THE UNIVERSITY OF CALGARY

FACULTY OF SCIENCE

MIDTERM: Version 02 on Blue

CHEMISTRY 209

Date: Tuesday October 13th, 2015 Time: 7:00pm – 9:00pm

First Name: ______________________________ Last Name: ______________________________

When you start the test, please fill in your ID# on the next page!

Please circle your lecture section:

L01 Dr. Musgrove-Richer
TR 2:00 pm

L02 Dr. Sandblom
TR 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 Schulich-approved 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 **13 multiple choice** questions worth 2 marks each (total 26 marks) and **4 long answer** questions (total 22 marks). The total value for the test is 48 marks. The exam has **9 pages** (including this one), so please make sure you have all 9 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, version letter and lecture section will result in the loss of two points.

Write your ID# here:	Sec II - Q1	Sec II - Q2	Sec II - Q3	Sec II - Q4
	Do not write in the shaded part. For marking only.			

SECTION I – Machine-graded section (Total value 32)
To be answered on Optical Score Sheet

1. Which answer below correctly expresses the solution to: $\left(\ln \frac{8.431+1.68}{1.011}\right)$?
   a. 2.30
   b. 2.303
   c. 2.3027
   d. 2.30268

2. Which of the following samples will contain the largest number of molecules?
   a. 12.04 g of Br_2 (*l*)
   b. 6.02 g of CN (*g*)
   c. 4.04 g of CO_2 (*g*)
   d. 3.01 g of AsH_3 (*g*)

3. 5.392 g of methane (CH_4) is placed in a reaction vessel with excess Cl_2 gas. 4.891 g of the desired product, CH_2Cl_2, was obtained. What was the % yield for this reaction (shown below)?

$$CH_4\ (g) + Cl_2\ (g) \rightarrow CH_2Cl_2\ (l) + H_2\ (g)$$

   a. 9.290 %
   b. 17.14 %
   c. 82.86 %
   d. 90.71 %

4. Two reactions are both described by the equation *A → products*. Reaction 1 is first order with respect to [A], and Reaction 2 is second order with respect to [A]. Which option below correctly describes the initial rates of these reactions when [A] = 0.100 M?

   a. Reaction 1 will have a higher initial rate.

   b. Reaction 2 will have a higher initial rate.

   c. Both reactions will have a similar initial rate.

   d. Not enough information is given to determine initial rates.

5. While studying the decomposition of substance A, a chemist found that the initial rate of disappearance of A was 0.146 mol L^{-1} s^{-1} when the initial [A] was 0.325 M. The reaction was studied again, starting with $[A]_0$ = 0.163 M, and the initial rate of disappearance of A was found to be 0.0365 mol L^{-1} s^{-1}. What is the order of this reaction with respect to A?

   a. Zero order

   b. First order

   c. Second order

   d. Third order

6. The thermal decomposition of phosphine (PH_3) into phosphorous and molecular hydrogen is shown below:

$$2\ PH_3\ (g) \rightarrow 2P\ (s) + 3H_2\ (g)$$

At 680° C the rate constant for this first-order reaction is 0.0198 s^{-1}. What is the half-life for this reaction?

   a. 55 s

   b. 35 s

   c. 0.029 s

   d. 0.0056 s

7. The decomposition of cyclobutane is a first-order process with a rate constant of 87 s^{-1} at 1000.°C. How long will it take until only 60.0 % of the initial concentration of 1.00 M remains?

   a. 1.1×10^{-2} s
   b. 4.6×10^{-3} s
   c. 5.9×10^{-3} s
   d. 6.9×10^{-3} s

Questions 8 and 9 will be done in the Review Tutorial.

10. Which answer below correctly describes the calculation to find the equilibrium expression K_4?

$CH_4\,(g) + H_2O\,(g) \rightleftharpoons CO\,(g) + 3\,H_2\,(g)$ K_1

$CH_4\,(g) + 2\,S_2\,(g) \rightleftharpoons CS_2\,(g) + 2\,H_2S\,(g)$ K_2

$CO_2\,(g) + H_2\,(g) \rightleftharpoons CO\,(g) + H_2O\,(g)$ K_3

$CS_2\,(g) + 2\,H_2S\,(g) + 3\,CO_2\,(g) \rightleftharpoons 4\,CO\,(g) + 2S_2\,(g) + 2H_2O\,(g)$ K_4

   a. $K_1 \times (K_2)^{-1} \times (K_3)^3$
   b. $K_1 \times K_2 \times K_3$
   c. $3(K_1) \times K_2 \times K_3$
   d. $K_1 \times K_2 \times (K_3)^3$

