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 Code and Title	: **CYU4302 – Practical Chemistry II**
Academic Year	: 2020/2021
Date	: 31 -03-2022
Time	: 1.30 p.m. – 3.30 p.m.
Duration	: 02 hours
Index number	:

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **06** pages containing **04** questions.
3. Answer **all four** questions. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Draw fully labelled diagrams where necessary.
5. Relevant log tables are provided where necessary.
6. Having any unauthorized documents/ mobile phones in your possession is a punishable offense.
7. Use blue or black ink to answer the questions.
8. Circle the number of the questions you answered in the front cover of your answer script.
9. Clearly state your index number in your answer script.

Values of some physical constants are given below.

Gas constant (R)	=	$8.314\ \mathrm{J\,K^{-1}\,mol^{-1}}$
Avogadro constant (N_A)	=	$6.023\times10^{23}\ \mathrm{mol^{-1}}$
Faraday constant (F)	=	$96{,}500\ \mathrm{C\,mol^{-1}}$
Planck constant (h)	=	$6.63\times10^{-34}\ \mathrm{J\,s}$
Velocity of light (c)	=	$3.0\times10^{8}\ \mathrm{m\,s^{-1}}$
Standard atmospheric pressure	=	$10^{5}\ \mathrm{Pa}\left(\mathrm{N\,m^{-2}}\right)$
π	=	3.14159
$\mathrm{Log}_e(X)$	=	$2.303\ \mathrm{Log}_{10}(X)$

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

For $V = abc$; $$\left(\frac{\delta V}{V}\right)^2 = \left(\frac{\delta a}{a}\right)^2 + \left(\frac{\delta b}{b}\right)^2 + \left(\frac{\delta c}{c}\right)^2$$

$$-\frac{d[A]}{dt} = k \qquad [A] = -kt + \text{constant} \qquad A = -\log_{10}\left(\frac{I}{I_0}\right) = \varepsilon C l$$

$$\Lambda_Y = \frac{\kappa_Y}{C_Y} \qquad \Lambda_{MX} = \lambda_{M^{Z+}} + \lambda_{X^{Z-}} \qquad \log_{10}(\gamma_\pm) = -\frac{A\left|Z_+Z_-\right|\sqrt{I}}{1 + aB\sqrt{I}}$$

1. (a) i. Define the error in an experimentally determined value of a physical quantity.
ii. Briefly explain why the error cannot be determined exactly.

(b) A student was asked to determine the volume of a given match box. He determined its length, width and height using a ruler whose smallest graduation is 1 mm. His readings were 2.5 cm, 1.8 cm and 1.4 cm respectively.

i. List the three types of systematic errors involved in the above-mentioned experiment.
ii. Giving reasons state the maximum random error the student may have made in each of his measurements if he was using the correct technique in measuring using a ruler.
iii. Calculate the volume of the match box and error. State the volume to the correct number of significant figures and indicate its uncertainty (in standard form).
Hint: For $y = a \times b \times c$

$$\left(\frac{\delta y}{y}\right)^2 = \left(\frac{\delta a}{a}\right)^2 + \left(\frac{\delta b}{b}\right)^2 + \left(\frac{\delta c}{c}\right)^2$$

(50 marks)

(c) Answer **either** Part A or Part B (but **NOT** both).

Part A

A student conducted a weak monobasic acid (HX) - strong base (BOH) titration using pH measurements. To determine the end point, he measured the pH (of the reaction mixture) after the addition of known volumes of titrant. The volume of titrant used was 30.00 cm^3 and its concentration was 0.10 mol dm^{-3}. The values pH vs. Volume of the titrant in the plot is as follows.

Volume of the titrant/ cm^3	**pH**
12.10	5.0 (half end point)
24.20	7.5 (end point)
48.40	9.5

i. Sketch the full plot, pH vs. the volume of titrant added.
ii. Giving reasons state whether the titrant is acid or base.
iii. Determine the concentration of analyte or titrand.
iv. Determine the dissociation constant, K of the acid at the temperature the experiment was performed. Briefly explain your answer.

Part B

KHT is a sparingly soluble salt which dissociates as $KHT_{(s)} \longrightarrow K^+_{(aq)} + HT^-_{(aq)}$.
A student was asked to determine its thermodynamic solubility product at 25 °C.
i. Write down the definition of the concentration solubility product, K_c, of KHT and identify all the terms in it.
ii. Write down the definition of the thermodynamic solubility product, K_T, of KHT and identify all the terms in it.
iii. Derive a relationship between K_C and K_T.

