Department of Chemistry
Memorial University
Chemistry 1051

Winter 2019 Final Examination
Time 2 hours

Read the Following Carefully

1. This exam has 11 pages. Question are on pages 2 through 9 and a periodic table and equation sheet are at the end of the exam. Ensure that all pages for the examination paper are present.

2. The sheets containing the periodic table, physical constants and equations which may be useful to you are provided. These **<u>should be detached for easier use.</u>**

3. **<u>Read each question carefully</u>** and answer each question in the space provided.

4. Show all relevant calculations.

5. Numerical answers should be reported to the appropriate number of significant digits and MUST include the correct units.

Questions	Points	Grade
1 - 2	6	
3	6	
4 - 5	9	
6	6	
7 - 9	10	
10 - 12	9	
13	10	
14 - 15	10	
total	66	

1. Water has a boiling point of 100.00 ^{o}C at 1 atm. What mass of sodium chloride is required to increase the boiling point of 500.0 g of water to 101.50 ^{o}C? $K_b(H_2O)$ = 0.51 ^{o}C kg mol^{-1} and the molar mass of sodium chloride, NaCl, is 58.44 g mol^{-1}. **(3 marks)**

2. A solution is made by dissolving 17.1 g of a non-electrolyte solute in 90.0 g of water (18.015 g mol^{-1}) at 30.0 ^{o}C. The vapour pressure of this solution was found to be 31.539 Torr. What is the molar mass of the solute? The vapour pressure of pure water at 30.0 ^{o}C is 31.855 Torr. **(3 marks)**

3. Consider the reaction that occurs between nitric oxide and hydrogen at 1001 °C:

$$2\,NO(g) + 2\,H_2(g) \rightarrow N_2(g) + 2\,H_2O(g)$$

The initial rates data are listed in the table below:

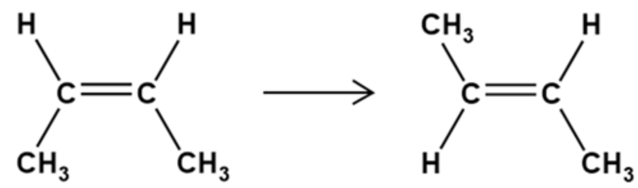
Exp.	[NO] / mol L^{-1}	[H_2] / mol L^{-1}	initial rate / mol L^{-1} s^{-1}
1	1.20 x 10^{-2}	1.52 x 10^{-3}	1.38 x 10^{-6}
2	1.20 x 10^{-2}	2.92 x 10^{-3}	2.66 x 10^{-6}
3	5.50 x 10^{-2}	3.50 x 10^{-3}	6.69 x 10^{-5}

a) Determine the order of the reaction for each reactant and the rate law. **(4 marks)**

rate law ________________

b) Determine the rate constant for this reaction. **(2 marks)**

4. For the isomerization of cis-2-butene to trans-2-butene:



a) the activation energy is 259.8 kJ mol^{-1}. At 552 °C, the rate constant is 1.28 x 10^{-3} s^{-1}? Compute the rate constant at 875 °C. **(4 marks)**

5. In an experiment, 5.50 bar of NO and 3.50 bar H_2 were placed into a flask at 1950 K. The reaction that occurs is as follows:

$$2\,NO(g) + H_2(g) \longrightarrow N_2O(g) + H_2O(g)$$

a) At equilibrium, the total pressure is 6.56 bar. Determine the partial pressures of each of the reactants and products, and the equilibrium constant, *K*. **(4 marks)**

b) Once at equilibrium, the reaction chamber was compressed. What effect, if any, would this have on the partial pressures of the reactants and products once equilibrium was re-established? Explain your answer. **(1 mark)**

6. Phenylacetic acid, $C_6H_5CH_2COOH$, is a weak monoprotic acid with a K_a of 4.9×10^{-5}. A 20.00 mL aliquot of 0.01500 mol L^{-1} solution of phenylacetic acid was titrated with a 0.03125 mol L^{-1} solution of NaOH. Determine: **(6 marks)**

a) the volume of NaOH solution required to reach the equivalence point of the titration;

b) and the pH at the endpoint of the titration.

