



SCHOOL OF SCIENCE AND TECHNOLOGY

Semester 1, 2026

FINAL EXAMINATION PAPER

CHE 211: PHYSICAL & INORGANIC CHEMISTRY

Important Instructions to Students:

1. There are eleven (11) pages. Read the questions, instructions carefully and answer the questions.
2. You are allowed an **extra 10 minutes reading time** (during this time, you are not allowed to write with pen) and **180 minutes (3 Hours) to complete this paper**.
3. Silent, non-programmable calculators are allowed, but not supplied.
4. Write all your answers in the answer booklet provided. If you need extra sheets, please ask from the supervisor. Write your name, course code and student identification number in the answer booklet and in the attendance sheet.
5. This paper contains TWO (2) sections. **Section A comprises of 10 multiple choice questions and Section B is short Answer Question with sub-sections, compromising of FIVE (5) questions. All questions are compulsory.**
6. Write all your answers legibly. The marker has the right to award zero for answers that are not legible.
7. This is a **Closed Book Examination**. The University views plagiarism, cheating and dishonest practice as serious offences and if found, offenders are penalized.

Examination Paper Content:

<u>Section</u>	<u>Questions</u>	<u>Content</u>	<u>Marks</u>	<u>Suggested Time</u>
A	1-10	Multiple Choice	10	20 minutes
B	1-5	Short Answer Questions	90	160 minutes
	TOTAL		100	180 Minutes

There are ten (10) multiple choice questions. All are compulsory. Write only the question number and the letter corresponding to the correct answer in the answer booklet.

1. What is the main function of catalyst in a chemical reaction?
 - A. Increase activation energy
 - B. Decrease reaction rate
 - C. Increase the rate of reaction
 - D. Change equilibrium constant
2. In an electrochemical cell, oxidation occurs at the:
 - A. Cathode
 - B. Salt bridge
 - C. Anode
 - D. Electrolyte
3. What is the value of the standard hydrogen electrode potential?
 - A. 1.0 V
 - B. 0.0 V
 - C. -1.0 V
 - D. 0.5 V
4. Which factor does not affect the rate of a chemical reaction?
 - A. Temperature
 - B. Concentration
 - C. Catalyst
 - D. Colour of container
5. What is the value of gas constant R ?
 - A. $0.0721 \text{ L atm mol}^{-1} \text{ K}^{-1}$
 - B. $8.314 \text{ J mol}^{-1} \text{ K}^{-1}$
 - C. Both A and B
 - D. 96500 C mol^{-1}
6. What is the main function of salt bridge in a galvanic cell?
 - A. Produces electrons
 - B. Maintain electrical neutrality
 - C. Increase temperature
 - D. Stop oxidation
7. A general rate law is written as:
 - A. $\text{Rate} = k[A]^0$
 - B. $\text{Rate} = k[A]^n$
 - C. $\text{Rate} = k/t$
 - D. $\text{Rate} = [A]/t$

8. In which direction does electrons flow in a galvanic cell?
- A. Cathode to Anode
 - B. Anode to Cathode
 - C. Anode to Salt bridge
 - D. Electrolyte to wire
9. Which factor increases the rate of reaction most effectively?
- A. Decreasing temperature
 - B. Increasing concentration
 - C. Decreasing surface area
 - D. Removing catalyst
10. The unit of rate constant for a first-order reaction is:
- A. mol L^{-1}
 - B. s^{-1}
 - C. $\text{L mol}^{-1} \text{s}^{-1}$
 - D. $\text{mol}^2 \text{L}^{-2} \text{s}^{-1}$

There are five (5) questions in this section and all five questions are compulsory. Each question contains sub-parts and is worth 18 marks. Answer all the questions in the answer booklet.

