DAWSON COLLEGE

DEPARTMENT OF CHEMISTRY & CHEMICAL TECHNOLOGY

FINAL EXAMINATION CHEMISTRY 202-NYB-05
May 21, 2010
9:30 – 12:30

Print your Name: _____

Student Number: _____

INSTRUCTORS: ***Please circle the name of your instructor:***

J. Ali	I. Dionne	M. Haniff
D. Baril	M. Di Stefano	S. Holden
O. Behar	N. Duxin / Y-S. Uh	S. Mutic

INSTRUCTIONS:

This exam set consists of **16** questions. Please ensure that your copy of this examination is complete.

Answer all questions in the space provided.

1. Calculators may not be shared. Programmable calculators are not permitted.
2. No books or extra paper are permitted.
3. In order to obtain full credit, you must show the method used to solve all problems involving calculations and express your answers to the correct number of significant figures.
4. Your attention is drawn to the College policy on cheating.
5. A Periodic Table is provided. (last page).
6. If a mathematical equation is used to solve a problem, the equation should be clearly written.
7. Write your answer in the appropriate space when required.

USEFUL DATA:

Avogadro's Number $N_A = 6.022 \times 10^{23}\ mol^{-1}$

Gas Constant R = $0.08206\ L{\cdot}atm{\cdot}K^{-1}{\cdot}mol^{-1}$ = $8.314\ L{\cdot}kPa{\cdot}K^{-1}{\cdot}mol^{-1}$ = $8.314\ J{\cdot}K^{-1}{\cdot}mol^{-1}$

1 atm = 101.3 kPa = 760 mmHg = 760 torr

1 J = 1 $kg{\cdot}m^2{\cdot}s^{-2}$

101.3 J = 1 L·atm

MARK DISTRIBUTION

1.	/ 8
2.	/ 5
3.	/ 3
4.	/ 6
5.	/ 5
6.	/ 8
7.	/ 6
8.	/ 6
9.	/ 9
10.	/ 7
11.	/ 6
12.	/ 7
13.	/ 7
14.	/ 6
15.	/ 6
16.	/ 5
TOTAL	**/100**

Question 1

Ethanol is the common alcohol with molecular formula C_2H_5OH. An alcohol-water solution is prepared by dissolving 10.00 cm^3 of ethanol, with density $d_{ethanol}$ = 0.789 g/cm^3, in a sufficient volume of water to produce 100.00 cm^3 of solution. Density of solution is d_{soln} = 0.932 g/cm^3.

For a given solution calculate the following for ethanol:

a. the mass percent *(2 marks)*

Ans. Mass%: _____

b. the molarity *(2 marks)*

Ans. molarity: _____

c. the molality *(2 marks)*

Ans. molality: _____

d. the mole fraction. *(2 marks)*

Ans. Mole fraction: _____

Question 2

Toluene, C_7H_8 is a component of gasoline (octane, C_8H_{18}). It is present in gasoline as an octane booster at concentrations between 3 to 5% by mass (25% in racing cars gasoline).
Consider a solution of octane with 20.% by mass of toluene at 20°C

a. Calculate the total vapor pressure of this solution *(3 marks)*

Data: $P°_{octane}$ = 10.5 mm Hg at 20°C, T_b = 126°C $P°_{toluene}$ 22 mm Hg at 20°C, T_b = 111°C

*ans. total vapor pressure:*_____ *(1 mark)*

b. Calculate the mole ratio of toluene to octane in the vapor phase above the solution

*ans. mole ratio: toluene/octane:*_____

c. If the actual vapor pressure measured is 15.2 mm Hg, will the boiling point of this solution be **higher or lower** than the one expected from Raoult's law? Explain. *(1 mark)*

Question 3

A 0.461 g sample of cumene, a non-volatile non-ionic compound, is dissolved in 10.0 g cyclohexane (C_6H_{12}), producing a solution that freezes at -1.25°C. Cyclohexane has a normal freezing point of 6.50°C and a freezing point depression constant of 20.2°C/*m*. What is the molar mass of cumene? *(3 marks)*

