2
Centre Number

Student Number

ABBOTSLEIGH

2023 **TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION**

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – **20 marks** (pages 2 – 12)

- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – **80 marks** (pages 13 – 35)

- Attempt Questions 21–33
- Allow about 2 hours and 25 minutes for this section

Section I

20 marks
Attempt Questions 1–20
Allow about 35 minutes for this part.

Use the multiple-choice answer sheet at the back of this paper for Questions 1–20.

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1 When a solution of a primary standard is prepared for titration, which of the following is required?

A. An electronic balance.

B. A burette.

C. A pipette.

D. An indicator.

2 What flame colour do copper ions produce when heated?

A. Brick red.

B. Blue-green.

C. Pale purple.

D. Yellow-orange.

3 Which list contains members of the same homologous series?

A. C_2H_6, C_4H_8, C_6H_{10}

B. C_2H_3Br, $C_2H_4Br_2$, $C_2H_3Br_3$

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

D. C_2H_5OH, C_2H_5Cl, $C_2H_5NH_2$

4 Identify the correct balanced equation for the incomplete combustion of C_4H_9OH.

A. $2C_4H_9OH(l) + 12O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$

B. $2C_4H_9OH(l) + 12O_2(g) \rightarrow 8CO(g) + 10H_2O(l)$

C. $C_4H_9OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$

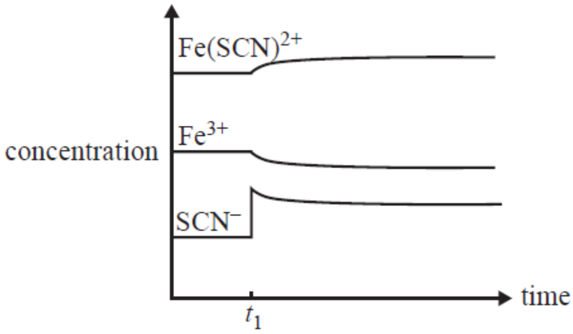
D. $C_4H_9OH(l) + 4O_2(g) \rightarrow 4CO(g) + 5H_2O(l)$

Questions 5 and 6 refer to the following information.

5 Belle studied the following equilibrium reaction:

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons [Fe(SCN)]^{2+}(aq) \quad \text{where } \Delta H < 0$$

The concentration profile below represents a change to the above equilibrium system at time t_1.



Which one of the following would account for the changes in concentration at time t_1?

A. the addition of SCN^{-}

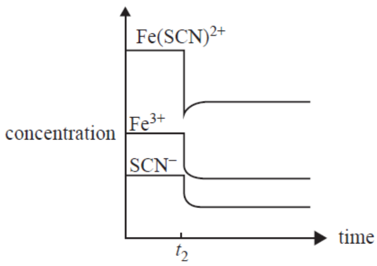
B. the removal of $[Fe(SCN)]^{2+}$

C. an increase in temperature

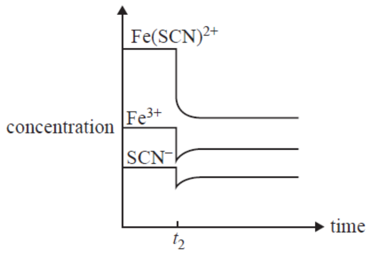
D. a decrease in temperature

6 Which one of the following best represents the changes in concentration when the equilibrium mixture is diluted at time t_2?

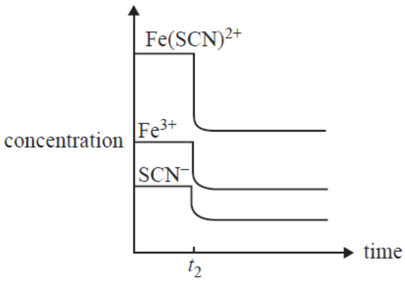
A.



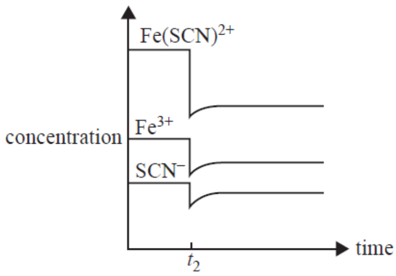
B.



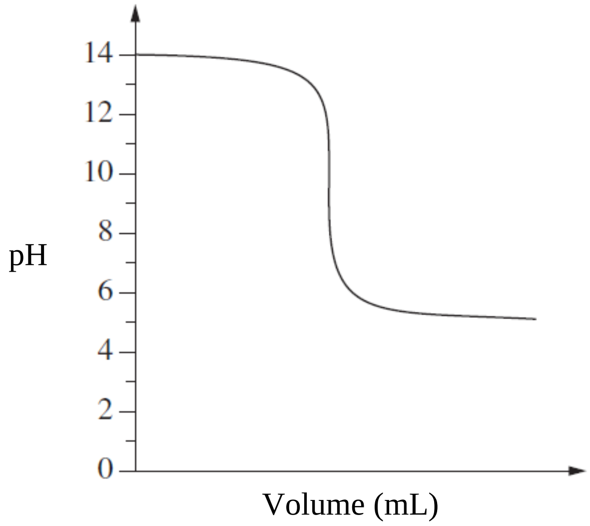
C.



D.



7 The graph shows the changes in pH during a titration.



Which pH range should an indicator have to best determine the end point of this titration?

A. 3.1 – 4.4

B. 5.0 – 8.0

C. 6.0 – 7.6

D. 8.3 – 10.0

8 Which list consists of amphiprotic substances only?

A. H_2CO_3, H_2O and HSO_4^-

B. HCO_3^-, H_2O and H_2SO_4

C. H_2CO_3, H_2O and SO_4^{2-}

D. HCO_3^-, H_2O and HSO_4^-

9 Consider the following equilibrium:

$$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g) \qquad \Delta H = +208 \text{ kJ mol}^{-1}$$

Which statement best describes the effect of increasing temperature in terms of collision theory?