QUESTION I

[18 marks]

1. Consider the reaction:



Suppose that, at a particular moment during the reaction, molecular oxygen is reacting at the rate of 0.035 M/s

- At what rate is N_2O_5 being formed? [2 marks]
 - At what rate is NO_2 reacting? [2 marks]
- The decomposition of HI has rate constants $k = 0.079 \text{ L mol}^{-1} \text{ s}^{-1}$ at 508°C and $k = 0.24 \text{ L mol}^{-1} \text{ s}^{-1}$ at 540°C . What is the activation energy of this reaction in kJ/mol? [3 marks]
 - The reaction: $2\text{NO}_2 (\text{g}) \longrightarrow 2\text{NO} (\text{g}) + \text{O}_2 (\text{g})$ has an activation energy of 125 kJ/mol. At 395°C , $k = 7.1 \text{ L mol}^{-1} \text{ s}^{-1}$. What is the value of k at 435°C ? [3 marks]
 - In the Arrhenius equation for a certain reaction, the value of A and E_a are $5 \times 10^{13} \text{ s}^{-1}$ and 88.6 kJ/mol, respectively. If the reaction is of first order, at what temperature will its half-life period be in 15 min? [4 marks]
 - The reaction of nitric oxide with hydrogen at 1280°C is



Experiment	[NO] (M)	[H ₂] (M)	Initial Rate (M/s)
1	5.0×10^{-3}	2.0×10^{-3}	1.3×10^{-5}
2	10.0×10^{-3}	2.0×10^{-3}	5.0×10^{-5}
3	10.0×10^{-3}	4.0×10^{-3}	10.0×10^{-5}

Using the above tabulated data at this temperature to determine the following:

- The rate law [2 marks]
- The rate constant [2 marks]

QUESTION II

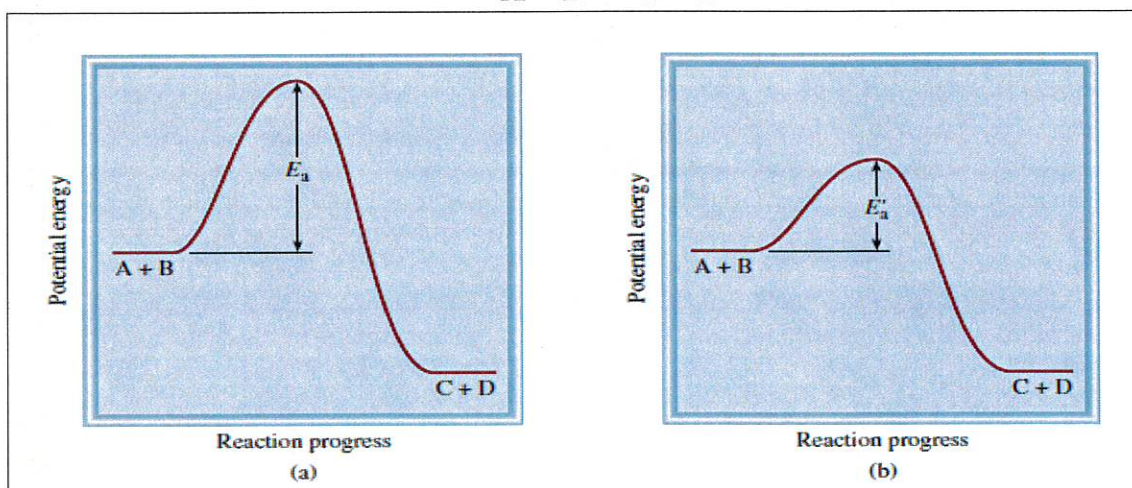
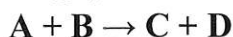
[18 marks]

- The decomposition of HI has rate constants $k = 0.089 \text{ L mol}^{-1} \text{ s}^{-1}$ at 518°C and $k = 0.34 \text{ L mol}^{-1} \text{ s}^{-1}$ at 540°C . What is the activation energy of this reaction in kJ/mol? [4 marks]
- The conversion of cyclopropane to propene in the gas phase is a first-order reaction with a rate constant of $6.7 \times 10^{-4} \text{ s}^{-1}$ at 500°C . If the initial concentration of cyclopropane was 0.25 M , what is the concentration after 8.8 min ? [3 marks]
- How long (in minutes) will it take for the concentration of cyclopropane to decrease from 0.25 M to 0.15 M ? [3 marks]
- Use the data table below to explain the variation in the mobility of the monovalent ions.

