

Good Hope School Mock Examination 2023-2024

S.6 CHEMISTRY PAPER 2

1 hour

This paper must be answered in English

Student Name	
Class	
Class Number	
Block Number	

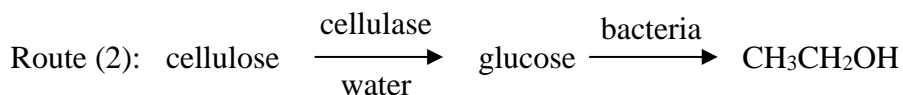
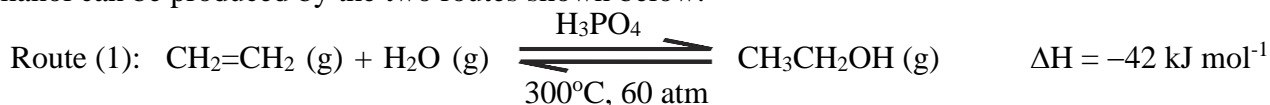
INSTRUCTIONS

- (1) This paper consists of **TWO** sections, A and B. Attempt **ALL** questions in both sections.
- (2) Write your answers in the Answer Book provided. Start each question (not part of a question) on a new page.
- (3) A Periodic Table is printed on page 8 of this question paper. Atomic numbers and relative atomic masses of elements can be obtained from the Periodic Table.

Section A Industrial Chemistry

Answer ALL parts of the question.

1. (a) Ethanol can be produced by the two routes shown below:



- (i) Suggest ONE reasons why Route (2) is considered greener than Route 1. (1 mark)

Less hazardous chemical is used in Route (2) while corrosive H_3PO_4 is used in route (1). [1]

Cellulose is a renewable feedstock in Route (2) whereas ethene used in route (1) is not. [1]

Less ambient conditions (e.g. lower temperature) are used in route (2) than (1). [1]

[must answer in COMPARATIVE approach]

[NOT accept: biological catalyst (cellulase) is used in Route (2) while non-biological catalyst (H_3PO_4) is used in Route (1) as this idea is NOT addressed in any of the 12 Green Chemistry Principles].

Poorly answered

- Many students did not compare the two routes.
- Many students compare whether the catalyst is biodegradable.
- Many students did not recognise that H_3PO_4 is an acid and is corrosive.

- (ii) Suggest ONE reason why ethanol used in industry is manufactured by Route (1) instead of route (2). (1 mark)

In route (1), the ethanol produced is more pure.

The rate of fermentation in route (2) is slower.

% atom economy is higher / there is less waste produced in Route (1) [1]

[NOT accept less synthetic steps]

Poorly answered

- Many students simply quoted route (2) involved more steps without mentioning less waste would be produced.
- Many students explained in terms of the reversible nature of the reaction.
- Some explained in terms of economics theory / costs of production.

- (iii) Explain why 300°C and 60 atm are used as the optimal conditions for Route (1). (2 marks)

A lower temperature shifts the equilibrium position to the right (and gives a higher % yield). However, lower temperature slows down the rate of reaction. [1]

Higher gas pressure shifts the equilibrium to the right (and gives a high % yield), yet higher gas pressure also increases construction cost/ of the plant/ energy cost/ higher risk. [1]

[Strategy: Should explain the effect why the optimal conditions are used e.g. explain why the gas pressure needs to be high, but not too high]

Poorly answered

- Many students did not explain that the conditions are a compromise of percentage yield and reaction rate.
- Many students only wrote about the shifts of equilibrium position without relating to the percentage yield.

[4 marks]

(b) The table below lists the rate constants for the decomposition of hydrogen peroxide at two temperatures.

Temperature (°C)	Rate constant (s ⁻¹)
25	7.77×10^{-6}
75	7.45×10^{-4}

(i) Calculate the activation energy of the decomposition of hydrogen peroxide.

