The Open University of Sri Lanka

Faculty of Natural Sciences

B.Sc / B. Ed Degree Programme

Department	**: Chemistry**
Level	**: 04**
Name of the Examination	**: Final Examination**
Course Title and Code	**: CYU4302 – Practical Chemistry II**
Academic Year	**: 2024 / 2025**
Date	**: 04. 05. 2025**
Time	**: 9.30 am - 11.30 am**
Duration	**: 2 hours**
Index No.:	**:**

General Instructions

1. Read all the instructions carefully before answering the questions.
2. This question paper consists of **09** pages containing **04** questions.
3. Answer **all four** questions. All questions carry equal marks.
4. Answer for **each question should commence on a new page.**
5. Draw fully labelled diagrams where necessary.
6. Having any unauthorized documents / mobile phones in your possession is a punishable offence.
7. Use blue or black ink to answer the questions.
8. Circle the number of the questions you answered on the front cover of your answer script.
9. Clearly state your index number in your answer script.

01. Answer **both** parts **A** and **B**

A. A student was assigned to determine the density (ρ) of a liquid by measuring its mass (m) and volume (V). The mass of the liquid was recorded as 63.6 g using an electronic balance with a precision of 0.1 g. The volume was measured as 26.50 cm^3 using a burette graduated in 0.1 cm^3 intervals. These measurements were then used to calculate the density of the liquid.

(i) Identify and describe three types of systematic errors that may have affected the measurements in this experiment. **(06 Marks)**

(ii) If the student used the correct measuring techniques, determine the maximum random error in each measurement and justify your answer. **(08 Marks)**

(iii) Calculate the density of the liquid in g cm^{-3} and determine its uncertainty. Express the final density with the correct number of significant figures and indicate its uncertainty in standard notation. **(26 Marks)**

(Hint: $\rho = \frac{m}{V}$; If the relationship is $Y = \frac{a}{b}$ then the expression for the resulting precision is $\left(\frac{\delta Y}{Y}\right)^2 = \left(\frac{\delta a}{a}\right)^2 + \left(\frac{\delta b}{b}\right)^2$

B. In investigating the acid-catalyzed hydrolysis of methyl acetate, a student added 5.00 cm^3 of methyl acetate to 50.00 cm^3 of a 0.5 mol dm^{-3} HCl solution. The hydrolysis reaction was carried out in a water bath at a constant temperature. The student monitored the production of acetic acid by titrating 5.00 cm^3 samples of the reaction mixture with NaOH. The samples were taken at various time intervals, t. The concentration of NaOH used in the titration was 0.25 mol dm^{-3}.

(i) What is meant by the half-draining time of a pipette? **(06 Marks)**

(ii) Briefly explain why the reaction start time should be considered as $t_0 + t_{1/2}$ instead of just t_0? **(10 Marks)**

Here, t_0 refers to the time when methyl acetate begins draining from the pipette (which could be zero), and $t_{1/2}$ is the time after half of the contents in the pipette have been drained.

(iii) State the purpose of adding the pipetted-out reaction mixture at time t into ice-cold water and explain why it is important to titrate it quickly with sodium hydroxide solution. **(10 Marks)**

(iv) The student recorded the data and plotted a graph based on the following equation.

$$t = -\frac{2.303}{k} log\,(V_\infty - V_t) + \frac{2.303}{k} log(V_\infty - V_0)$$

Based on the graph, the student found that the value of the gradient is -26200 s. One of the coordinates used to calculate the gradient is (720 s, 1.230).

a. Identify all the terms in the above equation **(08 Marks)**

b. Calculate the rate constant for the hydrolysis of methyl acetate under the experimental conditions. **(06 Marks)**

c. Calculate V_0. State any assumption/s you make. **(11 Marks)**

d. Calculate V_∞. **(09 Marks)**

02. Answer **only two parts** from A, B, and C

A. Potassium hydrogen tartrate (KHT) is a sparingly soluble salt. A student was tasked with determining its thermodynamic solubility product, K_T, at 25 °C.

(i) Write the balanced chemical equation for the dissociation of KHT in water. **(05 Marks)**

(ii) Describe an experimental procedure (not expecting calculation steps) that the student can follow to determine K_T of KHT at 25 °C. **(09 Marks)**

(iii) Part of the experimental results obtained are shown in the table below. The table shows the volume of titrant required to neutralize 10.00 cm^3 of HT^-. The concentration of the titrant is 0.04 M.

