NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

CHEMISTRY

Paper 2 Structured Questions

9729/02
24 August 2021
2 hours

Candidates answer on Question Paper.
Additional Materials: Data Booklet

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Answers **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/8
2	/12
3	/8
4	/11
5	/17
6	/19
Paper 2 Total	/75

	Marks	Weightings
Paper 1	/30	**15%**
Paper 2	/75	**30%**
Paper 3	/80	**35%**
Paper 4	/55	**20%**

Overall Percentage	
Grade	

This document consists of **23** printed pages and **1** blank page.

Answer **all** the questions in the spaces provided.

1 **(a)** Iodine can undergo a reaction with aqueous potassium hydroxide to form iodate and iodide ions as shown in the following equation.

$$3I_2(s) + 6KOH(aq) \longrightarrow KIO_3(aq) + 5KI(aq) + 3H_2O(l)$$

This reaction has a potential application in times of nuclear catastrophe when radioactive and volatile iodine-131 is produced. Spraying alkalis into the nuclear reactors can convert the volatile iodine into non-volatile iodate and iodide ions, thus minimizing the damaging radioactive effects.

(i) Name the type of reaction for the above equation.

Disproportionation

Note : I is simultaneously oxidized from O.S. = 0 in I_2 to O.S. = +5 in IO_3^- and reduced from O.S. = 0 in I_2 to O.S. = −1 in I^-

[1]

(ii) Write the two balanced half-equations for the above reaction.

[O] $I_2 + 12OH^- \longrightarrow 2IO_3^- + 6H_2O + 10e^-$

(construct by following the steps in balancing half equation)

[R] $I_2 + 2e^- \longrightarrow 2I^-$ (obtained from Data Booklet)

State symbols not required

[2]

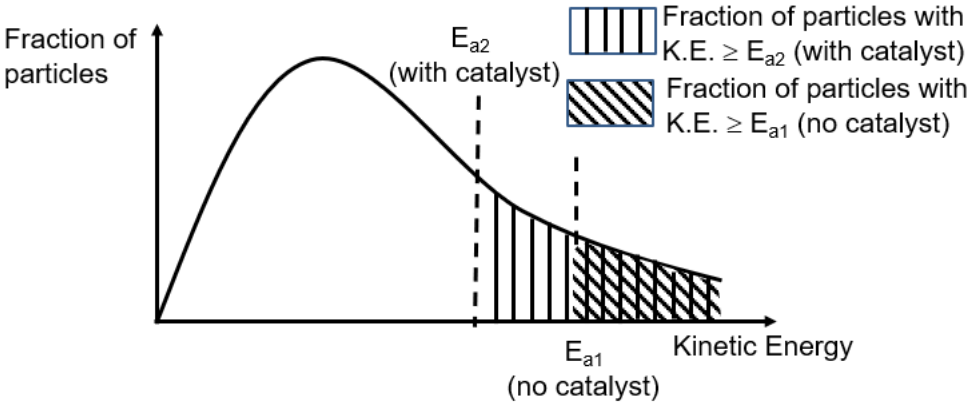
(b) The reaction of iodide and peroxodisulfate ions is very slow and can be catalysed by using a homogeneous catalyst.

$$S_2O_8^{2-}(aq) + 2I^-(aq) \longrightarrow 2SO_4^{2-}(aq) + I_2(aq)$$

(i) Explain why the rate of the above reaction is slow.
The rate of the reaction is very slow because the activation energy is very high due to the collision of two ions of the same charges.

[1]

(ii) With the aid of the Boltzmann distribution, explain how addition of a homogenous catalyst helps to increase the rate of a reaction.



A catalyst provides an alternative reaction pathway with lower activation energy (E_{a2}).
The fraction of particles with K.E. ≥ E_a increases as shown in the Boltzmann distribution.
The frequency of effective collisions increases hence rate of reaction increases.

1m diagram
1m explanation

[2]

(iii) By considering relevant $E^\ominus$ values from the *Data Booklet*, explain how $Fe^{3+}(aq)$ can act as a homogenous catalyst in this reaction.

Step 1: Formation of intermediate (Fe^{3+} colliding with I^-)

	$E^\ominus$/V
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54

Overall for Step 1: $2I^-(aq) + 2Fe^{3+}(aq) \longrightarrow I_2(aq) + 2Fe^{2+}(aq)$ [1/2m]

$E^\ominus_{cell} = +0.77 - 0.54 = +0.23$ V [1/2m]

Step 2: Regeneration of catalyst

	$E^\ominus$/V
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$S_2O_8^{2-}(aq) + 2e^- \rightleftharpoons 2SO_4^{2-}(aq)$	+2.01

$E^\ominus_{cell} = +2.01 - 0.77 = +1.24$ V[1/2m]

Overall for Step 2: $S_2O_8^{2-}(aq) + 2Fe^{2+}(aq) \longrightarrow 2SO_4^{2-}(aq) + 2Fe^{3+}(aq)$ [1/2m]

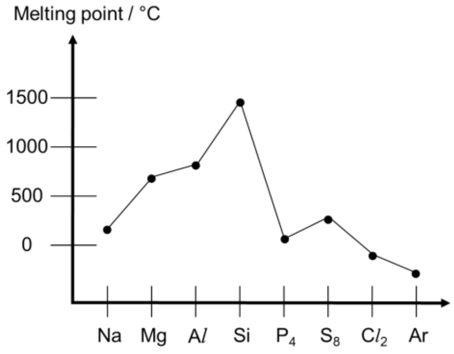
−1/2 m if missing/wrong state symbols. It is important to show $Fe^{3+}(aq)$ as a homogeneous catalyst.

