Last Name: ____

First name: ____

Student Number: ______________________________ **Seat #:** [ ]

Final Exam - CHM 1311 D

Prof. Natalie Goto
Monday December 18th, 2017
9h30 – 12h30 (3 hours)

Instructions:

- There are 13 pages in this exam.
- This is a closed book exam with no notes allowed.
- Non-graphing, non-programmable calculators are permitted.
- A periodic table, data tables, and a formula sheet are provided at the end. You may rip these 2 pages off of the exam.
- You must show all work so that it is clear how the question was solved.
- Final answers must include units where appropriate.
- Marks may be deducted if an unreasonable number of sig figs are shown in your final answer.
- If data calculated in previous sections of a multi-part question and used for subsequent calculations is incorrect, no additional mark deductions will be applied.

Cellular phones, unauthorized electronic devices or course notes are not allowed during this exam. Phones and devices must be turned off and put away in your bag. Do not keep them in your possession, such as in your pockets. If caught with such a device or document, academic fraud allegations may be filed which could then result in you obtaining a 0 (zero) for the exam.

By signing below, you acknowledge that you have read and ensured that you are complying with the above statement.

Signature:______________________________________

Question	Points Possible	Points Earned
1	18	
2	18	
3	4	
4	4	
5	10	
6	12	
7	9	
8	15	
TOTAL	90	

Question 1. (1 mark each)

a) Give the *n* and *l* values for the 4*p* subshell.

b) An isotope of lead with and isotopic molecular weight of 207 g mol^{-1} has __________ protons and _________ neutrons.

c) If NH_4Cl is added to water, will the pH increase, decrease or stay the same?

d) Write the partial electron configuration for the ground state of the element arsenic.

e) Why does a real gas does not always obey the ideal gas law? (There are a few reasons for this - you only need to give one.)

f) It takes more time for the cheese on a pizza to cool down, even thought the pizza crust cools relatively quickly. Which substance has the larger heat capacity, cheese or pizza crust?

g) For the reaction:

$$4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$$

If the rate of change for NH_3 is -0.612 mol L^{-1} s^{-1}, what is the rate of change for O_2?.

h) Will the solubility of calcium fluoride increase, decrease or stay the same if hydrochloric acid is added to a saturated solution containing calcium fluoride crystals?

i) Name one compound that could be added to a solution of Na_3PO_4 that would create a buffer.

j) Circle the species below with the largest K_b, given that $K < 1$ for this reaction.

$$HPO_4^{2-}\ (aq) + SO_3^{2-}\ (aq) \leftrightarrows PO_4^{3-}\ (aq) + HSO_3^{-}\ (aq)$$

k) Mr. Citrus is wearing cologne made from methyl octanoate ($C_9H_{18}O_2$) while Granny Smith wears a perfume composed of ethyl octanoate ($C_{10}H_{20}O_2$). Suppose you are blindfolded so that you are only able to identify each character by smell. Who will you detect first by smell when they enter a room together?

l) Suppose a mixture of argon and helium gas is introduced into a sealed glass bottle containing solid iodine. Suppose a small amount of the solid iodine becomes gas (*i.e.* it sublimes). Will this sublimation of iodine cause the partial pressure of argon in the bottle to increase, decrease, or stay the same? (Assume that the temperature of the gas is constant.)

m) Draw a partial (valence shell) orbital diagram for vanadium.

n) If the internal energy of an ideal gas increases by 500 J, and the gas does 600 J of work in the process, what is q?

q = ____________________

o) Name the orbital with quantum numbers $n = 4$, $l = 3$.

p) What is the net spin of the element titanium?

q) How many atoms of chlorine are contained in 0.15 mol of $PbCl_2$?

r) What will precipitate first if NaOH is added to a solution containing 0.1 M $FeCl_2$ and 0.1 M $CdCl_2$? K_{sp}=4.8x10^{-17} for $Fe(OH)_2$ and K_{sp}=7.2x10^{-15} for $Cd(OH)_2$.

______________________________ will precipitate first.

Question 2 (2 marks each unless otherwise indicated)

a) How many moles of solid aluminum sulfide can be prepared from the reaction of 0.025 mol of solid aluminum and 0.025 mol of solid sulfur?

