



University of Ruhuna- Faculty of Technology
Bachelor of Engineering Technology Honours Degree
Level 1 (Semester I) Examination, November/December 2025
Academic year 2024/2025

Course Unit: TMS 1122 – Chemistry of Materials (Written)

Duration: 2 hours

- Answer **Only FOUR (04)** out of FIVE (05) questions.
- All questions carry equal marks.
- All symbols have their usual meaning.
- Calculators are allowed.

1)

- a) A scientist analyzes a newly discovered element X. The mass number of X is 52 and it contains 26 neutrons.
- Determine the atomic number of element X. (2 mark)
 - Write the full electronic configuration of a neutral atom of X. (4 marks)
 - State the four (04) quantum numbers for the **last electron added** in a neutral atom of X. (8 marks)
 - "X tend to form X^{3+} ions". Justify this statement in terms of stability and electron configuration. (6 marks)
 - Identify the block and period of element X. (4 marks)

b) Arrange the following elements in their increasing order of the given parameters.

P, O, C, Na, Al

- Atomic radius (4 marks)
- Ionization Energy (8 marks)
- Electronegativity (6 marks)

c) Answer the following questions with reference to the molecules BF_3 and CH_2O .

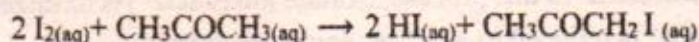
- Determine the shapes of the following molecules using Valence Shell Electron Pair Repulsion (VSEPR) theory. (Hint: Identify the number of electron groups by drawing Lewis structures) (20 marks)

- ii) For each molecule, indicate the direction of the dipole moment for all bonds and state whether the molecules are polar or non-polar. (12 marks)
- d) The beryllium molecule (Be_2) does not exist as a stable entity under normal conditions. Justify this statement using Molecular Orbital Theory. (Hint: Sketch the relevant molecular orbital diagram and calculate the bond order) (26 marks)
- [100 marks]
- 2)
- a) Compare the melting points of fluorine (F_2), sodium (Na), and magnesium oxide (MgO) discussing their bonding type and structure. (18 marks)
- b) Select the most suitable material for each application given below from Cu , Al_2O_3 , and NaCl . Give reasons for your selection. (12 marks)
- Good electrical conductor/s in the solid state
 - Excellent electrical insulator/s
 - Conducts electricity when dissolved in water
- c) A rescue team uses a portable ethanol heater during cold-weather missions. The heater burns ethanol ($\text{C}_2\text{H}_5\text{OH}$) to produce carbon dioxide and water. (Molar Mass of carbon dioxide and ethanol are 44 g mol^{-1} and 46 g mol^{-1} respectively)
- Write the **balanced** chemical equation for the complete combustion of ethanol. (8 marks)
 - Calculate the mass of CO_2 produced when 9.2 g of ethanol undergoes complete combustion. (20 marks)
- d) A chloride ion sensor in an environmental water-testing device gives a warning when chloride concentration exceeds 0.010 mol/L . A technician prepares a NaCl calibration solution and performs a dilution.
- A 3.50% (w/v) sodium chloride solution is prepared by dissolving 3.50 g of NaCl in 100.0 mL of water. Calculate the molar concentration of this solution. (Molar mass of $\text{NaCl} = 58.44 \text{ g/mol}$) (12 marks)
 - The technician dilutes the solution by mixing 30.0 mL of the stock with 70.0 mL of water. Calculate the concentration of the diluted solution. (10 marks)
 - Will this diluted solution activate the chloride sensor? Justify your answer. (4 marks)
- e) A pharmaceutical company modifies a drug molecule by replacing a O-H bond with a S-H bond in one region of the structure. Predict how this substitution will affect the molecule's acidic strength considering their bond energies. (Bond energies of O-H and S-H are 463 kJ/mol and 347 kJ/mol respectively) (16 marks)
- [100 marks]

3) Answer all parts.

a)

i) The following experimental data were obtained during kinetic studies of the reaction.



