Suggested Answers

Paper 2

Section A

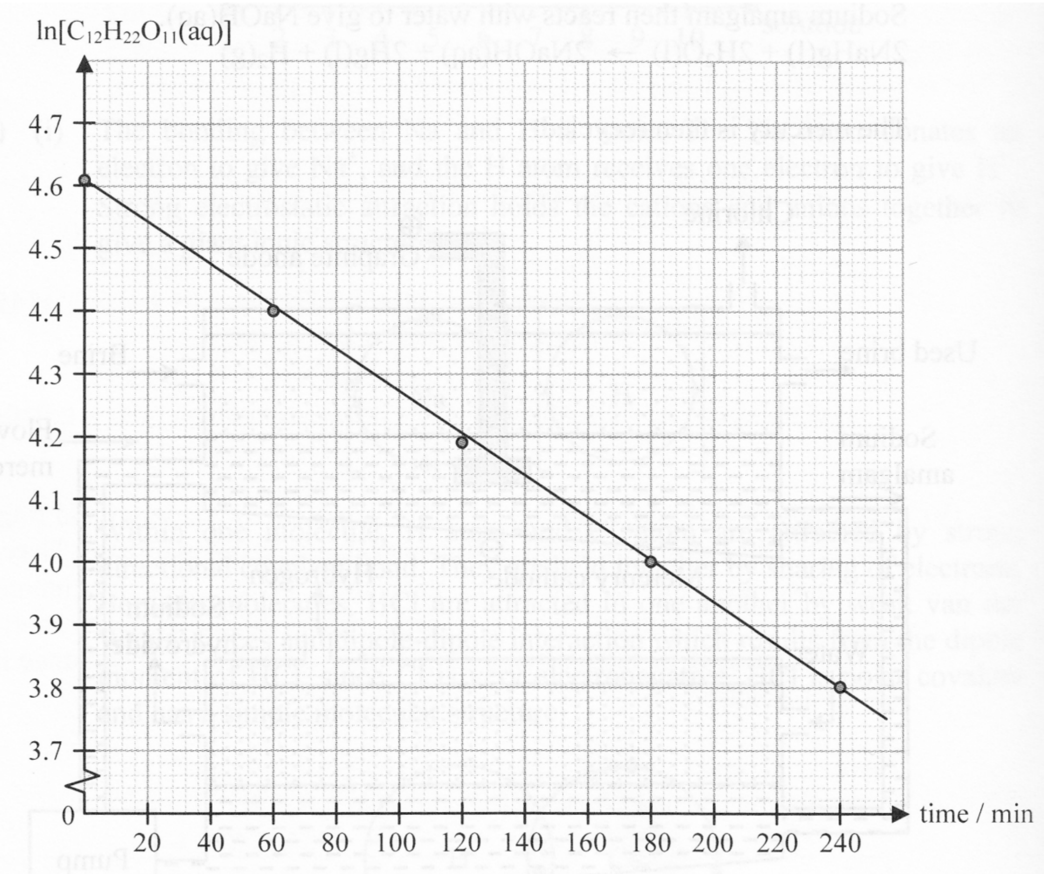
1 (a)

(i) Polarimetric analysis can be used as sucrose, glucose and fructose are optically active.

By plotting the angle of rotation of plane-polarized light with time with a calibrated polarimeter, the concentration of sucrose can be found.

(ii) By plotting ln [$C_{12}H_{22}O_{11}(aq)$] against time:

t / min	0	60	120	180	240
[$C_{12}H_{22}O_{11}(aq)$]	100	81.3	66.3	54.0	44.1
ln [$C_{12}H_{22}O_{11}(aq)$]	4.6	4.4	4.2	4.0	3.8



ln [$C_{12}H_{22}O_{11}(aq)$] against time gives a straight line.

Thus, the reaction is first order with respect to sucrose.

(iii) Slope $= -k' = \frac{3.8 - 4.6}{240 - 0} = -3.33 \times 10^{-3}$

$$k' = \underline{\underline{3.33 \times 10^{-3}\ \text{min}^{-1}}}$$

(iv) Conduct the experiments several times with different [HCl(aq)] while keeping all the concentrations of the other reactants constant.
Record the initial rates in each experiment.
By plotting ln Rate vs ln [HCl(aq)], a straight line is obtained.
If slope = 1, the hydrolysis is also first order with respect to HCl.

