KPU | KWANTLEN POLYTECHNIC UNIVERSITY

CHEMISTRY 1210
Final Exam
April 17, 2014

Time: 3 hours

Name: ____________________________ Student #: _________________________

Instructions:

Answer all questions on the exam paper.

Circle correct answers for multiple choice questions.

Show all work for non-multiple choice problems.

The left hand pages may be used for rough work; these pages will not be graded.

A formula sheet and periodic table are provided; no other materials may be used.

Work independently. Cheating will not be tolerated.

This exam should have 34 questions.

Unless otherwise specified you may assume the temperature is 25ºC

Page	Mark	Maximum
2		5
3		6
4		5
5		5
6		6.5
7		4
8		5
9		7.5
10		7
11		6
12		7
13		6
14		8
15		6
16		5
Total		89

1) **[5 marks total]** The following oxidation-reduction reaction occurs in ***basic*** solution:

$P_4 + ClO_3^{-1} \longrightarrow PO_4^{3-} + Cl^{1-}$

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

b) **[1 mark]** Which species is the reducing agent? _______________

2) **[3 marks total]** A 25.00-mL sample of a solution of Mo^{3+} solution was reacted with 0.0600 N $KMnO_4$:

$$MnO_4^{-1}(aq) + Mo^{3+}(aq) \longrightarrow Mn^{2+} + MoO_2^{2+}(aq)$$

a) **[1 mark]** If the Mo^{3+} in the reaction came from $MoCl_3$ (molar mass 202.3 grams), what is the equivalent mass of the $MoCl_3$?

b) **[2 marks]** The 25.00 mL sample of Mo^{3+} solution required 15.00 mL of the $KMnO_4$ solution for complete reaction. Determine the ***molarity*** of the Mo^{3+} in the solution.

3) **[1 mark]** The activation energy for the forward direction of a reaction is 50 kJ and for the reverse direction is 30 kJ. The ΔH for the overall reaction is:

a) -20 kJ
b) 20 kJ
c) -80 kJ
d) 80 kJ
e) There is not enough information to answer this question.

4) **[2 marks]** The uncoiling of DNA is a first order process with an activation energy of about 420 kJ/mol. At 50°C the half-life for uncoiling is estimated to be 2 minutes. What is the half-life at a normal body temperature of 37°C?

a) 2.8×10^{-3} min
b) 1.4 min
c) 2 min
d) 2.85 min
e) 1411 min

5) **[2 marks]** A reaction has a rate constant k = 1.25×10^{-4} mol L^{-1} s^{-1}. If the initial concentration of the reactant is 0.0750 M, what concentration remains after 10.0 minutes?

a) 0 M
b) 0.0696 M
c) 0.0738 M
d) 0.0749 M
e) 0.150 M

6) **[3 marks]** The rate of the reaction:

$$3I^{-1} + S_2O_8^{-2} \longrightarrow I_3^{-1} + 2SO_4^{-2}$$

was studied using the iodine clock technique and the following data were obtained (*t* is the time the reaction took):

Run	$[I^{1-}]_o$ (M)	$[S_2O_8^{2-}]_o$ (M)	*t* (s)
1	0.0400	0.0400	88.0
2	0.0800	0.0400	44.0
3	0.0800	0.0800	22.1

a) The order of this reaction with respect to $S_2O_8^{2-}$ is:

i) 0
ii) ½
iii) 1
iv) 2
v) 3

b) The overall order of this reaction is:

i) 0
ii) ½
iii) 1
iv) 2
v) 3

c) If a run is made with $[I^{1-}]_o$ = 0.120 M and $[S_2O_8^{2-}]_o$ = 0.0400, you would expect the reaction to complete in approximately:

i) 29 s
ii) 33 s
iii) 44 s
iv) 66 s
v) 88 s

7) **[5 marks total]** The Raschig reaction produces aqueous hydrazine, $N_2H_4(aq)$, from $NH_3(aq)$ and $OCl^{-1}(aq)$ in basic, aqueous solution. A proposed mechanism is:

Step 1 (fast): $NH_3(aq) + OCl^{-1}(aq) \xrightarrow{k_1} NH_2Cl(aq) + OH^{-1}(aq)$

Step 2 (slow): $NH_2Cl(aq) + NH_3(aq) \xrightarrow{k_2} N_2H_5^{+1}(aq) + Cl^{-1}(aq)$

Step 3 (fast): $N_2H_5^{+1}(aq) + OH^{-1} \xrightarrow{k_3} N_2H_4(aq) + H_2O(l)$

a) **[3 marks]** Determine the rate law based on this reaction mechanism, show all your work clearly.

b) **[1 mark]** The following substances are intermediates: ______________________

c) **[1 mark]** This reaction mechanism involves a catalyst (circle one): YES NO

8) **[2 marks]** Find K_p for the following reaction at 25°C:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $K_c = 2.4 \times 10^{-3}$ at 25°C

a) 3.9×10^{-10}
b) 5.6×10^{-8}
c) 3.9×10^{-6}
d) 5.6×10^{-4}
e) 1.5
f) 100

9) **[2.5 marks total]** For the equilibrium mixture at 200°C:

$NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$ $\Delta H > 0$

Indicate if the partial pressure of NH_3 will increase, decrease or remain the same when the following changes are made:

(Circle your choice: I – increase D – decrease NC – no change)

Add some Ne	I	D	NC
Add some H_2S	I	D	NC
Add some NH_4HS	I	D	NC
Increase the temperature	I	D	NC
Double the volume of the container (at constant T)	I	D	NC

10) **[2 marks]** Given the following equilibria:

$\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons NO(g)$ $K_c = 4.8 \times 10^{-10}$
$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$ $K_c = 1.1 \times 10^{-5}$

K_c for the equilibrium:

$2NO_2(g) \rightleftharpoons N_2(g) + 2O_2(g)$

will be:

a) 2.5×10^{-24}
b) 5.3×10^{-15}
c) 2.1×10^{-14}
d) 2.3×10^{4}
e) 4.8×10^{13}

11) **[2 marks]** At a given temperature, $K_c = 3.24$ for the reaction:

$H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$

If 0.800 mol of both H_2 and CO_2 are placed in a 1.00 L container at this temperature, when the system comes to equilibrium the concentration of CO(g) will be:

a) 1.60 M
b) 0.800 M
c) 0.611 M
d) 0.514 M
e) 0.247 M

12) **[1 mark]** For the reaction:

$I_2(g) + Br_2(g) \rightleftharpoons 2IBr(g)$ $K_p = 280$

If a container is filled with these gases, such that $P(I_2) = 10.0$ bar, $P(Br_2) = 5.0$ bar, and $P(IBr) = 20.0$ bar, in which direction will the reaction proceed?

a) The reaction proceeds to the left.
b) The reaction proceeds to the right.
c) The reaction is at equilibrium.
d) The reaction volume is required in order to answer this question.
e) The temperature is required in order to answer this question.

13) **[1 mark]** Choose the correct statement when the reaction

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

is at equilibrium:

a) The rate constant for the forward reaction is equal to the rate constant for the reverse reaction.
b) The rate for the forward reaction is equal to the rate for the reverse reaction.
c) The concentrations of all reactants and products are equal.
d) Increasing the volume of the reaction container will increase the yield of ammonia.
e) The equilibrium expression for the reaction is $K_c = \frac{[N_2][H_2]^3}{[NH_3]^2}$

14) **[2 marks]** An indicator (pK_a = 5.0) changes colour from yellow to blue. It last appears yellow when $[Ind^{-1}]/[HInd]$ = 0.04 and appears completely blue when $[Ind^{-1}]/[HInd]$ = 4.

a) 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)

b) Would this be a suitable indicator to use for the titration of NH_3 with HCl? (Circle your choice.)

