



**STRATHMORE UNIVERSITY**  
**SCHOOL OF COMPUTING AND ENGINEERING SCIENCES**  
**Bachelor of Electrical Engineering**  
**Final Examination**  
**CHE 1201: CHEMISTRY II**

**DATE: 14<sup>th</sup> March 2022**

**TIME: 3 hours**

**Instruction: Answer question one and any two other questions.**

**Question One**

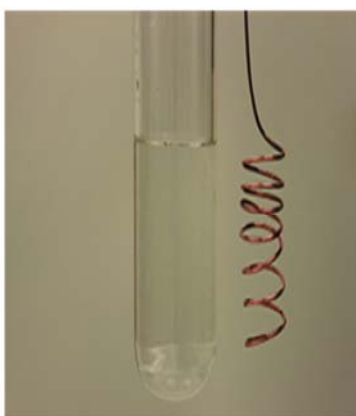
Electrochemistry Processes

**I. Replacement and Oxidation [6 marks]**

An electrochemical cell produces electricity directly from a chemical reaction

In an experiment copper wire is placed in a clear silver nitrate solution for an hour.

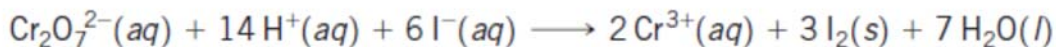
- Explain why the solution color changes as the reaction proceeds (**2 marks**)
- Explain why there is a deposit of material on the copper wire (**2 marks**)
- Write complete equations for the reaction (**2 marks**)



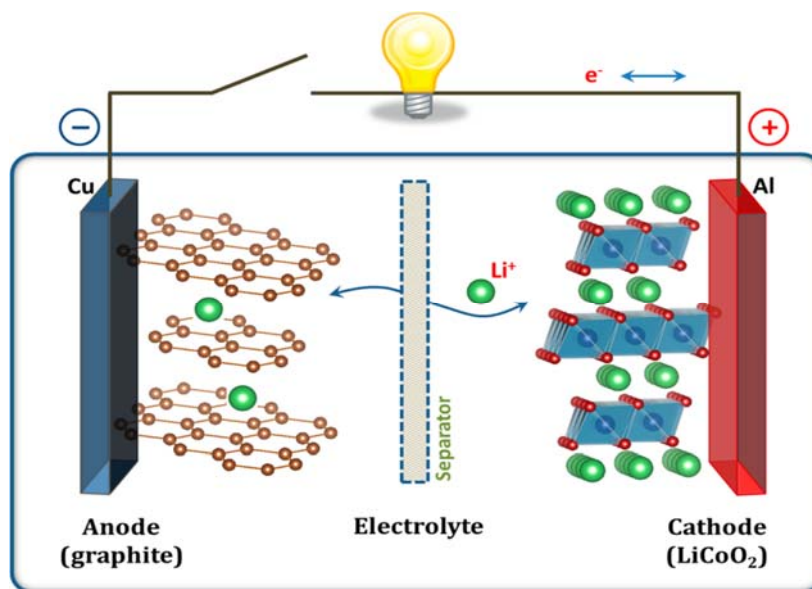
## II. Batteries [24 marks]

- a) A solution containing  $\text{K}_2\text{Cr}_2\text{O}_7$  and  $\text{H}_2\text{SO}_4$  is poured into one beaker, and a solution of  $\text{KI}$  is poured into another. A salt bridge is used to join the beakers. A platinum foil is suspended in each solution, and the two conductors are connected with wires through a voltmeter. The resulting voltaic cell generates an electric current.

The reaction proceeds as shown



- i) Draw a diagram of the set up. Indicate the reaction occurring at the anode and the reaction at the cathode (4 marks)
- ii) Indicate direction of electron migration, the direction of ion migration, and the signs of the electrodes (3 marks)
- iii) Calculate the standard free energy of the cell and equilibrium constant at 298K (2 marks)
- b) Lithium-ion batteries, have many unique advantages in comparison to conventional batteries, and are used in phones and laptops . The figure below shows a Lithium-ion cell.
- i) Explain using chemical equations, the working mechanism of the cell during discharge and charging cycles. (5 marks).



- ii) Why is graphite preferred for the anode and lithium cobalt oxide for the cathode? (5 marks)
- iii) The lithium-ion cell has an open circuit voltage  $V_{oc}$  of 4 V and ionic current  $I_i$  of 2 A. The internal resistance  $R_b$  is 0.4 ohms. Calculate the discharge voltage ( $V_{dis}$ ) and the charging voltage ( $V_{ch}$ ). (3 marks)
- c) The reaction in the voltaic cell occurs spontaneously while in an electrolytic cell. Explain why this is the case. (2 marks)

### Question Two (Inter- molecular Forces and Liquid Properties)

- a) The boiling points, surface tensions, and viscosities of water and several alcohols are as shown below:

	Boiling Point °C	Surface Tension (J/m <sup>2</sup> )	Viscosity (Kg/m-s)
Water, H <sub>2</sub> O	100	$7.3 \times 10^{-2}$	$0.9 \times 10^{-3}$
Ethanol, CH <sub>3</sub> CH <sub>2</sub> OH	78	$2.3 \times 10^{-2}$	$1.1 \times 10^{-3}$
Propanol, CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> OH	97	$2.4 \times 10^{-2}$	$2.2 \times 10^{-3}$
n-Butanol, CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> OH	117	$2.6 \times 10^{-2}$	$2.6 \times 10^{-3}$
Ethylene Glycol, HOCH <sub>2</sub> CH <sub>2</sub> OH	197	$4.8 \times 10^{-2}$	$26 \times 10^{-3}$

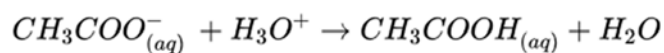
- i) From ethanol to propanol to *n*-butanol the boiling points, surface tensions, and viscosities all increase. What is the reason for this increase? (2 marks)
- ii) How do you explain the fact that propanol and ethylene glycol have similar molecular weights (60 versus 62 amu), yet the viscosity of ethylene glycol is more than 10 times larger than propanol? (3 marks)
- iii) How do you explain the fact that water has the highest surface tension but the lowest viscosity? (2 marks)
- b) The following table gives the vapor pressure of hexafluoro-benzene C<sub>6</sub>F<sub>6</sub> as a function of temperature:

Temperature (K)	Vapor Pressure (mmHg)
280	32.42
300	92.47
320	225.1
330	334.4
340	482.9

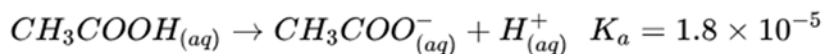
- i) Plot the data in a suitable fashion (3 marks)
- ii) Use the plot to determine the molar heat of vaporization (2 marks)
- iii) Use the plot to determine the boiling point of the compound (3 marks)

### Question Three (Acids and Bases)

- a) An acetic acid sodium acetate buffer can be prepared by the reaction.



- i) If 12.0 g of NaCH<sub>3</sub>COO is added to 0.300 L of 0.200 M HCl, what is the pH of the resulting solution? (2 Marks)
  - ii) If Ba(OH)<sub>2</sub> 1.00 g is added to the solution in part (i), what is the new pH? (3 Marks)
  - iii) What is the maximum mass of that can be neutralized by the buffer solution of part (i)? (3 Marks)
  - iv) What is the pH of the solution in part (i) following the addition of 5.50 g Ba(OH)<sub>2</sub>? (3 Marks)
- b) In an experiment increasing amount of a 0.10M, NaOH solution is added to 100 mL of a buffer solution in which, initially, [CH<sub>3</sub>CO<sub>2</sub>H] = 0.10 M and [CH<sub>3</sub>CO<sub>2</sub><sup>-</sup>] = 0.10M.



Using an appropriate plot of the data, calculate the buffer capacity. (4 Marks)

0.500M acetate buffers	
mL of NaOH	pH
0	4.86
10	4.91
20	4.95
30	5
40	5.06
50	5.11
60	5.37
70	5.50
80	5.90
90	6.00
100	7
100	8
100	9
100	10

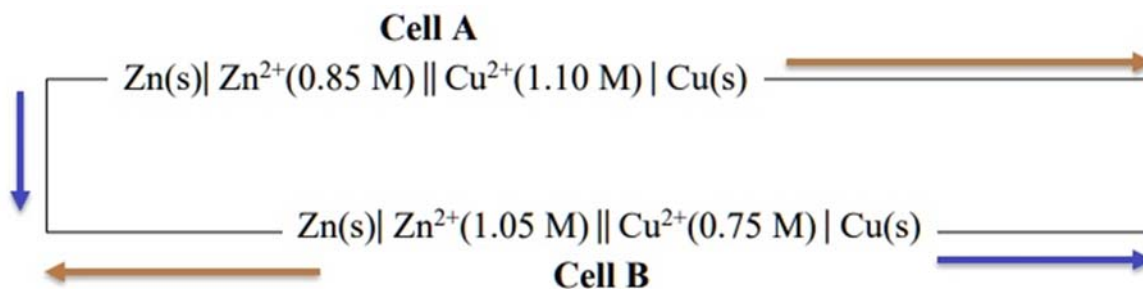
#### Question Four (Organic Chemistry)

- a) Using diagrams explain hybridization in Ethane, Ethene and Ethyne ( 6 marks)
- b) When 2,2-dimethyl -1-propanol is heated with an acid catalyst, 2-methyl-2-butene is obtained. Suggest a mechanism that shows how 2-methyl-2-butene is formed (4 marks)
- c) The table below shows the heat of combustion (heat released when the compounds are burned).
- Explain why there is an increasing trend in heats of combustion for alkanes and cycloalkanes ( 1 mark)
  - Why is the estimated heat of combustion for cycloalkanes lower than the corresponding experimental values? (4 marks)

Alkane	Experimental $\Delta H^\circ_{\text{comb}}$ in kJ/mol	Cycloalkane	Experimental $\Delta H^\circ_{\text{comb}}$ kJ/mol	Estimated $\Delta H^\circ_{\text{comb}}$ kJ/mol
Propane	-2220	Cyclopropane	-2092	-1974
Butane	-2877	Cyclobutane	-2744	-2632
Pentane	-3536	Cyclopentane	-3320	-3290
Hexane	-4194	Cyclohexane	-3948	-3948

#### Question Five (Batteries)

Two electrochemical cells are connected as shown.