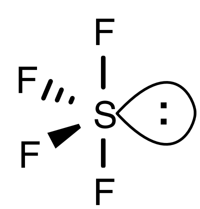
b) What is the energy absorbed by a hydrogen atom with an electron in the n=2 energy level that is promoted to n=5?

Energy = ______________________

c) Complete the reaction below, and indicate whether the equilibrium will favor the products or reactants, and provide a brief explanation for your answer. On the reactant side, the pK_a of hypobromous acid is 8.55 and the pK_b of pyridine is 8.77.

$$C_5H_5N\,(aq) + HBrO\,(aq) \rightleftharpoons$$

d) Name the molecular shape of SF_4 (shown on the right).
Is this a polar molecule? If so, draw the molecular dipole on the structure.



e) For a theoretical reaction, the reaction mechanism was determined to be:

$$A \rightarrow B + C$$
$$B + D \rightarrow E$$
$$C + E \rightarrow F + D$$

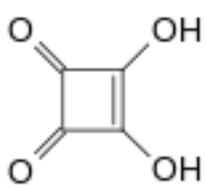
i) What is(are) the intermediate(s)?

ii) Is this reaction catalyzed? If so, what is the catalyst?

f) Hydrogen fluoride gas is produced industrially by the action of concentrated aqueous sulphuric acid on solid CaF_2, with solid $CaSO_4$ being a by-product of the reaction. Suppose 5.75 mol of CaF_2 is treated with an excess of sulphuric acid and 3.95 mol of HF is produced. What is the percent yield of HF?

g) A 0.65 mol sample of methane gas at 50.0 °C has a pressure of 875 mmHg. What is the volume of methane are in this sample?

h) Write the balanced chemical equation for the combustion of solid squaric acid ($C_4H_2O_4$). Be sure to indicate the phases for all species in the reaction.



i) In order to break a bond in ozone (O_3), an energy of 8.26×10^{-19} J must be absorbed. What wavelength of light would be required to break one of the bonds in ozone? Give your answer in units of nm.

Question 3.

Calculate the solubility of BaF_2 in 0.013 M $Ba(NO_3)_2$ (Ksp=1.8 x 10^{-7}). (4 marks)

Question 4.

The combustion of 1.00 mol of glucose, $C_6H_{12}O_6$, releases 2820 kJ of heat. If 0.0110 mol of glucose is burned in a calorimeter containing 1.0 kg of water (c_{H_2O} = 4.184 J K^{-1} g^{-1}), and the temperature increases by 3.5 ^{o}C, what is the heat capacity of the calorimeter? (4 marks)

Question 5.

When one aspirin tablet is dissolved in 200.0 mL of water, a 0.0090 mol/L solution of salicyclic acid ($C_8H_7O_2COOH$, pKa = 4.8) is produced. Suppose this solution is titrated with a 0.075 mol/L solution of NaOH.

a) What is the total volume of the titrated solution when the titration reaches the stoichiometric point? (3 marks)

b) Find the pH of the solution at the stoichiometric point. Demonstrate the validity of one of the assumptions you used to solve the question. (7 marks)

Question 6.

The data in the table shows the effect of reactant concentration on the rate of reaction:

$$A + 2\,B \rightarrow C$$

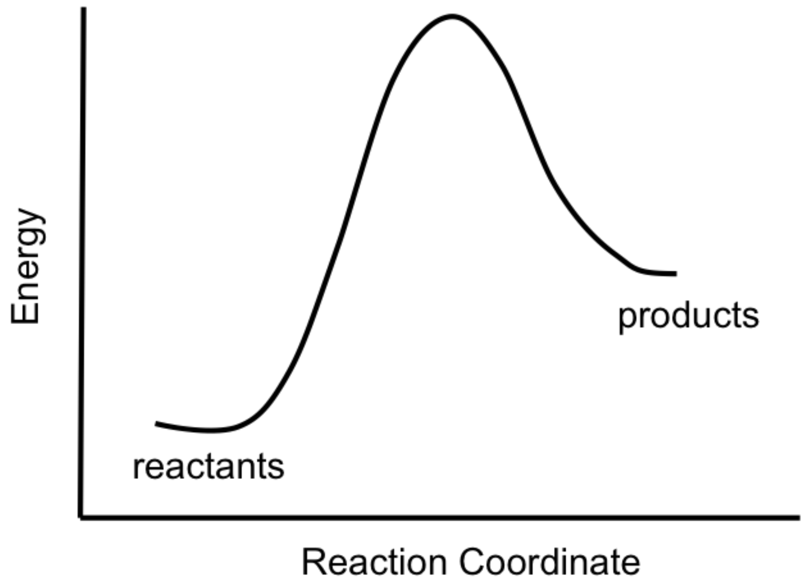
$[A]_o$ (mol L^{-1})	$[B]_o$ (mol L^{-1})	Initial Rate (mol L^{-1} s^{-1})
0.0013	0.012	4.70×10^{-3}
0.0013	0.018	1.06×10^{-2}
0.0027	0.012	4.70×10^{-3}

