

The Open University of Sri Lanka
Faculty of Natural Sciences
B.Sc/B.Ed Degree Programme



Department	: Chemistry
Level	: 4
Name of the Examination	: Final Examination
Course Title and Code	: CYU4301 – Concepts in Chemistry
Academic Year	: 2025/2026
Date	: 30.12.2025
Time	: 9.30 a.m. – 11.30 a.m.
Duration	: 2 hours

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **four (04)** questions on **eight (08)** pages.
3. Answer **required parts** of **all questions** as instructions given. All questions carry equal marks.
4. Answer for each question should be started on a fresh page.
5. Answers to all parts of any question should be written together.
6. Draw fully labelled diagrams where necessary.
7. Involvement in any activity that is considered as an examination offense will lead to punishment.
8. Use blue or black ink to answer the questions.
9. Clearly write your index number on all pages of your answer script.
10. Use of non-programmable calculators will be allowed.
11. Mobile phones and other electronic equipment are not allowed. Switch off and leave them outside.
12. A list of constants and equations are provided overleaf for your reference.

Gas constant (R)	=	8.314 J K ⁻¹ mol ⁻¹
Avogadro constant (N _A)	=	6.023 × 10 ²³ mol ⁻¹
Faraday constant (F)	=	96,500 C mol ⁻¹
Planck constant (h)	=	6.63 × 10 ⁻³⁴ J s
Velocity of light (c)	=	3.0 × 10 ⁸ m s ⁻¹
Standard pressure	=	10 ⁵ Pa (Nm ⁻²) = 1 bar
Protonic charge (e)	=	1.602177 × 10 ⁻¹⁹ C
π	=	3.14159
Log _e (X)	=	2.303 Log ₁₀ (X)

Some equations used in chemistry are given below using standard notation.

$$\log(\gamma_{\pm}) = -A Z_+ |Z_-| \sqrt{I}, \quad E_J = BJ(J+1), \quad \bar{B} = \frac{h}{8\pi^2 \mu R^2 c}, \quad \bar{\nu} = 2\bar{B}(J+1),$$

$$\rho = \frac{I}{h\nu c}, \quad u = \frac{xak}{Q}, \quad \lambda_B = u_B |Z_B| F, \quad v_B = u_B E, \quad j = \kappa E, \quad A = \epsilon C l,$$

$$j_B = v_B c_B |Z_B| F, \quad \Lambda_Y = \frac{\kappa_Y}{C_Y}, \quad \lambda_B = \frac{\kappa_B}{c_B}, \quad \kappa_B = u_B c_B |Z_B| F.$$

1. Answer all three parts, Part A, Part B and Part C.

Part A

- (a) Two aqueous solutions, A and B, of a coloured dye Y were prepared using distilled water as the solvent and was filled to three identical cells with A, B and distilled water then the absorbance of A and B was measured using a double-beam spectrometer with wavelength ν (strongly absorbed by the coloured dye Y), the absorbance values recorded for solution A was 0.25 and solution B was 0.60.
- Which solution has the higher concentration of Y?
 - If solution B is placed in the sample beam and A in the reference beam, what is the approximate value for the absorbance can be recorded?
- (b) (i) Suppose you have a solution of several non-interacting species where there is no complex formation or chemical reaction among the species then write down expression for the absorbance of the solution using Beer-Lambert law and identify all the terms in it.

- (ii) Explain why you have assumed that the chemical species to be non-interacting in the above question Q(1)(b)(i).
- (iii) A mixture contains two non-interacting absorbing species, P and Q. Their molar absorptivity at 425 nm is, $\epsilon_P = 2000 \text{ L mol}^{-1} \text{ cm}^{-1}$ and $\epsilon_Q = 3500 \text{ L mol}^{-1} \text{ cm}^{-1}$. The total absorbance of the mixture at 425 nm, at 25°C. ($l = 1 \text{ cm}$) is 1.85. If the concentration of Q is $2.5 \times 10^{-4} \text{ mol L}^{-1}$, calculate the concentration of P.

(30 marks)

Part B

- (a) Define the
- Electronic energies of a molecule
 - Vibrational energies of a molecule
 - Mixed transition
- (b) The energy components of four molecular energy levels, E_a , E_b , E_c and E_d , are (N1,e2,V5,R10), (N1,e3,V5,R10), (N2,e3,V5,R10) and (N1,e2,V6,R10), respectively. Identify the molecular energy transitions among these levels which involve pure nuclear, pure electronic and pure vibrational transitions.
- (c) A molecule having only five (05) energy levels is identified by two Quantum numbers, (α , β), which are indicated in Figure (1) below. The selection rules in absorption spectroscopy of the molecule are $\Delta\alpha = 0, \pm 1$ and $\Delta\beta = \pm 2$.

