

**HKDSE
Past Paper Questions
Analytical Chemistry**

2012

3. (a) Compound X (molar mass < 118 g) contains a $-C_6H_5$ group. Two chemical tests are performed on X and the results are as follows:

Test (1): X turns acidified potassium dichromate solution green.

Test (2): X gives a negative result when tested with 2,4-dinitrophenylhydrazine.

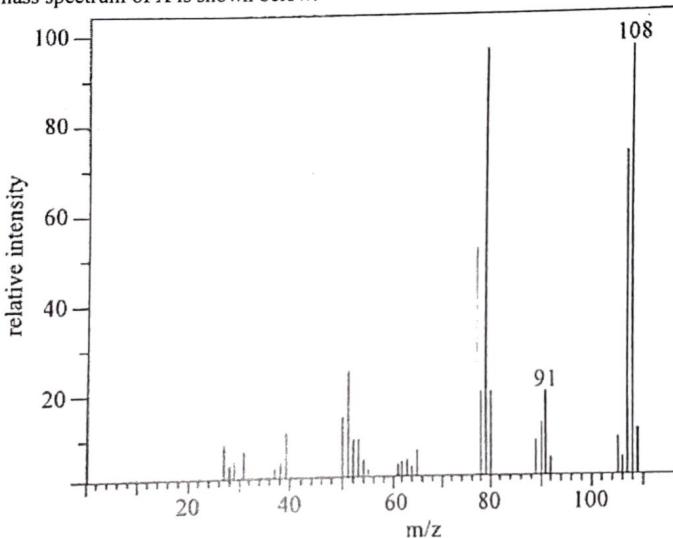
- (i) With reference to the result of Test (1) only, suggest TWO functional groups that X may have. (2 marks)

- (ii) (1) What is the purpose of using 2,4-dinitrophenylhydrazine in Test (2)?

- (2) State the expected observation if X gives a positive result in Test (2). (2 marks)

- (iii) With reference to the results of both Test (1) and Test (2), suggest one functional group that may be present in X. (1 mark)

- (iv) The mass spectrum of X is shown below:



Suggest one chemical species corresponding to each of the signals at $m/z = 91$ and 108 . (2 marks)

(1 mark)

- (v) Draw a possible structure of X.

- (b) The dioxin levels in air are generally measured through instrumental analysis but not gravimetric analysis or volumetric analysis. (1 mark)

- (i) Suggest a source of dioxins in air. (1 mark)

- (ii) Explain why there is a need to measure the dioxin levels in air. (1 mark)

(1 mark)

- (iii) Suggest an instrument analytical method for measuring the dioxin levels in air, and state why this method, rather than methods based on gravimetric analysis or volumetric analysis, is to be used. (2 marks)

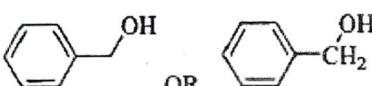
- (c) An aqueous solution only contains $HCl(aq)$ and $HI(aq)$. Based on the fact that $AgCl(s)$, but not $AgI(s)$, can dissolve in excess $NH_3(aq)$, you are required to plan a gravimetric analysis to determine the mole ratio of $Cl^-(aq)$ to $I^-(aq)$ in the solution. [Out of syllabus]

- (i) Suggest TWO reagents, other than deionized water, that should be used in the analysis. (2 marks)

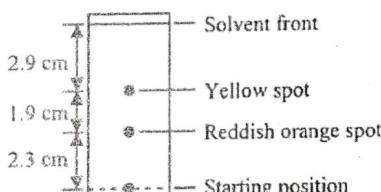
(4 marks)

- (ii) Outline the experimental steps involved in the analysis. (4 marks)

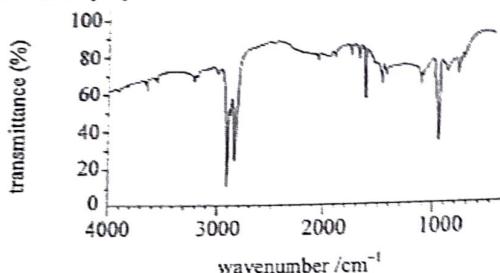
- (iii) Outline the steps in the calculation of the mole ratio of $Cl^-(aq)$ to $I^-(aq)$ in the solution using the data obtained from (ii) above. (2 marks)

3. (a) (i) hydroxyl (group) ---OH / alcohol [Do not accept phenol]
 aldehyde (group) ---CHO / aldehyde
 1
 1
- (ii) (1) Test for aldehyde (group) or ketone (group) / carbonyl (group) / aldehyde (group) and
 ketone (group) / RCHO and RCOR'
 (Accept: aldehyde, but do not accept ketone)
 (2) 2,4-dinitrophenylhydrazine reacts with aldehyde or ketone to give yellow/orange or
 red precipitate. [Do not accept brown colour]
 1
 1
- (iii) hydroxyl (group) ---OH
 1
- (iv) m/z = 91 suggested the presence of C_7H_7^+ [$\text{C}_6\text{H}_5\text{CH}_2$] (ion).
 [Must show plus sign]
 m/z = 108 suggested the presence of $\text{C}_7\text{H}_9\text{O}^+$ [$\text{C}_6\text{H}_5\text{OH}^+$ / $\text{C}_6\text{H}_5\text{CH}_2\text{OH}$] (ion).
 [Must show plus sign]
 If there is no description of m/z, mark sequentially.
 1
 1
- (v) 
 OR
 1
- (b) (i) Combustion of materials containing chlorine / PVC OR
 Incineration of materials containing chlorine / PVC OR
 Emission from incinerators OR
 Burning / combustion of plastic waste OR
 Burning / combustion of waste
 (Do not accept car exhaust)
 1
 1
- (ii) Dioxin is carcinogenic / can cause cancer.
 1
- (iii) Gas chromatography-mass spectrometry / GC-MS / GC/MS / GC/MS / GC/MS
 It can measure more accurately the low level of dioxin than using gravimetric analysis or
 volumetric analysis. [Do not accept faster / Dioxins are gaseous]
 1
 1
- (c) (i) $\text{AgNO}_3\text{(aq)}$ and $\text{NH}_3\text{(aq)}$ / Accept: acidified $\text{AgNO}_3\text{(aq)}$ [Mark only first TWO answers]
 1+1
- (ii) Step 1: Add excess $\text{AgNO}_3\text{(aq)}$ to the solution to form AgCl(s) and AgI(s) .
 Step 2: Filter the mixture, wash with deionised water and dry the residue.
 Step 3: Determine Weigh the total mass of AgCl(s) and AgI(s) collected.
 Step 4: Wash the solid residue with excess ammonia solution to dissolve remove AgCl(s) , filter and dry the residue, and determine the mass of AgI(s) remains.
 1
 1
 1
 1
- (iii) • Subtracting the total mass of AgCl(s) and AgI(s) determined in Step 3 by the mass
 of AgI(s) determined in Step 4 to get the mass of AgCl(s) .
 • Number of mole of AgCl and AgI can be obtained by dividing their respective mass
 by the corresponding molar mass. Mole ratio of $\text{Cl}^-(\text{aq})$ to $\text{I}^-(\text{aq})$ can then be
 determined.
 1
 1

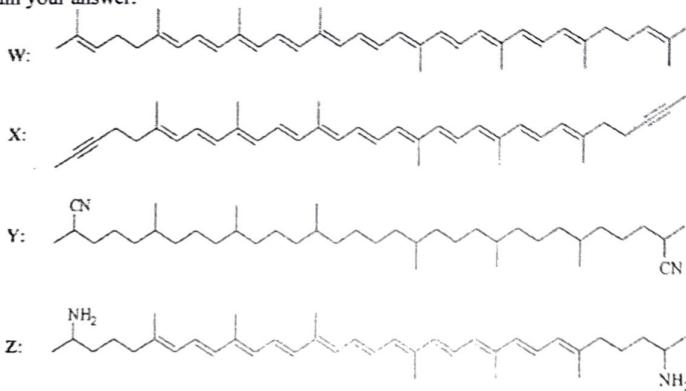
2013

3. (a) Outline how hex-1-ene can be obtained from a mixture of hex-1-ene, octane and water by physical methods. (Boiling points: hex-1-ene = 63 °C, octane = 125°C, water = 100°C) (4 marks)
- (b) Both white wine and red wine contain SO₂ preservative which is fixed in different forms. A volumetric analysis experiment was performed to determine the total concentration of SO₂ in a sample of white wine. In the experiment, 25.00 cm³ of the wine sample was transferred to a conical flask. Following certain stipulated procedures, NaOH(aq) and H₂SO₄(aq) were successively added to the flask to liberate all SO₂ from the wine. The resultant solution was immediately titrated with 0.00412 mol dm⁻³ I₂(aq) using freshly prepared starch solution as indicator. The experiment was repeated several times, and the mean volume of I₂(aq) required to reach the end point was 10.50 cm³.
- (i) A reaction must fulfill certain conditions in order that it can be used in volumetric analysis. State ONE such condition. (1 mark)
- (ii) Explain why the resultant solution needed to be titrated immediately. (1 mark)
- (iii) State the expected colour change at the end point of the titration. (1 mark)
- (iv) The chemical equation for the reaction involved in the titration is as follows:
SO₂(aq) + I₂(aq) + 2H₂O(l) → 2HI(aq) + H₂SO₄(aq)
Calculate the total concentration of SO₂, in mg dm⁻³, in the white wine sample. (4 marks)
- (v) Explain whether the total concentration of SO₂ in a sample of red wine can be determined in such an experiment. (1 mark)
- (c) The main pigments in a certain brand of tomato paste are lycopene (reddish orange) and β-carotene (yellow). In order to isolate lycopene from the tomato paste, an experiment involving solvent extraction, thin-layer chromatography (TLC) and column chromatography was performed.
- (i) The result of TLC is shown below:
- 
- Calculate the R_f value for the lycopene spot. (1 mark)
- (ii) With reference to the result of TLC, explain whether the first-collected coloured fraction in the column chromatography is lycopene or β-carotene, if the same stationary phase and mobile phase are used. (1 mark)
- (iii) Suggest an instrumental method that can be used to determine the concentration of lycopene in the collected lycopene fraction. State the physical property of the lycopene fraction that needs to be measured. (2 marks)

(iv) The infra-red spectrum of lycopene is shown below:



By referring to the Characteristic Infra-red Absorption Wavenumber Ranges (Stretching modes) given in the table below, suggest which of the following structures (W, X, Y or Z) may be the structure of lycopene. Explain your answer.



(4 marks)

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 acid 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

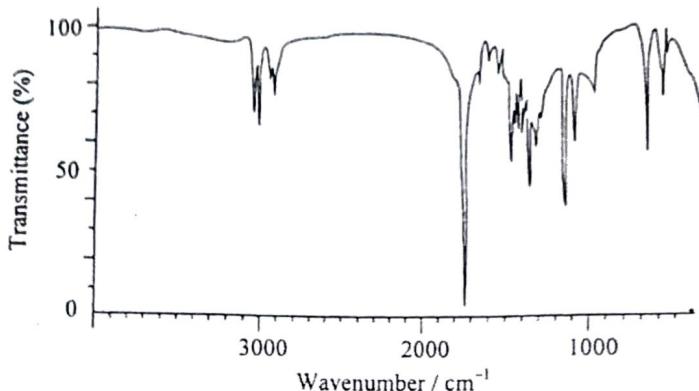
3. (a) Use separating funnel to remove water (the lower liquid layer) from the mixture. The remaining upper/organic layer (remaining in the funnel) is hex-1-ene and octane. Carry out fractional distillation / distillation on the upper layer: The first distillate collected is hex-1-ene. The second distillate collected is octane. If candidate reversed the steps (i.e. carry (fractional) distillation before separating funnel), deduct 1 mark. If candidates only drew diagrams without any explanation, deduct 1 mark.
- (b) (i) Any ONE of the following: --- a significant observable change can easily be detected with the complete consumption of the reagent in the conical flask, i.e. availability of suitable indicator --- the reaction must be significantly complete / it is not a reversible reaction --- the rate of reaction must be fast enough to be practical
(Accept other correct answer.)
- (ii) SO_2 easily escapes from solution / I_2 is volatile.
- (iii) from colourless to blue-black / blue / dark blue
[i.e. must have the word "blue"; "to" can be replaced by \rightarrow]
- (iv) No. of mole of I_2 used = $0.00412 \times 10.50 \times 10^{-3}$
 $= 4.33 \times 10^{-5}$
 $\text{No. of mole of } \text{SO}_2 = \text{No. of mole of } \text{I}_2$
 $= 4.33 \times 10^{-5}$
- Mass of SO_2 in the wine sample = $4.33 \times 10^{-5} \times 64.1$
 $= 2.77 \times 10^{-3} \text{ g}$
 $= 2.77 \text{ mg}$
- Concentration of SO_2 in the wine sample = $\frac{2.77}{0.025} = 111 (\text{mg dm}^{-3})$
[Range: 110 – 112]
- (v) This method cannot be used as the intense red colour of red wine may mask the colour of iodine / iodine-starch complex which leads to a difficulty in the end-point detection.
Or
This method can be used if the colour of red wine can be removed.
- (c) (i)
$$\frac{2.3}{2.3 + 1.9 + 2.9} = \frac{2.3}{7.1} = 0.32$$
 [Accept also 0.324 and 0.3239 BUT NOT 0.3]
[If the fraction given, the numbers therein must be correct.]
- (ii) (β) -carotene because lycopene has a smaller R_f value / lycopene moves slower / lycopene takes a longer time to reach the bottom of the column.
OR argue in terms of (β) -carotene