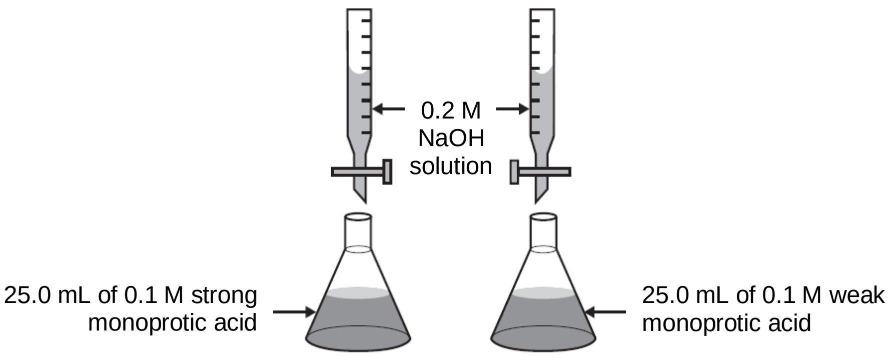
A. All reactant and product molecules have more energy and move more quickly; increased temperature has a greater effect on the exothermic reaction than the endothermic reaction and so the equilibrium shifts to the right.

B. All reactant and product molecules have more energy and move more quickly; increased temperature has a greater effect on the endothermic reaction than the exothermic reaction and so the equilibrium shifts to the right.

C. All reactant and product molecules have less energy and move more slowly; increased temperature has a greater effect on the endothermic reaction than the exothermic reaction and so the equilibrium shifts to the right.

D. All reactant and product molecules have less energy and move more quickly; increased temperature has a greater effect on the endothermic reaction than the exothermic reaction and so the equilibrium shifts to the left.

10 Two titrations were performed as shown below:



Which one of the following statements is true?

A. The weak acid will require a greater volume of NaOH solution than the strong acid to reach equivalence point.

B. The weak acid will require a smaller volume of NaOH solution than the strong acid to reach equivalence point.

C. The weak acid will require the same volume of NaOH solution as the strong acid to reach equivalence point.

D. The strong acid will require double the volume of NaOH solution as the weak acid to reach equivalence point.

11 A solution containing an unknown salt was tested using a number of steps. The table below shows the tests carried out and the observed results.

Step	*Procedure*	*Results*
1	Added nitric acid	No reaction
2	Added barium nitrate	No reaction
3	Added silver nitrate	White precipitate formed
4	Added sodium sulfate to a fresh sample	No reaction
5	Added sodium hydroxide to a fresh sample	A green precipitate formed which turned brown on standing

The student identified the salt as:

A. Iron (II) chloride

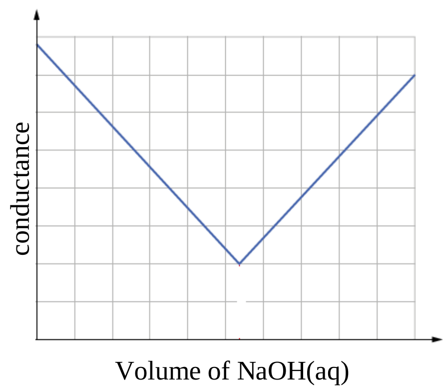
B. Iron (III) chloride

C. Iron (II) sulfate

D. Iron (III) sulfate

12 Identify the correct conductometric titration curve for acetic acid and sodium hydroxide.

A.



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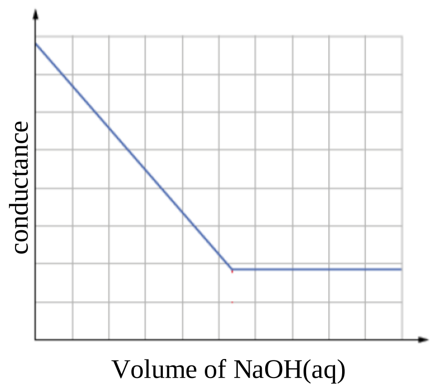

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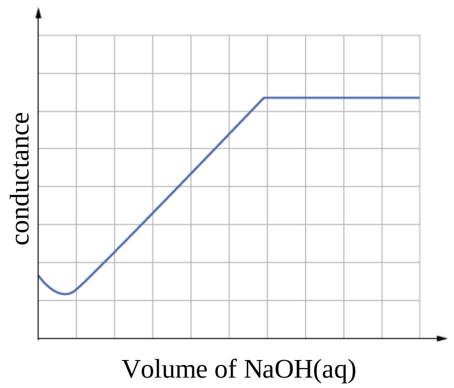
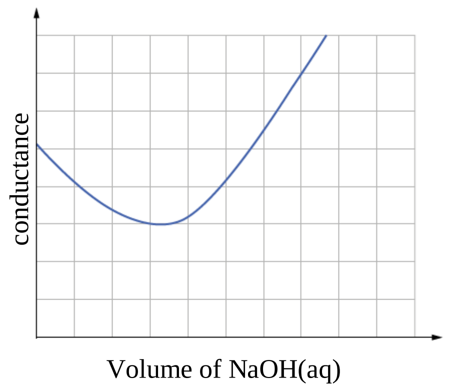


D.



13 A 0.10 M solution of fluoride ions is gradually added to a solution containing Ba^{2+}, Ca^{2+} and Pb^{2+} ions, each at a concentration of 0.0010 M.

In what order, from first to last, will the precipitates of BaF_2, CaF_2 and PbF_2 form?

Salt	K_{sp}
BaF_2	1.8×10^{-7}
CaF_2	1.5×10^{-10}
PbF_2	7.1×10^{-7}

A. CaF_2, PbF_2, BaF_2

B. BaF_2, CaF_2, PbF_2

C. PbF_2, BaF_2, CaF_2

D. CaF_2, BaF_2, PbF_2

14 Mulan prepares a dilute solution of cobalt (II) chloride in a small beaker, stirring until it becomes a consistent colour. The equilibrium is endothermic as written below:

$$\underset{\textit{pink}}{[Co(H_2O)_6]^{2+}(aq)} + 4Cl^-(aq) \leftrightharpoons \underset{\textit{blue}}{[CoCl_4]^{2-}(aq)} + 6H_2O(l)$$

Mulan pours some of the solution into three separate test tubes. To the first test tube she adds some hydrochloric acid. To the second test tube she adds some silver nitrate solution, and a precipitate immediately forms. She places the third test tube in a larger beaker of ice water.

