00020

Kwantlen Polytechnic University
Department of Chemistry
CHEM 1154 Final Examination

Wednesday, April 13, 2011

Time: 3 hours

Name: ANSWERS

Student Number: ______________________

Instructions:

1) Please ensure that your exam has this cover page, **18** pages of questions, the formula sheet, and a periodic table.

2) You are to work independently. Any sharing of any information of any kind in any way with anyone is strictly forbidden.

3) There are **25** questions. Read the exam carefully and judge your time accordingly.

4) All calculations must be shown in order to receive any credit for a question requiring them.

5) If you need extra space to do a question, use the back of one of the pages of the exam and clearly indicate the question number there. Please also refer me to that page to ensure I find your work.

Page	Mark	Maximum
2		4
3		4
4		6
5		4
6		5
7		5
8		7
9		8
10		7
11		3
12		5
13		2
14		6
15		5
16		4
17		6
18		7
19		5.5
Total		93.5

1) **[4 marks]** In one experiment, 0.500-grams of an impure sample of Na_2CO_3 (106.0 g/mol) was dissolved in enough water to make 100.0 mL of solution. A 25.0-mL aliquot was taken and 20.0 mL of 0.125 M HCl added:

$$Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

The excess HCl was titrated with 20.0 mL of 0.0250 M NaOH:

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

What was the percent purity of the sample?

excess HCl: $20\,mL \times 0.025 \frac{moles}{L} = 0.5\,mmol \times \frac{1\,HCl}{1\,NaOH} = 0.5\,mmol$

reacted HCl: $20\,mL \times 0.125 \frac{moles}{L} - 0.5\,mmol$

$= 2\,mmol$

reacted HCl in 100 mL $= 2\,mmol \times \frac{100}{25} = 8\,mmol$

$\therefore Na_2CO_3$ in 100 mL $= 8\,mmol\,HCl \times \frac{1\,Na_2CO_3}{2\,HCl} = 4\,mmol$

$\therefore$ mass $Na_2CO_3 = 4\,mmol \times \frac{106\,g}{1\,mol} = 424\,mg$

$$\frac{424\,mg}{500\,mg} \times 100 = \boxed{84.8\%}$$

2) **[4 marks]** When a 380.9-mg mixture of CH_4 (16.04 g/mol) and C_3H_8 (44.10 g/mol) was burned, 1100.25 mg of CO_2 (44.01 g/mol) was collected. What was the mole fraction of CH_4 in the original mixture?

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$$
$$C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l)$$

x = ~~m~~mmoles CH_4

y = mmoles C_3H_8

then: $16.04x + 44.10y = 380.9$ (I)

and $x + 3y = \frac{1100.25}{44.01} = 25$ (II)

multiply (II) by 16.04:

$16.04x + 48.12y = 401$ (III)

$\therefore\ -4.02y = -20.1$

$y = 5$

$x + 15 = 25 \quad \therefore x = 10$

$\therefore X_{CH_4} = \frac{10}{15} = \boxed{\frac{2}{3}}$

3) **[6 marks]** Cholesterol is known to contain carbon, hydrogen, and oxygen. An 1160-mg sample of cholesterol was burned, and as a result 3564 mg of CO_2 (44.0 g/mol) and 1242 mg of H_2O (18.0 g/mol) were collected.

a) What is the empirical formula of cholesterol?

$$\text{moles C} = 3564\,\text{mg} \times \frac{1\,\text{mol}}{44.0\,\text{g}} \times \frac{1\,C}{1\,CO_2} = 81\,\text{mmol};\ \text{mass C} = 972.891\,\text{mg}$$

$$\text{moles H} = 1242\,\text{mg} \times \frac{1\,\text{mol}}{18.0\,\text{g}} \times \frac{2H}{1\,H_2O} = 138;\ \text{mass H} = 139.104\,\text{mg}$$

$$\text{mass O} = \overset{1160}{\cancel{[illegible]}} - 972.891 - 139.104 = \overset{48.005\,\text{mg}}{\cancel{[illegible]}}$$

$$\text{moles O} = \overset{48.005\,\text{mg}}{\cancel{[illegible]}} \times \frac{1\,\text{mol}}{16.00\,\text{g}} = 3$$

$$C_{81}H_{138}O_3 \longrightarrow \boxed{C_{27}H_{46}O}$$

b) Two moles of cholesterol react with two moles of sodium metal to give one mole of hydrogen gas. If 773.3 mg of cholesterol gave 22.4 mL of H_2 gas at STP, what is the molecular formula of cholesterol?