11. Which of the changes below would result in a shift towards the products if applied to this system at equilibrium?

$$CO_2\ (g) + C\ (graphite) \rightleftharpoons 2\ CO\ (g)$$

a. Adding more graphite to the reaction container

b. Adding more CO *(g)* to the reaction container

c. Adding some He *(g)* to the reaction container

d. Increasing the volume of the reaction container

12. In one experiment examining the reaction below, 1.00 g of solid calcium carbonate is heated to 1073 K, and the pressure of carbon dioxide at equilibrium was 0.023 bar. In another experiment at 973 K, 2.00 g of $CaCO_3$ generates an equilibrium pressure of 0.18 bar. Calculate ΔH for this reaction.

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

a. $- 178\ kJ \cdot mol^{-1}$

b. $+ 178\ kJ \cdot mol^{-1}$

c. $- 1.64\times10^{-3}\ kJ \cdot mol^{-1}$

d. $+ 1.64\times10^{-3}\ kJ \cdot mol^{-1}$

13. Indicate how many of these combinations are conjugate acid-base pairs.

CO_3^{2-}/CO_2
NH_3/NH_4^+
H^+/H_2
HSO_4^-/SO_3^{2-}

a. None

b. 1

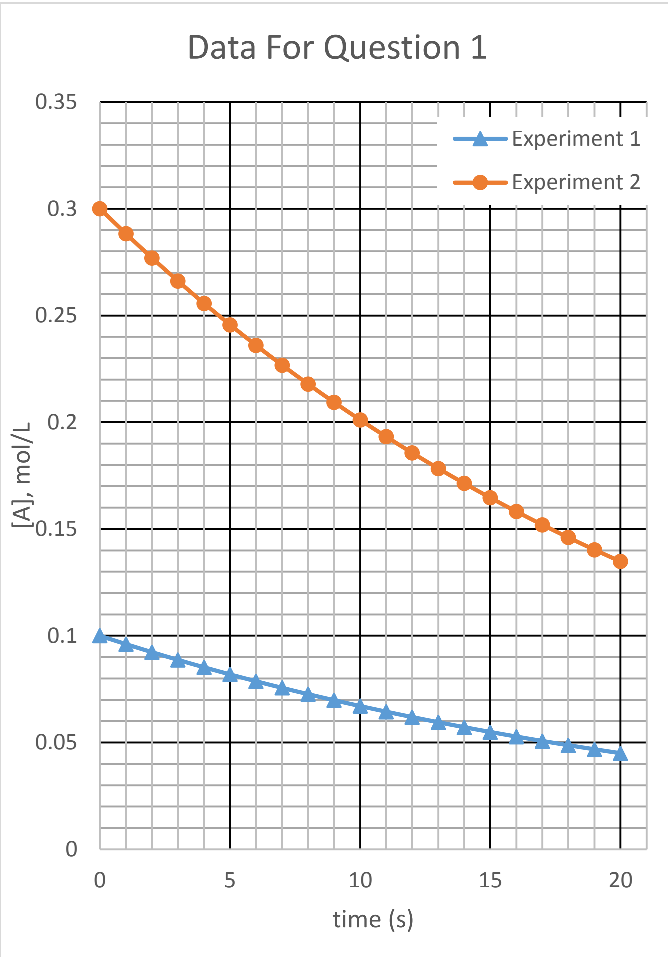
c. 2

d. 3

************END OF MULTIPLE CHOICE************

SECTION II: Long Answers: To be graded manually (Total value 21)
Answers must be written in non-erasable ink to be considered for re-grading.
For full marks show all your work.

Question 1 [Total value: 10 points]
The plot below describes experimental results for two different measurements of the reaction *A* → *products*. Use this plot to answer parts a) through d). Assume 2 significant figures when reading values from the plot.



a. [2 points] Calculate the average rate of consumption of A in the time period 0-10 s for Experiment 2.

b. [2 points] Calculate the initial rate of reaction for Experiment 1.

c. [2 points] Calculate the initial rate of reaction for Experiment 2.

d. [4 points] Using the $[A]_0$ values from the graph and your results from parts b. and c., write the rate law for this reaction, including the value of *k* and its units. Assume a whole-number order for all components.

