UNIVERSITY OF TORONTO
FACULTY OF ARTS AND SCIENCE

DECEMBER EXAMINATIONS 2014

CHM 139H1 F

Duration: 3 Hours

NAME (print): _____ Student Number: _____

Tutorial Group No.: _____

Calculators may be used; programmable calculators may not be used. The periodic table and the sheet of constants and equations found at the back of the Exam may be detached.

The Examination consists of a multiple choice component (Part A) and a written answer component (Part B). Both the computer answer sheet, answer sheet and the exam paper must be handed in at the end of the exam.

WHEN YOU RECEIVE YOUR TEST PAPER, ANSWER SHEET AND COMPUTER ANSWER SHEET:

1. Write your name, student number and tutorial group number on this page and **on the answer sheet.**
2. On the computer sheet:

(a) In the student number box at the top right of the form, print your student number as a ten digit number. If your student number begins with a 9, print zero in the first column. Across the ten columns, fill in the bubbles corresponding to the ten digits of your student number.

(b) In the name area on the reverse side of the form, print the letters of your family name/surname in the boxes, starting from the left. Fill in the bubbles corresponding to each letter of your family name/surname.

(c) **Do not make any stray marks on the computer sheet.**

AT THE END OF THE EXAM: Insert your computer answer sheet and answer sheet into this test paper. Remain seated until all of the test papers have been collected.

TOTAL MARKS = 65

Good Luck!

PART A: Multiple Choice Questions

There are 25 questions (1 mark each) for the multiple choice section of this exam.

Your answers are to be recorded on the computer answer sheet and on this exam paper, both of which must be handed in at the end of the exam. Nothing written on the multiple choice section of this exam paper will be marked. The computer answer sheet MUST be filled in DURING the time allotted for the exam.

A. Clearly circle on the exam paper the letter corresponding to your choice for the best answer to each question.
B. Using a soft pencil (No.2 or softer), blacken the circle on the computer sheet which corresponds to the answer you have chosen for each question. Make sure that only one answer is blackened. Make no stray marks on the computer answer sheet.

---

1. In which of the following sets do all species have the same number of **protons**?
a) Br^-, Kr, Sr^{2+} b) C, N^+, O^{2-} c) C, N^{3-}, O^{2-}
d) Mg^{2+}, Sr^{2+}, Ba^{2+} e) O, O^{2-}, O^{2+}

2. How many oxygen atoms are in 3.00 g of sodium dichromate, $Na_2Cr_2O_7$?
a) 0.0801 oxygen atoms
b) 9.85×10^{20} oxygen atoms
c) 6.90×10^{21} oxygen atoms
d) 4.83×10^{22} oxygen atoms
e) 9.83×10^{22} oxygen atoms

3. In the reaction between glucose and oxygen, 10.0 g of glucose reacts and 7.50 L of carbon dioxide is formed. What is the percent yield if the density of CO_2 is 1.26 g/L?

$$C_6H_{12}O_6(s) + 6\ O_2(g) \rightarrow 6\ CO_2(g) + 6\ H_2O(l)$$

a) 26.1%
b) 40.6%
c) 43.1%
d) 57.4 %
e) 64.5%

4. Some assumptions from the kinetic molecular theory are listed below. Which one can be used to explain the compressibility of gases?
a) The average kinetic energy of gas particles is proportional to the temperature in Kelvin.
b) Collisions of gas particles are elastic and the total kinetic energy of the gas is constant.
c) A gas consists of tiny particles moving in random straight line motion.
d) The volume of the particles is negligible compared to the volume of the gas.
e) None of the above

5. Which of the following noble gases should show the greatest deviation from the ideal gas law at high pressures?
a) He
b) Ne
c) Ar
d) Rn
e) All of the gases would show the same deviation

6. Which of the following substances has the highest boiling point?
a) $CH_3CH_2CH_2CH_2CH_2CH_3$
b) H_2
c) CH_4
d) Kr
e) O_2

