2021
JAMES RUSE AGRICULTURAL HIGH SCHOOL
TRIAL HSC EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A formula sheet, data sheet and Periodic Table are provided
- For questions in Section II, show all relevant working in questions involving calculations
- Please scan your paper after completion and submit it in the Year 12 Chemistry Google classroom

Total Marks – 100

Section I – 20 marks (pages 2-10)

- Attempt questions 1-20
- Complete these questions on the google doc provided
- Allow about 35 minutes for this section

Section II – 80 marks (pages 11-30)

- Attempt questions 21-34
- Complete these questions on the hard copy provided
- Allow about 2 hours and 25 minutes for this section

1. Which list contains members of the same homologous series?

A. C_2H_6, C_4H_8, C_6H_{10}

B. C_2H_5Br, $C_2H_4Br_2$, $C_2H_3Br_3$

C. C_2H_6, C_4H_{10}, C_6H_{14}

D. C_2H_5OH, C_2H_5Cl, $C_2H_5NH_2$

2. Which of the following ions would form metal complexes with a dark green colour?

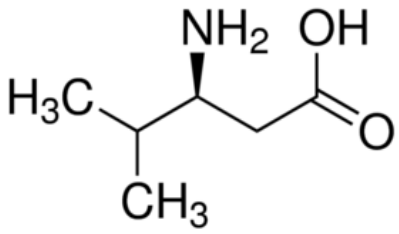
A. Mg^{2+}

B. Fe^{2+}

C. Fe^{3+}

D. Cu^{2+}

3. What is the preferred IUPAC name of this compound?



A. 2-methyl-2-amino butanoic acid

B. 4,4-dimethyl, 3-amino butanoic acid

C. 1-hydroxy-3-amino-4-methyl pentanal

D. 3-amino-4-methyl pentanoic acid

4. Lucas reagent (anhydrous zinc chloride and hydrochloric acid) can be used to distinguish between which pair of compounds?

A. propan-1-ol and 2-methyl propan-2-ol

B. propan-1-ol and propanoic acid

C. propan-1-ol and propylamine

D. propan-1-ol and propane

5. An investigation was carried out to test for the presence of iodide anions.

Which of the following series of observations would confirm this?

	Addition of $AgNO_3$	*Addition of HNO_3*	*Precipitate Colour*
A.	solution forms a precipitate	precipitate does not dissolve	black
B.	solution forms a precipitate	precipitate dissolves	yellow
C.	solution forms a precipitate	precipitate dissolves	white
D.	no precipitate forms.	solution forms a precipitate	blue

6. Which of the following compounds is an isomer of methyl propanoate?

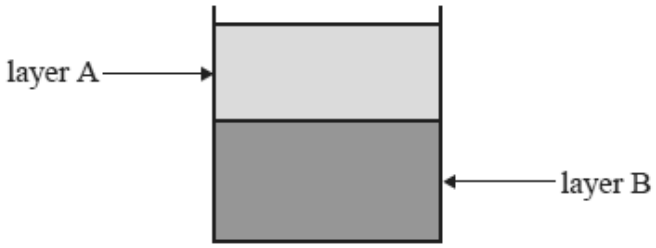
A. butanone

B. butanoic acid

C. methyl butanoate

D. butanal

7. Canola oil is completely converted into biodiesel fuel. One of the components of this biodiesel is ethyl stearate, an ester. Once cooled, the product mixture of the conversion of canola oil to biodiesel separates into two layers. The top layer, layer A, is the biodiesel fuel.



The following chemicals are involved in the production of biodiesel
(i) glycerol (1,2,3 propantriol)
(ii) potassium hydroxide
(iii) ethanol

Which of these chemicals are found in layer B?

A. i and ii only

B. i and iii only

C. ii and iii only

D. i, ii and iii

8. Which combination of solutes forms a buffer solution in water?

A. Ammonia and potassium nitrate

B. Citric acid and potassium citrate

C. Nitric acid and potassium nitrate

D. Hydrochloric acid and sodium hydroxide

9. Atomic Absorption Spectroscopy is a technique that can be used to determine the concentration of metal cations in solutions in the presence of one or more different metal cation species.

Which of the following statements explains how this is achieved?

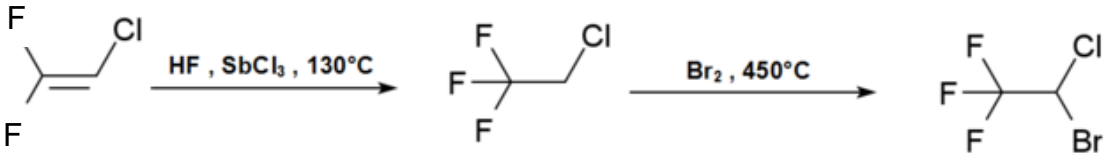
A. Each metal cation absorbs a particular wavelength of light.

B. Each metal cation emits a particular wavelength of light.

C. Each metal cation absorbs a different amount of light.

D. Each metal cation emits a different amount of light.

10. The diagram below shows the reaction pathway for the formation of haloethane, a general anaesthetic.



Trichloroethene step 1 molecule X step 2 haloethane

Which of the following correctly identifies the IUPAC name of molecule X and the type of reaction at step 1?

	Molecule X	*Type of reaction at step 1*
A.	1-chloro-2,2,2-trifluoroethane	addition
B.	2-chloro-1,1,1-trifluoroethane	addition
C.	1-chloro-2,2,2-trifluoroethane	substitution
D.	2-chloro-1,1,1-trifluoroethane	substitution

11. A 20mL volume of 0.10 mol L^{-1} nitric acid solution is diluted to 100mL.

What is the change in pH for the nitric acid solution after this dilution?

A. 1.0 to 1.7

B. 1.0 to 2.5

C. 2.0 to 2.7

D. 2.0 to 9.0

12. How many unique hydrogen environment signals would you expect to see in the proton NMR spectrum for 2,2-dimethylpropan-1-ol?

A. 2

B. 3

C. 4

D. 5

13. 1.60 g of anhydrous metal sulfate was dissolved in water. The addition of excess barium chloride resulted in the precipitation of 2.33 g of barium sulfate.

What was the identity of the anhydrous metal sulfate?

A. copper (II) sulfate

B. magnesium sulfate

C. sodium sulfate

D. calcium sulfate

14. In a titration of a strong base with a strong acid, the following procedure was used:

i) A burette was rinsed with water and then filled with the standard acid
ii) A pipette was rinsed with the base solution
iii) A conical flask was rinsed with the base solution
iv) The pipette was used to transfer a measured volume of base solution into the conical flask
v) *Indicator was added to the base sample in the conical flask and it was titrated to the endpoint with the acid*

Which statement is correct?

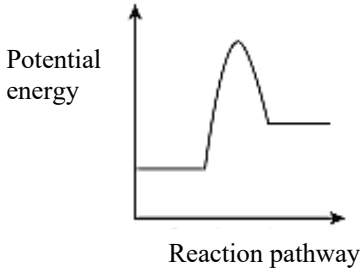
A. The calculated base concentration will be correct

B. The calculated base concentration will be too low

C. The calculated base concentration will be too high

D. No definite conclusion can be reached about the base concentration

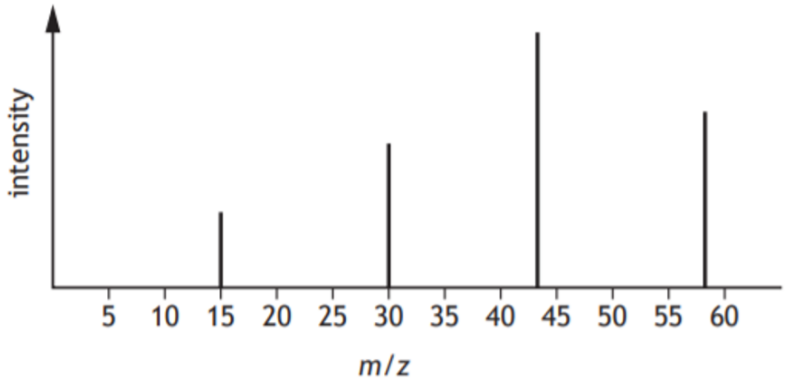
15. The energy profile diagram for an equilibrium reaction is given below.



When the temperature of the system is decreased, how will the activation energy and value of K_{eq} change?

	Activation Energy	*Value of K_{eq}*
A.	Decrease	Increase
B.	Same	Increase
C.	Decrease	Decrease
D.	Same	Decrease

16. An impure sample of propanone was analysed using mass spectroscopy to generate the spectrum shown.



The mass spectrum of propanone should only contain THREE major fragment peaks.

Which of the following signals corresponds to a fragment from the impurity?

A. m / z = 15

B. m / z = 30

C. m / z = 43

D. m /z = 58

17. Complete combustion of an organic compound forms 50 mL of carbon dioxide and 50 mL of water vapour under the same conditions of temperature and pressure. Which of the following could be the molecular formula for the organic compound?

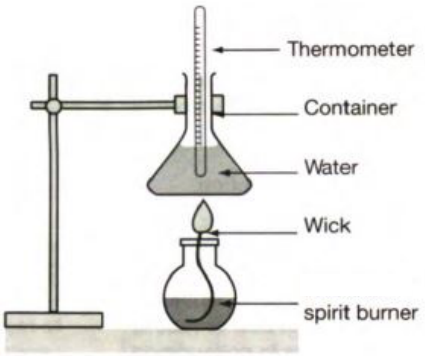
A. C_4H_{10}

B. CH_4

C. C_2H_3N

D. C_4H_8O

18. The following experiment was set up to measure the temperature change for a heat of combustion reaction.



200.0 mL of water at 298 K was heated by the burning of 1.40 g of propan-1-ol in the spirit burner. Only 35.0% of the energy produced was used to heat the water. The molar heat of combustion of propan-1-ol is 2021 kJ mol^{-1}. What is the final temperature of the water?

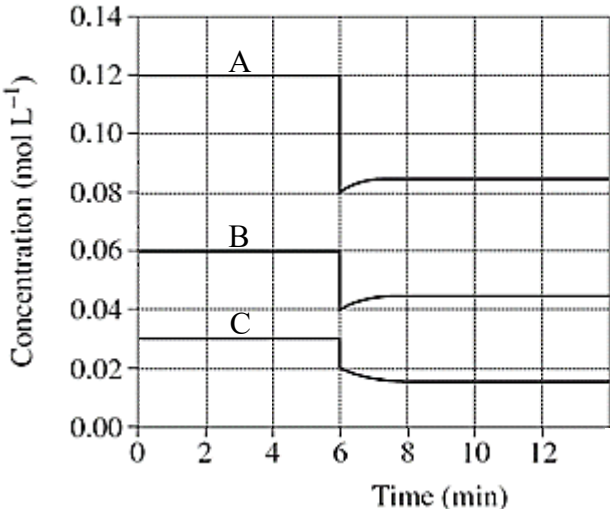
A. 19.7°C

B. 25.02°C

C. 44.7°C

D. 64.4°C

Use the following graph of the concentration of reactants and products of an established equilibrium over time to answer questions 19 and 20.



19. Which equation would be consistent with data shown in the graph?

A. $4A\ (g) + 2B\ (g) \rightleftharpoons C\ (g)$

B. $4A\ (g) \rightleftharpoons 2B\ (g) + C\ (g)$

C. $A\ (g) + B\ (g) \rightleftharpoons C\ (g)$

D. $A\ (g) \rightleftharpoons B\ (g) + C\ (g)$

20. The graph indicates that a change occurred at 6 minutes.

Which statement would be consistent with this data?

A. The pressure decreases by one-third of the initial amount.

B. The pressure increases by one-third of the initial amount.

C. The pressure decreases by three times the initial amount.

D. The pressure increases by three times the initial amount.

Start your scan from the next page (11) when you submit your work for marking and feedback.