1 (b)

(i)

	$E^\ominus$ / V
$Cr(s) \rightleftharpoons Cr^{2+}(aq) + 2e^-$	+ 0.91
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Cr(s) + 2H^+(aq) \rightleftharpoons Cr^{2+}(aq) + H_2(g)$	+ 0.91

The $E^\ominus$ value is positive.
Thus, Cr(s) is oxidized to $Cr^{2+}(aq)$ and a blue solution is formed.

(ii)

	$E^\ominus$ / V
$2\ Cr^{2+}(aq) \rightleftharpoons 2\ Cr^{3+}(aq) + 2e^-$	+ 0.40
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$2\ Cr^{2+}(aq) + 2H^+(aq) \rightleftharpoons 2\ Cr^{3+}(aq) + H_2(g)$	+ 0.40

The $E^\ominus$ value is positive.
Thus, $Cr^{2+}(aq)$ is oxidized to $Cr^{3+}(aq)$ and the colour of solution changes from blue to green.

1 (b)

(iii)

	$E^\ominus$ / V
$Zn(s) \rightleftharpoons Zn^{2+}(aq) + 2e^-$	+ 0.76
$2\ Cr^{3+}(aq) + 2\ e^- \rightleftharpoons 2\ Cr^{2+}(aq)$	– 0.40
$2\ Cr^{3+}(aq) + Zn(s) \rightleftharpoons 2\ Cr^{2+}(s) + Zn^{2+}(aq)$	+ 0.36

The $E^\ominus$ value is positive.
Thus, $Cr^{3+}(aq)$ is reduced to $Cr^{2+}(aq)$ and the colour of solution changes from green to blue.

1 (c)

(i) After mixing, $[CH_3CH_2COOH] = 0.10 \times \frac{6}{6+4} = 0.06\ M$

$$[CH_3CH_2COONa] = 0.20 \times \frac{4}{6+4} = 0.08\ M$$

$$pH = pKa + \log \frac{[Salt]}{[Acid]}$$

$$pH = -\log(1.3 \times 10^{-5}) + \log \frac{0.08}{0.06}$$

$$pH = \underline{\underline{5.01}}$$

(ii) This buffer solution contains comparable amount of CH_3CH_2COOH and $CH_3CH_2COO^-$.
When small amount of acid is added, $CH_3CH_2COO^-$ reacts with H_3O^+ to form CH_3CH_2COOH:

$$CH_3CH_2COO^- + H_3O^+ \rightarrow CH_3CH_2COOH + H_2O$$

Thus, $[H_3O^+(aq)]$ is kept nearly constant.
When small amount of base is added, CH_3CH_2COOH reacts with OH^- to form $CH_3CH_2COO^-$ and H_2O:

$$CH_3CH_2COOH + OH^- \rightarrow CH_3CH_2COO^- + H_2O$$

Thus, OH^- will not react with H_3O^+ in the buffer and $[H_3O^+(aq)]$ is kept nearly constant.
As a result, the buffer can resist pH change upon addition of small

amount of acid or base.

(iii) In swimming pool, the pH is kept constant by using $HOCl/OCl^-$ buffer.

2 (a)

(i)

For reaction (1):

$$K_c = \frac{[Ag(NH_3)_2{}^+(aq)]}{[Ag^+(aq)][NH_3(aq)]^2}$$

For reaction (2):

$$K_c = [Ag^+(aq)][Cl^-(aq)]$$

(ii)

$$\begin{aligned} K_c &= \frac{[Cl^-(aq)][Ag(NH_3)_2{}^+(aq)]}{[NH_3(aq)]^2} \\ &= \frac{[Ag(NH_3)_2{}^+(aq)]}{[Ag^+(aq)][NH_3(aq)]^2} \times [Ag^+(aq)][Cl^-(aq)] \\ &= (1.8 \times 10^7)(2.0 \times 10^{-10}) \\ &= \underline{\underline{0.0036}} \end{aligned}$$