7. An ionic compound, M_XA_y, crystallizes with the cation M in a face-centered cubic structure and with eight anions (A) entirely within its unit cell. What is the empirical formula of this compound?
a) MA
b) MA_2
c) M_2A
d) $M_{14}A_8$
e) M_3A_8

8. The normal boiling point of pure benzene is 80.10 °C. What is the approximate molecular weight of a covalent compound if a solution of 3.55 g of the substance dissolved in 100.0 g of benzene has a normal boiling point of 80.19 °C? $K_b = 5.12°C/m$ for benzene.
a) 2 g/mol
b) 20 g/mol
c) 500 g/mol
d) 2000 g/mol
e) 20,000 g/mol

9. Which of the following is **not** a valid set of quantum numbers?
a) $n = 2, l = 1, m_l = 0$, and $m_S = -1/2$
b) $n = 2, l = 1, m_l = -1$, and $m_S = -1/2$
c) $n = 3, l = 0, m_l = 0$, and $m_S = +1/2$
d) $n = 3, l = 2, m_l = 3$, and $m_S = +1/2$
e) $n = 3, l = 1, m_l = 0$, and $m_S = +1/2$

10. For a particular first-order reaction, it takes 48 minutes for the concentration of the reactant to decrease to 25% of its initial value. What is the value for rate constant (in s^{-1}) for the reaction?
a) $1.0 \times 10^{-4}\ s^{-1}$
b) $4.8 \times 10^{-4}\ s^{-1}$
c) $6.0 \times 10^{-3}\ s^{-1}$
d) $2.9 \times 10^{-2}\ s^{-1}$
e) $5.2 \times 10^{-2}\ s^{-1}$

11. For the zeroth-order reaction: A → products, what will happen to the rate of reaction if the concentration of A is doubled?
a) The rate will be halved.
b) The rate will be doubled.
c) The rate will be quadrupled.
d) The rate will remain the same.
e) The rate will decrease.

12. In the presence of KI, the decomposition of hydrogen peroxide is thought to occur by the following mechanism:

Step 1: $H_2O_2 + I^- \rightarrow H_2O + IO^-$
Step 2: $IO^- + H_2O_2 \rightarrow H_2O + O_2 + I^-$

i. I^- is a catalyst for the reaction.
ii. IO^- is a catalyst for the reaction.
iii. For every two moles of H_2O_2 that decomposes, 1 mole of O_2 forms.

Which of the above statements is true?
a) i only b) i and ii only c) i and iii only d) ii and iii only e) i, ii and iii

13. 50 mL of 0.10 M NaF is added to 50 mL of 0.10 M HF. Relative to the pH of the 0.10 M HF solution, the pH of the resulting solution will
a) become 7.
b) decrease.
c) increase.
d) remain the same.
e) cannot answer without K_a of HF

14. Determine the acid dissociation constant for a 0.010 M nitrous acid solution that has a pH of 2.70. Nitrous acid is a weak monoprotic acid and the equilibrium equation of interest is

$$HNO_2\,(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + NO_2^-(aq).$$

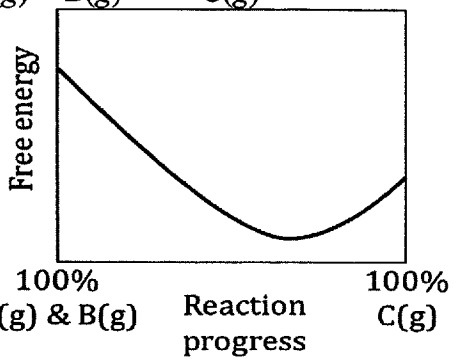
a) 8.0×10^{-3}
b) 2.0×10^{-3}
c) 5.0×10^{-4}
d) 4.0×10^{-4}
e) 2.0×10^{-4}

15. For the reaction shown below, which change in conditions made to the system at equilibrium will result in a net reaction to the right to form more product?

$$C(s) + 2\,H_2(g) \rightleftharpoons CH_4(g) \quad \Delta H° = -74.8\ \text{kJ}$$

a) adding more C
b) decreasing the concentration of H_2
c) increasing the concentration of CH_4
d) decreasing volume
e) increasing temperature