Conical flask No:	Initial burette reading (cm^3) (± 0.05 cm^3)	Final burette reading (cm^3) (± 0.05 cm^3)	Consumed volume of titrant (cm^3)
01 (Distilled water only)	0.00	8.00	8.00
02. (0.5 M Na_2SO_4)	0.00	15.00	15.00

The thermodynamic solubility product (K_T) was determined using a graph plotted from titration data. Using the titration data provided, determine the x and y coordinates for conical flasks 1 and 2, respectively. **(36 Marks)**

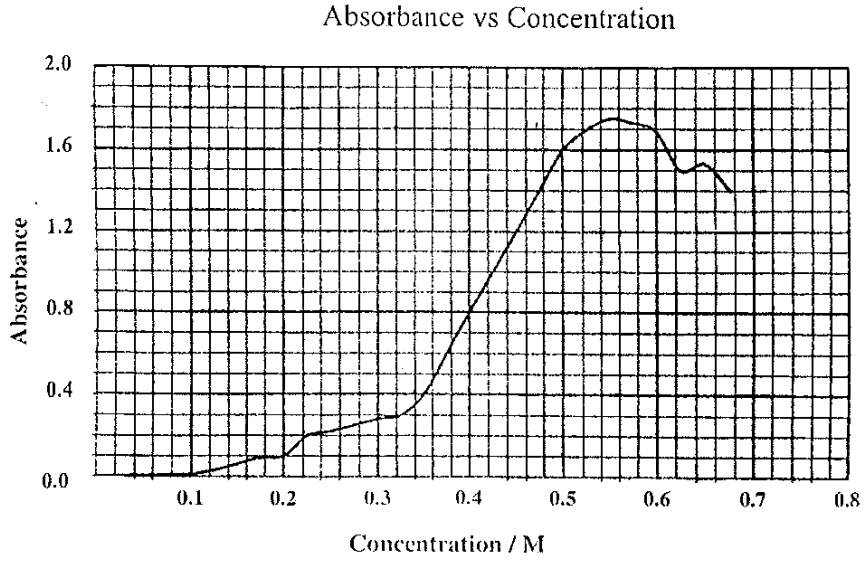
Hint 1: The equation for the corresponding graph is given by:

$$log_{10}(K_c) = 2\left[\frac{0.509\sqrt{I}}{1 + 1.25\sqrt{I}}\right] + log_{10}(K_T)$$

Hint 2: The equation for Ionic Strength.

$$I = \frac{1}{2}\Sigma_{i=1}^{n} C_i Z_i^2$$

B. A student was asked to determine the range of validity of the Beer-Lambert law for an aqueous Co^{2+} solution. First, using a known concentration of Co^{2+} solution, the student identified the wavelength (λ_o) at which the sensitivity of the spectrometer is maximum for Co^{2+}. Then, the student measured the absorbance of Co^{2+} at λ_o for a series of solutions with varying concentrations. The path length of the cuvette used was 1.5 cm. Based on the results, the student plotted a graph of absorbance versus concentration, which is provided below.



(i) What do you understand by the phrase "the wavelength (λ_o) at which the sensitivity of the spectrometer is maximum for Co^{2+}"? **(05 Marks)**

(ii) If Na^- is added to the solution instead of Co^{2+} and the absorbance is measured at the same wavelength (λ_0), what would you observe in the absorbance reading? Explain your answer. **(10 Marks)**

(iii) Write down the Beer-Lambert law and identify all the parameters in it. **(09 Marks)**

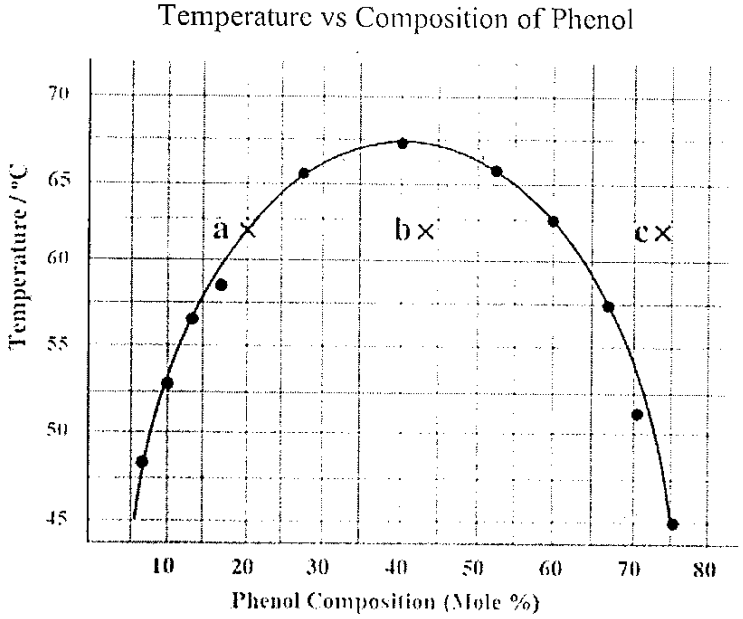
(iv) Estimate the range of validity of Beer-Lambert law for Co^{2+} using the above graph. Briefly explain your answer. **(06 Marks)**