(Gas constant $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$; Arrhenius equation: $\log k = \text{constant} - \frac{E_a}{2.3RT}$)

(2 marks)

$$\log \frac{7.77 \times 10^{-6}}{7.45 \times 10^{-4}} = - \frac{E_a}{2.3R} \left(\frac{1}{298} - \frac{1}{348} \right) \quad [1 \text{ for correct substitution}]$$

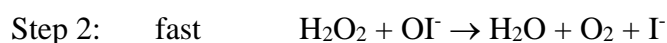
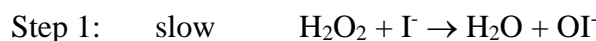
$$E_a = 78560 \text{ J mol}^{-1}$$

$$E_a = 78600 \text{ J mol}^{-1} \text{ or } 78.6 \text{ kJ mol}^{-1} \quad [1] \quad [0 \text{ for wrong or missing unit}]$$

Well answered

- Some students did not convert temperature in °C into K scale.
- Some students gave a negative sign for E_a , which is always be positive.
- A few could not remember the correct relationship between rate constant and temperature.

(ii) The decomposition of hydrogen peroxide in the presence of a catalyst is believed to occur by the following mechanism:



(1) Which of the above species works as the catalyst?

(1 mark)

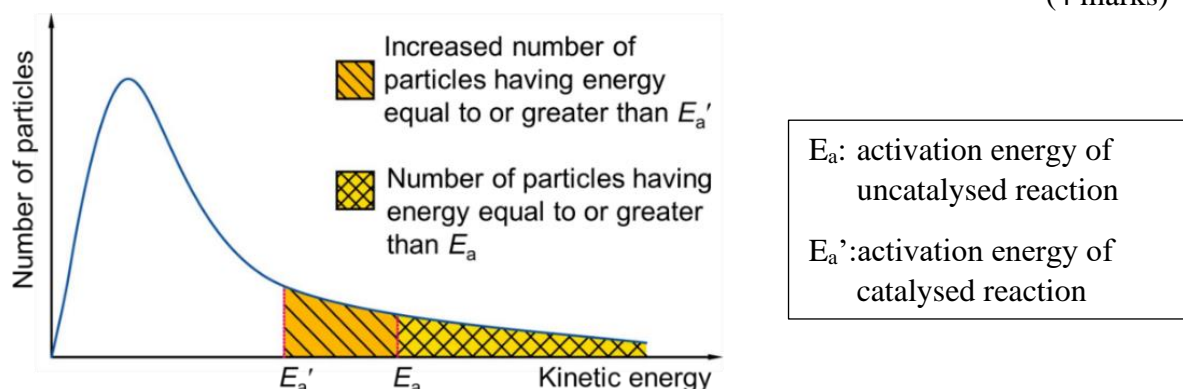
I^- / iodide ion [1]

Poorly answered.

- Many students wrongly chosen OI^- to be the catalyst, showing that they do not understand the criteria of a catalyst which is a substance that is used up in one of the mechanistic step, but regenerated at the end of the reaction.
- OI^- is an 'intermediate' in this reaction. It is produced in step 1, but used on in step 2.

- (2) With the aid of a Maxwell-Boltzmann distribution curve, explain why the reaction becomes faster in the presence of a catalyst.

(4 marks)



[1 mark for labels of x and y axes; 1 mark for shape of curve and label of E_a and E_a']

A catalyst provides an alternative pathway of lower activation energy [1]. As there are more particles with energy greater than or equal to activation energy, frequency of effective collisions increases [1], hence increasing the rate of reaction.

Satisfactory

The curve

- Some students could not label the two axes correctly.
- Some students did not start the curve from zero.
- Many students drew two curves instead of one (two curves are drawn **ONLY** when there is a change in temperature which affects the distribution of molecular K.E.).

The explanation

- Some students wrongly claimed that the activation energy of the pathway is lowered by the presence of the catalyst.

[7 marks]

- (c) Flowing mercury cells and membrane electrolytic cells are used in industry to produce chlorine, hydrogen and sodium hydroxide.

- (i) Write an overall equation for the electrolysis involved in the chloralkaline industry. (1 mark)



Well answered

- (ii) Explain how sodium hydroxide is produced in flowing mercury cell. (2 marks)

At the mercury cathode, sodium ions are preferentially discharged to form sodium. [1]

Sodium dissolves in mercury to form sodium mercury amalgam which reacts with water to form sodium hydroxide [1]

Poorly answered

- Many students considered H^+ ions to discharge even though mercury is used as cathode; the fact is Na^+ ions would be discharged instead of H^+ ions if mercury is used as the cathode.
- Those who chose Na^+ to discharge, many students did not mention what electrodes at which Na^+ ions are discharged.