- (iii) Method: colorimetry / (use of) colorimeter / use of spectrophotometer |
- Measurement: absorbance / colour intensity / light intensity / transmittance |
- (iv) Compound W is lycopene. |
- The absence of (absorption) peaks at around 2070 – 2250 (cm^{-1}) suggesting it does not contain C≡C groups / ruling out the possibility of compound X. |
- The absence of (absorption) peaks at around 2290 – 2280 (cm^{-1}) suggesting it does not contain C≡N groups / ruling out the possibility of compound Y. |
- OR |
- The presence of (absorption) peaks at around 1630 (cm^{-1}) (1600 – 1680 cm^{-1}) (shows the presence of C=C/C-C double bonds) ruling out the possibility of compound Y. | (1)
- (Note: 2 marks for the absence of (absorption) peaks at around 2070 – 2280 (cm^{-1}), suggesting it does not contain C≡C and C≡N groups / ruling out (the possibility of compounds) X and Y.) |
- The absence of sharp (absorption) peaks at around 3350 – 3500 (cm^{-1}) suggesting it does not contain $-\text{NH}_2$ groups / ruling out the possibility of compound Z. |
- Compound W is a hydrocarbon which contains only C-H, C-C and C=C bonds. This agrees with the feature of the spectrum as there are small peaks at around 1630 cm^{-1} , showing the presence of C-C double bonds. |

2014

3. (a) Answer the following short questions:
- (i) Suggest a chemical test to show the presence of each of the following:
- (1) HCl(g)
(2) >C=O functional group
- (4 marks)
- (ii) Which of the following chemicals is most suitable for drying ethyl ethanoate?
anhydrous magnesium sulphate, concentrated sulphuric acid, solid sodium hydroxide
- (1 mark)
- (b) A powdered limestone sample mainly consists of CaCO_3 , and a small amount of MgCO_3 and FeCl_3 . The following steps were performed in an experiment to determine the percentage of CaCO_3 by mass in the sample.
- Step 1: 2.025 g of the limestone sample was added to excess amount of 6M HCl(aq).
- Step 2: The mixture obtained was gently heated until no signs of further reaction. It was then allowed to cool to room temperature.
- Step 3: The cooled mixture was diluted with distilled water, and made slightly alkaline by adding $\text{NH}_3\text{(aq)}$ to precipitate the $\text{Fe}^{3+}\text{(aq)}$ ions present.
- Step 4: The mixture obtained was filtered to collect the filtrate.
- Step 5: Excess ammonium oxalate solution, $(\text{NH}_4)_2\text{C}_2\text{O}_4\text{(aq)}$, was added to the filtrate, and the mixture obtained was then made slightly alkaline by using $\text{NH}_3\text{(aq)}$ to selectively precipitate the calcium oxalate formed.
- Step 6: The mixture was filtered. After washing and drying, 2.374 g of calcium oxalate solid was collected.
- (i) Why is it necessary to heat the mixture in Step 2? (1 mark)
- (ii) (1) How does one know when the reaction involved in Step 2 has been completed?
(2) State the observation in Step 3. (2 marks)
- (iii) It is given that magnesium oxalate is soluble in alkaline solutions but calcium oxalate is not.
Calculate the percentage of CaCO_3 by mass in the limestone sample. (3 marks)
- (iv) State the quantitative analysis method used in this experiment. (1 mark)

- (c) Under room temperature, T ($C_xH_yO_z$) is a colourless oily liquid and is immiscible with water. Moreover, T does not react with $NaHCO_3(aq)$.
- (i) A sample of T contains an organic acid as impurity. Outline the experimental steps for purifying the sample by using $NaHCO_3(aq)$ and pentane. (2 marks)
- (ii) With reference to the information given below, deduce the functional group(s) that T may have.
- (I) T is NOT an ester, and it gives negative result with Tollens' reagent.
- (II) T gives the following infra-red spectrum:



Characteristic Infra-red Absorption Wavenumber Ranges
(Stretching modes)

Bond	Compound type	Wavenumber range/ cm ⁻¹
C=C	Alkenes	1610 to 1680
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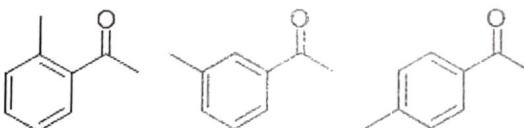
- (iii) The mass spectrum of T shows a parent peak at $m/z = 134$, and a strong peak at each of $m/z = 43$ and 91 . Suggest one chemical species corresponding to each of the signals at $m/z = 43$ and 134 . (2 marks)
- (iv) Draw one possible structure of T. (1 mark)

3.	(a)	(i)	(1)	<ul style="list-style-type: none"> • Place HCl(g) near NH₃(g/conc). • Dense <u>white fume</u> is observed. <p>OR</p> <p>Dissolve HCl(g) in deionised water.</p> <ul style="list-style-type: none"> • + Na₂CO₃ (s/aq) gives a gas • + AgNO₃/H⁺ gives a white ppt <p>OR</p> <ul style="list-style-type: none"> • HCl + Na₂CO₃ (aq) gives a gas • HCl + AgNO₃/H⁺ gives a white ppt 	1 1
		(2)		<ul style="list-style-type: none"> • Add 2,4-dinitrophenylhydrazine. • Yellow/ orange/ red precipitate is formed. 	1 1
		(ii)		(anhydrous) magnesium sulphate	1
	(b)	(i)		To ensure the <u>reaction go to completion</u> / To increase the reaction rate.	1
		(ii)	(1)	No more <u>gas</u> is given out. / All solids are <u>dissolved</u> .	1
			(2)	<u>Brown precipitate</u> formed.	1
		(iii)		No. of mole of CaC ₂ O ₄ formed in step 6: $2.374 / 128.1 = 0.01853$	1*
				Mass of CaCO ₃ in the limestone sample: $0.01853 \times 100.1 = 1.855$ g	1*
				Percentage of CaCO ₃ by mass in the limestone sample: $1.855 \text{ g} / 2.025 \text{ g} = 91.60 (\%)$ [91.3 – 91.9 Accept up to 5 sig. fig. or 91/92]	1
		(iv)		Gravimetric analysis	1
	(c)	(i)		<ul style="list-style-type: none"> • Dissolve the sample in <u>pentane</u> and shake the solution with <u>NaHCO₃(aq)</u> in a <u>separating funnel</u>. • Collect the <u>organic layer</u> and carry out <u>fractional distillation</u> / <u>distillation</u>. [Only fractional distillation / distillation: 0 mark] 	1

- (ii) • The spectrum does not show strong absorption at about $3230\text{-}3670\text{ cm}^{-1}$, ruling out the presence of a hydroxyl group (the possibility of being an alcohol). The absence of absorption at $2070\text{-}2250\text{ cm}^{-1}$ ruled out the presence of $\text{C}\equiv\text{C}$ group. The absence of absorption at $1610\text{-}1680\text{ cm}^{-1}$ ruled out the presence of $\text{C}=\text{C}$ group. 1 (1)
- The spectrum has a strong absorption at 1730 (one number from 1700 to 1750) cm^{-1} / 1680 to 1800 cm^{-1} , which corresponds to C=O stretching. The compound may contain an aldehyde group or a ketone group.
 [Accept without cm^{-1}]
 [if write cm^{-1} as cm or $/ \text{cm}^{-1}$: deduct 1 mark.] 1
- The negative result in Tollens' test ruled out the presence of aldehyde group in the compound. // The compound may contain a ketone group [IR: C=O]. 1
- (iii) $m/z = 43$: $[\text{CH}_3\text{CO}]^+$
 $m/z = 134$: $[\text{C}_7\text{H}_7\text{COCH}_3]^-$ 或 $[\text{C}_6\text{H}_5\text{C}_3\text{H}_5\text{O}]^+$
 [Accept: (); without []; use structures below to represent]
 [If not write any numbers (43 and 134), regard the first one to appear as 43.]
 [Not accept: $[\text{C}_2\text{H}_3\text{O}]^+ / [\text{C}_6\text{H}_{10}\text{O}]^+$.] 1



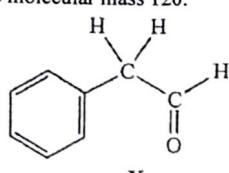
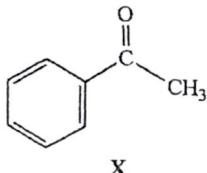
Other possible structures:



3. (a) Answer the following short questions:

- (i) Suggest a chemical test to show the presence of Br^- (aq). (2 marks)
- (ii) Suggest an instrumental method for determining the content of octane in a petrol sample. (1 mark)
- (iii) Suggest how copper powder can be obtained from a mixture of copper powder and iron(III) oxide by chemical method. (2 marks)

- (b) Compounds X and Y shown below are isomers with relative molecular mass 120.



- (i) Each of X and Y can react with 2,4-dinitrophenylhydrazine solution to give a similar observation. State the observation. (1 mark)
- (ii) Suggest a chemical test to distinguish between X and Y. (2 marks)
- (iii) Illustrate how X and Y can be distinguished from their mass spectra. (2 marks)
- (iv) With reference to the information given in the table below, suggest whether infra-red spectroscopy can be used to distinguish between X and Y. (2 marks)

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 acid and derivatives	1680 to 1800
C≡C	Alkynes	2070 to 2250
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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

(2 marks)

- (c) An experiment consisting of the following four steps was performed to determine the amount of nitrogen in a milk powder sample:

Step (1): 3.00 g of the milk powder sample was heated with excess concentrated sulphuric acid so as to turn all nitrogen in it into $(\text{NH}_4)_2\text{SO}_4$ (aq).

Step (2): The reaction mixture obtained was heated with excess NaOH(aq) to liberate NH_3 (g). All NH_3 (g) liberated was then absorbed by 50.00 cm³ of 1.00 M HCl(g).

Step (3): The solution formed was diluted to 250.0 cm³ with deionised water.

Step (4): 25.00 cm³ portions of the diluted solution were titrated with 0.100 M KOH(aq) using methyl orange as an indicator. An average of 13.55 cm³ of the KOH(aq) was required to reach the end point.

- (i) Write the chemical equations for the following reactions in Step (2):

- (1) the reaction of $(\text{NH}_4)_2\text{SO}_4$ (aq) with NaOH(aq)
 (2) the reaction of NH_3 (g) with HCl(aq)

(2 marks)

- (ii) State the colour change at the end point of the titration in Step (4). (1 mark)

- (iii) Calculate the percentage by mass of nitrogen in the milk powder sample.