(iii)

$$AgCl(s) + 2\,NH_3(aq) \rightleftharpoons Ag(NH_3)_2{}^+(aq) + Cl^-(aq)$$

Start:	0.10	0	0
At eqm.	0.10 – 2x	x	x

$$K_c = \frac{[Cl^-(aq)][Ag(NH_3)_2{}^+(aq)]}{[NH_3(aq)]^2}$$

$$0.0036 = \frac{x^2}{(0.01-2x)^2}$$

$$x = 5.36 \times 10^{-3}\ \text{mol dm}^{-3}$$

Solubility of AgCl(s) in 0.10 M NH_3(aq) at 298 K is 5.36×10^{-3} mol dm^{-3}

2 (b)

Upon heating, lithium nitrate gives lithium oxide, nitrogen dioxide and oxygen but other Group I nitrates form nitrites and oxygen.

$$4\ LiNO_3(s) \xrightarrow{heat} 2\ Li_2O(s) + 4\ NO_2(g) + O_2(g)$$

$$2\ NaNO_3(s) \xrightarrow{heat} 2\ NaNO_2(s) + O_2(g)$$

Upon heating, lithium carbonate undergoes decomposition but other Group I carbonates are stable towards thermal decomposition.

$$Li_2CO_3(s) \xrightarrow{heat} Li_2O(s) + CO_2(g)$$

2 (c)

When sulphur dioxide acts as an oxidizing agent, it is reduced to sulphur.

$$2\ Mg(s) + SO_2(g) \rightarrow 2\ MgO(s) + S(s)$$
$$2\ H_2S(aq) + SO_2(g) \rightarrow 2\ H_2O(l) + 3\ S(s)$$

When sulphur dioxide acts as a reducing agent, it is oxidized to sulphate ion.

$$Fe_2(SO_4)_3(aq) + SO_2(g) + 2\ H_2O(l) \rightarrow 2\ FeSO_4(aq) + 2\ H_2SO_4(aq)$$
$$Cl_2(g) + SO_2(g) + 2\ H_2O(l) \rightarrow H_2SO_4(aq) + 2\ HCl(aq)$$

3 (a)

Their oxidizing power is in the following order:

$$F_2 > Cl_2 > Br_2$$

F_2 can displace Cl^- and Br^- ions to form Cl_2 and Br_2 respectively.

$$F_2(g) + 2\ Cl^-(aq) \rightarrow 2\ F^-(aq) + Cl_2(aq)$$
$$F_2(g) + 2\ Br^-(aq) \rightarrow 2\ F^-(aq) + Br_2(aq)$$

Cl_2 cannot displace F^-. It can only displace Br^- ions to form Br_2.

$$Cl_2(g) + 2\ Br^-(aq) \rightarrow 2\ Cl^-(aq) + Br_2(aq)$$

Br_2 cannot displace both F^- and Cl^-.

3 (b)

Concentrated sulphuric acid can be used to remove stains of colloidal sulphur in a conical flask.

In the reaction between concentrated sulphuric acid and sulphur, sulphur is oxidized to sulphur dioxide and can be washed away.

3 (c)

(i) Element **X** is technetium (Tc).

Since the relative atomic mass of **X** is smaller than 110, its atomic number should be less than 48.

As the highest oxidation state of **X** is +7, **X** should have 7 valence electrons in its outermost s and d orbitals. Thus, **X** can only be manganese (Mn) or technetium (Tc).

All isotopes of **X** are radioactive. Since all the isotopes of manganese are not radioactive and all the isotopes of technetium are radioactive, **X** can only be technetium (Tc).

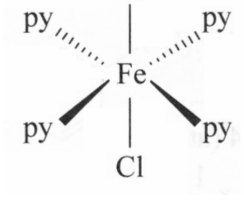
(ii) It should have a half-life which is long enough for detection. However, the half-life should not be too long which may affect the health of the patient.

4 (a)

(i) The nitrogen in pyridine is sp^2 hybridized.

(ii) The oxidation state in iron in $[Fe(py)_4Cl_2]$ is +2.