- (iii) Explain why sodium hydroxide obtained in the membrane electrolytic cells does not contain sodium chloride. (1 mark)

The membrane only allows cations to pass through, but not anions. [1]

Well answered

[4 marks]

- (d) Currently, methanol is produced primarily by catalytic conversion of syngas.

- (i) Write the chemical equation for the reaction involved. (1 mark)



Well answered

- (ii) State an advanced method of methanol production. (1 mark)

[1] Any one of the following:

- Direct conversion of methane to methanol with the use of a metal oxide catalyst at high temperature and atmospheric pressure.
- Oxidation of methane to methanol by microbial reaction.
- Conversion of biomass to syngas/ biogas for methanol production.
- Carbon dioxide in flue gas can be converted to form methanol
- Unconsumed hydrogen from chemical industries is allowed to react with carbon monoxide to form methanol.

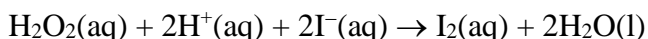
[Should state the feedstock used]

Fair performance

- Answers were unclear, e.g.
 - direct conversion to methanol without mentioning the source and catalyst
 - microbial reaction

[2 marks]

- (e) Iodide ions are oxidized to iodine by hydrogen peroxide under acidic conditions.



The rate equation for the reaction can be written as:

$$\text{rate} = k[\text{H}_2\text{O}_2\text{(aq)}]^a[\text{H}^+\text{(aq)}]^b[\text{I}^-\text{(aq)}]^c$$

- (i) In the presence of large excess of both $\text{H}_2\text{O}_2\text{(aq)}$ and $\text{I}^-\text{(aq)}$, the rate equation can be simplified as:

$$\text{rate} = k_I[\text{H}^+\text{(aq)}]^b$$

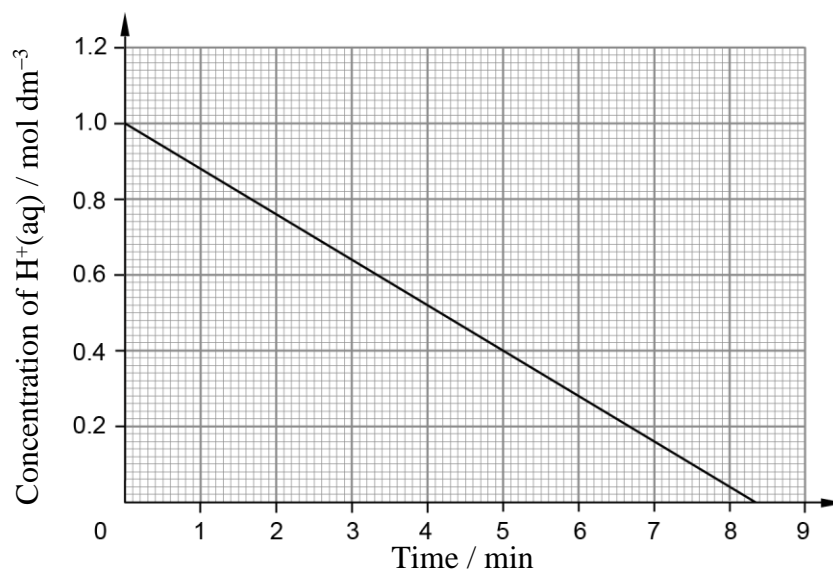
Explain why the rate equation can be simplified as above under such condition. (1 mark)

When large excess of both $\text{H}_2\text{O}_2\text{(aq)}$ and $\text{I}^-\text{(aq)}$ are used, change in $[\text{H}_2\text{O}_2\text{(aq)}]$ and $[\text{I}^-\text{(aq)}]$ is negligibly small [0.5], hence $[\text{H}_2\text{O}_2\text{(aq)}]$ and $[\text{I}^-\text{(aq)}]$ almost remain constant / only $[\text{H}^+\text{(aq)}]^b$ is a variable [0.5].

Fair performance

- Many simply mentioned that the concentrations of H_2O_2 and I^- ions remained fairly constant, without mentioning the cause, i.e. relatively small changes in their concentrations.