- a) Do electrons flow in the direction of the brown arrows or the blue arrows? Explain your answer. (5 marks)
- b) What are the ion concentrations in the half-cells at the point at which current ceases to flow? (10 marks)

$E_{\text{red}}^{\circ}(\text{V})$	Reduction Half-Reaction
+2.87	$\text{F}_2(\text{g}) + 2 \text{e}^{-} \longrightarrow 2 \text{F}^{-}(\text{aq})$
+1.51	$\text{MnO}_4^{-}(\text{aq}) + 8 \text{H}^{+}(\text{aq}) + 5 \text{e}^{-} \longrightarrow \text{Mn}^{2+}(\text{aq}) + 4 \text{H}_2\text{O}(\text{l})$
+1.36	$\text{Cl}_2(\text{g}) + 2 \text{e}^{-} \longrightarrow 2 \text{Cl}^{-}(\text{aq})$
+1.33	$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14 \text{H}^{+}(\text{aq}) + 6 \text{e}^{-} \longrightarrow 2 \text{Cr}^{3+}(\text{aq}) + 7 \text{H}_2\text{O}(\text{l})$
+1.23	$\text{O}_2(\text{g}) + 4 \text{H}^{+}(\text{aq}) + 4 \text{e}^{-} \longrightarrow 2 \text{H}_2\text{O}(\text{l})$
+1.06	$\text{Br}_2(\text{l}) + 2 \text{e}^{-} \longrightarrow 2 \text{Br}^{-}(\text{aq})$
+0.96	$\text{NO}_3^{-}(\text{aq}) + 4 \text{H}^{+}(\text{aq}) + 3 \text{e}^{-} \longrightarrow \text{NO}(\text{g}) + 2 \text{H}_2\text{O}(\text{l})$
+0.80	$\text{Ag}^{+}(\text{aq}) + \text{e}^{-} \longrightarrow \text{Ag}(\text{s})$
+0.77	$\text{Fe}^{3+}(\text{aq}) + \text{e}^{-} \longrightarrow \text{Fe}^{2+}(\text{aq})$
+0.68	$\text{O}_2(\text{g}) + 2 \text{H}^{+}(\text{aq}) + 2 \text{e}^{-} \longrightarrow \text{H}_2\text{O}_2(\text{aq})$
+0.59	$\text{MnO}_4^{-}(\text{aq}) + 2 \text{H}_2\text{O}(\text{l}) + 3 \text{e}^{-} \longrightarrow \text{MnO}_2(\text{s}) + 4 \text{OH}^{-}(\text{aq})$
+0.54	$\text{I}_2(\text{s}) + 2 \text{e}^{-} \longrightarrow 2 \text{I}^{-}(\text{aq})$
+0.40	$\text{O}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{l}) + 4 \text{e}^{-} \longrightarrow 4 \text{OH}^{-}(\text{aq})$
+0.34	$\text{Cu}^{2+}(\text{aq}) + 2 \text{e}^{-} \longrightarrow \text{Cu}(\text{s})$
0 [defined]	$2 \text{H}^{+}(\text{aq}) + 2 \text{e}^{-} \longrightarrow \text{H}_2(\text{g})$
-0.28	$\text{Ni}^{2+}(\text{aq}) + 2 \text{e}^{-} \longrightarrow \text{Ni}(\text{s})$
-0.44	$\text{Fe}^{2+}(\text{aq}) + 2 \text{e}^{-} \longrightarrow \text{Fe}(\text{s})$
-0.76	$\text{Zn}^{2+}(\text{aq}) + 2 \text{e}^{-} \longrightarrow \text{Zn}(\text{s})$
-0.83	$2 \text{H}_2\text{O}(\text{l}) + 2 \text{e}^{-} \longrightarrow \text{H}_2(\text{g}) + 2 \text{OH}^{-}(\text{aq})$
-1.66	$\text{Al}^{3+}(\text{aq}) + 3 \text{e}^{-} \longrightarrow \text{Al}(\text{s})$
-2.71	$\text{Na}^{+}(\text{aq}) + \text{e}^{-} \longrightarrow \text{Na}(\text{s})$
-3.05	$\text{Li}^{+}(\text{aq}) + \text{e}^{-} \longrightarrow \text{Li}(\text{s})$