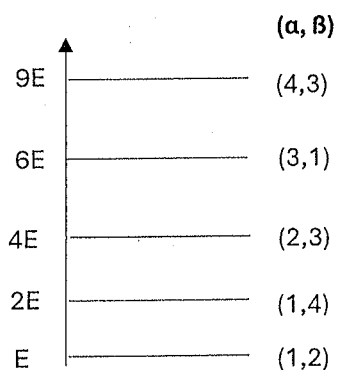


Figure: 1

- According to the selection rules, the maximum number of lines one may observe in the absorption spectrum of a sample of these molecules is three. Indicate them, in the usual form, using the quantum numbers of the upper and lower energy levels involved [i.e. $(\alpha_1, \beta_1) \rightarrow (\alpha_2, \beta_2)$].
- Determine the absorption frequencies, in terms of energy "E".

(40 Marks)

Part C

- (a) Find the positions of the first 5 transitions, which involve the lowest frequency radiation, in the microwave absorption spectrum of H^{35}Cl . Indicate the corresponding transitions. The rotational constant of H^{35}Cl is 10.42 cm^{-1} .
- (b) In the microwave spectrum of gaseous diatomic molecule AB, four consecutive absorption lines appeared at 50.416 cm^{-1} , 75.624 cm^{-1} , 100.832 cm^{-1} and 126.04 cm^{-1} .
- Show that AB behaves as a rigid rotor.
 - Assign each of the above absorption lines to a particular transition.
 - Calculate the equilibrium bond length of AB.
- [Relative atomic masses: A = 27.00; B = 1.00]

(30 Marks)

2.

- a) (i) Consider a chemical reaction occurring at two different temperatures, T_1 and T_2 , whose corresponding rate constants are k_1 and k_2 , respectively. Using the Arrhenius equation show that the activation energy (E_a) of the reaction is given by the equation,

$$E_a = \frac{RT_1T_2 \ln\left(\frac{k_1}{k_2}\right)}{(T_1 - T_2)}$$

What are the assumptions you have made in deriving this equation?

- (ii) Based on the kinetic data obtained from experiments investigating the isomerization of cyclopropane to propene, determine the activation energy of the reaction.

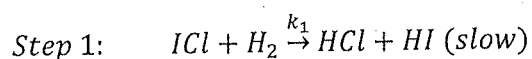
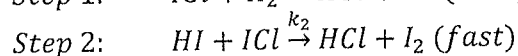


Temperature/ $^{\circ}\text{C}$	204	350
k/s^{-1}	0.00018	0.26

According to the experimental results, it can be seen that the isomerization reaction was carried out at a relatively high temperature. Considering the value of activation energy you calculated above, state why it is necessary to maintain high temperatures for this experiment.

(30 marks)

- b) When iodine monochloride (ICl) reacts with hydrogen gas (H_2) at 400 K, the following multi-step reaction mechanism is observed. Each step is an elementary reaction with its own specific rate constant, as shown below.



- Giving reasons, identify the rate determining step and write the differential form of the rate law for this reaction mechanism.
- Determine the overall order of the reaction between ICl and H₂.
- Identify the intermediate involved in this reaction mechanism.
- Write down the overall balanced equation for the reaction between ICl and H₂.
- Using the given mechanism, show that the steady state concentration of HI is given by:

$$[\text{HI}] = \frac{k_1[\text{H}_2]}{k_2}$$

(30 marks)

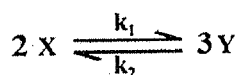
- c) (i) Consider a 1st order elementary reaction of the form $\text{A} \rightarrow \text{P}$. If the initial concentration of A is "a" and after a time interval of "t" the amount of A reacted to form P is "x", show that the rate constant of this reaction "k" is given by,

$$k = \frac{1}{t} \ln \left(\frac{a}{a-x} \right)$$

- (ii) A drug is considered ineffective once it has undergone 30% decomposition. The initial concentration of the drug is 500 units/mL. After 20 months, a sample was analyzed and found to have a concentration of 420 units/mL. Assuming the decomposition follows first-order kinetics, calculate: the rate constant for the decomposition, the expiration time, and the half-life. Assume that the drug was kept at a constant temperature during the study period.

(30 marks)

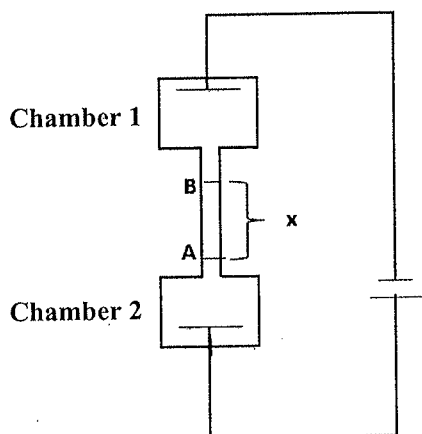
- d) Consider the following elementary reversible reaction and write down the rate equation in terms of $\frac{d[\text{X}]}{dt}$.