Ans. Mol. mass cumene: _____

Question 4

Hydrofluoric acid, (HF) is a weak acid that can be used in the fluoridation of water. An aqueous solution of 0.100 *M* HF has an osmotic pressure of 2.64 atm at 25°C.

a. Calculate the van't Hoff factor for HF at this concentration *(2 marks)*

*Ans. van't Hoff factor:*_____

b. Does it differ from the maximum van't Hoff factor expected for a monoprotic acid?
If so, explain why. *(2 mark)*

c. What is the percent ionization of HF at this concentration? *(2 marks)*

*Ans. % ionization:*_____

Question 5

Iodide ion is oxidized in acidic solution to triiodide ion I_3^- by hydrogen peroxide.

$$H_2O_2(aq) + 3\,I^-(aq) + 2\,H^+(aq) \rightarrow I_3^-(aq) + 2H_2O(l) \qquad \text{Rate} = \frac{\Delta[I_3^-]}{\Delta t}$$

A series of four experiments was run at different concentrations, and the initial rates of I_3^- formation were determined (see table).

	Initial concentration ($mol \cdot L^{-1}$)	Initial concentration ($mol \cdot L^{-1}$)	Initial concentration ($mol \cdot L^{-1}$)	Initial rate ($mol \cdot L^{-1} \cdot s^{-1}$)
	H_2O_2	I^-	H^+	
Exp 1	0.010	0.010	0.00050	1.15×10^{-6}
Exp 2	0.020	0.010	0.00050	2.30×10^{-6}
Exp 3	0.010	0.020	0.00050	2.30×10^{-6}
Exp 4	0.010	0.010	0.00100	1.15×10^{-6}

a. From the table above, obtain the reaction orders with respect to each of the following species:

H_2O_2, I^-, H^+. *(3 marks)*

Ans. Reaction order: H_2O_2: _____ I^-: _____ H^+: _____

b. Find the rate constant with its units. *(2 marks)*

Ans. rate constant: _____

Question 6

The reaction below was monitored as a function of time at a temperature of 400 K:

$$2NOC\ell\,(g) \rightarrow 2NO(g) + C\ell_2(g)$$

A plot of $1/[NOC\ell]$ against time yielded a straight line with slope of 6.7×10^{-4} $L \cdot mol^{-1} \cdot s^{-1}$.

a. Write the rate law for the reaction. *(2 marks)*

b. What is the half-life for the reaction if the initial concentration of $NOC\ell$ is 0.20 *M*? *(2 marks)*

Ans. half-life: _____

c. If the initial concentration of $NOC\ell$ is 0.35 *M*, what is the concentration of $NOC\ell$ after 5.0 min? *(2 marks)*

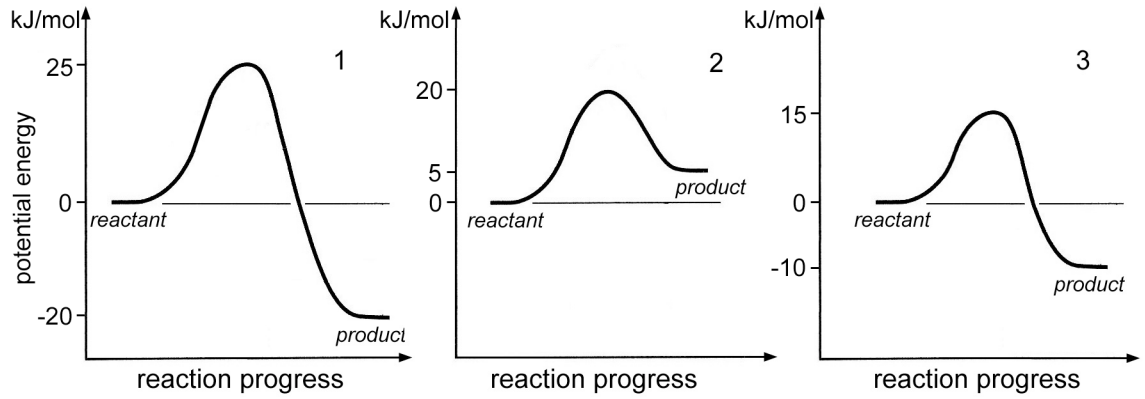
Ans. [$NOC\ell$] after 5.0 min: _____

d. If the initial concentration of $NOC\ell$ is 0.35 *M*, How long will it take for the concentration to drop to 20% of its original value? *(2 marks)*