(Relative atomic mass: N = 14.0)

(4 marks)

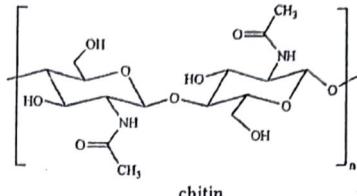
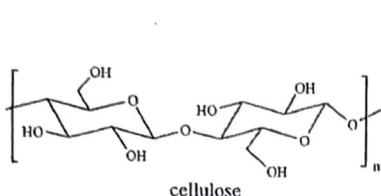
- (iv) In finding out the protein content in a milk powder sample, a common method is to determine the amount of nitrogen, but not to directly determine the amount of protein in the sample. Suggest one limitation of this common method. (1 mark)

3. (a) (i) Addition of (acidified) silver nitrate solution (acidified by nitric acid)
 Pale yellow precipitate formed (which is insoluble in aqueous ammonia).
 [Add Cl_2 (aq). Next, add an organic solvent.
 The solution turns brown. The organic solvent becomes orange/brown.] 1
 1
 (ii) Chromatography / GC / GCMS / HPLC but NOT Accept C 1
- (iii) Add dilute HCl (aq) / dilute H_2SO_4 (aq) / very dilute HNO_3 (aq) to the mixture (for dissolving the Fe_2O_3)
 Collect the copper powder from filtering the mixture obtained. 1
 1
- (b) (i) yellow / orange / red precipitate (solid/ppt) 1
- (ii) Add acidified $\text{K}_2\text{Cr}_2\text{O}_7$ (aq).
 Only Y turns the solution from orange to green.
 OR
 Only Y turns $\text{MnO}_4^-/\text{H}^+$ from purple to colourless. 2
 OR
 Only Y gives a silver mirror in Tollens' test. 2
 OR
 Only X gives a yellow precipitate with I_2/NaOH (aq). 2
- (iii) A significant peak appears at m/Z 105 ($\text{C}_6\text{H}_5\text{CO}^-$) or 43 (CH_3CO^-) or 15 (CH_3^+) in mass spectrum of X only.
 A significant peak appears at m/Z 91 ($\text{C}_6\text{H}_5\text{CH}_2^+$) or 29 (HCO^+) in mass spectrum of Y only. 1
 1
- (iv) Both compounds show a characteristic absorption in the wavenumber range (1680 to 1800 cm^{-1}) which is characteristic of carbonyl group ($>\text{C=O}$ bond).
 As the two compounds do not possess other different functional groups, they cannot be differentiated from each other using the given information. 1
 1
- (c) (i) (1) $\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$
 OR $(\text{NH}_4)_2\text{SO}_4 + 2\text{NaOH} \rightarrow 2\text{NH}_3 + \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$ 1
- (2) $\text{NH}_3 + \text{H}^+ \rightarrow \text{NH}_4^+$
 OR $\text{NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl}$ 1
- (ii) from red to orange 1
- (iii) No. of moles of KOH used in the titration = $0.100 \times 13.55 \times 10^{-3}$
 No. of moles of H^+ ions remained after Step 2 = $0.100 \times 13.55 \times 10^{-3} \times 10$ [$\times 10$] $= 0.01355$ 1*
 No. of moles of H^+ ions used in Step 2 = $1.00 \times 50 \times 10^{-3}$
 $= 0.05$
 No. of moles of NH_3 liberated = $0.05 - 0.01355$ [total – remained]
 $= 0.03645$ 1*
 Mass of N in the sample = $0.03645 \times 14 = 0.5103 \text{ g}$ [$\times 14$] [NOT accept $\times 14 \times 2$] 1*
 Percentage by mass of N in the sample = $\frac{0.5103}{3} \times 100 = 17.01 (\%)$ [Accept 17, 17.0] 1
- (iv) The amount of nitrogen determined may come from other nitrogen-containing substances present in milk powder. 1

2016

3. (a) Answer the following short questions:

- Give one property of solid sodium hydroxide making it NOT suitable to be weighed for preparing a standard solution. (1 mark)
- Suggest a chemical test to show the presence of hypochlorite ions in an aqueous solution. (2 marks)
- Both cellulose and chitin are natural polymers. Their structures are shown below:



By referring to the data given in the table below, suggest one similarity and one difference between the infrared spectra of cellulose and chitin.

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

Bond	Compound type	Wavenumber range/ cm ⁻¹
C=C	Alkenes	1610 to 1680
C=O	Alddehydes, 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
O-H	Alcohols, phenols (hydrogen-bonded)	3230 to 3670

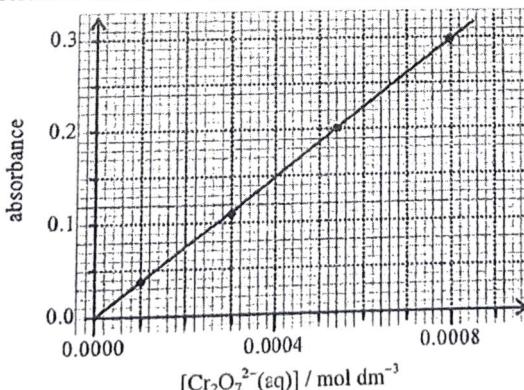
(2 marks)

- (b) The concentration of a $\text{Na}_2\text{Cr}_2\text{O}_7(\text{aq})$ sample A was determined by volumetric analysis; while the concentration of another $\text{Na}_2\text{Cr}_2\text{O}_7(\text{aq})$ sample B was determined by colorimetry.

- 25.00 cm³ of sample A was transferred to a conical flask and acidified with dilute $\text{H}_2\text{SO}_4(\text{aq})$. Then the mixture was titrated with 0.0642 mol dm⁻³ $\text{Fe}^{2+}(\text{aq})$ solution with a suitable indicator. It required 26.88 cm³ of the $\text{Fe}^{2+}(\text{aq})$ solution to reach the end point.
 - Write a balanced equation for the reaction involved.
 - Calculate the concentration of $\text{Na}_2\text{Cr}_2\text{O}_7(\text{aq})$ in A.

(3 marks)

- In colorimetry, various standard $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ solutions were first prepared, and then the absorbance of these solutions were measured with a colorimeter installed with a blue filter. The calibration curve below shows the variation of absorbance with the concentration of $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ ions.



- Suggest why a blue filter was used.
- With reference to the above calibration curve, state the relationship between absorbance and $[\text{Cr}_2\text{O}_7^{2-}(\text{aq})]$.
- Sample B was diluted 100 times. The absorbance of the diluted solution was measured as 0.26 by the colorimeter. Based on the information given from the above calibration curve, calculate the concentration of $\text{Na}_2\text{Cr}_2\text{O}_7(\text{aq})$ in B.

(4 marks)

- (iii) Explain whether volumetric analysis or colorimetry is more appropriate in determining the concentration of a very dilute $\text{Na}_2\text{Cr}_2\text{O}_7$ (aq), such as around 10^{-4} mol dm⁻³. (1 mark)
- (c) X and Y are isomeric compounds with their structures shown below:



- (i) Suggest, with explanation, how X and Y can be differentiated from their respective mass spectra. (2 marks)
- (ii) The melting point of X is 50°C while that of Y is 77°C. Both of them are insoluble in water but soluble in dichloromethane. When treated with dilute Na_2CO_3 (aq), no reaction occurs for X but reaction occurs for Y to form a soluble salt.
- (1) You are provided with dilute Na_2CO_3 (aq) and dilute H_2SO_4 (aq). Outline an experimental procedure, based on solvent extraction, to separate solid Y from a solution of X and Y in dichloromethane.
- (2) Suggest how you can identify that the solid obtained in (1) is pure compound Y. (5 marks)

3. (a) (i) Any one of the following answers:
 Sodium hydroxide (solid) is deliquescent / hygroscopic / can absorb H_2O / can dissolve in H_2O . (react with water 0 mark)
 Sodium hydroxide (solid) absorbs / reacts with carbon dioxide (gas from air). (accept any reasonable acidic gas e.g. SO_2 / NO_2 ...) (absorb H_2O / CO_2 0 mark)

1

- (ii) • Add a few drops of $HCl(aq)$ / a dilute acid / acid.
 • Pale (yellowish-)green gas evolved / which turns (moist) blue litmus paper red and then bleaches it / gas with swimming pool water (bleaching solution) smell evolved / gas evolved which turns colourless iodide solution brown / yellow / orange. / a yellow gas is evolved which turns blue litmus paper red and then bleaches it.
 (use conc. acid 0 mark for reagent, 1 mark for correct observation)
 (wrong reagent, 0 mark total)

1

1

WITHOUT the use of dilute acid

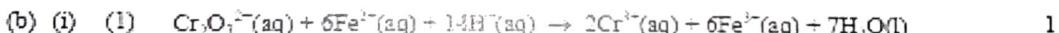
Reasonable test of the bleaching property with correct observation

e.g. use a red litmus paper;	red → (blue) → white (NOT colourless)
use a blue litmus paper;	blue → white (NOT colourless)
use a pH paper;	yellow → (green / blue) → white (NOT colourless)
use litmus solution;	purple → (blue) → colourless (NOT white)
coloured flowers (petals) / cloth;	blue → colourless (NOT white)

coloured flowers (petals) / cloth; decolourise
 (test method: use litmus paper, litmus solution, pH paper, dye, petal / cloth 1 mark)

Observation: correct colour change 1 mark)
 (0 mark if testing with iodide solution)

- (iii) • Similarity: Both show an absorption peak at 3230–3670 (cm^{-1}) (O–H groups) 1
 • Difference: Only chitin shows an absorption peak at 1680–1800 (cm^{-1}) (C=O groups). (comparison must be shown) (wrong unit, 0 mark) 1



(2) No. of moles of $Fe^{2+} = 0.0642 \times 26.88 \times 10^{-3}$
 $= 0.0017257$ (mol)

$$[Cr_2O_7^{2-}(aq)] \times 25.00 \times 10^{-3} \times 6 = 0.0017257$$
 $[Cr_2O_7^{2-}(aq)] = 0.0115 \text{ mol dm}^{-3} / 0.01150 \text{ mol dm}^{-3} / 0.012 \text{ mol dm}^{-3}$
 $(0.011505 \text{ mol dm}^{-3} / 0.0120 \text{ mol dm}^{-3} / \text{wrong unit } 0 \text{ mark})$

- (ii) (1) (Blue filter allows blue light to pass through and the) orange $Na_2Cr_2O_7(aq)$ solution absorbs blue light to a large extent. 1

- (2) The absorbance is directly proportional to / \propto the concentration of $Cr_2O_7^{2-}(aq)$. / linear relationship / shows a straight line / Just mention direct proportional (horizontal line / higher concentration of $Cr_2O_7^{2-}$ then higher absorbance / absorbance is proportional to the concentration of $Cr_2O_7^{2-}$ 0 mark) 1

- (3) Absorbance = 0.26, $[Cr_2O_7^{2-}(aq)]$ found from the graph is 7.0×10^{-4} (mol dm⁻³)
 [If unit mentioned for 0.0007, the unit must be correct. Accept without unit.] 1
 $[Cr_2O_7^{2-}(aq)]$ in sample B = $7.0 \times 10^{-4} \times (100) = 0.07 \text{ mol dm}^{-3}$
 (concentration in diluted solution in range: 6.85×10^{-4} to 7.05×10^{-4} mol dm⁻³)
 concentration in B = 0.0685 to 0.0705 mol dm⁻³ (accept M as mol dm⁻³)
 (final answer with 4 or more significant figures 0 mark)

3. (b) (iii) Colorimetry is more appropriate. / Volumetric analysis is less appropriate.
 The low colour intensity of the solution can still be determined by colorimetry.
 (0 mark if just mention pale colour without mentioning colour intensity)
 (0 mark if mention colorimetry is not appropriate or volumetric analysis is appropriate.)
 (0 mark if just mention colorimeter is sensitive)

- (c) (i) The mass spectra of X and Y are recorded respectively.
 - In the mass spectrum of X, a significant peak at m/z = 43 appears for CH_3CO^+ ions which does not appear in the mass spectrum of Y.
 - In the mass spectrum of Y, a significant peak at m/z = 119 appears for $\text{C}_6\text{H}_5\text{CH}_2\text{CO}^+$ ions which does not appear in the mass spectrum of X.

(refer to the following table for some possible comparisons:)

Mass spectrum of X	Mass spectrum of Y
CH_3^- or m/z 15	—
CH_3CO^+ or m/z 43	—
$\text{C}_6\text{H}_5\text{O}^+$ or m/z 93	—
$\text{C}_6\text{H}_5\text{OCO}^+$ or m/z 121	—
—	OH^- or m/z 17
—	COOH^+ or m/z 45
—	$\text{C}_6\text{H}_5\text{CH}_2^-$ or C_6H_5^- or m/z 91
—	$\text{C}_6\text{H}_5\text{CH}_2\text{CO}^+$ or $\text{C}_6\text{H}_5\text{CO}^+$ or m/z 119

(any 2 answers each with comparisons : 1 mark each)

(if no comparisons are given for both answers, penalize ONCE only)

(if more than 2 answers are given, mark the first two answers.)