What would be the expected observations for each test tube?

	Expected observations		
	Test tube 1: HCl(*aq*) added	*Test tube 2:* $AgNO_3$(*aq*) added	*Test tube 3:* ice bath
A.	More pink	More blue	More pink
B.	More blue	More pink	More pink
C.	More blue	More blue	More blue
D.	More blue	More pink	More blue

15 A 2.45 g sample of a supermarket brand lawn fertiliser was analysed using gravimetric analysis for its sulfate content. After filtration and drying to constant mass, 2.18 g of barium sulfate was recovered.

What is the % w/w of sulfate in the fertiliser?

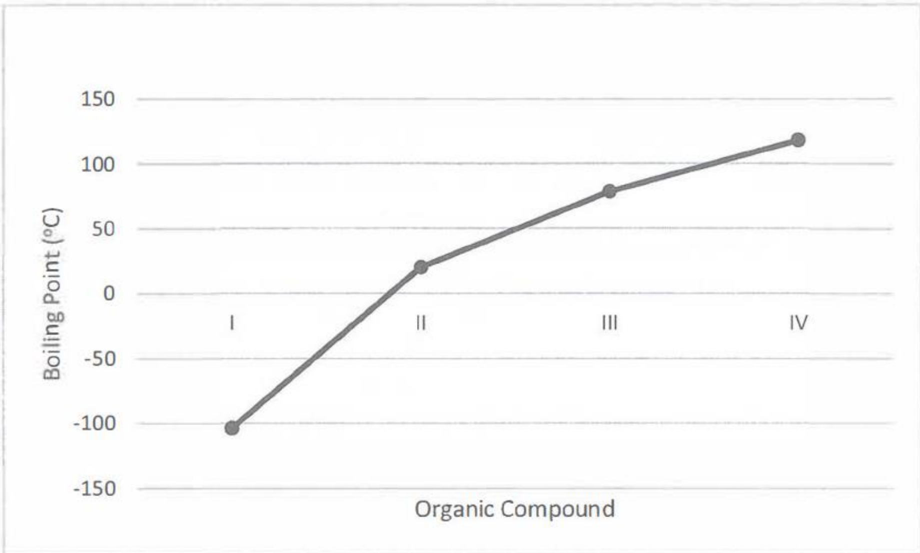
A. 16.8%

B. 36.6%

C. 46.2%

D. 89.7%

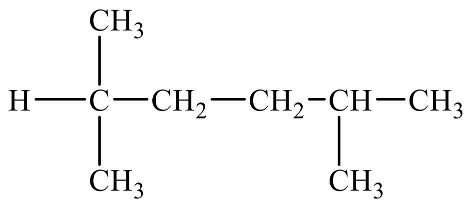
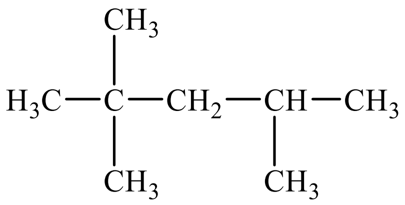
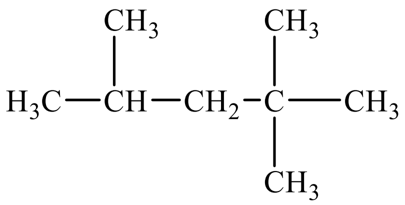
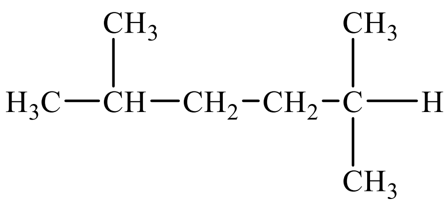
16 The graph below shows the boiling point of four different organic compounds.



Which row of the table correctly classifies the following compounds based on their boiling point.

	I	II	III	IV
A.	ethane	ethanal	ethanol	ethanoic acid
B.	ethanal	ethane	ethanol	ethanoic acid
C.	ethanal	ethane	ethanoic acid	ethanol
D.	ethane	ethanal	ethanoic acid	ethanol

17 Look at the structures below:

I	
II	
III	
IV	

Which structure is that of 2,2,4-trimethylpentane?

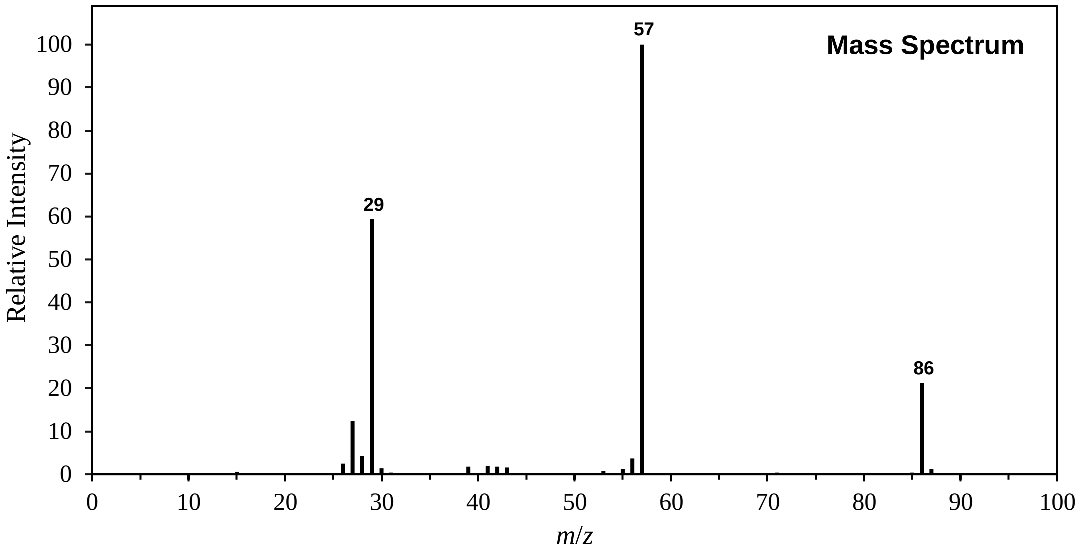
A. I and III only

B. I and IV only

C. II and III only

D. II and IV only

18 The mass spectrum of pentan-3-one is shown below.



Which ion is responsible for the base peak in the mass spectrum of pentan-3-one?

