AL/2/E/62

Confidential

Department of Examinations – Sri Lanka

G.C.E. (A/L) Examination – 2023(2024)

02 - Chemistry

Marking Scheme

This has been prepared for the use of marking examiners. Some changes would be made according to the views presented at the Chief Examiners' meeting.

Amendments to be included

G.C.E. (A/L) Examination - 2023 (2024)

02 - Chemistry

Distribution of Marks

Paper I	:	1 X 50	=	50
Paper II	:			
Part A	:	100 X 4	=	400
Part B	:	150 X 2	=	300
Part C	:	150 X 2	=	300
Total			=	1000

Paper II - Final Marks = 100

Common Techniques of Marking Answer Scripts.

It is compulsory to adhere to the following standard method in marking answer scripts and entering marks into the mark sheets.

1. Use a red color ball point pen for marking. (Only Chief/Additional Chief Examiner may use a mauve color pen.)
2. Note down Examiner's Code Number and initials on the front page of each answer script.
3. Write off any numerals written wrong with a clear single line and authenticate the alterations with Examiner's initials.
4. Write down marks of each subsection in a $\triangle$ and write the final marks of each question as a rational number in a $\square$ with the question number. Use the column assigned for Examiners to write down marks.

Example: **Question No. 03**

(i) ....
.... √ $\frac{4}{5}$
....

(ii) ....
.... √ $\frac{3}{5}$
....

(iii) ....
.... √ $\frac{3}{5}$
....

03 (i) $\frac{4}{5}$ + (ii) $\frac{3}{5}$ + (iii) $\frac{3}{5}$ = $\boxed{\frac{10}{15}}$

MCQ answer scripts: (Template)

1. Marking templets for G.C.E.(A/L) and GIT examination will be provided by the Department of Examinations itself. Marking examiners bear the responsibility of using correctly prepared and certified templates.
2. Then, check the answer scripts carefully. If there are more than one or no answers Marked to a certain question write off the options with a line. Sometimes candidates may have erased an option marked previously and selected another option. In such occasions, if the erasure is not clear write off those options too.
3. Place the template on the answer script correctly. Mark the right answers with a 'V' and the wrong answers with a '0' against the options column. Write down the number of correct answers inside the cage given under each column. Then, add those numbers and write the number of correct answers in the relevant cage.

structured essay type and assay type answer scripts:

1. Cross off any pages left blank by candidates. Underline wrong or unsuitable answers. Show areas where marks can be offered with check marks.

2. Use the right margin of the overland paper to write down the marks.

3. Write down the marks given for each question against the question number in the relevant cage on the front page in two digits. Selection of questions should be in accordance with the instructions given in the question paper. Mark all answers and transfer the marks to the front page, and write off answers with lower marks if extra questions have been answered against instructions.

4. Add the total carefully and write in the relevant cage on the front page. Turn pages of answer script and add all the marks given for all answers again. Check whether that total tallies with the total marks written on the front page.

Preparation of Mark Sheets.

Except for the subjects with a single question paper, final marks of two papers will not be calculated within the evaluation board this time. Therefore, add separate mark sheets for each of the question paper. Write paper 01 marks in the paper 01 column of the mark sheet and write them in words too. Write paper II Marks in the paper II Column and wright the relevant details.

***

0003501

0003504

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව

Department of Examinations – Sri Lanka

අ.පො.ස.(උ.පෙළ)විභාගය/G.C.E. (A/L)- 2023 (2024)

විෂයය අංකය Subject No	02	විෂයය Subject	**Chemistry**

ලකුණු දීමේ පටිපාටිය/Marking Scheme

I පත්‍රය/Paper I

ප්‍රශ්න අංකය Question No.	පිළිතුරු අංකය Answer No.	ප්‍රශ්න අංකය Question No.	පිළිතුරු අංකය Answer No.	ප්‍රශ්න අංකය Question No.	පිළිතුරු අංකය Answer No.	ප්‍රශ්න අංකය Question No.	පිළිතුරු අංකය Answer No.	ප්‍රශ්න අංකය Question No.	පිළිතුරු අංකය Answer No.
01.	3	11.	5	21.	3	31.	5	41.	2
02.	2	12.	3	22.	3	32.	5	42.	4
03.	1	13.	3	23.	2	33.	2	43.	1
04.	5	14.	2	24.	1	34.	1	44.	1
05.	4	15.	2	25.	5	35.	5	45.	2
06.	4	16.	4	26.	5	36.	3	46.	1
07.	3/5	17.	2	27.	1	37.	5	47.	4
08.	4	18.	1	28.	5	38.	4	48.	3
09.	2	19.	5	29.	2	39.	4	49.	2/3
10.	5	20.	2	30.	3	40.	5	50.	3

✪විශේෂ උපදෙස්/Special Instructions:

එක් පිළිතුරකට ලකුණු 01 බැගින්/ 01 Mark for each question

මුළු ලකුණු/Total Marks 01 × 50 = 50

PART A — STRUCTURED ESSAY

Answer all four questions on this paper itself. (Each question carries 100 marks.)

1. (*a*) Write the answers to the questions given below on the dotted lines.

(i) Of the following sets of quantum numbers I, II and III, which one is **not** acceptable in describing an atomic orbital?
(I) $n=2$ $l=1$ $m_l=-1$ (II) $n=3$ $l=1$ $m_l=+2$ (III) $n=4$ $l=3$ $m_l=-3$ ..... (II) or $n = 3$ $l = 1$ $m_l = +2$

(ii) Of the three ions Na^+, K^+ and Ca^{2+}, which one has the **largest** ionic radius? ..... K^+

(iii) Of the three cations Li^+, Na^+ and Mg^{2+}, which one has the **least** polarizing power? ..... Na^+

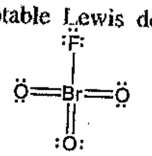
(iv) Of the three elements Li, Be and B, which one has the **lowest** second ionization energy? ..... Be

(v) Of the three elements Li, C and Na, which one has the **most** negative value for electron gain energy? C

(vi) Of the three compounds CH_3OH, CH_3CH_2OH and $CH_3CH_2CH_2OH$, which one has the **strongest** intermolecular forces? ..... $CH_3CH_2CH_2OH$

(04 marks X 6 - 24marks) $\boxed{\textbf{1(a): 24 marks}}$

(*b*) (i) Draw the **most** acceptable Lewis dot-dash structure for the molecule $FBrO_3$.



(05)

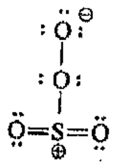
If the Lewis str wrong no marks

(ii) Give (I) the shape around the central atom and (II) the oxidation number of the central atom of the structure drawn in (i) above.

(01) + (01)

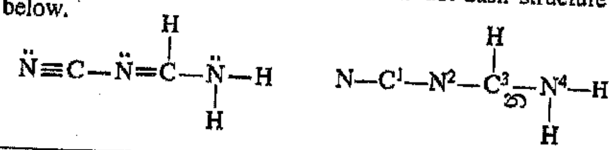
(I) ....tetrahedral...... (shape) (II) ....+7............. (oxidation number)

(iii) The compound SO_4 can be prepared by the reaction of SO_3 and O_3. An acceptable (stable) Lewis dot-dash structure for the molecule SO_4 is given below. Draw **three** more Lewis dot-dash structures (resonance structures) for this molecule and indicate their stabilities relative to the structure given by writing **stable** or **less stable** or **unstable** under these structures.



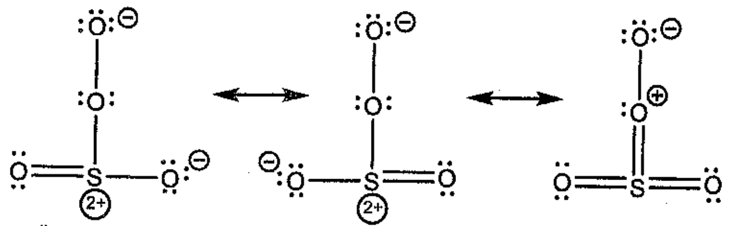
See attached sheet (09 marks)

(iv) Complete the given table based on the Lewis dot-dash structure and its labelled skeleton given below.

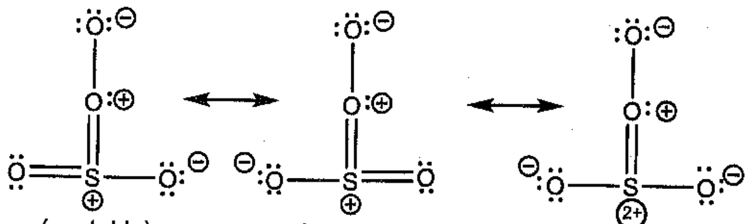


		C^1	N^2	C^3	N^4
I	The number of VSEPR pairs around the atom	2	3	3	4
II	electron pair geometry around the atom	linear	trigonal planar	trigonal planar	tetrahedral
III	Shape around the atom	linear	angular/ V / bent	trigonal planar	pyramidal / trigo Pyram
IV	Hybridization of the atom	*sp*	sp^2	sp^2	Sp^3

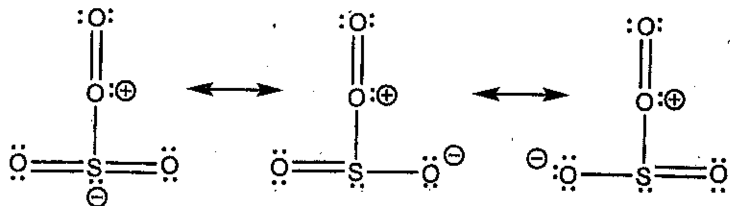
(01 mark X 16 = 16 marks)



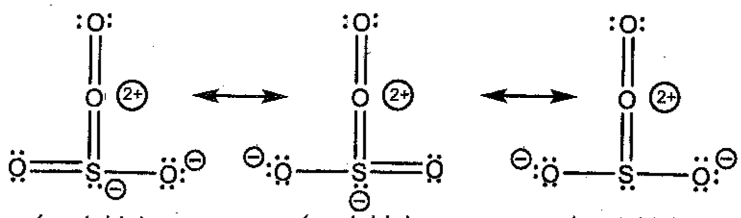
(less stable) (less stable) (unstable)



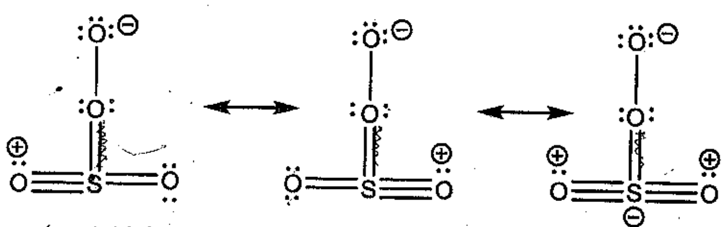
(unstable) (unstable) (unstable)



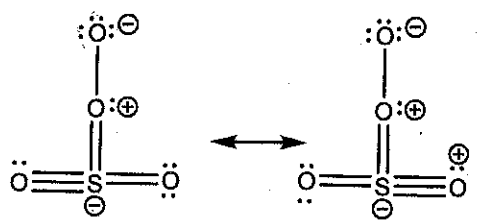
(unstable) (unstable) (unstable)



(unstable) (unstable) (unstable)



(unstable) (unstable) (unstable)



(unstable) (unstable)

Any **three** (**03** marks x 3 = **09 marks**) (**02** structure + **01** stability)

- Parts (v) to (viii) are based on the Lewis dot-dash structure given in part (iv) above. Labelling of atoms is as in part (iv).