(if species is $[\text{---}]^-$, 0 mark)

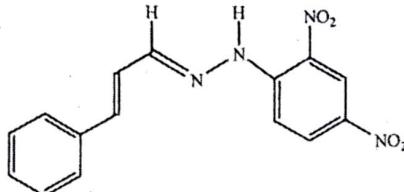
- (ii) (i) • $\text{Na}_2\text{CO}_3(\text{aq})$ is added to the dichloromethane solution of X and Y.
 (If $\text{NaHCO}_3(\text{aq})$ instead of $\text{Na}_2\text{CO}_3(\text{aq})$, this mark will not be given but has to mark the remaining answers.)
- The mixture is shaken in a separating funnel.
 The mixture in the separating funnel is allowed to settle, and the aqueous layer was then separated from the organic layer.
- Dilute $\text{H}_2\text{SO}_4(\text{aq})$ is added to the aqueous layer / upper layer / lower aqueous layer / (until no more precipitate is formed.) / (the solution becomes acidic).
 (If other acids such as HCl are mentioned to be used, 0 mark for this point but has to consider whether the subsequent filtration mark to be given.)
- Solid Y can be obtained by filtration.
 (incorrect steps, use of separating funnel mentioned ; only give 1 mark)
 (For marks other than separating funnel, has to mark step by step. Once illogical, the rest of the marks will not be awarded.)
 If an incorrect layer is chosen, the subsequent two marks will not be given (i.e. $\text{H}_2\text{SO}_4(\text{aq})$ is added to the lower layer or organic layer, both the mark for addition of acid and filtration will not be given.)
 (The use of ether is also accepted if solid Y can be obtained. Note that no mark is given to the use of ether but mark according to above principle.)

- (2) Measure the melting point of the solid obtained.
If the melting point of the solid is 77°C / a sharp m.p measured / a narrow melting point range / 76 – 78°C / $77 \pm 1^\circ\text{C}$ / one value in the range , it may be pure compound Y. 1
(mixed melting point technique → sharp melting point / m.p. 77°C;
OR compare the IR spectrum / mass spectrum / NMR spectrum of the solid obtained with that of authentic sample, if identical the same → pure
OR run a TLC / paper chromatography for the sample; if only one spot is detected on the chromatogram → pure)
(if a sharp m.p. of 50°C is recorded,... 0 mark)

2017

3. (a) Answer the following short questions:
- Suggest a test to distinguish between sodium ions and potassium ions. (2 marks)
 - Suggest a chemical test for detecting sulphur dioxide gas. (2 marks)
 - An organic compound X reacts with 2,4-dinitrophenylhydrazine to form a yellow solid Z.

The structure of Z is shown below:

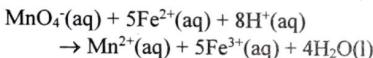


Given that the molecular formula of X is C_9H_8O , draw the structure of X. (1 mark)

- (b) Hydroxylamine ($HONH_2$) reacts with $Fe^{3+}(aq)$ ions under acidic conditions to form products including $Fe^{2+}(aq)$ ions and an oxide of nitrogen. An experiment, consisting of the following two steps, was carried out to deduce the oxidation number of N in the oxide.

Step (1): An aqueous solution containing 0.875 g of $HONH_2$ and excess $Fe_2(SO_4)_3$ was heated under an acidic condition until the reaction was complete. The resulting solution was then diluted to 250.0 cm³.

Step (2): 25.00 cm³ of the diluted solution was acidified with excess $H_2SO_4(aq)$ and then titrated with 0.0282 mol dm⁻³ $KMnO_4(aq)$ until the end point was reached. The chemical equation for the reaction involved is as follows:



- (i) State the colour change at the end point of the titration. (1 mark)

- (ii) Four trials of the titration were carried out and the results are listed below:

Trial	1	2	3	4
Volume of $KMnO_4(aq)$ used / cm ³	38.34	37.62	37.58	37.60

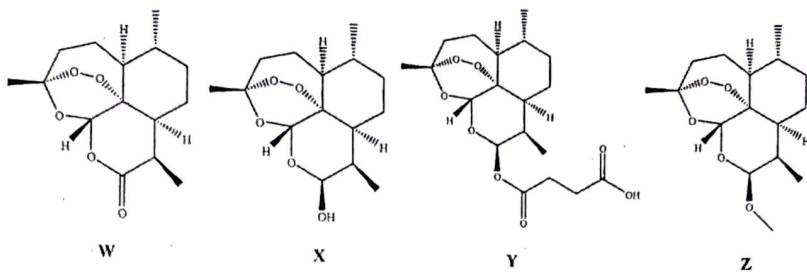
- Calculate a reasonable average of the volume of $KMnO_4(aq)$ used in the titration.
- Based on the experimental results, calculate the mole ratio of $HONH_2(aq) : Fe^{2+}(aq)$ required for the completion of the reaction in Step (1). (Relative atomic masses: H = 1.0, N = 14.0, O = 16.0)
- Given that the oxidation number of N in $HONH_2$ is -1, and the oxidation numbers of H and O remain unchanged, deduce the oxidation number of N in the oxide.

- (iii) According to (ii)(3), suggest a reasonable empirical formula for the oxide. (6 marks)

- (c) Many plants contain useful organic compounds which can be obtained by extraction using suitable solvents.
- The leaf of a certain plant contains a useful organic compound S. S can dissolve gradually in a warm organic solvent, and can be extracted from the leaves by using this solvent.
 - 'Heating under reflux' is a method commonly used to carry out this kind of extraction. State the advantage of this method.
 - After extraction, the solvent can be removed from the extract by simple distillation. Draw a labelled diagram for the set-up required for this simple distillation.
 - S obtained from the extraction may contain other organic impurities. Suggest a method for separating S from these impurities.

(4 marks)

- (ii) Artemisinin is an organic compound obtained from a certain plant. Artemisinin cannot react with $NaHCO_3(aq)$. Its infra-red spectrum shows a strong absorption peak at around 1700 cm⁻¹. Suggest which one of W, X, Y and Z below would be a possible structure of artemisinin. Explain your answer.

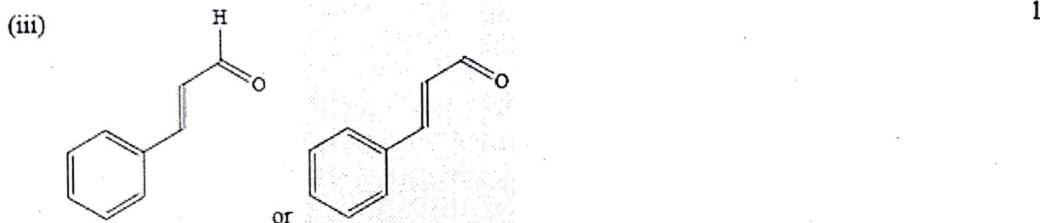


**Characteristic Infra-red Absorption Wavenumber Ranges
(Stretching modes)**

Bond	Compound type	Wavenumber range/ cm ⁻¹
C=C	Alkenes	1610 to 1680
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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

(3 marks)

3. (a) (i) Flame test(s) are carried out.
Sodium ions give an intense golden yellow flame while potassium ions give a lilac flame. 1
1
- (ii) Add a piece of filter paper which is soaked with acidified $K_2Cr_2O_7$ to the gas,
the paper turns from orange to green.
OR Pass the gas to $Cr_2O_7^{2-}/H^+$ (or MnO_4^-/H^+).
The solution turns from orange to green (or purple to colourless / pale pink)
[No acidification: 0 mark]
OR It decolourises petals temporarily.
OR It turns $Br_2(aq)$ from brown/orange to colourless.
1 mark for correct reagent and 1 mark for correct observation



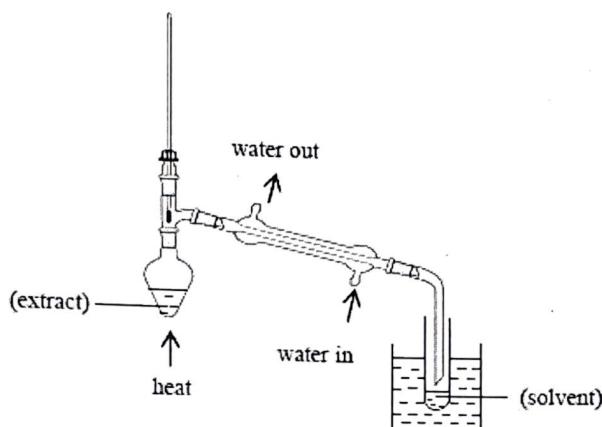
- (b) (i) From (yellowish)green to pale pink 1
- (ii) (1) $(37.62+37.58+37.60) \div 3 = 37.60 \text{ cm}^3$
[NOT accept 37.6]
Must show step and unit 1
- (2) number of moles of Fe^{2+} ions formed in Step (1)
 $= 0.0282 \times 37.60 \times 10^{-3} \times 5 \times 10$
 $= 0.0530$
number of moles of Fe^{3+} ions reacted in Step (1) = 0.0530 (1*)
- [Accept 37.785 / 37.79 / 37.6 for 37.60
Range: 0.053 – 0.0533]
- number of moles of $HONH_2$ reacted = $0.875 \div 33.0$
 $= 0.0265$ (1*)
- mole ratio of $HONH_2 : Fe^{3+} = 1 : 2$ 1
3
- (3) The oxidation number of iron changes from +3 to +2 and the oxidation number of N in $HONH_2$ is -1.
Since the mole ratio of $HONH_2 : Fe^{3+} = 1 : 2$,
the oxidation number of N in this oxide = $-1+2 = +1$ [Can be presented in words] 1*
- (iii) N_2O 2
1

(c) (i) (1) The solvent / product will not lose due to heating.

1

(2)

2



1 mark for correct experimental set-up, 1 mark for correct labels

Experimental set-up: 0 mark for closed system, wrong position of thermometer / delivery tube etc.

[Accept: No cold water to condense the solvent.]

1 mark for labelling heat, water in and water out

(3) (column) chromatography / thin layer chromatography / TLC / GCMS
[NOT accept C]

1

(ii) W

It has $>\text{C}=\text{O}$ / carbonyl group as it has a strong absorption (peak) at around 1700 cm^{-1} in its IR spectrum [Y OR W; NOT X and Z]

1

It has no $-\text{COOH}$ / carboxyl group as it does not react with $\text{NaHCO}_3(\text{aq})$. [NOT Y]
[NOT accept $\text{NaHCO}_3(\text{s})$]

1

Accept: From the given information in IR spectrum, it has $>\text{C}=\text{O}$ group

From the given information on the reaction with NaHCO_3 , it has no $-\text{CO}_2\text{H}$ group.

NOT accept: From the given information, it has $>\text{C}=\text{O}$ / no $-\text{CO}_2\text{H}$ group (i.e. without further elaboration)]

2018

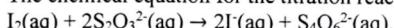
3. (a) Answer the following short questions:

- (i) An ionic compound gives a brick red flame in a flame test. Suggest one cation the compound may contain. (1 mark)
- (ii) Suggest a chemical test to distinguish between $K_2SO_3(aq)$ and $K_2SO_4(aq)$. (2 marks)
- (iii) What is meant by the ‘ R_f value’ of a substance in a paper chromatogram? (2 marks)

(b) An experiment was performed to determine the percentage by mass of $NaClO_3(s)$ in a sample. 1.63 g of the sample was dissolved in deionized water and then made up to 250.0 cm^3 . 10.00 cm^3 of the solution was transferred to the conical flask. Then 10 cm^3 of 1M $KI(aq)$ and 20 cm^3 of 6M $HCl(aq)$ were added in the flask. The resulting mixture was titrated with 0.112 M $Na_2S_2O_3(aq)$, adding starch solution as an indicator at appropriate time. The titration was repeated several times, and the mean volume of $Na_2S_2O_3(aq)$ required to reach the end point was 27.88 cm^3 .

- (i) Describe how the sample dissolved in deionized water can be made up to 250.0 cm^3 . (2 marks)
- (ii) It is known that in the conical flask, $ClO_3^-(aq)$ reacted with $I^-(aq)$ in the presence of $H^+(aq)$ to form $I_2(aq)$ and $Cl^-(aq)$. Write an ionic equation for the reaction. (1 mark)
- (iii) State the colour change at the end point of the titration. (1 mark)

- (iv) The chemical equation for the titration reaction is as follows:



Assuming that no other species in the sample would react with $I^-(aq)$, calculate the percentage by mass of $NaClO_3(s)$ in the sample.