Ions	$U (10^{-4} \text{ cm}^2 \text{ s}^{-1} \text{ v}^{-1})$
H^+	36.23
Li^+	4.01
Na^+	5.19
K^+	7.62

Use Grotthuss mechanism to explain abnormally high conductivity and mobility of ions in aqueous solution. [3 marks]

- The racemisation of pinene is a first order reaction. In the gas phase the specific rate constant for the reaction was found to be $2.2 \times 10^{-5} \text{ min}^{-1}$ at 457.6 K and $3.07 \times 10^{-3} \text{ min}^{-1}$ at 510 K . Estimate the activation energy of the reaction from these data. [3 marks]
- The diagrams (a) and (b) show the potential energy profiles for the same reaction, where:



- Identify which diagram represents the **uncatalysed reaction** and which represents the **catalysed reaction**. [2 marks]

QUESTION III

[18 marks]

- In an experiment, solutions of 1.0 M KCl and 0.1 M AgNO₃ were found to have a resistance of 30.2 Ω and 35.0 Ω , respectively. Conductivity of KCl = $1.2886 \times 10^{-2} \Omega \text{ cm}^{-1}$. Calculate the:
 - Cell constant [2 marks]
 - Conductivity [2 marks]
- Find the limiting molar conductivity (Λ^0) of BaCl₂.

Limiting Ionic Conductivities Some ions ($\text{S cm}^2 \text{ mol}^{-1}$)

H ⁺	349.6	OH ⁻	100.1
Li ⁺	38.7	Cl ⁻	76.4
Na ⁺	50.1	Br ⁻	78.1
K ⁺	73.5	SO ₄ ²⁻	160.0
Zn ²⁺	105.6	NO ₃ ⁻	71.5
Ba ²⁺	127.2	CH ₃ COO ⁻	40.9

[3 marks]

- Calculate Λ^0 for CH₃COOH from Λ^0 values of the following substances:

HCl = 426 $\text{S cm}^2 \text{ mol}^{-1}$
NaCl = 126 $\text{cm}^2 \text{ mol}^{-1}$
CH ₃ COONa = 191 $\text{cm}^2 \text{ mol}^{-1}$

[3 marks]

- Calculate the **ionic strength** of a 1.00 molal (mol/kg) solution of La₂(SO₄)₃. [4 marks]
- Estimate the **mean activity coefficient** $\gamma_{\pm}$ of a 0.00500 mol kg⁻¹ KCl (aq) at 25 °C. [4 marks]

QUESTION IV

[18 marks]

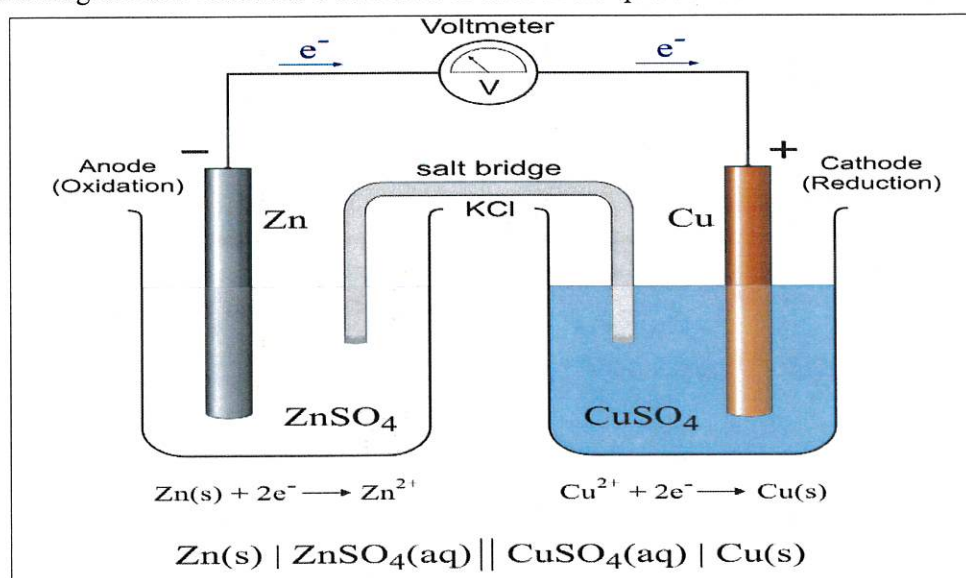
1. Differentiate between a weak and a strong electrolyte. [2 marks]
2. Estimate the limiting conductivity of NaCl from mobility values.