16. A plot of free energy vs. reaction progress is shown below for the reaction
$A(g) + B(g) \rightleftharpoons C(g)$



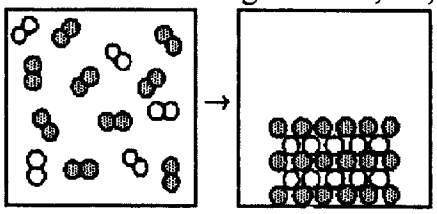
How many of the statements (i-v) are **true**?

i. The minimum energy corresponds to the mixture of reactants and products present at equilibrium.
ii. At equilibrium, all of A and B have reacted to give C.
iii. For the reaction, the change in entropy is positive.
iv. The value of K is greater than 1.
v. The standard enthalpy change for the reaction must be negative.

a) 1 b) 2 c) 3 d) 4 e) 5

17. How long must a constant current of 50.0 A be passed through an electrolytic cell containing aqueous Cu^{2+} ions to produce 3.00 moles of copper metal?
a) 0.311 hours
b) 0.621 hours
c) 1.61 hours
d) 3.22 hours
e) 4.18 hours

18. What are the signs of ΔH, ΔS, and ΔG for the following spontaneous change?



a) $\Delta H = +$, $\Delta S = +$, $\Delta G = -$
b) $\Delta H = +$, $\Delta S = -$, $\Delta G = -$
c) $\Delta H = -$, $\Delta S = +$, $\Delta G = -$
d) $\Delta H = -$, $\Delta S = -$, $\Delta G = -$
e) $\Delta H = -$, $\Delta S = -$, $\Delta G = +$

19. How much heat is absorbed/released when 20.0 g of $NH_3(g)$ reacts in the presence of excess $O_2(g)$ to produce $NO(g)$ and $H_2O(l)$ according to the following chemical equation?

$$4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(l) \quad \Delta H° = +1168\ kJ$$

a) 343 kJ of heat are absorbed.
b) 343 kJ of heat are released.
c) 1370 kJ of heat are absorbed.
d) 1370 kJ of heat are released.
e) None of the above

20. When 50.0 mL of 0.400 M $Ca(NO_3)_2$ is added to 50.0 mL of 0.800 M NaF, CaF_2 precipitates, as shown in the net ionic equation below. The initial temperature of both solutions is 25.00 °C. Assuming that the reaction goes to completion, that no heat is lost from the solution, and that the resulting solution has a mass of 100.00 g and a specific heat of 4.18 J/(g · °C), calculate the final temperature of the solution.

$$Ca^{2+}(aq) + 2F^-(aq) \rightarrow CaF_2(s) \quad \Delta H° = -11.5\ kJ$$

a) 24.45 °C
b) 25.55 °C
c) 26.10 °C
d) 26.65 °C
e) 26.89 °C

21. The following forward reaction is spontaneous:

$A(s) + B(s) \rightleftharpoons A^-(aq) + B^+(aq)$

Which of the following statements is TRUE?

i) A galvanic cell based on the above reaction would have A(s) as the cathode.
ii) The sign of the cell potential, E, for the galvanic cell is positive.
iii) $Q < K$

a) i only b) ii only c) iii only d) i, ii only e) i, ii and iii

22. Balance the following reaction in basic solution:

$ClO^-(aq) + Cr(OH)_4^-(aq) \rightarrow CrO_4^{2-}(aq) + Cl^-(aq)$

What is the coefficient in front of $CrO_4^{2-}(aq)$ in the balanced reaction?

a) 1 b) 2 c) 3 d) 4 e) 6

23. Silver bromide is a sparingly soluble salt that dissolves according to the following equation:

$$AgBr(s) \rightleftharpoons Ag^+(aq) + Br^-(aq)$$

Use **some** of the data below to calculate K_{sp}, the equilibrium constant associated with the dissolution reaction, at 25°C for AgBr.