- (ii) An experiment was performed at 25°C to study the chemical kinetics of the reaction. The following graph shows the variation of concentration of $\text{H}^+(\text{aq})$ with time.



- (1) Deduce the value of b .

(1 mark)

From the concentration-time graph, a straight line with a constant slope is obtained. This suggests that the rate of the reaction is independent of the concentration of $\text{H}^+(\text{aq})$. Hence, the order of reaction with respect to $\text{H}^+(\text{aq})$ is zero, i.e. $b = 0$. [1]

Poorly answered

- Students could not relate straight line to order of reaction. Constant slope in concentration-time graph represents zeroth order.

- (2) Determine the value of k_1 .

(1 mark)

Since the order of reaction w.r.t. H^+ is 0, the rate equation can be simplified as:

$$\text{Rate} = k_1$$

$$\text{Rate} = \text{rate of consumption of } \text{H}^+ = \text{rate of change of } [\text{H}^+(\text{aq})] = k_1$$

$$k_1 = \text{slope} = \frac{(1.0 - 0.4) \text{ mol dm}^{-3}}{(0 - 5) \text{ min}} = 0.12 \text{ mol dm}^{-3} \text{ min}^{-1} \quad [1]$$

Poorly answered

- Some students gave a negative sign for the rate constant, k , which is always positive.
- A few did not read the units in the graph carefully and put down ' $\text{mol dm}^{-3} \text{ s}^{-1}$ ' as the unit.

[3 marks]

[20 marks]

END OF SECTION A

Section B Analytical Chemistry

Answer **ALL** parts of the question.

2. (a) Suggest a chemical test to distinguish between NaI(s) and NaNO₃(s). (2 marks)

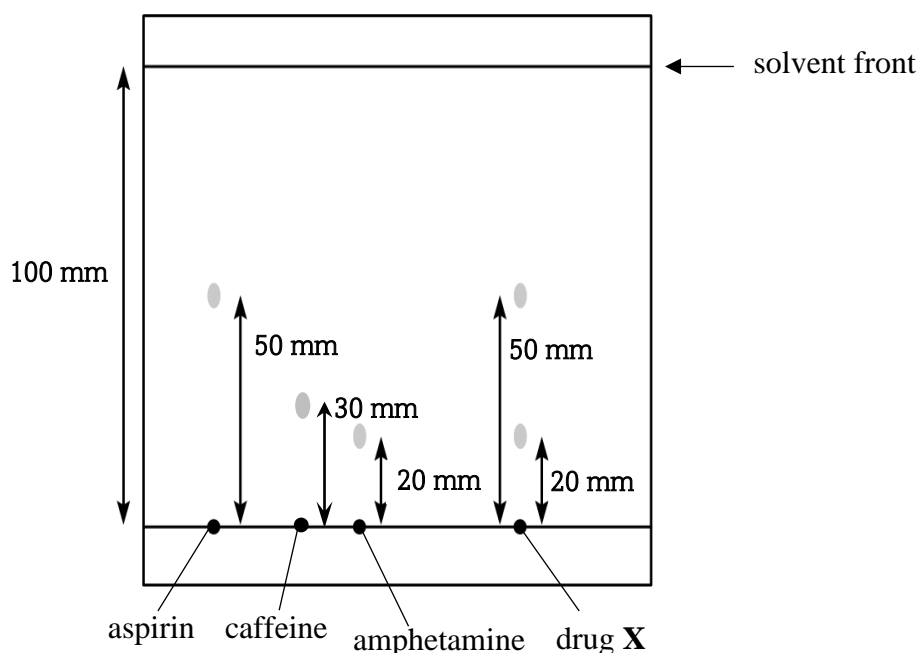
Dissolve each sample with deionized water, then mix each sample with AgNO₃(aq). [1]

A yellow precipitate will be formed only in NaI(aq). [1]

Fair performance

Most students could give the AgNO₃(aq) as the reagent, but many did not mention that the solid samples have to be dissolved in **deionized / distilled** water before addition of AgNO₃(aq).

