THE UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
MIDTERM
CHEMISTRY 209

Date: Wednesday October 30th, 2013 Time: 7:00pm – 9:00pm

FIRST NAME: ____________________ **LAST NAME:** ________________________________

After writing your name, please fill in ID # on next page!

Please circle your lecture section number below.

Lec. 01 Dr. Sandblom **(Tu/Th 2:00 pm)**

Lec. 02 Dr. E. Sullivan **(Tu/Th 12:30 pm)**

This is a closed-book examination. The use of camera devices, MP3 Players and headphones, or wireless access devices such as cell phones, Blackberries, etc., during the examination will not be allowed.

Only non-programmable calculators are permitted. A Chemical Data Sheet is provided at the end of the exam and can be removed for quick reference.

All questions must be answered to obtain full marks. The answers to the multiple choice section must be entered on the optical score sheet within the 2 hour exam. The answers to the long answer questions must be written in the space provided on the question sheets **AND** written in **non-erasable ink** to be eligible for re-grading.

This test consists of **17 multiple choice** questions **worth 2 marks each** (total 34 marks) and **5 long answer** questions (total 26 marks). The total value for the test is **60 marks**. The exam has 14 pages make sure you have all 14 pages.

AT THE END OF THE EXAMINATION, HAND IN THE OPTICAL SCORE SHEET AND THE ENTIRE EXAM PAPER

Failing to encode this Exam Booklet or your Optical Score Sheet correctly, for your name, ID and lecture section, will result in the loss of two marks

ID…………………	Q18…… Q19……. Q20……. Q21……. Q22……. **DO NOT WRITE IN THIS BOX, FOR GRADING PURPOSES ONLY!**

SECTION I - Machine graded section (Total value 34)
To be answered on provided Optical Score Sheet

1. The reaction between aluminum (Al) and bromine (Br_2) gives a white solid Al_2Br_6. If we had 50.0 grams of Br_2 and 13.0 grams of Al. How much Al_2Br_6 could we make?

$$2Al \quad + \quad 3Br_2 \quad \rightarrow \quad Al_2Br_6$$

   a) 13.0 g
   b) 17.1 g
   c) 55.5 g
   d) 128 g
   e) 167 g

2. What is the molarity of 43.2 g of $CO_2(g)$ at 32.0 °C and a pressure of 720.0 torr?

   a) 3.79×10^{-2} M
   b) 3.4×10^{-2} M
   c) 2.7×10^{-1} M
   d) 3.56×10^{-3} M
   e) 16.0 M

3. A compound is found to contain 62.0% C, 10.4% H and 27.6% O. If the molecular weight for this compound was between 170 and 190 a.m.u, what is its molecular formula?

   a) $C_6H_{14}O_4$
   b) $C_7H_{16}O_4$
   c) $C_8H_{14}O_3$
   d) $C_9H_{18}O_3$
   e) $C_{10}H_{12}O_2$

4. If the fading of phenolphthalein was a first order reaction, which of the following plots would be linear?

a) $k_1' t = -\ln [Ph^{2-}] + \ln [Ph^{2-}]_0$ would be linear

b) $\frac{1}{[Ph^{2-}]} = k_2't + \frac{1}{[Ph^{2-}]_0}$ would be linear

c) $k_0' t = [Ph^{2-}]_0 - [Ph^{2-}]$ would be linear

d) All of the above would be linear

e) None of the above would be linear

5. For the reaction below, the following data were collected at constant temperature. Determine the correct rate law for this reaction.

$$A(g) + 2B(g) \rightarrow 2C(g) + 2D(g)$$

Trial	Initial [A] (mol/L)	Initial [B] (mol/L)	Initial Rate (mol/(L·min))
1	0.125	0.200	7.25
2	0.375	0.200	21.75
3	0.250	0.400	14.50
4	0.375	0.400	21.75

a) Rate = k[A] [B]
b) Rate = $k[A]^2$ [B]
c) Rate = k[A] $[B]^2$
d) Rate = k[A]
e) Rate = $k[A]^3$

6. Sulfuryl chloride, $SO_2Cl_2(g)$, decomposes at high temperature to form $SO_2(g)$ and $Cl_2(g)$. The rate constant at a certain temperature is $4.68 \times 10^{-5}\ s^{-1}$. What is the order of the reaction?

a) Zero
b) First
c) Second
d) Third
e) More information is needed to determine the order.