Instructions about scanning apps for your phone will be in your email.

2021
JAMES RUSE AGRICULTURAL HIGH SCHOOL
TRIAL HSC EXAMINATION

Chemistry

Name ……..

Class……

Section II - 80 marks

Attempt Questions 21 – 34

Allow about 2 hours and 25 minutes for this section

- Answer all questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering and direct the examiner to your answer.

Question 21 (4 marks)

Arrhenius and Bronsted-Lowry were instrumental in improving our understanding of acids and bases. Compare the ideas about acids and bases proposed by these scientists and discuss any limitations to their models. **4**

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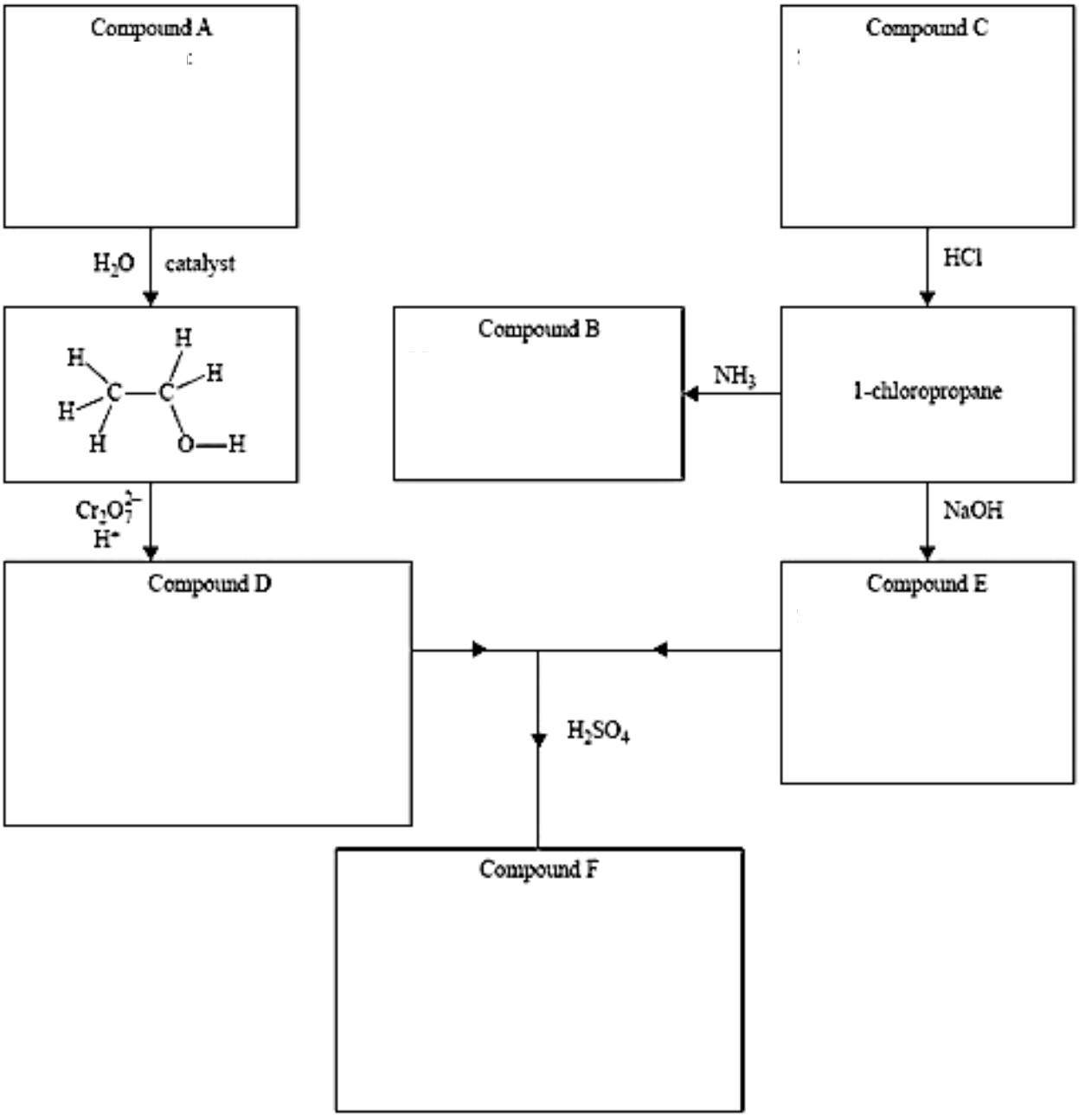
Question 22 (6 marks)

The flowchart shows reactions involving a range of organic compounds.

Draw the structural formula of each organic compound A-F in the boxes provided. **6**



Question 23 (4 marks)

When 1.00 mol hydrogen iodide gas is injected into a sealed 10.00 L flask at a temperature of 225 °C, it decomposes until 0.182 mol iodine gas is formed.

Calculate the equilibrium constant for this reaction. **4**

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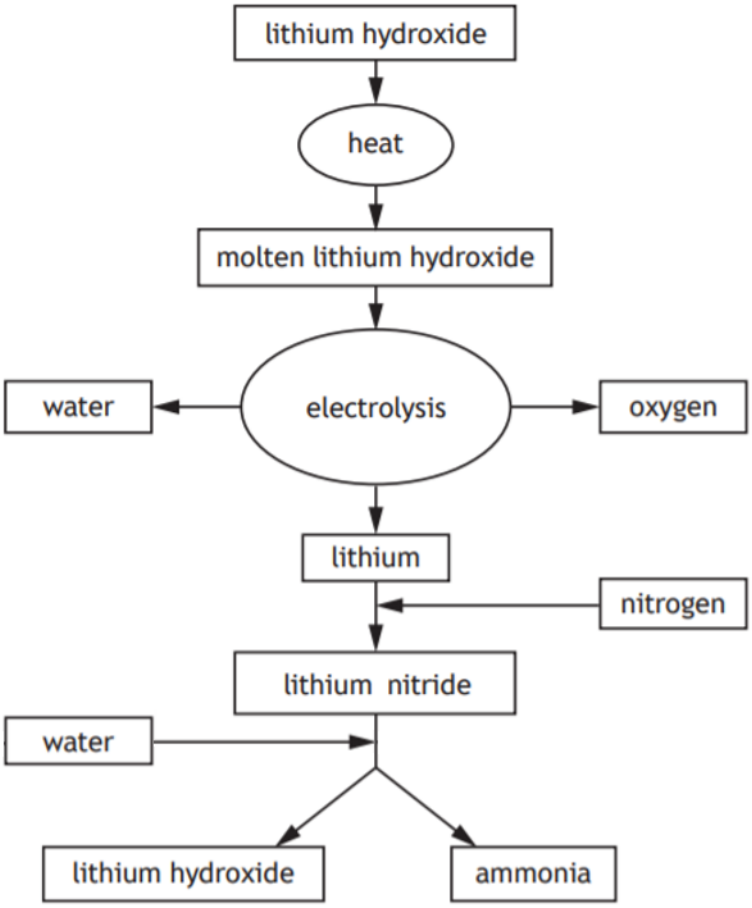
Question 24 (4 marks)

Chemists are constantly working towards developing alternative industrial processes that are more efficient than existing methods. A more efficient means of producing ammonia in contrast to the Haber process is outlined in the flowchart diagram below.



(a) Draw TWO arrows on the flowchart diagram above to show how this process can be made more economical by recycling. **2**

(b) Explain how the arrows drawn in part (a) make this process more economical. **2**

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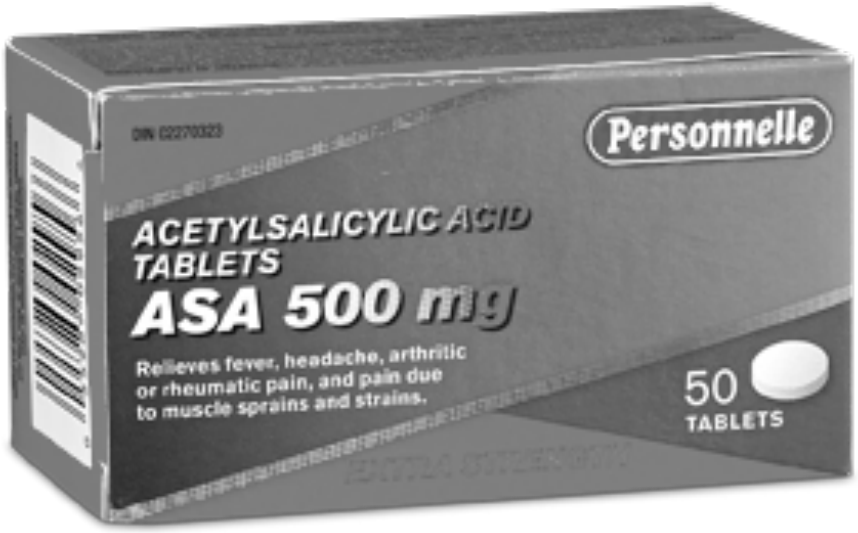
Question 25 (6 marks)

Aspirin contains acetylsalicylic acid widely used to relieve pain and fever.

Pharmaceutical companies are required to list the amount of active ingredient per tablet on the packaging as shown below.



A titration was undertaken to check the purity of the tablets using the following reaction.

$$C_9H_8O_4\,(aq) + NaOH(aq) \rightarrow NaC_9H_7O_4\,(aq) + H_2O\,(l)$$

acetylsalicylic acid | sodium hydroxide | sodium acetylsalicylate | water

A standardised sodium hydroxide solution of 0.0250 mol L^{-1} was placed in a 50.0 mL burette.

One tablet was crushed and dissolved in 15.0 mL of ethanol in a 100 mL volumetric flask. The solution was then made up to the mark with distilled water.

A 20.0 mL sample of the dilute tablet solution was pipetted into a conical flask with a few drops of the indicator phenolphthalein.

After an initial 'rough titration', a further three titrations were performed each time using 20.0 mL of acetylsalicylic acid solution. These results are shown in the following table.

Titration number	Burette readings (mL)		
	Initial	Final	Titre
1	1.70	23.6	21.9
2	23.6	45.3	21.7
3	1.50	23.3	21.8

Question 25 continues on page 17

Using the information collected, determine whether the mass of acetylsalicylic acid in the tablet matches the information on the packaging and determine the percentage purity of the tablet. **6**

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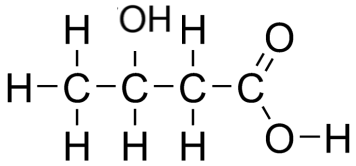
Question 26 (10 marks)

Polyhydroxy butyrate (PHB) is a bio-derived polymer that can be used in biodegradable plastics. PHB is formed from the monomer drawn below with a molar mass of 104.1g mol^{-1}.



(a) Give the IUPAC name for the PHB monomer. **1**

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(b) Use structural formulae to show the products formed when two PHB monomers combine to begin to form the polymer polyhydroxy butyrate. **2**

(c) The PHB monomer has a solubility of 53.9 g/100 mL in water at 25°C.
Calculate its concentration in mol L^{-1}. **2**

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Question 26 continues on page 19

(d) Use a labelled diagram to show the intermolecular forces acting between water and the PHB monomer. **2**

(e) Compare TWO environmental implications of using PHB as a plastic instead of a petrochemical plastic made from crude oil. **3**

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Question 27 (3 marks)

Blood pH is maintained in a narrow range of 7.35 to 7.45 by a buffering system involving carbon dioxide and bicarbonate ions.

Explain how this buffer works in blood using a relevant equation in your answer. **3**

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Question 28 (8 marks)

Propanoic acid is a weak monoprotic acid.