(v) Identify the atomic/hybrid orbitals involved in the formation of σ bonds between the two atoms given below.

I.	$N-C^1$	N ....2p / sp....	C^1 ....sp....
II.	C^1-N^2	C^1 ....sp....	N^2 ....sp^2....
III.	N^2-C^3	N^2 ....sp^2....	C^3 ....sp^2....
IV.	C^3-N^4	C^3 ....sp^2....	N^4 ....sp^3....
V.	N^4-H	N^4 ....sp^3....	H ....1s....
VI.	C^3-H	C^3 ....sp^2....	H ....1s....

(01 mark X 12 = 12 ma

(vi) Identify the orbitals involved in the formation of π bonds between the two atoms given below.

I.	$N-C^1$	N ....2p....	C^1 ....2p....
		N ....2p....	C^1 ....2p....
II.	N^2-C^3	N^2 ....2p....	C^3 ....2p....

(01 mark X 6 = 06 ma

(vii) State the approximate bond angles around the C^1, N^2, C^3 and N^4 atoms.

C(180° ± 1) N^2(117° ± 2), C^3 (120° ± 1) N^4(107° ± 1) (01 mark X 4 = 04 ma

(viii) Arrange the atoms C^1, N^2, C^3 and N^4 in the **increasing** order of electronegativity.

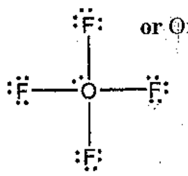
.....C^3.... < .....C^1.... < ..N^4...... < .N^2.......(02 marks)

1(b): 56 marks

(c) State whether the following statements are **true** or **false**. Give reasons for your choice.

(i) An acceptable Lewis dot-dash structure **cannot** be drawn for the OF_4 molecule.

True (03)



or Oxygen has five pairs of electrons around it (03)

Hence electrons around oxygen exceeds 8 (02)

Oxygen is a second period element and cannot exceed the octet (01 + 01)

or Octet rule violated at the central atom oxygen

(10 marks)

(ii) The **increasing** order of electronegativity of nitrogen in NO_2^+, NBr_3, NO_2Cl and HNO_2 is $NBr_3 < NO_2Cl < HNO_2 < NO_2^+$.

False (03)

	NO_2^+	NBr_3	NO_2Cl	HNO_2
Hybridization of N	sp	sp^3	sp^2	sp^2
Charge on N	(+1)	(0)	+1	0

(02)
(02)

Higher the s character, higher the electronegativity (01)

Higher the positive charge, greater the electronegativity than neutral (01)

Hence, variation is $NBr_3 < HNO_2 < NO_2Cl < NO_2^+$ (01)

or in words

(10 marks)

Note – No marks foe decisions based on oxidation states/ numbers

1(c): 20 marks

0003489

2. (*a*) **A** is a *s*-block element in the Periodic Table. Its atomic number is less than 20. When **A** is heated with nitrogen and oxygen separately, two stable compounds **B** and **C** are formed respectively. **B** reacts with water to give the basic compound **D**, and a colourless gas **E** with a pungent odour that turns red litmus blue. Reaction of **A** with water at room temperature also gives **D**, and liberates a colourless, odourless, homonuclear diatomic gas **F**. **A** reacts with dil. H_2SO_4 and gives salt **G** and gas **F**. Compound **H** is formed on reaction of **D** with CO_2. **H** decomposes on heating to give compound **C** and CO_2.

(i) Identify species **A** to **H**. (Give chemical formulae.)

A ....Li.... **E** ....NH_3....

B ....Li_3N.... **F** ....H_2....

No marks as they have not identified.

C ....Li_2O.... **G** ....Li_2SO_4....

D ....$LiOH$.... **H** ....Li_2CO_3.... **(05 marks x 8 = 40 marks)**

(ii) Write balanced chemical equations for the following reactions.

I. **A** with water $2Li + 2H_2O \rightarrow 2LiOH + H_2$

II. **A** with dil. H_2SO_4 $2Li + H_2SO_4 \rightarrow Li_2SO_4 + H_2$

III. **B** with water $Li_3N + 3H_2O \rightarrow 3LiOH + NH_3$

IV. Decomposition of **H** $Li_2CO_3 \rightarrow Li_2O + CO_2$ **(05 marks x 4 = 20 marks)**

(iii) Write the colour of the flame given by salts of **A** in the flame test.

crimson- red / red / crimson (05)

Note: Do not award marks for 2(a) if Li is not correctly identified.

2(a): 65 marks

(*b*) Write the chemical formulae of **P**, **Q**, **R** and **S**.

(i) **P** is a colourless solution. When CO_2 is bubbled through **P**, the solution turns milky. When excess CO_2 is bubbled through the milky solution, a clear colourless solution is obtained. **P** gives an orange-red flame when subjected to the flame test. Identify **P**.

P ....$Ca(OH)_2$....

(ii) The metal **M** belongs to the third row of the Periodic Table. **M** reacts with dilute aqueous strong acids and bases. When **M** reacts with a certain dilute aqueous strong acid, it gives the salt **Q** as one of the products. When aqueous $BaCl_2$ is added to this solution, a white precipitate is formed. The precipitate is insoluble in dilute acids. Identify **Q**.

Q ....$Al_2(SO_4)_3$....

(iii) **R** is an ionic compound. When **R** is reacted with dil HCl, a colourless, odourless, linear triatomic gas is evolved as one of the products. **R** gives a yellow colour flame when subjected to the flame test. The metal ion in **R** is found in borax. Identify **R**.

R ....award 07 marks....

(iv) **S** is an ionic compound. When **S** is heated, a red-brown gas is evolved. The metal in **S** burns with a bright light in air. The metal reacts slowly with hot water, to give a basic compound and $H_2(g)$. The metal ion contributes to hardness of water. Identify **S**.

S ....$Mg(NO_3)_2$.... **(07 marks x 4 = 28 marks)**

(v) Give balanced chemical equations for the following reactions. Indicate precipitates with the symbol $\downarrow$. no marks if P & Q are wrong.

I. $3Ca(OH)_2 + Al_2(SO_4)_3 \rightarrow 3CaSO_4\downarrow + 2Al(OH)_3\downarrow$ **(05 + 02)** 7 one of

II. No marks

III. No marks

Note: Marks (02) allocated for $\downarrow$ should be awarded to either $CaSO_4$ or $Al(OH)_3$.

2(b): 35 marks

3. (*a*) (i) A closed non-rigid container contains *n* moles of an ideal gas at a given temperature (*T*) and pressure (*P*). Write the relationship between the number of moles of the gas and volume *V*.

$pV = nRT$ or $n = \frac{pV}{RT}$ or $n \propto V$ **(05)**

(ii) A closed non-rigid container of volume 150 cm^3, contains 3.75 g of $O_2(g)$ at a given temperature and pressure. If another 1.25 g of $O_2(g)$ is introduced into this container at the same temperature and pressure, what will be the new volume of the container? (O = 16)

Alternative answer
$150 cm^3 + 50 cm^3 = 200 cm^3$ (15)

$n_1 = \frac{3.75}{32}$ **(05)**

$n_2 = \frac{5.00}{32}$ **(05)**

$\frac{3.75/32}{5.0/32} = \frac{150\ cm^3}{V}$ **(05)**

$V_2 = 200\ cm^3$ **(04+01)**

Alternate answer

$\frac{1.25/32}{3.75/32} = \frac{V'}{150\ cm^3}$ **(05)**

$V' = 50\ cm^3$

Total volume = (150+50) cm^3 = 200 cm^3 **(04+01)**

Note: Award marks for correct answers obtained using pV=nRT

(iii) At constant temperature and pressure, show that the molar mass (*M*) of an ideal gas is directly proportional to its density (*d*).

At constant T and P, $d = \frac{m}{V}$ (05) $n = \frac{m}{M}$ (05)

$n \propto V$

$\frac{m}{M} \propto V$ **(05)**

$\frac{m}{V} \propto M$ **(05)**

$d \propto M$ **(05)**

Note: Award marks for correct answers obtained using pV=nRT

3(a): 40 marks

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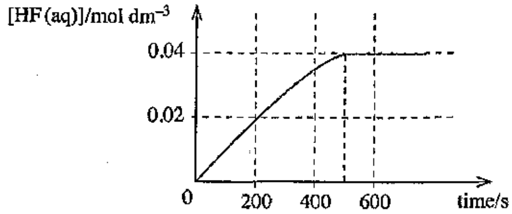
(*b*) Consider the reversible reaction given below.

$$BF_4^-(aq) + H_2O(l) \rightleftharpoons BF_3OH^-(aq) + HF(aq)$$

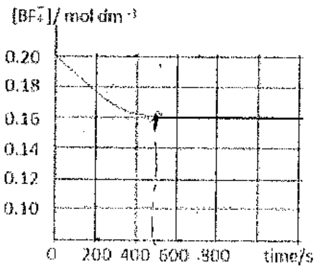
(**Note:** Neglect the ionization of HF.)