$$n_{H_2} = \frac{(1)(22.4)}{(0.0820575)(273.15)} = 1\,\text{mmol}$$

$$\therefore n_{ch} = 2\,\text{mmol}$$

$$\therefore \text{MM ch.} = \frac{773.3\,\text{mg}}{2\,\text{mmol}} = 386.65\,\frac{\text{g}}{\text{mol}}$$

$$\begin{array}{r} 27 \times 12.011 \\ +\ 46 \times 1.008 \\ +\ 1 \times 16.00 \\ \hline 386.67 \end{array}$$

$$\frac{386.65}{386.67} = \sim 1, \text{ so EF is MF is } \boxed{C_{27}H_{46}O}$$

4) **[1 mark]** A sample of "gas X" effuses 2.827 times more slowly than helium. What is the molar mass of "gas X"?

$$4.0026(2.827r)^2 = Mr^2$$

$$\Rightarrow \boxed{M = 31.99 \frac{g}{mol}}$$

5) **[3 marks]** A sample of impure propane (C_3H_8, molar mass 44.096 g) had a total pressure of 5.6163 atm in a 0.100-litre flask at 25°C. This sample was burned in excess oxygen:

$$C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g)$$

The combined pressure of the $CO_2(g)$ and $H_2O(g)$ was found to be 45.740 atm at 125°C. What was the mole fraction of propane in the original mixture?

total moles gas after : $\frac{(45.740)(0.1)}{(0.0820575)(398.15)} = 0.14$

∴ moles C_3H_8 must be:

0.14 moles product × $\frac{1\ C_3H_8}{7\ \text{product}}$ = 0.020 moles.

moles gas before = $\frac{(5.6163)(0.1)}{(0.0820575)(298.15)}$ = 0.022956 moles

$$\therefore X_{C_3H_8} = \boxed{0.8712}$$

6) **[4 marks]** Sodium sulphide (Na_2S) is used in the cleanup of mercury spills because the K_{sp} of mercury(II) sulphide is vanishingly small:

$$HgS(s) \rightleftharpoons Hg^{+2}(aq) + S^{-2}(aq) \qquad K_{sp} = 2 \times 10^{-53} \qquad \Delta H^\circ > 0$$

Predict the effect of the following actions, each taken on a fresh sample at equilibrium, on the value of K_{sp} and on the amount of HgS dissolving in solution. Your choices are **I**ncrease from the current value, **D**ecrease from the current value, or **N**ot **C**hange from the current value. Circle your choice. You may assume constant temperature unless explicitly told otherwise.

	Effect on					
	HgS			K_{sp}		
Adding some $Hg(NO_3)_2$	[✓ I]	D	NC	I	D	[✓ NC]
Cooling the reaction mixture	[✓ I]	D	NC	I	[✓ D]	NC
Adding sodium sulphide	[✓ I]	D	NC	I	D	[✓ NC]
Adding H^+ (H_2S is a weak acid)	I	[✓ D]	NC	I	D	[✓ NC]

7) **[1 mark]** Calculate the value of K_c at 300 K for the equilibrium

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

if the value of K_p at 300 K is 1.0 x 10^{90}.

$$K_p = K_c(0.0820575 \times 300)^{-1}$$

$$\boxed{K_c = 2.46 \times 10^{91}}$$

8) **[2 marks]** The solubility of sparingly soluble ionic salts may be increased by addition of a chemical with which the cation in the ionic salt reacts. One example of this is silver sulphide, Ag_2S:

$Ag_2S(s) \rightleftharpoons 2Ag^+(aq) + S^{-2}(aq)$ $K_{sp} = 6.0 \times 10^{-51}$

Its solubility may be increased by introducing NaCN into the solution:

$Ag^+(aq) + 2CN^{-1}(aq) \rightleftharpoons [Ag(CN)_2]^{-1}(aq)$ $K_f = 5.6 \times 10^{18}$

Use the two equilibria above to calculate the equilibrium constant for the reaction of Ag_2S with CN^{-1}:

$Ag_2S(s) + 4CN^{-1}(aq) \rightleftharpoons 2[Ag(CN)_2]^{-1}(aq) + S^{-2}(aq)$

$Ag_2S \rightleftarrows 2Ag^+ + S^{-2}$ $K_{sp} = 6.0\times10^{-51}$

$2Ag^+ + 4CN^- \rightleftarrows 2[Ag(CN)_2]^{-1}$ $K_{sp} = 3.136\times10^{37}$

$Ag_2S + 4CN^- \rightleftarrows 2[Ag(CN)_2]^{-1} + S^{-2}$ $\boxed{K = 1.8816\times10^{-13}}$

9) **[3 marks]** Ozone (O_3), O_2, and O coexist according to the equilibrium:

$2O_2(g) \rightleftharpoons O(g) + O_3(g)$ $K_p = 6.25 \times 10^{-70}$

If a flask is charged with 4.0 atm of O_2, what will be the pressure of O(g) at equilibrium?

$2O_2 \rightleftarrows O + O_3$

i	4	0	0
c	$-2x$	$+x$	$+x$
e	$4-2x$	x	x

$$\frac{x^2}{(4-2x)^2} = 6.25\times10^{-70}$$

$$\frac{x}{\cancel{4-2x}} = 2.5\times10^{-35}$$

$$\boxed{x = 1\times10^{-34} \text{ atm} = P_O}$$

10) **[4 marks]** The value of K_{sp} for $PbCl_2$ is 1.7×10^{-5}.

a) Calculate the molar solubility of $PbCl_2$ in water.

$$4x^3 = 1.7 \times 10^{-5}$$

$$x = \boxed{0.0162\ M}$$

b) Would it be possible to lower the molar solubility of $PbCl_2$ to 1×10^{-5} M using solid $Pb(NO_3)_2$? How do you know?

$$\begin{array}{lccc} & PbCl_2 \rightleftharpoons & Pb^{2+} + & 2Cl^- \\ i & & a & 0 \\ c & & +x & +2x \\ e & & a+x & 2x \end{array}$$

$x = 1 \times 10^{-5}$, so:

$$(a + 1\times10^{-5})(2\times10^{-5})^2 = 1.7\times10^{-5}$$

$$\Rightarrow a = \sim 42{,}500\ M$$

↑

∴ No, not possible

11) **[3 marks]** Calculate the pH of a saturated solution of $Mg(OH)_2$ ($K_{sp} = 5.6 \times 10^{-12}$) at 25°C.

$$4x^3 = 5.6\times10^{-12}$$

$$\Rightarrow x^{\cancel{3}} = 1.19\times10^{-4}\ M$$

$$\Rightarrow [OH^-]_e = 2.24\times10^{-4}\ M$$

$$\therefore pOH = 3.65$$

$$pH = 14 - pOH = 10.35$$

12) **[8 marks total]** Benzoic acid is a weak acid with a $K_a = 6.4 \times 10^{-5}$. Calculate the pH of the following solutions of benzoic acid. You may assume that all solutions were made at 25°C.

a) **[2 marks]** 25.0 mL of 1.0 M benzoic acid

$$HA_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + A^-_{(aq)}$$

	HA	H_3O^+	A^-
I	1.0	0	0
C	$-x$	$+x$	$+x$
E	$1.0-x$	x	x

$$ka = \frac{x^2}{1.0-x} = 6.4 \times 10^{-5} \Rightarrow x = 7.97 \times 10^{-3} M$$

pH = [illegible] 2.10

b) **[3 marks]** 25.0 mL of 1.0 M benzoic acid mixed with 15.0 mL of 1.0 M potassium benzoate.