7. Explain why chloroacetic acid ($ClCH_2COOH$) is a stronger acid than bromoacetic acid ($BrCH_2COOH$) but a weaker acid than dichloroacetic acid ($Cl_2CHCOOH$). **(2 marks)**

8. Consider the following equilibrium

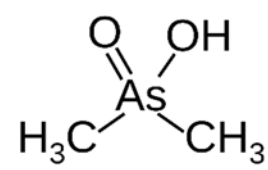
$$NH_4^+(aq) + OH^-(aq) \rightleftharpoons NH_3(g) + H_2O(l) \qquad \Delta_r H^\circ = 31.6 \text{ kJ mol}^{-1}$$

a) Write the expression for the thermodynamic equilibrium constant, *K*. **(1 mark)**

b) What would happen to the concentration of NH_4^+ if the temperature were increased? Briefly explain your answer. **(1 mark)**

c) What would happen to the pressure of NH_3 above the solution if a small amount of acid such as HCl were added to the solution? Briefly Explain your answer. **(1 mark)**

9. a) Dimethylarsenic acid, $(CH_3)_2AsOOH$ is a weak acid with a K_a of 5.4×10^{-7}. What mass of NaOH (39.997 g mol^{-1}) must be added to 500.0 mL of a 0.500 mol L^{-1} solution of dimethylarsenic acid to make a buffer with a pH=6.47. **(5 marks)**



Dimethylarsenic acid

10. The K_{sp} of $PbBr_2$ is 3.22×10^{-6}. What are the concentrations of Pb^{2+} and Br^- in a saturated aqueous solution of $PbBr_2$? **(3 marks)**

11. Determine whether or not a precipitate of $PbBr_2$ will form when 200.0 mL of 3.00×10^{-2} mol L^{-1} $Pb(NO_3)_2(aq)$ is mixed with 300.0 mL of 8.83×10^{-3} mol L^{-1} $KBr(aq)$. K_{sp} of $PbBr_2$ = 3.22×10^{-6}? **(4 marks)**

12. Explain how you would differentiate between a catalyst and a reaction intermediate in a reaction mechanism. **(2 marks)**

13. Given the thermochemical information in the table to the right.

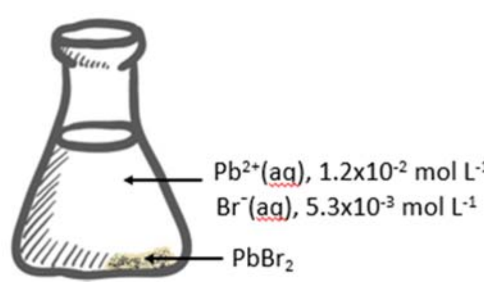
	$\Delta_f H^\circ$ / kJ mol^{-1}	S° / J K^{-1} mol^{-1}
$PbBr_2(s)$	-278.7	161.5
$Pb^{2+}(aq)$	0.92	18.5
$Br^{-}(aq)$	-121.4	80.71

a) Compute the standard enthalpy change, $\Delta_r H^\circ$, the standard entropy change, $\Delta_r S^\circ$, and the 298 K Gibbs energy change, $\Delta_r G^\circ$, for the following dissolution of lead (II) bromide. **(3 marks)**

$$PbBr_2(s) \rightleftharpoons Pb^{2+}(aq) + 2\,Br^{-}(aq)$$

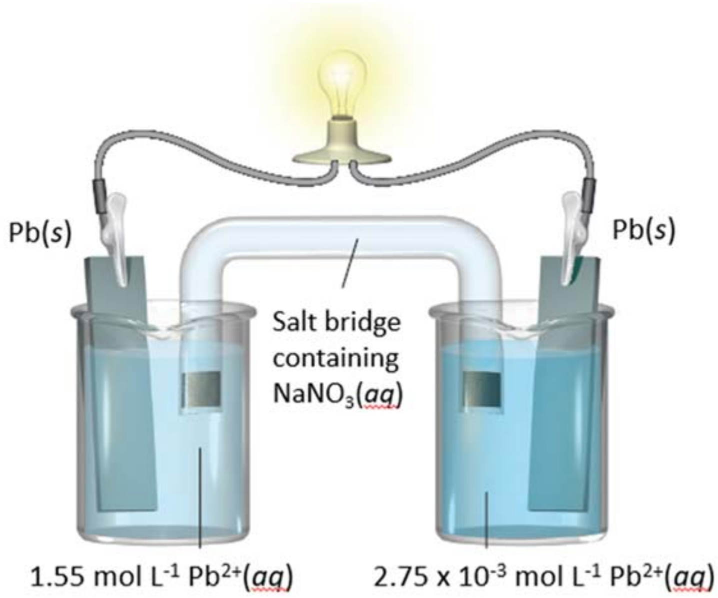
b) Determine the equilibrium constant, K_{sp}, for the dissolution of $PbBr_2$ at 298 K. **(3 marks)**

c) Determine $\Delta_r G$ at 298 K under the conditions depicted to the right. **(3 marks)**



d) What does the sign of $\Delta_r G$ determined in c) tell us about the direction of the reaction? **(1 mark)**