In an experiment carried out to study the kinetics of the above reaction, 0.20 mol dm^{-3} BF_4^-(aq) was used and the concentration of the product HF(aq) was measured with time, at a constant temperature. The results obtained are shown in the graph below.



Concentration of HF(aq) reached the constant value of 0.04 mol dm^{-3} at the equilibrium. It was found that the forward reaction follows the rate law, rate = $k_f[BF_4^-(aq)]$ and the value of k_f is 1.0×10^{-5} s^{-1}.

(i) Draw a graph to show the variation of $[BF_4^-(aq)]$ with time.



(10)

To award marks starting and ending positions of the curve must be correct and the shape of the curve must be correct.

(ii) At this temperature, calculate the rate of the forward reaction after 600 s.

After 600 s,

$[BF_4^-]$ = 0.16 mol dm^{-3} **(04+01)**

Rate$_{(forward)}$ = 1.0×10^{-5} s^{-1} x 0.16 mol dm^{-3} **(05)**

= 1.6×10^{-6} mol dm^{-3} s^{-1} **(04+01)**

15

(iii) It was found that the reverse reaction is first order with respect to $[BF_3OH^-(aq)]$ and first order with respect to [HF(aq)]. Taking k_r as the rate constant of the reverse reaction, write the rate law of the reverse reaction and calculate the value of k_r at this temperature.

Rate$_{(reverse)}$ = $k_r [BF_3OH^-][HF]$ ← physical status is not required. **(10)**

= k_r 0.04 mol dm^{-3} x 0.04 mol dm^{-3} **(05)**

= k_r 1.6×10^{-3} mol^2 dm^{-6}

At equilibrium, Rate$_{(forward)}$ = Rate$_{(reverse)}$ **(05)**

Or

k_r 1.6×10^{-3} mol^2 dm^{-6} = 1.6×10^{-6} mol dm^{-3} s^{-1}

k_r = 1.0×10^{-3} mol^{-1} dm^3 s^{-1} **(04+01)**

25

(iv) State whether the initial rate method can be used to find the rate law of the reverse reaction in the above experiment. Give reasons for your answer.

Initial rate method cannot be used. only for this particular experiment. **(05)**

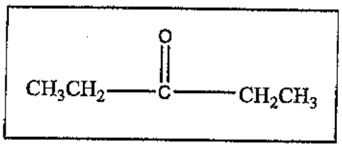
At time=0, $[BF_3OH^-]$ =0 or [HF]=0 or both are zero. **(05)**

10

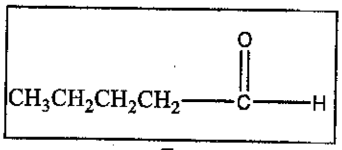
3(b): 60 marks

4. (*a*) **A**, **B** and **C** are structural isomers having the molecular formula $C_5H_{10}O$. None of them show optical isomerism. All three compounds **A**, **B** and **C** give coloured precipitates with 2,4-dinitrophenylhydrazine (2,4-DNP). Of the three compounds **A**, **B** and **C**, only **B** gives a silver mirror with ammonical $AgNO_3$. When **A**, **B** and **C** are reacted separately with $NaBH_4/CH_3OH$, compounds **D**, **E** and **F** are produced respectively. When **D** is heated with conc. H_2SO_4, compounds **G** and **H**, which are diastereomers of each other are formed. When **E** and **F** are heated separately with conc. H_2SO_4, compound **E** gives **I** while compound **F** gives all three compounds **G**, **H** and **I**. Compounds **G**, **H** and **I** decolourize Br_2/H_2O.

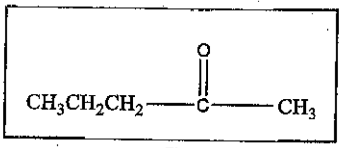
Draw the structures of **A**, **B**, **C**, **D**, **E**, **F**, **G**, **H** and **I** in the boxes given below.



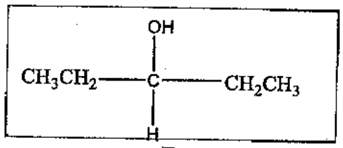
A



B



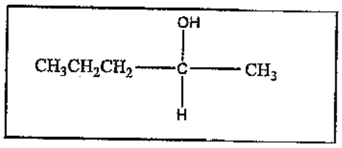
C



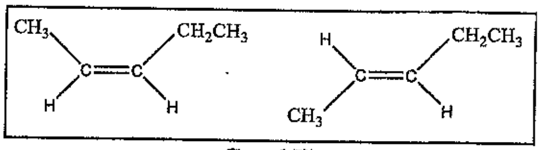
D

$CH_3CH_2CH_2CH_2CH_2OH$

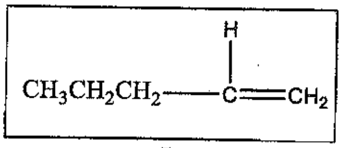
E



F



G and H



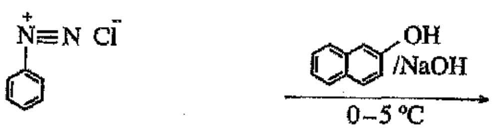
I

Note: Structures of G and H given in linear form award only 06 marks

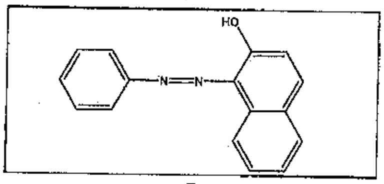
(06 x 9 = 54 marks)

4(a): 54 marks

(*b*) (i) Draw the structures of the products **J**, **K**, **L**, **M** and **N** of the following reactions (I – V) in the given boxes.

(I) 

Note: $-C_6H_5$ not accepted

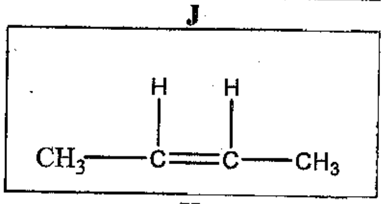


OH / O^- / O^-Na^+

J

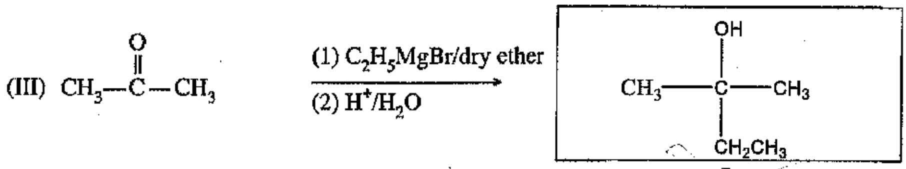
(II) $CH_3-C\equiv C-CH_3 \xrightarrow[\text{Quinoline}]{H_2/Pd\text{-}BaSO_4}$

Note: showing the stereochemistry is not necessary

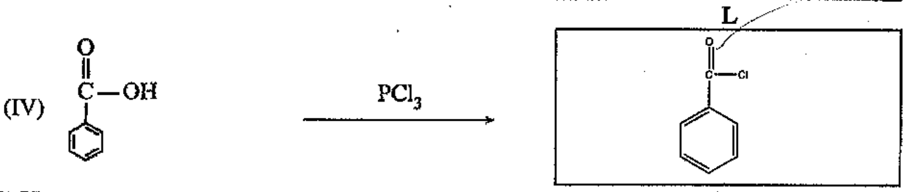


K

0003485

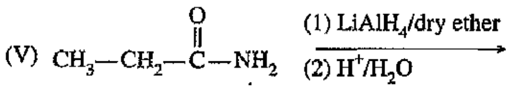


L



M

Note: -C_6H_5 not accepted -COCl accepted



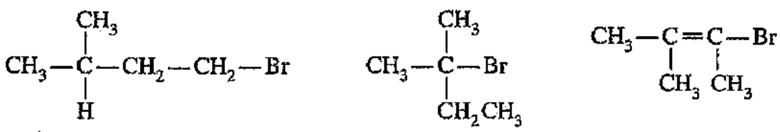
$CH_3CH_2CH_2NH_2$

N

(05 x 5 = 25 marks)

4(b): 25 marks

(*c*) Consider the compounds **P**, **Q** and **R** given below.



P **Q** **R**

(i) When compounds **P**, **Q** and **R** are separately treated with aqueous NaOH;

I. Which compound is least likely to undergo a nucleophilic substitution reaction?

R or correct structure

II. Which compound is most likely to undergo a nucleophilic substitution reaction which takes place in **one** step?

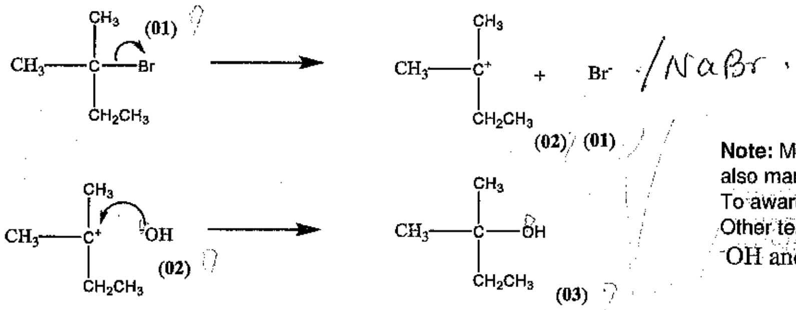
P or correct structure

III. Which compound is most likely to undergo a nucleophilic substitution reaction which takes place in **two** steps?

Q or correct structure

(04 x 3 = 12 marks)

(ii) Give the mechanism and the structure of the product formed relevant to the reaction in (*c*)(i)III above.



(09 marks)

Note: Mark (c) (ii) independently and also mark (c) (ii) independent to (c) (i) III.
To award marks, structure of Q should be correct.
Other tertiary alkyl halides will not be accepted.
^-OH and OH^- both accepted

4(c): 21 marks

PART B - ESSAY

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

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

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 $Ca(OH)_2$.)

q = msθ

q = (200 g) (4.2 J g^{-1} $^0C^{-1}$) (75-25) ^0C **(04+01)**

= 42 or 42 kJ or 42000 J   42 kJ mol⁻¹ no marks. **(05)**

(5(a)(i) : 10 marks)

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

The amount of CaO needed to increase temperature from 25 ^0C to 75 ^0C.