(a) A student dissolved 7.4 g of propanoic acid in 100.0 mL of water, at 25°C.
The acid ionisation constant Ka = 1.35×10^{-5} mol L^{-1}.
Calculate the pH of the equilibrium mixture. **3**

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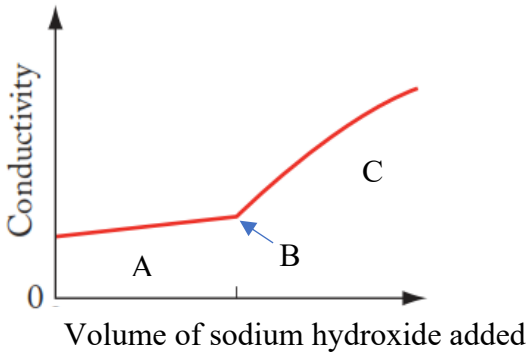
Question 28 continues on page 21

(b) Explain the shape/point of the conductivity curve at the sections/point labelled A, B and C, produced when propanoic acid is titrated with sodium hydroxide. **5**



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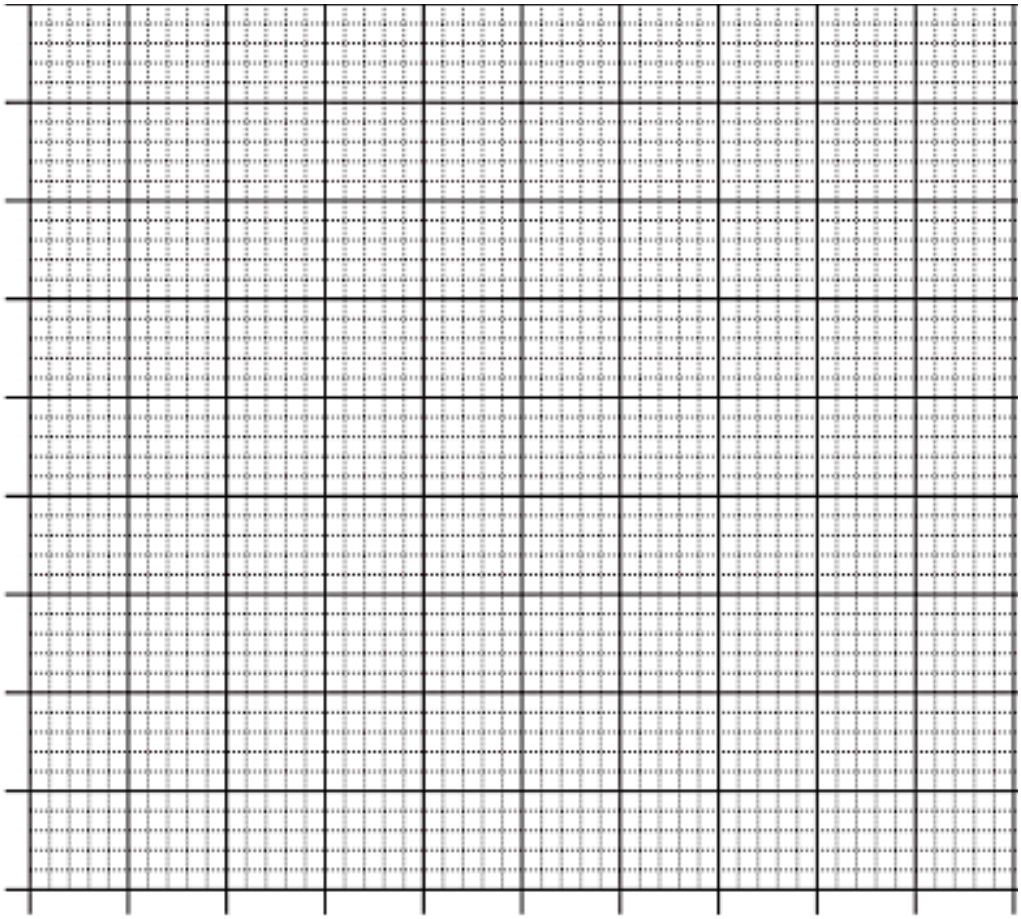
Question 29 (12 marks)

The solubility of copper (II) sulfate at different temperatures was accurately determined experimentally. The results are tabulated below.

Temperature (ºC)	Solubility (g/100g)	Temperature (ºC)	Solubility (g/100g)
0	13	60	40
10	15	70	47
20	19	80	56
30	24	90	67
40	29	100	80
50	34		

(a) Graph the data from the table. **4**



Question 29 continues on page 23

(b) Explain the change in colour intensity of a saturated solution as temperature increases. Include a relevant equation in your answer. **4**

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(c) A copper (II) sulfate saturated solution was prepared at 45 °C.

(i) Determine the concentration of copper (II) sulfate in mol L^{-1} at that temperature. **2**

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(ii) Calculate the Ksp of the solution at that temperature. **2**

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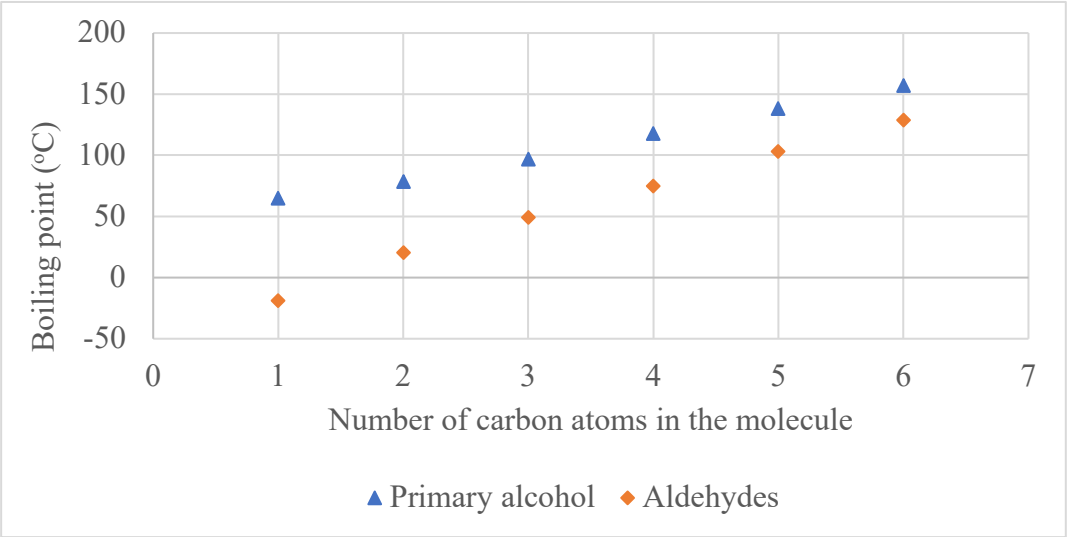
Question 30 (4 marks)

The boiling points of straight chain primary alcohols and aldehydes are given in the following graph.



Explain the trends in the boiling points shown in the graph. **4**

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Question 31 (4 marks)

What is the pH of the final solution when 100 mL of 0.60 mol L^{-1} hydrochloric acid is added to 100 mL of 0.20 mol L^{-1} magnesium hydroxide? **4**

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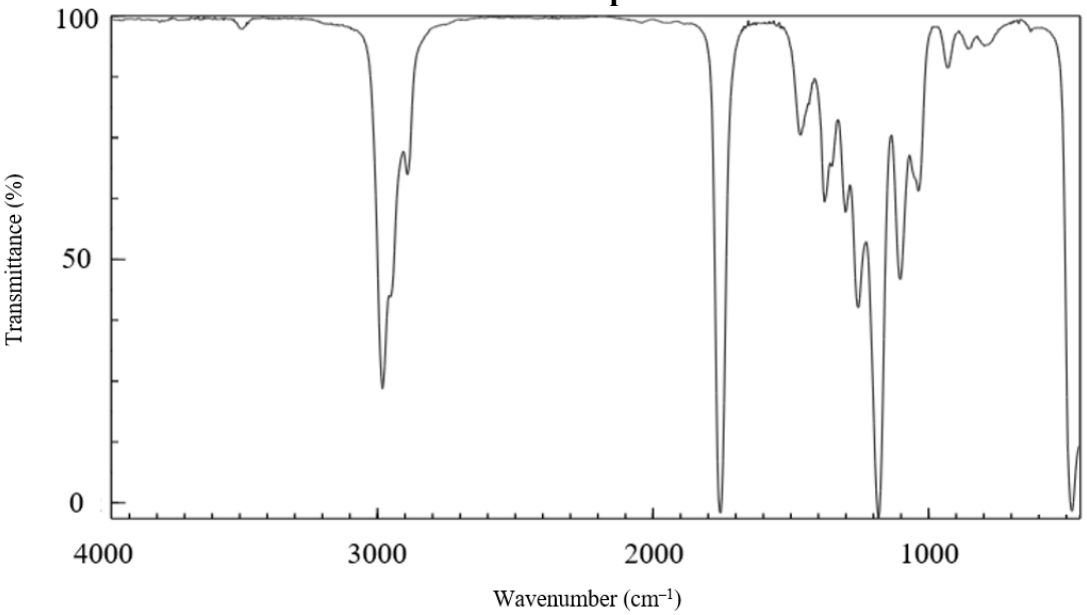
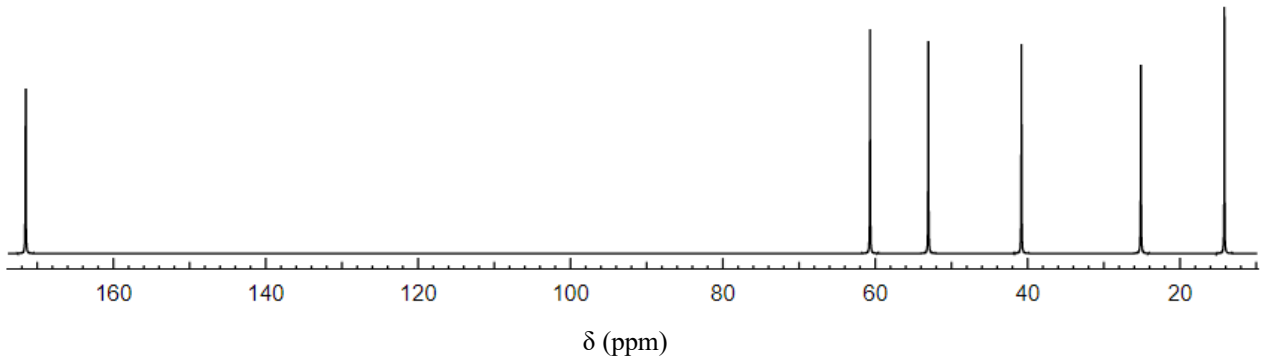
Question 32 (7 marks)

A mystery compound was discovered in an organic chemistry laboratory with the chemical formula $C_6H_{11}O_2Cl$. In order to determine its structure a range of analysis techniques were performed on the sample including infrared, ^1H NMR and ^{13}C NMR spectroscopy. The spectra obtained from this analysis are presented as follows:

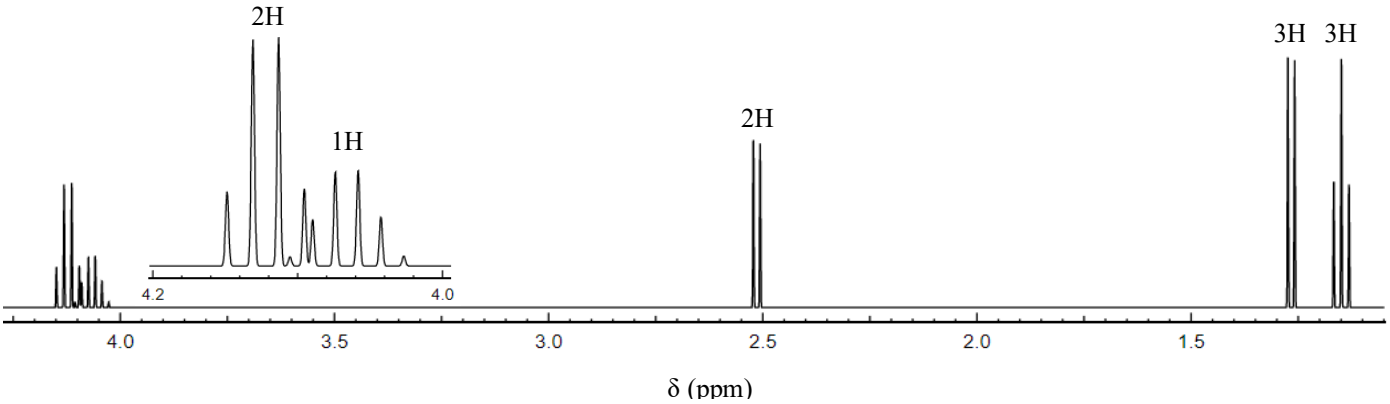
Infrared spectrum



^{13}C NMR spectrum



^1H NMR spectrum



The ^{1}H NMR data is on the last page of this exam, p32

In the space provided, draw the structural formula for the mystery compound that is consistent with all the information. Justify your answer with reference to the information provided. **7**

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End of Question 32

Question 33 (4 marks)

As part of this course, students conducted quantitative investigations to analyse inorganic substances. In one such instance a group of students determined the chloride ion concentration present in seawater using two different methods.

