G.C.E.(A.L.) Support Seminar - 2015
Chemistry I
Answer Guide

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Question number	Answer
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2 × 50 = 100 marks

[see page two

G.C.E.(A.L.) Support Seminar - 2015
Chemistry II
Answer Guide

PART A - STRUCTURED ESSAY

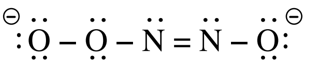
1. (*a*) (i) $NH_2^- < N_2H_4 < NH_2OH$

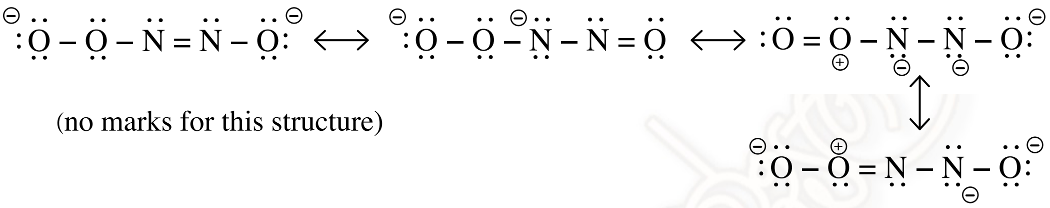
(ii) $O_2 < O_3 < H_2O_2$

(iii) $SF_6 < SF_4 < SF_2$

(iv) Na < Zn < V

(v) $Al(OH)_3 < Mg(OH)_2 < Ba(OH)_2$ (06 × 5 = 30 marks)

(*b*) (i)  (05 marks)

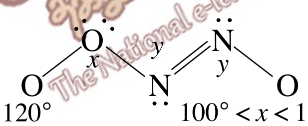
(ii) 

(no marks for this structure)

(04 × 3 = 12 marks)

(iii) O^2 - tetrahedral N^3 - trigonal planer (03 × 2 = 06 marks)

(iv) N^4 - sp^2 O^5 - sp^3 / 2p (03 × 2 = 06 marks)

(v) 

$115° < y < 120°$ $100° < x < 110°$ (06 marks)

(*c*) (i) Lyman (05 marks)

(ii) −36 and −327 kJ mol^{-1} (03 + 03 marks)

(iii) $-36 - (-327)$ kJ mol^{-1} (03 + 01 marks)

$= 291$ kJ mol^{-1} (03 + 01 marks)

(iv) Energy of a photon, $E = \dfrac{291\ kJ\ mol^{-1}}{6.022 \times 10^{23}\ mol^{-1}} = 48.32 \times 10^{-23}\ kJ$ (03 + 01 marks)

$\nu = \dfrac{E}{h} \Rightarrow \nu = \dfrac{48.32 \times 10^{-23} \times 10^3\ J}{6.626 \times 10^{-34}\ J\ s} = 7.29 \times 10^{14}\ s^{-1}$ (03 + 01 marks)

(v) $E = 0 - (-1311)\ kJ\ mol^{-1}$ (03 + 01 marks)

$= 1311\ kJ\ mol^{-1}$ (03 + 01 marks)

[see page three

2. (*a*) (i) (I) NH_3

(II) NH_3, H_2S, HI

(III) H_2S and HI (03 × 6 = 18 marks)

(ii) (I) $Na + H_2S \longrightarrow Na_2S + H_2$ or

$2Na + 2NH_3 \longrightarrow 2NaNH_2 + H_2$ or

$2Na + 2HI \longrightarrow 2NaI + H_2$ or

(excess) $2H_2S + 2Na \longrightarrow 2NaHS + H_2$

(II) $H_2S + Cl_2 \longrightarrow 2HCl + S$ or

$3Cl_2 + 2NH_3 \longrightarrow N_2 + 6HCl$ or

$3Cl_2 + 8NH_3 \longrightarrow 2N_2 + 6NH_4Cl$ or

$3Cl_2 + NH_3 \longrightarrow NCl_3 + 3HCl$ or

$Cl_2 + H_2S \longrightarrow 2HCl + S$ or

$Cl_2 + 2HI \longrightarrow I_2 + 2HCl$

(III) $SO_2 + 2H_2S \longrightarrow 3S + 2H_2O$ (05 × 3 = 15 marks)

(iii) $(NH_4)I$ (05 marks)

covalent bonds

ionic bonds

dative bonds / dative covalent bonds / coordinate covalent bonds (02 × 3 = 06 marks)

(iv) (I) NH_3

(II) NH_3, H_2S, HI (03 × 4 = 12 marks)

(v) $(NH_4)_2S$ / NH_4HS

ammonium sulphide / ammonium hydrogensulphide / ammonium bisulphide (03 × 2 = 06 marks)

(*b*) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ (04 × 2 = 08 marks)

(ii) Electron configuration of Zn is more stable. So, the ability to release electrons to the delocalised sea of electrons is low. Thus the strength of metallic bond is relatively low, and melting point of Zn is lower than that of other elements in 3d series.

(02 × 3 = 06 marks)

(iii) (I) Black precipitate is obtained. (02 + 2 = 04 marks)

(II) Dark blue solution is formed. (02 + 2 = 04 marks)

(iv) (I) hexaaquazinc(II) ion (04 marks)

(II) octahedral (02 marks)

(v) $7Zn + 16HNO_3 \longrightarrow 7Zn(NO_3)_2 + N_2H_4 + 6H_2O$ (10 marks)

[see page four

3. (*a*) (i) $H_2A(aq) \rightleftharpoons H^+(aq) + HA^-(aq)$ or $H_2A(aq) + H_2O(l) \rightleftharpoons HA^-(aq) + H_3O^+(aq)$ (05 marks)

$$K_a = \frac{[H_3O^+(aq)][HA^-(aq)]}{[H_2A(aq)]} \quad \text{or} \quad K_{a_1} = \frac{[H^+(aq)][HA^-(aq)]}{[H_2A(aq)]}$$ (05 marks)