= (42 kJ/64 kJ mol^{-1}) x 56 g mol^{-1} **(04+01)**

= 36.75 g **(04+01)**

(5(a)(ii) : 10 marks)

(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.

no ΔS should be written

$\Delta S^0 = \sum S^0_{products} - \sum S^0_{reactants}$ Note- Standard states must be shown **(04)**

= (80-(40+70)) J K^{-1} mol^{-1} **(04+01)**

= - 30 J K^{-1} mol^{-1} **(04+01)**

(5(a)(iii) : 14 marks)

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

$\Delta G^0 = \Delta H^0 - T\Delta S^0$ Note- Standard states must be shown **(04)**

= (-64 -300 (-30x10^{-3})) kJ mol^{-1} **(04+01)** 6

= - 55 kJ mol^{-1} **(04+01)**

The reaction is spontaneous at 300 K **(02)**

Note – 02 marks can be award for the correct prediction according to the answer

Assumption: ΔH^0 *and* ΔS^0 are independent of temperature **(01+01)**

no need of standard for verbal expression

(5(a)(iv) : 18 marks)

0003483

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

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

When steam is used instead of liquid water, ΔH^0 changes.

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

$\Delta H^0 = -108\ kJ\ mol^{-1}$ ——— (04+01)

ΔS^0 = (80-(40+190)) J mol^{-1} K^{-1} ——— (04+01)

= -150 J mol^{-1} K^{-1} ——— (04+01) 10

ΔG^0 = -108 kJ mol^{-1} -400K (-150x10^{-3}) kJ mol^{-1} K^{-1} ——— (04+01)

= - 48 kJ mol^{-1} ——— (04+01) 10.

The reaction is still spontaneous ——— (03)

Note – 03 marks can be award for the correct prediction according to the answer

(5(a)(v) : 28 marks)

5(a) : 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}).

$K_p = P_{H2O}$

$= 7.0 \times 10^5$ Pa (03+01)

$K_c = K_p (RT)^{-\Delta n}$ or $K_p = K_c (RT)^{\Delta n}$ ——— (03) 15

$= \dfrac{7.0x10^5\ Pa}{7.0x10^3\ Jmol^{-1}}$ ——— (03+01)

=100 mol m^{-3} or 1.0 x10^{-1} mol dm^{-3} (03+01)

(5(b)(i) : 15 marks)

(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.

There is no effect **(02)**. Concentration of a solid is constant. **(03)**

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

Reaction occurs in the forward direction **(02)**

According to the Le Chatelier's principle, the reaction proceeds to generate more water. **(03)**

Or

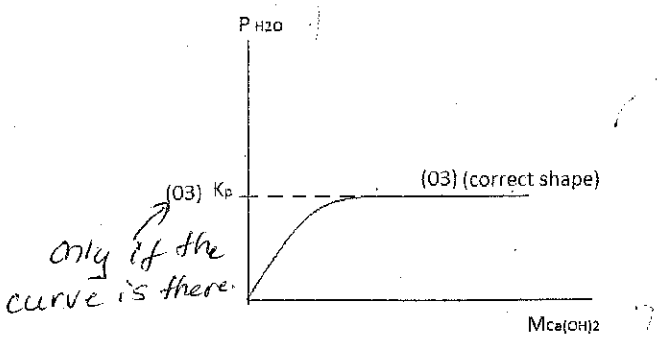
Reaction occurs in the forward direction **(02)** to produce more $H_2O(g)$ to increase P_{H_2O} to K_p. **(03)**

Or

To increase (reaction quotient) Q_p (Q_c) up to K_p (K_c), **(03)** reaction occurs in the forward direction. **(02)**

(5(b)(ii) : 10 marks)

(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.



Note : Axes must be correctly labeled to award marks

As $Ca(OH)_2$ is introduced into the container, the pressure of $H_2O(g)$ is increased ———— (03)

In the beginning, $Ca(OH)_2$ (s) is completely converted to CaO(s) and $H_2O(g)$. ———— (03)

After reaching the equilibrium, P_{H_2O} will be constant, and solid $Ca(OH)_2$ remains in the container. ———— (03)

(5(b)(iii) : 15 marks)

5(b) : 40 marks

0003481

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

$$\underset{}{Ca(OH)_2(s)} \rightleftharpoons \underset{x}{Ca^{2+}(aq)} + \underset{2x}{2\,OH^-(aq)}$$

Note – Physical states are required **(04)**

(5(c)(i) : 04 marks)

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

$K_{sp} = [Ca^{2+}(aq)][OH^-(aq)]^2$ **(04)**

Note: Physical states are required for all the species.

$K_{sp} = x\,(2x)^2$

4.0×10^{-6} mol^3 dm^{-9} $= 4x^3$ **(04+01)**

x = molar solubility of $Ca(OH)_2(s)$

$x = 1.0\times10^{-2}$ mol dm^{-3} **(04+01)**

14

(5(c)(ii) : 14 marks)

(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.

In NaOH : Solubility will be less **(02)** Common ion effect. **(02)** or explanation / $[OH^-(aq)]\uparrow$

In NaCl : No change in solubility **(02)** No common ion effect. **(02)**

In $Ca(NO_3)_2$: Solubility will be less **(02)** Common ion effect. **(02)**

(5(c)(iii) : 12 marks)

5(c): 30 marks

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.

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

$C(1-\alpha)$ $\quad\quad$ $C\alpha$ $\quad\quad$ $C\alpha$

$K_b = \frac{[HCOOH(aq)][OH^-(aq)]}{[HCOO^-(aq)]}$ Note – Physical states are required **(05)**

Assuming $1 - \alpha \approx 1$

$= \frac{1.0\times10^{-6}\,mol\,dm^{-3} \times 1.0\times10^{-6}\,mol\,dm^{-3}}{1.0\times10^{-1}\,mol\,dm^{-3}}$ **(04+01)**

Or

$C\alpha = 1.0 \times 10^{-6}$ mol dm^{-3}

$\alpha = 1.0 \times 10^{-6}$ mol dm^{-3} / 0.1 mol dm^{-3} = 1.0×10^{-5}

$K_b = \frac{1.0\times10^{-6}\,mol\,dm^{-3} \times 1.0\times10^{-6}\,mol\,dm^{-3}}{1.0\times10^{-6}\,mol\,dm^{-3}(1-1.0\times10^{-5})}$ **(04+1)**

$= 9.9 \times 10^{-12}$ mol dm^{-3} $\cong 1.0 \times 10^{-11}$ mol dm^{-3} **(04+01)**

II. The value of K_a of methanoic acid.
($K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6} at 25 °C)

$K_a K_b = K_w$ **(05)**

$K_a = \frac{1\times10^{-14}\,mol^2\,dm^{-6}}{1\times10^{-11}\,mol\,dm^{-3}}$ **(04+01)**

$K_a = 1.0\times10^{-3}$ mol dm^{-3} **(04+01)**

(6(a)(i) : 30 marks)

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

$HCOOH(aq) + H_2O(l) \rightleftharpoons HCOO^-(aq) + H_3O^+(aq)$ If HA is written no marks.

Or

$HCOOH(aq) \rightleftharpoons HCOO^-(aq) + H^+(aq)$ (equations with physical states) —— (05)

$C(1\text{-}\alpha)$ $C\alpha$ $+ C\alpha$ (at equilibrium)

$$K_a = \frac{(C\alpha)^2}{C(1-\alpha)}$$

$1 - \alpha \approx 1$ —— (05)

$[H_3O^+] = (K_aC)^{1/2}$

$[H_3O^+] = (1.0 \times 10^{-3}\ mol\ dm^{-3} \times 0.10\ mol\ dm^{-3})^{1/2}$ —— (04+01)

$[H_3O^+] = 1.0 \times 10^{-2}\ mol\ dm^{-3}$

Note: If the problem is solved without neglecting α, award (09+01) marks for the correct steps.

pH = - log $[H_3O^+(aq)]$ Or pH = - log $[H^+(aq)]$ —— (05)

= - log(1.0×10^{-2})

= 2.0 —— (04+01)

25

(6(a)(ii) : 25 marks)

(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.

Molecular mass of HCOONa = (12+32+1+23) g mol^{-1} = 68 g mol^{-1} —— (01)

The amount of HCOONa $= \frac{3.4 g}{68\ g\ mol^{-1}}$

= 0.05 mol —— (01)

Concentration of HCOONa $= \frac{5.0\times10^{-2} mol \times 1000\ cm^3 dm^{-3}}{50.0\ cm^3}$

= 1.0 mol dm^{-3} —— (01+01)

$pH = pK_a + log\left[\frac{[salt]}{[acid]}\right]$ —— (05)

$= -\log(1.0 \times 10^{-3}) + log\left[\frac{1.0}{0.1}\right]$ (05)

Note: If the calculation is done using the expression for K_a award (10) marks for the correct steps.

= 4.0 (04+01)

19

II. Explain how this solution acts as a buffer solution.

Physical states are not required.

Addition of an acid ; $HCOO^-(aq) + H_3O^+(aq) \rightleftharpoons HCOOH(aq) + H_2O(l)$ **(03)**

Or $HCOO^-(aq) + H^+(aq) \rightleftharpoons HCOOH(aq)$

Note : Physical states are not required and → is accepted

Or when an acid is added, formate ion accepts the proton reducing the H^+ concentration.

Addition of a base: $HCOOH(aq) + OH^-(aq) \rightleftharpoons HCOO^-(aq) + H_2O(l)$ **(03)**

Note : Physical states are not required and → is accepted

Or when a base is added formic acid dissociates decreasing the OH^- concentration.