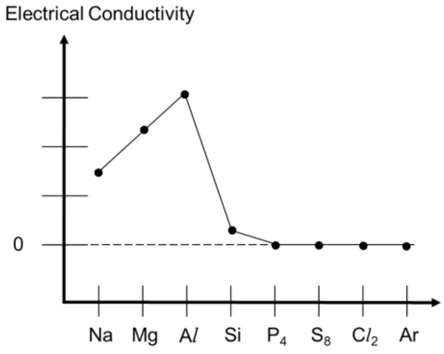
[2]

[Total: 8]

2 **(a)** The Period 3 elements vary in their physical properties.

(i) On the axes below, sketch the melting point and electrical conductivity trends for the **stated elements**.





Note:

Melting point trend

For metals, Na to Al, mp increases because of ***stronger metallic bond strength*** between cations and sea of delocalized electrons as the charge of cations increases and number of delocalised electrons increases.

Si has giant covalent lattice structure. ***Much energy*** is required to break the strong covalent bonds between Si atoms.

P_4, S_8, Cl_2 and Ar have simple molecular structure. ***Little energy*** is required to overcome the weaker id-id between molecules.
As strength of id-id ∝ no. of electrons in a molecule/atom,
mp decrease in order: **S_8 > P_4 > Cl_2 > Ar**

Electrical conductivity trend

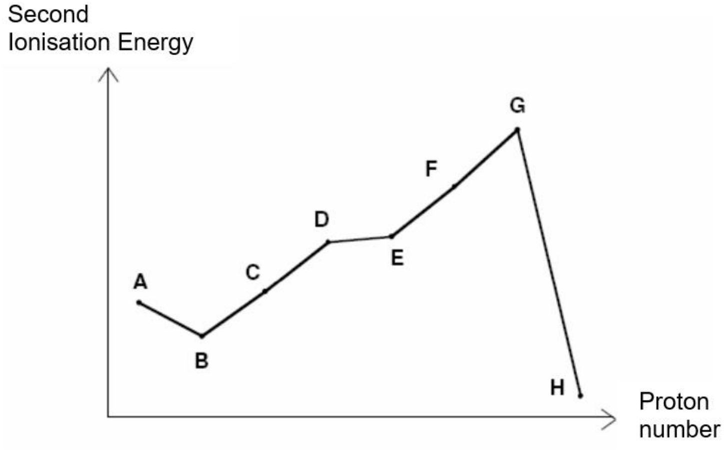
For metals, electrical conductivity **increases** as no. of delocalized electrons (mobile charge carriers) *increases* from Na to Al.

Si is a ***metalloid*** which behaves as a semi-conductor and have some electrical conductivity.

P_4, S_8, Cl_2 and Ar are ***non-conducto***r of electricity as they do not have mobile charge carriers.

[2]

(ii) Sulfur is an element in Period 3 of the Periodic Table. The graph below shows the second ionisation energies of eight elements with consecutive proton number.



Which of the elements **A** to **H** represents sulfur? Explain your answer.

The sharp drop in 2nd I.E. from **G** to **H** indicates that **H** is in Group 2 where its 2nd I.E. involves the removal of the most loosely held electron from an outer principal quantum shell as compared to that of **G**.

OR

The sharp drop of 2nd I.E. from **G** to **H** indicates that **G** is in Group 1 where its 2nd I.E. involves the removal of an electron from the inner quantum shell, which is much closer to the nucleus as compared to that of H.

1m explanation

Hence **D** is a Group 16 element and it is sulfur. [1]

[2]

(b) A 0.400 g solid sample of a mineral, $\mathbf{XY(CO_3)_2}$ (where **X** and **Y** are Group 2 elements) was heated strongly to give a mixture of oxides of **X** and **Y** and carbon dioxide. The solid mixture has a total mass of 0.275 g.

The solid mixture was added to excess water and stirred. The suspension was filtered, and the oxide of **X** was obtained as a residue. The dried residue weighed 0.057 g.

(i) Write a balanced equation for the decomposition of $\mathbf{XY(CO_3)_2}$

$$XY(CO_3)_2 \longrightarrow XO + YO + 2\,CO_2$$

[1]

(ii) Calculate the mass of carbon dioxide produced.

Mass of CO_2 = 0.400 – 0.275 = 0.125 g

[1]

(iii) Hence, or otherwise, identify the metals, **X** and **Y**, showing your working clearly.

Mass of YO = 0.275 – 0.057 = 0.218 g

	$XY(CO_3)_2$ $\longrightarrow$	XO (insoluble) +	YO (soluble) +	$2\,CO_2$
Mass / g :	0.400	0.057	0.218	0.125

Let A_r of **X** be **a** and A_r of **Y** be **b**

Amt of $\mathbf{CO_2}$ **=** $\frac{0.125}{44.0}$ = 0.00284 mol [1/2]

Amt of **XO =** Amt of **YO =** $\frac{0.284}{2}$ = 0.00142 mol [1/2]

For **XO,**

$$\frac{0.057}{a + 16.0} = 0.00142$$

a = 24.1 , X is Mg [1]

For **YO,**

$$\frac{0.218}{b + 16.0} = 0.00142$$

b = 137.5 , Y is Ba [1]

[3]

(c) Aluminium is commonly extracted from its oxide, Al_2O_3.

(i) Al_2O_3 dissolves in hot aqueous solution of sodium hydroxide.