(ii) point *B* (05 marks)

(iii)
$$[H_2A(aq)] = [HA^-(aq)]$$
$$K_{a_1} = [H^+(aq)]$$
$$pH = pK_{a_1}$$
$$K_{a_1} = \text{antilog}\,(-3.0)$$
$$K_{a_1} = 1 \times 10^{-3}\,\text{mol dm}^{-3}$$ (10 marks)

(iv) point *C* (05 marks)

	$HA^-(aq) + H_2O(l)$	$\rightleftharpoons$	$H_3O^+(aq)$	+	$A^{2-}(aq)$
initial concentration(mol dm^{-3})	0.05		–		–
equiliblium concentration(mol dm^{-3})	$0.05 - x$		x		x

$$K_{a_2} = \frac{[H_3O^+(aq)][A^{2-}(aq)]}{[HA^-(aq)]}$$

$$5.0 \times 10^{-8}\,\text{mol dm}^{-3} = \frac{[H_3O^+(aq)]^2}{(0.05 - x)\,\text{mol dm}^{-3}}$$

since $x <<< 0.05$;

$$(0.05 - x) \simeq 0.05$$
$$[H_3O^+(aq)]^2 = 25 \times 10^{-10}\,\text{mol}^2\,\text{dm}^{-6}$$
$$[H_3O^+(aq)] = 5 \times 10^{-5}\,\text{mol dm}^{-3}$$
$$pH = -\log_{10}[H_3O^+(aq)]$$
$$= -\log_{10}(5 \times 10^{-5})$$
$$= 4.301$$ (20 marks)

(v) point *E* (05 marks)

(vi) point *B* or point *D* (05 marks)

at point *B*

Solution contains H_2A and HA^- with the same concentration.

* When a small amount of H^+ is added
$HA^-(aq) + H^+(aq) \rightleftharpoons H_2A(aq)$

* When a small amount of OH^- is added
$H_2A(aq) + OH^-(aq) \rightleftharpoons HA^-(aq) + H_2O(l)$

at point *D*

This can be explained by using HA^- instead of H_2A and A^{2-} instead of HA^-.

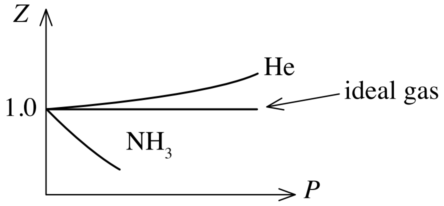
(10 marks)

[see page five

(*b*) (i) The maximum temperature at which a gas can be converted to a liquid by compression. (06 marks)

(ii) $He < CO_2 < NH_3$ (05 marks)

(iii)

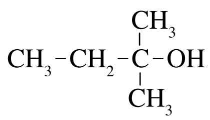


($02 \times 6 = 12$ marks)

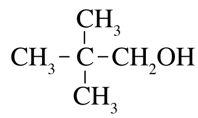
(iv) When the intermolecular attractive forces of a real gas are strong, Z value decreases, so the critical temperature increases. (07 marks)

4. (*a*) (i)

A



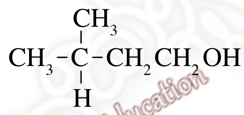
D



($05 \times 2 = 10$ marks)

(ii)

$CH_3CH_2CH_2CH_2CH_2OH$



($05 \times 2 = 10$ marks)

(iii)

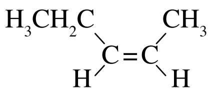
B

$CH_3-CH_2-CH_2-CH_2-CH_2-OH$

(05 marks)

(iv)

H



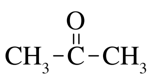
(05 marks)

(v) geometrical isomerism / cis - trans isomerism (03 marks)

(vi) pent - 2 - ene or 2 - pentene (03 marks)

(*b*) (i)

Q



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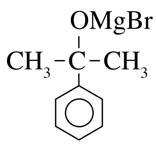

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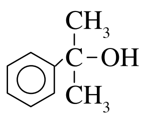
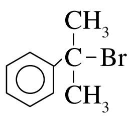


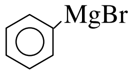
T



($05 \times 4 = 20$ marks)

(ii) *a* - Hg^{2+} / $HgSO_4$ and dil. H_2SO_4

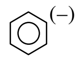
[see page six

b -  / dry ether

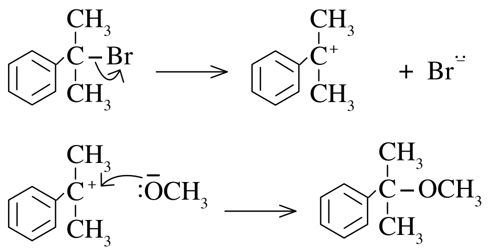
c - HCl(aq) / H_3O^+(aq) or H^+ / H_2O (03 × 4 = 12 marks)

d - CH_3OH / Na

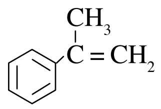
(iii)

Reaction	Type of reaction	Active species
1	A_E	H^+
2	A_N	
3	O	–
4	S_N	Br^-
5	S_N	CH_3O^-

(01 × 10 = 10 marks)

(iv) 

(03 × 5 = 15 marks)

(v) 

(05 marks)

(vi) as a base (02 marks)

**

[see page seven

PART B - ESSAY

5. (*a*) (i) A solution which obeys Raoult's law for any composition

or

If the intermolecular forces of a binary solution prepared by completely mixing liquids A and B are equal, i.e. (06 marks)

$$f(A-B) = f(A-A) = f(B-B),$$

such a solution is an ideal solution.