Yes No

15) **[1 mark]** In the equilibrium system

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

Bronsted-Lowry theory would designate:

a) NH_3 and H_2O as the bases.
b) H_2O and OH^{1-} as a conjugate pair.
c) NH_2^{1-} and H_3O^+ as the acids.
d) NH_2^{1-} and H_2O as a conjugate pair.
e) NH_3 as amphiprotic.

16) **[2 marks]** A 10.0 mL sample of a 0.125 M solution of an unknown monoprotic acid has a pH = 2.95. What is its ionization constant, K_a?

a) 1.0×10^{-7}
b) 1.3×10^{-6}
c) 1.0×10^{-5}
d) 1.1×10^{-3}
e) 9.8×10^{-3}

17) **[3 marks]** Methylamine, CH_3NH_2, has a $K_b = 3.2 \times 10^{-5}$. What is its percent ionization in 1.0 and 0.1 M solutions, respectively?

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

18) **[2.5 marks]** Match the descriptions given below with one of the mixtures described 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 NaCl in enough water to make 1.0 L ____
b) A mixture of 1 mole NaCl and 1 mole $CaCl_2$ 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 ____

19) **[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}.

20) **[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 x 10^{-5})

21) **[2 marks]** How many moles of SrF_2 will dissolve in 1 L of 0.10 M $Sr(NO_3)_2$ if K_{sp} for SrF_2 is 7.9 x 10^{-10}?

a) 2.8 x 10^{-5}
b) 4.4 x 10^{-5}
c) 7.9 x 10^{-8}
d) 4.0 x 10^{-9}
e) 7.9 x 10^{-9}

22) **[2 marks]** A solution is 0.120 M in Pb^{2+}. If the K_{sp} for $PbCrO_4$ = 1.8 x 10^{-14}. In order to precipitate 99.9% of all the Pb^{2+} present, the [CrO_4^{2-}] must be:

a) 1.8 x 10^{-17}
b) 1.8 x 10^{-14}
c) 1.5 x 10^{-13}
d) 1.5 x 10^{-10}
e) 1.3 x 10^{-7}

23) **[6 marks total]** Given the reaction:

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$ $\Delta H^o_{298} = -189.32$ kJ

a) **[2 marks]** Estimate the bond dissociation energy for the O-O single bond. The bond energy for the O_2 molecule is 498.3 kJ/mol, and the enthalpies of vaporization of $H_2O_2(aq)$ and $H_2O(l)$ are approximately equal.

b) **[1 mark]** Give two reasons why your answer above is an estimate and not an accurate calculation of the bond dissociation energy.

c) **[3 marks]** One litre of a solution initially 0.0100 M in H_2O_2 and at 25.000ºC is reacted. If all the heat produced in the reaction is retained in the solution, what would be the final temperature? Assume the specific heat capacity of the solution to be 4.184 J $g^{-1}K^{-1}$, and that the density of the solution is 1.00 g/mL.

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

$C_4H_8(l) + 6O_2(g) \longrightarrow 4CO_2(g) + 4H_2O(l)$ $\Delta H° = -2696.9$ 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 butane ($C_4H_8(l)$) is:

a) +2017 kJ/mol
b) -20.3 kJ/mol
c) -107.6 kJ/mol
d) -2017 kJ/mol
e) +20.3 kJ/mol

25) **[8 marks total]** For the following system:

$$(NH_4)_2SO_4(s) \rightleftharpoons 2NH_3(g) + H_2O(g) + SO_3(g)$$

$\Delta H°_{298} = +449.6$ kJ
$\Delta S°_{298} = +609.62$ J/mol K

a) $\Delta G°_{298} = 267.9$ kJ

i) **[2 marks]** $K_{p,298}$ for this reaction is:

(1) 1.0×10^{-4696}
(2) 1.1×10^{-47}
(3) 2.0×10^{-5}
(4) 0.90
(5) 9.1×10^{46}

ii) **[2 marks]** Determine the value of ΔG_{298} when $P(NH_3) = 0.0010$ bar, $P(H_2O) = 0.0020$ bar and $P(SO_3) = 0.0020$ bar.