Write an ionic equation to explain the reaction.
$Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \rightarrow 2[Al(OH)_4]^- (aq)$

Must include state symbol for ionic equation and exclude $Na^+(aq)$ spectator ion

[1]

(ii) Al_2O_3 is dissolved in molten cryolite. The mixture is electrolysed using graphite electrodes. The cell operates at a very high current of 50 000 A.

Calculate the time needed to obtain 1 kg of pure aluminium.

[R] $Al^{3+} + 3e^- \longrightarrow Al$
Amount of Al to be produced = $\frac{1000}{27.0}$ = 37.04 mol [1/2]
Amount of electrons required = 3 × 37.04 = 111.1 mol [1/2]

$Q = I \times t = n_e \times F$

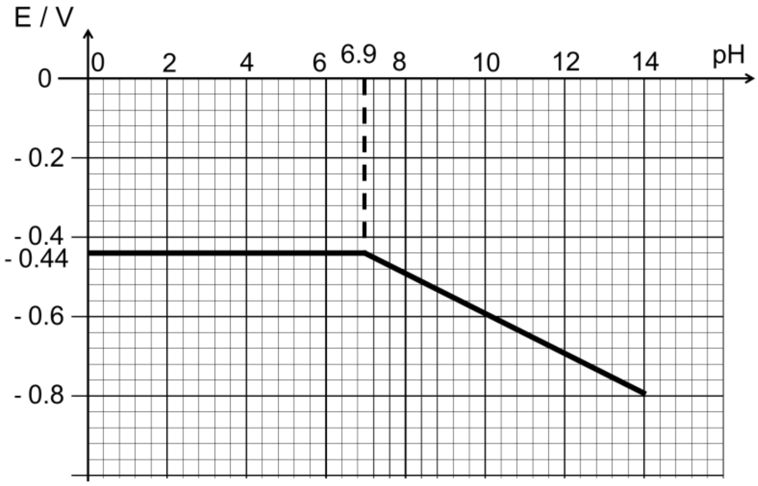
$t = \frac{111.1 \times 96500}{50000}$ = 214 s [1]

[2]

[Total : 12]

3 A student wanted to investigate the effect of pH on the electrode potential, *E*, of an iron(II)/ iron half-cell.

She started the experiment with 1 mol dm^{-3} Fe^{2+} with Fe electrode at pH 0. NaOH(aq) was added dropwise to the solution and the following data was collected.



(i) Using the information provided, show that the green $Fe(OH)_2$ precipitate is produced at approximately pH 6.9.
(Solubility product, K_{sp}, of $Fe(OH)_2 = 6.0 \times 10^{-15}$ mol^3 dm^{-9} at 25 °C)

For ppt to occur, Ionic Product ≥ K_{sp}
$[Fe^{2+}] \times [OH^-]^2 = 6.0 \times 10^{-15}$
$(1.0) \times [OH^-]^2 = 6.0 \times 10^{-15}$
$[OH^-]^2 = 6.0 \times 10^{-15}$
$[OH^-] = 7.746 \times 10^{-8}$ [1m]

$pOH = -\lg [OH^-] = (7.746 \times 10^{-8}) = 7.1$

$pH = 14 - 7.1 = 6.9$ [1m]

OR
At pH = 6.9, pOH = 7.1
$[OH^-] = 10^{-7.1} = 7.943 \times 10^{-8}$ mol dm^{-3}
Ionic Product of $Fe(OH)_2$ $= [Fe^{2+}] \times [OH^-]^2$
$= (1.0) \times (7.943 \times 10^{-8})^2$
$= 6.29 \times 10^{-15} > K_{sp}$
Since ionic product > K_{sp}, ppt will be formed.

[2]

(ii) With the use of the *Data Booklet*, explain the shape of the graph as fully as you can.

$Fe^{2+} + 2e^{-} \rightleftharpoons Fe \quad E^{\ominus} = -0.44$ [1m]

From pH 0 to 6.9,
the Fe^{2+}/Fe half-cell contains 1.0 mol dm^{-3} Fe^{2+}, hence $E^{\ominus}$ is −0.44V. [1m]

After pH 6.9, $Fe(OH)_2$ precipitate starts to form. $[Fe^{2+}(aq)]$ decreases as pH continues to increase. The position of equilibrium shifts to the left and E becomes more negative. [1m]

[3]

(iii) Explain why $Fe(OH)_2$ is green.
Transition Element concepts

[3]

[Total : 8]

4 **(a)** Nitroglycerin, $C_3H_5(NO_3)_3$, is a flammable oil commonly used to manufacture dynamite. The atomisation of nitroglycerin is represented by the equation:

$$C_3H_5(NO_3)_3(l) \longrightarrow 3C(g) + 5H(g) + 3N(g) + 9O(g)$$

Table 4.1

Standard enthalpy change of formation of nitroglycerin(l) / kJ mol^{-1}	−364
Standard enthalpy change of atomisation of carbon (graphite) / kJ mol^{-1}	+715
Standard enthalpy change of formation of $H_2O(g)$ / kJ mol^{-1}	−242
Standard enthalpy change of formation of $CO_2(g)$ / kJ mol^{-1}	−394

(i) Using data from Table 4.1 and relevant values from the *Data Booklet*, draw an energy cycle and use it to calculate the standard enthalpy change of atomisation of nitroglycerin.