(ii) $A(l) \rightleftharpoons A(g)$

$B(l) \rightleftharpoons B(g)$ (03 × 2 = 06 marks)

(iii) Considering A, when rate of forward reaction is r_1 and rate of backward reaction is r_2.

$$r_1 = \mathrm{K}_1\,[A(l)]$$
$$r_2 = \mathrm{K}_2\,[A(g)]$$

at dynamic equiliblium, $r_1 = r_1$

$$\mathrm{K}_1\,[A(l)] = \mathrm{K}_2\,[A(g)]$$

$[A(l)] \propto X_A$ and $[A(g)] \propto P_A$

$$\therefore\ \mathrm{K}_1 X_A = \mathrm{K}_2 P_A$$
$$P_A = \frac{\mathrm{K}_1}{\mathrm{K}_2} . X_A$$
$$P_A = \mathrm{K} . X_A$$

(12 marks)

(iv) when $x = 1$, $P_A = P_A^\circ$

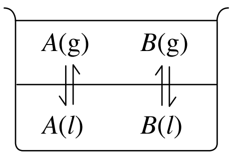
$$\therefore\ P_A^\circ = \mathrm{K}$$
$$P_A = P_A^\circ . X_A$$

(06 marks)

(*b*) (i) number of moles of A, $n_A = \dfrac{0.8314\ \mathrm{dm^3}}{8.314 \times 10^{-2}\ \mathrm{dm^3\,mol^{-1}}} = 10\ \mathrm{mol}$ (04 marks)

number of moles of B, $n_B = \dfrac{0.8314\ \mathrm{dm^3}}{4.157 \times 10^{-2}\ \mathrm{dm^3\,mol^{-1}}} = 20\ \mathrm{mol}$ (04 marks)

(ii)



$X_A(g) = 0.2$

assuming the ideal behaviour of the vapour,

$$P_A = X_A(g) . P_T$$
$$= 0.2\ (3 \times 10^5\ \mathrm{Pa})$$
$$P_A = 6 \times 10^4\ \mathrm{Pa}$$

(05 marks)

$$X_A(g) + X_B(g) = 1.0$$
$$\therefore\ X_B(g) = (1.0 - 0.2) = 0.8$$
$$\therefore\ P_B = 0.8\ (3 \times 10^5\ \mathrm{Pa})$$
$$P_B = 2.4 \times 10^5\ \mathrm{Pa}$$

or

$$P_B = P_T - P_A$$
$$= 3.00 \times 10^5\ \mathrm{Pa} - 6.00 \times 10^4\ \mathrm{Pa}$$
$$= 2.4 \times 10^5\ \mathrm{Pa}$$

(05 marks)

[see page eight

(iii) $PV = nRT$

for gas A $\Rightarrow$ $n_A = \dfrac{6 \times 10^4\,\text{Pa} \times 100 \times 0.8314 \times 10^{-3}\,\text{m}^3}{8.314\,\text{J mol}^{-1}\,\text{k}^{-1} \times 300\,\text{K}}$ (02 marks)

$n_A = 2\,\text{mol}$ (05 marks)

for gas B $\Rightarrow$ $n_B = \dfrac{2.4 \times 10^5\,\text{Pa} \times 100 \times 0.8314 \times 10^{-3}\,\text{m}^3}{8.314\,\text{J mol}^{-1}\,\text{k}^{-1} \times 300\,\text{K}}$

$n_B = 8\,\text{mol}$ (05 marks)

(iv) at equilibrium;

n_A in liquid phase $= (10 - 2)\,\text{mol} = 8\,\text{mol}$

n_B in liquid phase $= (20 - 8)\,\text{mol} = 12\,\text{mol}$ (02 marks)

from Raoult's law,

$P_A = P_A^\circ . X_A$ (02 marks)

$6 \times 10^4\,\text{Pa} = P_A^\circ \times \dfrac{8}{20}$

$P_A^\circ = \dfrac{6 \times 10^4}{8} \times 20\,\text{Pa} = 1.5 \times 10^5\,\text{Pa}$

$P_A^\circ = 1.5 \times 10^5\,\text{Pa}$ (05 marks)

$P_B^\circ = \dfrac{P_B}{X_B}$

$= \dfrac{2.4 \times 10^5\,\text{Pa}}{12} \times 20$

$P_B^\circ = 4 \times 10^5\,\text{Pa}$ (05 marks)

(v) (I)

	A(g)	$\rightleftharpoons$ $2C$(g)
initial amounts (mol)	10	–
at equilibrium (mol)	$10 - x$	$2x$

(02 marks)

$PV = nRT$

$\dfrac{1.4 \times 10^6\,\text{Pa} \times 100.8 \times 0.8314 \times 10^{-3}\,\text{m}^3}{8.314\,\text{J k}^{-1}\,\text{mol}^{-1} \times 403.2\,\text{K}} = n$ (03 marks)

$n = 35\,\text{mol}$

$n_A + n_C + n_B = 35\,\text{mol}$

$10 - x + 2x + 20 = 35$

$x = 5\,\text{mol}$ (04 marks)

$P_A = P_T . X_A$

$= 1.4 \times 10^6\,\text{Pa} \times \dfrac{5}{35}$

$= 2 \times 10^5\,\text{Pa}$ (03 marks)

$P_C = 1.4 \times 10^6\,\text{Pa} \times \dfrac{10}{35}$

$= 4 \times 10^5\,\text{Pa}$ (03 marks)

$P_B = 1.4 \times 10^6\,\text{Pa} \times \dfrac{20}{35}$

$= 8 \times 10^5\,\text{Pa}$ (03 marks)

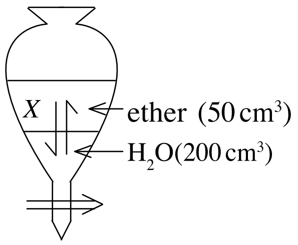
[see page nine

(II) $K_P = \dfrac{P^2_C(g)}{P_A}$ (05 marks)

