අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2023 (2024)
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2023 (2024)
General Certificate of Education (Adv. Level) Examination, 2023 (2024)

රසායන විද්‍යාව	II
இரசாயனவியல்	II
Chemistry	II

02 E II

* Universal gas constant $R = 8.314\ J\ K^{-1}\ mol^{-1}$
* Avogadro constant $N_A = 6.022 \times 10^{23}\ mol^{-1}$

PART B — ESSAY

*Answer **two** questions only. (Each question carries **150** marks.)*

5. (*a*) CaO(s) reacts with water as shown below.

$$CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(s)\ \Delta H^\circ = -64\ kJ\ mol^{-1}$$

The following questions are based on the reaction given above.

(i) When 200 g of $H_2O(l)$ was reacted with a certain mass of CaO(s), the temperature of water changed from 25 °C to 75 °C. Calculate the amount of heat (in kJ) absorbed by water. Specific heat capacity of water is $4.2\ J\ g^{-1}\ °C^{-1}$.
(**Note**: Disregard the change in the mass of water due to the formation of $Ca(OH)_2$.)

(ii) What is the minimum mass of CaO(s) needed to make the temperature change that occurred in (i) above? (O = 16, Ca = 40)

(iii) Standard entropy values of CaO(s), $H_2O(l)$ and $Ca(OH)_2(s)$ are 40, 70 and 80 $J\ K^{-1}\ mol^{-1}$ respectively. Calculate the entropy change of the reaction.

(iv) Predict the spontaneity of the reaction at 300 K. State any assumptions made.

(v) Predict the spontaneity of the reaction at 400 K if steam ($H_2O(g)$) is used instead of liquid water.

$$H_2O(g) \longrightarrow H_2O(l)\ \Delta H^\circ = -44\ kJ\ mol^{-1}$$
$$S^\circ_{H_2O(g)} = 190\ J\ K^{-1}\ mol^{-1}$$

(80 *marks*)

(*b*) (i) At temperature 570 °C, the equilibrium given below exists in a closed rigid container.

$$Ca(OH)_2(s) \rightleftharpoons CaO(s) + H_2O(g)$$

The pressure of the container was found to be 7.0×10^5 Pa.
Calculate K_P and K_C for the reaction at the temperature 570 °C (at 570 °C, RT = 7000 $J\ mol^{-1}$).

(ii) Giving reasons briefly explain the effect on the equilibrium in (*b*)(i) above when the following changes are done.

I. When $Ca(OH)_2(s)$ is added.

II. When some amount of $H_2O(g)$ is removed.

(iii) To determine the relationship between the pressure of the water vapour produced (P_{H_2O}) and the mass of $Ca(OH)_2(s)$ introduced into the container ($M_{Ca(OH)_2}$), the pressure was measured introducing small quantities of $Ca(OH)_2(s)$ into an evacuated rigid container at 570 °C. Draw the expected graph for the variation of P_{H_2O} with $M_{Ca(OH)_2}$ and briefly describe it.

(40 *marks*)

(*c*) (i) Write the reversible reaction for the dissolution of $Ca(OH)_2(s)$ in water at temperature 25 °C.

(ii) At temperature 25 °C the solubility product (K_{sp}) of $Ca(OH)_2(s)$ is $4.0 \times 10^{-6}\ mol^3\ dm^{-9}$. Calculate the molar solubility of $Ca(OH)_2(s)$ at this temperature.

(iii) State giving reasons whether the solubility of $Ca(OH)_2(s)$ will be higher, lower or the same in aqueous solutions of NaOH, NaCl and $Ca(NO_3)_2$ (concentrations of solutions 0.1 mol dm^{-3}) when compared with the solubility of $Ca(OH)_2(s)$ in water. **(30 *marks*)**

[*see page ten*

6. (*a*) At 25 °C the methanoate ion, $HCOO^-(aq)$ reacts with water to form methanoic acid, HCOOH(aq) and $OH^-(aq)$ as shown below.

$$HCOO^-(aq) + H_2O(l) \rightleftharpoons HCOOH(aq) + OH^-(aq)$$

(i) Given that $[OH^-(aq)] = 1.0 \times 10^{-6}$ mol dm^{-3} in a solution prepared by dissolving 0.10 mol of HCO_2Na in 1.0 dm^3 of water, calculate the following at 25 °C.

