NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY

9729/02
Paper 2 Structured Questions
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.

……...
[1]

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

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……...
[2]

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

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

(i) Explain why the rate of the above reaction is slow.

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[1]

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

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[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.

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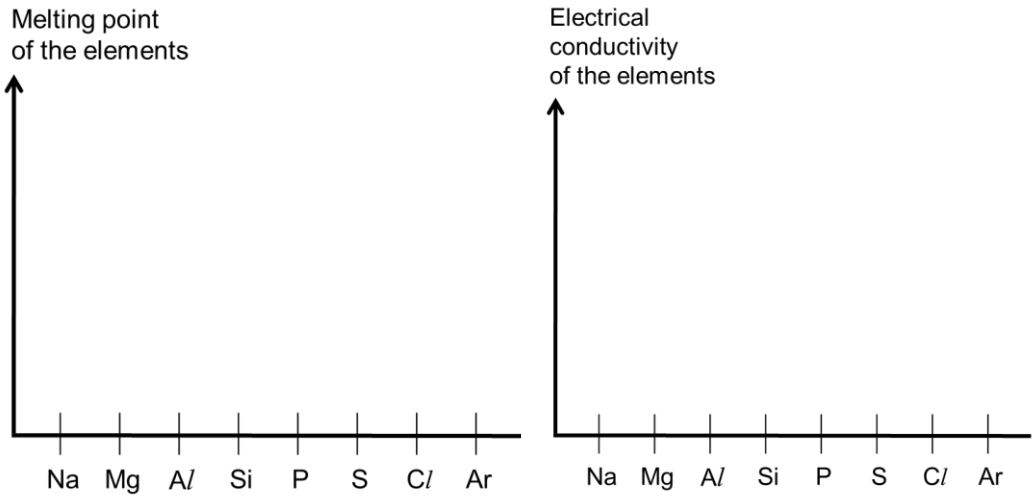
[2]

[Total : 8]

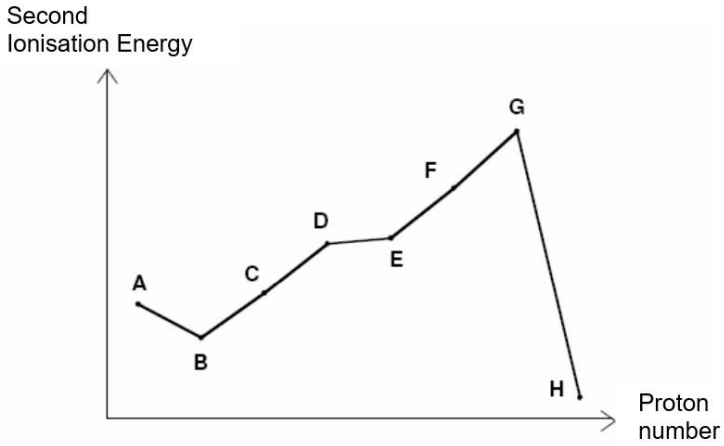
2 **(a)** The Period 3 elements vary in their physical properties.

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



[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.

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[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 $\mathbf{XY(CO_3)_2}$

……...

[1]

(ii) Calculate the mass of carbon dioxide produced.

[1]

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

[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.

……...

[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.

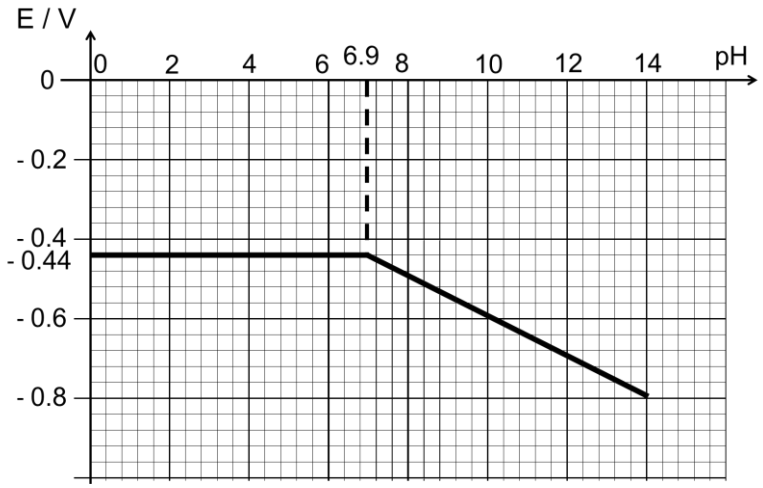
Calculate the time needed to obtain 1 kg of pure aluminium.