$= \dfrac{(4 \times 10^5\,\text{Pa})^2}{2 \times 10^5\,\text{Pa}}$

$= 8 \times 10^5\,\text{Pa}$ (03 marks)

(*c*)



(i) $X(H_2O) \rightleftharpoons X\,(\text{ether})$ (04 marks)

$K_D = \dfrac{[X]\,\text{ether}}{[X]\,H_2O}$ (05 marks)

(ii) for 1st extraction;

Let's assume that the number of moles of X remaing in H_2O is n_1 and number of moles of X extracted to ether is n_2 ;

$$16 = \dfrac{\dfrac{n_2}{50} \times 1000\,\text{mol dm}^{-3}}{\dfrac{n_1}{200} \times 1000\,\text{mol dm}^{-3}}$$

$$16 = \dfrac{n_2}{n_1} \times 4$$

$$\dfrac{n_2}{n_1} = \dfrac{4}{1}$$ (20 marks)

∴ Amount of X remaining in water after 1st extraction (as a fraction to the initial amount)

$$= \dfrac{n_1}{n_1 + n_2}$$

$$= \dfrac{1}{4+1} = \dfrac{1}{5}$$

(iii) Amount of X remaing in water after 3rd extraction (as a fraction) $= \dfrac{1}{5} \times \dfrac{1}{5} \times \dfrac{1}{5} = \dfrac{1}{125}$

(15 marks)

∴ Amount of X extracted into the ether as a percentage $= \dfrac{124}{125} \times 100\%$

$= 99.2\%$

(iv) (I) Ether and water are completely immiscible.

(II) X, exists in the same molecular form in both ether and water. (03 × 2 = 06 marks)

(III) Temperture remains constant.

(any two)

6. (*a*) (i) (I) $CH_4(g) + CO_2(g) \longrightarrow 2CO(g) + 2H_2(g)$; x kJ mol⁻¹ ——— (1)

$C(s) + H_2O(g) \longrightarrow CO(g) + H_2(g)$; -125 kJ mol⁻¹ ——— (2)

$C(s) + O_2(g) \longrightarrow CO_2(g)$; -394 kJ mol⁻¹ ——— (3)

$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$; -800 kJ mol⁻¹ ——— (4)

(03 × 4 = 12 marks)

[see page ten

$$(2) \times 2 \Rightarrow \quad 2C(s) + 2H_2O(g) \xrightarrow[\Delta H = -\,250\,kJ\,mol^{-1}]{\Delta H = 2\times(-125)\,kJ\,mol^{-1}} 2CO(g) + 2H_2(g)$$

$$\therefore \quad 2CO(g) + 2H_2(g) \xrightarrow[\Delta H = +\,250\,kJ\,mol^{-1}]{} 2C(s) + 2H_2O(l) \text{ —— } (5)$$

(02 × 3 = 06 marks)

$$(1) + (5) \Rightarrow \quad CH_4(g) + CO_2(g) \xrightarrow{(250 + x)\,kJ\,mol^{-1}} 2\,C(s) + 2H_2O(g)$$

$$2O_2(g) + CH_4(g) + CO_2(g) \xrightarrow{(250 + x)\,kJ\,mol^{-1}} 2\,C(s) + 2H_2O(g) + 2O_2(g)$$

$$-800\,kJ\,mol^{-1} \searrow \qquad \swarrow 2(-394)\,kJ\,mol^{-1}$$

$$2CO_2(g) + 2H_2O(l)$$

(02 × 3 = 06 marks)

from Hess's law ;

$250\,kJ\,mol^{-1} + x + 2(-394)\,kJ\,mol^{-1} = -800\,kJ\,mol^{-1}$ (02 + 01 = 03 marks)

$x = (-800 + 788 - 250)\,kJ\,mol^{-1}$

$\underline{\underline{x = -262\,kJ\,mol^{-1}}}$ (02 + 01 = 03 marks)

(*b*) (i) Initial number of moles of X $= \frac{2.0}{1000} \times 50\,mol$

$\therefore$ Number of moles of X reacted $= \frac{2.0}{1000} \times 50 \times \frac{20}{100}\,mol$

$\therefore$ Rate of consumption of X $= \frac{2 \times 50 \times 20}{1000 \times 100} \times \frac{1000}{200} \times \frac{1}{4}\,mol\,dm^{-3}\,s^{-1}$ (12 marks)

$= 0.025\,mol\,dm^{-3}\,s^{-1}$

(ii) Rate of consumption of Y $= 2(0.025)\,mol\,dm^{-3}\,s^{-1}$

$= 0.05\,mol\,dm^{-3}\,s^{-1}$ (04 marks)

(iii) $r = K\,[X]^x\,[Y]^y\,[Z]^z$ (05 marks)

(iv) $x = 1,\ y = 1,\ z = 0$ (09 marks)

(v) $r = K\,[X]\,[Y]$ (05 marks)

(vi) Z is required. The reaction is zeroth order with respect ot Z. Therefore Z is required for the reaction but it does not affect the rate of reaction. (Rate of reaction does not depend on Z) (06 marks)

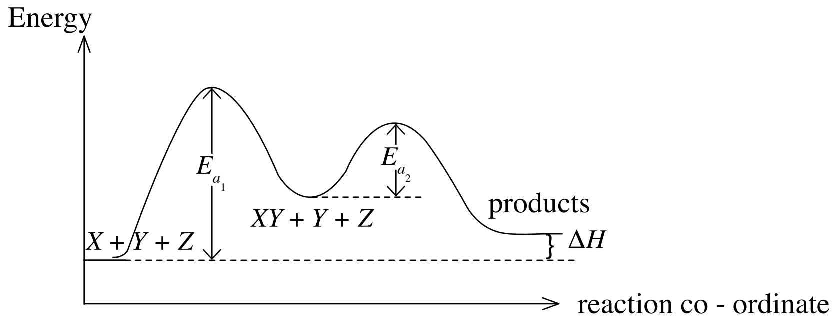
(vii) $X + Y \longrightarrow XY$ (04 marks)

(viii) molecularity is 2 (03 marks)

(ix) XY (06 marks)

[see page eleven

(x)



(02 × 8 = 16 marks)

(*c*) (i) burette (03 marks)

(ii) * Stopcock of the burette should be colsed tightly.