$Ag^+(aq) + e^- \rightarrow Ag(s)$ $\quad E° = +0.800\ V$
$AgBr(s) + e^- \rightarrow Ag(s) + Br^-(aq)$ $\quad E° = +0.071\ V$
$Br_2(l) + 2\ e^- \rightarrow 2\ Br^-(aq)$ $\quad E° = +1.066\ V$

a) 6.3×10^{-2}
b) 4.9×10^{-13}
c) 1.9×10^{-15}
d) 2.4×10^{-34}
e) 1

Use the following potentials to answer questions 24 and 25.

	E° (V)
$Au^{3+}(aq) + 2e^- \rightleftharpoons Au^+(aq)$	1.40
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	-1.66
$Fe^{3+}(aq) + 3e^- \rightleftharpoons Fe(s)$	-0.04
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	0.80
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	1.09

24. Which substances could be spontaneously oxidized by Ag^+?
a) Au^{3+} b) Al^{3+} c) Br^- d) Al e) Au^+

25. Which of the following galvanic cells would have the highest standard cell potential?
a) $Ag(s) \mid Ag^+(aq) \parallel Fe^{3+}(aq) \mid Fe(s)$
b) $Fe(s) \mid Fe^{3+}(aq) \parallel Au^{3+}(aq), Au^+(aq) \mid Pt(s)$
c) $Ag(s) \mid Ag^+(aq) \parallel Au^{3+}(aq), Au^+(aq) \mid Pt(s)$
d) $Fe(s) \mid Fe^{3+}(aq) \parallel Br_2(l), Br^-(aq) \mid Pt(s)$
e) $Ag(s) \mid Ag^+(aq) \parallel Br_2(l), Br^-(aq) \mid Pt(s$

Physical and Chemical Constants

Avogadro's number	$N_A = 6.0221367 \times 10^{23}$ mole^{-1}
Mass of an electron	$m_e = 9.109 \times 10^{-31}$ kg
Boltzmann's constant	$k = 1.380658 \times 10^{-23}$ J K^{-1}
Fundamental unit of charge	$e = 1.60217733 \times 10^{-19}$ C
Zero point	0°C = 273.15 K
Gas constant	R = 8.314510 J mole^{-1} K^{-1}
	= 0.082058 L atm mole^{-1} K^{-1}
Density of dry air (at 0° *C* and 1 *atm*)	$\rho_{air} = 1.292 \times 10^{-3}$ g mL^{-1}
Heat capacity of water	C = 4.184 J g^{-1} K^{-1}
	= 75.4 J mol^{-1} K^{-1}
Density of water (at 25°C)	$\rho_{water} = 0.997$ g mL^{-1}
Density of mercury (at 25°C)	$\rho_{Hg} = 13.6$ g mL^{-1}
Planck's constant	$h = 6.6260755 \times 10^{-34}$ J s
Speed of light	$c = 2.99792458 \times 10^{8}$ m s^{-1}
Faraday's constant	$F = 9.6485309 \times 10^{4}$ J V^{-1} mole^{-1}
Rydberg's constant	$R_\infty = 1.0974 \times 10^{7}$ m^{-1}
Acceleration due to gravity	g = 9.80 m s^{-2}
Ion-product constant of water (at 25°C)	$K_w = 1 \times 10^{-14}$

Conversion Factors

1 a.m.u. = $1.6605402 \times 10^{-27}$ kg

1 atmosphere (atm) = 1.01325×10^{5} Pa = 760.0 mm Hg (torr) = 1.01325 bar

1 calorie (cal) = 4.184 joules (J)