7. Carbon-14 is a radioactive isotope that decays with a half-life of 5730 years. What is the first-order rate constant for its decay, in units of years^{-1}?

   a) 5.25×10^{-5} years^{-1}
   b) 1.21×10^{-4} years^{-1}
   c) 1.75×10^{-4} years^{-1}
   d) 3.49×10^{-4} years^{-1}
   e) 3.97×10^{3} years^{-1}

8. A rate constant obeys the Arrhenius equation, has a factor *A* of 2.2×10^{13} s^{-1} and an activation energy of 150. kJ mol^{-1}. What is the value of the rate constant at 227°C, in s^{-1}?

   a) 2.1×10^{13} s^{-1}
   b) 6.7×10^{-22} s^{-1}
   c) 1.5×10^{11} s^{-1}
   d) 4.7×10^{-3} s^{-1}
   e) 9.4×10^{-3} s^{-1}

9. What is the molecularity of the following elementary reaction?

   $$NH_2Cl(aq) + OH^-(aq) \rightarrow NHCl^-(aq) + H_2O(l)$$

   a) Unimolecular
   b) Bimolecular
   c) Termolecular
   d) Tetramolecular
   e) Need to know the reaction order before molecularity can be determined.

10. Carbon monoxide and chlorine combine in an equilibrium reaction to produce the highly toxic product, phosgene ($COCl_2$):

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$$

If the equilibrium constant for this reaction is K_c = 248, predict, if possible, what will happen when 0.010 moles of CO, 0.010 moles of Cl_2 and 0.070 moles of $COCl_2$ are combined in a 1.0 L container?

a) The reaction will proceed to the right, since $Q_c > K_c$.
b) The reaction will proceed to the right, since $Q_c < K_c$.
c) The reaction is at equilibrium, and no change in concentrations will occur.
d) The reaction will proceed to the left, since $Q_c < K_c$.
e) The reaction will proceed to the left, since $Q_c > K_c$.

11. Consider the following two equilibria and their respective equilibrium constants:

$$NO(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons NO_2(g) \qquad K_1$$
$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g) \qquad K_2$$

Which one of the following is the correct relationship between the equilibrium constants K_1 & K_2?

a) $K_2 = (1/K_1)^2$
b) $K_2 = 2/K_1$
c) $K_2 = -K_1/2$
d) $K_2 = 1/(2K_1)$
e) $K_2 = 1/(2K_1)^2$

12. What would be the pH of a 0.23 M solution of sodium lactate, NaC_2H_5OCOO? (The K_a of lactic acid, C_2H_5OCOOH, is 1.4×10^{-4}).

a) 5.39
b) 8.61
c) 9.51
d) 10.80
e) 11.75

Questions 13 - 17 removed, as this exam was done later in term (material not covered yet)

<u>SECTION II: To be graded manually (Total value 26)</u>

Answers must be <u>written in non-erasable ink</u> to be considered for re-grading!

For full marks <u>show all your work.</u>

QUESTION 18 VALUE 5 MARKS

18. Methane, $CH_4(g)$, and $O_2(g)$ undergo a combustion reaction that produces $CO_2(g)$ and $H_2O(g)$.

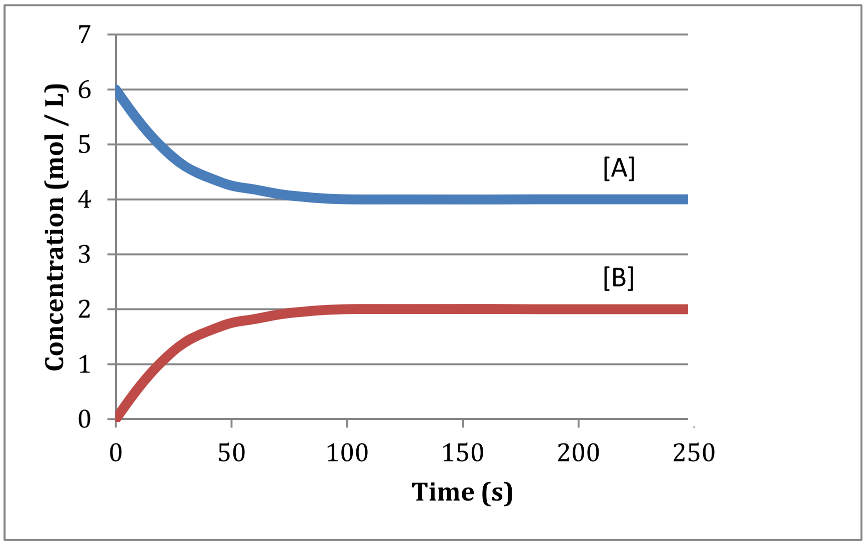
    a) [1 point] Write the balanced equation for this reaction.

    b) [2 points] How many grams of CH_4 would exist in a 1.0 L container at 320 K and 1100 torr?

    c) [2 points] How many mL of $O_2(g)$ will be needed to react with this if the $O_2(g)$ is at 320 K & 760 torr?

QUESTION 19 VALUE 6 MARKS

19. For the questions on this page, please refer to the diagram below showing how concentrations change over time for the conversion of A → B



a) [1 point] Calculate the average rate of consumption of A between 0 s to 100 s.		
b) [1 point] At 200 seconds, the reaction has stopped because the reaction is complete.	Circle:	True False
c) [1 point] The rate of formation of B initially is equal in magnitude to the rate of consumption of A.	Circle:	True False
d) [1 point]The K_c for this reaction can be calculated based on the information in the diagram.	Circle:	True False

e) [1 point] Explain your choice in part (d) using one to two grammatically correctly sentences.
f) [1 point] At 300 seconds, more A is added so that [A] = 6.0 M. Calculate Q_c and describe what will happen to the concentration of [B].