* Burette should be completely filled with HCl acid without air bubbles before starting the reaction. (03 × 2 = 06 marks)

(iii) (I) Assuming the ideal behaviour of H_2 gas and applying

$PV = nRT$ for its average volume (02 marks)

$n_{H_2} = \frac{1.0 \times 10^5 \text{Pa} \times 33 \times 10^{-6} \text{m}^3}{8.314 \text{J mol}^{-1} \text{K}^{-1} \times 300 \text{K}} = 0.0013 \text{mol}$ (05 marks)

(II) $Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$ (04 marks)

$n_{Mg} = n_{H_2} = 0.0013 \text{mol}$ (04 marks)

(III) $n = \frac{m}{M}$ (for average mass)

$0.0013 \text{mol} = \frac{34 \times 10^{-3}}{M} \text{g}$

$M_{Mg} = 26.15 \text{g mol}^{-1}$

(Deduct 05 marks if average values are not taken)

$\therefore A_r(Mg) = 26.15$ (12 marks)

(iv) There is a small change.
Leak in burette.
Impurities in magnesium ribbon.
Errors when making measurements. (02 × 2 = 04 marks)

(v) Difficult
Errors can arise when measuring the volume of H_2 when the reaction proceedes faster. (04 marks)

(vi) Do not agree
When 100.0 mg of Mg is used, percentage error in the mass of Mg can be reduced. But other erros remain unchanged.

(06 marks)

[see page twelve

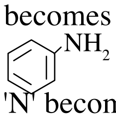
7. (*a*) (i) $CH_3OH + H_3O^+ \rightleftharpoons CH_3O^+H_2 + H_2O$
alkyl oxonium ion

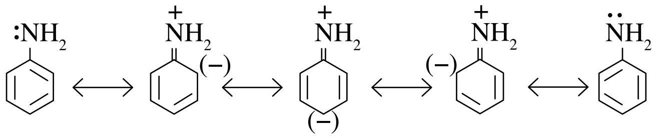
$CH_3NH_2 + H_3O^+ \rightleftharpoons CH_3N^+H_3 + H_2O$
alkyl ammonium ion (10 marks)

Since 'O' atom is more electronegative than 'N' atom, ability to donate the lone pair of electrons on 'N' is higher than that of 'O'. Therefore, alkyl ammonium ion is more stable relative to amine compared to alkyl oxonium ion relative to alcohol.

(10 marks)

(ii) Since the alkyl group in $CH_3CH_2NH_2$ repels electrons towards 'N' atom (Inductive effect), electron density of 'N' becomes higher. Then ability to donate electrons will increase.

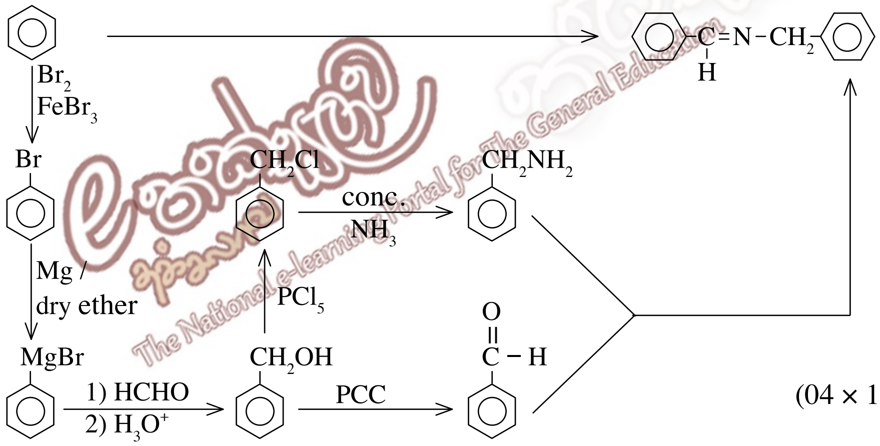
But lone pair on 'N' in  gets delocalized with the benzene ring through resonance, so electron density on 'N' becomes lower.



According to the above structures, and (+) charge on 'N', ability to donate electrons by 'N' becomes low.

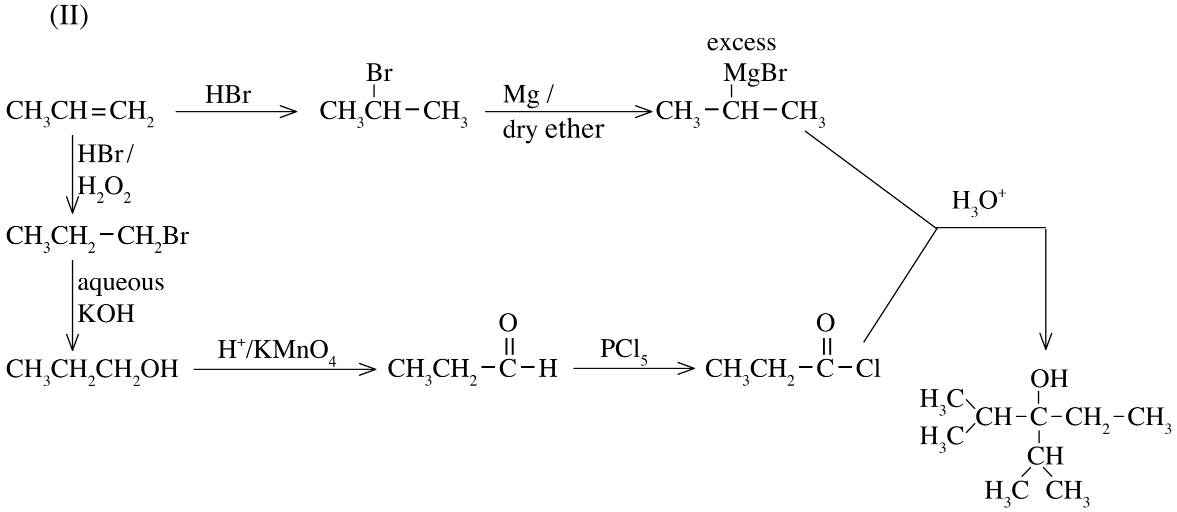
(20 marks)