- (b) The chromatograms from thin-layer chromatography (TLC) of aspirin, caffeine, amphetamine and a drug X are shown below.:



- (i) Calculate the R_f value of amphetamine. (1 mark)

$$\text{The } R_f \text{ value of amphetamine} = \frac{20 \text{ mm}}{100 \text{ mm}} = 0.2 \text{ [1]}$$

Well done

- (ii) What chemicals are present in drug X? (1 mark)

Drug X contains aspirin and amphetamine. [1]

Well done

- (c) An experiment was done to determine the percentage by mass of iron in an impure iron sample. 2.65 g of the sample was first warmed with excess dilute nitric acid. The resultant solution was then boiled. After cooling and filtration, the solution was diluted to 250.0 cm³ with distilled water. 25.0 cm³ of the solution required 17.60 cm³ of 0.020 M acidified potassium permanganate solution to reach the end point of the titration.

- (i) Write the ionic equation for the reaction between the filtrate and acidified potassium permanganate solution. (1 mark)



Satisfactory performance.

Iron reacts with HNO₃ as follows: $\text{Fe}(\text{s}) + 2\text{H}^{+}(\text{aq}) \rightarrow \text{Fe}^{2+}(\text{aq}) + \text{H}_2(\text{g})$

But some students did not understand the reactions involved and wrongly put down Fe(s) as the R.A. to react with MnO₄⁻.

- (ii) Assuming that the impurities do not react with dilute nitric acid, calculate the percentage by mass of iron in the sample.

(Relative atomic mass: Fe = 55.8)

(3 marks)

Number of moles of $\text{MnO}_4^- = 0.020 \text{ M} \times 0.0176 \text{ dm}^3 = 3.52 \times 10^{-4} \text{ mol}$

Number of moles of Fe^{2+} in 25.0 cm^3 solution = $3.52 \times 10^{-4} \text{ mol} \times 5 = 1.76 \times 10^{-3} \text{ mol}$ [1]

Number of moles of Fe^{2+} in 250.0 cm^3 solution = $1.76 \times 10^{-3} \text{ mol} \times 10 = 0.0176 \text{ mol}$ [1]

Mass of Fe in the sample = $55.8 \text{ g mol}^{-1} \times 0.0176 \text{ mol} = 0.982 \text{ g}$

Percentage by mass of Fe in the sample = $\frac{0.982}{2.65} \times 100\% = 37.1\%$ [1]

Satisfactory performance

Most students gave correct answer if part (i) is correct. Some students were unaware of the dilution factor.

2. (d) The molecular formula of three structural isomers **A**, **B** and **C** is $\text{C}_8\text{H}_8\text{O}$.

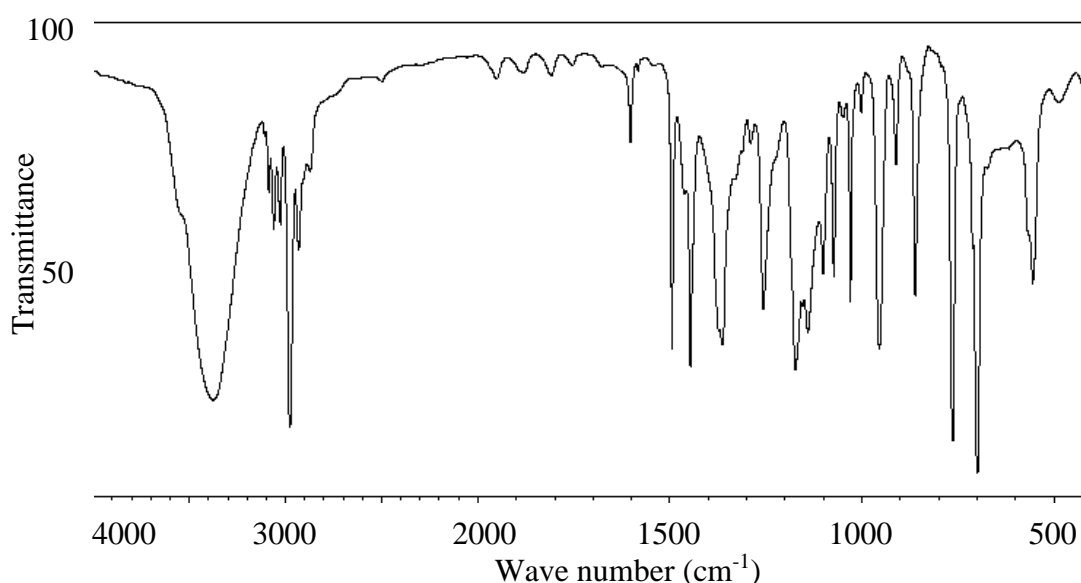
- (i) Isomers **A** and **B** are carbonyls. Suggest a test to show that they are carbonyls, stating the expected observations. (2 marks)