$$[HA] = \frac{25}{40} \times 1 = 0.625 M$$

$$[A^-] = \frac{15}{40} \times 1 = 0.375 M$$

$$HA \rightleftharpoons H^+ + A^-$$

	HA	H^+	A^-
i	0.625	0	0.375
c	$-x$	$+x$	$+x$
e	$0.625-x$	x	$0.375+x$

$$\frac{x(0.375+x)}{(0.625-x)} = 6.4 \times 10^{-5}$$

$$x = [H^+]_e = 1.06 \times 10^{-4}$$

$$\boxed{pH = 3.97}$$

c) **[3 marks]** 15.0 mL of 1.0 M potassium benzoate

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

	A^-	HA	OH^-
i	1	0	0
c	$-x$	$+x$	$+x$
e	$1-x$	x	x

$$\frac{x^2}{1-\cancel{x}} = \frac{1 \times 10^{-14}}{6.4 \times 10^{-5}}$$

~~x = [OH-]e~~

$$x = [OH^-]_e = 1.25 \times 10^{-5} M$$

$$pOH = 4.90$$

$$\boxed{pH = 9.10}$$

13) **[10 marks total]** Pyridine is a weak base with a $K_b = 1.6 \times 10^{-9}$. Calculate the pH of the following solutions made using pyridine. You may assume that all solutions were made at 25°C.

a) **[3 marks]** 25.0 mL of 1.0 M pyridine mixed with 15.0 mL of 1.0 M $HClO_4$.

$$[B] = \frac{25}{40} \times 1 = 0.625\,M ; \quad [H^+] = \frac{15}{40} \times 1 = 0.375\,M$$

$$\begin{array}{ccc} B & + H^+ \rightleftharpoons & BH^+ \\ 0.625 & 0.375 & 0 \\ -0.375 & -0.375 & +0.375 \\ \hline 0.250 & & 0.375 \end{array}$$

~~BH+~~

$$\begin{array}{llll} & BH^+ \rightleftharpoons & B \; + & H^+ \\ i & 0.375 & 0.25 & 0 \\ c & -x & +x & +x \\ e & 0.375-x & 0.25+x & x \end{array}$$

$$\frac{x(0.25+\cancel{x})}{0.375-\cancel{x}} = \frac{1\times10^{-14}}{1.6\times10^{-9}}$$

$\Rightarrow x = [H^+]_e$

$\approx 9.375 \times 10^{-6}\,M$

$\boxed{pH = 5.03}$

b) **[4 marks]** 25.0 mL of 1.0 M pyridine mixed with 25.0 mL of 1.0 M $HClO_4$.

$[H^+] = [B] = 0.50\,M$

$$\begin{array}{ccc} B & + H^+ \rightarrow & BH^+ \\ 0.5 & 0.5 & 0 \\ -0.5 & -0.5 & +0.5 \end{array}$$

$\Rightarrow x = [H^+]_e \approx 1.77 \times 10^{-3}\,M$

$\boxed{pH = 2.75}$

$$\begin{array}{llll} & BH^+ \rightleftharpoons & B \; + & H^+ \\ i & 0.5 & 0 & 0 \\ c & -x & +x & +x \\ e & 0.5-x & x & x \end{array}$$

$$\frac{x^2}{0.5-\cancel{x}} = \frac{1\times10^{-14}}{1.6\times10^{-9}}$$

c) **[2 marks]** 25.0 mL of 1.0 M pyridine mixed with 25.5 mL of 1.0 M $HClO_4$.

$$[H^+] = \frac{25.5}{50.5} \times 1 = \frac{51}{101}\text{ M} \; ; \; [B] = \frac{25}{50.5} \times 1 = \frac{50}{101}$$

$$H^+ + B \longrightarrow BH^+$$

$$\begin{array}{cc} \frac{51}{101} & \frac{50}{101} \\ -\frac{50}{101} & -\frac{50}{101} \\ \hline \frac{1}{101} & 0 \end{array}$$

$$pH = \log(101) = \boxed{2.00}$$

d) **[1 mark]** What should be the pK_{In} of an indicator used in the titration of 1.0 M pyridine with 1.0 M $HClO_4$?

2.75

14) **[3 marks]** You make an NaOH solution by taking 10.0 grams of NaOH pellets (40.0 g/mol) and adding them to 100.0 mL of water (S=4.184 J/g·°C, D=1.00 g/mL) at 20.0°C:

$NaOH(s) \longrightarrow NaOH(aq)$ $\Delta H° = -40.0\text{ kJ}$

What is the temperature of the resulting solution?