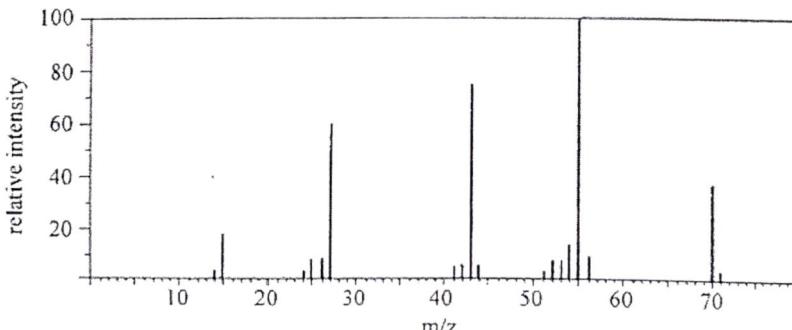
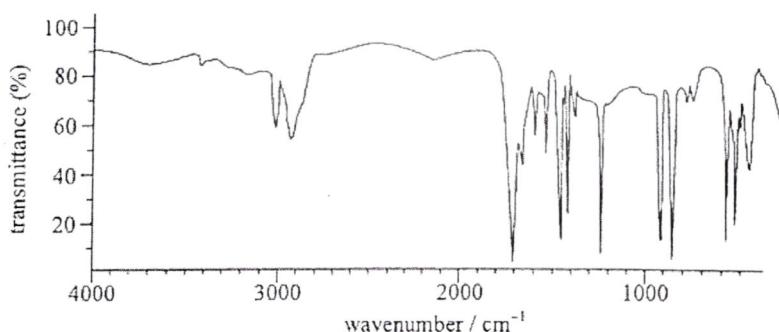
(Relative atomic masses: O = 16.0, Na = 23.0, Cl = 35.5)

(3 marks)

(c) A liquid mixture consists of two organic compounds X and Y:

	X	Y
molecular formula	$C_6H_{10}O$	C_4H_8O
boiling point / $^{\circ}\text{C}$	81.4	79.6

- (i) Explain why fractional distillation is NOT a suitable method to separate X from the mixture. (1 mark)
- (ii) X gives the following infra-red spectrum and mass spectrum:



- (1) By referring to the infra-red spectrum and the information given in the table below, deduce one functional group that may be present in X.

**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 (hydrogen-bonded)	3230 to 3670
N-H	Amines	3350 to 3500

- (2) By referring to the mass spectrum, suggest one chemical species corresponding to each of the signals at m/z = 43 and 55.

- (3) According to (1) and (2) above, draw a possible structure of X. (4 marks)

- (iii) Compound Y shows a positive result in 2,4-dinitrophenylhydrazine test, and a negative result in Tollens' reagent test. Deduce what Y may be. (3 marks)

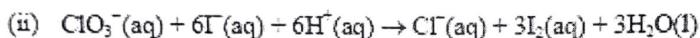
3. (a) (i) calcium (ion) / Ca^{2+}

- (ii) Add $\text{Ba}(\text{NO}_3)_2$ (aq) acidified with HNO_3 (aq) to the sample,
white precipitate forms for K_2SO_4 (aq) whereas no precipitate will form for K_2SO_3 (aq).
[Accept other answers: 1 mark for the reagent and 1 mark for the observation]
[Cl_2 (aq) : reagent – 0 mark, observation – 0 mark
if use Br_2 / Br_2 (l): reagent - 0 mark, correct observation – 1 mark]

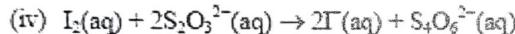
Reagent	Observation
H^+ (aq) / acid	Only SO_3^{2-} gives a gas with pungent smell
$\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$ (aq)	Only SO_3^{2-} turns the solution from orange to green
$\text{MnO}_4^-/\text{H}^+$ (aq)	Only SO_3^{2-} turns the solution from purple to colourless
Br_2 (aq)	Only SO_3^{2-} turns the solution from orange / brown to colourless
I_2 (aq)	Only SO_3^{2-} turns the solution from brown to colourless

- (iii) 'R_f value' of a substance is the ratio between the migration distance of the substance and the migration distance of the solvent front during chromatography.
[1 mark: indicating ratio; 1 mark: other parts correct]
[Can be represented by labeled diagram indicating 2 distances and correct mathematical expression]

(b) (i) Place the dissolved sample into a (250.0 cm³) volumetric flask.
(Deionised) water should be added to the mark of the volumetric flask.



(iii) The solution turns from blue to colourless.



$$\text{number of moles of I}_2(\text{aq}) = 0.112 \times 0.02788 \times \frac{1}{2} = 0.001561$$

$$\text{number of moles of NaClO}_3 \text{ in the sample} = 0.001561 \div 3 \times (250.0 / 10.00) = 0.01301$$

$$\text{percentage by mass of NaClO}_3 \text{ in the sample}$$

$$= 0.01301 \times 106.5 \div 1.63 \times 100\% = 85.0\%$$

[Range: 84 – 86, Accept 0 / 1 / 2 decimal places]

(c) (i) Boiling points of X and Y are too close.

(ii) (1) Absorption peak at wavenumber about 1700 cm⁻¹ corresponds to a C=O group. / Absorption peak at wavenumber about 1650 cm⁻¹ corresponds to a C=C group.
[Range: C=O, 1680 – 1800; C=C, 1610 – 1680]

one number: C=O: 1680 – 1720; C=C: 1630 – 1670]

(2) At m/z = 43: CH_3CO^+ / $\text{C}_2\text{H}_3\text{O}^+$ [CH_2CHO^+ not accepted]
At m/z = 55: CH_2CHCO^+ / $\text{C}_3\text{H}_3\text{O}^+$

(3) $\text{CH}_2=\text{CHCOCH}_3$ [Must show C=C]

- (iii) • positive result for 2,4-dinitrophenylhydrazine test: presence of carbonyl group
• negative result for Tollens' reagent test: not an aldehyde
[Note: If just have the conclusion, it is a ketone : 1 mark]
• Y may be $\text{CH}_3\text{CH}_2\text{COCH}_3$ / butanone.

2019

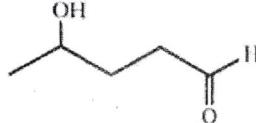
3. (a) Answer the following short questions:

- (i) The infra-red spectrum of a hydrocarbon (relative molecular mass = 40.0) shows an absorption peak at around 2150 cm^{-1} . According to the table below, deduce the possible structural formula of this hydrocarbon.
(Relative atomic masses: H = 1.0, C = 12.0)

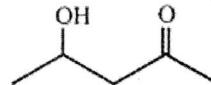
Characteristic Infra-red Absorption Wavenumber Ranges (Stretching modes)		
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C=O	Aldehydes, ketones, carboxylic acids and derivatives	1680 to 1800
C≡C	Alkynes	2070 to 2250
C≡N	Nitriles	2200 to 2280
O-H	Acids (hydrogen-bonded)	2500 to 3300
C-H	Alkanes, alkenes, arenes	2840 to 3095
O-H	Alcohols (hydrogen-bonded)	3230 to 3670
N-H	Amines	3350 to 3500

(2 marks)

- (ii) Organic compounds can be extracted by suitable solvents from their aqueous solutions. The solvents should dissolve the organic compound to be extracted without reacting with them. State one other property these solvents should have. (1 mark)
- (iii) Suggest a chemical test to show how compound A and B below can be distinguished:



A



B

(2 marks)

- (b) In order to determine the sodium contents (existing as NaCl) in a bacon sample, its Cl^- contents should be first found. 2.0 g of the bacon sample was added to 2.50 cm^3 of 1.0 M $\text{AgNO}_3(\text{aq})$. After that, excess dilute $\text{HNO}_3(\text{aq})$ was added to the mixture obtained. The AgCl(s) formed was then removed by filtration. The excess $\text{AgNO}_3(\text{aq})$ remaining in the filtrate was then titrated with 0.10 M $\text{KSCN}(\text{aq})$ to give AgSCN(s) in the presence of a suitable indicator until the end point was reached. All steps were repeated several times and the mean volume of $\text{KSCN}(\text{aq})$ used to reach the end point was 9.42 cm^3 .
- (i) Why was excess dilute $\text{HNO}_3(\text{aq})$ added to the mixture? (1 mark)
- (ii) Draw a diagram for the set-up be used in the titration, labelling all apparatus and reagents. (2 marks)
- (iii) Assuming that all Cl^- comes from NaCl in the bacon sample, calculate the percentage by mass of sodium in the bacon sample.
(Relative atomic masses: Na = 23.0, Cl = 35.5, Ag = 107.9) (4 marks)

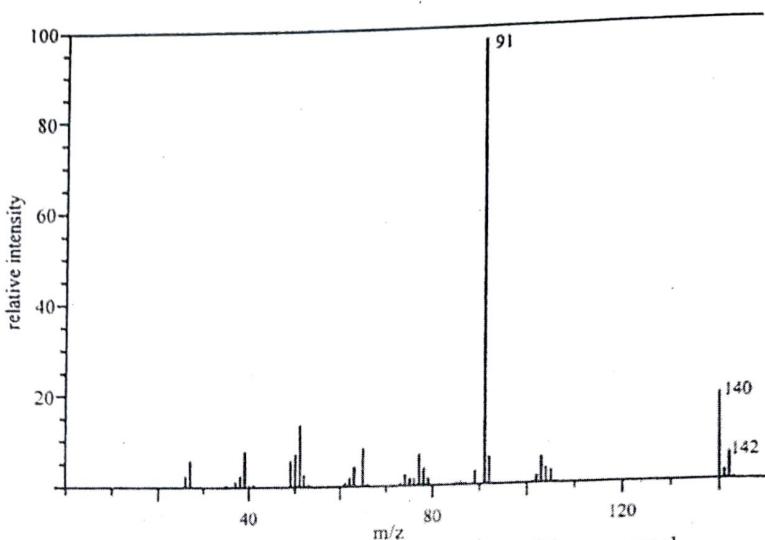
- (c) Chlorine reacted with ethylbenzene () under sunlight to give a mixture different chlorinated compounds.

- (i) Thin layer chromatography (TLC) was used to separate a small amount of the mixture.
(1) Explain briefly why chromatography can be used to separate a mixture.

- (2) Based on the result in TLC, suggest a method to separate a large amount of the mixture.

(3 marks)

- (ii) A monochlorinated compound was isolated from the mixture. It is known that chlorine has two isotopes, ^{35}Cl and ^{37}Cl . The mass spectrum of the compound is shown below:



By referring to the labelled peaks, deduce a possible structure of the compound.

(3 mark)

- (iii) Pollutants, such as dioxins, can be formed in the manufacturing process of certain chlorine-containing products.

(1) Explain why there is a need to measure dioxin levels.

(2) Suggest why dioxin levels are generally measured using modern instrumentation.

(2 marks)

3. (a) (i) (IR) Peak / at $2070 - 2250 / 2150 \text{ cm}^{-1}$ corresponds to $\text{C}\equiv\text{C}$
 Relative molecular mass of 40 confirms it to be $\text{HC}\equiv\text{CCH}_3$
- (ii) Immiscible (with water) / low boiling point / easily evaporate
- (iii) (Heating) with Tollen's reagent / $\text{Ag}(\text{NH}_3)_2^+$,
 only A gives silver (mirror). [A comparative sense]
- React with 2,4-dinitrophenylhydrazine. Recrystallise the products, carry melting point test and check literature values.
- (b) (i) To prevent the formation of solid ($\text{Ag}_2\text{CO}_3 / \text{Ag}_2\text{SO}_3 / \text{Ag}_2\text{SO}_4$) etc.
 $/ \text{AgNO}_3(\text{aq})$ can form precipitate / solid with carbonate / sulphite / sulphate ions.
- (ii)
- 
- Correct labelling:
 Burette, conical flask, $\text{KSCN}(\text{aq})$, (acidified) bacon / sample with / $\text{AgNO}_3(\text{aq})$
- (iii)
- No. of mole of $\text{KSCN}(\text{aq}) = /$ No. of mol of $\text{Ag}^+(\text{aq})$ left in the mixture = / No. of mol of $\text{Ag}^+(\text{aq})$ reacted with $\text{KSCN}(\text{aq}) = 0.1 \times 0.00942$
 - No. of mol of AgCl formed
 $= 1.0 \times 0.0025 - 0.1 \times 0.00942 = 0.001558$ [“0.0025 –”]
 - Percentage by mass of sodium = $(0.001558 \times 23.0 / 2.0) \times 100\% = 23/2$ [“23/2”]
 $= 1.79\%$ [1.78 – 1.81] [Accept 1 to 3 decimal places]
- (c) (i) (1) Because different substances have different adsorptivity to the stationary phase and different solubility in mobile phase.
 [Different adsorptivity / absorptivity / polarity / attraction (1)
 Concept of different phases (1)]
- (2) Column chromatography

- (ii) The chemical species for the peak at m/z = 91 may be $C_6H_5CH_2^- / C_7H_7^+$
OR m/z = 91 => contains $C_6H_5CH_2$

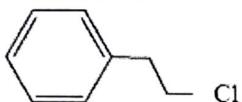
The chemical species for the peak at m/z = 140 may be $C_6H_5CH_2CH_2^{35}Cl^-$
(or m/z = 142 may be $C_6H_5CH_2CH_2^{37}Cl^-$)

OR m/z = 140 => contains $C_6H_5CH_2CH_2^{35}Cl$

OR m/z = 142 => contains $C_6H_5CH_2CH_2^{37}Cl$

If both chemical species do not have + sign, deduct only 1 mark.