(iii)



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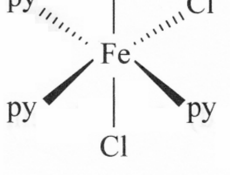


cis

4 (b)

(i) Disproportionation is a special type of redox reaction in which a chemical species is oxidized and reduced in the same reaction.

(ii) Copper(I) sulphate(VI) dissolves to give a blue solution.
Some reddish solid is also formed at the same time.

$$Cu_2SO_4(aq) \rightarrow CuSO_4(aq) + Cu(s)$$

4 (c)

(i) The standard enthalpy change of formation of a compound is the enthalpy change of the formation of one mole of compound from its constituent elements in their standard physical states under standard conditions (298 K, 1 atm).

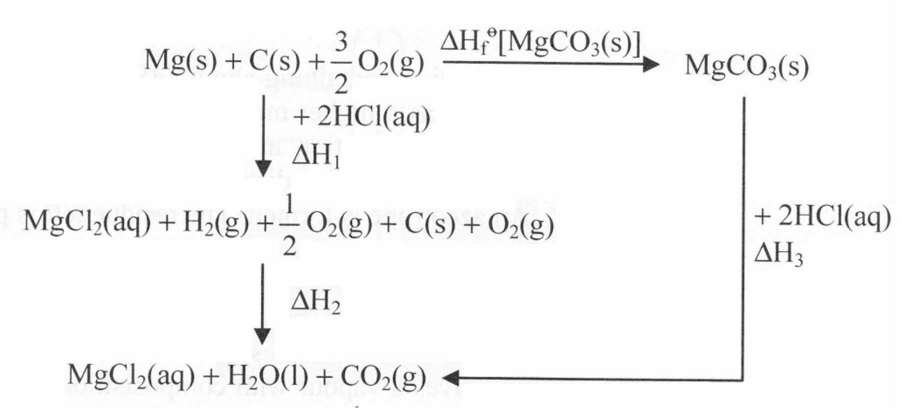
(ii) The energy released in the reaction = 494 × 4.3 = 2124.2 J
Number of moles of magnesium used in the reaction

$= \frac{0.1}{24.3} = 4.115 \times 10^{-3}$ mol

The molar enthalpy change for the reaction

$= -\frac{2124.2}{4.115 \times 10^{-3}} = \underline{\underline{-516.2\ \text{kJ mol}^{-1}}}$

(iii) In the following enthalpy diagram:



$$\Delta H_f^{\ominus}[MgCO_3(s)] = \Delta H_1 + \Delta H_2 - \Delta H_3$$
$$= -516 + (-285 - 393) - (-90)$$
$$= \underline{\underline{-1104\ \text{kJ mol}^{-1}}}$$

4 (d)

(i)

	N	**O**	**F**
% mass	21.6	49.2	29.2
$\frac{\text{\% mass}}{\text{relative atomic mass}}$	$\frac{21.6}{14.0}$	$\frac{49.2}{16.0}$	$\frac{29.2}{19.0}$
	1.543	3.075	1.537
Mole ratio	1	2	1

The empirical formula of **A** is NO_2F.

(ii) By PV = nRT

$$1.01 \times 10^5\ V = (1)(8.314)(298)$$

$$V = 24.53\ \text{dm}^3$$

The molar mass of **A** = 24.53 × 2.65 = 65 g mol^{-1}

Let $N_nO_{2n}F_n$ be the molecular formula of **A**.

$14n + (16 \times 2)n + 19n = 65$

$65n = 65$

$n = 1$

The molecular formula of **A** is NO_2F.

(3 marks)

Section B

5 (a)

(i) The relative atomic mass of Cl is greater than that of C and of H.

Thus, one unit mass of polystyrene contains more C and H than one unit mass of PVC.

Moreover, oxidation of Cl is less exothermic than that of C and H.