$$\begin{tikzcd}
C_3H_5(NO_3)_3(l) \arrow[r, "\Delta H_{atomisation}"] & 3\ C(g) + 5\ H(g) + 3\ N(g) + 9\ O(g) \\
3\ C(s) + 5/2\ H_2(g) + 3/2\ N_2(g) + 9/2\ O_2(g) \arrow[u, "-364"'] \arrow[r, "3 \times (+715)"'] & 3\ C(g) + 5/2\ H_2(g) + 3/2\ N_2(g) + 9/2\ O_2(g) \arrow[u, "5/2 \times (+436) + 3/2 \times (+944) + 9/2 \times (+496)"']
\end{tikzcd}$$

By Hess' law

$\Delta H^{\ominus}_{atm} = +364 + 3 \times (+715) + 5/2 \times (+436) + 3/2 \times (+944) + 9/2 \times (+496)$

$\Delta H^{\ominus}_{atm} = +7247 \approx +7250$ kJ mol^{-1}

Cycle 2m
−1m for missing state symbol/label of enthalpy
−1m for not balanced equation

Final answer 1m

[3]

(ii) At high temperature, nitroglycerin decomposes to produce nitrogen, oxygen, carbon dioxide and steam.

Write a balanced equation, with state symbols, for the decomposition of nitroglycerin.

$C_3H_5(NO_3)_3(l) \longrightarrow 3CO_2(g) + \frac{5}{2}H_2O(g) + \frac{3}{2}N_2(g) + \frac{1}{4}O_2(g)$

[1]

(iii) Using data from Table 4.1, calculate the standard enthalpy change of decomposition of nitroglycerin.

$\Delta H^{\ominus}_{decomposition} = \Sigma\Delta H^{\ominus}_{formation}\,(Products) - \Sigma\Delta H^{\ominus}_{formation}\,(Reactants)$
$= [3(-394) + 5/2(-242)] - (-364)$
$= -1423$
$\approx \mathbf{-1420\ kJ\ mol^{-1}}$

Note: $\Delta H^{\ominus}_{decomposition}$ should be based on per mol of nitroglycerin used.

[1]

(iv) Given that $\Delta S^{\ominus} = +208\ J\ K^{-1}mol^{-1}$, calculate $\Delta G^{\ominus}$ for this decomposition and hence predict the spontaneity of the reaction.

$\Delta G^{\ominus}_{decomposition} = \Delta H^{\ominus}_{decomposition} - T\Delta S^{\ominus}$
$= -1423 - [298 \times (+208/1000)]$
$= -1485 \approx \mathbf{-1490\ kJ\ mol^{-1}}$ [1m]

Since $\Delta G^{\ominus}$ is negative, the reaction is spontaneous at 25 °C. [1m]

Note: temperature of standard condition is 298 K

[2]

(v) Is the reaction spontaneous at all temperatures? Explain.

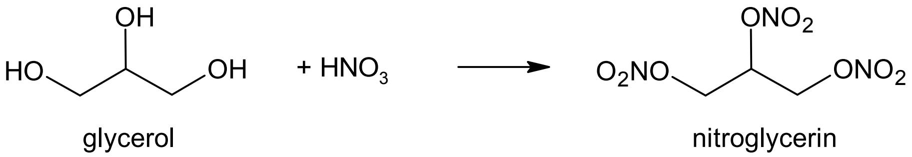
$\Delta H^{\ominus}_{decomposition}$ is negative, T is always positive and $\Delta S^{\ominus}$ is positive, hence ΔG is always < 0. [1m]

i.e. $\Delta G = \Delta H - T\Delta S$ = negative – [(positive) × (positive)] = negative

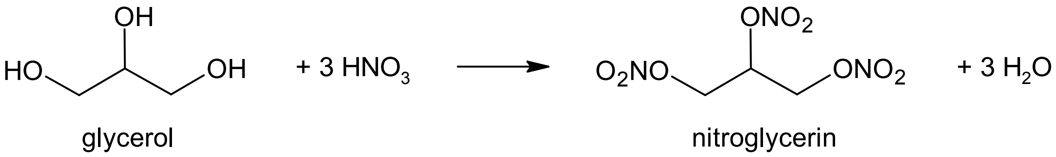
Thus, the decomposition reaction of nitroglycerin is spontaneous at all temperatures.

[1]

(b) Nitroglycerin can be produced by reaction of glycerol with nitric acid.



(i) Write a balanced equation for the reaction and hence identity the type of reaction.



Type of reaction : Condensation

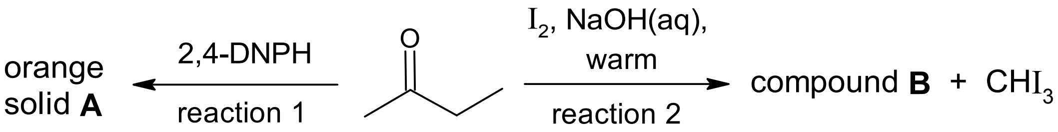
[2]

(ii) Give the IUPAC name for glycerol.
Propane-1,2,3-triol

[1]

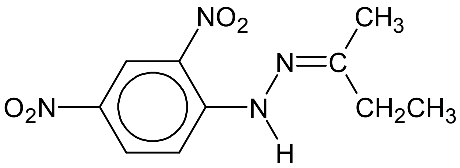
[Total : 11]

5 **(a)** Butanone, $CH_3COCH_2CH_3$, is a commonly used organic solvent.



(i) Butanone reacts with 2,4-dinitrophenylhydrazine to give an orange solid **A**. Suggest the type of reaction and draw the structure of **A**.

Type of reaction : Condensation



structure of **A**

[2]

(ii) Suggest the identity of compound **B**.
$CH_3CH_2COO^-Na^+$ or CH_3CH_2COONa (No net charge for compound)

[1]

(iii) When CHI_3 is heated strongly with OH^-(aq), a mixture containing $HCOO^-$ and I^- is obtained.