(6(a)(iii) : 25 marks)

6(a) : 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° and P_B° 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	only zero. 0 (zero)	$\Delta H > 0$ / (+)	$\Delta H < 0$ / (−)
Relation among f_{A-B}, f_{A-A} and f_{B-B}	$f_{A-B} = f_{A-A} = f_{B-B}$	$f_{A-B} < f_{A-A}$, f_{B-B} or $f_{A-A} > f_{A-B} < f_{B-B}$	$f_{A-B} > f_{A-A}$, f_{B-B} or $f_{A-A} < f_{A-B} > f_{B-B}$
Relation among P_A^0, P_A and x_A	$P_A = P_A^0 x_A$	$P_A > P_A^0 x_A$	$P_A < P_A^0 x_A$

(05 x 9)

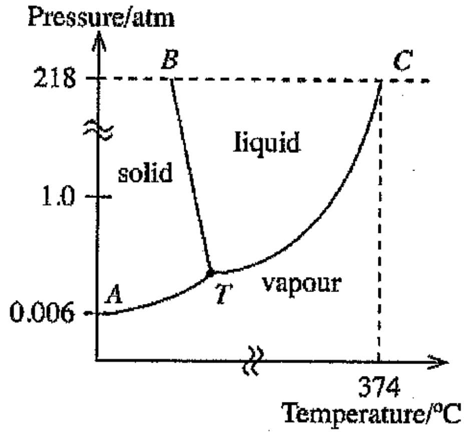
(6(b)(i) : 45 marks)

(ii) The phase diagram of pure water is given below. Copy the diagram on to your answer script and answer the following questions.

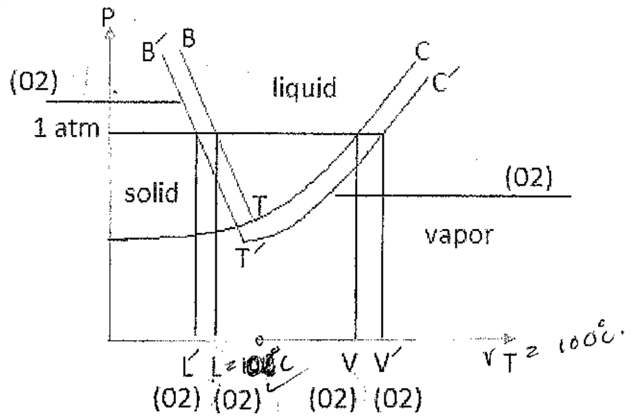
I. Mark the normal boiling point (V) and melting point (L) of pure water.

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.



(ii) (I) and (III)



*B', T', V', L', C' should be there as there given in the graph. ~~10~~ 12

(II)

Line BT = Variation of melting point with pressure Or solid liquid equilibrium. /Melting / solidification **(04)**

LineTC = Variation of boiling point with pressure Or Liquid-vapor equilibrium. **(04)**

Point T = Triple point **(05)**

(6(b)(ii) : 25 marks)

6(b) : 70 marks

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.

Anode = Zn (Zn-rod) } no physical states (05)

Cathode = Cu (Cu-rod) (05)

(7(a)(i) : 10 marks)

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

⇌ not accepted.

Anodic reaction $Zn(s) \rightarrow Zn^{2+}(aq) + 2e$ (05)

Note: physical states are required.

(7(a)(ii) : 05 marks)

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

⇌ not accepted.

Cathodic reaction $Cu^{2+}(aq) + 2e \rightarrow Cu(s)$ (05)

Note: physical states are required

(7(a)(iii) : 05 marks)

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

$Zn(s)|ZnSO_4(aq, 1.0\ mol\ dm^{-3}) \vdots CuSO_4(aq, 1.0\ mol\ dm^{-3})| Cu(s)$ (10)

Or

$Zn(s)|Zn^{2+}(aq, 1.0\ mol\ dm^{-3}) \vdots Cu^{2+}(aq, 1.0\ mol\ dm^{-3})| Cu(s)$

(7(a)(iv) : 10 marks)

(v) Calculate the electromotive force (E^{o}_{cell}) of the Daniel cell given above at 25 °C.

$E^{o}_{Cu^{2+}(aq)/Cu(s)} = 0.34$ V $\quad E^{o}_{Zn^{2+}(aq)/Zn(s)} = -0.76$ V

$E^{0}_{cell} = E^{0}_{cathode} - E^{0}_{anode}$ or Emf = $E_C^{\ominus} - E_A^{\ominus}$ (02)

$= 0.34\ V - (-0.76\ V)$ (03+01)

$= 1.10$ V (03+01)

(7(a)(v) : 10 marks)

(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})

The amount of charge Q = It (03)

This charge should deposit 3.175 g of Cu.

Amount of Cu deposited $= \frac{3.175\ g}{63.5\ g\ mol^{-1}}$ (03+01)

$= 0.05$ mol

Therefore, $t = \frac{0.05\ mol \times 96500\ C\ mol^{-1} \times 2}{5.0\ C\ s^{-1}}$ (03+01)

$t = 1930\ s$ (03+01)

(7(a)(vi) : 15 marks)

0003486

(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.

Conductivity increases. **(04)**

This is due to the release of Zn^{2+} **(02)** and migration of SO_4^{2-} in to the compartment. **(02)**

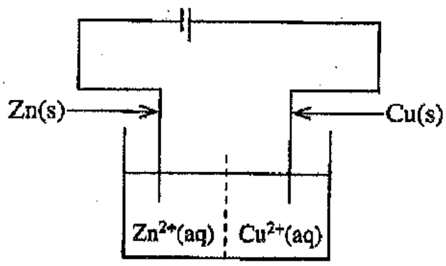
(7(a)(vii) : 08 marks)

(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.

The intensity of blue color decreases. **(04)**
This happens due to the deposition of Cu^{2+} as Cu **(04)**

(7(a)(viii) : 08 marks)

(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.



$Cu(s) + Zn^{2+}(aq) \rightarrow Zn(s) + Cu^{2+}(aq)$ **(04)**

or $2H_2O(l) + Cu(s) \rightarrow H_2(g) + 2OH^-(aq) + Cu^{2+}(aq)$

or $2H_2O(l) + Cu(s) + Zn^{2+}(aq) \rightarrow Zn(OH)_2(s) + H_2(g) + Cu^{2+}(aq)$

Note: physical states are required

* This reaction cannot be used for a long time as both Zn^{+2} and Cu^{+2} deposit together the membrane is permeable to Cu^{+2}, so both can deposit.
∴ Daniel cell is not rechargeable

(7(a)(ix) : 04 marks)

7(a): 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)?

+2, +3 Fe^{+2}, Fe^{+3}

(03 + 03)

(7(b)(i) : 06 marks)

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

$AgBr$ **(03)**

Conc. NH_3 / Conc. NH_4OH **(02)**

(7(b)(ii) : 05 marks)

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

A : NH_3, H_2O **(01+01)**

B: NH_3, H_2O **(01+01)**

C: NH_3, Br^- no marks **(01+01)**

D: H_2O, Br^- **(01+01)**

Note: No marks for Br

(7(b)(iii) : 08 marks)

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

I. write the oxidation state of iron.

A : +2 or +II **(02)**

B: +3 or +III **(02)**

C: +2 or +II **(02)**

D: +3 or +III **(02)**

II. write the electronic configuration of iron.

A : $1s^22s^22p^63s^23p^63d^6$ **(02)**

B: $1s^22s^22p^63s^23p^63d^5$ **(02)**

C: $1s^22s^22p^63s^23p^63d^6$ **(02)**

D: $1s^22s^22p^63s^23p^63d^5$ **(02)**

(7(b)(iv) : 16 marks)

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

A : $[Fe(NH_3)_3(H_2O)_3]Br_2$ or $[Fe(H_2O)_3(NH_3)_3]Br_2$ **(10)**

B: $[Fe(NH_3)_2(H_2O)_4]Br_3$ or $[Fe(H_2O)_4(NH_3)_2]Br_3$ **(10)**

C: $[Fe(NH_3)_5Br]Br$ or $[FeBr(NH_3)_5]Br$ **(10)**

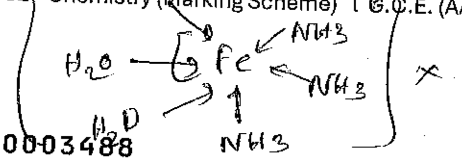
D: $K[FeBr_4(H_2O)_2]$ or $K[Fe(H_2O)_2Br_4]$ **(10)**

Note: Award marks if correct structures are drawn with anion/cation instead of formulae.

* The correct structure should be including the anions and cations.

(7(b)(v) : 40 marks)

7(b): 75 marks



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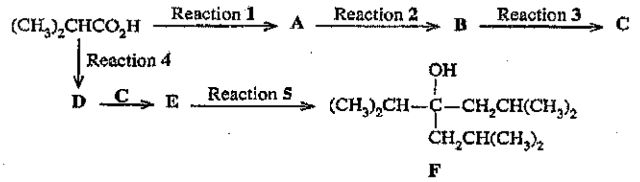
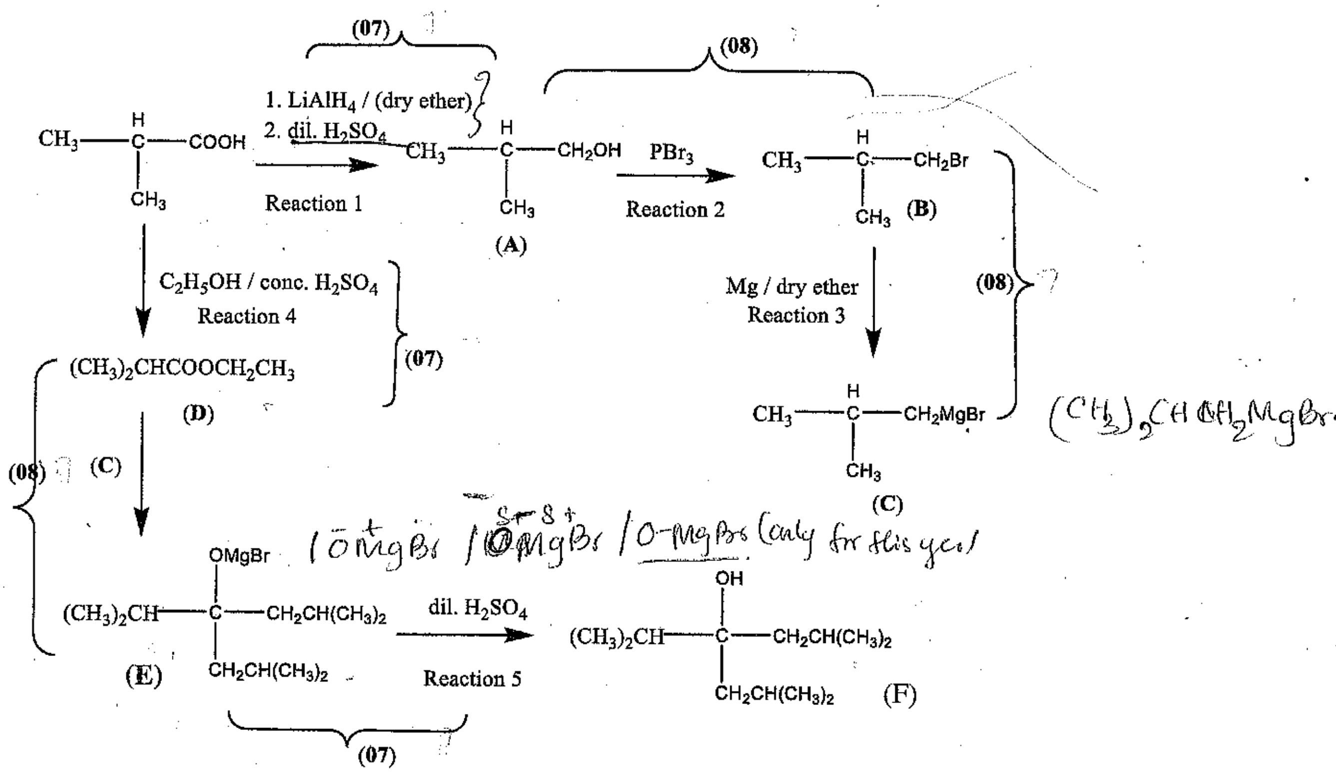
8. (*a*) $(CH_3)_2CHCO_2H$ has been converted to compound **F** by using the reaction scheme given below.