14. Consider the concentration cell depicted below.



a) Indicate in the diagram in which direction the electrons spontaneously flow in this cell. Explain your answer. **(2 marks)**

b) Label the anode and cathode in the figure. **(1 mark)**

c) What happens to the concentration of Pb^{2+} in each half cell? **(1 mark)**

d) Compute the cell potential, E_{cell}. **(3 marks)**

15. Determine the time in minutes required to produce 1.63 g of iron metal at the cathode of an electrolysis cell containing $Fe(NO_3)_3(aq)$ if a constant current of 15.0 amperes is used. **(3 marks)**

$$k = \mathrm{A}e^{-E_a/RT}$$

$$\ln [\mathrm{A}]_\mathrm{t} = -k\mathrm{t} + \ln [\mathrm{A}]_\mathrm{o}$$

$$\frac{1}{[\mathrm{A}]_\mathrm{t}} = k\mathrm{t} + \frac{1}{[\mathrm{A}]_\mathrm{o}}$$

$$[\mathrm{A}]_\mathrm{t} = -k\mathrm{t} + [\mathrm{A}]_\mathrm{o}$$

$$S_\mathrm{gas} = k_H P_\mathrm{gas}$$

$$\Delta\mathrm{T_b} = \mathrm{K_b} \times i\mathrm{m}$$

$$\Delta\mathrm{T_f} = \mathrm{K_f} \times i\mathrm{m}$$

$$\Pi = i(\mathrm{MRT})$$

$$\mathrm{P_{solvent}} = \frac{n_\mathrm{solvent}}{i n_\mathrm{solute} + n_\mathrm{solvent}} \times \mathrm{P^o_{solvent}}$$

$$\mathrm{P_{solvent}} = \mathrm{X_{solvent}} \times \mathrm{P^o_{solvent}}$$

$$\ln\frac{k_2}{k_1} = \frac{-E_\mathrm{a}}{\mathrm{R}}\left(\frac{1}{\mathrm{T_2}} - \frac{1}{\mathrm{T_1}}\right) = \frac{E_\mathrm{a}}{\mathrm{R}}\left(\frac{1}{\mathrm{T_1}} - \frac{1}{\mathrm{T_2}}\right)$$

$$\ln\frac{\mathrm{K_2}}{\mathrm{K_1}} = \frac{-\Delta_\mathrm{r}H^o}{\mathrm{R}}\left(\frac{1}{\mathrm{T_2}} - \frac{1}{\mathrm{T_1}}\right) = \frac{\Delta_\mathrm{r}H^o}{\mathrm{R}}\left(\frac{1}{\mathrm{T_1}} - \frac{1}{\mathrm{T_2}}\right)$$

$$\ln K = \frac{-\Delta_\mathrm{r}H^o}{\mathrm{RT}} + \frac{\Delta_\mathrm{r}S^o}{\mathrm{R}}$$

$$K_\mathrm{P} = K_\mathrm{C}(RT)^{\Delta n_\mathrm{gases}}$$

$$\Delta_\mathrm{r}G^\mathrm{o} = -\mathrm{RT}\ \ln K$$

$$\Delta_\mathrm{r}G^\mathrm{o} = -\mathrm{nF}E^\mathrm{o}_\mathrm{cell}$$

$$E^\mathrm{o}_\mathrm{cell} = \frac{\mathrm{RT}}{\mathrm{nF}}\ln K$$

$$E^\mathrm{o}_\mathrm{cell} = \frac{0.0257\ \mathrm{V}}{\mathrm{n}}\ln K \quad \text{at } 25\ {}^\mathrm{o}\mathrm{C}$$

$$E_\mathrm{cell} = E^\mathrm{o}_\mathrm{cell} - \frac{\mathrm{RT}}{\mathrm{nF}}\ln Q$$

$$E_\mathrm{cell} = E^\mathrm{o}_\mathrm{cell} - \frac{0.0257\ \mathrm{V}}{\mathrm{n}}\ln Q \quad \text{at } 25\ {}^\mathrm{o}\mathrm{C}$$

$$\Delta_\mathrm{r}G^\mathrm{o} = \Delta_\mathrm{r}H^\mathrm{o} - \mathrm{T}\,\Delta_\mathrm{r}S^\mathrm{o}$$