Write a balanced equation for this reaction.
$CHI_3 + 4OH^- \longrightarrow HCOO^- + 3I^- + 2H_2O$

[1]

(iv) **The use of the table of characteristic infra-red absorption frequencies for some selected bonds in the *Data Booklet* is relevant to this question.**

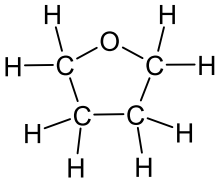
Tetrahydrofuran is a functional group isomer of butanone and has no reaction with anhydrous $SOCl_2$ nor $Br_2(aq)$.

Infra-red absorptions can be used to identity functional groups in organic compounds. For example, butanone shows absorption at 1680 cm^{-1} due to the C=O bond.

The analysis of tetrahydrofuran shows infra-red absorption at 1000 cm^{-1}.

Identify the bond present in tetrahydrofuran and suggest its structure.

Bond present : C−O



structure of tetrahydrofuran

Note: no −OH and no C=C functional group.
Also accept any other cyclic ether.

[2]

(b) Compound **C** has the molecular formula $C_7H_{14}O$. It contains two functional groups.

Data about the reactions of **C** are given in Table 5.1.

Table 5.1

reaction	reagent	Result
b1	Na(s)	colourless gas evolved.
b2	I_2 in CCl_4	one organic product formed with M_r = 367.8
b3	$KMnO_4$, H_2SO_4(aq), heat	butanone and compound **D**, $C_3H_4O_3$, formed.

(i) Name the functional group that reaction **b1** shows to be present in **C**.
Alcohol or hydroxy

[1]

(ii) Write the balanced equation for reaction **b1**.
$C_7H_{14}O + Na \longrightarrow C_7H_{13}ONa + \frac{1}{2} H_2$

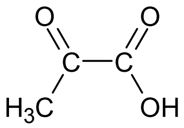
[1]

(iii) Deduce the molecular formula of the organic product formed in reaction **b2**.
$C_7H_{14}OI_2$ (M_r = 367.8)

Note: Electrophilic Addition of I_2 to C=C

[1]

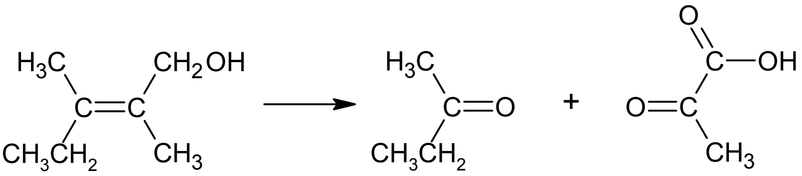
(iv) Draw the structure of compound **D** produced from reaction **b3**.



Note: Vigorous oxidation of C=C and alcohol group. Molecular formula of D suggests presence of both the ketone and carboxylic acid group.

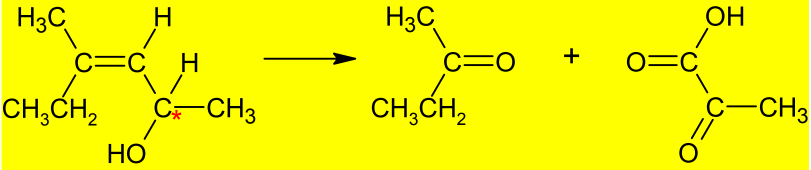
[1]

(v) Draw the structure of **C** given that it is optically inactive.



Compound **C**
(optically inactive, no chiral C)

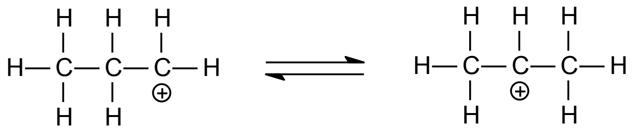
Note: The following compound will give the same products, however it has a chiral carbon and hence it is not compound **C**.



[1]

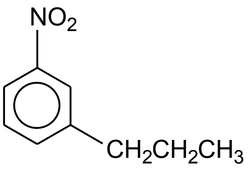
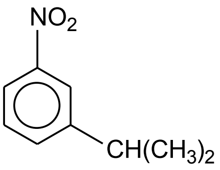
(c) Propene can undergo protonation by an acid to give a mixture of two carbocations that co-exist in equilibrium:

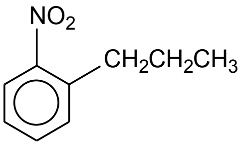
equation 5.1



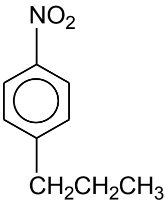
carbocation **G1** carbocation **G2**

When the equilibrium mixture of the two carbocations was added to nitrobenzene, the following products were obtained.

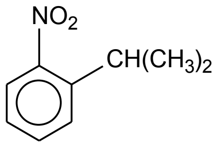
	 **H**	 **I**
percentage in product mixture:	29%	70%



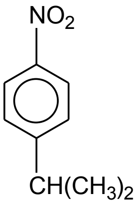
J



K



L



M

these four were obtained in trace quantities

(i) Suggest a reason why **J**, **K**, **L** and **M** were obtained in trace quantities only.
$-NO_2$ group in nitrobenzene is 3-directing.