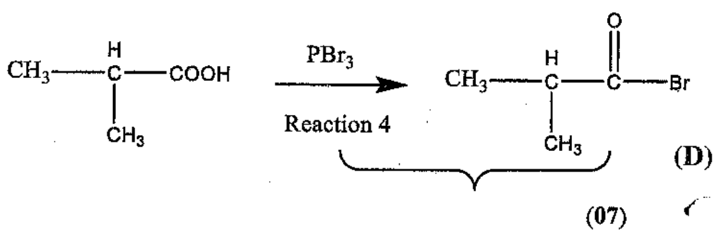
Complete the above reaction scheme by giving the structures of compounds **A, B, C, D** and **E** and the reagents required for the reactions 1 - 5. Only the chemical substances given below should be used (either singly or as combinations) as reagents.

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



Note: In structure E -OMgBr with +/ – charges or with partial charges accepted

Alternate answer to Reaction 4



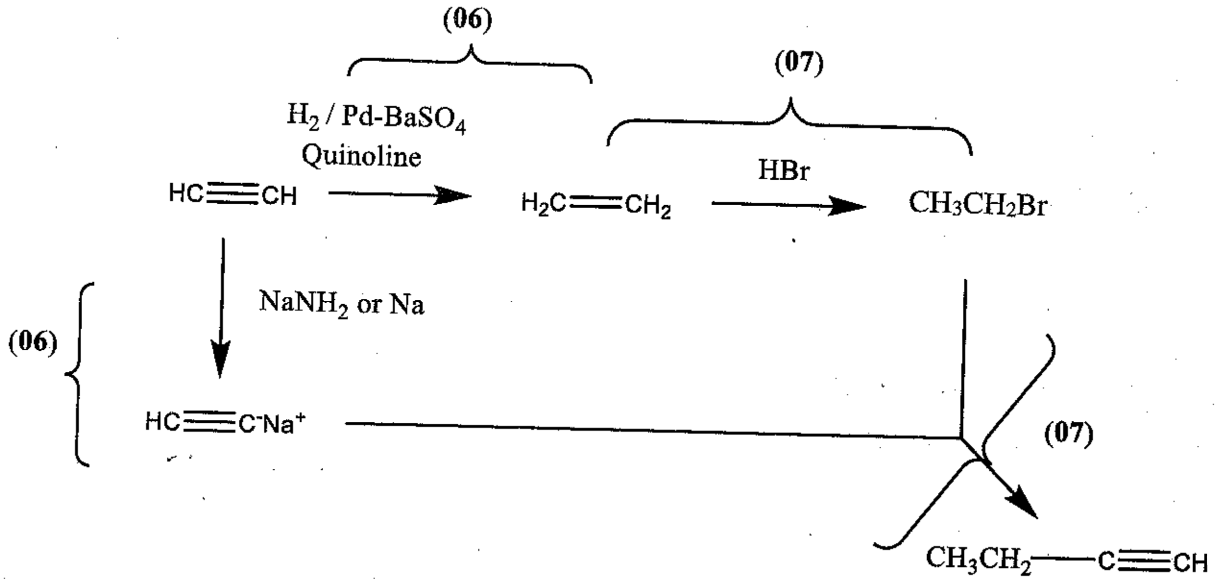
Note: Acyl bromides are not frequently encountered and the reaction of acyl halides with Grignard reagents are not in the syllabus

8(a): 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



(G)

(8(b)(i) : 26 ma

Note: Marks will not be given for writing only the name of the catalyst (Lindlar catalyst) instead of writing H_2/Pd-$BaSO_4$/Quinoline.

HBr is most appropriate. HCl and HI can be accepted.

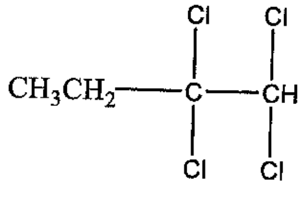
Alkene can be given with C=C as shown or written as C_2H_4 or CH_2CH_2

$NaNH_2$ (liq. NH_3) or Na (liq. NH_3)

C^-Na^+ or CNa accepted (C-Na not accepted)

Award marks for the alkene preparation and sodium salt of alkyne preparation steps. If the synthetic route is more than a total of 04 steps do not award marks for the other steps even if they are correct.

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



(H)

(8(b)(ii) : 04 marks)

8(b): 30 marks

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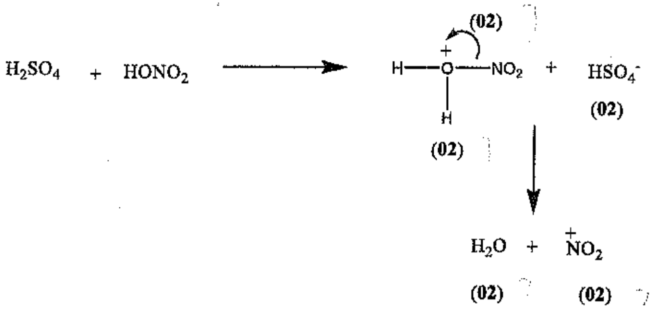
(c) Write the product and the mechanism of the reaction of benzene with conc. HNO_3/conc. H_2SO_4.



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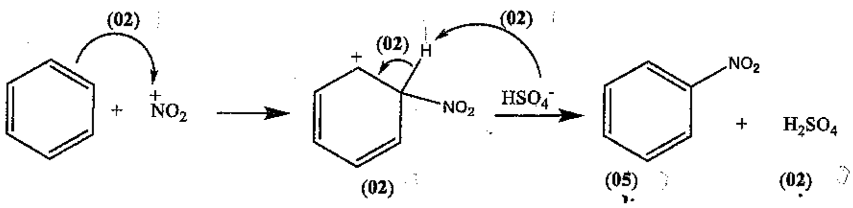

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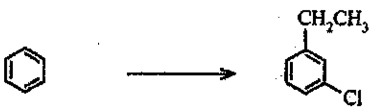
Note: mark $^{+}NO_2$ ion generation independently

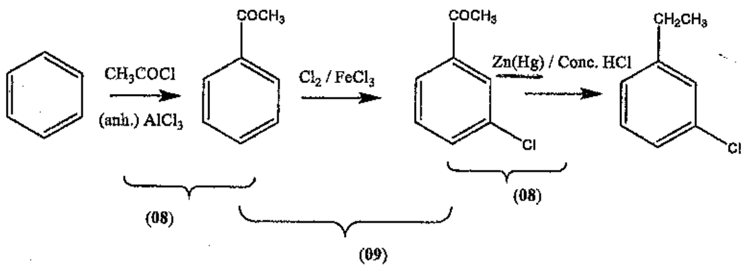
Mark reaction of benzene with $^{+}NO_2$ ion independently, however to award marks for the arenium ion its generation from benzene and $^{+}NO_2$ should be shown

If only reaction of benzene with $^{+}NO_2$ ion is written ($^{+}NO_2$ ion generation is not written) award 02 marks for the $^{+}NO_2$ ion

8(c): 25 marks

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

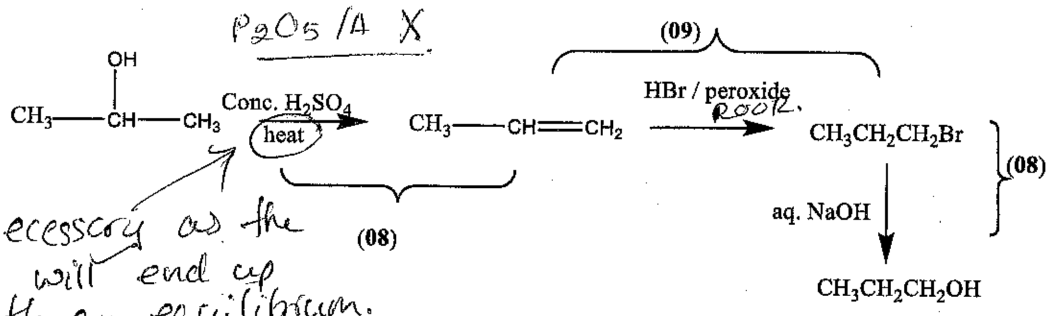
(i) 



Note: Cl_2 / $FeCl_3$ or Cl_2 / Lewis acid such as Fe/$FeBr_3$/$AlCl_3$/$AlBr_3$

(8(d)(i) : 25 marks)

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



necessary as the r^n will end up with an equilibrium.