> *Volumetric method – a sample of seawater was titrated with standardised silver nitration solution until precipitation ceased.*
>
> *Gravimetric method – a sample of seawater was reacted with silver nitrate solution to form a precipitate, which was collected via filtration and weighed.*

The sample of seawater was titrated with the standardised silver nitrate solution and the average titre volume was found to be 2.1 mL.

(a) Suggest ONE improvement that could be made to improve the accuracy of the titre values and explain your reasoning **2**

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A difficulty encountered with titration reactions is to accurately determine when the reaction has reached completion.

(b) Describe a technique students could use to determine that all the chloride ions had been precipitated in the gravimetric method with reference to a relevant observation. **2**

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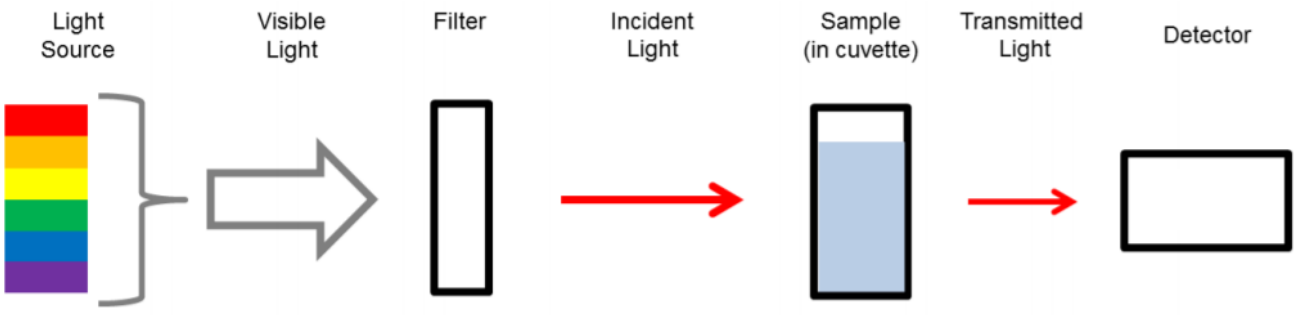
Question 34 (4 marks)

A colorimetric investigation was carried out to determine the concentration of barium ions present in waste water. The sample was placed into a quartz cuvette (2 cm x 2 cm x 5 cm) and analysed using the colorimetry setup illustrated in the diagram provided.



It was discovered that the detector for the colorimeter was faulty, so a luxmeter was used to record the light intensity values in this experiment. The light intensity of the incident ray was found to be 683 lumens whereas the transmitted ray had an intensity of 294 lumens. Given that the barium ions have a molar extinction coefficient of 80.5 mol^{-1} cm^{-1}, determine the concentration of barium ions in the solution in ppm. **4**

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Part B extra writing space
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Type of proton		δ/ppm
$Si(CH_3)_4$	(TMS)	0
R—CH_3		0.7–1.3
R—CH_2—R		1.2–1.5
R—CHR_2		1.5–2.0
H_3C—CO—	(aldehydes, ketones or esters)	2.0–2.5
—CH—CO—	(aldehydes, ketones or esters)	2.1–2.6
H_3C—O—	(alcohols or esters)	3.2–4.0
—CH—O—	(alcohols or esters)	3.3–5.1
R_2—CH_2—O—	(alcohols or esters)	3.5–5.0
R—OH		1–6
R_2C=CHR	(alkene)	4.5–7.0
R—CHO	(aldehyde)	9.4–10.0
R—COOH		9.0–13.0

JRAHS Chemistry Trial 2021 Answers

Section I

Multiple Choice Answer Sheet

1.	A ○	B ○	C ■	D ○
2.	A ○	B ■	C ○	D ○
3.	A ○	B ○	C ○	D ■
4.	A ■	B ○	C ○	D ○
5.	A ○	B ■	C ○	D ○
6.	A ○	B ■	C ○	D ○
7.	A ○	B ○	C ○	D ■
8.	A ○	B ■	C ○	D ○
9.	A ■	B ○	C ○	D ○
10.	A ■	B ○	C ○	D ○
11.	A ■	B ○	C ○	D ○
12.	A ○	B ■	C ○	D ○
13	A ■	B ○	C ○	D ○
14.	A ○	B ○	C ■	D ○
15.	A ○	B ○	C ○	D ■
16.	A ○	B ■	C ○	D ○
17.	A ○	B ○	C ○	D ■
18.	A ○	B ○	C ■	D ○
19.	A ○	B ○	C ■	D ○
20.	A ■	B ○	C ○	D ○

1. Which list contains members of the same homologous series?

A. C_2H_6, C_4H_8, C_6H_{10}

B. C_2H_5Br, $C_2H_4Br_2$, $C_2H_3Br_3$

C. C_2H_6, C_4H_{10}, C_6H_{14}

D. C_2H_5OH, C_2H_5Cl, $C_2H_5NH_2$

2. Which of the following ions would form metal complexes with a dark green colour?

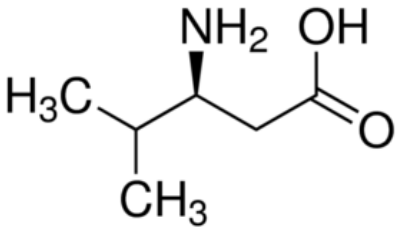
A. Mg^{2+}

B. Fe^{2+}

C. Fe^{3+}

D. Cu^{2+}

3. What is the preferred IUPAC name of this compound?



A. 2-methyl-2-amino butanoic acid

B. 4,4-dimethyl, 3-amino butanoic acid

C. 1-hydroxy-3-amino-4-methyl pentanal

D. 3-amino-4-methyl pentanoic acid

4. Lucas reagent (anhydrous zinc chloride and hydrochloric acid) can be used to distinguish between which pair of compounds?

A. propan-1-ol and 2-methyl propan-2-ol

B. propan-1-ol and propanoic acid

C. propan-1-ol and propylamine

D. propan-1-ol and propane

5. An investigation was carried out to test for the presence of iodide anions.

Which of the following series of observations would confirm this?

	Addition of $AgNO_3$	*Addition of HNO_3*	*Precipitate Colour*
A.	solution forms a precipitate	precipitate does not dissolve	black
B.	**solution forms a precipitate**	**precipitate dissolves**	**yellow**
C.	solution forms a precipitate	precipitate dissolves	white
D.	no precipitate forms.	solution forms a precipitate	blue

6. Which of the following compounds is an isomer of methyl propanoate?

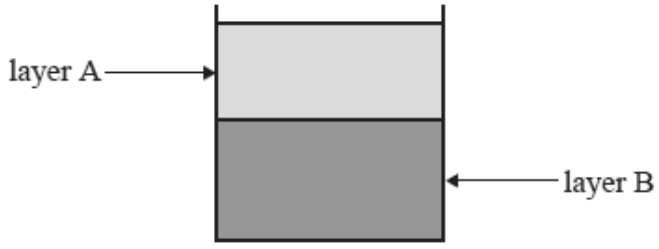
A. butanone

B. butanoic acid

C. methyl butanoate

D. butanal

7. Canola oil is completely converted into biodiesel fuel. One of the components of this biodiesel is ethyl stearate, an ester. Once cooled, the product mixture of the conversion of canola oil to biodiesel separates into two layers. The top layer, layer A, is the biodiesel fuel.



The following chemicals are involved in the production of biodiesel
(i) glycerol (1,2,3 propantriol)
(ii) potassium hydroxide
(iii) ethanol

Which of these chemicals are found in layer B?

A. i and ii only

B. i and iii only

C. ii and iii only

D. i, ii and iii

8. Which combination of solutes forms a buffer solution in water?

A. Ammonia and potassium nitrate

B. Citric acid and potassium citrate

C. Nitric acid and potassium nitrate

D. Hydrochloric acid and sodium hydroxide

9. Atomic Absorption Spectroscopy is a technique that can be used to determine the concentration of metal cations in solutions in the presence of one or more different metal cation species.

Which of the following statements explains how this is achieved?

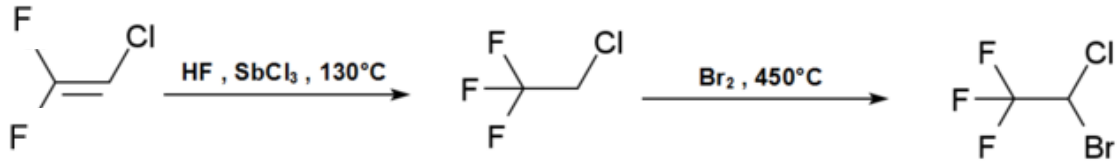
A. Each metal cation absorbs a particular wavelength of light.

B. Each metal cation emits a particular wavelength of light.

C. Each metal cation absorbs a different amount of light.

D. Each metal cation emits a different amount of light.

10. The diagram below shows the reaction pathway for the formation of haloethane, a general anaesthetic.



Trichloroethene step 1 molecule X step 2 haloethane

Which of the following correctly identifies the IUPAC name of molecule X and the type of reaction at step 1?

	Molecule X	*Type of reaction at step 1*
A.	**1-chloro-2,2,2-trifluoroethane**	**addition**
B.	2-chloro-1,1,1-trifluoroethane	addition
C.	1-chloro-2,2,2-trifluoroethane	substitution
D.	2-chloro-1,1,1-trifluoroethane	substitution

11. A 20mL volume of 0.10 mol L^{-1} nitric acid solution is diluted to 100mL.

What is the change in pH for the nitric acid solution after this dilution?

A. 1.0 to 1.7

B. 1.0 to 2.5

C. 2.0 to 2.7

D. 2.0 to 9.0

12. How many unique hydrogen environment signals would you expect to see in the proton NMR spectrum for 2,2-dimethylpropan-1-ol?

A. 2

B. 3

C. 4

D. 5

13. 1.60 g of anhydrous metal sulfate was dissolved in water. The addition of excess barium chloride resulted in the precipitation of 2.33 g of barium sulfate.

What was the identity of the anhydrous metal sulfate?

A. copper (II) sulfate

B. magnesium sulfate

C. sodium sulfate

D. calcium sulfate

14. In a titration of a strong base with a strong acid, the following procedure was used:

i) A burette was rinsed with water and then filled with the standard acid
ii) A pipette was rinsed with the base solution
iii) A conical flask was rinsed with the base solution
iv) The pipette was used to transfer a measured volume of base solution into the conical flask
v) *Indicator was added to the base sample in the conical flask and it was titrated to the endpoint with the acid*

Which statement is correct?