[1]

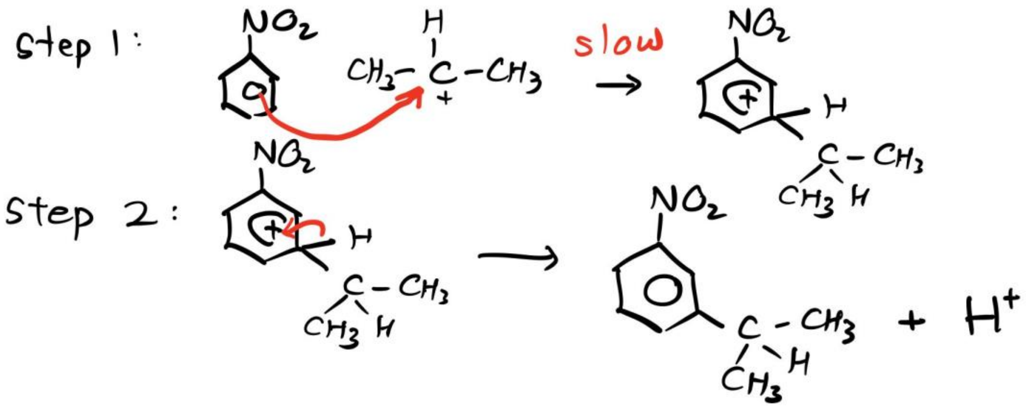
(ii) By considering the position of equilibrium for equation 4.1, suggest why **I** was obtained in larger quantity than **H**.
Carbocation G2 is more stable due to the greater number of electron donating alkyl group that stabilizes the positive charge of the carbocation. [1/2]

Carbocation G2 exist in a greater proportion than carbocation G1. [1/2] Hence during the reaction with nitrobenzene, a larger quantity of **I** is obtained.

Note: Discuss the stability of the **carbocation intermediate,** NOT stability of compound H and I.

[1]

(iii) Describe the mechanism for the formation of **I** from nitrobenzene.
In your answer, show any relevant charges, dipoles or lone pairs of electrons you consider important in this mechanism.
Electrophilic substitution [1m]



2m mechanism
−½ for each mistake

[3]

(iv) **H** can be reduced to 3-propylphenylamine.

Suggest a suitable reagents and conditions for this reaction.
1) Sn, conc HC*l*, heat
2) followed by excess NaOH(aq)

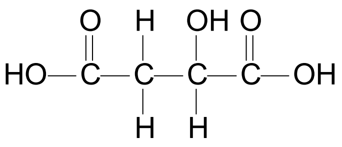
Note: NaOH (aq) is required in step 2 to remove the excess HC*l* in order to generate basic phenylamine.

[1]

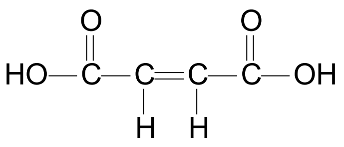
[Total : 17]

6 Bubble tea is a popular beverage in Singapore. NJC Chemistry department has conducted extensive studies on the effect of bubble tea on health.

(a) Bubble tea drinks are acidic in nature due to the presence of acids such as malic acid. Malic acid can undergo an elimination reaction to produce but-2-enedioic acid.


$HO-C(=O)-CH_2-CH(OH)-C(=O)-OH$

malic acid

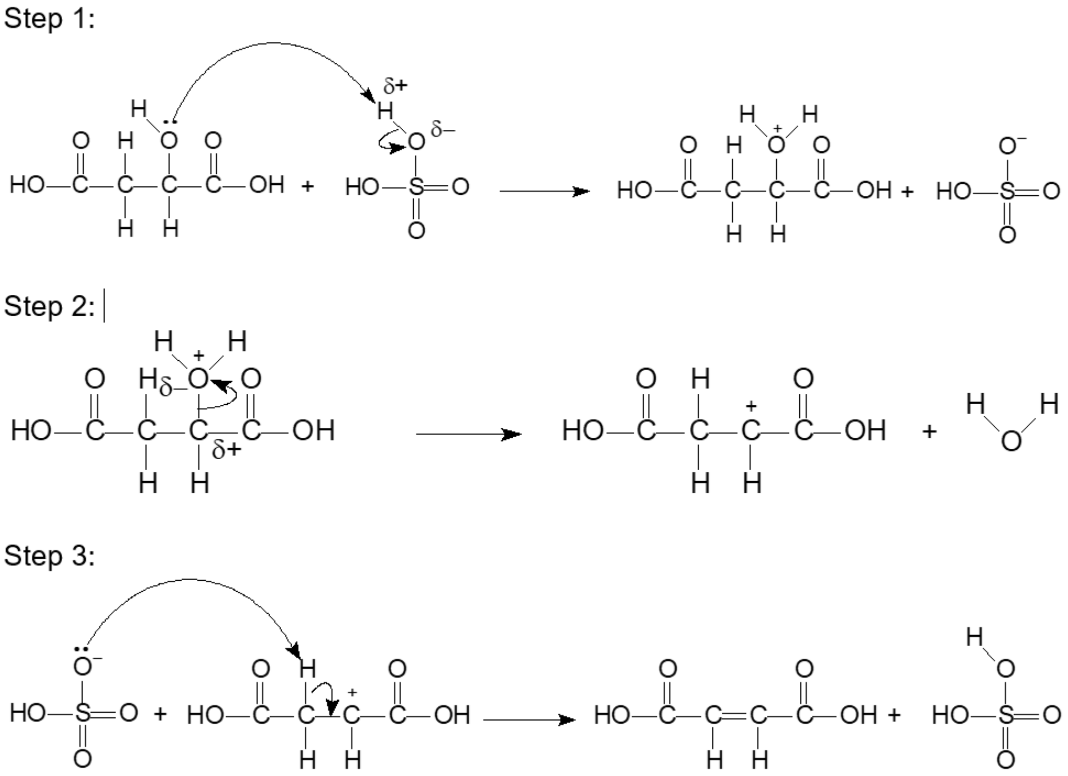

$HO-C(=O)-CH=CH-C(=O)-OH$

but-2-enedioic acid.

