THE UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
MIDTERM
CHEMISTRY 209

Date: Wednesday, February 26th, 2014 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. M. Parvez	**Lec. 02 Dr. E. Sullivan**
(Tu/Th 12:30 pm)	**(Tu/Th 8:00 am)**

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 **21 multiple choice** questions **worth 2 marks each** (total 42 marks) and **4 long answer** questions (total 30 marks). The total value for the test is **72 marks**. The exam has 15 pages make sure you have all 15 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

Student ID # ____________________________________

DO NOT WRITE IN THIS BOX, FOR GRADING PURPOSES ONLY!

Q 22	Q 23	Q24	Q25

SECTION I - Machine graded section (Total value 42)
To be answered on provided Optical Score Sheet

1. The result of (3.8621 × 1.5630) – 5.98 is properly written as.

A) 0.06
B) 0.056
C) 0.0565
D) 0.05646
E) 0.056462

2. Tetraphosphorus hexaoxide ($\mathcal{M}$ = 219.9 g/mol) is formed by the following reaction of phosphorus, P_4, with oxygen gas:

$$P_4(s) \quad + \quad 3\ O_2(g) \quad \rightarrow \quad P_4O_6(s)$$

If a mixture of 75.3 g of phosphorus and 38.7 g of oxygen produce 43.3 g of P_4O_6, what is the percent yield for the reaction?

A) 57.5 %
B) 48.9 %
C) 38.0 %
D) 32.4 %
E) 16.3 %

3. Dr. I. M. A. Brightguy adds 0.1625 g of an unknown gas to a 125-mL flask. If Dr. B finds the pressure to be 0.981 bar at 20.0 °C, is the gas likely to be methane (CH_4), nitrogen (N_2), oxygen (O_2), neon (Ne), or argon (Ar)?

A) N_2
B) Ne
C) Ar
D) CH_4
E) O_2

4. Which of the following samples has the most moles of the compound?

A) 50.0 g of Li_2O
B) 75.0 g of CaO
C) 200.0 g of Fe_2O_3
D) 50.0 g of CO_2
E) 100.0 g of SO_3

5. Terephthalic acid, used in the production of polyester fibers and films, is composed of carbon, hydrogen, and oxygen. When 0.6943 g of terephthalic acid was subjected to combustion analysis it produced 1.471 g CO_2 and 0.226 g H_2O. If its molar mass is between 158 and 167 g/mol, what is its molecular formula?

A) $C_4H_6O_7$
B) $C_6H_8O_5$
C) $C_7H_{12}O_4$
D) $C_4H_3O_2$
E) $C_8H_6O_4$

6. Consider the general reaction

$$5\,Br^-(aq) + BrO_3^-(aq) + 6\,H^+(aq) \rightarrow 3\,Br_2(aq) + 3\,H_2O(aq)$$

For this reaction, the rate when expressed as $\Delta\,[Br_2]\;/\;\Delta\,t$ is the same as

A) $-\Delta\,[H_2O]\;/\;\Delta t$

B) $3\,\Delta\,[BrO_3^-]\;/\;\Delta t$

C) $-5\,\Delta\,[Br^-]\;/\;\Delta t$

D) $-0.6\,\Delta\,[Br^-]\;/\;\Delta t$

E) none of the above

7. Consider the following general reaction and data:

$$2\,A + 2\,B + C \rightarrow D + 3\,E$$

Experiment	Initial Rate (mol/L·s)	Initial [A] (mol/L)	Initial [B] (mol/L)	Initial [C] (mol/L)
1	6.0×10^{-6}	0.024	0.085	0.032
2	9.6×10^{-5}	0.096	0.085	0.032
3	1.5×10^{-5}	0.024	0.034	0.080
4	1.5×10^{-6}	0.012	0.170	0.032

A) Rate = k[A] [B] [C]

B) Rate = $k\,[A]^2\,[B]$

C) Rate = $k\,[A]^2\,[C]$

D) Rate = $k\,[A]\,[B]^2$

E) Rate = $k\,[A]^2\,[B]^2\,[C]$

8. A reaction has the following rate law: Rate = k[A] [B]^2

In experiment 1, the concentrations of A and B are both 0.10 mol L^{-1}; in experiment 2, the concentrations are both 0.30 mol L^{-1}. If the temperature stays constant, what is the value of the ratio, Rate(2)/Rate(1)?