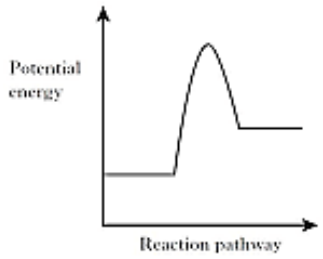
A. The calculated base concentration will be correct

B. The calculated base concentration will be too low

C. The calculated base concentration will be too high

D. No definite conclusion can be reached about the base concentration

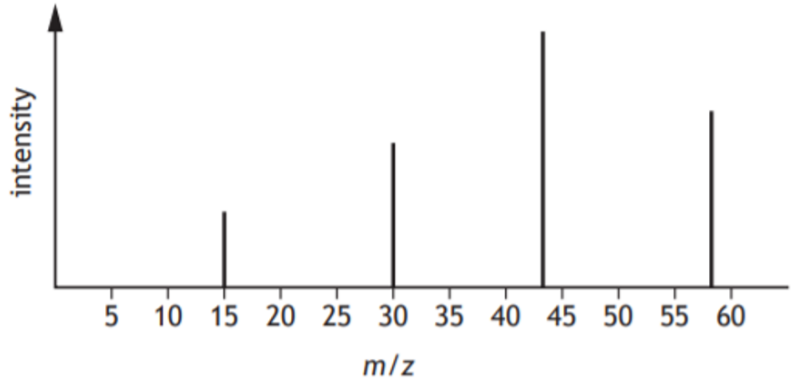
15. The energy profile diagram for an equilibrium reaction is given below.



When the temperature of the system is decreased, how will the activation energy and value of K_{eq} change?

	Activation Energy	*Value of K_{eq}*
A.	Decrease	Increase
B.	Same	Increase
C.	Decrease	Decrease
D.	**Same**	**Decrease**

16. An impure sample of propanone was analysed using mass spectroscopy to generate the spectrum shown.



The mass spectrum of propanone should only contain THREE major fragment peaks.

Which of the following signals corresponds to a fragment from the impurity?

A. m / z = 15

B. m / z = 30

C. m / z = 43

D. m/z = 58

17. Complete combustion of an organic compound forms 50 mL of carbon dioxide and 50 mL of water vapour under the same conditions of temperature and pressure. Which of the following could be the molecular formula for the organic compound?

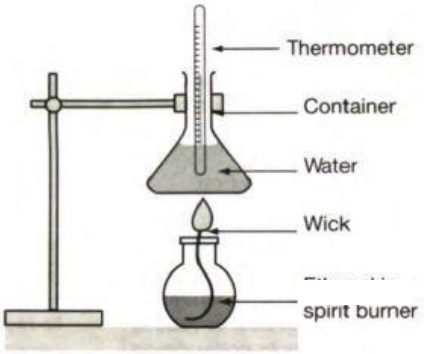
A. C_4H_{10}

B. CH_4

C. C_2H_3N

D. C_4H_8O

18. The following experiment was set up to measure the temperature change for a heat of combustion reaction.



200.0 mL of water at 298 K was heated by the burning of 1.40 g of propan-1-ol in the spirit burner. Only 35.0% of the energy produced was used to heat the water. The molar heat of combustion of propan-1-ol is 2021 kJ mol^{-1}. What is the final temperature of the water?

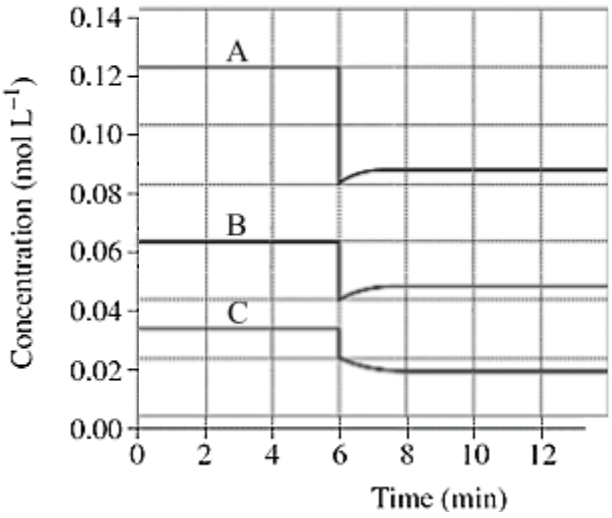
A. 19.7°C

B. 25.02°C

C. 44.7°C

D. 64.4°C

Use the following graph of the concentration of reactants and products of an established equilibrium over time to answer questions 19 and 20.



19. Which equation would be consistent with data shown in the graph?

A. $4A\ (g) + 2B\ (g) \rightleftharpoons C\ (g)$

B. $4A\ (g) \rightleftharpoons 2B\ (g) + C\ (g)$

C. $A\ (g) + B\ (g) \rightleftharpoons C\ (g)$

D. $A\ (g) \rightleftharpoons B\ (g) + C\ (g)$

20. The graph indicates that a change occurred at 6 minutes.

Which statement would be consistent with this data?

A. The pressure decreases by one-third of the initial amount.

B. The pressure increases by one-third of the initial amount.

C. The pressure decreases by three times the initial amount.

D. The pressure increases by three times the initial amount.

Question 21 (4 marks)

Arrhenius and Bronsted-Lowry were instrumental in improving our understanding of acids and bases. Compare the ideas about acids and bases proposed by these scientists and discuss any limitations to their models. **4**

Arrhenius :

Acids have the general formula HX and can ionise in water to produce hydrogen ions.

general formula $HX \leftrightarrows H^+ + X^-$

Bases dissociate to produce OH^-

general formula $MOH \leftrightarrows M^+ + OH^-$

This is limited because:

-It applied only to aqueous solutions

-It does not explain why some salts act as acids and some as bases

-It cannot explain how some substance can act as both acid and base

-Some bases don't have hydroxide ions ie NH_3

Brønsted–Lowry:

An acid-base reaction is a proton transfer reaction and an acid is a proton donor and a base is a proton acceptor.

The reaction is not limited to aqeous solutions and proton transfer can occur in gaseous phases in solvents other than water.

This means that species other than MOH are bases

$NH_3 + H_2O \leftrightarrows NH_4^+ + OH^-$

An acid base reaction is one in which a proton is transferred from an acid to a base.

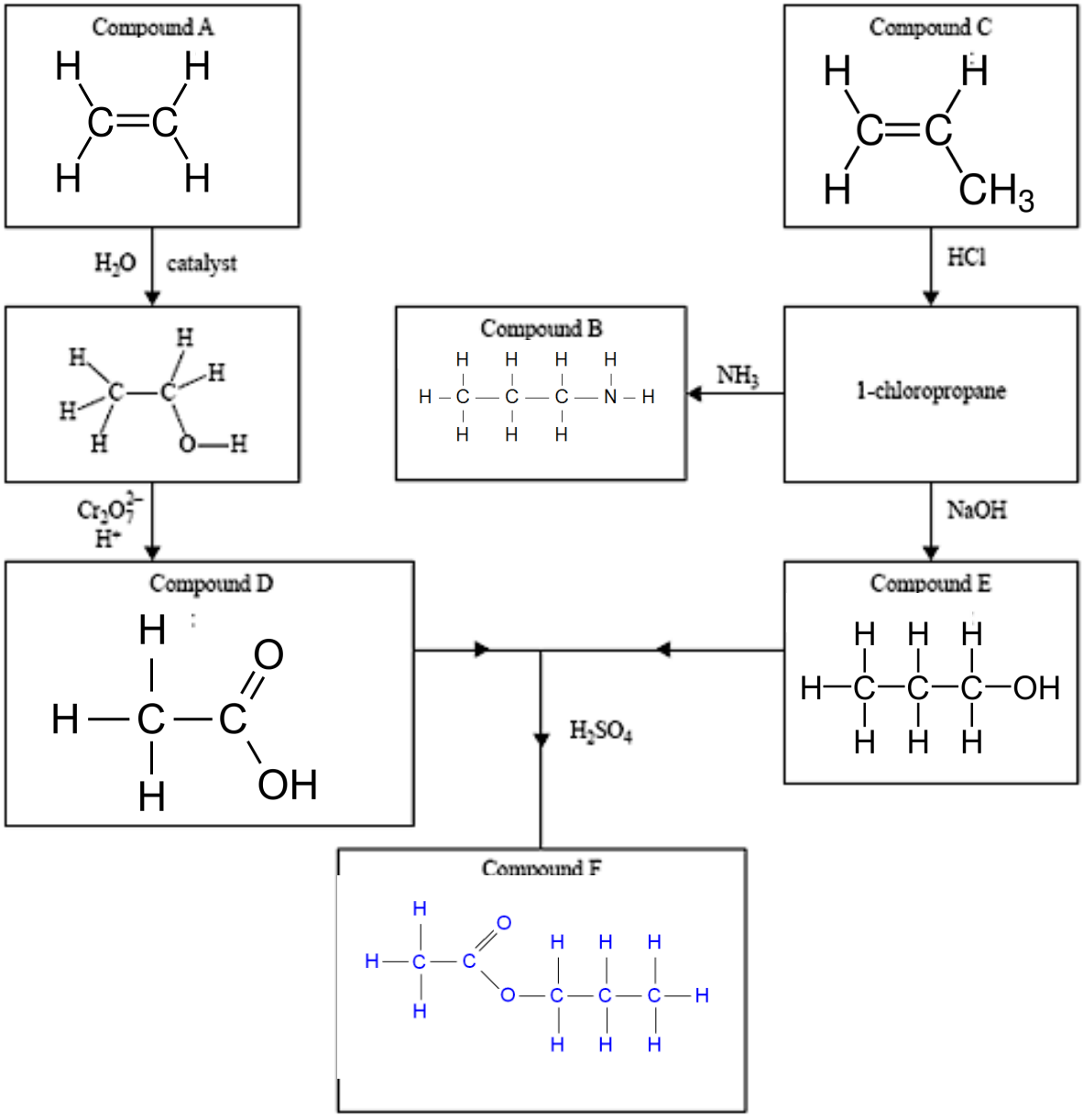
The new acid and new base are called the conjugate acid and conjugate base of the original base and acid. Conjugate acid base pairs are related by the gain or loss of a proton.

Limitation of Bronsted-Lowry definition is it does not explain acidic /basic oxides and amphoteric substances.

Marking Criteria	*Mark(s)*
• Outlines Arrhenius definition acids and bases • Outlines Bronsted-Lowry definition on acids and bases AND • identify a difference or similarity AND • States a limitation of one theory OR • States TWO limitations (one for each theory)	4
• Outlines Arrhenius definition acids and bases • Outlines Bronsted-Lowry definition on acids and bases ***and*** • States a limitation of one theory OR states one difference or similarity of one theory	3
• Outlines Arrhenius definition acids and bases and • Outlines Bronsted-Lowry definition on acids and bases	2
• Correctly states any one of the above	1

Question 22 (6 marks)

The flowchart shows reactions involving a range of organic compounds.
Draw the structural formula of each organic compound A-F in the boxes provided.



Marking Criteria	*Mark(s)*
• Correctly draws the structures for compounds A-F	6
• Correctly draws the structures for 5 compounds	5
• Correctly draws the structures for 4 compounds OR • Gives some molecular formulas and structures for all 5/6 compounds	4
• Some correct compounds identified	3

• Two correct compounds identified	2
• One correct compound identified	1

Question 23 (4 marks)

When 1.00 mol hydrogen iodide gas is injected into a sealed 10.00 L flask at a temperature of 225 °C, it decomposes until 0.182 mol iodine gas is formed.