a) Use the data provided in the table to determine the rate law for this reaction and solve for k. (4 marks)

b) Is it possible that this overall reaction is also an elementary reaction? Briefly explain (2 marks)

c) How long does it take for 75% of a 0.019 mol L^{-1} solution of B to react? (3 marks)

d) Shown below is an activation energy diagram for this reaction. Label label E_a, and ΔE for the forward reaction, and on the same graph draw the reaction energy profile for a catalyzed version of this same reaction. (3 marks)



Question 7.
Answer the questions below for the redox reaction:

$$HClO_2\,(aq) + Co(s) \rightarrow Cl_2\,(g) + Co^{2+}(aq)$$

a) Write oxidation numbers for each atom underneath the chemical equation. (3 marks)

b) What is the oxidizing agent in this reaction? (1 mark)

c) Balance the equation in acidic solution. (5 marks)

Question 8: For the 3 molecules below:

i) Calculate the total number of valence electrons.
ii) Draw the most favored (lowest energy) Lewis dot structure.
iii) Write the formal charge for the indicated atom.
iv) Write the electron group geometry and molecular shape.
v) Write the ideal bond angles, and if they are larger, smaller, or equal to ideal angles.

a) H_3O^+ (5 marks)

b) Total number of valence electrons: ____________ Formal charge on O: ___________

c) Electron group geometry: ____

d) Molecular shape: ____

e) Ideal bond angles: ___________________ Actual bond angles: ____________________

f) NO_2^- (5 marks)

Total number of valence electrons: ____________ Formal charge on N: ___________

Electron group geometry: ____

Molecular shape: ____

Ideal bond angles: ___________________ Actual bond angles: ____________________

g) ICl_4^- (5 marks)

Total number of valence electrons: ____________ Formal charge on I: ___________

Electron group geometry: ____

Molecular shape: ____

Ideal bond angles: ___________________ Actual bond angles: ____________________

Post-Midterm 2 Equations

$$\mathrm{pH} = \mathrm{p}K_a + \log\frac{[\mathrm{A^-}]}{[\mathrm{HA}]} \qquad c = \lambda \times \nu \qquad \Delta E = h\nu \qquad \Delta x \Delta p = \frac{h}{4\pi} \qquad \lambda = \frac{h}{mv} \qquad E_n = -\frac{2.18\times 10^{-18}\ \mathrm{J}}{n^2}$$

Equations Covered Since Midterm 1

$$\mathrm{Rate} = \frac{1}{v_{\mathrm{X}}}\frac{\Delta[\mathrm{X}]}{\Delta t} \qquad \mathrm{Rate} = k[\mathrm{A}]^y[\mathrm{B}]^z\ldots \qquad \frac{\text{Initial Rate 1}}{\text{Initial Rate 2}} = \frac{k[\mathrm{A}]_1^y[\mathrm{B}]_2^z\ldots}{k[\mathrm{A}]_2^y[\mathrm{B}]_2^z\ldots} \qquad k = Ae^{-\frac{E_a}{RT}}$$

$$[\mathrm{A}]_t = [\mathrm{A}]_o - akt \qquad \ln\frac{[\mathrm{A}]_o}{[\mathrm{A}]_t} = akt \qquad \frac{1}{[\mathrm{A}]_t} - \frac{1}{[\mathrm{A}]_o} = 2kt \qquad \ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$t_{\frac{1}{2}} = \frac{[\mathrm{A}]_o}{2ak} \qquad t_{\frac{1}{2}} = \frac{\ln 2}{a\mathrm{k}} \qquad t_{\frac{1}{2}} = \frac{1}{2k[\mathrm{A}]_o} \qquad K_{eq} = \frac{[\mathrm{C}]_{eq}^c[\mathrm{D}]_{eq}^d}{[\mathrm{A}]_{eq}^a[\mathrm{B}]_{eq}^b} \qquad K_{eq} = \frac{p_{C,eq}^c\, p_{D,eq}^d}{p_{A,eq}^a\, p_{B,eq}^b}$$