I. The value of K_b of methanoate ion.

II. The value of K_a of methanoic acid.

($K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6} at 25 °C)

(ii) Calculate the pH of a methanoic acid solution of concentration 0.10 mol dm^{-3}.

(iii) When 3.40 g of HCO_2Na was dissolved in 50.00 cm^3 of 0.10 mol dm^{-3} HCOOH(aq) solution, it was observed that there was no change in volume.
(H = 1, C = 12, O = 16, Na = 23)

I. Determine the pH of this solution.

II. Explain how this solution acts as a buffer solution. **(80 *marks*)**

(*b*) (i) This question is in respect of a solution that could be made by mixing two completely miscible liquids **A** and **B**. Copy the following table on to your answer script and fill in the blanks. Different types of solutions (ideal, non-ideal/positive deviation, non-ideal/negative deviation) that could be made are given in the table.

While the mole fractions of **A** and **B** in the solution are X_A and X_B, and the vapour pressures of **A** and **B** at a given temperature are P_A and P_B respectively.

The saturated vapour pressures of **A** and **B** at this temperature are P_A^o and P_B^o respectively.

Intermolecular forces between **A** and **A**, **B** and **B** and **A** and **B** are f_{A-A}, f_{B-B} and f_{A-B} respectively.

Property	Ideal solution	Non-ideal solution	
		Positive deviation from Raoults law	Negative deviation from Raoults law
ΔH of mixing			
relationship among f_{A-A}, f_{B-B} and f_{A-B}			
relationship among P_A^o, P_A and X_A			

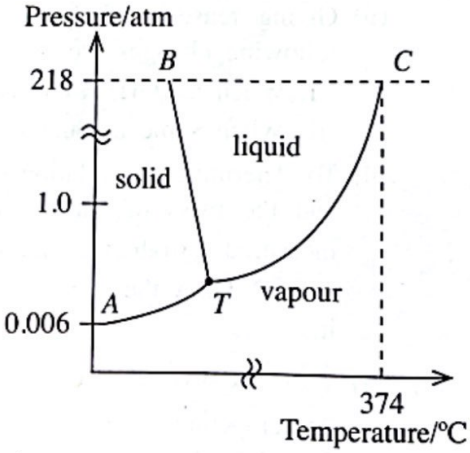
(ii) The phase diagram of pure water is given below.

Copy the diagram on to your answer script and answer the following questions.

I. Mark the normal boiling point (V) and melting point (L) of pure water.

II. What are represented by lines BT, TC and point T?

III. Assume that a small amount of salt (NaCl) is added to the pure water sample. After the addition of salt, positions of the lines BT and TC in the phase diagram were changed. Their new positions are $B'T'$ and $T'C'$ respectively. Draw their new positions on the phase diagram you have copied and label them as $B'T'$ and $T'C'$. Mark the new boiling point (V') and the new melting point (L') on the phase diagram.



(70 *marks*)

[*see page eleven*

7. (*a*) A Daniel cell consists of Zn and Cu rods immersed in $ZnSO_4$(aq, 1.0 mol dm^{-3}) and $CuSO_4$(aq, 1.0 mol dm^{-3}) respectively. The solutions are separated by a porous membrane. The overall cell reaction when the cell is operating is given below.

$$Zn(s) + Cu^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Cu(s)$$

(i) Identify the anode and the cathode.

(ii) Write the anodic half reaction of the cell.

(iii) Write the cathodic half reaction of the cell.

(iv) Give the cell notation of the cell above.

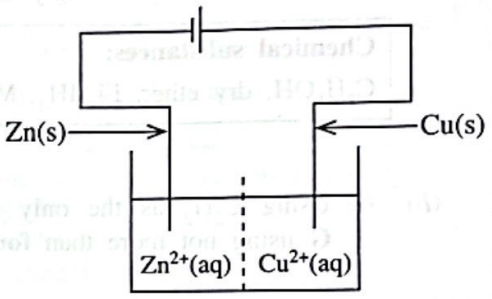
(v) Calculate the electromotive force (E°_{cell}) of the Daniel cell given above at 25 °C.
$E^{\circ}_{Cu^{2+}(aq)/Cu(s)} = 0.34$ V $\quad E^{\circ}_{Zn^{2+}(aq)/Zn(s)} = -0.76$ V

(vi) Calculate the time in seconds required to deposit 3.175 g of Cu(s) when a current of 5.0 A flows through the cell. (Cu = 63.5, 1 F = 96500 C mol^{-1})

(vii) How does the conductivity of the solution in the cell compartment containing the Zn-rod change when a current is drawn from the cell? Explain giving reasons.

