THE UNIVERSITY OF CALGARY

FACULTY OF SCIENCE

MIDTERM: Version A on White

CHEMISTRY 209

Date: Thursday October 30th, 2014 Time: 7:00pm – 9:00pm

FIRST NAME: Answer KEY LAST NAME: ______________________

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

Please circle your lecture section:

L01 Dr. Parvez
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 **17 multiple choice** questions **worth 2 marks each** (total 34 marks) and **4 long answer** questions (total 26 marks). The total value for the test is **60 marks.** The exam has 14 pages, so please 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, version letter and lecture section will result in the loss of two points

Write your ID# here

Q18	Q19	Q20	Q21
Do not write in this shaded part. For the markers.			

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

1. How many grams of NaCl are contained in 350. mL of a 0.250 M solution of sodium chloride?

a) 5.11 g $= (350.\,mL)\left(\frac{L}{1000\,mL}\right)\left(\frac{0.250\,mol_{NaCl}}{L}\right)\left(\frac{58.44\,g_{NaCl}}{mol_{NaCl}}\right)$

b) 14.6 g

c) 41.7 g

d) 87.5 g

2. The molar mass of an insecticide, dibromoethane, is 187.9. Its molecular formula is $C_2H_4Br_2$.

What percent by mass of bromine does dibromoethane contain?

a) 37.8%

b) 42.5%

c) 85.0% $= 100 \times \left(\frac{79.9\,g_{Br}}{mol\,Br}\right)\left(\frac{2\,mol_{Br}}{1\,mol\,C_2H_4Br_2}\right)\left(\frac{1\,mol_{C_2H_4Br_2}}{187.9\,g_{C_2H_4Br_2}}\right)$

d) 89.3%

3. Several experiments have revealed some of the components of the rate law for the reaction below:

$$A(g) \quad + \quad 2B(g) \quad + \quad 2C(g) \rightarrow 2D(g) \qquad \text{Rate} = k\,[A][B]^2[C]^x$$

In one experiment, when all of the initial concentrations of reactants were 0.10 M, the initial rate equalled 5.0 x 10^{-3} M s^{-1}. In a separate experiment, when all of the initial concentrations of reactants were 0.010 M, the initial rate equalled 5.0 x 10^{-9} M s^{-1}. What is the overall order?

(a) 3

(b) 4

(c) 5

(d) 6

$$\frac{Rate_1 = 5.0 \times 10^{-3}\,M\,s^{-1} = \cancel{k}(0.1)^1(0.1)^2(0.1)^x}{Rate_2 = 5.0 \times 10^{-9}\,M\,s^{-1} = \cancel{k}(0.01)^1(0.01)^2(0.01)^x}$$

$$1.0 \times 10^6 = \frac{1.0 \times 10^{-3}\,(0.1)^x}{1.0 \times 10^{-6}\,(0.01)^x}$$

$1+2+3=6$ $\quad 1000 = 10^x \quad \therefore \quad x = 3$

4. The rate law for the rearrangement of CH_3NC to CH_3CN at 800 K is Rate = $(1300\ s^{-1})[CH_3NC]$. What is the half-life for this reaction?

(a) 7.69×10^{-4} s

(b) 5.3×10^{-4} s $= t_{1/2} = \frac{0.693}{k}$

(c) 1.9×10^{-3} s

(d) 5.2×10^{2} s

5. The decomposition of hydrogen peroxide is a first-order process with a rate constant of $1.06 \times 10^{-3}\ min^{-1}$. How long will it take for the concentration of H_2O_2 to drop from 0.0200 mol L^{-1} to 0.0120 mol L^{-1}?

a) 7.55 min

b) 482 min

c) 4.55×10^{3} min

d) 3.14×10^{4} min

$\ln[A] = -kt + \ln[A]_0$

$\ln(0.012) = -(1.06 \times 10^{-3}\ min^{-1})t + \ln(0.02)$

$t = \ln\left(\frac{0.012}{0.2}\right) / -(1.06 \times 10^{-3}\ min^{-1})$

6. The rate constant for the reaction 3A → 4B is 6.00×10^{-3} L mol^{-1} min^{-1}.
How long will it take the concentration of A to drop from 0.75 mol L^{-1} to 0.25 mol L^{-1}?

a) 2.2×10^{-3} min

b) 5.5×10^{-3} min

c) 1.8×10^{2} min

d) 4.4×10^{2} min

$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$

$\frac{1}{0.25M} = kt + \frac{1}{0.75M}$

$t = \frac{2.67\ M^{-1}}{6.00 \times 10^{-3}\ M^{-1}\ min^{-1}}$

7. Butadiene, C_4H_6 (used to make synthetic rubber and latex paints) reacts to make C_8H_{12} with a rate law of rate = 0.014 L/(mol·s) $[C_4H_6]^2$. What will be the concentration of C_4H_6 after 3.0 hours if the initial concentration is 0.025 mol L^{-1}?