Ans. time after 20% drop: _____

Question 7

a. Consider the potential energy profiles for three different chemical reactions. *(2 marks)*



Indicate which reaction is the slowest one. Explain your choice

b. Consider the potential energy profiles for a chemical reaction. *(2 marks)*

Mechanism 1

$2A + B \xrightarrow{\text{fast}} C$

$C \xrightarrow{\text{slow}} D$

Mechanism 2

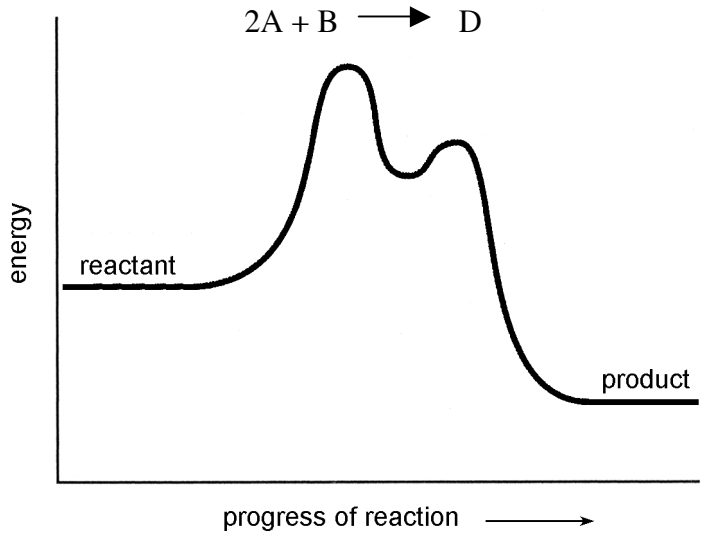
$2A \xrightarrow{\text{slow}} C$

$B + C \xrightarrow{\text{fast}} D$

Mechanism 3

$A \xrightarrow{\text{fast}} C$

$A + B + C \xrightarrow{\text{slow}} 2D$



Circle the proposed mechanism that is consistent with the reaction profile shown and explain your choice.

c. Beside concentration and pressure, give two parameters you can change that could affect the reaction rate of a chemical reaction: *(2 marks)*

i. _____ ii. _____

Question 8

At elevated temperature (997°C) limestone dissociates according to the equation

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g) \qquad \Delta H = +42.5 \text{ kJ}$$

a. If 50.0 g $CaCO_3$ (100.1 g/mol) is placed in an evacuated 4.00 L container and heated up to 997°C, how many grams of $CaCO_3$ will decompose if the pressure at equilibrium is 392 kPa? *(2 marks)*

b. If the volume of the container is expanded to 10.0 L at 997°C, what will be the CO_2 pressure at equilibrium? *(1 mark)*

c. Calculate K_c for this reaction at 997°C *(1 mark)*

d. Predict the effect of each of the following changes will have on the equilibrium position. *(2 marks)*

		equilibrium position shift		
	change	to the left	no change	to the right
i.	CO_2 is added	☐	☐	☐
ii.	$CaCO_3$ is added	☐	☐	☐
iii.	Pressure is increased (adding N_2 gas, volume unchanged)	☐	☐	☐
iv.	The temperature is increased	☐	☐	☐

Question 9

Consider the following set of data:

Formula	K_a (at 25°C)
$[Al(H_2O)_6]^{3+}$	1.4×10^{-5}
HNO_2	4.0×10^{-4}
HF	7.2×10^{-4}

a. What is the strongest acid in the table? _____ *(1 mark)*

b. With the help of the table, arrange the following in order of most basic to least basic: *(2 marks)*