(*b*) (i) (I)



(04 × 12 = 48 marks)

(II)



(04 × 13 = 52 marks)

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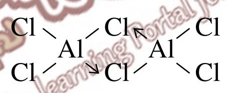
(ii) (I) with Na - a, b, c, d
with aqueous NaOH - a, d (10 marks)

PART C - ESSAY

8. (*a*) (i) *A* = Al
B = $AlCl_3$
C = $Al(OH)_3$
D = Al_2O_3
E = $NaAlO_2$ / $Na[Al(OH)_4]$
F = H_2 (03 × 6 = 18 marks)

(ii) $Al_2O_3 + 2NaOH \longrightarrow 2NaAlO_2 + H_2O$
or
$Al_2O_3 + 2NaOH + 3H_2O \longrightarrow 2Na[Al(OH)_4]$ (05 marks)

(iii) $AlCl_3$ is hydrolysed as follows.
$AlCl_3 + 3H_2O \rightleftharpoons Al(OH)_3 + 3HCl$
or
$AlCl_3 + 3H_2O \rightleftharpoons Al(OH)_3 + H^+ + Cl^-$
HCl is a strong acid.
∴ It is completly ionized in solution and H^+/ H_3O^+ concentration is higher in the medium.
(10 marks)

(iv) $AlCl_3$ dimerizes as follows  (07 marks)

(*b*) (i) *E* = O_2 / oxygen
Q = N_2 / nitrogen
R = Ca / calcium
L = CaO / calcium oxide
T = $Ca(OH)_2$ / calcium hydroxide
U = Ca_3N_2 / calcium nitride
V = NH_3 / ammonia (03 × 7 = 21 marks)

(ii) (I) $3Ca + N_2 \longrightarrow Ca_3N_2$

(II) $Ca_3N_2 + 6H_2O \longrightarrow 3Ca(OH)_2 + 2NH_3$ (05 × 2 = 10 marks)

(iii) to produce slaked lime
to produce calcium carbide
to reduce acidity of soil
to produce bleaching powder
to neutralise acidic gases
to construct buildings / to make mortar
(any one) (03 marks)

[see page fourteen

to produce fertilizers containing nitrogen
to produce HNO_3 acid
to produce nylon/polymers
to neutralise acidic substances in petroleum industry
to control pH of water
to neutralise SO_2 produced by combustion of fuel in motor vechicles
as a coolant
to prevent coagulation of rubber
to produce sodium carbonate (06 marks)
(any two)

(*c*) (i) *X* = $BaSO_4$ / barium sulphate
Y = CuI / Cu_2I_2 / copper(I) iodide / cuprous iodide (03 × 2 = 06 marks)

(ii)
$S^{2-} + 8NO_3^- + 8H^+ \longrightarrow SO_4^{2-} + 8NO_2 + 4H_2O$
$Fe^{2+} + NO_3^- + 2H^+ \longrightarrow Fe^{3+} + NO_2 + H_2O$
$Ba^{2+} + SO_4^{2-} \longrightarrow BaSO_4$
$2Cu^{2+} + 2I^- \longrightarrow 2Cu^+ + I_2$ or $2Cu^{2+} + 2I^- \longrightarrow Cu_2^{2+} + I_2$
or $2Cu^{2+} + 4I^- \longrightarrow 2CuI + I_2$ or $2Cu^{2+} + 4I^- \longrightarrow Cu_2I_2 + I_2$
$2Fe^{3+} + 2I^- \longrightarrow 2Fe^{2+} + I_2$
$I_2 + 2S_2O_3^{2-} \longrightarrow 2I^- + S_4O_6^{2-}$ (02 × 6 = 12 marks)

(iii) amount of moles of $BaSO_4$ = $\frac{0.1864\,g}{233\,g\,mol^{-1}}$
= 0.0008 mol

amount S in the sample = $0.0008 \times \frac{250}{25}$ mol
= 0.008 mol
mass of S = $0.008\,mol \times 32\,g\,mol^{-1}$
= 0.256 g
mass percentage of S = $\frac{0.256\,g}{1.000\,g} \times 100$
= 25.6% (12 marks)

amount of moles of CuI = $\frac{0.0381\,g}{190.5\,g\,mol^{-1}}$
= 0.0002 mol

amount Cu in the sample = $0.0002 \times \frac{250}{25}$ mol
= 0.002 mol
mass of Cu = $0.002\,mol \times 63.5\,g\,mol^{-1}$
= 0.127 g
mass percentage of Cu = $\frac{0.127\,g}{1.000\,g} \times 100$
= 12.7% (18 marks)

[*see page fifteen*

amount of $S_2O_3^{2-}$ $= \dfrac{0.0400 \times 20.00}{1000}$ mol

amount of I_2 $= \dfrac{0.0400 \times 20.00}{1000 \times 2}$ mol

$= 0.0004$ mol

amount of I_2 generated by Cu^{2+} $= \dfrac{0.002 \text{ mol}}{2}$

$= 0.0001$ mol

$\therefore$ amount of I_2 generated by Fe^{3+} $= (0.0004 - 0.0001)$ mol

$= 0.0003$ mol

$\therefore$ amount of Fe^{3+} in 25.00 cm^3 $= 0.0003 \text{ mol} \times 2$

$= 0.0006$ mol

amount Fe in the sample $= 0.0006 \times \dfrac{250}{25}$ mol

$= 0.006$ mol

mass of Fe $= 0.006 \text{ mol} \times 56 \text{ g mol}^{-1}$

$= 0.336$ g

mass percentage of Fe $= \dfrac{0.336 \text{ g}}{1.000 \text{ g}} \times 100$

$= 33.6\%$ (22 marks)

alternative method :

