.0×10^{-7}
b) 1.3×10^{-6}
c) 1.0×10^{-5}
d) 5.0×10^{-4}
e) 1.1×10^{-3}

19) **[3 marks]** Methyamine, CH_3NH_2, has a $K_b = 3.2 \times 10^{-5}$. What is the percent ionization in 1.0 and 0.1 M solutions of methylamine?

a) 0.018% (1 M) and 0.056% (0.1 M)
b) 0.032% (1 M) and 0.0032% (0.1 M)
c) 0.56% (1 M) and 1.8% (0.1 M)
d) 0.56% in both
e) 0.32% in both

20) **[1 mark]** Match the numbers I through V with the appropriate solutions in questions (a) – (e):

I – A solution with a pH less than 7 that is not a buffer
II – A buffer solution with a pH between 4 and 7
III – A solution with a pH of 7
IV – A buffer solution with a pH between 7 and 10
V – A solution with a pH greater than 7 that is not a buffer

a) A mixture of 1 mole NaOH and 1 mole HCl in enough water to make 1.0 L ____
b) A mixture of 1 mole NaF and 1 mole $NaCH_3COO$ in enough water to make 1.0 L ____
c) A mixture of 1 mole NaF and 0.5 mole HF in enough water to make 1.0 L ____
d) A mixture of 50.0 mL 0.10 M HCl with 25.0 mL 0.10 M NH_3 ____
e) A mixture of 25.0 mL 0.10 M HCl with 50.0 mL 0.10 M NH_3 ____

21) **[2 marks]** What mass of sodium acetate (molar mass 82 g) should be dissolved in 200.0 mL of 0.20 M acetic acid to form a buffer of pH = 5.0? K_a for acetic acid is 1.8×10^{-5}.

a) 3.3 g
b) 5.9 g
c) 9.1 g
d) 16.4 g
e) 45 g

22) **[3 marks]** What is the pH at the equivalence point for the titration of 0.10 M benzoic acid by 0.10 M sodium hydroxide? (K_a for benzoic acid is 6.3×10^{-5})

a) 5.40
b) 5.55
c) 8.45
d) 8.60
e) 11.25

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:

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

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

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

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 $\Delta G° > 0$
iv) Non-spontaneous, because $\Delta S°_{univ} < 0$
v) Non-spontaneous, because $Q < K$
vi) Non-spontaneous, because $\Delta G° > 0$

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

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

a) **[2 marks]** ε° for the simultaneous conversion of the IO_3^- ion into HIO and H_3IO_6 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) $HIO(aq) + 2H_2O \longrightarrow IO_3^-(aq) + 5H^+(aq) + 4e^-$

29) **[1 mark]** The normal boiling point of a liquid:

a) Is the temperature at which the liquid and vapour at in equilibrium.
b) Varies with the atmospheric pressure
c) Is the temperature at which the vapour pressure is 1 atm
d) Is the temperature at which the vapour pressure equals the external pressure
e) Is directly proportional to the molar mass of the liquid.