1 debye (D) = 3.335617×10^{-30} C m

1 eV/particle = 96.485 kJ mole^{-1} = 23.061 kcal mole^{-1}

1 eV = 1.602×10^{-19} J = 8067 cm^{-1}

1 kJ mole^{-1} = 0.23901 kcal mole^{-1} = 83.591 cm^{-1}

1 L atm = 101.325 J = 24.217 cal

ln x = 2.3026 log x

$\pi = 3.1415927$

1 V = 1 J C^{-1}

1 A = 1 C s^{-1}

1 J = 1 kg m^2 s^{-2}

CHM 139H Equations Sheet

$$E = h\nu \qquad c = \lambda\nu \qquad E_n = \frac{-2.18\times10^{-18}\,J}{n^2} \quad n = 1,2,3,\ldots$$

$$PV = nRT \qquad E_{kin} = \frac{3}{2}RT \qquad u_{avg} = \left(\frac{3RT}{M}\right)^{1/2} \qquad \ln\left(\frac{P_2}{P}\right) = -\frac{\Delta H}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$P_A = X_A P_A^o \qquad \Delta T_b = K_b c_m \qquad \Delta T_f = -K_f c_m \qquad \Pi = MRT$$

$$\Delta H = \Delta E + P\Delta V \qquad S = k\ln W \qquad \Delta S_{univ} = \frac{q}{T}$$

$$\Delta G = \Delta H - T\Delta S \qquad \Delta G = -nFE_{cell} \qquad \Delta G = \Delta G^o + RT\ln Q$$

$$q = C\Delta T \qquad w = -P\Delta V \qquad \Delta E = q + w$$

$$\ln k = \ln A - \frac{E_a}{RT} \qquad \ln\left(\frac{[A]}{[A]_0}\right) = -kt \qquad \frac{1}{[A]} - \frac{1}{[A]_0} = kt$$

$$K_p = K_c(RT)^{\Delta n} \qquad pH = pK_a + \log\left(\frac{[A^-]}{[HA]}\right) \qquad E_{cell} = E_{cell}^o - \frac{RT}{nF}\ln Q$$

$$V = \tfrac{4}{3}\pi r^3 \qquad For\ \ ax^2 + bx + c = 0,\quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

For a right angle triangle with side lengths x and y, and a hypotenuse of h, $x^2 + y^2 = h^2$

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** 47.87	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** 65.39	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** 88.9	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** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (263)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (267)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 **Cn** (285)	113 (284)	114 (289)	115 (288)	116 (292)		118 (294)

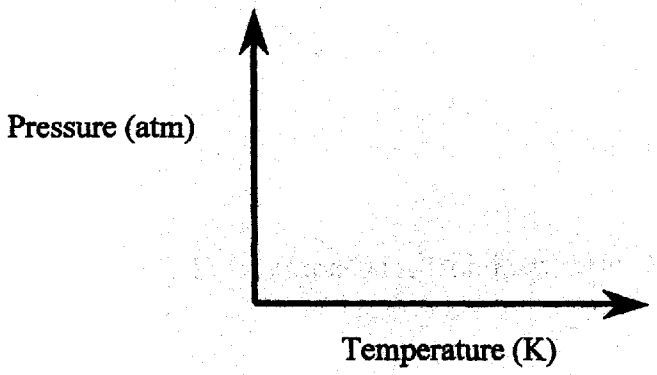
58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (147)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	94 **Pu** (242)	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)

CHM 139H Term Test 1 Answer Sheet

NAME: _____ **Student #:** _____ **Tut.Grp.:**

PART B – Written Answer Questions There are 4 questions worth a total of 40 marks. Clear and concise answers, which are essential for full marks, must be written in the spaces provided on this answer paper. Be sure to show your work.

1 (10 marks) a) Sketch a phase diagram for benzene, C_6H_6, which has a triple point at 279 K and 0.0473 atm and a normal boiling point of 353 K and a normal melting point of 280 K. You do not need to draw the graph to scale (it is easier if you don't). Label the temperatures and pressures of the data points. Label the region where the solid, liquid and gas phases are most stable.



For each statement, write T (true) or F (false) in the space provided.

	T/F
i) Liquid benzene is more dense than solid benzene.	___
ii) At atmospheric pressure, it is possible for benzene to sublime.	___
iii) At 0 °C, it is possible for benzene to sublime.	___
iv) At 0.0025 atm and 278 K, the most stable phase of benzene is a gas.	___

b) The minimum energy required to eject electrons from mercury metal is 7.22×10^{-19} J. Can visible light (frequencies from 4×10^{14} to 8×10^{14} Hz) produce the photoelectric effect in mercury metal?