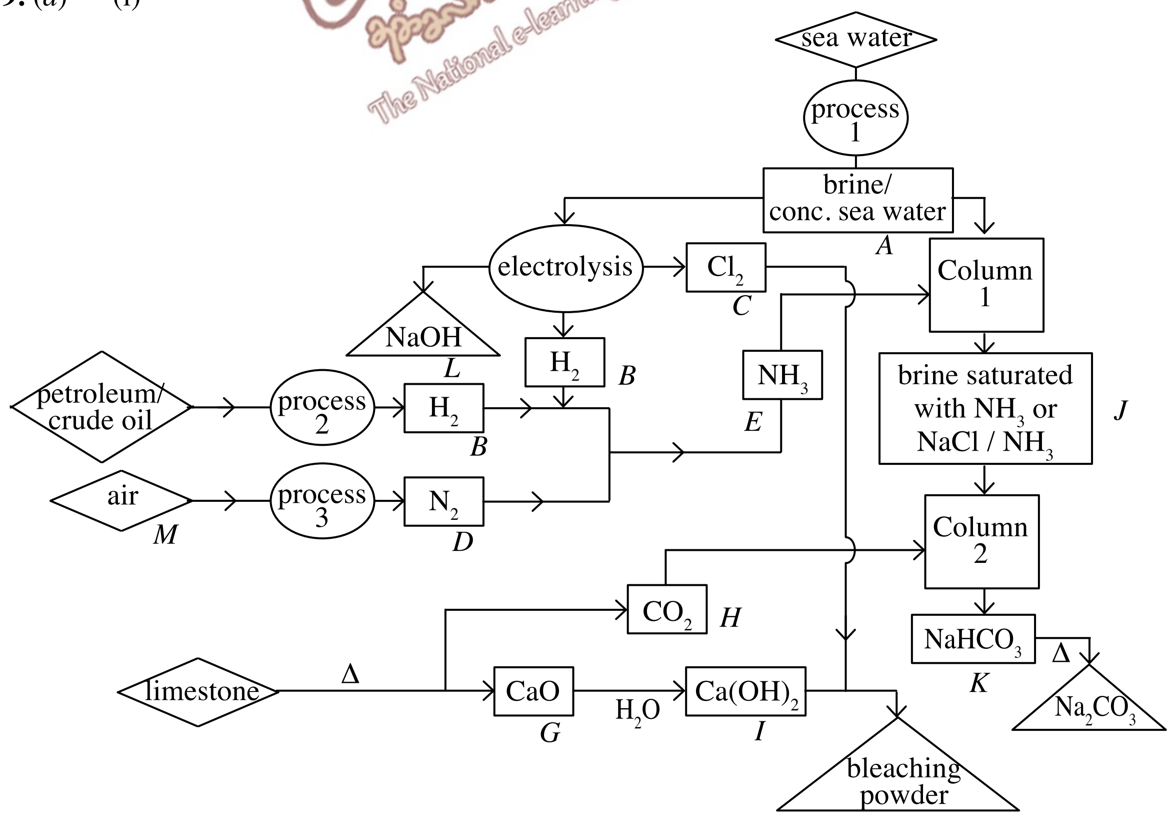
n (S) $= n$ (Fe) $+ n$ (Cu)

$\therefore n$ (Fe) $= n$ (S) $- n$ (Cu)

$= 0.008 \text{ mol} - 0.002 \text{ mol}$

$= 0.006$ mol

9. (*a*) (i)



(03 × 13 = 39 marks)

[see page sixteen

(ii) Process 1 : concentration/evaporation
Process 2 : reaction with steam/partial combustion with O_2
Process 3 : fractional distillation (02 × 3 = 06 marks)

(iii) Column 1 : $NH_3(aq) + H_2O \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
or
$NH_3(aq) + NaCl(aq) \rightleftharpoons NH_4^+Cl^-(aq) + Na^+(aq) + OH^-(aq)$ (05 marks)
Column 2 : $OH^-(aq) + CO_2(g) \rightleftharpoons HCO_3^-(aq)$ (05 marks)

(iv) $2NaCl(aq) + 2NH_3(aq) + 2CO_2(aq) + 2H_2O(l) \xrightarrow[\Delta]{} Na_2CO_3(s) + 2NH_4Cl(aq) + CO_2(g) + H_2O(l)$
$2NaCl(aq) + 2NH_3(aq) + CO_2(aq) + H_2O(l) \xrightarrow[\Delta]{} Na_2CO_3(s) + 2NH_4Cl(aq)$ } (08 marks)
$2NaCl\ (aq) + CaCO_3\ (s) \longrightarrow Na_2CO_3\ (s) + CaCl_2\ (aq)$

(v) gas dissolution is an exothermic process. Therefore mixing gases with water is accelerated by cooling. (04 marks)

(vi) $3Ca(OH)_2(s) + 2Cl_2(g) \longrightarrow Ca(OCl)_2 . Ca(OH)_2 . CaCl_2 . 2H_2O$ (08 marks)

(*b*) (i) It is too difficult to break the triple bond between N atoms in N_2./
It is a very stable molecule. (05 marks)

(ii) NO, NO_2, ..., N_2O, N_2O_4 (any two) (05 × 2 = 10 marks)

(iii) lightening, burning fossil fuels, internal combustion in motor vehicle engines, combustion related with cooking purposes.
(any three) (04 × 3 = 12 marks)