a) 0.0052 mol L^{-1}

b) 0.024 mol L^{-1}

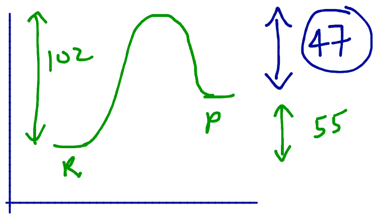
c) 43 mol L^{-1}

d) 190 mol L^{-1}

$\frac{1}{[A]} = \left(\frac{0.014\ L}{mol\ s}\right)\left(\frac{60\ s}{min}\right)\left(\frac{60\ min}{hr}\right)(3.0\ hr) + \frac{1}{(0.025M)}$

8. The decomposition of dinitrogen pentaoxide has an activation energy of 102 kJ/mol and ΔH°_{rxn} = + 55 kJ/mol. What is the activation energy for the reverse reaction?

(a) 47 kJ/mol
(b) 55 kJ/mol
(c) 102 kJ/mol
(d) 157 kJ/mol



9. Nitrosyl chloride, NOCl, dissociates on heating as shown below. When a 1.50 gram sample of pure NOCl is heated at 350 °C in a volume of 1.00 liter, the percent dissociation is found to be 57.2%. Calculate the equilibrium concentration of NOCl.

$$NOCl(g) \rightleftharpoons NO(g) + \tfrac{1}{2} Cl_2(g)$$

(a) 4.28×10^{-1} M
(b) 8.58×10^{-1} M
(c) 1.31×10^{-2} M
(d) 9.80×10^{-3} M $= (1.50\ g_{NOCl})\left(\frac{100-57.2}{100}\right)\left(\frac{mol\ NOCl}{65.46\ g\ NOCl}\right)\left(\frac{1}{1.00\ L}\right)$

10. At high temperatures, carbon reacts with O_2 to produce CO as follows:

$$2C(s) + O_2(g) \rightleftharpoons 2CO(g)$$

When 0.350 mol of O_2 and excess carbon were placed in a 5.00 L container and heated, the equilibrium concentration of CO was found to be 0.060 M. What is the equilibrium constant, K_c, for this reaction?

(a) 0.010
(b) 0.072
(c) 0.090 $= \frac{[CO]^2}{[O_2]} = \frac{(0.06)^2}{0.04}$
(d) 1.5

$2C(s) + O_2(g) \rightleftharpoons 2CO(g)$

	O_2	CO
	0.35/5	0
	−x	+2x
	0.07−x	0.06

x = 0.03

11. If the pH of an acid rain storm is approximately 3.0, how many times greater is the $[H_3O^+]$ in the rain than in a cup of coffee having a pH of 5.0?

(a) 1000

(b) 100 $= \frac{10^{-3.0}}{10^{-5.0}}$

(c) 20

(d) 1.7

12. A 1.25 M solution of the weak acid HA is 9.2% dissociated. What is the pH of the solution?

$HA + H_2O \rightleftharpoons H_3O^+ + A^-$

	HA		H_3O^+	A^-
I	1.25		0	0
C	$-x$		$+x$	$+x$
E	$1.25-x$		x	x

(a) 0.64

(b) 0.94

(c) 1.13

(d) 2.16

$x = \left(\frac{9.2}{100}\right)(1.25) = 0.115$ $pH = -\log(0.115)$

[redacted]

14. Which is the most significant reaction affecting pH when NH_4Br dissolves in water?

(a) $NH_4^+ + OH^- \rightleftharpoons NH_4OH$ OH- is not present in major quantities

(b) $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ Ammonia is not present in major quantities

(c) $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

(d) $Br^- + H_2O \rightleftharpoons HBr + OH^-$ Bromide does not react with water in this way.

[redacted]

17. Given the following reactions: [redacted]

$AgBr(s)$			$\rightleftharpoons$	$Ag^{+}(aq)$	+ $Br^{-}(aq)$	$K_{sp} = 5.4 \times 10^{-13}$
$Ag^{+}(aq)$	+	$2\ CN^{-}(aq)$	$\rightleftharpoons$	$Ag(CN)_2^{-}(aq)$		$K_f = 1.2 \times 10^{21}$

Determine the equilibrium constant for the reaction below.

ADD RXNS ∴ MULTIPLY $K_{sp} \cdot K_f$

$$AgBr(s) + 2\ CN^{-}(aq) \rightleftharpoons Ag(CN)_2^{-}(aq) + Br^{-}(aq) \qquad K = ?$$

(a) 4.5×10^{-34}
(b) 1.5×10^{-9}
(c) 6.5×10^{8}
(d) 2.2×10^{33}

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

SECTION II: Long Answers: To be graded manually (Total value 26)
Answers must be written in non-erasable ink to be considered for re-grading!
For full marks show all your work.