Add each sample dropwisely into a test tube containing 2,4-dinitrophenylhydrazine. [1]

A yellow / orange / red precipitate is formed in both samples. [1]

Well answered.

- (ii) The infrared spectra of compound **A** and **B** are similar, but that of compound **C** is significantly different. The infrared spectrum of compound **C** is shown below:



**Characteristic Infra-red Absorption Wavenumber Ranges
(Stretching modes)**

Bond	Compound type	Wavenumber range / cm^{-1}
C=C	Alkenes	1610 to 1680
C=O	Aldehydes, ketones, carboxylic acids and derivatives	1680 to 1800
C≡C	Alkynes	2070 to 2250
C≡N	Nitriles	2200 to 2280
O-H	Acids (hydrogen-bonded)	2500 to 3300
C-H	Alkanes, alkenes, arenes	2840 to 3095
O-H	Alcohols, phenols (hydrogen-bonded)	3230 to 3670
N-H	Amines	3350 to 3500

With reference to the table above, suggest two differences in the infrared spectra of compound **C** and those of compounds **A** and **B**. (2 marks)

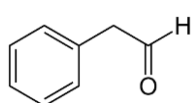
A broad/ strong absorption can be found at around 3230 – 3670 cm⁻¹ in the IR spectrum of C but not in the other two. [1]

A strong absorption peak can be found at around 1680 – 1800 cm⁻¹ in the spectra of A and B but not in that of C. [1]

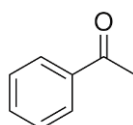
Satisfactory performance

- Some students did not compare the difference between two spectra.
- Some students did not write down the units and some gave specific region of absorption instead of the range of the absorption peak. Candidates are expected to give the absorption range given in the question.

2. (d) (iii) The structures of **A** and **B** are shown below:

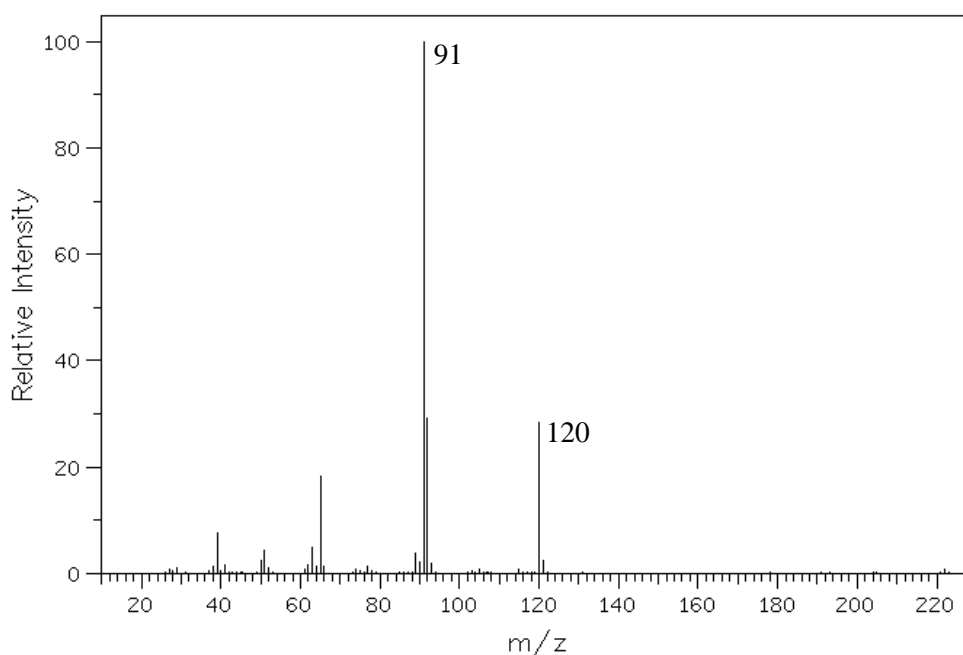


A



B

(1) The mass spectrum of one of the compounds is given below.