(iv) acid rain, global warming
photochemical smog, depletion of the ozone layer (04 × 4 = 16 marks)

(v) acid rain

$N_2(g) + O_2(g) \xrightarrow{\text{lightening}} 2NO(g)$

$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

$4NO_2(g) + 2H_2O(l) + O_2(aq) \longrightarrow 4HNO_3(aq)$

$HNO_3(aq) \longrightarrow H^+(aq) + NO_3^-(aq)$

photochemical smog
photolysis of NO_2 by absorbing sunlight

$NO_2 \xrightarrow{h\nu} NO + O$

(*a*) Atomic oxygen combines with O_2 melecules to form ozone.
$O + O_2 + M \longrightarrow O_3 + M$
(M is a gas or particle in air which can absorb excess energy)

(*b*) Atomic oxygen reacts with water vapour to from OH free radicals.
$O + H_2O \longrightarrow 2^{\bullet}OH$
(°OH can initiate reaction to produce different chemical compounds like aldehydes, PAN, PBN ect)

[*see page seventeen*

Ozone layer depletion

$$^{\bullet}NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g) \text{ ——— } (1)$$

$$O_2(g) \longrightarrow 2O(g) \text{ ——— } (2)$$

$$NO_2(g) + O(g) \longrightarrow {}^{\bullet}NO(g) + O_2(g) \text{ ——— } (3)$$

(1) × 2 + (2) + (3) × 2

$$2O_3(g) \longrightarrow 3O_2(g)$$

(any three) (12 × 2 = 24 marks)

(vi) reduce the temperature of the combustion process
reduce the combustion of fuel containing 'N'
connect catalytic converters to motor vehicles
reduce NO_x by using catalysts in furnances
reduce acidic gases by absorption (04 × 2 = 08 marks)

10. (*a*) (i) $Hg_2Cl_2(s) + 2e \rightleftharpoons 2Hg(l) + 2Cl^-(aq)$ (08 marks)

(ii) $Hg(l), Hg_2Cl_2(s) / Cl^-(aq)\ (1.0\,mol\,dm^{-3})\ //\ Cl^-(aq)\ (1.0\,mol\,dm^{-3}) / Cl_2(g)\ (1\,atm), Pt(s)$
(10 marks)

(iii)
$$E^{\theta}_{cell} = E^{\theta}_{cathode} - E^{\theta}_{anode}$$
$$= 1.36\,V - 0.24\,V$$
$$= 1.12\,V$$
(12 marks)

(*b*) (i) anodic reaction, $Mg(s) \longrightarrow Mg^{2+}(aq) + 2e$

cathodic reaction, $2e + 2H_2O(l) \longrightarrow H_2(g) + 2OH^-(aq)$

overall reaction,
$Mg(s) + 2H_2O(l) \longrightarrow Mg^{2+}(aq) + 2OH^-(aq) + H_2(g)$ (05 × 3 = 15 marks)

(ii) $Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$
By the reaction of electrolysis, Mg^{2+} and OH^- are formed with the molar ratio 1 ; 2 just after forming turbidity or when the solution becomes saturated with $Mg(OH)_2$, concentration of $[Mg^{2+}] = x$

$$Ksp = [Mg^{2+}(aq)][OH^-(aq)]^2$$
$$4.0 \times 10^{-12}\,mol^3\,dm^{-9} = (x)\,(2x)^2$$
$$x = 1 \times 10^{-4}\,mol\,dm^{-3}$$
$$n_{Mg^{2+}} = \frac{1 \times 10^{-4}}{1000} \times 250 = 2.5 \times 10^{-5}\,mol$$
$$Q = 2.5 \times 10^{-5}\,mol \times 96500\,c\,mol^{-1} \times 2$$
$$Q = It = 50 \times 10^{-3}\,A \times t$$
$$t = \frac{2.5 \times 10^{-5} \times 96500 \times 2}{50 \times 10^{-3}}\,s$$
$$t = 9650\,s$$
(30 marks)

(iii) no other reactions occur during electrolysis. (05 marks)

[see page eighteen

(*c*) (i) $2Mn^{2+} + 5PbO_2 + 4H^+ \longrightarrow 2MnO_4^- + 5Pb^{2+} + 2H_2O$ (10 marks)

(ii) Similar test tubes (similar cross sectional area and height) should be used. (04 marks)

(iii) to have equal colour intensities, concentrations should be equal.
Since the final volumes are equal,

$$n_{MnO_4^-} \text{ in } 5\,cm^3 \text{ of } X = n_{MnO_4^-} \text{ in the test tube (4)}$$
$$= \frac{0.05}{1000} \times 8\,mol$$
$$\therefore n_{MnO_4^-} \text{ in } 250\,cm^3 \text{ of } X = \frac{0.05}{1000} \times 8 \times \frac{250}{5}\,mol$$
$$= 0.02\,mol$$
$$n_{MnO_4^-} = n_{Mg^{2+}}$$

relative atomic mass of Mn = 55.

$$\frac{m_{Mn}}{m}\% \Rightarrow \frac{0.02\,mol \times 55\,g\,mol^{-1}}{3.0\,g} \times 100$$
$$= 36.67\%$$
(28 marks)

(iv) There are no other coloured substances except MnO_4^- are present in the solution *X*.
(04 marks)

(v)
- Potassium permanganate does not exist as a pure substance.
- Since it is a strong oxidising agent, it can easily get reduced. (08 marks)

(vi)
- Prepare an oxalic acid solution of known concentration.
- Take a known volume of given $KMnO_4$ solution and acidify with dilute H_2SO_4.
- Titrate with oxalic acid by maintaing the temperature at about 60°C.

(06 marks)

(vii) $4KMnO_4 + 4KOH \longrightarrow 4K_2MnO_4 + 2H_2O + O_2$ (05 marks)

(viii) purple $\longrightarrow$ green (05 marks)

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