Question 18 [Total Value 8 points]

Analysis of a sample of compound X yields 1.82 g of $H_2(g)$, 7.19 g of C(s) and 38.3 g of Te(s).

18 a). [2 points] What volume of $H_2(g)$ was produced if the collection temperature was 373 K and the pressure was 103 kPa?

$$V = \frac{nRT}{P} = \frac{(1.82\,\cancel{g\,H_2})\left(\frac{\cancel{mol\,H_2}}{2.016\,\cancel{g\,H_2}}\right)\left(8.314\,\frac{\cancel{J}}{\cancel{mol\,K}}\right)(373\,\cancel{K})\left(\frac{1\,\cancel{kg}\,m^2\,\cancel{s^{-2}}}{1\,\cancel{J}}\right)}{(103\,\cancel{kPa})\left(\frac{1000\,\cancel{Pa}}{1\,\cancel{kPa}}\right)\left(\frac{1\,\cancel{kg}\,m^{-1}\,\cancel{s^{-2}}}{1\,\cancel{Pa}}\right)}$$

$$= 0.0272\,m^3$$

18 b). [2 points] What is the empirical formula of the compound X?

$$mol_H = (1.82\,g\,H_2)\left(\frac{1\,mol\,H_2}{2.016\,g\,H_2}\right)\left(\frac{2\,mol\,H}{1\,mol\,H_2}\right) = 1.806\,mol\,H$$

$$mol_C = (7.19\,g\,C)\left(\frac{1\,mol\,C}{12.01\,g\,C}\right) = 0.599\,mol_C$$

$$mol_{Te} = (38.3\,g\,Te)\left(\frac{1\,mol\,Te}{127.6\,g\,Te}\right) = 0.300\,mol\,Te$$

DIVIDE all 3 by lowest value (0.300 mol Te)

$C_2H_6Te_1$

18 c). [1 point] Tellurium can be recovered from the refining of copper ores. One of the steps in this refining process is provided below. Balance the reaction:

1 3/2 1 1

$\boxed{2}\ Cu_2S + \boxed{3}\ O_2 \rightarrow \boxed{2}\ Cu_2O + \boxed{2}\ SO_2$

18 d). [3 points] If 3.3 x 10³ g of copper sulfide reacts with 3.3 x 10³ g of oxygen, how much copper oxide will be produced?

$$3.3 \times 10^3 \text{ g } Cu_2S \left(\frac{\text{mol } Cu_2S}{159.17 \text{ g } Cu_2S}\right)\left(\frac{2 \text{ mol } Cu_2O}{2 \text{ mol } Cu_2S}\right) = 20.7 \text{ mol } Cu_2O$$

$\therefore$ Cu_2S is Limiting Reactant

$$3.3 \times 10^3 \text{ g } O_2 \left(\frac{\text{mol } O_2}{32 \text{ g } O_2}\right)\left(\frac{2 \text{ mol } Cu_2O}{3 \text{ mol } O_2}\right) = 68.75 \text{ mol } Cu_2O$$

$$(20.7 \text{ mol}_{Cu_2O})\left(\frac{143.1 \text{ g}_{Cu_2O}}{\text{mol } Cu_2O}\right) = \underline{3.0 \times 10^3 \text{ g } Cu_2O}$$

Question 19 [Total Value 6 points]

You need to make large quantities of X(g) in a chemical plant.

The balanced chemical reaction is:

$$2\,A(g) + B(g) \rightleftharpoons X(g) + \text{heat}$$

The rate law is:

$$\text{Rate} = k\,[A][B]$$

19. a.) [1.5 points] Provide three ways you could speed up this reaction.

1.	increase T add a catalyst
2.	add [A] increase P_A
3.	add [B] increase P_B

19. b.) [1.5 points] Provide three ways you could increase the yield of X(g).

1.	add [A], [B]
2.	remove [X]
3.	decrease V / increase P decrease T

Question 19 continued.

19. c.) [1 point] One proposed mechanism for this reaction suggests that the slow step is 2 A → Y. where Y is an intermediate. Could this mechanism be valid? Explain your answer using one to three grammatically correct sentences.

No, this mechanism would not be valid
The rate law from this proposed mechanism would be Rate = k[A]^2. This rate law does not match the exp't'l one.

* The proposed step does not include B, but the experimental rate law does.

19. d.) [2 points] The rate law was determined using a similar procedure to that used in Experiment 2. Keeping [A] in large excess generated a pseudo-rate constant of $k' = k$ [A].

Extrapolate the other details of the experiment:

What data must have been collected?
[B] vs t
What data would need to be plotted to provide information about the order with respect to B?
[B] vs t ln[B] vs t → Since order is 1, this plot will be linear $\frac{1}{[B]}$ vs t

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 constants, R = 0.08205 L atm mol^{-1} K^{-1}
= 8.314 J 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^{8} m/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^{-1} 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 bar

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

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

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

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

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

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

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

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