(10 marks)

3. Write the answers for both **Part A** and **Part B**.**Part A**

A student performed a moving boundary experiment to determine the ionic mobility of Z^{2+} using a 0.02 mol dm^{-3} solution of ZCl_2 , and the setup is shown below.



The molar conductivity of ZCl_2 solution is $0.20 \text{ S m}^2 \text{ mol}^{-1}$.

In the laboratory, the student had access to following solution: YCl , ZBr_2 and XCl_3 .

The given data are:

- Increasing order of cationic mobility: $Y^+ > Z^{2+} > X^{3+}$.
- Increasing order of solutions densities: $YCl > ZBr_2 > XCl_3 > ZCl_2$

The student selected the most suitable following solution and passed a 3.0 A current through the set up for 20 minutes.

- Determine the conductivity of the ZCl_2 solution in S cm^{-1} ?
- Identify the most suitable following solution from YCl , ZBr_2 , and XCl_3 . Justify your answer.
- Which chamber (1 or 2) should be filled with the following solution? Justify your answer.
- If the boundary moved 20.0 cm through a tube with a cross-sectional area of 0.4 cm^2 , determine the mobility of the Z^{2+} ion (Hint: $u_{Z^{2+}} = \frac{xak}{Q}$)

(60 Marks)

Part B

A student performed a conductimetric titration of 25.00 cm^3 of a weak monoprotic acid, HZ, with $0.020 \text{ mol dm}^{-3}$ NaOH. The equivalence point was reached at a NaOH volume of 20.00 cm^3 . The molar conductivities at infinite dilution are:

$$\lambda_{H^+}^0 = 2.0 \times 10^{-3} \text{ S m}^2 \text{ mol}^{-1}$$

$$\lambda_{Z^-}^0 = 7.0 \times 10^{-3} \text{ S m}^2 \text{ mol}^{-1}$$

Before adding any base, the conductivity of the solution is 0.0432 S m^{-1} .

- (i) Determine the concentration of the weak acid HZ.
- (ii) Determine the molar conductivity of the HZ solution.
- (iii) Express the relationship between the molar conductivity of the HZ (weak acid) and its ionic species. Define all the symbols.
- (iv) Determine the acid dissociation constant (K_a) of the weak acid HZ.

(40 Marks)

4. (a) What do you understand by the following terms?

- (i) Extensive variable.
- (ii) Positive deviation from Raoult's Law.
- (iii) An Azeotrope

(15 Marks)

(b) 10.00 ml of a liquid L [relative molar mass 100 and density 900 kg m^{-3}] is mixed with 25.00 g of a liquid M [relative molar mass = 125]. Assuming that this binary system is fully miscible, calculate the mole fraction of L in the solution.

(10 Marks)

(c) Two liquids, 23.0 g of methylbenzene and 40.0 g of a compound A (assumed to form an ideal mixture with methylbenzene), were mixed together at room temperature. The vapour pressures of pure methylbenzene and pure A at this temperature are 50 torr and 30 torr respectively. Total vapour pressure of the mixture is 42 torr . With the aid of relevant laws and their mathematical expressions and neglecting the amounts that have gone into the gaseous phase,

- (i) Calculate the molar mass of A.
- (ii) Calculate the corresponding composition of the vapour at this temperature.
[Relative atomic masses: H = 1.0, C = 12.0; O = 16.0]

(15 Marks)

(d) The normal boiling points of pure liquids, P and Q, respectively, are 260°C and 300°C . An equimolar mixture of P and Q forms an azeotrope whose normal boiling point is 250°C .

- (i) Sketch a fully labelled Temperature vs Composition (X_P) phase diagram for the above system.
- (ii) What type of deviation from Raoult's law occurred in the above azeotropic mixture?
- (iii) With the aid of above sketch briefly outline the result of carrying out fractional distillation corresponding to a mixture whose composition is
 - (A) The azeotrope
 - (B) Given as mole fraction of P is 0.4.

(30 Marks)

(e) Two metals X and Y (melting point of X = 1100°C ; melting point of Y = 800°C) are said to form a simple eutectic system. The eutectic composition corresponds to a melt containing 6 moles of X and 3 moles of Y. The cooling curve corresponding to the eutectic composition shows a 'halt' at 550°C .

- (i) Sketch a fully labelled phase diagram for the above system.
- (ii) Sketch the fully labelled cooling curve corresponding to 70 mol % of X.

(30 Marks)