Calculate the equilibrium constant for this reaction. **4**

Sample answer

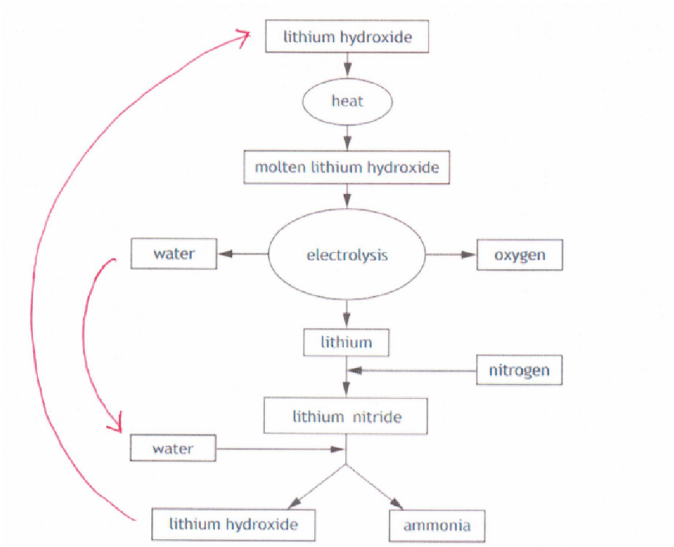
	$2HI(g)$	$\rightleftharpoons$	$H_2(g)$	+	$I_2(g)$
Initial concentration	*1.00/10*		*0*		*0*
Change	*2 x 0.0182*				
Final concentration	*0.0636*		*0.182/10*		*0.182/10*

$$K = \frac{[H_2][I_2]}{[HI]^2} = \frac{(0.0182)^2}{(0.0636)^2} = 0.0819$$

Marking Criteria	*Marks*
• Changes mol to concentration • Calculates equilibrium concentrations • Gives the K expression • Completes the calculation	4
• Most relevant working given	3
• Some relevant working given	2
• Gives the equation OR • Gives the K expression OR • Calculates one concentration	1

Question 24 (4 marks)

Chemists are constantly working towards developing alternative industrial processes that are more efficient than existing methods. A more efficient means of producing ammonia in contrast to the Haber process is outlined in the flowchart diagram below.



(a) Draw TWO arrows on the flowchart diagram above to show how this process can be made more economical by recycling. **2**

Sample answer: drawn on the diagram above.

Marking Criteria	*Mark(s)*
• Provides TWO correctly drawn arrows.	2
• Provides ONE correctly drawn arrow.	1

(b) Explain how the arrows drawn in part (a) make this process more economical **2**

Sample answer:

The by-products from this process (water and lithium hydroxide) can be recycled to make the process more economical. This is achieved by using the remaining by-products as reactants in other steps of the process to reduce the costs required to purchase additional reactants, thus reducing the expense costs of this process.

Marking Criteria	*Mark(s)*
• Explains how recycling by-products reduces costs (lower material costs and / or waste management costs).	2
• Provides some relevant information.	1

Question 25 (6 marks)
Aspirin contains acetylsalicylic acid widely used to relieve pain and fever.

Pharmaceutical companies are required to list the amount of active ingredient per tablet on the packaging as shown below.

A titration was undertaken to check the purity of the tablets using the following reaction.

$$C_9H_8O_4\,(aq) + NaOH(aq) \rightarrow NaC_9H_7O_4\,(aq) + H_2O\,(l)$$

acetylsalicylic acid sodium hydroxide sodium acetylsalicylate water

A standardised sodium hydroxide solution of 0.0250 mol L^{-1} was placed in a 50.0 mL burette.

One tablet was crushed and dissolved in 15.0 mL of ethanol in a 100 mL volumetric flask. The solution was then made up to the mark with distilled water.

A 20.0 mL sample of the dilute tablet solution was pipetted into a conical flask with a few drops of the indicator phenolphthalein.

After an initial 'rough titration', a further three titrations were performed each time using 20.0 mL of acetylsalicylic acid solution. These results are shown in the following table.

Titration number	**Burette readings (mL)**		
	Initial	**Final**	**Titre**
1	1.70	23.6	21.9
2	23.6	45.3	21.7
3	1.50	23.3	21.8

Using the information collected, determine whether the mass of acetylsalicylic acid in the tablet matches the information on the packaging and determine the percentage purity of the tablet. **6**

Marking Criteria	*Mark(s)*
• All relevant working shown to calculate the purity of the tablet with correct sig figs • Calculates moles NaOH on average • Identifies moles in 20 mL conical flask $n_{ASA} = n_b$ • Calculates moles of ASA per tablet $= n_{ASA} \times 5$ • Mass of ASA calculated correctly • Mass given in mg • Calculate percentage purity including Sig Figs	6
• Most relevant working shown to calculate the purity of the tablet with correct sig figs OR • All relevant working shown to calculate the purity of the tablet with incorrect sig figs	5
• Most relevant working shown to calculate the purity of the tablet	4
• Some relevant steps in the working shown	3
• Some working shown	2
• Some relevant information	1

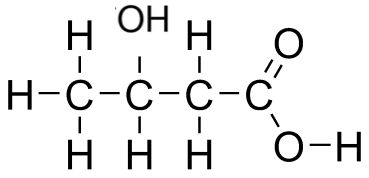
Average titre = 21.9 + 21.7 + 21.8 /3 = 21.8 mL
mol NaOH = c x V
= 0.025 x 21.8/1000
= 5.45×10^{-4} mol

mol acid = mol base

mol acid = 5.45×10^{-4} mol in 20mL of solution
mol acid in one tablet = 5.45×10^{-4} /0.2 or x 5
= 2.725×10^{-3}
mol acid = m/MM
mass acid = n x MM
= 2.725×10^{-3} x (9(12.01) + 8(1.008) + 4(16))
= 2.725×10^{-3} x 180.2
= 0.49104g
= 491.04 mg
% purity = $\frac{\text{Actual mass of aspirin}}{\text{theoretical mass of aspirin}} \times 100\%$
(491.04/500) x 100 = 98.2%

Question 26 (10 marks)

Polyhydroxy butyrate (PHB) is a bio-derived polymer that can be used in biodegradable plastics. PHB is formed from the monomer below with a molar mass of 104.1g mol^{-1}.

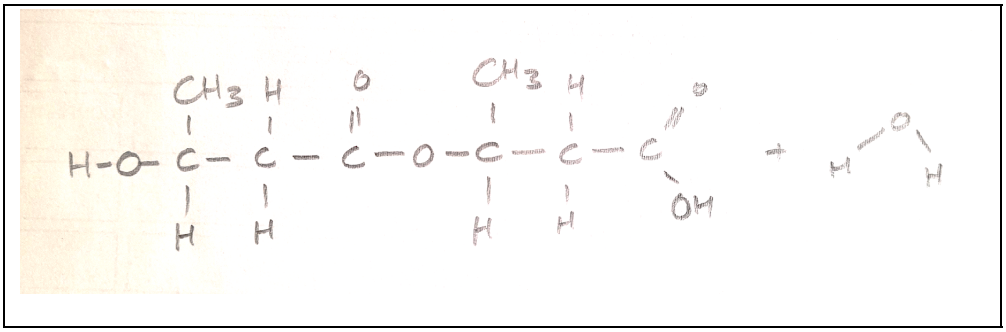


(a) Give the IUPAC name for the PHB monomer. **1**

3-hydroxy butanoic acid.

Marking Criteria	*Mark(s)*
• Correctly names the monomer	1

(b) Use structural diagrams to show the products formed when two PHB monomers combine to begin to form the polymer polyhydroxy butyrate. **2**



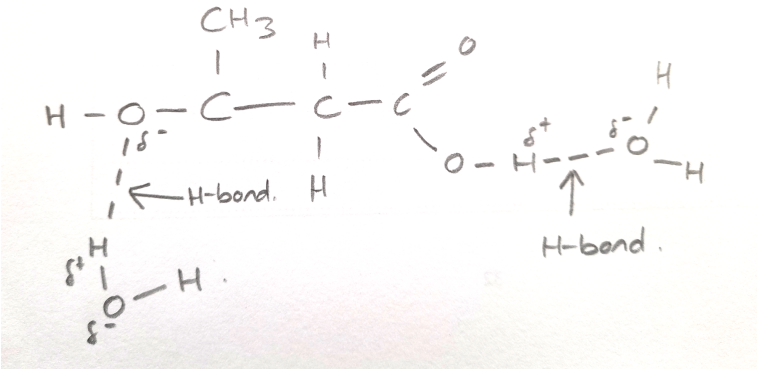
Marking Criteria	*Mark(s)*
• Correctly draws two monomers combining to give two products	2
• Mostly correct addition of two monomers	1

(c) The PHB monomer has a solubility of 53.9 g/100 mL in water at 25°C.
Calculate its concentration in mol L^{-1}. **2**

n 3-hydroxy butanoic acid = m/MM = 53.9/104.1 = 0.5177 mol in 100 mL
[3-hydroxy butanoic acid] = 0.5177 x 10 mol/L. = 5.18 molL^{-1}

Marking Criteria	*Mark(s)*
• Correctly calculates the concentration of 3-hydroxy butanoic acid showing relevant working	2
• Shows some calculation	1

(d) Use a labelled diagram to show the intermolecular forces acting between water and The PHB monomer. **2**



Marking Criteria	*Mark(s)*
• Correctly shows hydrogen bonding of the molecule with water	2
• Shows some interaction between the molecule and water OR correctly labels an intermolecular force	1

(e) Compare TWO environmental implications of using PHB as a plastic instead of a petrochemical plastic. **3**

PHB is bio-derived so it is a renewable resource and is also biodegradable so it can be of benefit to the environment in that waste is not created. A petrochemical plastic, eg polythene, is made from crude oil which is not renewable. The plastic is not biodegradable and therefore can build up as waste in landfill, or be discarded into the ocean, having a negative effect on the environment.

Marking Criteria	*Mark(s)*
• Compares the environmental implications of using PHB instead of an identified petrochemical plastic	3
• Compares the environmental implications of using PHB instead of a petrochemical plastic	2
• Gives some relevant information	1

Question 27 (3 marks)

Blood pH is maintained in a narrow range of 7.35 to 7.45 by a buffering system involving carbon dioxide ad bicarbonate ions.

Explain how this buffer works in blood using a relevant equation in your answer. **3**

Buffers are solutions that contain equitable amounts of a weak acid and its a conjugate base As such, they can absorb excess H^+ ions or OH^- ions, thereby limiting any change to the pH in the solution. They **are able to neutralise small amounts of other acids and bases (in the form of H_3O^+ and OH^-) when added to the solution.**
The buffer that maintains the pH of human blood involves carbonic acid (H_2CO_3), bicarbonate ion (HCO_3^-), and carbon dioxide (CO_2). When bicarbonate ions combine with hydrogen ions and become carbonic acid, hydrogen ions are removed, reducing pH changes and shifting the equilibrium to the right. If excess base is in the blood, the equilibrium will shift to the left as the hydrogen ions are neutralised.

$$H^+(aq) + HCO_3^-(aq) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H_2O(l) + CO_2(g)$$

Marking Criteria	*Mark(s)*
• Defines a buffer • Explains how this buffer works in blood including a correct relevant equation	3
• Explains how this buffer works in blood including a relevant equation OR • Defines a buffer and explains how this buffer works in blood	2
• Defines a buffer OR • Provides some information about this buffer in blood	1

Question 28 (4 marks)

Propanoic acid is a weak monoprotic acid.

(a) A student dissolved 7.4g of propanoic acid in 100.0 mL of water, at 25°C.

The acid ionisation constant Ka = 1.35×10^{-5} mol L^{-1}.