The mechanism of the elimination reaction occurs in three steps.

Complete the mechanism in Fig. 6.1 by showing clearly lone pair electrons and movement of electrons by curly arrows.

Fig. 6.1



Note: Identify the bond broken/formed for each step.

For breaking of polar bond, identify the δ+ and δ− of the atoms involved in the bond, electron pair from the bond will move to the more electronegative element involved in the bond.

For bond formation, electron pair move from electron rich region (lone pair electrons or existing bond) to target atom.

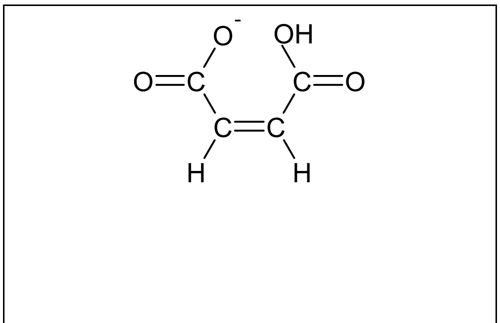
For step 3, formation of pi bond involves the movement of electron pair to existing sigma bond.

[3]

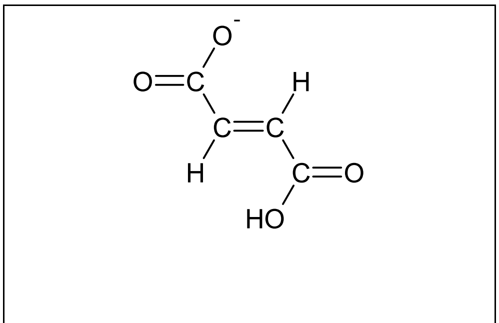
(b) But-2-enedioic acid exhibits cis-trans isomerism.

	pK_{a1}	pK_{a2}
maleic acid (cis-isomer)	1.9	6.0
fumaric acid (trans-isomer)	3.0	4.4

(i) Draw the monoanion of the two isomers.



monoanion of maleic acid



monoanion of fumaric acid

[1]

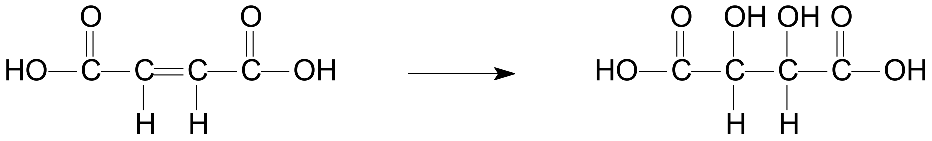
(ii) Hence or otherwise, explain why pK_{a1} of maleic acid is smaller than that of fumaric acid.

The monoanion of maleic acid (cis-isomer) is stabilized by intramolecular H-bonding, and it is more stable than the monoanion of fumaric acid. [1]

Dissociation of maleic acid into its monoanion and H^+ is more favourable than fumaric acid. Hence maleic acid is more acidic and has a smaller pK_{a1}. [1]

[2]

(c) But-2-enedioic acid can be converted to tartaric acid.



$HO{-}C(=O){-}CH{=}CH{-}C(=O){-}OH \longrightarrow HO{-}C(=O){-}CH(OH){-}CH(OH){-}C(=O){-}OH$

but-2-enedioic acid

tartaric acid

(i) State the reagents and conditions to convert but-2-enedioic acid to tartaric acid.
$KMnO_4$, NaOH(aq), cold, followed by H_2SO_4(aq)
Also accept $KMnO_4$, H_2SO_4(aq), cold

Note: The −COOH group will be neutralized by NaOH(aq), hence we will need to acidify the reaction mixture to convert back to −COOH.

[1]

(ii) But-2-enedioic acid can also undergo an enzyme catalysed reaction to produce tartaric acid.

A reactant in an enzymatic reaction is known as a substrate. The effect of substrate concentration on the rate of reaction is shown in Fig. 6.2.

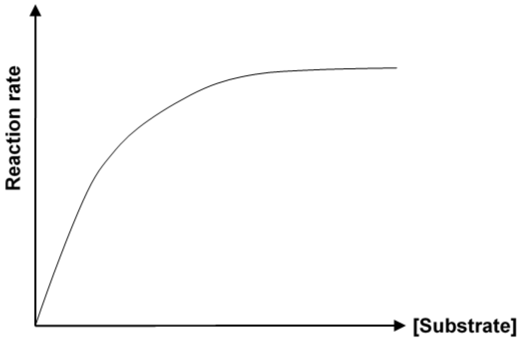


Fig. 6.2

Explain the shape of the graph at low [substrate] and high [substrate].
At low [substrate], not all of the active sites are occupied. The rate of reaction increases proportionally with substrate concentration. [1m]

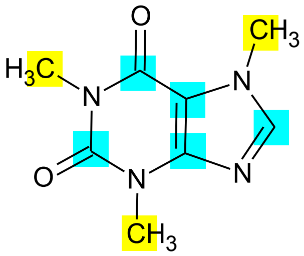
At high substrate concentration, the **active sites of the enzymes are saturated**. **Increase in the concentration of substrate cannot increase the rate of reaction any further.** [1m]

[2]

(d) Bubble tea contains a high amount of caffeine.