(v) Determine the molar extinction coefficient of Co^{2+} at wavelength λ_o. **(08 Marks)**

(vi) Given below is the equation for calculating error for the gradient of a linear graph. Estimate the error of your calculated value. **(12 Marks)**

$$\left(\frac{\delta m}{m}\right)^2 = \left(\frac{1}{x_2 - x_1}\right)^2 ((\delta x_1)^2 + (\delta x_2)^2) + \left(\frac{1}{y_2 - y_1}\right)^2 ((\delta y_1)^2 + (\delta y_2)^2)$$

C. A student wanted to find the upper critical solution temperature (Tcs) of the phenol-water system. He first prepared a mixture of phenol and water and heated it to find the temperature at which the turbidity disappeared. Then, he added more water to the mixture and recorded the new temperature where turbidity disappeared. This process was repeated several times to collect enough data. Using these results, the student created the phase diagram for the phenol-water system, shown below.



(i) Explain the role of the Tcs in determining phase separation and determine its approximate value. **(11 Marks)**

(ii) Describe what happens to a mixture with 30% phenol at 50 °C. Will it exist as a single phase or two separate phases? **(05 Marks)**

(iii) If a 60% phenol mixture is gradually heated from 50 °C to 75 °C, describe the phase changes it undergoes. **(09 Marks)**

(iv) Calculate the volume of phenol and water of an equimolar mixture. Where the amount of phenol is 0.25 mol in an equimolar mixture. **(15 Marks)**

(Phenol: density = 1.071 g cm^{-3}; molar mass = 94.0 g mol^{-1} /
Water: density = 1.00 g cm^{-3}; molar mass = 18.0 g mol^{-1})

(v) Give the number of phases, components, and degrees of freedom for the points a, b, and c on the phase diagram. **(10 Marks)**

03. (a) i. Write three different properties of the solvents used for liquid-liquid extraction process.

ii. Hyoscyamine is an alkaloid, which is used medicinally to provide relief for a variety of gastrointestinal disorders. Its solubility data are as follows.

Solubility in 20°C water: 0.354 g / 100 mL solvent

Solubility in 20°C diethyl ether: 1.44 g / 100 mL solvent

Calculate the distribution ratio (K_d) of hyoscyamine between water and diethyl ether.

iii. A nearly saturated solution of 0.25 g of hyoscyamine in 150 mL water is extracted into 150 mL of diethyl ether. Calculate the amount of hyoscyamine extracted into the diethyl ether layer in this process.

iv. Instead of using 150 mL diethyl ether at once, the above extraction is carried out using two 75 mL portions of diethyl ether. How much hyoscyamine would be extracted into diethyl ether with this method?

vi. From the above two extraction processes, which method is more efficient to extract hyoscyamine to diethyl ether?

(60 Marks)

(b) i. You have been given an impure benzoic acid sample, and you are asked to purify it to use for a specific organic reaction.

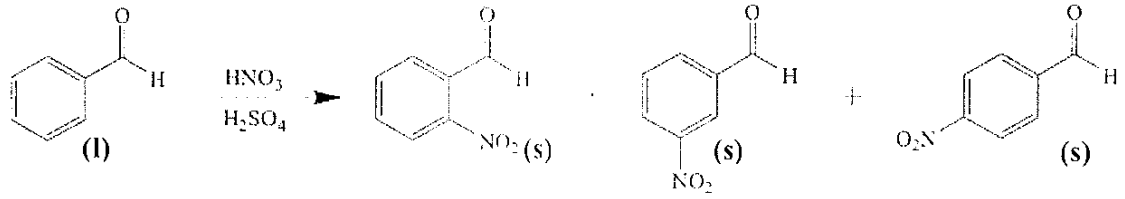
A) What is the best method you will use to purify this benzoic acid sample?

B) How would you purify benzoic acid using this method?

ii. What is meant by "drying of solutions" in organic synthesis?

(25 Marks)

(c) The nitration of benzaldehyde is expected to give 3-nitrobenzaldehyde solid. However, sometimes it may undergo the following reaction.