Experiment	$[\text{I}_2] / \text{mol L}^{-1}$	$[\text{CH}_3\text{COCH}_3] / \text{mol L}^{-1}$	Initial Rate / $\text{mol L}^{-1} \text{min}^{-1}$
1	0.10	0.10	6.0×10^{-3}
2	0.30	0.20	7.3×10^{-2}
3	0.30	0.40	2.88×10^{-1}
4	0.10	0.40	2.40×10^{-2}

(I) Determine the order of the reaction with respect to I_2 and CH_3COCH_3 . (24 marks)

(II) Write the rate law for the reaction. (8 marks)

(III) Calculate the rate constant k . (12 marks)

(IV) Determine the rate of formation of HI when $[\text{I}_2] = 0.25 \text{ mol L}^{-1}$ and $[\text{CH}_3\text{COCH}_3] = 0.15 \text{ mol L}^{-1}$. (10 marks)

b) A corrosion-inhibiting chemical "A" is added to cooling-tower water to prevent scale formation. The engineer monitoring the system wants to determine whether this degradation follows a first-order or second-order kinetic pathway so that the chemical dosage rate can be optimized. Following experimental data are provided for the concentration of A in water over time, at 25°C .

Time /s	$[\text{A}] / \text{M}$
0	0.50
300	0.30
600	0.20

i) Write the integrated rate law expressions for first order and second-order reactions. (4 marks)

ii) Complete the table by calculating the relevant $\ln [\text{A}]$ and $1/[\text{A}]$ values. (6 marks)

Time (s)	$[\text{A}] (\text{M})$	$\ln [\text{A}]$	$1/[\text{A}]$
0	0.500		
300	0.286		
600	0.200		

iii) Using the values calculated above, sketch suitable graphs and verify whether the degradation is first or second order. (12 marks)

c) Aqueous hydrogen peroxide (H_2O_2) decomposes by a first-order mechanism under certain catalytic conditions. At 25°C the measured rate constant for the decomposition is $k = 3.50 \times 10^{-3} \text{ s}^{-1}$. Calculate the half-life of H_2O_2 under these conditions. (12 marks)

d) Explain briefly how catalytic converters used in vehicle exhaust systems reduce environmental pollution. (12 marks)

[100 marks]

4)

a) A chemical engineer is evaluating an industrial wastewater treatment process in which permanganate ion (MnO_4^-) acts as a strong oxidizing agent in acidic medium to degrade organic pollutants. In this process, oxalate ion ($\text{C}_2\text{O}_4^{2-}$) is oxidized to carbon dioxide (CO_2), while MnO_4^- is reduced to Mn^{2+} in acidic medium.

i) Assign oxidation numbers to all elemental atom in: (8 marks)

(I) MnO_4^-

(II) $\text{C}_2\text{O}_4^{2-}$

ii) Write balanced half-ionic reactions for the oxidation and reduction reactions. (12 marks)

iii) Write the balanced redox equation for the reaction above. (8 marks)

b) A galvanic cell is constructed using $\text{Ni(s)} \mid \text{Ni}^{2+}(1.0 \text{ M})$ and $\text{Cu(s)} \mid \text{Cu}^{2+}(1.0 \text{ M})$ solutions connected by a KNO_3 salt bridge. The standard reduction potentials are,

$$E^\circ(\text{Ni}^{2+}/\text{Ni}) = -0.25 \text{ V}$$

$$E^\circ(\text{Cu}^{2+}/\text{Cu}) = +0.34 \text{ V}$$

i) Determine anode and the cathode giving reasons. (Hint: Oxidation take place at the electrode with most negative standard reduction potential) (4 marks)

ii) Draw a labeled diagram of this cell including anode, cathode, direction of electron flow and the salt bridge. (12 marks)

iii) Write the half-cell reactions. (12 marks)

iv) Write the overall cell reaction. (6 marks)

v) Write the cell diagram/notation. (6 marks)

vi) Calculate the standard cell potential (E°_{cell}). (6 marks)

c) The same cell galvanic cell in part (b) above when operating under nonstandard conditions, the ion concentrations change to $[\text{Ni}^{2+}] = 0.020 \text{ M}$ and $[\text{Cu}^{2+}] = 1.50 \text{ M}$. Calculate the cell potential under these conditions using the Nernst equation. (10 marks)

d) Iron structures such as bridges, pipelines, and coastal constructions undergo corrosion due to electrochemical reactions occurring on their surfaces. Engineers commonly use sacrificial protection (galvanic protection) by attaching a more active metal such as Mg or Zn to prevent the steel from corroding. Explain briefly, in point form, how sacrificial protection prevents corrosion of steel. (Hint: Identify the anode and cathode)