Note: Al_2O_3 / heat accepted (reaction 1) HBr/H_2O_2 accepted (reaction 2)

aq./ dil. NaOH or aq./ dil. KOH accepted NaOH or KOH not accepted (reaction 3)

For (d) (i) and (ii) do not award marks for synthetic routes with more than 03 steps even if there is an overlap of given reaction

(8(d)(ii) : 25 marks)

8(d): 50 marks

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**.

A: $BaCl_2$
B: Na_2SO_4
C: $MgSO_4$
D: $Zn(NO_3)_2$
E: NaOH

(05 marks x 5 =25 marks)

(9(a)(i): 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**.

I. Ag^+, Mn^{2+}, Ba^{2+}

II. P_1 AgCl

P_2 MnS

P_3 $BaCO_3$

(04 marks x 6 =24 marks)

(9(a)(ii): 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)
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.

I.

X: I^-, (04)
Y: SO_3^{2-}, (04)
Z: S^{2-} (04)

Do not accept the compounds NaI etc...

II.

1. $Pb(CH_3COO)_2 + 2NaI \rightarrow PbI_2 + 2CH_3COONa$ or $Pb^{2+} + 2I^- \rightarrow PbI_2$
2. $BaCl_2 + Na_2SO_3 \rightarrow BaSO_3 + 2NaCl$ or $Ba^{2+} + SO_3^{2-} \rightarrow BaSO_3$
3. $BaSO_3 + 2HCl \rightarrow BaCl_2 + SO_2 + H_2O$ or
   $BaSO_3 + 2H^+ \rightarrow Ba^{2+} + SO_2 + H_2O$
4. $3SO_2 + Cr_2O_7^{2-} + 2H^+ \rightarrow 2Cr^{3+} + 3SO_4^{2-} + H_2O$
5. $2AgNO_3 + Na_2S \rightarrow Ag_2S + 2NaNO_3$ or $2Ag^+ + S^{2-} \rightarrow Ag_2S$
6. Na2S $\cancel{Ag_2S} + 2HCl \rightarrow$ 2NaCl $\cancel{2AgCl} + H_2S$
7. $Pb(CH_3COO)_2 + H_2S \rightarrow PbS + 2CH_3COOH$

(02 marks x 7 = 14 marks)

(9(a)(iii): 26 marks)

9(a): 75 marks

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(*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.

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

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)

(i) $Fe_3O_4 + 2I^- + 8H^+ \rightarrow 3Fe^{2+} + 4H_2O + I_2$ ← given

$Fe_2O_3 + 2I^- + 6H^+ \rightarrow 2Fe^{2+} + 3H_2O + I_2$ **(05)**

Or $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$

$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$ **(05)**

$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$ **(05)**

(9(b)(i): 15 marks)

(ii) In the sample **X**,

Let the number of moles of $Fe_3O_4 = n_1$ & moles of $Fe_2O_3 = n_2$ **(02 + 02)**

Moles of $S_2O_3^{2-}$ $= \frac{0.5}{1000} \times 15$ = 7.5×10^{-3} **(02)**

Hence, moles of I_2 in 25.00 cm^3 $= \frac{0.5}{1000} \times 15.0 \times \frac{1}{2}$ = 3.75×10^{-3} **(02)**

Hence, moles of I_2 in 100.0 cm^3 $= \frac{0.5}{1000} \times 15.0 \times \frac{1}{2} \times \frac{100}{25}$ **(02)**

$= 0.015$ **(02)**

08

According to the equation,

n_1 moles of Fe_3O_4 gives n_1 moles of I_2 **(02)**

n_2 moles of Fe_2O_3 gives n_2 moles of I_2 **(02)**

Hence, $n_1 + n_2 = 0.015$ ....(1) **(04)**

08.

Moles of MnO_4^- $= \frac{0.25}{1000} \times 14$ = 3.5×10^{-3} **(02)**

Moles of Fe^{2+} formed $= 5 \times \frac{0.25}{1000} \times 14$ = 17.5×10^{-3} **(02)**

Moles of Fe^{2+} in the dilute solution(s) $= 5 \times \frac{0.25}{1000} \times 14.0 \times \frac{100}{50}$ **(02)**

$= 5 \times \frac{0.25}{1000} \times 14.0 \times 2$

$= 0.035$ **(02)**

1 mole of Fe_3O_4 gives 3 moles of Fe^{2+} **(01)**

n_1 mole of Fe_3O_4 gives $3n_1$ moles of Fe^{2+} **(01)**

1 mole of Fe_2O_3 gives 2 moles of Fe^{2+} **(01)**

n_2 moles of Fe_2O_3 gives $2n_2$ moles of Fe^{2+} **(01)**

Hence, $3n_1 + 2n_2 = 0.035$ ....(2) **(04)**

Equation (1) x 2

$2n_1 + 2n_2 = 0.03$ ....(3)

(2) – (3) $n_1 = 0.005$ moles **(03)**

Hence, $n_2 = 0.015 - 0.005$

$n_2 = 0.01$ moles **(03)**

Molar mass of $Fe_3O_4 = 232\ g\ mol^{-1}$ **(02)**

Mass of Fe_3O_4 in sample **X** $= 0.005 \times 232$

$= 1.16\ g$ **(02)**

Molar mass of $Fe_2O_3 = 160\ g\ mol^{-1}$ **(02)**

Mass of Fe_2O_3 in sample **X** $= 0.01 \times 160$

$= 1.6\ g$ **(02)**

$\% Fe_3O_4 = \frac{1.16}{3.2} \times 100 = \boxed{36.25}$ **(05)**

$\% Fe_2O_3 = \frac{1.6}{3.2} \times 100 = \boxed{50.00}$ **(05)**

(9(b)(ii): 60 marks)

<u>Alternate Method</u> **(i)**

(ii) $Fe_3O_4 \equiv Fe_2O_3.FeO$

1 mol $Fe_3O_4 \equiv$ 2 mol Fe^{3+} + 1 mol Fe^{2+}

In the sample **X**,

Let the number of moles of $Fe_3O_4 = n_1$ & moles of $Fe_2O_3 = n_2$ **(02 + 02)**

Moles of $S_2O_3^{2-}$ $= \frac{0.5}{1000} \times 15$ **(02)**

Hence, moles of I_2 in 25.00 cm^3 $= \frac{0.5}{1000} \times 15.0 \times \frac{1}{2}$ **(02)**

Hence, moles of I_2 in 100.0 cm^3 $= \frac{0.5}{1000} \times 15.0 \times \frac{1}{2} \times \frac{100}{25}$ **(02)**

$= 0.015$ **(02)**

According to the equation,

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Hence, number of moles of Fe^{3+} reacted with I^- = 2 x 0.015 = 0.03 (02)

Number of moles of Fe^{2+} obtained from Fe^{3+} = 0.03 (02)

Hence, $2n_1 + 2n_2 = 0.03$ ....(1) (04)

Moles of MnO_4^- $= \frac{0.25}{1000} \times 14$ (02)

Moles of Fe^{2+} formed $= 5 \times \frac{0.25}{1000} \times 14$ (02)

Moles of Fe^{2+} in the dilute solution(s) $= 5 \times \frac{0.25}{1000} \times 14.0 \times \frac{100}{50}$ (02)

$= 5 \times \frac{0.25}{1000} \times 14.0 \times 2$

$= 0.035$ (02)

1 mole of Fe_3O_4 gives 3 moles of Fe^{2+} (01)

n_1 mole of Fe_3O_4 gives $3n_1$ moles of Fe^{2+} (01)

1 mole of Fe_2O_3 gives 2 moles of Fe^{2+} (01)

n_2 moles of Fe_2O_3 gives $2n_2$ moles of Fe^{2+} (01)

Hence, $3n_1 + 2n_2 = 0.035$ ....(2) (04)

08

$2n_1 + 2n_2 = 0.03$ ....(1)

(2) – (1) $n_1 = 0.005$ moles (03)

Hence, $n_2 = 0.015 - 0.005$

$n_2 = 0.01$ moles (03)

Molar mass of $Fe_3O_4 = 232\ g\ mol^{-1}$ (02)

Mass of Fe_3O_4 in sample **X** $= 0.005 \times 232$

$= 1.16\ g$ (02)

Molar mass of $Fe_2O_3 = 160\ g\ mol^{-1}$ (02)

Mass of Fe_2O_3 in sample **X** $= 0.01 \times 160$

$= 1.6\ g$ (02)

$\% Fe_3O_4 = \frac{1.16}{3.2} \times 100 = \mathbf{36.25}$ (05)

$\% Fe_2O_3 = \frac{1.6}{3.2} \times 100 = \mathbf{50.00}$ (05)

(60 marks)

Alternate Method **(ii)**

(ii) In the sample **X**,

Let the mass of $Fe_3O_4 = m_1 g$ & mass of $Fe_2O_3 = m_2 g$

Molar mass of $Fe_3O_4 = 232\ g\ mol^{-1}$ (02)

Molar mass of $Fe_2O_3 = 160\ g\ mol^{-1}$ (02)

Moles of Fe_3O_4 $= \frac{m1}{232}$ **(02)**

Moles of Fe_2O_3 $= \frac{m2}{160}$ **(02)**

Moles of $S_2O_3^{2-}$ $= \frac{0.5}{1000} \times 15$ **(02)**

Hence, moles of I_2 in 25.00 cm^3 $= \frac{0.5}{1000} \times 15.0 \times \frac{1}{2}$ **(02)**

Hence, moles of I_2 in 100.0 cm^3 $= \frac{0.5}{1000} \times 15.0 \times \frac{1}{2} \times \frac{100}{25}$ **(02)**

$= 0.015$ **(02)**

According to the equation,

$\frac{m1}{232}$ moles of Fe_3O_4 gives $\frac{m1}{232}$ moles of I_2 **(02)**

$\frac{m2}{160}$ moles of Fe_2O_3 gives $\frac{m2}{160}$ moles of I_2 **(02)**

Hence, $\frac{m1}{232} + \frac{m2}{160} = 0.015$ ....(1) **(04)**

Moles of MnO_4^- $= \frac{0.25}{1000} \times 14$ **(02)**

Moles of Fe^{2+} formed $= 5 \times \frac{0.25}{1000} \times 14$ **(02)**

Moles of Fe^{2+} in the dilute solution(s) $= 5 \times \frac{0.25}{1000} \times 14.0 \times \frac{100}{50}$ **(02)**