QUESTION 20 VALUE 5 MARKS

20. For the questions on this page, please refer to this mechanism for a hypothetical reaction.

Step 1:	$A + B \rightarrow X + Y$	Slow step
Step 2:	$A + X \rightarrow Y$	Fast step

a) [1 point] Write the overall reaction.	
b) [1 point] Predict a rate law for this reaction.	
c) [1 point] What role does X play in this mechanism? *[A one-word answer is sufficient]*	

d) [2 points] A catalyst is added to this reaction. Write one or two grammatically correct sentences to describe what happens to the rate of the reaction and how the reaction energy diagram could be changed.

QUESTION 21 VALUE 4 MARKS

21. Vinegar is a 0.83 M solution of acetic acid. If the acetic acid in vinegar is 0.47% dissociated or ionized, calculate K_a for acetic acid.

QUESTION 22 VALUE 6 MARKS

22. The 20.0 mL of a 0.10 M HCN solution is titrated with 0.050 M NaOH. The K_a of HCN is 6.2×10^{-10}.

a) [2 points] What is the pH before any base is added to the solution?

Parts (b) and (c) removed as this exam was later in term (material not covered yet)

1 1A	2 2A	3	4	5	6	7	8	9	10	11	12	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.008																	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57* **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.0	89** **Ac** (227)	104 **Rf** (261)	105 **Ha** (262)	106 **Sg** (263)	107 **Ns** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **Uun** (269)	111 **Uuu** (272)							

Lanthanides *	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
Actinides **	90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237.0	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Strong Acids: HCl, HBr, HI, HNO_3, H_2SO_4, $HClO_4$

Strong Bases: Hydroxides of Group 1A (Li to Cs) and Group 2A (Ca, Sr, Ba)

Constants:

Gas constant, *R* = 0.08205 L atm mol^{-1} K^{-1}
= 8.314 J mol^{-1} K^{-1} or 0.08314 bar L mol^{-1} K^{-1}

Avogadro's number: N_A = 6.022 x 10^{23} mol^{-1}

Faraday: F = 96,485 C / mol electrons

Planck's constant *h* = 6.626 x 10^{-34}Js

Speed of light , c = 2.998x 10^8m/s

Rydberg constant, R = 1.09678 x 10^{-7} m^{-1}

Conversion factors:

1 J = 1 kg m^2 s^{-2} 1 Pa = 1 kg m s^{-2}

T K = *T* °C + 273.15

1 L atm = 101.3 J

1atm = 760.0 torr = 101.3 kPa = 760.0 mm Hg = 1.013 bar

1 L = 10^{-3} m^3

1 C = 1 J / V 1 A = 1 C s^{-1}

STP conditions: 0 °C, 1 atm

$$[A]_t = -kt + [A]_0 \qquad \ln[A]_t = -kt + \ln[A]_0 \qquad \frac{1}{[A]_t} = kt + \frac{1}{[A]_0} \qquad \ln\left(\frac{[A]_0}{[A]_t}\right) = kt$$

$$t_{1/2} = \frac{[A]_0}{2k} \qquad t_{1/2} = \frac{0.693}{k} \qquad t_{1/2} = \frac{1}{k[A]_0} \qquad k = Ae^{\frac{-E_a}{RT}} \qquad \ln\left(\frac{K_2}{K_1}\right) = \frac{\Delta H}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \qquad PV = nRT \qquad K_p = K_c(RT)^{\Delta n} \qquad ax^2 + bx + c = 0$$

$$\text{pH} = -\log[\text{H}^+] \qquad K_w = K_aK_b \qquad K_{sp} = 1/K_d \qquad K_f = 1/K_d \qquad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\text{pH} = \text{p}K_a + \log\left(\frac{[\text{cong. base}]}{[\text{cong. acid}]}\right) \quad \text{or} \quad \text{pOH} = \text{p}K_b + \log\left(\frac{[\text{cong. acid}]}{[\text{cong. base}]}\right)$$

$$E^\circ = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} \qquad E = E^\circ - \frac{0.0592}{n_e}\log Q \qquad E^\circ = \frac{0.0592}{n_e}\log K \quad \text{or} \quad nFE^\circ = RT\ln K$$

$$q = It \qquad q = n_eF \qquad c = \lambda v \qquad E = hv \qquad E = mc^2 \qquad \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \qquad \Delta E = -R_H\left(\frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2}\right)$$

$$E = -R_H\left(\frac{Z}{n}\right)^2 \quad \text{or} \quad E_n = -\frac{Rhc}{n^2} \quad \text{for single electron species}$$