[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 $Fe(OH)_2$ = 6.0×10^{-15} mol^3 dm^{-9} at 25 °C)

[2]

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

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[3]

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

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[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.

[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.

……...

[1]

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

[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.

[2]

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

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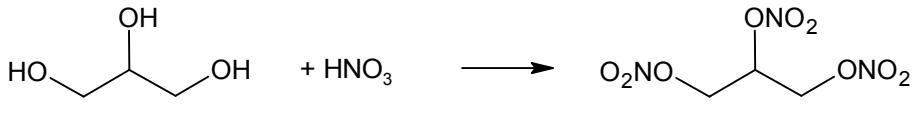
[1]

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



glycerol nitroglycerin

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

Type of reaction : ……..

[2]

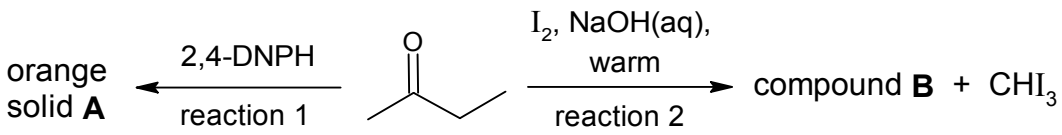
(ii) Give the IUPAC name for glycerol.

……..

[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 : ……..

structure of **A**

[2]

(ii) Suggest the identity of compound **B**.

……..

[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.

……

[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 : ……..……..

structure of tetrahydrofuran

[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**.

……

[1]

(ii) Write the balanced equation for reaction **b1**.

……

[1]

(iii) Deduce the molecular formula of the organic product formed in reaction **b2**.

……

[1]

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

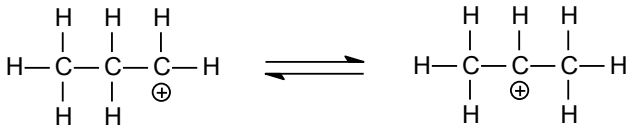
[1]

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

[1]

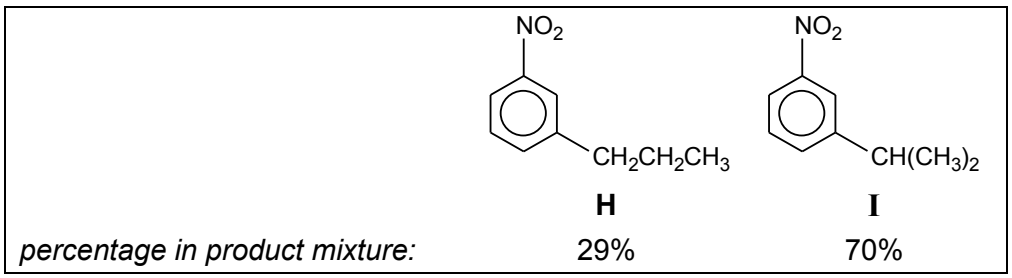
(c) Propene can undergo protonation by an acid to give a mixture of two carbocations that co-exist in equilibrium:

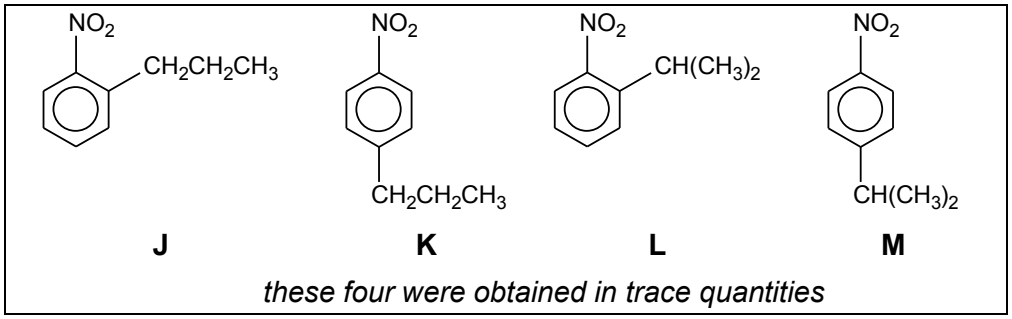
equation 5.1



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

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





(i) Suggest a reason why **J**, **K**, **L** and **M** were obtained in trace quantities only.

……...

……...

……...

[1]

(ii) By considering the position of equilibrium for equation 5.1, suggest why **I** was obtained in larger quantity than **H**.

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……...
[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.

[3]

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

Suggest a suitable reagents and conditions for this reaction.

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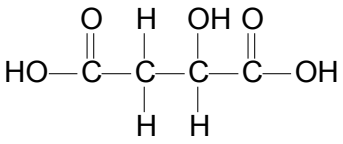
……...
[1]

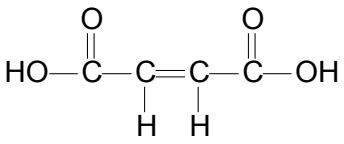
[Total : 17]

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.



malic acid

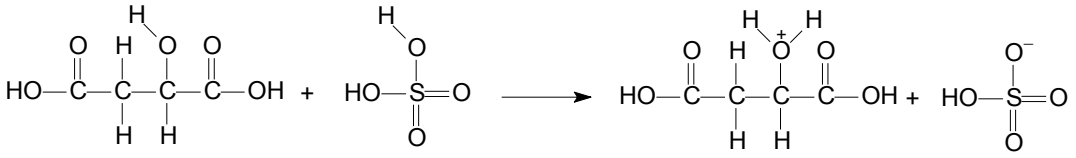


but-2-enedioic acid.

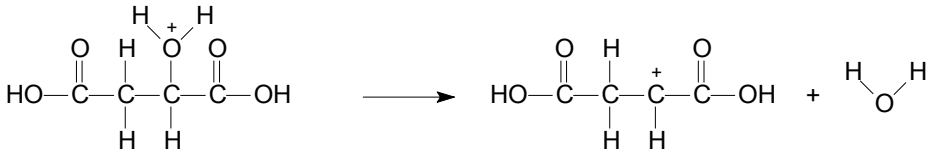
The mechanism of the elimination reaction occurs in three steps.

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

Step 1:



Step 2:



Step 3:

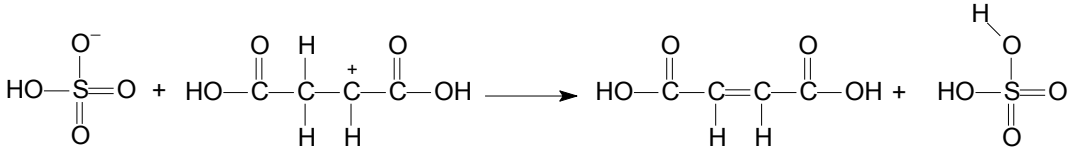


Fig. 6.1

[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.

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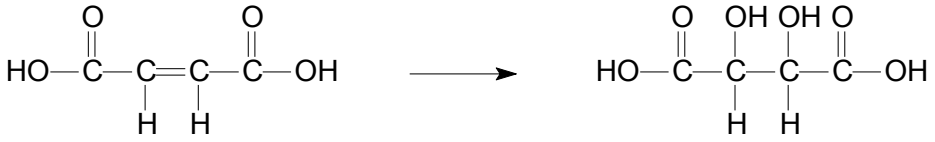
[2]

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



but-2-enedioic acid tartaric acid

(i) State the reagents and conditions to convert but-2-enedioic acid to tartaric acid.