(viii) It was observed that when a current is drawn from the cell, the intensity of the colour of the solution in the cell compartment containing the Cu-rod changes. Explain this observation.

(ix) As shown in the diagram, an external voltage higher than the calculated electromotive force in (v) above, was applied to the Daniel cell using another electrochemical cell. Write the overall cell reaction of the Daniel cell under this condition.



(75 *marks*)

(*b*) **A**, **B**, **C** and **D** are coordination compounds of iron with an octahedral geometry. The molecular formulae of the compounds are (**not in order**) $FeH_{14}N_2O_4Br_3$, $FeH_{15}N_5Br_2$, $FeKH_4O_2Br_4$ and $FeH_{15}N_3O_3Br_2$.

In each compound **two** types of ligands are coordinated to the metal ion.

Compound **A** : Gives three ions in aqueous solution. When $AgNO_3$(aq) is added to an aqueous solution of **A**, two moles of a yellow precipitate are formed per mole of **A**.

Compound **B** : Gives four ions in aqueous solution. When $AgNO_3$(aq) is added to an aqueous solution of **B**, three moles of a yellow precipitate are formed per mole of **B**.

Compound **C** : Gives two ions in aqueous solution. When $AgNO_3$(aq) is added to an aqueous solution of **C** one mole of a yellow precipitate is formed per mole of **C**.

Compound **D** : Gives two ions in aqueous solution. A yellow precipitate is not formed when $AgNO_3$(aq) is added to an aqueous solution of **D**.

(i) What are the common oxidation states of iron (Fe)?

(ii) Identify the yellow precipitate. (Give chemical formula.) Name a chemical reagent that can dissolve this precipitate.

(iii) Identify the ligands coordinated to the metal ion in each compound **A**, **B**, **C** and **D**.

(iv) In each of the compounds **A**, **B**, **C** and **D**,

I. write the oxidation state of iron.

II. write the electronic configuration of iron.

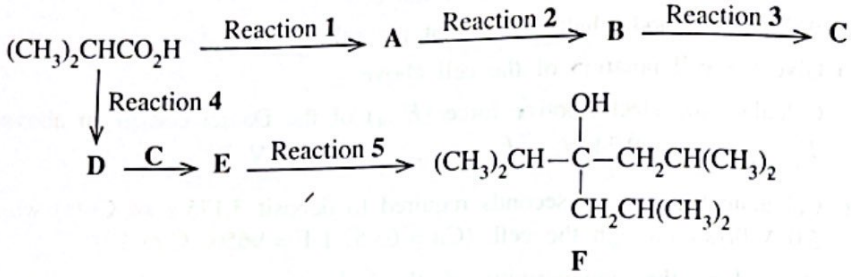
(v) Give the structures of **A**, **B**, **C** and **D**. **(75 *marks*)**

[*see page twelve*

PART C — ESSAY

Answer two questions only. (Each question carries **150** *marks.)*

8. (*a*) $(CH_3)_2CHCO_2H$ has been converted to compound **F** by using the reaction scheme given below.



F

Complete the above reaction scheme by giving the structures of compounds **A**, **B**, **C**, **D** and **E** and the reagents required for the reactions **1** - **5**. Only the chemical substances given below should be used (either singly or as combinations) as reagents.

Chemical substances:
C_2H_5OH, dry ether, $LiAlH_4$, Mg, PBr_3, conc. H_2SO_4, dil. H_2SO_4

(45 ***marks*****)**

(*b*) (i) Using C_2H_2 as the only starting compound, show how you would prepare compound **G** using not more than **four (04)** steps.

$$CH_3CH_2{-}C{\equiv}CH$$

G

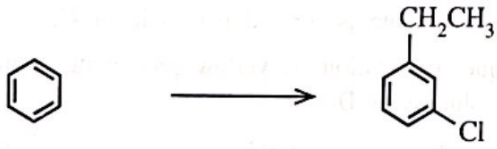
(ii) Give the structure of the compound **H** which is formed when compound **G** is reacted with excess Cl_2.

(30 ***marks*****)**

(*c*) Write the product and the mechanism of the reaction of benzene with conc. HNO_3/conc. H_2SO_4.