iii) **[1 mark]** Under the conditions in part (c) the forward reaction is: (circle one)

spontaneous **non-spontaneous**

b) **[1 mark]** At what temperature will this reaction be at equilibrium under standard conditions?

c) **[2 marks]** $K_{p,1000}$ for this reaction will be:

i) 4.4×10^{-9}
ii) 1.0×10^{-14}
iii) 2.3×10^{8}
iv) 9.9×10^{13}
v) 8.8×10^{835}

26) **[3 marks total]** A concentration cell uses a standard hydrogen electrode (SHE) for one half cell. The other half-cell also uses $H_2(g)$ at 1 bar pressure, but the hydrogen ions in solution come from a weak acid. The cell so constructed produces 0.245 V.

a) **[0.5 marks]** The SHE is the (circle one): ANODE CATHODE

b) **[0.5 marks]** The process occurring at the SHE is (circle one):

OXIDATION REDUCTION

c) **[2 marks]** Determine the pH of the buffered solution.

27) **[2 marks]** Determine the equilibrium constant (K_c) for the following reaction at 25ºC.

$Pb^{2+}(aq) + Cu(s) \longrightarrow Pb(s) + Cu^{2+}(aq)$

Given the standard reduction potentials: $Pb^{2+}/Pb = -0.125$ V and $Cu^{2+}/Cu = +0.337$ V

a) 2.41×10^{-16}
b) 6.80×10^{-8}
c) 1.65×10^{-7}
d) 1.46×10^{7}
e) 4.15×10^{15}

28) **[2 marks]** Given the reaction:

$2Al(s) + 3Ni^{2+}(aq) \longrightarrow 2Al^{3+}(Aq) + 3Ni(s)$ $\quad\quad \varepsilon° = +1.4100$ V

What would be the voltage if $[Ni^{2+}] = 0.020$ M and $[Al^{3+}] = 3.60$ M?

a) 1.3880 V
b) 1.4322 V
c) 1.4712 V
d) 1.3488 V
e) 1.3182 V

29) **[2 marks]** A copper electrode weighs 35.42 g before electrolysis (of a $CuSO_4$ solution) and 36.69 g after. The electrolysis was performed using a current of 3.50 amperes. How long did the electrolysis take?

a) 9.2 s
b) 275 s
c) 551 s
d) 1102 s
e) 1.35×10^{4} s

30) **[2 marks]** Given the reaction:

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$ $\quad\quad \varepsilon° = 1.092$ V

What is $\Delta G°$?

a) -2108 kJ
b) -211 kJ
c) -105 kJ
d) 211 kJ
e) 2108 kJ

31) **[1 mark]** The normal boiling point of a liquid:

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

32) **[2 marks]** At 35°C, the vapour pressure of CS_2 is 512 mmHg, and of acetone, CH_3COCH_3, is 344 mmHg. It is known that the acetone-CS_2 intermolecular forces are weaker than the acetone-acetone or CS_2-CS_2 intermolecular forces. Given this information, you would expect that:

a) A mixture of 100.0 mL of acetone and 100.0 mL of CS_2 has a volume of 200.0 mL.
b) A mixture of 100.0 mL of acetone and 100.0 mL of CS_2 has a volume less than 200.0 mL.
c) When acetone and CS_2 are mixed at 35°C heat is absorbed.
d) When acetone and CS_2 are mixed at 35°C heat is evolved.
e) The vapour pressure above the solution would be lower than predicted.

33) **[3 marks]** The primary constituent of lemon oil is the hydrocarbon, limonene, that is 88.16% C and 11.84% H. A solution of 8.362 g of limonene in 50.00 g of benzene freezes at 2.37°C. Pure benzene freezes at 5.5°C. The freezing point depression constant for benzene is 5.12°C kg/mol. Determine the molecular formula of limonene.

34) **[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.