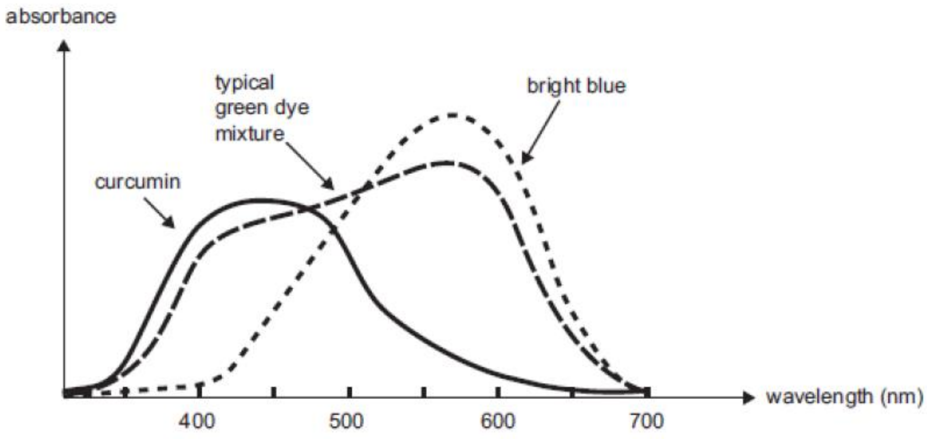
A. $[CH_3CH_2]^+$

B. $[CH_3COCH_2]^+$

C. $[CH_3CH_2CO]^+$

D. $[CH_3CH_2CH_2CH_2]^+$

19 A green dye used to colour tinned peas is made by mixing the yellow chemical, curcumin, with another colouring agent called bright blue. The individual spectra of curcumin, bright blue and a typical green dye are represented below.



UV-Vis spectrometry was used to analyse the curcumin content of tinned peas.

Identify the wavelength which would be best used for absorbance measurements to determine the curcumin content of the peas.

A. 700 nm

B. 575 nm

C. 450 nm

D. 400 nm

20 What is the pH of the resulting solution when 50.0 mL of 0.600 mol L^{-1} sodium hydroxide and 50.0 mL of 0.250 mol L^{-1} sulfuric acid are mixed?

A. 1.30

B. 11.7

C. 12.7

D. 13.2

End of Section I

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2023 **TRIAL HSC EXAMINATION**

2
Centre Number

Student Number

Chemistry

Section II Answer Booklet

80 marks
Attempt Questions 21–35
Allow about 2 hours and 25 minutes for this section

Instructions

- Write your Student Number at the top of this page.
- Answer the 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.

Please turn over

Question 21 (3 marks)

Jasmine and Ariel were curious if cherries could be used as a natural indicator. **3**

Outline how Jasmine and Ariel could both prepare and test a natural indicator made from cherries.

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Question 22 (3 marks)

The Gunwinggu people in the Northern Territory eat the roots of a bitter yam plant, which they call *mangindjeg*. These roots contain salts (oxalates) that would be toxic if consumed raw. **3**

Using this example OR another food prepared by Indigenous peoples, identify at least THREE steps in the preparation and explain how these steps effectively remove the toxins.

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Question 23 (3 marks)

Initially a 2.00 L glass vessel contains a mixture of only 1.00 mole of hydrogen gas and 1.00 mole of iodine gas. The gases react as follows: **3**

$$H_2(g) + I_2(g) \leftrightharpoons 2HI(g)$$

At 400°C, equilibrium is achieved, and the concentration of hydrogen iodide gas is 0.760 mol L^{-1}.

Calculate the equilibrium constant for this reaction at 400°C and state what the value indicates about the reaction. Show all working.

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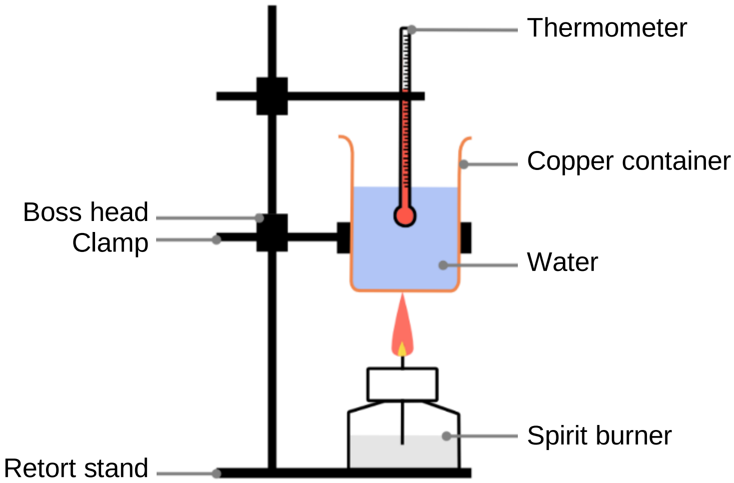
Question 24 (5 marks)

In an experiment to determine the standard enthalpy change of combustion of propan-1-ol, C_3H_7OH, Anna used the apparatus shown below.



(a) Anna measured 50.0 mL of water into the copper calorimeter and lit the Bunsen burner. When the temperature of the water had gone up by 12.8°C, she found that 0.100 g of propan-1-ol had been burnt. **3**

Calculate the molar enthalpy of combustion for propan-1-ol.