YES or NO Explanation:

If the intensity of the visible light was increased, what would happen? Explain briefly.

If the wavelength of light was increased, what would happen? Explain briefly.

1	2	3	4	Total
/10	/10	/10	/10	/40

2 (10 marks) A reaction important for the formation of smog is shown below:

$$NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g)$$

The reaction was determined experimentally to be first order in NO and O_3. The rate constant of the reaction is 80 $M^{-1}s^{-1}$ at 25 °C and 3000 $M^{-1}s^{-1}$ at 75 °C.

a) Is it possible that the reaction occurs in a single step? Explain briefly.

b) What is the activation energy for the reaction?

c) What is the rate of reaction at 25 °C when the initial concentration of NO is 1.0×10^{-5} M and O_3 is 2.5×10^{-9} M?

d) Given $\Delta G_f°$ of NO is 87.6 kJ/mol, $\Delta G_f°$ of O_3 is 163 kJ/mol and $\Delta G_f°$ of NO_2 is 51.3 kJ/mol, draw the potential energy profile for the reaction at 25° C, assuming it occurs in a single step. Label the activation energy, free energy change, the reactants (R) and the products (P) for the reaction.

e) How does increasing temperature affect the reaction rate? Explain why briefly.

3 (10 marks) Lime (CaO) is used in large quantities in construction, in production of chemicals and in wastewater treatment. Lime can be produced from the thermal decomposition of calcium carbonate:

	$CaCO_3(s)$	$\longrightarrow$	$CaO(s)$	+	$CO_2(g)$
ΔH_f° (kJ mol^{-1})	-1207		-636		-394
S° (J mol^{-1}K^{-1})	93		40		214

a) Explain, in 6 words or less, why the standard molar entropy of $CaCO_3(s)$ is greater than that of $CaO(s)$.

b) At what temperature is the equilibrium pressure of CO_2 1.00 atm? (Assume ΔH° and ΔS° are independent of temperature.)

c) How would increasing temperature affect the equilibrium pressure of CO_2? Explain.

d) If 2.00 g of $CaCO_3$ are placed in an evacuated 1.00 L flask, how many grams of $CaCO_3$ will be left when the reaction reaches equilibrium? Use the same conditions as in b) above.

4 (10 marks) A galvanic cell is made up of the following two half-cells at 298 K:

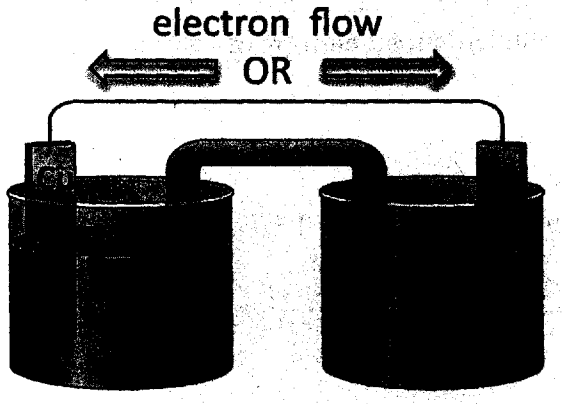
i) Cu electrode in a 0.50 M $Cu(NO_3)_2$ solution

ii) Cu electrode in a 0.20 M $Cu(NO_3)_2$ solution

a) On the diagram of the galvanic cell below:

(i) circle the anode.

(ii) indicate the direction of electron flow by circling one of the two arrows.



b) What is E° for this galvanic cell?

c) What is E for this galvanic cell?

d) What will happen to the concentration of Cu^{2+} in the half-cell that was originally 0.50 M as the cell operates? Explain. (No calculations are necessary.)

e) Addition of sodium carbonate, Na_2CO_3, to $Cu(NO_3)_2$ results in the formation of a precipitate, $CuCO_3$. To increase E of the galvanic cell above, to which half-cell would sodium carbonate be added ? Explain.