(25 ***marks*****)**

(*d*) Show how you would carry out each of the following conversions in not more than **three (03)** steps.

(i) 

(ii) $CH_3CH(OH)CH_3 \longrightarrow CH_3CH_2CH_2OH$

(50 ***marks*****)**

[*see page thirteen*

9. (*a*) (i) Aqueous solutions of compounds $MgSO_4$, NaOH, $BaCl_2$, Na_2SO_4 and $Zn(NO_3)_2$ are contained in five 100 cm^3 beakers labelled **A**, **B**, **C**, **D** and **E** (**not in order**). Identify **A**, **B**, **C**, **D** and **E** based on the observations given below. (Reasons **not** required.)

Note : Small portions of the solutions are mixed in test tubes.

On mixing **D** and **E** a white precipitate is formed. When excess **E** is added to the precipitate, the precipitate dissolves giving a colourless solution. A white precipitate is formed when **E** is added to **C**. Precipitates are not formed when **E** is added to **A** and when **E** is added to **B**. On mixing **A** and **B** a white precipitate is formed. When **C** is added to **A**, a white precipitate is formed. However, a precipitate is not formed when **C** is added to **B**.

(25 *marks*)

(ii) An aqueous solution **M** contains **three** cations. The following tests (1-5) were carried out to identify these cations.

Test No.	Test	Observation
1	Dilute HCl was added to solution **M**.	A white precipitate (P_1)
2	P_1 was separated by filtration and H_2S was bubbled through the solution.	No precipitate
3	The solution was boiled until all the H_2S was removed and then cooled. NH_4Cl/NH_4OH was added.	No precipitate
4	H_2S was bubbled through this solution.	A pale pink precipitate (P_2)
5	P_2 was separated by filtration and the solution was boiled until all the H_2S was removed. $(NH_4)_2CO_3$ solution was added.	A white precipitate (P_3)

The following tests were carried out for the precipitates P_1, P_2 and P_3.

Precipitate	Test	Observation
P_1	Dilute ammonia solution was added to P_1.	P_1 dissolved.
P_2	P_2 was dissolved in dil. HNO_3 and excess dilute NaOH was added to the solution.	A white precipitate which turns brown on standing
P_3	P_3 was dissolved in conc. HCl and the solution was subjected to the flame test.	A green colour flame

I. Identify the **three** cations in solution **M**. (Reasons **not** required.)

II. Write the chemical formulae of the precipitates P_1, P_2 and P_3. **(24 *marks*)**

(iii) **X**, **Y** and **Z** are ionic solids. Sodium is the cation in all three compounds. The following tests were carried out to identify the anions in **X**, **Y** and **Z**.

Test No.	Test	Observation
1	(i) A portion of **X** was dissolved in water in a test tube.	A colourless solution
	(ii) $Pb(CH_3COO)_2$ solution was added to the colourless solution.	A yellow precipitate
	(iii) The resulting mixture (yellow precipitate and solution) was heated.	The precipitate dissolved giving a colourless solution.
	(iv) This colourless solution was cooled.	A yellow precipitate (as golden yellow plates)

[*see page fourteen*

2	(i) A portion of **Y** was dissolved in water in a test tube.	A colourless solution
	(ii) A $BaCl_2$ solution was added to the colourless solution.	A white precipitate
	(iii) Dilute HCl was added to the resulting mixture (white precipitate and solution).	A clear colourless solution with the evolution of a gas
	(iv) The gas evolved was tested by holding a filter paper moistened with acidified $K_2Cr_2O_7$ over the mouth of the test tube.	Orange filter paper turned green.
3	(i) A portion of **Z** was dissolved in water in a test tube.	A colourless solution
	(ii) $AgNO_3$ solution was added to the colourless solution.	A black precipitate
	(iii) Dilute HCl was added to a portion of **Z** in a test tube.	A colourless gas evolved.
	(iv) The gas evolved was tested by holding a filter paper moistened with $Pb(CH_3COO)_2$ solution over the mouth of the test tube.	Filter paper turned black

I. Identify the anions in **X**, **Y** and **Z**. (Reasons **not** required.)

II. Write balanced chemical equations for the reactions taking place in the above tests.

(26 *marks*)

(*b*) A solid sample **X** contains the compounds **P**, **Q** and an inert substance. Here **P** = Fe_2O_3 and **Q** = Fe_3O_4. **Q** is a **single** compound and contains iron in Fe^{2+} and Fe^{3+} oxidation states. It reacts with I^- in an acidic medium as follows.

$$Fe_3O_4 + 2I^- + 8H^+ \longrightarrow 3Fe^{2+} + 4H_2O + I_2$$

The following experimental procedure was used to determine the mass percentages of **P** and **Q** in **X**.