$$q_{rxn} = 10g \times \frac{1\text{ mol}}{40g} \times \frac{-40{,}000J}{1\text{ mol}} = -10{,}000J$$

$$+ \; q_{sol'n} = 10{,}000J = 110 \times 4.184 \times (T-20)$$

$$\overline{\quad 0 \quad}$$

$$\Rightarrow \boxed{T = 41.7°C}$$

15) **[2 marks]** Nitroglycerine, $C_3H_5(NO_3)_3(l)$, is both a powerful explosive (used in dynamite, among others), and one of the most effective drugs known in the treatment of heart disease. Nitroglycerine has an enthalpy of formation of -1783.7 kJ/mol. When nitroglycerine detonates, the reaction is:

$$4C_3H_5(NO_3)_3(l) \longrightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$$

If the enthalpies of formation of $CO_2(g)$ and $H_2O(g)$ are -393.5 kJ/mol and -241.8 kJ/mol respectively, what is ΔH° for the detonation of nitroglycerine above?

$$12(-393.5) + 10(-241.8) - 4(-1783.7) = \boxed{-5.2\text{ kJ}}$$

16) **[2 marks]** Because of the sulphur it contains, combustion of coal is one of the leading causes of acid rain.

$S_8(s) + 8O_2(g) \longrightarrow 8SO_2(g)$	ΔH° = -2374.4 kJ
$2SO_2(g) + O_2(g) \longrightarrow 2SO_3(g)$	ΔH° = -202 kJ
$S_8(s) + 8H_2(g) + 16O_2(g) \longrightarrow 8H_2SO_4(l)$	ΔH° = -6512 kJ
$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$	ΔH° = -483.6 kJ

Acid rain is caused when the SO_3 combines with moisture in the air to produce sulphuric acid:

$SO_3(g) + H_2O(g) \longrightarrow H_2SO_4(l)$

Use the four reactions above to calculate ΔH° for the reaction of SO_3 with H_2O to form sulphuric acid.

SO_3 ~~+H2O~~ $\rightarrow \cancel{SO_2} + \cancel{\tfrac{1}{2}O_2}$ $\Delta H° = 101$ kJ

$H_2O \rightarrow \cancel{H_2} + \cancel{\tfrac{1}{2}O_2}$ $\Delta H° = 241.8$ kJ

$\cancel{\tfrac{1}{8}S_8} + \cancel{H_2} + \cancel{2O_2} \rightarrow H_2SO_4$ $\Delta H° = -814$ kJ

$\cancel{SO_2} \rightarrow \cancel{\tfrac{1}{8}S_8} + \cancel{O_2}$ $\Delta H° = 296.75$

$SO_3 + H_2O \rightarrow H_2SO_4$ $\boxed{\Delta H° = -174.45}$

17) **[4 marks total]** In one experiment, a 20.5216-gram sample of S_8 (256.52 g/mol) was burned in a bomb calorimeter with a heat capacity of 50.756 kJ/°C.

a) **[3 marks]** If the temperature of the bomb calorimeter increased by 5.000°C, calculate $\Delta H°_{298}$ for the reaction:

$S_8(s) + 12O_2(g) \longrightarrow 8SO_3(g)$

q_{cal} $50.756\frac{kJ}{°C} \times 5°C = 253.78$ kJ

$+ \ q_{rxn} = $ ~~+80~~ -253.78 kJ

$\overline{\quad 0 \quad}$

$\Delta H = -3172.25 + \frac{(-4)(8.314472)(298)}{1000}$

$= \boxed{-3182.2 kJ}$

$n_{rxn} = 20.5216 g \times \frac{1 mol}{256.52 g} \times \frac{1 rxn}{1 S_8} = 0.08$ moles rxn

$\Delta E = \frac{-253.78 kJ}{0.08} = -3172.25$ kJ

b) **[1 mark]** What is $\Delta H°_f$ for $SO_3(g)$?

$\frac{-3182.2}{8} = \boxed{-397.8 \frac{kJ}{mol}}$

18) **[2 marks]** If the natural state of element A is $A_2(g)$, then which of the following is true about the reaction:

$2A_3(g) \rightleftharpoons 3A_2(g)$

[✓ a)] $\Delta S_{sys} > 0$ and $\Delta S_{univ} > 0$
b) $\Delta H_{sys} > 0$ and $\Delta G > 0$
c) $\Delta G > 0$ and $\Delta S_{sys} > 0$
d) $\Delta S_{univ} < 0$ and $\Delta G < 0$
e) $\Delta H_{sys} < 0$ and $\Delta S_{univ} < 0$