$$\Delta_\mathrm{r}G = \Delta_\mathrm{r}G^\mathrm{o} + \mathrm{RT}\ \ln Q$$

$$\mathrm{x} = \frac{-\mathrm{b} \pm \sqrt{\mathrm{b}^2 - 4\mathrm{ac}}}{2\mathrm{a}}$$

$$\mathrm{R} = 8.314\ \mathrm{J\ K^{-1}\ mol^{-1}}$$
$$= 0.08314\ \mathrm{bar\ L\ K^{-1}\ mol^{-1}}$$

$$\mathrm{F} = 96\,485\ \mathrm{C\ mol^{-1}}$$

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

Chemistry 1051

PERIODIC TABLE OF THE ELEMENTS

KEY: atomic number 6, C, atomic mass 12.0107

d-block (groups 3–12)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.0107	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.9984	10 **Ne** 20.1797
11 **Na** 22.9898	12 **Mg** 24.3050											13 **Al** 26.9815	14 **Si** 28.0855	15 **P** 30.9738	16 **S** 32.065	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.9559	22 **Ti** 47.867	23 **V** 50.9415	24 **Cr** 51.9961	25 **Mn** 54.9380	26 **Fe** 55.8475	27 **Co** 58.9332	28 **Ni** 58.6934	29 **Cu** 63.546	30 **Zn** 65.409	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.9216	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.798
37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.9059	40 **Zr** 91.224	41 **Nb** 92.9064	42 **Mo** 95.94	43 **Tc** (99)	44 **Ru** 101.07	45 **Rh** 102.9055	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.411	49 **In** 114.818	50 **Sn** 118.710	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.9045	54 **Xe** 131.29
55 **Cs** 132.9054	56 **Ba** 137.327	57 **La** 139.9055	72 **Hf** 178.49	73 **Ta** 180.9479	74 **W** 183.84	75 **Re** 186.207	76 **Os** 190.23	77 **Ir** 192.217	78 **Pt** 195.078	79 **Au** 196.9665	80 **Hg** 200.59	81 **Tl** 204.3833	82 **Pb** 207.2	83 **Bi** 208.9804	84 **Po** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (269)	109 **Mt** (268)									

Lanthanides	58 **Ce** 140.116	59 **Pr** 140.9077	60 **Nd** 144.24	61 **Pm** (147)	62 **Sm** 150.36	63 **Eu** 151.964	64 **Gd** 157.25	65 **Tb** 158.925	66 **Dy** 162.50	67 **Ho** 164.9303	68 **Er** 167.259	69 **Tm** 168.9342	70 **Yb** 173.04	71 **Lu** 174.967
Actinides	90 **Th** 232.0381	91 **Pa** 231.0359	92 **U** 238.0289	93 **Np** (237)	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** (262)

Parenthesis Indicates the most stable isotope

SOME USEFUL CONSTANTS

Quantity and Symbol	Value	Quantity and Symbol	Value
ΔH_{fusion}, $H_2O(s)$ at 273 K	6.01 kJ mol^{-1}	Rydberg constant, R_H	1.0973×10^{7} m^{-1}
$\Delta H_{vaporization}$, $H_2O(\ell)$ at 373 K	40.7 kJ mol^{-1}	Velocity of light in a vacuum, c	2.998×10^{8} m s^{-1}
Specific Heat Capacity of $H_2O(\ell)$	4.184 J g^{-1} K^{-1}	Planck's Constant, h	6.626×10^{-34} J s
Specific Heat Capacity of $H_2O(s)$ at 0°C	1.960 J g^{-1} K^{-1}	Density of $H_2O(\ell)$ (near 0°C)	1.000 g mL^{-1}

Faraday Constant, F 9.6485×10^{4} C mol^{-1} Avogadro Constant, N 6.022×10^{23} particles·mol^{-1}

Ideal Gas Constant, R 8.314 L kPa mol^{-1} K^{-1} = 8.314 J mol^{-1} K^{-1} = 8.206×10^{-2} L atm mol^{-1} K^{-1} = 0.08314 L bar mol^{-1} K^{-1}

CONVERSION FACTORS

1 bar = 10^5 Pa = 100 kPa = 750.1 mmHg = 750.1 torr = 0.9869 atm

1 L = 1 dm^3 (exactly)

1 L bar = 100 J

1 cal = 4.184 J (exactly)

$K_w = 1.008 \times 10^{-14}$ at 25ºC

0 ºC = 273.15 K