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Question 24 continues on page 17

Question 24 (continued)

(b) Anna used a draught shield the second time she carried out this experiment. **2**

Identify how using a draught shield may affect the accuracy of her experimental data and state the effect on the calculated value from part (a).

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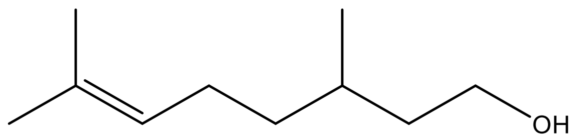
Question 25 (5 marks)

Citronellol is a compound that is found in citronella oils. The structural formula of citronellol is shown below.



(a) Give the molecular formula of citronellol. **1**

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(b) Identify the two most prominent functional groups found in citronellol. **1**

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(c) Predict and justify the solubility of citronellol in water. **3**

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Question 26 (8 marks)

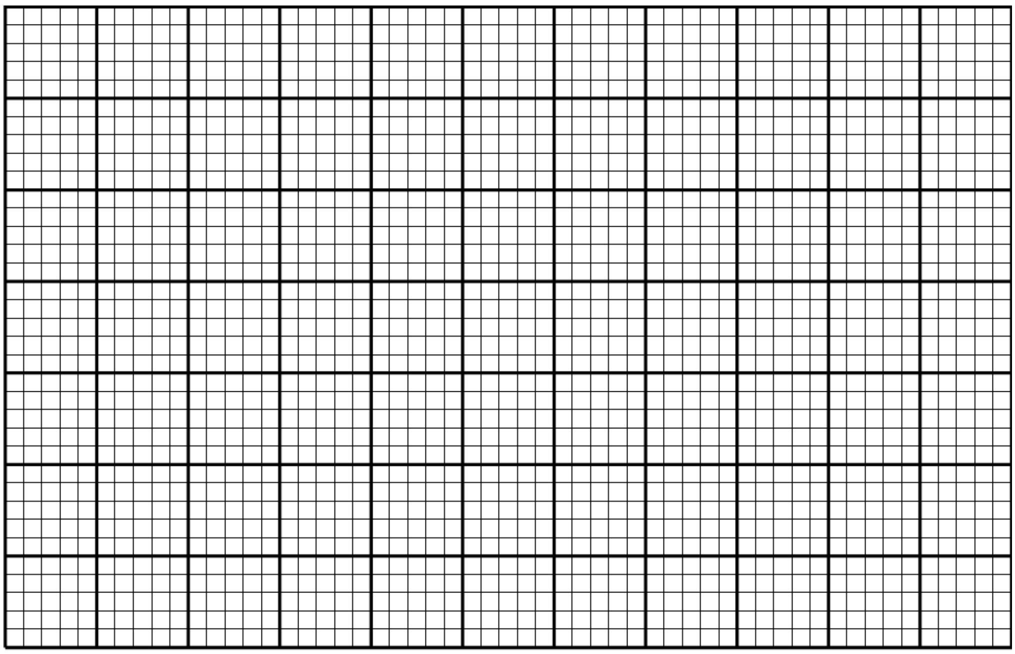
The concentration of copper ions in one sample of river water was determined by colorimetry. An almost colourless sample of the river water was complexed with excess ammonia to form a deep blue solution:

$$\underset{\textit{copper(II) ions}}{Cu^{2+}(aq)} + 4NH_3(aq) \rightleftharpoons \underset{\textit{copper tetraamine ions}}{[Cu(NH_3)_4]^{2+}(aq)}$$

A set of standards were produced, and the absorbance of each standard was measured to produce the table of results below:

Concentration of $[Cu(NH_3)_4]^{2+}$ *ions* (ppm)	*Absorbance*
0.0	0.000
5.0	0.120
10.0	0.219
15.0	0.325
20.0	0.450
25.0	0.567

(a) Draw a calibration graph of the data on the axes provided: **3**



Question 26 continues on page 19

Question 26 (continued)

(b) The intensity of the light after passing through the sample was 42.6%. **3**

The formula below can be used to determine the absorbance, A, of the sample.

$$A = \log_{10} \frac{I_0}{I}$$

Where:

I_o = intensity of the light before passing through the sample

I = intensity of the light after passing through the sample

Use the formula to determine the absorbance of the sample solution and hence calculate the concentration of copper ions in the original solution in mol L^{-1}.

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(c) Outline an alternative technique to colorimetry that could be used to accurately determine the concentration of copper ions if ammonia was not available. **2**