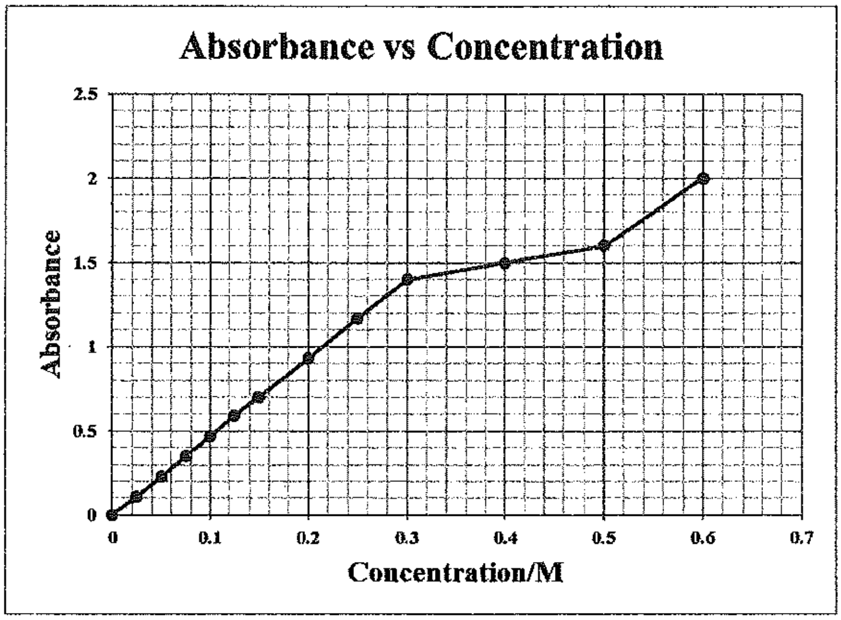
iv. Give the definition of the ionic strength, I, of a solution and identify all the terms in it.

v. Write down a relationship among K_C and K_T of KHT and the ionic strength of the solution.

vi. Outline an experiment (experimental details are **NOT** necessary) the student can conduct to determine K_T of KHT at 25 °C.

(50 marks)

2. (a) In an experiment to understand the use of Beer-Lamber law, a student measured the absorbance of an ionic species in a series of aqueous solutions of different concentrations at 25 °C. using a 1 cm path length of radiation. In recording the absorbance, he used the same sample cell and radiation of the same frequency. The plot he made using his readings is shown below.



i. Write a correct expression in standard notation for the Beer–Lamber law and define all the terms.

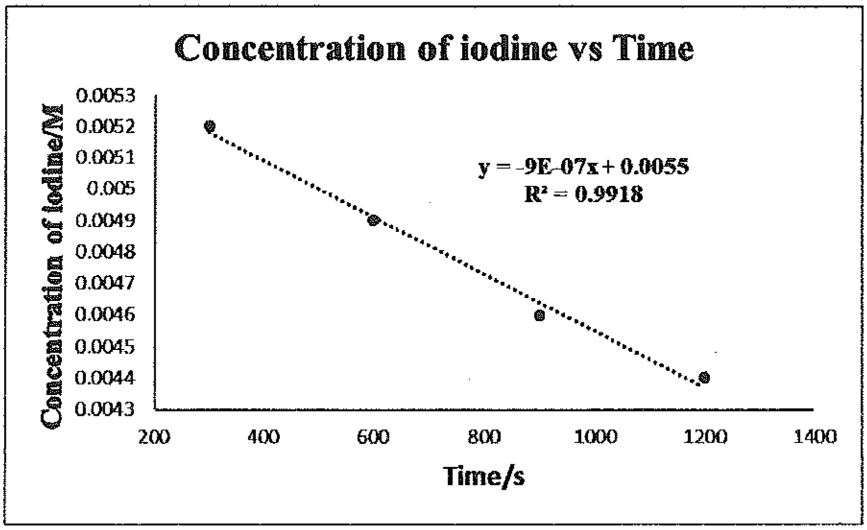
ii. What is the largest concentration range where Beer–Lamber law is applicable for this ionic species?

iii. Calculate the molar absorption coefficient of the ionic species.

iv. He measured the absorbance of an unknown solution of this ionic species and found that it was 0.75. Calculate/Estimate the concentration of the unknown solution.

(50 marks)

(b) In studying the kinetics of acid catalyzed iodination of acetone, a student placed 5.00 cm^3 of acetone, 10.00 cm^3 of 1.0 M HCl and 75.00 $cm^3$of distilled water in a stoppered bottle. Then he added 10.00 $cm^3$of 0.05 M iodine solution into the above mixture. After every 5 minutes after the commencement of the reaction, 10.00 cm^3 of the reaction mixture was transferred into 10 $cm^3$of sodium bicarbonate solution, shaken well and then titrated with 0.01 M sodium thiosulphate solution to determine the concentration of iodine in the mixture. The above procedure was repeated to obtain 4 concentration readings at 5 minutes time intervals. After that he plotted the concentration of iodine vs. time and obtained a graph as shown below.