State, with reasons, what the compound is.

(1 mark)

(Relative atomic masses: H = 1.0, C = 12.0)

The compound is **A** because a strong peak at m/z = 91 in the mass spectrum represents C₆H₅CH₂⁺ / indicating the structure C₆H₅CH₂- in the compound. [1]

Satisfactory performance

Some students gave wrong structure for the peak at m/z = 91. Some did not give the correct charge for the chemical species representing m/z = 91.

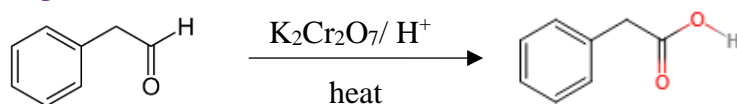
- (2) To extract compound **A** from a mixture of compounds **A** and **B**, the mixture was warmed with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ to convert **A** into an acid. After cooling, ether was added to the mixture and then the aqueous layer was discarded. Outline the additional steps required to collect pure **B**. (2 marks)

The ether layer is transferred to a separating funnel containing NaOH / NaHCO_3 / Na_2CO_3 solution. [1]

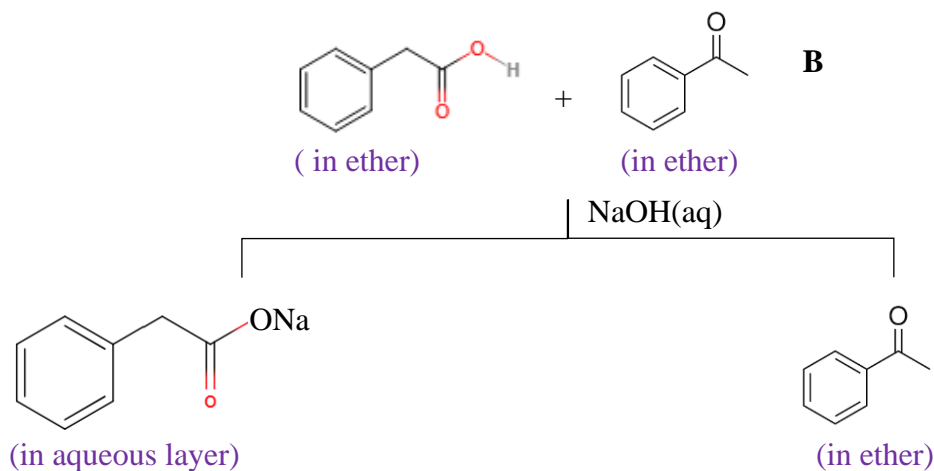
Collect the ether/top/upper layer and carry out distillation to collect pure **B**. [1]

Poorly answered

Explanation:



Though the carboxylic acid has polar $-\text{COOH}$ group, however it is weakly polar due to the relatively large non-polar hydrocarbon part. The acid thus dissolves in ether, together with **B**.



Most students did not realise that the organic layer contains both the carboxylic acid and **B**. Thus, subsequent steps should be the extraction of **B** from the organic layer.

- (3) Other than using acidified $\text{K}_2\text{Cr}_2\text{O}_7$, suggest how **A** and **B** can be distinguished. (2 marks)

Warm each sample with Tollen's reagent in a clean test tube. [1]

Only **A** gives a silver mirror on the inner wall of the test tube. [1] /

Add acidified $\text{KMnO}_4(\text{aq})$ dropwisely to each sample in a clean test tube. [1]

Only **A** turns acidified $\text{KMnO}_4(\text{aq})$ from purple to colourless [1]