Question 2 [Total value: 4 points]

Calcium carbide (CaC_2), a solid, reacts with water to produce acetylene gas (C_2H_2) and aqueous calcium hydroxide ($Ca(OH)_2$).

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

b. If 75.00 g of calcium carbide is consumed in this reaction and the acetylene produced is captured in a 40.00 L container at 25.0 °C, at what pressure will the container be after the reaction is complete? [3 points]

Question 3 [Total value: 4 points]

One step in coal gasification relies upon the following endothermic process:

$$C(s) + H_2O\,(g) \rightleftharpoons CO(g) + H_2(g) \qquad K_P = 0.797 \text{ at } 700.0\ {}^{0}C.$$

a. If 1.00 g of carbon is added to a reaction vessel containing 1.00 M each of H_2O, CO, and H_2 gases, predict the direction in which the reaction will proceed. Justify your answer. [2 points]

[Question 3 continued next page]

b. Based on the fact that the reaction is endothermic, compare the yield of the reaction at room temperature to the yield at $700^{0}C$. Use 1 to 3 grammatically correct sentences to explain your answer. [2 points]

Question 4 will be done in the Review Tutorial.

Data Sheet – CHEM 209

Periodic Table

Legend:

1	← Atomic number (Z)
H	← Atomic symbol
1.008	← Atomic mass (amu)

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 1 (Li to Cs) and Group 2 (Ca, Sr, Ba)

Constants:	**Conversion Factors:**
Gas Constant: R = 0.08205 L·atm·mol^{-1}·K^{-1}	1 J = 1 kg·m^2·s^2
= 8.314 L·kPa·mol^{-1}·K^{-1} = 8.314 J·mol^{-1}·K^{-1}	T (K) = T (°C) + 273.15
= 0.08314 L·bar·mol^{-1}·K^{-1}	1 Pa = 1 kg·m^{-1}·s^{-2} = 10^{-5} bar
Avogadro's number: N_A = 6.022×10^{23} mol^{-1}	1 L·atm = 101.3 J
Faraday's Constant: F = 96 485 C/mol electrons	1 atm = 760.0 torr = 101.3 kPa = 760.0 mm Hg = 1.013 bar
Planck's Constant: h = 6.626×10^{-34} J·s	1 L = 10^{-3} m^3
Speed of Light: c = 2.998×10^8 m·s^{-1}	1 C = 1 J/V
Rydberg Constant: R = 1.096776×10^7 m^{-1}	STP conditions: 0°C, 100 kPa
Factoring Rydberg Constant: R_H = R·h·c = 2.18×10^{-18} J	Electrochemical standard state: 1 atm, 1 M, 25°C

$$[A]_t = -kt + [A]_0 \qquad \ln[A]_t = -kt + \ln[A]_0 \qquad PV = nRT \qquad E^\circ = E^\circ_{cathode} - E^\circ_{anode} \qquad c = \lambda\nu$$

$$\ln\left(\frac{[A]_0}{[A]_t}\right) = kt \qquad \frac{1}{[A]_t} = kt + \frac{1}{[A]_0} \qquad K = K_C(RT)^{\Delta n} \qquad E = E^\circ - \frac{0.0592}{n_e}\log Q \qquad E = h\nu$$

$$pH = -\log[H^+] \qquad E = mc^2$$

$$t_{1/2} = \frac{[A]_0}{2k} \qquad t_{1/2} = \frac{0.693}{k} \qquad K_w = K_a \cdot K_b \qquad E^\circ = \frac{RT}{zF}\ln K \qquad \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$ax^2 + bx + c = 0$$

$$t_{1/2} = \frac{1}{k[A]_0} \qquad k = Ae^{(-E_a/RT)} \qquad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \qquad E^\circ = \frac{0.0592}{n_e}\log K \qquad \Delta E = -R_H\left(\frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2}\right)$$

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \qquad \ln\left(\frac{K_2}{K_1}\right) = \frac{\Delta H}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \qquad pH = pK_a + \log\left(\frac{[base]}{[acid]}\right) \qquad nFE^\circ = RT\ln K$$