Benzaldehyde | 2-Nitrobenzaldehyde mp 42-44°C | 3-Nitrobenzaldehyde mp 55-58°C | 4-Nitrobenzaldehyde mp 103-106°C

Briefly explain how you would confirm the formation of 3-nitrobenzaldehyde as the only product in nitration of benzaldehyde reaction.

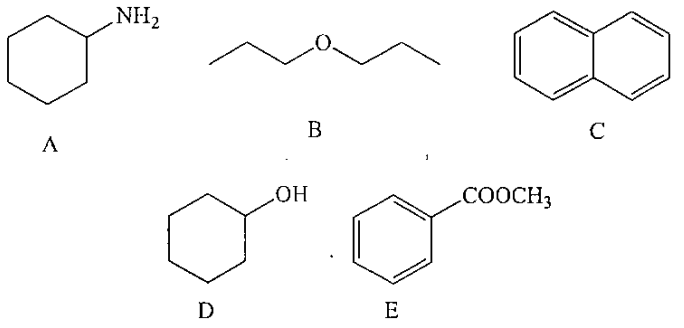
(15 Marks)

04. Answer the following questions about TLC (Thin Layer Chromatography) analysis.

(60 Marks)

(a) i. Why must you only use pencil to mark the TLC plates, not pen?

ii. Arrange the following compounds, in order of increasing R_f in TLC. (stationary and the mobile phases are the same for each compound).



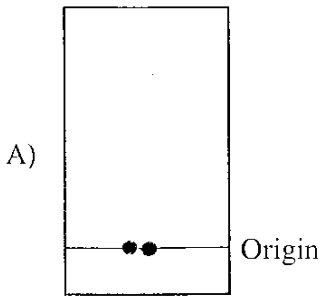
A B C D E

iii. It is suspected a commercial food coloring contains a banned coloring.

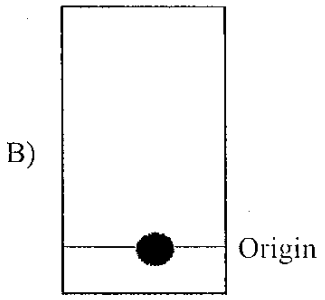
A) Suggest a suitable technique to check the presence of banned coloring in the commercial food coloring.

B) Draw a labelled diagram to show the experimental setup for this TLC analysis.

iv. Following are some common errors students do when they run TLCs for their experiments. Mention what do you expect after running each TLC for the given incidents?



Spots too close together



Spot too concentrated or too broad

v. Suppose you need to separate the compounds X and Y in a mixture. Which solvent would be better for separation of X and Y and why?

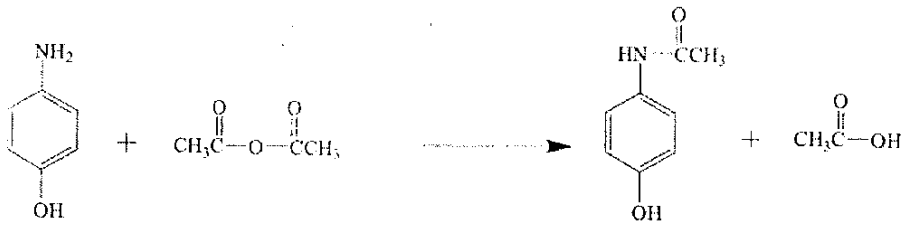
Solvent	X_{Rf}	Y_{Rf}
Dichloromethane	0.80	0.75
Hexane	0.55	0.28

vi. Assume you analyze a reaction mixture by TLC technique using a hexane: ethyl acetate (1:1) mixture as the mobile phase. TLC shows only one spot with $R_f = 0.97$.

A) Does it mean that the given mixture contains only one component?

B) What changes would you do specifically in the mobile phase to obtain more accurate information about the contents of the mixture?

(b) p-aminophenol (2.1 g) is reacted with acetic anhydride (2.0 mL) to synthesize acetaminophen and the reaction for this synthesis is given below.



	p-aminophenol	acetic anhydride	acetaminophen
MW	109.1 g/mol	102.2 g/mol	151.2 g/mol
Density	1.13 g/mL	1.08 g/mL	

i. Calculate the limiting reagent and the theoretical yield for the reaction.

ii. If the experimental yield is 2.16 g, calculate the percentage yield of acetaminophen.

(30 Marks)

(c) What is the most common apparatus for carrying out liquid-liquid extractions in organic chemistry? Draw a labelled diagram of this apparatus.

(10 Marks)

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