……...
[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.

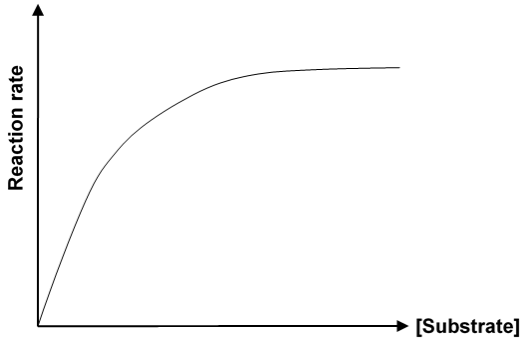


Fig. 6.2

Explain the shape of the graph at low [substrate] and high [substrate].

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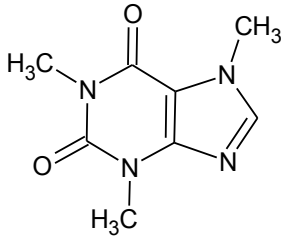
[2]

(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.

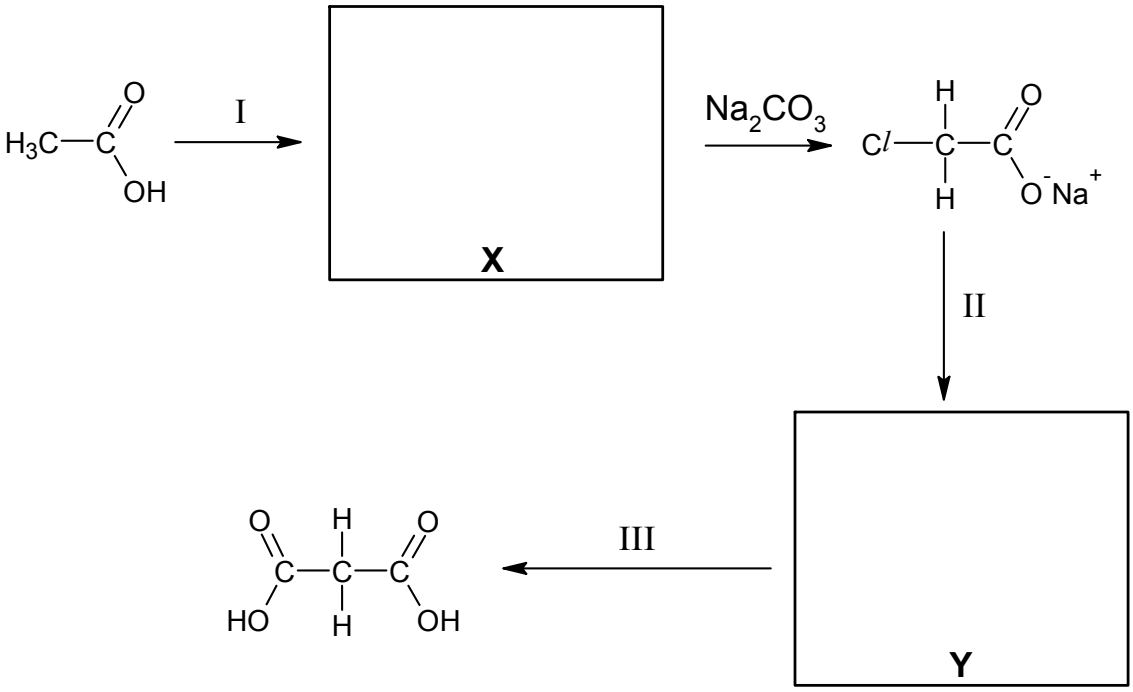
number of sp^2 hybridised carbon atoms : ……..

number of sp^3 hybridised carbon atoms : ……..

[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**.

[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 : ……..…...

Step II : ……

Type of reaction for step III : ……

[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.

[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.

[2]

[Total : 19]

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