(ii) Propan-2-ol

$$CH_3CH{=}CH_2 + H_2O \xrightarrow{\text{catalyst}} CH_3CH(OH)CH_3$$

5 (b)

(i) Addition polymerization

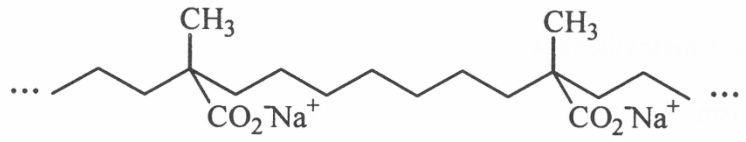
(ii) No. There is no cross-link between polymer chains.

(iii) The attraction between polymer chains is hydrogen bond.

Increase in the 2-methylpropenoic acid : ethane ratio gives rise to an increase in number of hydrogen bonds per unit length. Thus, attraction between polymer chains increases.

(iv)

(1) The structure of **P**:

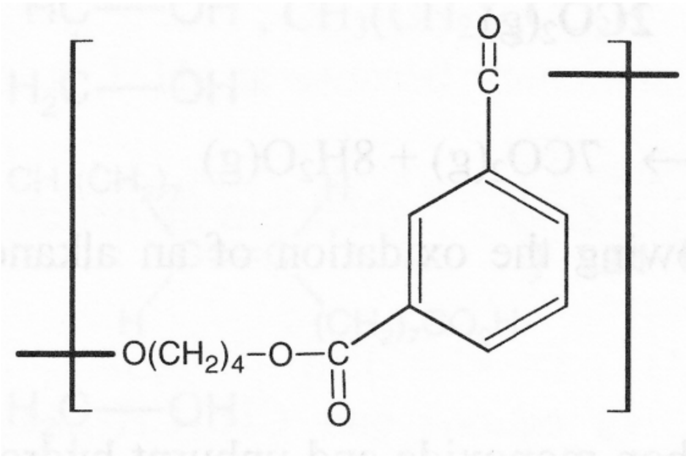


(2) **P** is stronger than **N**.

After treating with NaOH, the attraction between polymer chains would be changed from hydrogen bond to ionic bond.

5 (c)

(i) The repeating unit of **M**:



(ii) Condensation polymerization

(iii) Number of moles of 2.8 g butane-1,4-diol

$= \frac{2.8}{4 \times 12 + 1 \times 10 + 2 \times 16} = 0.03111$ mol

Number of moles of 6.3 g of benzene-1,3-dicarbonyl chloride

$= \frac{6.3}{8 \times 12 + 4 \times 1 + 2 \times 16 + 2 \times 35.5} = 0.03103$ mol

Thus, benzene-1,3-dicarbonyl chloride is the limiting reactant.

Relative molecular mass of one repeating unit of **M**

$= 12 \times 12 + 12 \times 1 + 4 \times 16 = 220$

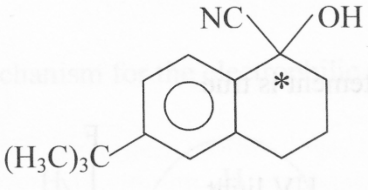
Number of moles of repeating units formed

$= \frac{6.4}{220} = 0.02909$ mol

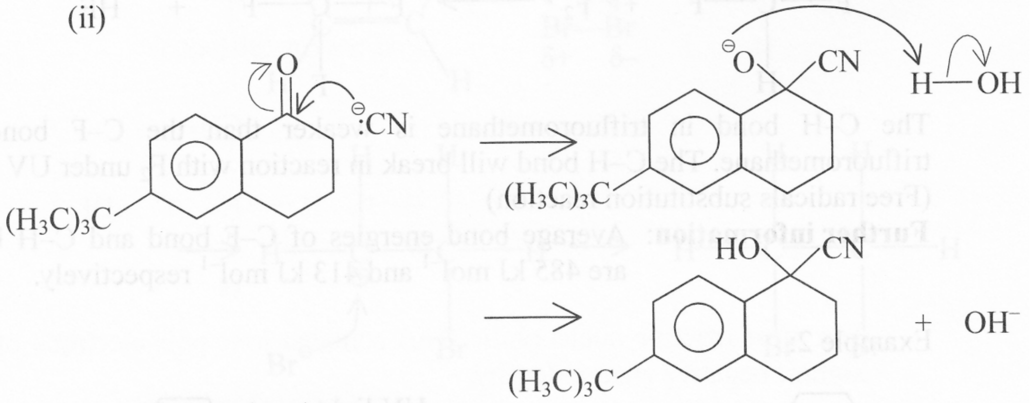
Percentage yield $= \frac{0.02909}{0.03103} \times 100\% = \underline{\underline{93.7\%}}$

6 (a)

(i)



(ii)



(iii) No. The product obtained is a racemic mixture. It is because the CN^- nucleophile has equal probabilities of attacking from the above or below of planar carbonyl group. The concentration of each enantiomer is the same.