19) **[5 marks total]** The reaction

$A + 2B \rightleftharpoons C + D$

has $\varepsilon^\circ = 1.00$ V and $\Delta G^\circ = -289.5$ kJ at 25°C

a) **[1 mark]** How many electrons are transferred in the reaction?

$$n = \frac{\Delta G^\circ}{-\mathcal{F}\varepsilon} = \boxed{3}$$

b) **[3 marks]** $\varepsilon^\circ = 2.00$ V at 225°C. What are ΔH° and ΔS° for the reaction?

$$\Delta G^\circ = -3(96485.3399)(2) = -578912.0394$$

$$-578912.0394 = \Delta H^\circ - 498\,\Delta S^\circ$$

$$-289500 = \Delta H^\circ - 298\,\Delta S^\circ$$

$$-289412.0394 = -200\,\Delta S^\circ$$

$$\boxed{\Delta S^\circ = 1447.060197\ \frac{J}{K}}$$

$$-578912.0394 = \Delta H^\circ - 498(1447.060197)$$

$$\Rightarrow \boxed{\Delta H^\circ = 141.7\ kJ}$$

c) **[1 mark]** What is K at 25°C?

$$-289500 = -8.314472 \times 298.15 \times \ln K$$

$$\Rightarrow \ln K = 116.78\ldots$$

$$\boxed{K = 5.2 \times 10^{50}}$$

20) **[2 marks]** Given the half-reactions:

$Al^{+3}(aq) + 3e^{-1} \rightleftharpoons Al(s)$ ε° = -1.66 V
$Pb^{+2}(aq) + 2e^{-1} \rightleftharpoons Pb(s)$ ε° = -0.13 V

Would it be theoretically possible to stick a rod of solid aluminum in a solution of Pb^{+2} and convert lead ions into solid lead? How do you know?

$Al(s) \rightarrow Al^{+3} + 3e^-$ $\varepsilon° = 1.66V$
$Pb^{+2} + 2e^- \rightarrow Pb(s)$ $\varepsilon° = -0.13V$

$\varepsilon° = 1.53V$
$\varepsilon° > 0$, so yes.

21) **[2 marks]** Given the following half-reactions:

$Cl_2 + 2e^{-1} \rightleftharpoons 2Cl^{-1}$ ε° = 1.36 V
$HClO + H^+ + e^{-1} \rightleftharpoons \frac{1}{2}Cl_2(g) + H_2O$ ε° = 1.63 V

Calculate ε° for the half-reaction:

$HClO + H^+ + 2e^{-1} \rightleftharpoons Cl^{-1} + H_2O$

$\frac{1}{2}\cancel{Cl_2} + e^- \rightleftharpoons Cl^-$
$HClO + H^+ + e^- \rightleftharpoons \frac{1}{2}\cancel{Cl_2} + H_2O$

$HClO + H^+ + 2e^- \rightleftharpoons Cl^- + H_2O$

$-2\mathfrak{F}\varepsilon°_{rxn} = -1\cdot\mathfrak{F}\cdot 1.36 + -1\cdot\mathfrak{F}\cdot 1.63$

$\Rightarrow \boxed{\varepsilon° = 1.495V}$

22) **[9 marks total]** A battery is constructed based on the following half-reactions:

$Al^{+3}(aq, 0.10\ M) + 3e^{-1} \rightleftharpoons Al(s)$ $\varepsilon° = -1.66\ V$

$Be^{+2}(aq), 0.0010\ M) + 2e^{-1} \rightleftharpoons Be(s)$ $\varepsilon° = -1.85\ V$

a) **[1 mark]** Identify the anode and cathode.

Anode: Be/Be^{+2}

Cathode : Al^{+3}/Al

b) **[1 mark]** What will be the overall reaction occurring in the battery?

$$\left(Be \rightarrow Be^{+2} + 2e^-\right) \times 3$$
$$\left(Al^{+3} + 3e^- \rightarrow Al\right) \times 2$$
$$3Be(s) + 2Al^{3+}(0.1M) \rightleftharpoons 3Be^{+2}(1\times10^{-3}M) + 2Al(s)$$

c) **[1 mark]** What voltage will the battery produce under standard conditions?