A) 3.0
B) 6.0
C) 9.0
D) 18
E) 27

9. The active ingredient in an over the counter pain killer analgesic decomposes with a rate constant, $k = 9.05 \times 10^{-4}$ day^{-1}. How many days does it take for 15% of the original ingredient to decompose?

A) 730 days
B) 414 days
C) 365 days
D) 180 days
E) 78 days

10. A reaction has an activation energy of 195.0 kJ/mol. When the temperature is increased from 200.°C to 220.°C, the rate constant will increase by a factor of

A) 1.00
B) 1.10
C) 3.23
D) 7.52
E) none of the above

11. Nitrosyl chloride, NOCl, decomposes to NO and Cl_2 at high temperature.

$$2\ NOCl \rightleftharpoons 2\ NO + Cl_2$$

At a certain temperature 3.00 moles of NOCl is added to a 750. mL closed flask and allowed to equilibrate. At equilibrium 0.500 moles of Cl_2 exist. What is the K_c at this temperature?

A) 1.69×10^{-1}
B) 1.39×10^{-2}
C) 2.68×10^{-2}
D) 4.01×10^{-2}
E) 8.33×10^{-2}

12. Based on the information provided below, which of the following expressions would relate K_1 to K_2?

$$4\ SO_3(g) \rightleftharpoons 4\ SO_2(g) + 2\ O_2(g) \qquad K_1$$
$$SO_2(g) + \tfrac{1}{2}\ O_2(g) \rightleftharpoons SO_3(g) \qquad K_2$$

A) $K_2 = 4K_1$
B) $K_2 = 1/K_1^{4}$
C) $K_2 = \sqrt[4]{K_1}$
D) $K_2 = \sqrt[4]{(1/K_1)}$
E) None, we cannot relate one equation to the other equation, as they are very different.

13. The oxidation of sulfur dioxide to sulfur trioxide is a key process in the industrial production of sulfuric acid. The ΔH for this reaction is -198 kJ/mol. If the rate constant is 2.7×10^{8} at 320 °C, what is the rate constant at 460 °C ?

A) 4.7×10^{-4}
B) 1.3×10^{5}
C) 2.1×10^{9}
D) 4.3×10^{10}
E) 5.8×10^{11}

14. Consider the following unbalanced reaction:

$$C_2H_4(g) \quad + \quad Cl_2(g) \quad \rightleftharpoons \quad C_2H_4Cl_2(g) \qquad \Delta H = 60 \text{ kJ/mol}$$

How would one maximize the amount of $C_2H_4Cl_2(g)$?

i. Increasing the reaction vessel volume

ii. Lowering the reaction temperature

iii. Increasing the reaction temperature

iv. Decreasing the reaction vessel volume

A) i and ii

B) i and iii

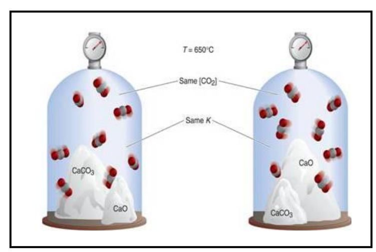
C) ii and iv

D) iii and iv

E) iii only

15. Consider the reaction: $CaCO_3(s) \rightleftharpoons CO_2(g) + CaO(s)$

If 1.0 moles of $CaCO_3(s)$ is introduced into a sealed 2.00 L container at a constant temperature of 970 K and the equilibrium constant for this reaction is K_c =2.4 x 10^{-1} at this temperature. Calculate the mass of $CaCO_3(s)$ at equilibrium.



A) 0.24 g

B) 24 g

C) 26 g

D) 52 g

E) We cannot calculate the amount of $CaCO_3$ since it is not part of our *K* expression.

16. If two aqueous solutions were prepared: one being a 0.10 M solution of HIO_3 (K_a is 1.6 x 10^{-1}) and the other being a 0.10 M solution of HIO (K_a of HIO is 2.3 x 10^{-11}), which of the following statements is false?

A) The pKa of HIO_3 is smaller than the pKa of HIO.
B) The concentration of conjugate base is higher in the HIO solution.
C) The pH of the HIO solution is higher.
D) The pOH of the HIO_3 solution is higher.
E) The percent ionization is larger in the HIO_3 solution.