Possible structure:

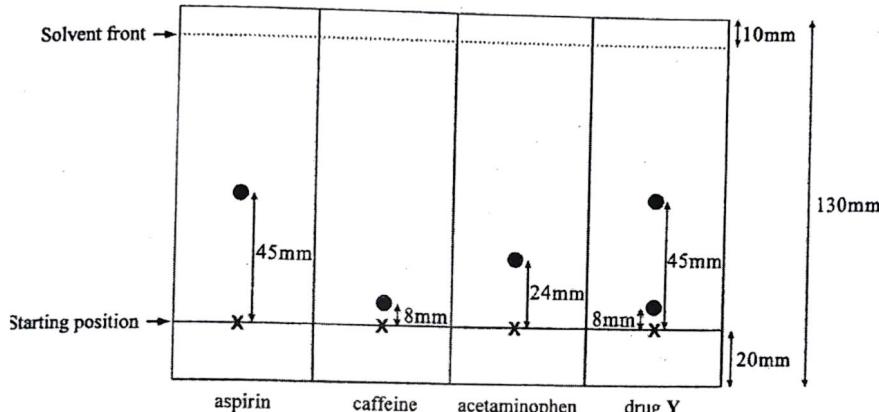


- (iii) (1) High levels of dioxins may cause cancer / are toxic .

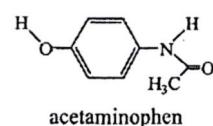
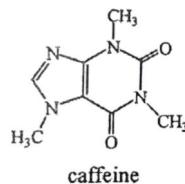
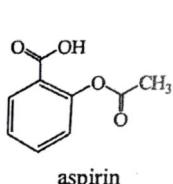
- (2) Modern analytical instruments are (accurate) and sensitive enough to / measure very low levels of dioxins.

3. (a) Answer the following short questions:
- Suggest how $\text{Na}_2\text{CO}_3(s)$ and $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}(s)$ can be distinguished. (2 marks)
 - In an acidified medium, $\text{I}_2(aq)$ in a conical flask is titrated with $\text{Na}_2\text{SO}_3(aq)$ using starch solution as indicator. State the colour change at the end point of the titration. (1 mark)
 - Suggest a chemical test to show how hex-1-ene and hexanal can be distinguished. (2 marks)

- (b) The chromatograms from the thin-layer chromatography (TLC) of aspirin, caffeine, acetaminophen and a drug Y are shown below.



- Draw a labelled diagram for the set-up in performing a TLC experiment. (2 marks)
- Calculate the R_f value for aspirin. (1 mark)
- Based on the chromatograms provided, suggest whether drug Y would contain aspirin, caffeine or acetaminophen. (1 mark)
- Consider the following structures:



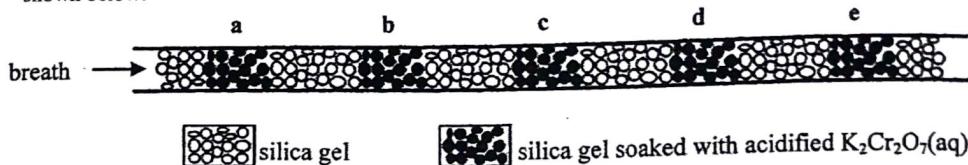
- (1) With reference to the table below, suggest how aspirin and caffeine can be distinguished from their infra-red spectra.

Characteristic Infra-red Absorption Wavenumber Ranges (Stretching modes)

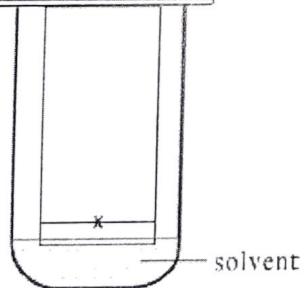
Bond	Compound type	Wavenumber range / cm^{-1}
$\text{C}=\text{C}$	Alkenes	1610 to 1680
$\text{C}=\text{O}$	Aldehydes, ketones, carboxylic acids and derivatives	1680 to 1800
$\text{C}\equiv\text{C}$	Alkynes	2070 to 2250
$\text{C}\equiv\text{N}$	Nitriles	2200 to 2280
$\text{O}-\text{H}$	Acids (hydrogen-bonded)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

- (2) A pure sample may be aspirin, caffeine or acetaminophen. There is a major peak at $m/z = 43$ in the mass spectrum of the sample. Explain whether this information can confirm that the sample is aspirin, caffeine or acetaminophen. (3 marks)

- (c) Road checking on ethanol intake of a driver can be done by having the driver exhale a breath into the tube as shown below:



- (i) (1) Suggest the colour change of the silica gel soaked with acidified $K_2Cr_2O_7(aq)$ if enough ethanol-contained breath is exhaled into the tube. Write a half equation for the colour change involved.
(2) A breath from driver A only changes colour at positions a and b; while a breath from driver B changes colour at positions a, b and c. Assuming the checking is performed in a fair manner, explain which driver has a higher ethanol intake.
(3) Suggest how the checking can be performed in a fair manner.
- (4 marks)
- (ii) In a certain country, a driver would be found guilty if the ethanol content in his / her blood exceeds '55 mg of ethanol per 100 cm^3 of serum'. 10.0 cm^3 of a treated serum sample obtained from the blood of a driver requires 4.38 cm^3 of 0.025 mol dm^{-3} $K_2Cr_2O_7(aq)$ in an acidified medium for complete reaction. Given that the mole ratio of $C_2H_5OH(aq)$ to $K_2Cr_2O_7(aq)$ is 3 : 1 in the reaction, calculate the mass of C_2H_5OH , in mg, in the serum sample. Determine whether the driver would be found guilty.
(Relative atomic masses: H = 1.0, C = 12.0, O = 16.0)
- (4 marks)

3. (a) (i)	Heat the solid samples in a test tube and place a piece of anhydrous/dry cobalt chloride paper near the mouth of the tube.	1
	The anhydrous/dry cobalt chloride paper turns from blue to pink. The solid is $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}(\text{s})$. The colour of cobalt chloride paper does not change for $\text{Na}_2\text{CO}_3(\text{s})$. (A comparative sense)	1
	(OR) Heat both samples. Condensed liquid can only be found in $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}(\text{s})$.	
	OR Heat both samples. Only $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}(\text{s})$ will have condensed liquid that can turn anhydrous/dry copper(II) sulphate from white to blue.) (A comparative sense)	
(ii)	From blue to colourless	1
(iii)	Hex-1-ene turns Br_2 (in organic solvent/aq) (not accept $\text{Br}_2(\text{l})$) from reddish-brown to colourless but hexanal does not. OR Warm hexanal with Tollen's reagent. It gives a silver mirror but hex-1-ene does not. (A comparative sense) (1 mark for the reagent and 1 mark for observation) (Accept other possible chemical tests with comparative sense.) Hexanal : $\text{Cr}_2\text{O}_7^{2-}(\text{aq})/\text{H}^+(\text{aq})$: from orange to green but hex-1-ene does not 2,4-dinitrophenylhydrazine: a yellow / red / orange precipitate but hex-1-ene does not (Not accept: Hex-1-ene : $\text{MnO}_4^-(\text{aq})/\text{H}^+(\text{aq})$: from purple to colourless)	(1) (1) 1 1 1 1 1 1 1 1 1
(b) (i)		2
	(1 mark for labelling: solvent 1 mark for the drawing: pencil line above solvent, spot of mixture, TLC plate and a container)	
(ii)	$R_f = 45 / (130 - 10 - 20) = 0.45$ (Only mark the answer.)	1
(iii)	Aspirin and Caffeine	1

- (iv) (1) IR spectrum of Aspirin shows (strong absorption) peak at $2500\text{ (cm}^{-1}\text{)}$ to $3300\text{ (cm}^{-1}\text{)}$ / corresponding to O-H group of carboxylic acid while that of caffeine does not.
 (A comparative sense) 1
- (2) m/z = 43 corresponds to a CH_3CO^+ ion.
 (Accept $\text{CH}_3\text{CO}^{\bullet+}$
 Not accept $\text{CH}_3\text{CO}^{\bullet+}$, CH_3CO)
 Both aspirin and acetaminophen have this fragment, only this information cannot help confirm which one of the three chemicals the sample is. 1
3. (c) (i) (1) orange to green
 $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$ 1
- (2) Driver B has a higher ethanol intake because the breath can also change the colour of the gel in position c while Driver A cannot.
 (A comparative sense and similar meaning) 1
- (3) (Exhale the) same amount / volume / strength of breath (into the tube). 1
- (ii) No. of mole of ethanol = $0.025 \times 4.38 \times 10^{-3} \times 3 = 0.0003285\text{ mol}$ (0.00033 / 0.000329)
 Mass of the ethanol = 0.0003285×46 ($\times 46$)
 = 0.01511 g = 15.11 mg
 The mass of ethanol in 100 cm^3 of serum sample = $15.11\text{ mg} \div 10 \times 100$ ($\div 10 \times 100$)
 = 151.1 mg
 (The mass is) 151.1 mg (which exceeds 55 mg. The driver would be found) guilty.
 (Range of answer: 150 – 152, max. 3 dec. places) 1

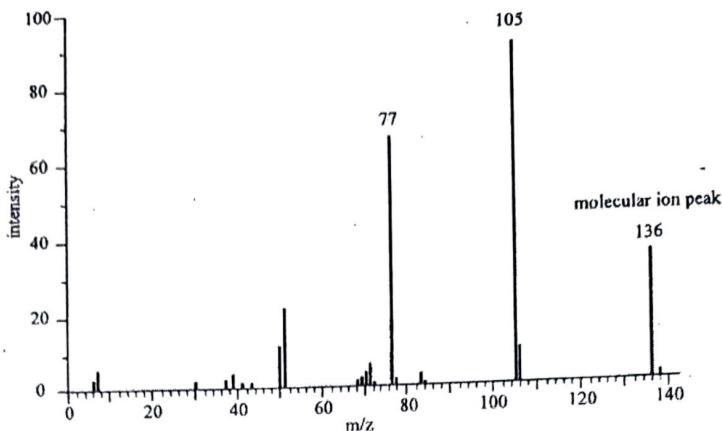
3. (a) Answer the following short questions:
- Suggest a chemical test to show how $\text{Al}_2(\text{SO}_4)_3(\text{aq})$ and $\text{ZnSO}_4(\text{aq})$ can be distinguished. (2 marks)
 - Suggest a chemical test to show how $(\text{CH}_3)_3\text{COH(l)}$ and $\text{CH}_3\text{COOH(l)}$ can be distinguished. (2 marks)
 - State the expected observation of adding 2,4-dinitrophenylhydrazine to propanone. (1 mark)
- (b) In an experiment to prepare cyclohexene from cyclohexanol using concentrated phosphoric acid as a dehydrating agent, a liquid mixture of cyclohexene, phosphoric acid and cyclohexanol was obtained.
(Boiling points: cyclohexene = 83 °C, cyclohexanol = 162 °C)
- Describe the steps how the phosphoric acid in the mixture can be removed by liquid-liquid extraction, using an aqueous solution. (3 marks)
 - After the removal of the phosphoric acid, a distillate of boiling point of 83 °C was obtained from fractional distillation of the remaining mixture.
 - Draw a labelled diagram for the set-up of the fractional distillation.
 - With the help of boiling point and infra-red spectroscopy, suggest how you can support the following statement:
'The distillate is cyclohexene, and without the presence of any cyclohexanol.'