H_2O, NO_2 , $[Al(H_2O)_5OH]^{2+}$

Most basic _____ > _____ > _____ Least basic

c. What is the value of K_b for F^- at 25°C ? *(2 marks)*

Ans. K_b *:* _____

d. Write the chemical reaction represented by the K_b for F^- in water and place the species involved in the appropriate place *(2 marks)*

_____ (Acid) + _____ (Base) $\rightleftharpoons$ _____ (Conjugate acid) + _____ (Conjugate base)

e. At 40°C, $K_w = 2.9\text{x}10^{-14}$. What is the neutral *pH* of water at this temperature? *(2 marks)*

Ans. _____

Question 10

a. A solution of the basic oxide CaO is prepared by adding water to 0.28 g CaO to make 0.50 L of solution.

i. Write the equations for the reactions that occur when CaO is dissolved in water *(1 mark)*

ii. Assuming that ion-pairing is non-existent, what is the expected *pH* of this solution? *(2 marks)*

*ans. pH:*_____

b. For which of the following salts will the solubility depend on *pH*? *(2 marks)*

		pH sensitive	*pH* independent
i.	$KC\ell O_4$	☐	☐
ii.	$Pb(OH)_2$	☐	☐
iii.	AgF	☐	☐
iv.	$Ba(NO_3)_2$	☐	☐

c. For each of the following salts dissolved in water, predict whether the aqueous solution will be acidic, neutral or basic. *(2 marks)*

		acid	neutral	basic
i.	$RbOH$	☐	☐	☐
ii.	$NaIO$	☐	☐	☐
iii.	NH_4OH	☐	☐	☐
iv.	$LiC\ell O_3$	☐	☐	☐

Question 11

a. Consider 0.500 L of a buffer that consists of 1.50 *M* $KC\ell O$ (K_a $HC\ell O$ = 3.5×10^{-8}) and 0.50 *M* $HC\ell O$. *(4 marks)*
What will be the *pH* of this buffer after the addition of 250 mL of 1.0 *M* HNO_3?

*ans. pH:*_____

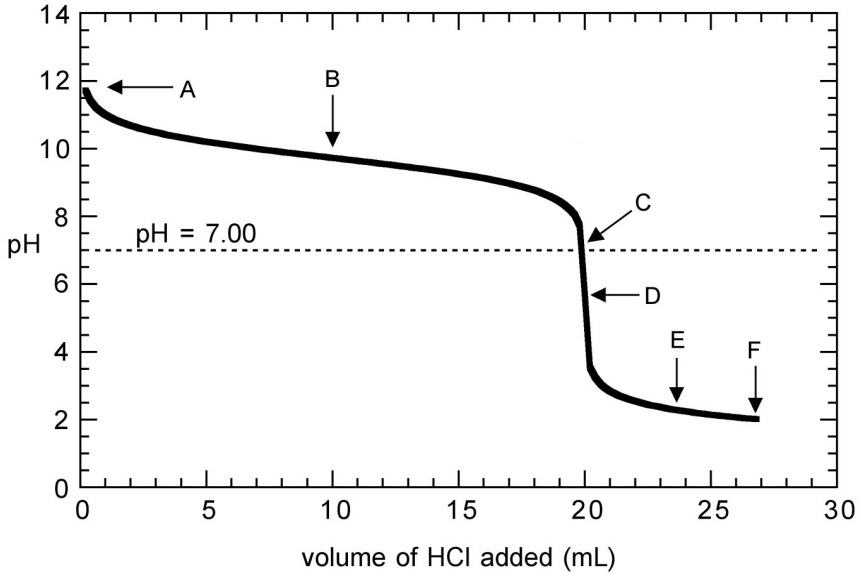
b. Which of the following mixtures would result in a buffer solution when 100 mL of each of the two solutions are mixed together? *(2 marks)*

				buffer	not a buffer
i.	0.1 *M* KOH	and	0.2 *M* NH_3	☐	☐
ii.	0.2 *M* $HC\ell$	and	0.2 *M* NH_3	☐	☐
iii.	0.2 *M* HNO_3	and	0.4 *M* $NaNO_3$	☐	☐
iv.	0.1 *M* HNO_3	and	0.2 *M* NaF	☐	☐