Calculate the pH of the equilibrium mixture. **3**

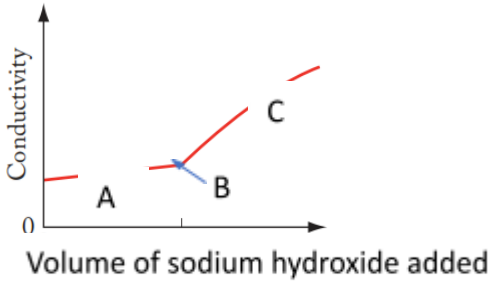
MM propanoic acid = 3(12.01) + 6(1.008) + 2(16)
mol acid = m/MM
= 7.4/74.078
= 0.09989… mol
c acid = n/v
$= \frac{7.4/74.078}{0.100}$
= 1.0 mol L^{-1} (0.9989… mol L^{-1})

$K_a = \frac{[CH_3CH_2COO^-][H^+]}{[CH_3CH_2COOH]}$
Let x mol L^{-1} = the amount of propanoic acid that ionises
So $[CH_3CH_2COO^-] = [H^+] = x$ therefore $[CH_3CH_2COOH] = 1.0 - x$
$K_a = \frac{x^2}{1.0 - x} = 1.35 \times 10^{-5}$ mol L^{-1}

Assume that x is very small so $1.0 - x = 1.0$ then solve for x.
$K_a = \frac{x^2}{1.0} = 1.35 \times 10^{-5}$ mol L^{-1}
Therefore $x = 3.67 \times 10^{-3}$ (so x is very small)
$[H^+] = 3.67 \times 10^{-3}$ mol L^{-1}
$[H^+] = 3.7 \times 10^{-3}$ mol L^{-1}
pH = $-\log[H^+]$
$= -\log 3.7 \times 10^{-3}$
= 2.43

Marking Criteria	*Mark(s)*
• Correctly calculates no moles and concentration of solution • Correctly calculates concentration of H^+ • Correctly calculates pH	3
• Shows most relevant working	2
• Shows some relevant working	1

(b) Explain the shape/point of the conductivity curve at the sections/point labelled A, B and C, produced when propanoic acid is titrated with sodium hydroxide. **5**



As propanoic acid is a weak organic acid with a small Ka, it is mostly molecular in solution and therefore in section A of the curve, conductivity is low as there are few ions in solution. This increases slowly as sodium ions are added. Equivalence is at B where there is the stoichiometric balance of reactants and neutralisation of the acid. In section C the conductivity increases as sodium and hydroxide ions are added in excess and are available to conduct current.

Marking Criteria	*Mark(s)*
• Explains the shape/point of the conductivity curve at A, B and C	5
• Describes the parts of the conductivity curve at A, B and C OR • Explains 2 shapes/point of the conductivity curve.	4
• Outlines the shapes of the conductivity curve at A, B and C OR • Explains A, B or C of the curve	3
• Outlines A, B or C of the curve	2
• Gives some relevant information	1

Question 29 (12 marks)

The solubility of copper (II) sulfate at different temperatures was accurately determined experimentally. The results are tabulated below.

Temperature °C	Solubility in g/100g	Temperature °C	Solubility in g/100g
0	13	60	40
10	17	70	47
20	21	80	56
30	24	90	67
40	29	100	80
50	34		

(a) Graph the data.

Marking Criteria	*Mark(s)*
• Correct graph features, axes, scale, plots, curve of best fit	4
• Most graph features correct	3
• Some graph features correct	2
• A relevant graph feature	1

(b) Explain the change in colour intensity of a saturated solution as temperature increases. Include a relevant equation in your answer. **4**

$CuSO_4\ (s) + heat \leftrightarrows CuSO_4\ (aq)$

The colour intensity increases with increasing temperature as more solid dissolves as the temperature increases. This shows that the dissolution of copper sulfate is endothermic, shifting equilibrium to the right with an increase in temperature (Le Chatelier).

Marking Criteria	*Mark(s)*
• Explains the increase in colour intensity using Le Chaletier's principle with a relevant equation	4
• Describes the increase in colour intensity	3
• Outlines the change in colour intensity	2
• Gives some relevant information	1

(c) A copper (II) sulfate saturated solution was prepared at 45 °C.

(i) Determine the concentration of copper (II) sulfate in $molL^{-1}$ at that temperature. **2**

From the graph, at 45 °C 31 g of copper (II) sulfate will be soluble in 100 g of water.
Mol $CuSO_4$ = m/MM = 31/159.6 = 0.194mol in 100g
Therefore $[CuSO_4] = 1.94\ mol\ L^{-1}$

Marking Criteria	*Mark(s)*
• Correctly interpret the graph. • Correctly converts the unit of concentration.	2

(ii) Calculate the Ksp of the solution at that temperature. **2**

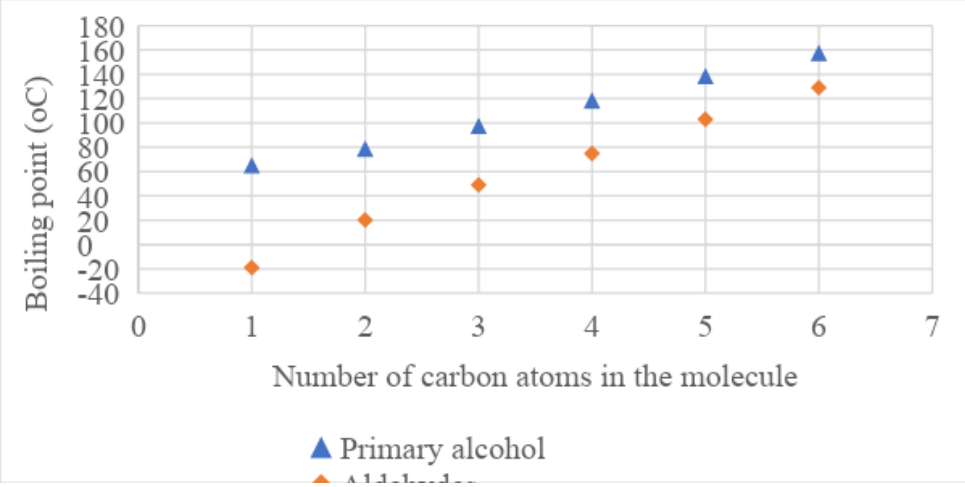
$[Cu^{2+}] = [SO_4{}^{2-}] = 1.94\ mol\ L^{-1}$
$K_{sp} = [Cu^{2+}][SO_4{}^{2-}]$

Hence $K_{sp} = (1.94)^2 = 3.78$

Marking Criteria	*Mark(s)*
• Correctly calculates the K_{sp}.	2
• Correctly gives the K_{sp} expression.	1

Question 30 (4 marks)

The boiling points of straight chain primary alcohols and aldehydes are given in the following graph.



Explain the trends in the boiling points shown in the graph. **4**

The boiling points for both the alcohols and the aldehydes increase with increasing number of carbon atoms. This is due to an increase in dispersion forces as the molar mass increases with increasing chain length.

The boiling point of the alcohol is always higher than the corresponding aldehyde. This is due to the hydrogen bonding between the alcohols being stronger intermolecular forces than the

dispersion and dipole-dipole forces between the molecules of the aldehydes.As it takes more energy to overcome these stronger intermolecular forces, the boiling points of the alcohols are higher than the aldehydes.

The difference between the boiling points of similar chain length molecules decreases with increasing chain length. e.g for one carbon in the chain the difference is approx. 85 degrees whereas, with 6 carbons in the chain the difference is only approx. 30 degrees This is due to the hydrogen bonding having a smaller contribution to the total intermolecular forces as the chain length increases and dispersion forces become the dominant intermolecular force. This is similar for the alcohols and the aldehydes.

Marking Criteria	*Mark(s)*
• Explains three patterns in the boiling points	4
• Explains most of the patterns in the boiling points	3
• Describes the patterns in the boiling points OR • Explains a pattern in the boiling points	2
• Provides some relevant information	1

Question 31 (4 marks)

What is the pH of the final solution when 100 mL of 0.60 $molL^{-1}$ hydrochloric acid is added to 100 mL of 0.20 $molL^{-1}$ magnesium hydroxide? **4**

$2HCl\ (aq) + Mg(OH)_2\ (aq) \rightarrow MgCl_2\ (aq) + 2H_2O\ (l)$

n HCl = c x v = 0.60 x 0.1 = 0.06 mol

n $Mg(OH)_2$ = c x v = 0.20 x 0.1 = 0.02 mol

n OH^- = 2 x mol $Mg(OH)_2$ = 2 x 0.02 = 0.04 mol

therefore, H^+ in excess = 0.06 – 0.04 = 0.02

$[H^+]$ = n/V = 0.02/0.1 + 0.1 = 0.1

pH = -log $[H^+]$ = -log 0.1 = 1

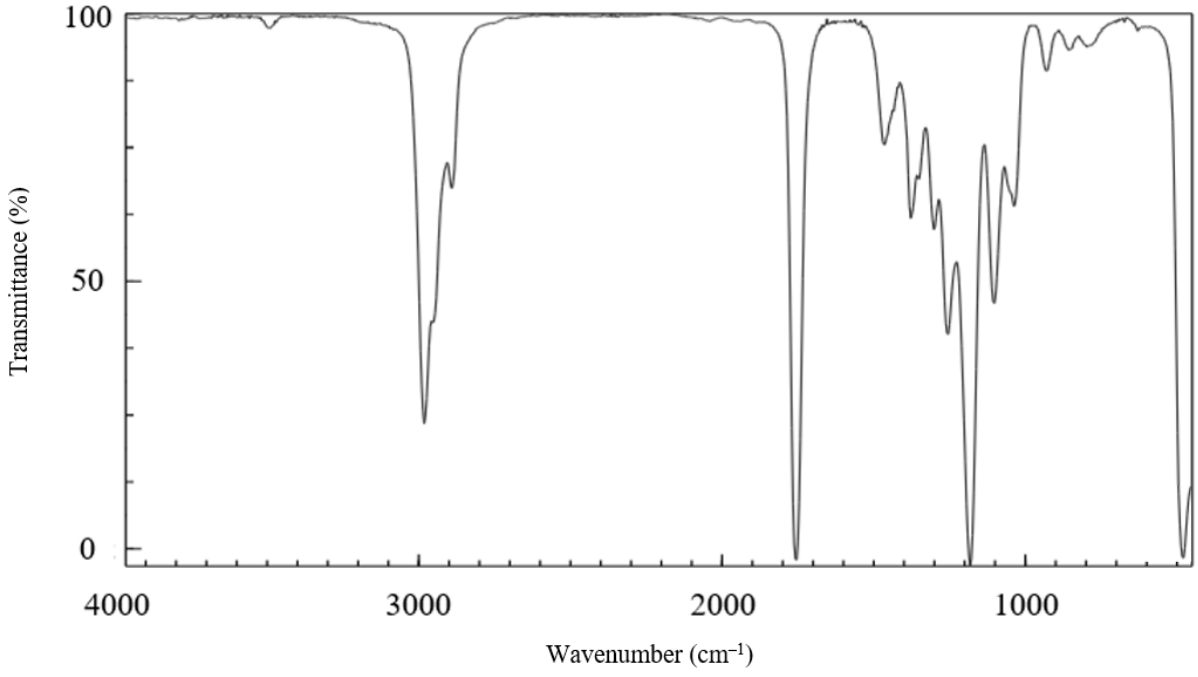
Marking Criteria	*Marks*
• Calculates mol of each reactant • Uses 2:1 ratio • Calculates concentration of excess H^+ • Calculates pH • Shows all relevant working	4

• Most relevant working shown	3
• Some relevant working shown	2
• Gives the equation OR • Calculates one mol amount • Calculates pH	1