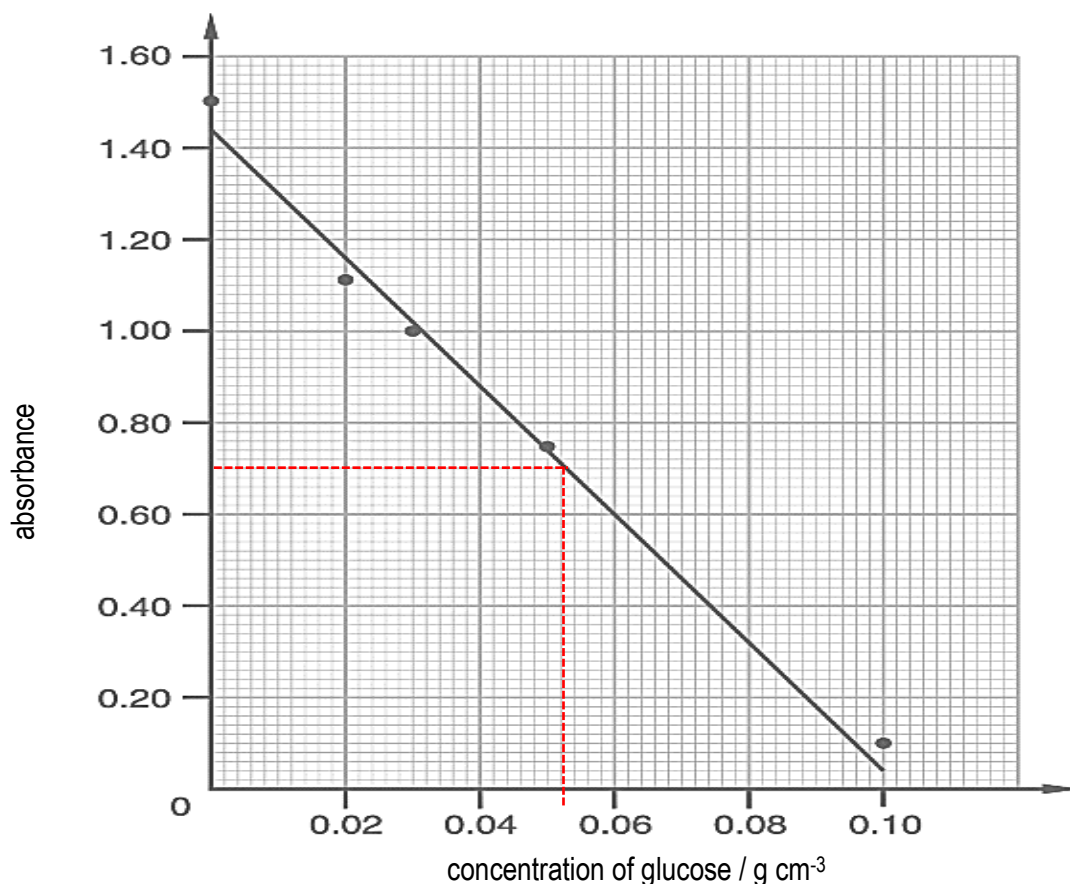
Well answered

2. (e) Colorimetry can be used to determine the glucose content in 7-Up soft drink. The following procedures are used to prepare a calibration graph to determine glucose concentration:

Step 1: A series of standard glucose solutions are prepared.

Step 2: 1 cm³ of each standard glucose solution is mixed with 5 cm³ of solution **X**. The solution is left in a hot water bath for 5 minutes. Glucose is oxidized by the Cu²⁺(aq) in solution **X** to form a brick-red precipitate (Cu₂O), which is removed by filtration.

Step 3: The absorbance of each filtrate is measured using a colorimeter with a red filter. A graph of absorbance against concentration of glucose is shown below:



- (i) Explain why the absorbance of filtrate decreases as the concentration of glucose increases.

(1 mark)

As the concentration of glucose increases, more Cu²⁺ in solution **X** is used up, lowering the concentration of Cu²⁺ in the mixture [0.5]. As a result, the blue solution becomes paler, leading to a lower absorbance [0.5]

Fair performance

Many students did not put down the cause of the drop in absorbance; some gave wrong explanation, e.g. relate the absorption to the ppt, which would be removed before absorbance measurement.

- (ii) Why is a red filter used in Step 3?

(1 mark)

The solution is blue in colour, indicating that it does not absorb blue light but absorbs red light. So, a red filter is used to select red colour for the analysis. [1]

Fair performance

Some students only mentioned the function of the filter, but did not relate the selection of light to the absorption of colour by the filtrate