The reaction between acetone and iodine and the reaction between iodine solution and sodium thiosulphate are shown below.

$$CH_3COCH_3 + I_3^- \xrightarrow{H^+(catalyst)} CH_3COCH_2I + H^+ + 2I^-$$

$$2Na_2S_2O_3 + I_3^- \longrightarrow Na_2S_4O_6 + 2NaI + I^-$$

i. If the volume of sodium thiosulphate spent at 5 min (300 s) is 10.40 cm^3, show that the molarity of iodine, $[I_3^-]$ in the mixture is $\mathbf{5.2 \times 10^{-3}}$ $\boldsymbol{M}$.

ii. Why do you have to add the reaction mixture into a sodium bicarbonate solution and shake well before you titrate it with sodium thiosulphate solution?

iii. The general rate equation for the reduction of $[I_3^-]$ of this system may be written as

$$\frac{-d[I_3^-]}{dt} = k[CH_3COCH_3]^p[I_3^-]^q[H^+]^r$$

Here, p, q and r are orders with respect to CH_3COCH_3, I_3^- and H^+ respectively. If you perform the experiment with excess acetone and acid, and the order with respect to iodine is zero, show that $[I_3^-]_t = -k^*t + [I_3^-]_0$. Here k^* is pseudo rate constant, $[I_3^-]_t$ is iodine concentration at any time t and $[I_3^-]_0$ is iodine concentration at the beginning of the reaction.

iv. Using the information given in the graph find the pseudo rate constant k^* for this reaction and concentration of iodine at t = 0, $[I_3^-]_0$.

(50 marks)

3. (a) A sample of solid **P** (100.0 g) is contaminated with an impurity **Q** (2%).

i. Calculate the amount of **P** present in the sample.

ii. Calculate the minimum volume of water required to dissolve the sample **P**. (Solubility of **P** and **Q** at 100 °C are 15.0 g and 2.5 g per 100.0 mL of water respectively.)

iii. Suppose a student recrystallized this sample using 700.0 mL of water. Calculate the amount of **P**, recrystallized. (Solubility of **P** and **Q** at room temperature are 1.0 g and 0.5 g per 100.0 mL of water respectively.)

iv. Find out the number of recrystallization cycles needed to remove the impurity **Q** completely.

v. Calculate the percentage loss of **P** in using 700.0 mL of water instead of using the minimum volume.

(60 marks)

(b) It was found that a sample of salicylic acid found in the laboratory is contaminated with an impurity (5%).

i. Describe the melting behavior of this contaminated salicylic acid sample. The melting point of pure salicylic acid is 158.5 °C.
ii. Suppose the contaminated sample was purified by recrystallization. Outline a method using melting point technique to prove that you have obtained pure salicylic acid. Assume that pure salicylic acid is available in the lab. *(Experimental details are not necessary).*

(25 marks)

(c) Answer either Part A or Part B (but **NOT** both).

Part A

Filtration performed in recrystallization is called 'hot filtration' (hot gravity filtration). List down three steps you would follow to make the 'hot filtration' more efficient.

Part B

Draw a completely labelled diagram of the experimental set up used for suction filtration.

(15 marks)

4. (a) A sample of aspirin (2.0 g), was extracted into 30 mL of diethyl ether from an aqueous solution (250 mL).

i. Prepare a list of items needed to carry out this extraction.
ii. The partition coefficient of aspirin between water and diethyl ether is 40. Calculate the weight of aspirin extracted into diethyl ether.
iii. Suppose the extraction was done using **two** 15 mL portions of diethyl ether. The weight of aspirin extracted into diethyl ether during the first and second extractions are X_1 and X_2 respectively.
Write expressions to calculate the amount of aspirin extracted during each extraction in terms of X_1 and X_2. *(Calculation of X_1 and X_2 is not necessary).*

(40 marks)

(b) Suppose a mixture of benzoic acid and benzaldehyde is provided to you. Outline a method to separate the two compounds. Indicate the purification method that you would use to purify each compound. Melting point of benzoic acid is 121 °C and boiling point of benzaldehyde is 178 °C. *(Experimental details are not necessary)*

(30 marks)

(c) A commercial sample of turmeric powder is suspected to be adulterated with the food colorant 'metanil yellow'. Assuming that pure 'metanil yellow' is available in the laboratory, describe a method to show the presence or absence of the adulterant in the sample. Support your answer with relevant diagrams.

(30 marks)

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