17. Aspirin, $HC_9H_7O_4$, has a K_a of 3.3 x 10^{-4}. If we had a 0.40 M aqueous solution of Aspirin, what is the pH?

A) 1.95
B) 2.88
C) 3.88
D) 10.12
E) 12.06

Question 18 removed since this exam was later in term (material not covered yet)

19. An aqueous solution only contains a 0.050 M in a weak base. Which one of the following statements would be true about the solution?

A) $[H_3O^+] = 0.050$ M
B) $[OH^-] = 0.050$ M
C) pH < 7
D) 7 < pH < 12.5
E) We would have to know the K_b in order to make any conclusion

Questions 20-21 removed since this exam was later in term
(material not covered yet)

*****************END OF MULITIPLE CHOICE QUESTIONS SECTION************************

SECTION II: To be graded manually (Total value 30)
Answers must be written in non-erasable ink to be considered for re-grading!
For full marks show all your work.

22. A truck tire has a volume of 218 L and is filled with air to 241 kPa at 295 K.

Marks **5**

After a drive, the air heats up to 318 K.

a). If the tire volume is constant, what is the pressure (kPa)?

b). If the tire volume increases 2.0%, what is the pressure (kPa)?

c). After the drive when the tire volume has increased (as in b), the tire is punctured with a nail. If the tire leaks 1.5 g of air per minute and both the temperature and volume are constant, how many minutes will it take for the tire to reach the original pressure of 241 kPa? ($\mathcal{M}$ of air = 28.8 g/mol)

23. Consider the general gas-phase reaction of a molecular substance, A

Marks
8

1. $A \rightarrow B$

At very low pressures many such reactions occur by the following mechanism:

2. $A + A \rightarrow A^* + A$ (slow)
3. $A^* \rightarrow B$ (fast)

(A^* represents a molecule with sufficient energy to overcome the activation energy barrier.)

a. Which of the three reactions above is/are elementary?

____

b. Where appropriate, identify the molecularity of the reactions.

____

c. If there is an intermediate or a catalyst in the above reaction mechanism, identify the species stating whether it is an intermediate or a catalyst.

____

d. Given the mechanism above, suggest a likely rate law for the overall reaction.

____

____

e. Briefly list the features/properties common to all catalysts and how they work (two to three short sentences).

____

____

____

____

f. Draw a labeled reaction energy diagram as part of your answer for (e) showing the difference between a catalyzed and an un-catalyzed reaction.

Question 24a removed since this exam was later in term (material not covered yet)

Marks **5**

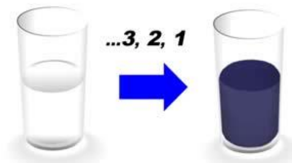
b. Calculate K_a for an unknown acid that has a concentration 3.6 M and 14.5% dissociated or ionized.

Marks **4**

Q 25. In the Iodine Clock reaction, also called the Briggs Rauscher Reaction, malonic acid was used as the "starch" component that iodine reacted with. Others have used different organic acids, an example being crotonic acid. If we intend to titrate 52.0 mL of a 0.080 M crotonic acid ($C_3H_5CO_2H$) solution with 0.050 M KOH solution..

Marks **8**

[The pK_a of crotonic acid is 4.69].



a) What will be the pH before any base has been added to the solution?

Questions 25b-d removed since this exam was later in term
(material not covered yet)

Data Sheet – CHEM 209

Periodic Table

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 L bar mol^{-1} K^{-1}
Avogadro's number: $N_A = 6.022 \times 10^{23}$ mol^{-1}
Faraday: F = 96,485 C / mol electrons
Planck's constant $h = 6.626 \times 10^{-34}$ Js
Speed of light = 2.998×10^8 m/s
STP conditions: 0 °C, 1 atm
Thermodynamic standard state: 1 atm, 1 M, 25 °C

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
R_H = 109,678 cm^{-1}
1 L = 10^{-3} m^3
1 C = 1 J / V
1 A = 1 C s^{-1}

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

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

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

$$\mathrm{pH} = -\log[\mathrm{H}^+] \qquad K_w = K_a K_b \qquad \mathrm{pH} = \mathrm{p}K_a + \log\left(\frac{[\text{cong. base}]}{[\text{cong. acid}]}\right) \qquad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

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

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