$1.85 - 1.66 = 0.19V$

d) **[2 marks]** What voltage will the battery produce under the conditions given?

$$Q = \frac{1\times10^{-9}}{1\times10^{-2}} = 1\times10^{-7}$$

$$\varepsilon = 0.19 - \frac{0.06}{6}\log 1\times10^{-7}$$

$$= \boxed{0.26V}$$

e) **[1 mark]** This battery cannot be recharged successfully. Give one reason why.

The $Be^{+2} + 2e^- \rightleftharpoons Be$ voltage is less positive than $\varepsilon°$ for water reduction.

f) **[3 marks]** After a while, the concentration of Be^{+2} has changed by 0.030 M. What voltage will the battery produce at this point?

~~3B~~ $2Al^{3+} \rightleftharpoons 3Be^{2+}$

$i \quad 0.1 \qquad 1\times10^{-3}$

$c \quad -0.03\times\frac{2}{3} \qquad +0.03$

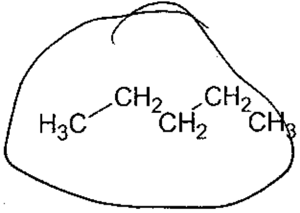
$e \quad 0.08 \qquad 0.031$

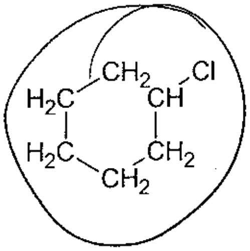
$$Q = \frac{(0.031)^3}{(0.08)^2} = 4.655\times10^{-3}$$

$$\varepsilon = 0.19 - \frac{0.06}{6}\log = \boxed{0.213V}$$

23) **[2 marks]** Of the three compounds shown below, which two are most likely to form a solution? Circle your choices.

$H_3C—OH$





24) **[2 marks]** A solution of 1.00 mole of liquid A (P* = 60 mmHg) and 3.00 moles of liquid B (P* = 100 mmHg) has a vapour pressure of 80 mmHg. Indicate which of the following statements is true:

a) The two liquids form an ideal solution and obey Raoult's Law.
[✓ b)] The two liquids form a solution that shows negative deviations from Raoult's Law.
c) The two liquids form a solution that shows positive deviations from Raoult's Law.
d) Liquid A must be polar.
e) None of the previous four statements is true.

$\frac{1}{4}(60) + \frac{3}{4}(100) = 90$

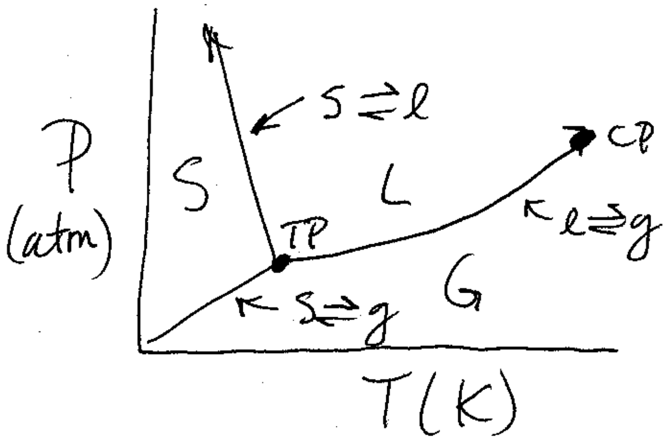
[5.5 marks total] "Substance X" has the following properties:

Property	Value
Triple point	200 K and 0.100 atm
Critical point	500 K and 64.0 atm
Liquid density	0.962 g/mL
Solid density	0.871 g/mL
Solid vapour pressure	150 K and 0.0500 atm

f) **[2.5 marks]** Use these data to sketch (not necessarily to scale) the phase diagram for "substance X." On your graph, clearly label:

i) All phases
ii) The axes (include units)
iii) All phase boundary lines
iv) All critical and triple points

Your graph should also unambiguously demonstrate the slope (positive or negative) of the solid-liquid phase boundary line.



g) **[2 marks]** What is the enthalpy of vaporization of "substance X"?

$$\ln\left(\frac{64}{0.1}\right) = \frac{\Delta H^0}{8.314472}\left(\frac{300}{200\times 500}\right) \Rightarrow \boxed{\Delta H^\circ = 17.9\ kJ}$$

h) **[1 mark]** Does "substance X" have a normal sublimation point? How do you know?

No – TP is < 1 atm, so all $S \rightleftharpoons g$ equilibria happen below 1 atm.