



MACHAKOS UNIVERSITY

University Examinations 2023/2024 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

FOURTH /THIRD YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF EDUCATION SCIENCE (SPECIAL NEEDS)

BACHELOR OF SCIENCE IN ANALYTICAL CHEMISTRY.

BACHELOR OF EDUCATION (SCIENCE)

SCH 401/310: ELECTROCHEMISTRY

DATE:

TIME:

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

USEFUL FORMULARS

$$R = \rho\left(\frac{l}{A}\right), \pi = 3.142 \quad \kappa = \frac{1}{R} \times \text{Cell constant}$$

$$\Lambda_m = \frac{\kappa \times 1000}{C} \quad \alpha = \frac{\Lambda_m^c}{\Lambda_m^\infty} \quad K = \frac{C\alpha^2}{1-\alpha}$$

$$\text{Log } K_c = \frac{nE_{cell}^0}{0.0591} \quad E = E^0 - \frac{0.059V}{n} \log k \quad \mu = \frac{\lambda}{zF}$$

$$1C\Omega = 1As\Omega = 1Vs$$

$$\Delta G^0 = -nFE_{cell}^0 \text{ where } F=96500\text{C/mol}$$

SECTION A

QUESTION ONE (30 MARKS)

- a) State two differences between electronic conductance and electrolytic conductance. (4 marks)
- b) Calculate the equilibrium constant for the following reaction at 25°C. (4 marks)
$$Sn_{(s)} + 2Cu^{2+}(aq) \rightleftharpoons Sn^{2+}(aq) + 2Cu^{+}(aq).$$
- c) Describe the working principle of the hydrogen -oxygen fuel cells. (3 marks)
- d) A galvanic cell consist of $Mg/Mg^{2+}(aq, 1.0 M)$ and $Ag/Ag^{+}(aq, 1.0 M)$. Calculate the standard EMF of this electrochemical cell at 25°C. (3 marks)
- e) Using suitable equations describe how lead-acid battery discharges. (3 marks)
- f) Predict using balanced equations what will happen when molecular bromine is added to solution containing sodium iodide solution at 25°C. (3 marks)
- g) Calculate the reduction potential of Ag^{+}/Ag electrode at 25°C when $[Ag]=0.010M$. (3 marks)
- h) Differentiate between electro-winning and electro-refining as used in electrolysis. (2 marks)
- i) Define junction potential as used in electrochemistry. (2 marks)
- j) State three disadvantages of standard hydrogen electrode (SHE) over the other secondary reference electrodes. (3 marks)

SECTION B

QUESTION TWO (20 MARKS)

- a) A voltaic cell is made of Zn/Zn^{2+} and $Pt/H_2/H^{+}$. In a certain experiment the EMF of the cell is found to be 0.54 V at 25°C. Given that $[Zn^{2+}] = 1.0 M$ and $[P_{H_2}] = 1.0 M$. Calculate the concentration of H^{+} . (7 marks)
- b) Describe three modes by which analyte move from bulk solution to electrode surface and state how the undesirable effects of the modes are minimized. (6 marks)
- c) Define a sensor and describe its three major components. (7 marks)

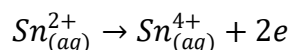
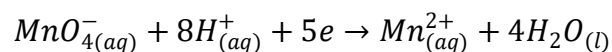
QUESTION THREE (20 MARKS)

- a) Write a balanced ionic equation to represent the oxidation of iodide ion by permanganate ion in basic solution to yield molecular iodine and manganese (IV) oxide



- b) Aqueous solution of a platinum salt is electrolysed by passing a current of 2.5 A for two hours. As a result 9.09 grams of metallic platinum is deposited at the cathode. Calculate the charge on the platinum ion in this solution (RFM of platinum salt is 195.1g). (6 marks)

- c) Two half cells reactions of an electrochemical cell are given below

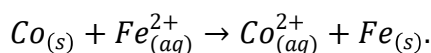


Construct a redox equation from the above half-cell reactions and predict if this reaction favours formation of reactants or products shown in the equations.

(6 marks)

QUESTION FOUR (20 MARKS)

- a) Predict whether the following reaction will proceed spontaneously in the given direction at 298 K.



Given that $[Co^{2+}] = 0.15M$ $[Fe^{2+}] = 0.68M$ (7 marks)

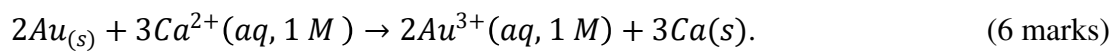
- b) Corrosion is essentially an electrochemical phenomenon. Explain the reactions occurring during corrosion of iron kept in an open atmosphere given that $E_{Fe^{2+}/Fe}^0 = -0.44V$ and $E_{H^+/O_2/H_2O}^0 = 1.23V$ (8 marks)

- c) The conductivity of 0.001M acetic acid is $4.0 \times 10^{-5} S cm^{-1}$. Calculate the dissociation constant (k_a) if Λ_m^0 for acetic acid is $390.5 S cm^2 mol^{-1}$. (5 marks)

QUESTION FIVE (20 MARKS)

- a) A current of 0.452 A is passed through an electrolytic cell containing molten calcium chloride for 1.5 hours. Write the electrode reactions and calculate the quantity of products (in grams) formed at the electrodes (RFM Ca=40, Cl=35.5). (7 marks)

- b) Calculate the standard free energy change for the following reaction at 25°C and state whether the reaction is spontaneous under the given condition.