Question 12

Consider the following titration curve of trimethylamine (C_3H_9N) a weak base with 0.100 *M* $HC\ell$ at 23°C.

ans.
K_b:__
_____
_____



Initial solution:
50.0 mL of C_3H_9N, 4.00x10^{-2} *M*

a. Draw on the graph the shape of the titration curve if this base had a smaller K_b value.

b. Which letter (A to F) on the graph corresponds to each of the following?

	letter
The equivalence point	_____
The point of half-neutralization	_____
The point corresponding to the pK_a of $C_3H_9NH^+$	_____

c. When 15.0 mL of 0.100 *M* $HC\ell$ is added, the *pH* of the solution is 9.255. Calculate K_b of trimethylamine.

(1 mark)

(3 marks)

(3 marks)

Question 13

a. A saturated aqueous solution of $Mg(OH)_2$ has a *pH* of 10.08, what is the K_{sp} of $Mg(OH)_2$? *(2 marks)*

ans. K_{sp}:_____

b. The K_{sp} of cobalt(III) hydroxide is 2.5×10^{-43}. Calculate the solubility of $Co(OH)_3$ in water in mol/L *(2 marks)*

*ans. solubility (mol/L):*_____

c. Does a precipitate form when 25 mL of 0.10 *M* lithium nitrate $LiNO_3$, is mixed with 35 mL of 0.75 *M* sodium carbonate Na_2CO_3? (K_{sp} Li_2CO_3 = 8.15×10^{-4}) **Show your work**. *(3 marks)*

ans: *yes* ☐ *no* ☐

Question 14

a. A system is made of a cylinder of gas with a piston. When 4.0 kJ of heat is transferred from the surroundings to the system, the gas in the piston expands from 12 L to 27 L and performs work on the surroundings. If the system gains 201 J of internal energy from this process, against what constant external pressure, in atmospheres, is the piston working? *(3 marks)*

Ans. pressure (atm): _____

b. Bromine is a liquid at room temperature. Calculate the freezing point of bromine if its heat of fusion is + 5.79 $kJ \cdot mol^{-1}$ and its entropy of fusion is 21.8 $J \cdot K^{-1} \cdot mol^{-1}$. *(3 marks)*

Ans. T_f bromine: _____

Question 15

a. Circle the substance in each of the following pairs that would have the greater entropy. *(2 marks)*

i. H_2O (ℓ, 1 mol, 75˚C, 1 atm) or H_2O (g, 1 mol, 75˚C, 1 atm)

ii. Fe (s, 50.0 g, 5˚C, 1 atm) or Fe (s, 0.80 mol, 5˚C, 1 atm)

iii. Br_2 (ℓ, 1 mol, 8˚C, 1 atm) or Br_2 (s, 1 mol, –8˚C, 1 atm)

iv. SO_2 (g, 0.312 mol, 32.5˚C, 0.110 atm) or SO_2 (g, 0.284 mol, 22.3˚C, 15 atm)

b. Methyl isothiocyanate, $CH_3—N{=}C{=}S$, is a highly irritating pesticide. It can be prepared by reacting carbon disulfide with methylamine. Given the thermodynamic data at 25˚C below, calculate the standard molar entropy of methyl isothiocyanate. *(4 marks)*

	CS_2 (g)	+	CH_3NH_2 (g)	→	$CH_3—N{=}C{=}S$ (g)	+	H_2S (g)
$\Delta G°$ (kJ·mol^{-1})	67.15		32.09		144.35		–33.56
$\Delta H°$ (kJ·mol^{-1})	117.36		–22.98		130.96		–20.63
$S°$ (J·mol^{-1}·K^{-1})	237.73		243.30		?		205.69