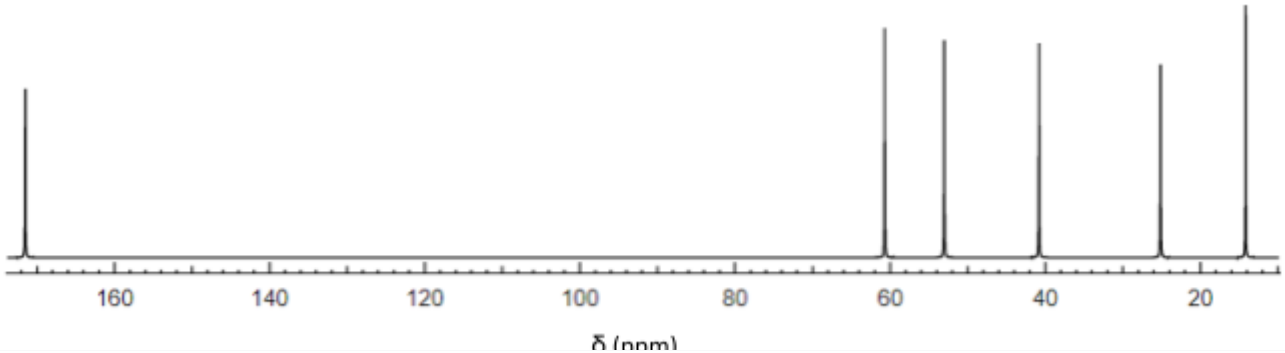
Question 32 (7 marks)

A mystery compound was discovered in an organic chemistry laboratory with the chemical formula $C_6H_{11}O_2Cl$. In order to determine its structure a range of analysis techniques were performed on the sample including infrared, ^1H NMR and ^{13}C NMR spectroscopy. The spectra obtained from this analysis are presented as follows:

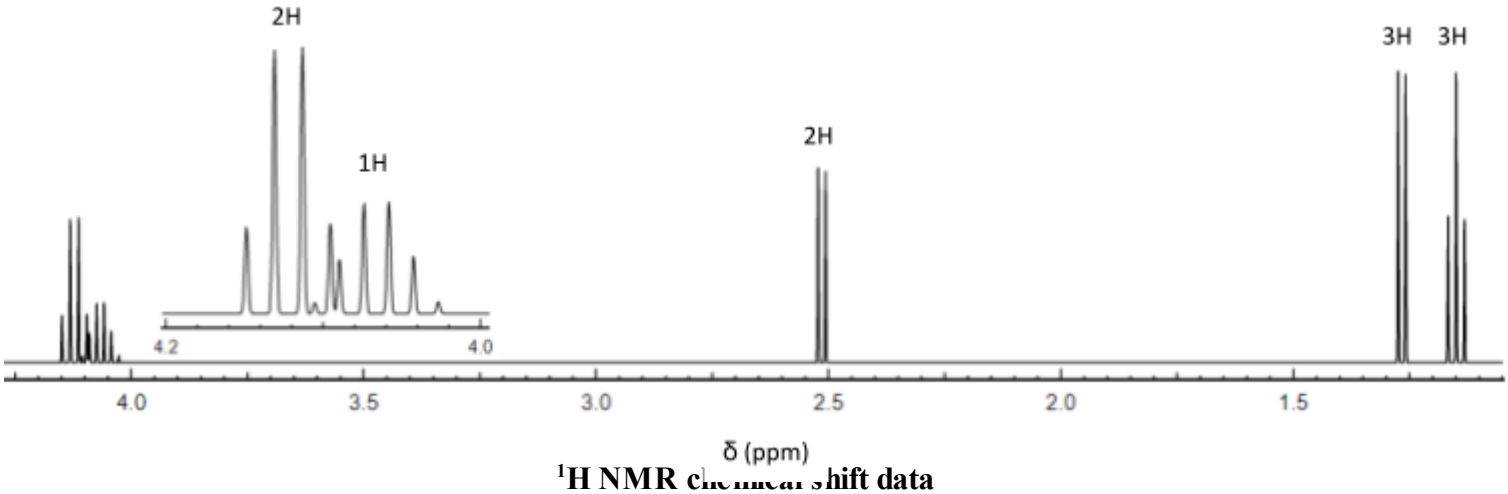
Infrared spectrum



^{13}C NMR spectrum



^{1}H NMR spectrum

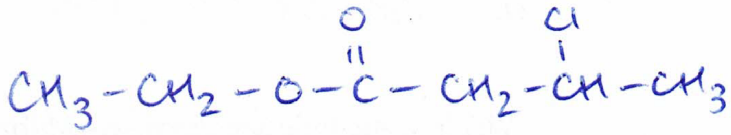


^{1}H NMR chemical shift data

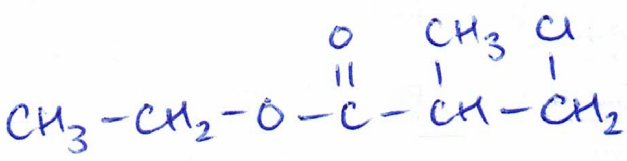
In the space provided, draw the structural formula for the mystery compound that is consistent with all the information provided. Justify your answer with reference to the information provided. **7**

Sample answer:

preferred solution:



also acceptable:



IR spectrum

The IR spectrum shows a strong absorption peak at 1750 cm^{-1} which identifies the presence of a C=O in the molecule. This suggests the functional group could be a carboxylic acid, ester,

ketone, or aldehyde. The absence of a broad O-H group at 2500 – 3000 cm^{-1} and the presence of a C-O stretch at 1200 cm^{-1} confirms the presence of an ester group in this molecule.

^{13}C NMR spectrum

The carbon spectrum has a clear signal at roughly 170 ppm which is diagnostic for the carbon atom present in an ester or carboxylic acid. This assignment is consistent with the confirmation that the functional group present is an ester. There is also a distinct signal at roughly 60 ppm which is outside the 5 – 40 ppm range for C-H and C-C bonds in the molecule. This peak must correspond to a carbon atom that is attached to a halogen, which in this case would be a C-Cl bond. There is also another carbon signal outside this range that most likely belongs to the carbon atom in the chain attached to the single bonded oxygen in the ester.

^{1}H NMR spectrum

There is a quartet at roughly 4.15 ppm which contains two hydrogen atoms that must have three neighbouring hydrogen atoms. This is coupled with the triplet signal at 1.15 ppm which contains three hydrogen atoms that must have two neighbouring hydrogen atoms. Both these signals correspond to a CH_2CH_3 ethyl chain in the molecule.

There is a sextet at roughly 4.05 ppm which contains one hydrogen atom that must have five neighbouring hydrogen atoms. The sextet signal must correspond to the hydrogen atom that is attached to the same carbon atom as the chlorine, due to the relatively high ppm value and lack of bonds available. This is coupled with two separate doublet signals. One doublet is at 1.25 ppm which contains three hydrogen atoms that must have one neighbouring hydrogen atom. Similarly, there is another doublet signal at 2.50 ppm which contains two hydrogen atoms that must also have one neighbouring hydrogen atom. These signals account for a $CH_2CHClCH_3$ chain in the molecule.

The spectroscopic data provided from both the carbon and hydrogen spectra both suggest that the ethyl chain is attached to the single oxygen atom in the ester group, with the other chain attached to the carbon atom of the ester group.

Marking Criteria	*Mark(s)*
• Draws the correct structural formula for ethyl-2-chlorobutanoate or ethyl-3-chloro-2-methylpropanoate (naming not required). • Justifies the correct structure showing an extensive understanding of the interpretation of spectroscopic data. • Refers explicitly to ALL relevant spectroscopic data.	7
• Draws the correct structural formula for an isomer of ethyl-2-chlorobutanoate or ethyl-3-chloro-2-methylpropanoate. • Justifies the structure showing a thorough understanding of the interpretation of spectroscopic data. • Refers to relevant spectroscopic data from all three spectra.	6
• Provides a structural formula consistent with analysis. • Shows a sound understanding of the interpretation of spectroscopic data. • Refers to relevant spectroscopic data from at least two spectra.	4-5

● Shows some understanding of the interpretation of spectroscopic data from at least two spectra.	2-3
● Provides some relevant information.	1

Question 33 (4 marks)

As part of this course, students conducted quantitative investigations to analyse inorganic substances. In one such instance a group of students determined the chloride ion concentration present in seawater using two different methods.

Volumetric method – a sample of seawater was titrated with standardised silver nitration solution until precipitation ceased.

Gravimetric method – a sample of seawater was reacted with silver nitrate solution to form a precipitate, which was collected via filtration and weighed.

The sample of seawater was titrated with the standardised silver nitrate solution and the average titre volume was found to be 2.1 mL.

(a) Suggest ONE improvement that could be made to improve the accuracy of the titre values. and explain your reasoning **2**

Sample answer:
Either the sample of seawater or the standardised silver nitrate solution should be diluted (by a factor of 10) before the titration experiment is carried out. By doing this, students will record larger titre volumes. The increase in the number of significant figures in the data obtained will increase the accuracy of the titre values.

Marking Criteria	*Mark(s)*
● Provides an appropriate suggestion and rationale to improve the accuracy of the titre values.	2
● Provides a relevant suggestion to improve the accuracy	1

A difficulty encountered with titration reactions is to accurately determine when the reaction has reached completion.

(b) Describe a technique, students could use to determine that all the chloride ions had been precipitated in the gravimetric method with reference to a relevant observation. **2**

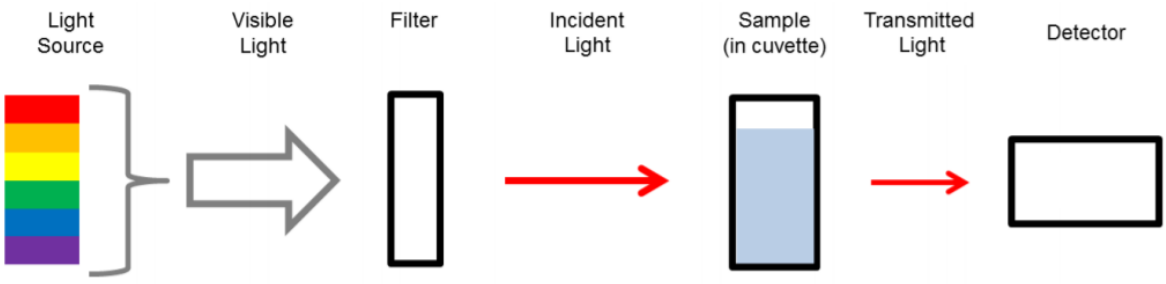
Sample answer:

The students can check that all the chloride ions have been precipitated by testing the filtrate with some silver nitrate solution. If no precipitation occurs when silver nitrate is added to the filtrate solution, then it confirms that there are no chloride ions remaining in solution.

Marking Criteria	*Mark(s)*
• Provides an appropriate suggestion and rationale to test for chloride content in gravimetric analysis.	2
• Provides a relevant suggestion to gravimetric analysis.	1

Question 34 (4 marks)

A colorimetric investigation was carried out to determine the concentration of barium ions present in waste water. The sample was placed into a quartz cuvette (2 cm x 2 cm x 5 cm) and analysed using the colorimetry setup illustrated in the diagram provided.



It was discovered that the detector for the colorimeter was faulty, so a luxmeter was used to record the light intensity values in this experiment. The light intensity of the incident ray was found to be 683 lumens whereas the transmitted ray had an intensity of 294 lumens. Given that the barium ions have a molar extinction coefficient of 80.5 mol^{-1} cm^{-1}, determine the concentration of barium ions in the solution in ppm. **4**

Sample answer:

$A = \log_{10} (Io / I) = \log_{10} (683 / 294) = 0.366$

$c(mol) = A / \varepsilon l = 0.366 / 80.5 \times 2 = 2.27 \times 10^{-3}$ mol L^{-1}

$c(ppm) = 2.27 \times 10^{-3} \times 137.3 = 0.312$ g $L^{-1} = 312$ mg $L^{-1} = 312$ ppm.

Marking Criteria	*Mark(s)*
• Correctly calculates the concentration of chloride ions in ppm (calculates the absorbance value, concentration of barium ions, unit conversion to mass per volume, and ppm).	4
• Provides the main steps of the calculation	3
• Provides some relevant steps of the calculation	2
• Provides some relevant information	1