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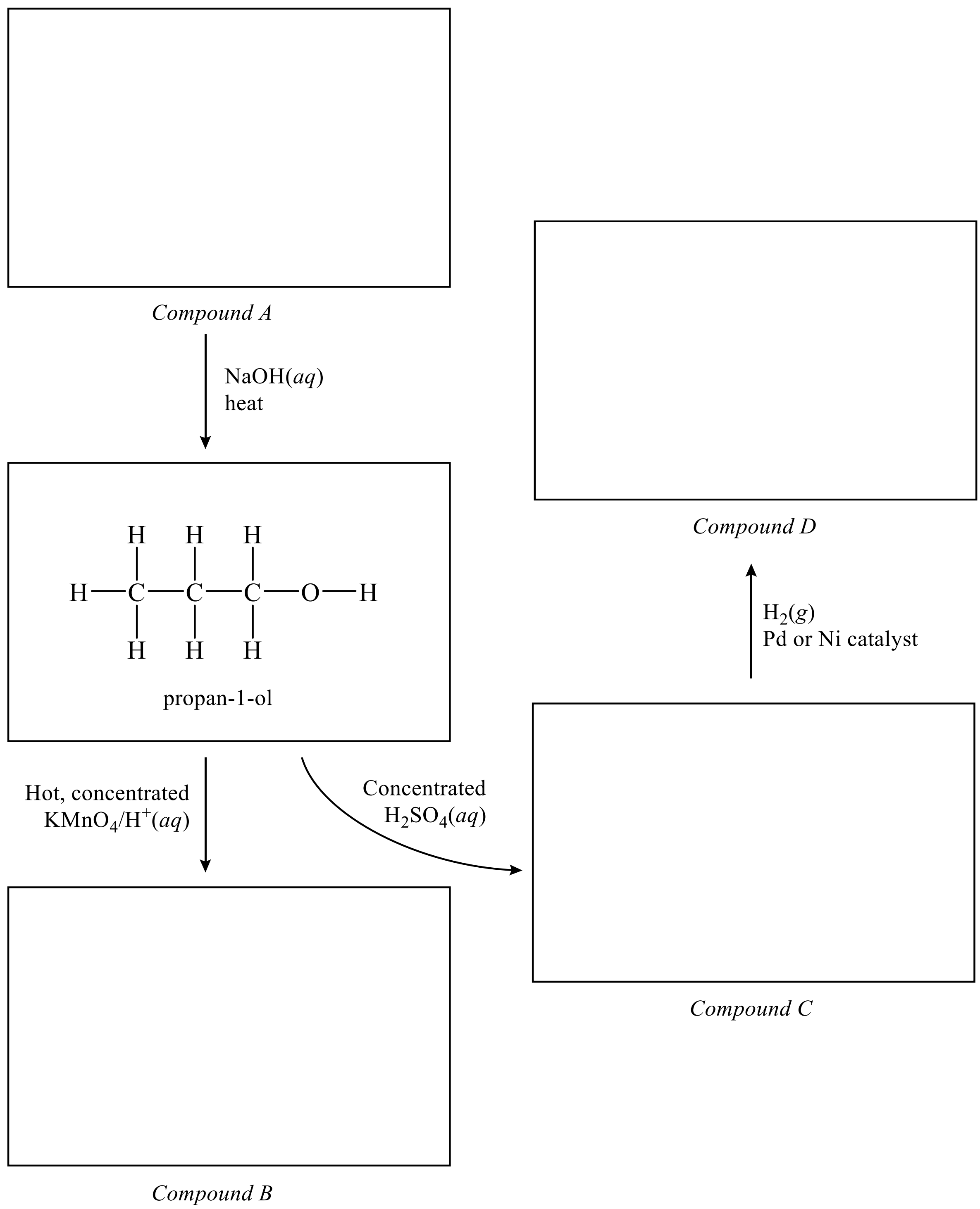
End of Question 26

Question 27 (6 marks)

Shown below is a flow chart of the chemical reactions of a range of organic compounds.



(a) In the appropriate boxes above, draw the structural formulae for compounds A, B, C and D. **4**

Question 27 continues on page 21

Question 27 (continued)

(b) Outline a chemical test that could be carried out in a school laboratory to identify compound C. **2**

Include an expected observation.

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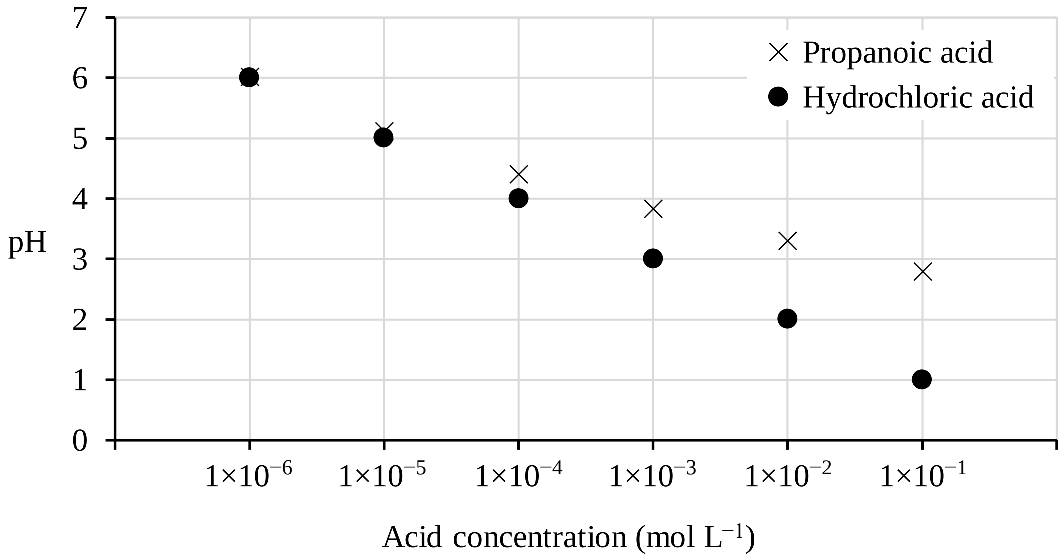
End of Question 27

Question 28 (4 marks)

The effect of concentration on the pH of propanoic acid (C_2H_5COOH) and hydrochloric acid (HCl) solutions are shown in the graph. Both these acids are monoprotic. **4**



Explain the trends in the graph. Include two relevant chemical equations in your answer.

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Question 29 (4 marks)

Lead(II) bromide is a sparingly soluble salt.

$$PbBr_2(s) \rightleftharpoons Pb^{2+}(aq) + 2Br^-(aq) \qquad K_{sp} = 2.1 \times 10^{-6}$$

The table states the molar solubility of lead(II) bromide in water and in various metal bromide solutions of equal concentration at 25°C.

Solvent	*Molar solubility of* $PbBr_2$ *in solvent* (M)
distilled water	8.1×10^{-3}
0.1 M sodium bromide	2.1×10^{-4}
0.1 M aluminium bromide	2.3×10^{-5}

(a) State the common ion effect. **1**

(b) Explain the difference in the molar solubility of lead(II) bromide in each of the solvents in the table. **3**

Question 30 (7 marks)

Snow White has noticed that her chickens' eggshells were noticeably thinner and easily cracked in summer. She found out that an average eggshell should contain between 85 – 93% calcium carbonate.