Ans: _____*:*

Question 16

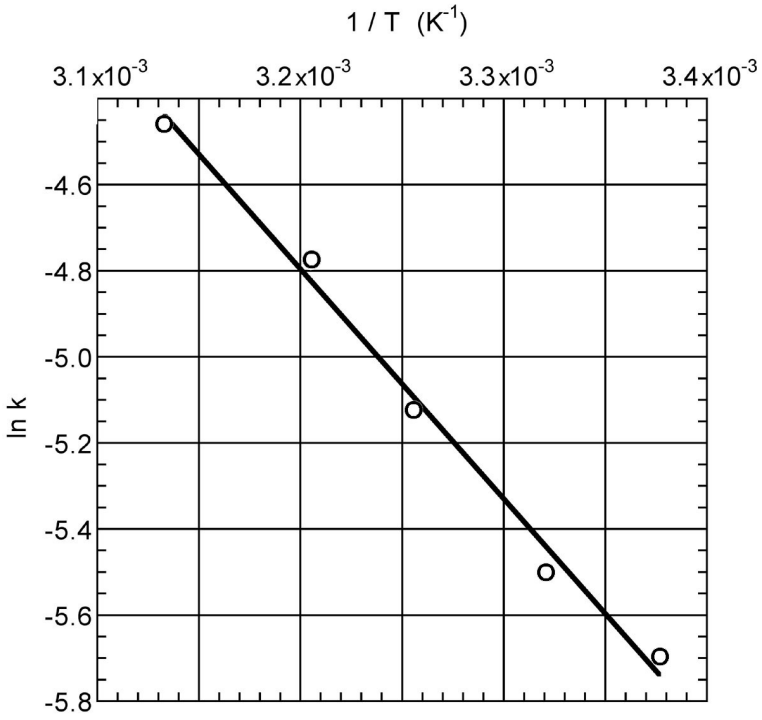
In the laboratory experiment 4, you want to determine the activation energy of the following reaction: *(5 marks)*

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightleftharpoons I_2(aq) + 2S_2O_4^{2-}$$

Where the reaction rate is: Rate = $-[\Delta I^-]/2\Delta t$ and the rate law for this reaction is: Rate = $k\,[I^-][S_2O_8^{2-}]$

By recording the reaction rate of several experiments at different temperatures, the following graph based on the linear form of the Arrhenius equation is obtained.

Arrhenius plot for the determination of the activation energy for the reaction of iodide with peroxydisulfate



From this graph, calculate the activation energy (with units) for this reaction.

Ans. E_a : _____

Periodic Table of the Elements

	1A																	8A
	1																	2
1	H																	He
	1.008	2A											3A	4A	5A	6A	7A	4.003
	3	4											5	6	7	8	9	10
2	Li	Be											B	C	N	O	F	Ne
	6.941	9.012											10.81	12.01	14.01	16.00	19.00	20.18
	11	12											13	14	15	16	17	18
3	Na	Mg											Al	Si	P	S	Cl	Ar
	22.99	24.31	3B	4B	5B	6B	7B	8B	9B	10B	1B	2B	26.98	28.09	30.97	32.07	35.45	39.95
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
	39.10	40.08	44.96	47.87	50.94	52.00	54.94	55.85	58.93	58.69	63.55	65.39	69.72	72.61	74.92	78.96	79.90	83.80
	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
	85.47	87.62	88.91	91.22	92.91	95.94	98.00	101.1	102.9	106.4	107.9	112.4	114.8	118.7	121.8	127.6	126.9	131.3
	55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
6	Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
	132.9	137.3	138.9	178.5	181.0	183.8	186.2	190.2	192.2	195.1	197.0	200.6	204.4	207.2	209.0	209.0	210.0	222.0
	87	88	89	104	105	106	107	108	109	110	111	112						
7	Fr	Ra	Ac[a]	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub						
	223.0	226.0	227.0	261.0	262.0	263.0	262.0	265.0	266.0	269.0	272.0	277.0						

= metalloid

	58	59	60	61	62	63	64	65	66	67	68	69	70	71
*Lanthanides	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	140	141	144	145	150	152	157	159	163	165	167	169	173	175
	90	91	92	93	94	95	96	97	98	99	100	101	102	103
[a]Actinides	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
	232	231	238	237.1	244	243	247	247	251	252	257	258	259	260