$$Q = \frac{p_C^c p_D^d}{p_A^a p_B^b} \qquad Q = \frac{[\mathrm{C}]^c[\mathrm{D}]^d}{[\mathrm{A}]^a[\mathrm{B}]^b} \qquad K_{eq} = K_1 \times K_2 \times K_3 \times \ldots \qquad K_{eq,reverse} = \frac{1}{K_{eq,forward}} \qquad K_{eq,new} = \left(K_{eq,old}\right)^n$$

$$ax^2 + bx + c = 0 \qquad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \qquad \mathrm{pH} = -\log[\mathrm{H_3O^+}] \qquad \mathrm{pOH} = -\log[\mathrm{OH^-}] \qquad \mathrm{pH} + \mathrm{pOH} = 14$$

$$pK_a = -\log K_a \qquad \%\ \text{error} = 100\% \times \frac{\text{difference from assumed value}}{\text{actual value}} \qquad K_a \times K_b = K_w = 10^{-14} \qquad pK_b = -\log K_b$$

Midterm 1 Equations

$$T(\text{in K}) = T(\text{in }^{\circ}\mathrm{C}) + 273.15\ \mathrm{K} \qquad n = \frac{m}{M} = \frac{N}{N_A} \qquad \%\ \text{Yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \qquad c(\mathrm{mol/L}) = \frac{n}{V}$$

$$c_1V_1 = c_2V_2 = n \qquad p = \frac{mg}{A} \qquad p = dgh \qquad pV = nRT \qquad \frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2} \qquad p_T = p_1 + p_2 + p_3 + \ldots$$

$$p_A = X_A \times p_T \qquad X_A = \frac{n_A}{n_T} \qquad d = \frac{m}{V} = \frac{p \cdot M}{RT} \qquad E_K = \frac{1}{2}m\mathrm{v}^2 \qquad \bar{E} = \frac{3RT}{2N_A} \qquad \bar{v} = \sqrt{\frac{3RT}{M}}$$

$$\frac{Rate\ A}{Rate\ B} = \sqrt{\frac{M_B}{M_A}} \qquad p = \frac{nRT}{(V - nb)} - a\frac{n^2}{V^2} \qquad \Delta E = w + q \qquad w = F \times d = -p\Delta V$$

$$q_{\text{calorimeter}} = C_{cal}\Delta T \qquad q = mC\Delta T \qquad \Delta E_{\text{reaction}} = \Sigma BE_{\text{reactant bonds broken}} - \Sigma BE_{\text{product bonds formed}} \qquad \Delta E_{\text{molar}} = \frac{\Delta E}{n}$$

$$\Delta H^o_{\text{reaction}} = \Sigma v_p \Delta H^o_{f,p} - \Sigma v_r \Delta H^o_{f,r} \qquad \Delta H_{\text{reaction}} = \Delta E_{\text{reaction}} + RT\Delta n_{gas} \qquad H = E + pV$$

Constants and Conversion Factors

1 mmHg = 1 torr   760 mmHg = 1 atm   1 atm = 101.325 kPa   1 atm = 1.013125 bar
1 bar = 10^5 Pa   1 cm^3 = 1 mL   1 dm^3 = 1000 mL = 1 L   1 m^3 = 1000 L   1 cal = 4.184 J
1 J = 1 kg m^2 s^{-2}

Avogadro's Number	N_A	6.022×10^{23} mol^{-1}
Gas constant	R	8.31451 $J \cdot K^{-1} \cdot mol^{-1}$
	R	0.08206 $atm \cdot L \cdot K^{-1} \cdot mol^{-1}$
	R	8.31451 $L \cdot kPa \cdot K^{-1} \cdot mol^{-1}$
	R	0.0831451 bar $L \cdot K^{-1} \cdot mol^{-1}$
Planck's constant	h	6.62608×10^{-34} $J \cdot s$
Speed of Light	c	2.99792458×10^8 $m \cdot s^{-1}$