Mobilities of ions in water at 25°C			
Ion	Mobility [$\text{m}^2/(\text{s} \cdot \text{V})$] ^a	Ion	Mobility [$\text{m}^2/(\text{s} \cdot \text{V})$] ^a
H^+	36.30×10^{-8}	OH^-	20.50×10^{-8}
K^+	7.62×10^{-8}	SO_4^{2-}	8.27×10^{-8}
NH_4^+	7.61×10^{-8}	Br^-	8.13×10^{-8}
La^{3+}	7.21×10^{-8}	I^-	7.96×10^{-8}
Ba^{2+}	6.59×10^{-8}	Cl^-	7.91×10^{-8}
Ag^+	6.42×10^{-8}	NO_3^-	7.40×10^{-8}
Ca^{2+}	6.12×10^{-8}	ClO_4^-	7.05×10^{-8}
Cu^{2+}	5.56×10^{-8}	F^-	5.70×10^{-8}
Na^+	5.19×10^{-8}	CH_3CO_2^-	4.24×10^{-8}
Li^+	4.01×10^{-8}		

a. The mobility of an ion is the velocity achieved in an electric field of 1 V/m.
Mobility = velocity/field. The units of mobility are therefore $(\text{m/s})/(\text{V/m}) = \text{m}^2/(\text{s} \cdot \text{V})$.

[3 marks]

3. Explain Kohlrausch's Law of Independent Migration of Ions and discuss how the electrophoretic effect and asymmetry (relaxation) effect influence the mobility of ions in electrolyte solutions. [3 marks]
4. Refer to the diagram of a Galvanic Cell below to answer the questions that follow:

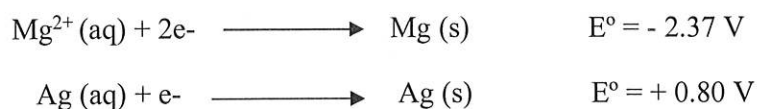


- a. Define Oxidation and Reduction in terms of electron transfer. [2 marks]
- b. In a Galvanic Cell, identify where oxidation and reduction occur. [1 mark]

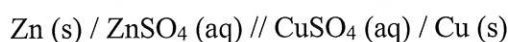
- c. Write the oxidation half-equation and the reduction half-equation for the cell shown in the diagram. [2 marks]
- d. State the direction of electron flow in the external circuit. [1 mark]
- e. State the purpose of the salt bridge in a galvanic cell. [2 marks]
- f. Write the correct cell notation for the galvanic cell shown. [2 marks]

QUESTION V**[18 marks]**

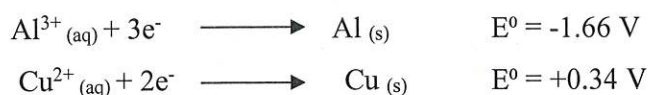
1. A cell is made using the following electrodes. Write down the cell reaction, cell notation and calculate the E° cell.