6 (b)

(i) CO_2 has a simple molecular structure. There are only very weak van der Waals forces between CO_2 molecules and they are far apart from each other. Thus, it has a very low boiling point and is a gas at room temperature and pressure.

SiO_2 has a giant covalent structure. There are very strong covalent bonds between silicon and oxygen atoms and they form a giant covalent network. Large amount of energy is required to melt SiO_2 since all the covalent bonds must be broken. Thus, SiO_2 has a very high melting point and is a solid at room temperature and pressure.

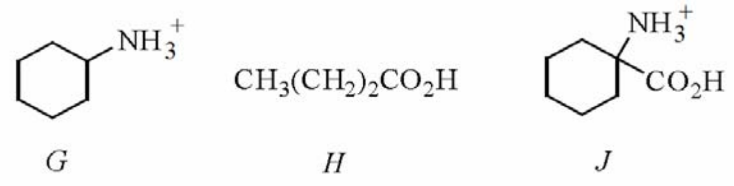
(ii) The carbon in CO_2 is sp hybridized.

The silicon in SiO_2 is sp^3 hybridized.

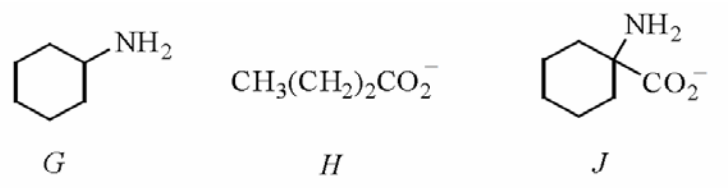
6 (c)

(i)

(1) In a pH 3 buffer solution:



(2) In a pH 11 buffer solution:



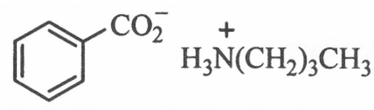
(iii) At pH 7, ***J*** will remain stationary because it exists mainly in the form of zwitterions which has no net charge. But ***G*** and ***H*** exist as a cation and an anion respectively and have net charge and thus they will be attracted by the two poles of battery.

7 (a)

(i) N-butylbenzaminde

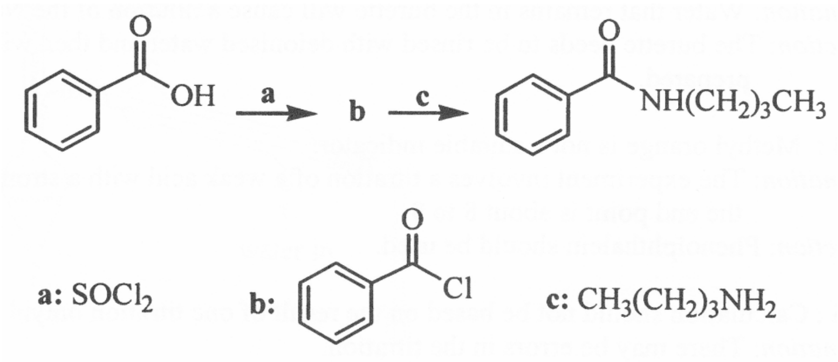
(ii) Nucleophilic substitution

(iii) The structure of **S**:



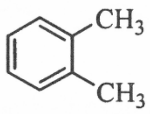
(iv) High temperature can drive the salt back to benzoic acid and butan-1-amine for the acyl substitution.

(v)



7 (b)

B:



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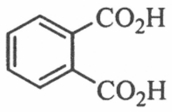

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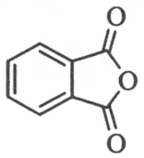

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