She decided to take the eggshells to her local chemical laboratory to determine the percentage by mass of calcium carbonate in the eggshells.

Snow White followed the steps below:

1. The shell was dried in a drying oven for 30 minutes to remove any water.
2. The shell was crushed into powder and the powder was weighed using an electronic balance. The mass of the dried eggshell was 1.25 g.
3. The powdered eggshell was transferred into a 250 mL conical flask.
4. Exactly 25.00 mL of 0.971 mol L^{-1} hydrochloric acid was added to the eggshell in the conical flask until the eggshell was completely dissolved. Three drops of phenolphthalein indicator were added to this solution.
5. A standardised solution of 0.598 mol L^{-1} sodium hydroxide was added to a 50.00 mL burette.
6. The sodium hydroxide was titrated against the solution in the flask once, and the titre value was found to be 12.55 mL.

(a) Calculate the percentage by mass of the calcium carbonate in the eggshell AND state whether Snow White has reason to be concerned about her chickens' eggshells. **5**

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Question 30 continues on page 25

Question 30 (continued)

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(b) Snow White read about the effect of heat on the formation of eggshells. **2**

Carbon dioxide is produced as a waste product of cellular respiration which leaves the body through exhalation (breathing out).

The equations below show the steps in the equilibrium system in chickens:

1. $CO_2(g)$ (in chicken breath) $\leftrightharpoons$ $CO_2(aq)$ (in bloodstream)
2. $CO_2(aq) + H_2O(l) \leftrightharpoons H_2CO_3(aq)$
3. $H_2CO_3(aq) \leftrightharpoons 2H^+(aq) + CO_3^{2-}(aq)$
4. $Ca^{2+}(aq) + CO_3^{2-}(aq) \leftrightharpoons CaCO_3(s)$ (egg shells)

When a chicken gets hot, it does not perspire, but it instead pants like a dog.

Using Le Châtelier's principle and the equations above, explain why chickens lay thin-shelled eggs in hot weather.

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End of Question 30

Question 31 (7 marks)

(a) A buffer was made using 50 mL of 0.025 M sodium carbonate solution and 50 mL of 0.025 M sodium hydrogen carbonate solution. **4**

A few drops of universal indicator were added, and the initial colour was observed to be dark blue. Using a probe the pH was determined to be 10.0.

When 1 mL of 0.10 M NaOH(*aq*) was added, no change in the colour of the solution was observed.

Explain the observations of the colour of the indicator before and after the addition of NaOH(*aq*). Support your answer with at least ONE chemical equation.

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Question 31 continues on page 27

Question 31 (continued)

(b) Aurora wished to make an acidic buffer using acetic acid and sodium acetate. She started with 100 mL of 0.100 M acetic acid in a conical flask. **3**

The K_a for acetic acid is 1.76×10^{-5} and the pH of the buffer solution is 5.00.

The chemical equation for this system is represented as:

$$CH_3COOH(aq) + H_2O(l) \leftrightharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

Calculate the mass of sodium acetate which should be added to the flask by Aurora to prepare the acidic buffer.

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End of Question 31

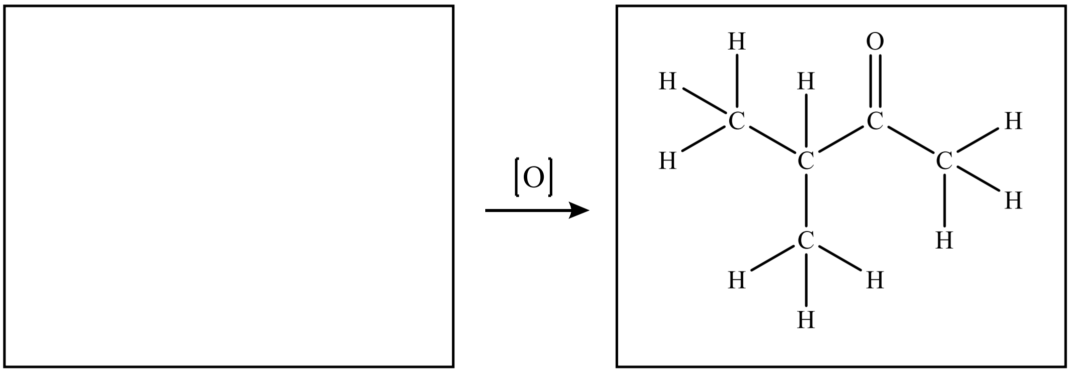
Question 32 (7 marks)

A partially labelled bottle was found in the chemical storeroom. The label indicated that the compound was flammable. **7**

Cinderella carried out an oxidation reaction and then had some spectroscopic testing completed on the product of the chemical reaction. From the spectroscopic testing the product of the oxidation reaction was identified as a ketone, 3-methylbutan-2-one.

In the space below, <u>*draw and name*</u> **Compound X** to complete the oxidation reaction.

Compound X



Name: ....