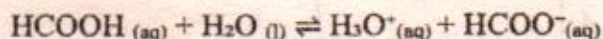
(16 marks)

[100 marks]

5)

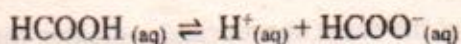
a) A manufacturing company uses acidic cleaning fluids containing organic acids to remove mineral deposits from machinery. During routine maintenance, a technician spills some of the cleaning solution, requiring an immediate chemical assessment. It is required to analyze the acid–base properties of the solution and recommend safe neutralization strategies.

- i) Compare the Brønsted–Lowry definition and Arrhenius definition of acids and bases. (8 marks)
- ii) The cleaning solution contains formic acid (HCOOH). In water it dissociates as follows,



Identify the conjugate acid–base pairs. (8 marks)

iii) The spilled cleaning solution contains 0.050 M HCOOH. Consider the simplified dissociation of formic acid given below.



- (I) Write an equilibrium expression (K_a) for the dissociation of formic acid. (10 marks)
- (II) Calculate the pH of this solution. (K_a of HCOOH = 1.8×10^{-5} M) (12 marks)

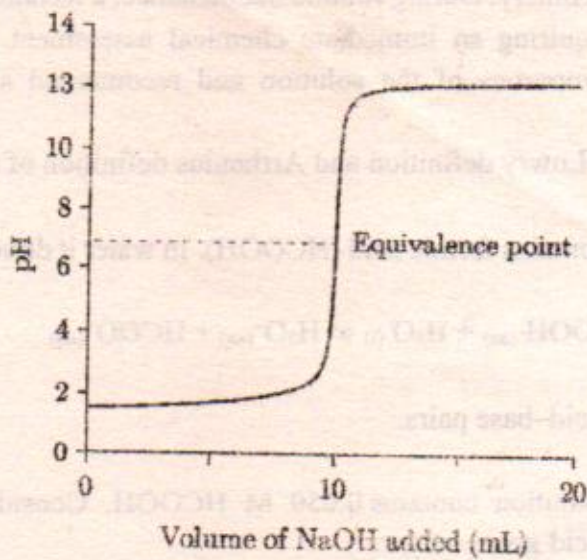
b) Briefly explain, using appropriate chemical equations, how a buffer made from acetic acid (CH_3COOH) and sodium acetate (CH_3COONa) resists changes in pH when small amounts of acid or base are added. (12 marks)

c) To determine the concentration of hydrochloric acid (HCl) in a sample, a 10.00 mL portion of the acid sample was titrated with $0.100 \text{ mol dm}^{-3}$ NaOH. The following burette readings were obtained.

Trial	Initial Reading /ml	Final Reading /ml
1	0.00	9.90
2	11.00	21.20
3	22.00	32.10

- i) Define equivalence point of an acid–base titration. (6 marks)
- ii) Write the balanced chemical reaction related to the above titration. (6 marks)
- iii) Using the table above, determine the average titration volume spent. (6 marks)
- iv) Calculate the unknown HCl concentration. (12 marks)

- v) The following diagram shows the pH curve obtained for the above titration. A table showing the indicators and their pH change ranges is provided alongside.



Indicator	pH Range
Methyl orange	3.1–4.4
Bromothymol blue	6.0–7.6
Phenolphthalein	8.3–10.0

- (I) Select the most appropriate indicator for this titration from the table above. Give reasons for your answer. (8 marks)

- (II) If HCl is replaced with 0.1 M CH_3COOH , identify the most suitable indicator for the titration. Justify your answer based on the expected shift in the equivalence point. (12 marks)

[100 marks]

Total Volume (ml)	Final Reading (ml)	Initial Reading (ml)
1	0.00	0.00
2	11.00	0.00
3	22.00	0.00

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