When 3.2 g of sample **X** was treated with excess KI solution in the presence of dilute H_2SO_4, all the Fe^{3+} in it was converted to Fe^{2+} with the liberation of iodine. The resulting solution was diluted to 100.00 cm^3 (labelled as S). To convert the iodine to iodide in a 25.00 cm^3 volume of this diluted solution (S), 15.00 cm^3 of 0.50 mol dm^{-3} $Na_2S_2O_3$ was required.
After complete removal of iodine from another 50.00 cm^3 volume of the diluted solution (S), in dil. H_2SO_4 medium, 14.00 cm^3 of 0.25 mol dm^{-3} $KMnO_4$ was required to oxidize all the Fe^{2+} contained in it.

(i) Write balanced chemical equations for the reactions taking place in the above procedure.

(ii) Calculate the mass percentages of **P** and **Q** in **X**.
(O = 16, Fe = 56)

(75 *marks*)

[*see page fifteen*

10. (*a*) The following questions are based on the extraction of magnesium by the Dow process.

(i) State the raw materials used.

(ii) Give balanced chemical equations/half reactions in the sequence they occur in the Dow process. Appropriate conditions must be stated as required.

(iii) Give **two** industrial uses of magnesium.

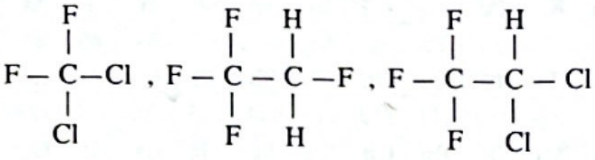
(iv) Give **two** ways in which the Dow process has a **negative** impact on the environment.

(50 *marks*)

(*b*) Given below are some pollutants that exist in the atmosphere.

Pollutant List

$CH_4, CO_2, NO, NO_2, N_2O, SO_2, SO_3, CH_3CH_2CH_2CH_2CH_3,$



The following questions are based on the pollutant list given above.

(i) Identify the pollutant that directly contributes towards increasing the level of ozone in the atmosphere.

(ii) Explain using balanced chemical equations how the pollutant you identified in (i) above increases the ozone level in the atmosphere.

(iii) Identify **two** pollutants that contribute to the reduction of ozone level in the upper atmosphere.

(iv) Briefly explain using balanced chemical equations how one of the pollutants you identified in (iii) above contributes to the reduction of ozone level in the upper atmosphere.

(v) Identify **two** pollutants that cause photochemical smog.

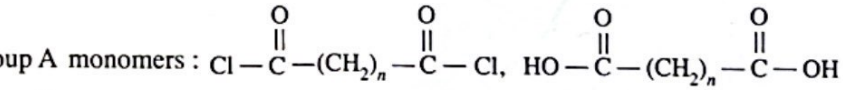
(vi) Identify **four** pollutants that can absorb infrared radiation in the atmosphere and remain stable in the atmosphere for a long period of time.

(vii) What is the commonly used name that describes the behaviour of the pollutants you identified in (vi) above?

(viii) Identify **two** pollutants that contribute to make a significant change in some water quality parameters when dissolved in water. State the water quality parameter(s) that will be affected by the pollutants you identified.

(50 *marks*)

(*c*) Consider the polymerization reactions between one monomer from group A and one monomer from group B given below.

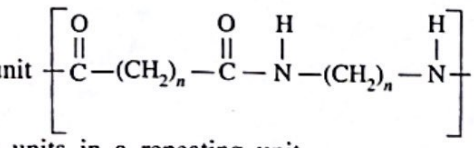


Group B monomers : $HO-(CH_2)_n-OH$, $H_2N-(CH_2)_n-NH_2$

where n is an integer.

(i) Write the pair/pairs of monomers that would release an acidic molecule during the polymerization reaction.

(ii) Write the pair/pairs of monomers that would release a neutral molecule during the polymerization reaction.

(iii) The molar mass of the repeating unit  is 226 g mol^{-1}.

Calculate the number of $-CH_2-$ units in a repeating unit.

(50 *marks*)

* * *

[*see page sixteen*