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 (hydrogen-bonded)	3230 to 3670
N-H	Amines	3350 to 3500

(4 marks)

(c) The mass spectrum of an ester A is shown below:

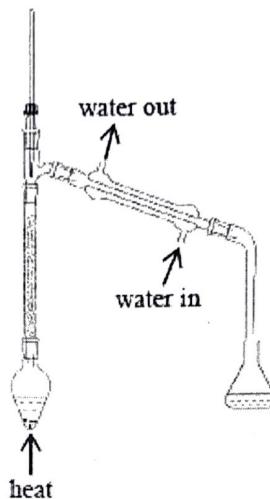


- (i) Deduce the molecular formula of A.
(Compositions by mass: C = 70.6%, H = 5.9%, O = 23.5%; Relative atomic masses: H = 1.0, C = 12.0, O = 16.0) (2 marks)
- (ii) Given that the signal at m/z = 77 corresponds to $C_6H_5^+$, deduce the structural formula of ester A. (2 marks)
- (iii) 2.75 g of a crude sample of A was heated with 50.0 cm³ of 0.060 M NaOH(aq) until no further reaction. The excess NaOH(aq) in the resulting mixture required 20.40 cm³ of 0.050 M HCl(aq) for complete neutralization.
(1) Write a chemical equation for the reaction between A and NaOH(aq).
(2) Assuming that only A in the sample can react with NaOH(aq), calculate the percentage by mass of A in the sample. (4 marks)

3. (a) (i) • Add $\text{NH}_3(\text{aq})$ to the two solutions separately until in excess. 1
 • $\text{Al}_2(\text{SO}_4)_3(\text{aq})$: a white ppt insoluble in excess $\text{NH}_3(\text{aq})$. $\text{ZnSO}_4(\text{aq})$: a white ppt soluble / and then a (clear) solution is formed in excess $\text{NH}_3(\text{aq})$. 1
- OR
 • Add excess $\text{NH}_3(\text{aq})$. (1)
 • Only $\text{Al}_2(\text{SO}_4)_3(\text{aq})$ gives a white precipitate. (1)
 [If observation wrote "Only $\text{ZnSO}_4(\text{aq})$ gives a white ppt which redissolves to form a colourless solution." 0 mark for observation]
- OR
 • Add $\text{Al}(\text{s})$. (1)
 • Only $\text{ZnSO}_4(\text{aq})$ gives (silvery / grey) solid deposits. (1)
 1 mark for correct reagent and 1 mark for correct observation
- (ii) • Reagent and conditions: $\text{Na}_2\text{CO}_3(\text{aq})$ / $\text{NaHCO}_3(\text{aq})$ / $\text{Mg}(\text{s})$ / $\text{Na}_2\text{CO}_3(\text{s})$ / $\text{NaHCO}_3(\text{s})$ is added to $\text{CH}_3\text{CO}_2\text{H}(\text{l})$ + water / $\text{CH}_3\text{COOH}(\text{aq})$ 1
 • Observation: $\text{CH}_3\text{COOH}(\text{l})$ gives out a (colourless) gas. No observable change for $(\text{CH}_3)_3\text{COH}(\text{l})$. 1
 (If no water is added, no mark for reagent but can give mark to correct observation)
- OR
 • Reagent and conditions: Add a specific alcohol / carboxylic acid + acid catalyst (1)
 • Observation: a fruity smell for $\text{CH}_3\text{CO}_2\text{H}$ / $(\text{CH}_3)_3\text{COH}$ but the other does not. (1)
 (If alcohol/carboxylic acid not specific or not mention acid catalyst, no mark for reagent but can give mark to correct observation (fruity smell)).
- OR
 • Reagent and conditions: Add conc. $\text{HCl}(\text{aq})$ ($\div \text{ZnCl}_2(\text{aq})$ catalyst) (1)
 • Observation: Only $(\text{CH}_3)_3\text{COH}$ forms 2 immiscible liquid layers. (1)
 (A comparative sense)
- (iii) Orange / yellow / red precipitate / solid 1
- (b) (i) • Add $\text{Na}_2\text{CO}_3(\text{aq})$ / $\text{NaHCO}_3(\text{aq})$ / $\text{NaOH}(\text{aq})$ to the crude sample in the separating funnel. Shake and release the pressure from time to time. 2
 (1 mark for separating funnel and 1 mark for adding the correct reagent)
 (Accept: adding a suitable organic solvent)
- Discard the lower layer / aqueous layer. OR 1
 Collect the upper layer / organic layer.
 (Accept: Discard the upper aqueous layer OR Collect the lower organic layer).
 (If the reagent is wrong, no mark for this step.)

3. (b) (ii) (1)

2



(1 mark for the sketch: including the pear-shaped flask, fractionating column (with something inside), thermometer, condenser, adapter and a container (such as conical flask, beaker) (Accept: space with thermometer inserted/close system)

(1 mark for labels: water in, water out (Accept arrows), heat)

- (2) • Boiling point = 83 °C and shows a peak at 1610 – 1680 (cm^{-1}) corresponding to cyclohexene.
• No (broad) peak at 3230 – 3670 (cm^{-1}) corresponding to cyclohexanol is shown.

(For IR, can state a number in the range. If write cm instead of cm^{-1} , no mark will be given once (i.e. can still give mark for the second same mistake if the wavenumber is correct))

(c) (i) Ratio of C : H : O = $70.6/12 : 5.9/1 : 23.5/16$
 $= 4 : 4 : 1$

1
(1)

From the mass spectrum, relative molecular mass of A = m/z ratio of the molecular ion = 136

Molecular formula is $C_8H_8O_2$ (with deduction, accept calculations as a means of deduction)

1

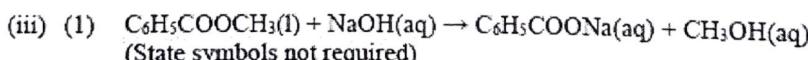
- (ii) The peak at m/z = 105 corresponds to $C_6H_5CO^+$ / implies that it contains C_6H_5CO group / fragment. (Not accept: $C_7H_5O^+$)

1

(If other peaks mentioned are wrong, no mark for deduction.)

The structure of A is $C_6H_5COOCH_3$.

1



1

(Accept: any chemical equation for ester hydrolysis. e.g. RCO_2R' as the ester)
(Accept: ionic equation)

(2) No. of moles of $HCl(aq)$ used = 0.05×0.0204

1

$= 0.00102$ = No. of moles of excess $NaOH(aq)$

No. of moles of $NaOH(aq)$ added = $0.06 \times 0.05 = 0.003$

No. of moles of A = $0.003 - 0.00102 = 0.00198$

1*

mass of A = $0.00198 \times 136 = 0.26928$ g

% by mass of A in the sample = $0.26928 / 2.75 = 9.79\%$

1

(range 9.77 – 9.82 1 – 3 decimal places)

3. (a)

Answer the following short questions:

- (i) Suggest a chemical to show how $\text{SO}_2(\text{g})$ and $\text{CO}_2(\text{g})$ can be distinguished. (2 marks)
- (ii) Illustrate how $\text{CH}_3\text{CH}_2\text{CHO(l)}$ and $\text{CH}_3\text{COCH}_3(\text{l})$ can be distinguished from their respective mass spectra. (2 marks)
- (iii) Which one of the following chemicals is the most suitable for drying ethyl butanoate?

concentrated sulphuric acid, solid sodium hydroxide, anhydrous sodium sulphate

(1 mark)

- (b) A solid sample consists of a compound **Y** and a small amount of an impurity **Z**. The following steps were performed in an experiment to obtain pure **Y(s)** from this solid sample.
(Given: **Y** is more soluble in deionized water at 80 °C than at 25 °C.)

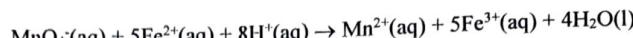
- | | |
|-----------|---|
| Step (1): | 1.40 g of this solid sample was added to 50 cm ³ of deionized water and heated to 80 °C. |
| Step (2): | Water-insoluble activated charcoal was then added to remove Z . The mixture obtained was filtered when it was still hot. |
| Step (3): | The hot filtrate obtained was allowed to cool slowly to 25 °C. Y(s) was formed. |
| Step (4): | The cooled mixture was filtered to collect Y(s) . After washing and drying, 0.75 g of Y(s) was collected. |

- (i) It is given that no more than 3.04 g of **Y(s)** can dissolve in 100 cm³ of deionized water at 80 °C. Show, by calculation, that all of **Y** in this solid sample should have dissolved in Step (1). (1 mark)
- (ii) Explain why the mixture was filtered in Step (2). (1 mark)
- (iii) Name the process of the formation of **Y(s)** in Step (3). (1 mark)
- (iv) Suggest one reason why the mass of **Y(s)** collected in Step (4) was smaller than the mass of **Y** in this solid sample. (1 mark)
- (v) **Y** and **Z** can be separated by chromatography. Thin layer chromatography (TLC) and column chromatography were performed separately with this solid sample using the same stationary phase and mobile phase.
(Given: R_f value of **Y** is greater than that of **Z**.)
(1) Sketch a labelled chromatogram of TLC to show the expected result.
(2) Explain whether the first-collected fraction in the column chromatography is **Y** or **Z**. (3 marks)

3. (c) The major ingredient in a certain brand of iron supplement tablets is FeSO_4 . Several pieces of these iron supplements were dissolved in deionized water to obtain an aqueous solution S. The concentration of $\text{Fe}^{2+}(\text{aq})$ ions in solution S was determined by using the following two methods:

(i) **Method (I): using volumetric analysis**

The chemical equation for the reaction involved in the titration is as follows:



25.00 cm³ of solution S was acidified and then titrated with 0.0041 M $\text{KMnO}_4(\text{aq})$. The mean volume of the $\text{KMnO}_4(\text{aq})$ required to reach the end point was 32.35 cm³.

- (1) The colour of the reaction mixture changed from pale yellow to pale pink at the point of the titration. Explain the colour change.
- (2) Calculate the concentration of $\text{Fe}^{2+}(\text{aq})$ ions in solution S.

(4 marks)

(ii) **Method (II): using colorimetry**

$\text{Fe}^{2+}(\text{aq})$ can completely react with a colourless organic reagent to form an orange-red species $\text{W}(\text{aq})$. (Given: number of moles of $\text{Fe}^{2+}(\text{aq})$ reacted : number of moles of $\text{W}(\text{aq})$ formed = 1 : 1)

- Step (1): Several standard $\text{FeSO}_4(\text{aq})$ solutions of various concentrations were separately treated with the colourless organic reagent to form the corresponding orange-red solutions of $\text{W}(\text{aq})$.
- Step (2): The absorbances of these solutions of $\text{W}(\text{aq})$ were measured using a colorimeter and a calibration curve was plotted.
- Step (3): Solution S was diluted 100 times. A sample of this diluted solution was treated in the same way as described in Step (1) to give a solution T which contains $\text{W}(\text{aq})$.
- Step (4): The absorbance of solution T was measured.

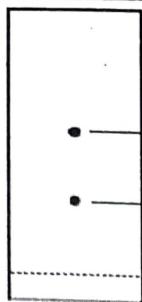
- (1) Sketch the calibration curve in Step (2) and label the axes. On this sketch, show how the concentration of $\text{W}(\text{aq})$ in solution T can be found.
- (2) Hence, suggest how the concentration of $\text{Fe}^{2+}(\text{aq})$ ions in solution S can be determined.

(4 marks)

3. (a) (i) • Pass the two gases to $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}^+(\text{aq})$ separately. 1
 • $\text{SO}_2(\text{g})$ can turn $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}^+(\text{aq})$ from orange to green, while there is no observable change for $\text{CO}_2(\text{g})$.
 (A comparative sense)
 (If H^+ is not present in $\text{K}_2\text{Cr}_2\text{O}_7$, 0 mark for both reagent and observation.)
- Or, Using $\text{KMnO}_4/\text{H}^+(\text{aq})$,
 $\text{SO}_2(\text{g})$ can turn $\text{KMnO}_4/\text{H}^+(\text{aq})$ from purple to colourless / (very) pale pink, while there is no observable change for $\text{CO}_2(\text{g})$.
 (If H^+ is not present in KMnO_4 , 0 mark for both reagent and observation.)
- Or, Using $\text{Br}_2(\text{aq})$ or $\text{Br}_2(\text{in organic solvent})$,
 $\text{SO}_2(\text{g})$ can turn $\text{Br}_2(\text{aq})$ from reddish brown to colourless / $\text{SO}_2(\text{g})$ can turn $\text{Br}_2(\text{in organic solvent})$ from orange/brown to colourless, while there is no observable change for $\text{CO}_2(\text{g})$.
 (Not accept: red or yellow for colour of $\text{Br}_2(\text{aq})$ or $\text{Br}_2(\text{in organic solvent})$)
 (Not accept: $\text{Br}_2(\text{l})/\text{Br}_2(\text{g})$ as the reagent, BUT can give mark to correct observation)
 (Accept: other possible chemical tests)
- (ii) The mass spectra of $\text{CH}_3\text{CH}_2\text{CHO}$ and CH_3COCH_3 are recorded respectively. 1
 • In the mass spectrum of $\text{CH}_3\text{CH}_2\text{CHO}$, a significant peak appears at $m/z = 29$ / corresponding to CHO^+ / CH_3CH_2^+ , while this peak does not appear in the mass spectrum of CH_3COCH_3 .
 • In the mass spectrum of $\text{CH}_3\text{CH}_2\text{CHO}$, a significant peak appears at $m/z = 57$ / corresponding to $\text{CH}_3\text{CH}_2\text{CO}^+$, while this peak does not appear in the mass spectrum of CH_3COCH_3 .
- Or, In the mass spectrum of CH_3COCH_3 , a significant peak appears at $m/z = 43$ / corresponding to CH_3CO^+ , while this peak does not appear in the mass spectrum of $\text{CH}_3\text{CH}_2\text{CHO}$.
 (A comparative sense)
- (iii) (Anhydrous) sodium sulphate / Na_2SO_4 1
- (b) (i) The maximum mass of Y can dissolve in 50 cm^3 water at $80^\circ\text{C} = 3.04 \times 50/100 = 1.52 \text{ g}$. 1
 As the mass of Y in the solid sample should be less than 1.4 g, therefore all Y should have dissolved.
 (or 3.04 g to compare with 2.8 g)
- (ii) To remove the water-insoluble activated charcoal. 1
- (iii) crystallisation † 1
- (iv) Some Y do not crystallise / are left on the filter paper / are washed away.
 (Not accept: 'Loss during the steps', need to mention the specific step.)