**[5 marks]**

2. Calculate the cell potential for the cell, $\text{Zn}/\text{Zn}^{2+} // \text{Cu}^{2+}/\text{Cu}$, when activity of Cu^{2+} is 0.1 M and that of Zn^{2+} is 0.01 M. **[3 marks]**
3. Calculate the equilibrium constant K for the reaction in the following cell.

**[3 marks]**

4. Write the cell reaction and calculate the standard cell potentials, E° cell, of the cell which consists of following two electrodes:

**[4 marks]**

5. Calculate the standard free energy change, ΔG° , for the following reaction at 25 °C.

**[3 marks]****THE END**

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Standard Potentials at 25 °C

	Reaction (Oxidised form + ne ⁻)	→ Reduced form)	E ⁰ /V
↑ Increasing strength of oxidising agent	F ₂ (g) + 2e ⁻	→ 2F ⁻	2.87
	Co ³⁺ + e ⁻	→ Co ²⁺	1.81
	H ₂ O ₂ + 2H ⁺ + 2e ⁻	→ 2H ₂ O	1.78
	MnO ₄ ⁻ + 8H ⁺ + 5e ⁻	→ Mn ²⁺ + 4H ₂ O	1.51
	Au ³⁺ + 3e ⁻	→ Au(s)	1.40
	Cl ₂ (g) + 2e ⁻	→ 2Cl ⁻	1.36
	Cr ₂ O ₇ ²⁻ + 14H ⁺ + 6e ⁻	→ 2Cr ³⁺ + 7H ₂ O	1.33
	O ₂ (g) + 4H ⁺ + 4e ⁻	→ 2H ₂ O	1.23
	MnO ₂ (s) + 4H ⁺ + 2e ⁻	→ Mn ²⁺ + 2H ₂ O	1.23
	Br ₂ + 2e ⁻	→ 2Br ⁻	1.09
	NO ₃ ⁻ + 4H ⁺ + 3e ⁻	→ NO(g) + 2H ₂ O	0.97
	2Hg ²⁺ + 2e ⁻	→ Hg ₂ ²⁺	0.92
	Ag ⁺ + e ⁻	→ Ag(s)	0.80
	Fe ³⁺ + e ⁻	→ Fe ²⁺	0.77
	O ₂ (g) + 2H ⁺ + 2e ⁻	→ H ₂ O ₂	0.68
	I ₂ + 2e ⁻	→ 2I ⁻	0.54
	Cu ⁺ + e ⁻	→ Cu(s)	0.52
	Cu ²⁺ + 2e ⁻	→ Cu(s)	0.34
	AgCl(s) + e ⁻	→ Ag(s) + Cl ⁻	0.22
	AgBr(s) + e ⁻	→ Ag(s) + Br ⁻	0.10
	2H ⁺ + 2e ⁻	→ H ₂ (g)	0.00
	Pb ²⁺ + 2e ⁻	→ Pb(s)	-0.13
	Sn ²⁺ + 2e ⁻	→ Sn(s)	-0.14
	Ni ²⁺ + 2e ⁻	→ Ni(s)	-0.25
	Fe ²⁺ + 2e ⁻	→ Fe(s)	-0.44
	Cr ³⁺ + 3e ⁻	→ Cr(s)	-0.74
	Zn ²⁺ + 2e ⁻	→ Zn(s)	-0.76
	2H ₂ O + 2e ⁻	→ H ₂ (g) + 2OH ⁻ (aq)	-0.83
	Al ³⁺ + 3e ⁻	→ Al(s)	-1.66
	Mg ²⁺ + 2e ⁻	→ Mg(s)	-2.36
	Na ⁺ + e ⁻	→ Na(s)	-2.71
	Ca ²⁺ + 2e ⁻	→ Ca(s)	-2.87
	K ⁺ + e ⁻	→ K(s)	-2.93
Li ⁺ + e ⁻	→ Li(s)	-3.05	
		↓ Increasing strength of reducing agent	