- c) A voltaic cell is made of Cu/Cu^{2+} and Ag/Ag^{+} .

i) Write the cell diagram for the above cell. (2 marks)

ii) Determine the concentration of Ag^{+} ions will the EMF of the cell be zero at 25°C if the concentration of Cu^{2+} is 0.01M? (5 marks)

	Half-Reaction	$E^\circ(\text{V})$	
↑ Increasing strength as oxidizing agent	$\text{F}_2(\text{g}) + 2\text{e}^- \longrightarrow 2\text{F}^-(\text{aq})$	+2.87	Decreasing strength as reducing agent ↓
	$\text{O}_3(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{O}_2(\text{g}) + \text{H}_2\text{O}$	+2.07	
	$\text{Co}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Co}^{2+}(\text{aq})$	+1.82	
	$\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow 2\text{H}_2\text{O}$	+1.77	
	$\text{PbO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + 2\text{e}^- \longrightarrow \text{PbSO}_4(\text{s}) + 2\text{H}_2\text{O}$	+1.70	
	$\text{Ce}^{4+}(\text{aq}) + \text{e}^- \longrightarrow \text{Ce}^{3+}(\text{aq})$	+1.61	
	$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \longrightarrow \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}$	+1.51	
	$\text{Au}^{3+}(\text{aq}) + 3\text{e}^- \longrightarrow \text{Au}(\text{s})$	+1.50	
	$\text{Cl}_2(\text{g}) + 2\text{e}^- \longrightarrow 2\text{Cl}^-(\text{aq})$	+1.36	
	$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \longrightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}$	+1.33	
	$\text{MnO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{Mn}^{2+}(\text{aq}) + 2\text{H}_2\text{O}$	+1.23	
	$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \longrightarrow 2\text{H}_2\text{O}$	+1.23	
	$\text{Br}_2(\text{l}) + 2\text{e}^- \longrightarrow 2\text{Br}^-(\text{aq})$	+1.07	
	$\text{NO}_3^-(\text{aq}) + 4\text{H}^+(\text{aq}) + 3\text{e}^- \longrightarrow \text{NO}(\text{g}) + 2\text{H}_2\text{O}$	+0.96	
	$2\text{Hg}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Hg}_2^{2+}(\text{aq})$	+0.92	
	$\text{Hg}_2^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow 2\text{Hg}(\text{l})$	+0.85	
	$\text{Ag}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Ag}(\text{s})$	+0.80	
	$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Fe}^{2+}(\text{aq})$	+0.77	
	$\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{H}_2\text{O}_2(\text{aq})$	+0.68	
	$\text{MnO}_4^-(\text{aq}) + 2\text{H}_2\text{O} + 3\text{e}^- \longrightarrow \text{MnO}_2(\text{s}) + 4\text{OH}^-(\text{aq})$	+0.59	
	$\text{I}_2(\text{s}) + 2\text{e}^- \longrightarrow 2\text{I}^-(\text{aq})$	+0.53	
	$\text{O}_2(\text{g}) + 2\text{H}_2\text{O} + 4\text{e}^- \longrightarrow 4\text{OH}^-(\text{aq})$	+0.40	
	$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Cu}(\text{s})$	+0.34	
	$\text{AgCl}(\text{s}) + \text{e}^- \longrightarrow \text{Ag}(\text{s}) + \text{Cl}^-(\text{aq})$	+0.22	
	$\text{SO}_4^{2-}(\text{aq}) + 4\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}$	+0.20	
	$\text{Cu}^{2+}(\text{aq}) + \text{e}^- \longrightarrow \text{Cu}^+(\text{aq})$	+0.15	
	$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Sn}^{2+}(\text{aq})$	+0.13	
	$2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{H}_2(\text{g})$	0.00	
	$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Pb}(\text{s})$	-0.13	
	$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Sn}(\text{s})$	-0.14	
	$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Ni}(\text{s})$	-0.25	
	$\text{Co}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Co}(\text{s})$	-0.28	
	$\text{PbSO}_4(\text{s}) + 2\text{e}^- \longrightarrow \text{Pb}(\text{s}) + \text{SO}_4^{2-}(\text{aq})$	-0.31	
	$\text{Cd}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Cd}(\text{s})$	-0.40	
	$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Fe}(\text{s})$	-0.44	
	$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \longrightarrow \text{Cr}(\text{s})$	-0.74	
	$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Zn}(\text{s})$	-0.76	
	$2\text{H}_2\text{O} + 2\text{e}^- \longrightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-0.83	
	$\text{Mn}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Mn}(\text{s})$	-1.18	
	$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \longrightarrow \text{Al}(\text{s})$	-1.66	
	$\text{Be}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Be}(\text{s})$	-1.85	
	$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Mg}(\text{s})$	-2.37	
	$\text{Na}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Na}(\text{s})$	-2.71	
	$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Ca}(\text{s})$	-2.87	
	$\text{Sr}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Sr}(\text{s})$	-2.89	
	$\text{Ba}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Ba}(\text{s})$	-2.90	
	$\text{K}^+(\text{aq}) + \text{e}^- \longrightarrow \text{K}(\text{s})$	-2.93	
	$\text{Li}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Li}(\text{s})$	-3.05	

*For all half-reactions the concentration is 1 M for dissolved species and the pressure is 1 atm for gases. These are the standard-state values.