Caffeine, a stimulant found in coffee and tea, was discovered by a German chemist, Friedrich Ferdinand Runge, in 1819.

The structure of caffeine is given below.



(i) State the number of sp^2 and sp^3 hybridised carbon atoms in caffeine.

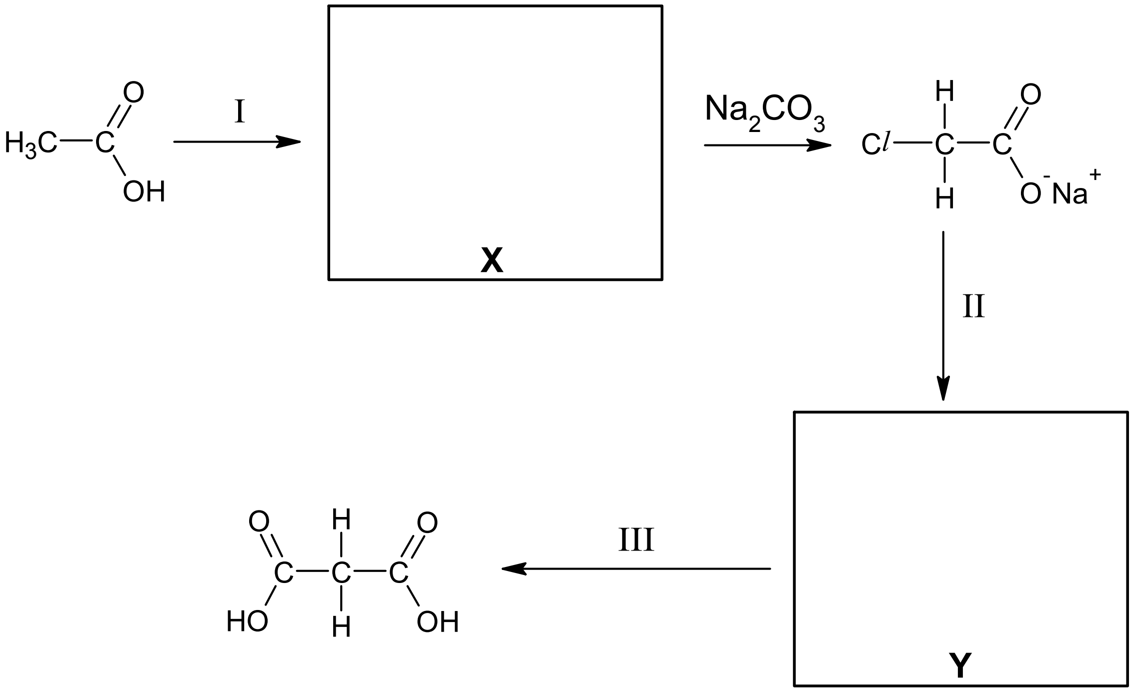
number of sp^2 hybridised carbon atoms : 5 (highlighted in light blue) [1/2m]

number of sp^3 hybridised carbon atoms : 3 (highlighted in yellow) [1/2m]

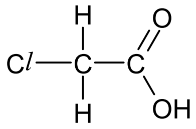
[1]

Caffeine can be synthesised in the laboratory using dimethyl urea, $(CH_3)NHCONH(CH_3)$ and malonic acid, $HOOC(CH_2)COOH$.

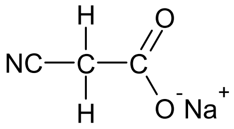
Malonic acid is usually prepared from ethanoic acid as follows:



(ii) Draw the structures of the intermediates **X** and **Y**.



X



Y

[2]

(iii) Suggest reagents and conditions for step I and II and identify the type of reaction for step III in the reaction sequence

Step I : **limited Cl_2 (g), UV (Note: limited Cl_2 would favour mono-substitution)**

Step II : **KCN in ethanol, heat**

Type of reaction for step III : **Acid hydrolysis**

[3]

(e) The caffeine content of some beverages is given in Table 6.1.

Table 6.1

	Red Bull (250 ml)	Coca-Cola (250 ml)	Espresso (60 ml)	Bubble tea (400 ml)
Caffeine content/ mg	80	25	100	160

The beverage consumption pattern of an 18-year-old student was monitored across a 12-hours period. The student followed the instructions and did not consume any caffeine containing products two days prior to the research study.

Time	**Drinks consumed**
0600	Espresso (60 ml)
1000	Coca-Cola (250 ml)
1400	Bubble tea (400 ml)
1800	-

(i) The Singapore Health Promotion Board recommends teenagers' (13-18 years old) total daily caffeine consumption to not exceed 3mg caffeine per kg of body weight.

Given that the student's weight is 54kg, deduce whether the student has exceeded the recommended daily caffeine intake.

Total daily caffeine intake of the student = 100 + 25 + 160 = 285mg [1]

Recommended daily caffeine intake = 54 × 3 = 162mg [1/2]

The student has exceeded the recommended daily caffeine intake. [1/2]

[2]

(ii) Caffeine's biological half-life is approximately 4 hours.

Determine the estimated amount of caffeine (in mg) remaining in the student at time 1800. Show your workings clearly.

Time	**Drinks consumed**	**Caffeine at 1800**
0600	Espresso (60 ml)	100 × ½ × ½ × ½ = 12.5mg
1000	Coca-Cola (250 ml)	25 × ½ × ½ = 6.25mg
1400	Bubble tea (400 ml)	160 × ½ = 80mg
1800	-	Total caffeine = 98.75mg

[2]

[Total: 19]