$= 5 \times \frac{0.25}{1000} \times 14.0 \times 2$

$= 0.035$ **(02)**

1 mole of Fe_3O_4 gives 3 moles of Fe^{2+} **(01)**

$\frac{m1}{232}$ mole of Fe_3O_4 gives $3 \times \frac{m1}{232}$ moles of Fe^{2+} **(01)**

1 mole of Fe_2O_3 gives 2 moles of Fe^{2+} **(01)**

$\frac{m2}{160}$ moles of Fe_2O_3 gives $2 \times \frac{m2}{160}$ moles of Fe^{2+} **(01)**

Hence, $\frac{3m1}{232} + \frac{2m2}{160} = 0.035$ ....(2) **(04)**

Equation (1) x 2

$\frac{2m1}{232} + \frac{2m2}{160} = 0.03$ ....(3)

(2) – (3) $\frac{m1}{232} = 0.005$ moles **(03)**

Hence, $m_1 = 0.005 \times 232$ g

$= 1.16$ g **(02)**

Hence, $\frac{m2}{160} = 0.015 - 0.005$

$= 0.01$ mol **(03)**

$m_2 = 0.01 \times 160$ g

$= 1.6$ g **(02)**

% Fe_3O_4 $= \frac{1.16}{3.2} \times 100 = \mathbf{36.25}$ **(05)**

% Fe_2O_3 $= \frac{1.6}{3.2} \times 100 = \mathbf{50.00}$ **(05)**

(60 marks)

9(b): 75 marks

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

(i) State the raw materials used.

disposable
Bittern (from sea water) / brine after desp reverse osmosis of sea water (04)
Lime stone or Dolomite ($CaCO_3$ or $CaCO_3.MgCO_3$) (04)
Conc. HCl (04)

(10(a)(i): 12 marks)

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

Step 1 (or production of CaO)

$CaCO_3(s) \xrightleftharpoons{\Delta} CaO(s) + CO_2(g)$ **(02)**

or

$CaCO_3.MgCO_3(s) \xrightleftharpoons{\Delta} CaO(s) + MgO(s) + CO_2(g)$

Note: Reversible arrows not required.

Step 2 (or preparation of $Mg(OH)_2$)

$CaO(s) + H_2O\ (l) \longrightarrow Ca(OH)_2(s)$ **(02)**

$Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$ **(02)**

$Mg^{2+}(aq) + 2OH^-(aq) \rightleftharpoons Mg(OH)_2(s)\downarrow$ **(02)**

06

Note: Reversible arrows not required.

Step 3 (or reaction of $Mg(OH)_2$ with conc HCl)

$Mg(OH)_2(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + 2H_2O(aq)$ **(02)**

Step 4 (or vaporization to remove water by strong heating)

$MgCl_2.6H_2O(s) \longrightarrow MgCl_2.4H_2O(s) + 2H_2O(l)$ **(01)**

and

$MgCl_2.4H_2O(s) \longrightarrow MgCl_2.2H_2O(s) + 2H_2O(l)$ **(01)**

04

Note : Physical states are not required for Steps 1-4

Step 5 (or fusing $MgCl_2$ and electrolysis)

Anode - graphite **(01)**

$2Cl^-(l) \longrightarrow Cl_2(g) + 2e$ **(03)**

Cathode - steel **(01)**

$Mg^{2+}(l) + 2e \longrightarrow Mg(l)$ **(03)**

Note: Physical states are required for Step 5
No marks for half reactions in Step 5, if anode and cathode are not mentioned.

Correct order **(10)**

Note : When considering the above sequence of steps,

If Step 1 is correct	**(02)**	If Steps 1 & 2 correct	**(04)**
If Steps 1, 2 & 3 correct	**(06)**	If Steps 1, 2, 3 & 4 correct	**(08)**
If all five steps correct	**(10)**		

(10(a)(ii): 30 marks)

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

1. Used in the production of alloys
2. Alloys used in aircraft and vehicle manufacture industry
   because they are strong and light weight
3. Preparation of Grignard Reagent
4. Used in the production of light-weight items such as camera, power tools, car seats, luggage etc.
5. Used in fireworks
6. Pharmaceutical industry – milk of magnesia
7. To remove sulfur from molten iron
8. Cathodic protection

(Any two, 02 marks x 2)
(10(a)(iii): 04 marks)

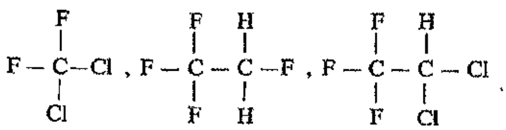
(iv) Give **two** ways in which the Dow process has a **negative** impact on the environment.

1. CO_2 is released to the atmosphere when burning limestone ($CaCO_3$) or dolomite ($CaCO_3.MgCO_3$). Contributes to global warming. **(02)**
2. CO_2 is released when burning petroleum fuels to obtain high temperature associated with an electrolyzing cell. Contributes to global warming. **(02)**

(10(a)(iv): 04 marks)

10(a): 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.

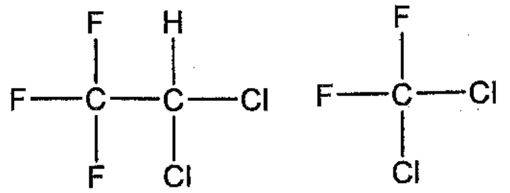
0003500

(b) (i) NO_2 **(02)**

(ii) $NO_2(g) \xrightarrow{\boxed{h\nu}} NO(g) + {}^{\cdot}O(g)$ ~~**(03)**~~ 2 + 01

$O_2(g) + {}^{\cdot}O(g) \longrightarrow O_3(g)$ **(03)**

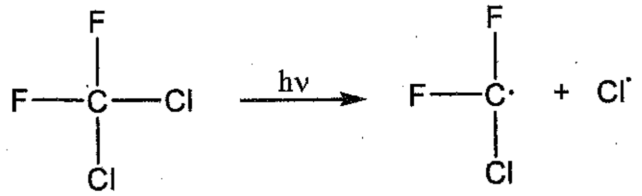
(iii)



NO **(02 + 02)**

(Any two)

(iv)



~~**(03)**~~ (02 + 01)

$Cl^{\cdot} + O_3 \longrightarrow O_2 + {}^{\cdot}OCl$ --------(1) **(03)**

$O_3 \longrightarrow O_2 + {}^{\cdot}O$ ---------(2) **(03)**

${}^{\cdot}OCl + {}^{\cdot}O \longrightarrow O_2 + Cl^{\cdot}$ ---------(3) **(03)**

15

(1) + (2) + (3)

$2O_3 \longrightarrow 3O_2$ **(03)**

$O_3 + {}^{\cdot}OCl \longrightarrow 2O_2 + {}^{\cdot}Cl$ (06)

or

${}^{\cdot}NO + O_3 \longrightarrow NO_2 + O_2$ **(15)**

or

${}^{\cdot}NO + O_2 \longrightarrow NO_2 + {}^{\cdot}O$ **(08)**

$O_3 + O_2 \longrightarrow 2O_2$ **(07)**

(• not required)

$NO + O_3 \longrightarrow NO_2 + O_2$ (04)

$NO_2 \longrightarrow NO + O$ (04)

$(O_3 + O \longrightarrow 2O_2)$ 2 (04)

$2O_3 \longrightarrow 3O_2$ (03)

(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.

(v) NO, NO_2 and $CH_3CH_2CH_2CH_2CH_3$ **(02 + 02)**

(Any two)

(vi) CH_4, CO_2, N_2O, $CF_3\text{-}CF_2H$, $CF_3\text{-}CHCl_2$, CF_2Cl_2

(Any four) **(02 marks x 4)**

(vii) Greenhouse gases/ Greenhouse effect **(03)**

(viii) NO_2, SO_2, SO_3, CO_2 **(02 + 02)**

(Any two)

pH & conductivity **(02 + 02)**

turbidity ×.

10(b): 50 marks

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

Group A monomers : $Cl-\overset{O}{\overset{\|}{C}}-(CH_2)_n-\overset{O}{\overset{\|}{C}}-Cl$, $HO-\overset{O}{\overset{\|}{C}}-(CH_2)_n-\overset{O}{\overset{\|}{C}}-OH$

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 $\left[\overset{O}{\overset{\|}{C}}-(CH_2)_n-\overset{O}{\overset{\|}{C}}-\overset{H}{\overset{|}{N}}-(CH_2)_n-\overset{H}{\overset{|}{N}}\right]$ is 226 g mol^{-1}.

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

(c) (i) $Cl-\overset{O}{\overset{\|}{C}}-(CH_2)_n-\overset{O}{\overset{\|}{C}}-Cl$ & $HO-(CH_2)_n-OH$ **(10)**

$Cl-\overset{O}{\overset{\|}{C}}-(CH_2)_n-\overset{O}{\overset{\|}{C}}-Cl$ & $H_2N-(CH_2)_n-NH_2$ **(10)**

(ii) $HO-\overset{O}{\overset{\|}{C}}-(CH_2)_n-\overset{O}{\overset{\|}{C}}-OH$ & $HO-(CH_2)_n-OH$ **(10)**

$HO-\overset{O}{\overset{\|}{C}}-(CH_2)_n-\overset{O}{\overset{\|}{C}}-OH$ & $H_2N-(CH_2)_n-NH_2$ **(10)**

(iii) Molar mass of the repeating unit

$$\left[-\overset{O}{\overset{\|}{C}}-(CH_2)_n-\overset{O}{\overset{\|}{C}}-\overset{H}{\overset{|}{N}}-(CH_2)_n-\overset{H}{\overset{|}{N}}- \right]$$

$28 \times 2 + 15 \times 2 + 14 \times 2 \times n = 226$ **(05)**
$56 + 30 + 28n = 226$
$28n = 140$
$n = 5$ **(02)**
Hence, number of $-CH_2-$ groups in the repeating unit $= 5 \times 2$
$= 10$ **(03)**

10

10(c): 50 marks

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