3. (b) (v) (1)

2



(1 mark for sketching correct chromatogram (2 points and 1 line for starting position / 3 points with one point representing the starting position);
1 mark for correct labels (Y and Z; Y is higher than Z))

(2) Y,

because Y has a larger R_f value / Y moves faster / Y takes a shorter time to reach the bottom of the column. 1

(c) (i) (1)

- pale yellow colour: $\text{Fe}^{3+}(\text{aq})$ ions
- pale pink colour: $\text{MnO}_4^-(\text{aq})$ ions

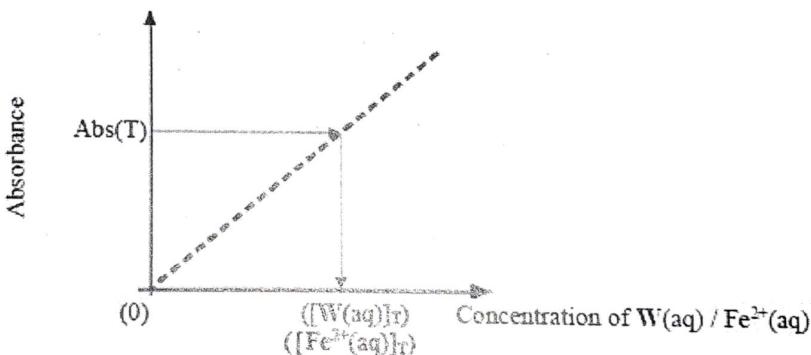
1
1

(2)

$$\begin{aligned} \text{concentration of } \text{Fe}^{2+}(\text{aq}) \text{ ions in solution } S &= 0.0041 \times 32.35 \div 25 \times 5 \\ &= 0.0265 \text{ M} \\ &\text{(Accept: 0.027, 0.02653)} \end{aligned}$$

1*
1

(ii) (1)



3

(1 mark for straight line of calibration curve;

1 mark for labels of axes;

1 mark for two lines to find $[\text{W}(\text{aq})]_T$)

(2)

Concentration of $\text{Fe}^{2+}(\text{aq})$ ion in solution S

= Concentration of W(aq) in solution T $\times 100$

= $([\text{W}(\text{aq})]_T \times 100)$ or $([\text{Fe}^{2+}(\text{aq})]_T \times 100)$

1

3. (a) (i) Suggest a test to distinguish between $\text{Ca}(\text{NO}_3)_2(s)$ and $\text{Mg}(\text{NO}_3)_2(s)$. (2 marks)
- (ii) Give one property of solid sodium hydroxide making it NOT suitable to be weighed for preparing a standard solution. (1 mark)
- (iii) Outline the steps to obtain hexan-1-ol from a mixture of hexanoic acid and hexan-1-ol by liquid-liquid extraction.
(Given : Both hexanoic acid and hexan-1-ol are immiscible with water.) (2 marks)
- (b) The manufacturer of a certain household bleach states that the concentration of sodium hypochlorite (NaOCl) in the bleach is 15.5 g dm^{-3} . In order to determine the actual concentration of NaOCl in the bleach, the following experiment was performed :

Step (1): 25.00 cm^3 of the bleach was diluted to 250.0 cm^3 to give a solution X.

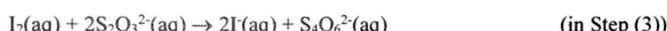
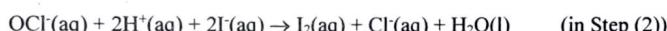
Step (2): Excess dilute sulphuric acid and excess potassium iodide solution were added to a conical flask containing 25.00 cm^3 of solution X.

Step (3): The reaction mixture obtained was titrated with $0.0512 \text{ M } \text{Na}_2\text{S}_2\text{O}_3(aq)$. When the colour of solution in the conical flask changed to pale yellow, starch solution was added as an indicator. The titration was continued until the end point was reached.

Step (4): The titration was repeated several times, and the mean volume of $\text{Na}_2\text{S}_2\text{O}_3(aq)$ required to reach the end point was 21.02 cm^3 .

- (i) Name an apparatus that should be used in Step (1). (1 mark)

- (ii) The chemical equations for the reactions involved in the experiment are as follows :



- (1) State the colour change at the end point of the titration. (1 mark)

- (2) Calculate the actual concentration of NaOCl , in g dm^{-3} , in the bleach.

(Relative atomic masses : O = 16., Na = 23.0, Cl = 35.5) (3 marks)

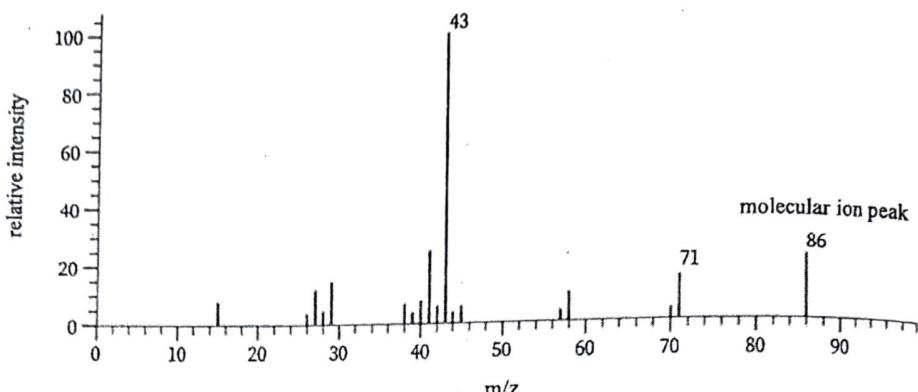
- (3) According to the quality control standards, the actual concentration of NaOCl in the bleach is required to lie within $\pm 5\%$ of the concentration stated by the manufacturer (15.5 g dm^{-3}). By calculation, determine whether the bleach fulfills the quality control standards.

(1 mark)

- (iii) Why was the titration repeated several times in Step (4) (1 mark)

3. (c) A, B and C are different straight-chain carbonyl compounds. They have the same general formula $C_nH_{2n}O$. Both A and B have the same functional group but C does not. D is a primary alcohol formed from the reduction of C.

The mass spectrum of A is shown below :



- (i) By referring to the mass spectrum of A,
 - (1) deduce the molecular formula of A,
(Relative atomic masses : H = 1.0, C = 12.0, O = 16.0) (1 mark)
 - (2) deduce the structural formula of A, (2 marks)
- (ii) Draw a possible structure for B. (1 mark)
- (iii) Suggest a chemical test to distinguish between B and C. (2 marks)
- (iv) With reference to the information given in the table below, suggest TWO expected differences between the infra-red spectra of C and D. (2 marks)

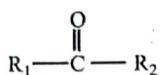
Characteristic Infra-red Absorption Wavenumber Ranges (Stretching modes)

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 (hydrogen-bonded)	3231 to 3670
N-H	Amines	3350 to 3500

3. (a) (i) Flame tests are carried out. 1
 (Accept: mention procedures of flame test)
 $\text{Ca}(\text{NO}_3)_2(s)$ gives a brick red flame while there is no observable change in $\text{Mg}(\text{NO}_3)_2(s)$. 1
 (Need comparison)
 (Accept: ONLY $\text{Ca}(\text{NO}_3)_2(s)$ gives a brick red flame.)
- Or,
 Dissolve $\text{Ca}(\text{NO}_3)_2(s)$ and $\text{Mg}(\text{NO}_3)_2(s)$ in deionised water separately, then add $\text{NH}_3(aq)$ to the two solutions. (1)
 $\text{Ca}(\text{NO}_3)_2(aq)$: no observable change (1)
 $\text{Mg}(\text{NO}_3)_2(aq)$: a white precipitate is formed
- Or,
 Dissolve $\text{Ca}(\text{NO}_3)_2(s)$ and $\text{Mg}(\text{NO}_3)_2(s)$ in deionised water separately, then add $\text{Na}_2\text{SO}_4(aq)$ to the two solutions. (1)
 $\text{Ca}(\text{NO}_3)_2(aq)$: a white precipitate is formed (1)
 $\text{Mg}(\text{NO}_3)_2(aq)$: no observable change
 (Accept: ONLY $\text{Ca}(\text{NO}_3)_2(aq)$ forms a white precipitate.)
- (ii) Sodium hydroxide solid would absorb water (vapour) / carbon dioxide (gas) (from air). 1
- (iii) $\text{NaHCO}_3(aq)$ / $\text{Na}_2\text{CO}_3(aq)$ / $\text{NaOH}(aq)$ is added to the mixture in a separating funnel. 2
 After shaking, the upper / organic layer is collected / the lower / aqueous layer is discarded.
 (1 mark for correct procedures; 1 mark for correct apparatus)
- (b) (i) \dagger (250.0 cm^3 -) volumetric flask / (25.0 cm^3 -) pipette 1
- (ii) (1) from (dark) blue to colourless 1
- (2) no. of moles of I_2 formed in 25 cm^3 of solution X
 $= 0.0512 \times 21.02 \div 1000 \div 2$ 1*
- Actual concentration of NaOCl in the bleach
 $= 0.0512 \times 21.02 \div 1000 \div 2 \times (250.0 / 25.00) \div (25.00 / 1000) \times 74.5$ 1*
 $= 16.0 (\text{g dm}^{-3})$ 1
- (3) The range of the concentration of NaOCl in the bleach that can fulfil the quality control standards is between 14.7 to 16.3 g dm^{-3} ($15.5 \pm 5\%$).
 As the actual concentration of NaOCl in the bleach (16.0 g dm^{-3}) lies within the range, it fulfils the quality control standards.
- (iii) To reduce errors of the titration results. / To have more reliable titration results. 1

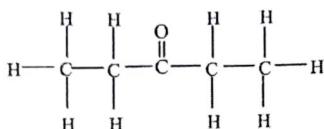
3. (c) (i) (1) The molecular ion peak is at $m/z = 86$.
 (The relative molecular mass of A is 86)
 The molecular formula of A is $C_5H_{10}O$.
 (2) The peak at $m/z = 43$ corresponds to CH_3CO^+ / $CH_3CH_2CH_2^+$ / and
 the peak at $m/z = 71$ corresponds to $CH_3CH_2CH_2CO^+$.
 The structural formula of A is $CH_3COCH_2CH_2CH_3$.

(ii)



(R_1 and R_2 : linear alkyl groups; R_1 and R_2 may be the same.)

e.g.



- (iii) Correct chemical reagent
 Correct observations with comparison between the tests on **B** and **C**

Possible chemical tests and the corresponding observations:

- | | |
|---|--|
| $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) / \text{H}^+(\text{aq})$ | B – no observable change;
C – from orange to green |
| Or, $\text{MnO}_4^-(\text{aq}) / \text{H}^+(\text{aq})$ | B – no observable change;
C – from purple to colourless |
| Or, Tollens' reagent | B – no observable change;
C – silver mirror is formed |

- (iv) The IR spectrum of **C** shows a strong absorption / peak in the region from 1680 cm^{-1} to 1800 cm^{-1} (corresponding to C=O group of aldehyde), while the IR spectrum of **D** does not show this peak.
 The IR spectrum of **D** shows a strong absorption / peak in the region from 3230 cm^{-1} to 3670 cm^{-1} (corresponding to O–H group of alcohol), while the IR spectrum of **C** does not show this peak.
 (Need comparison)