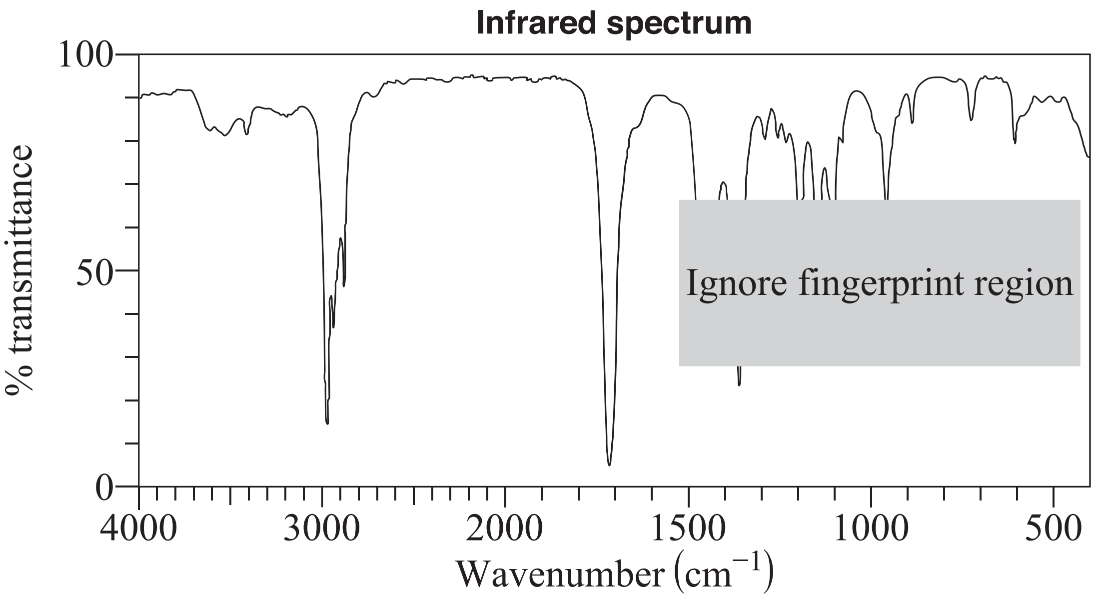
3-methylbutan-2-one

Question 32 continues on page 29

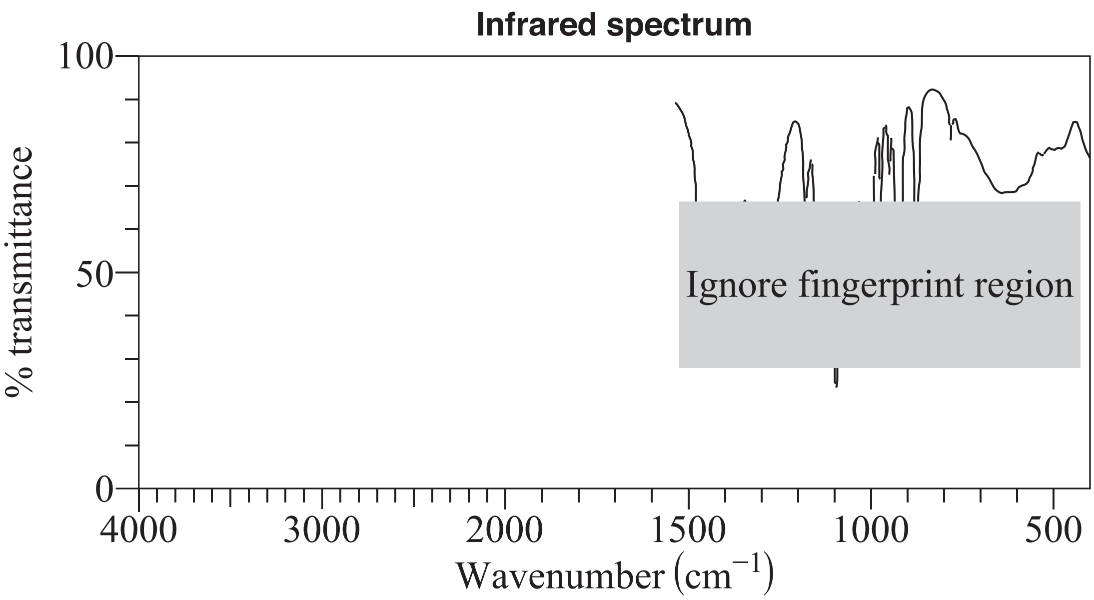
Question 32 (continued)

Figure 1 shows the IR spectrum for the product, 3-methylbutan-2-one.

Figure 1. *IR spectrum for the product, 3-methylbutan-2-one*



On the incomplete IR spectrum below *<u>sketch the peak</u>* you would expect to see for the functional group in **Compound X** in addition to any other relevant peak(s) in the region 4000 – 1600 cm^{-1}.

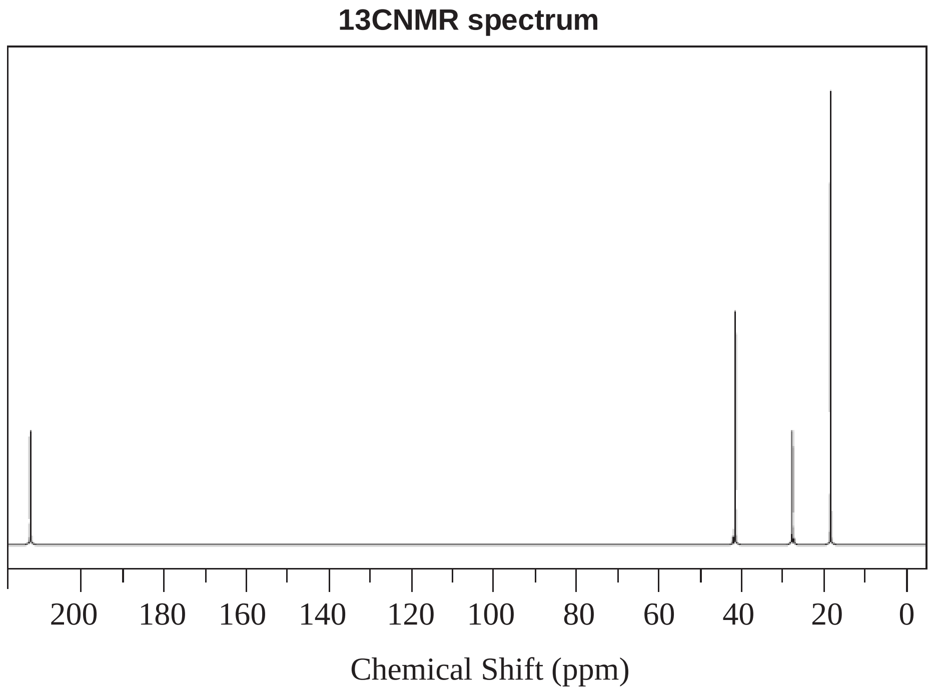


Question 32 continues on page 30

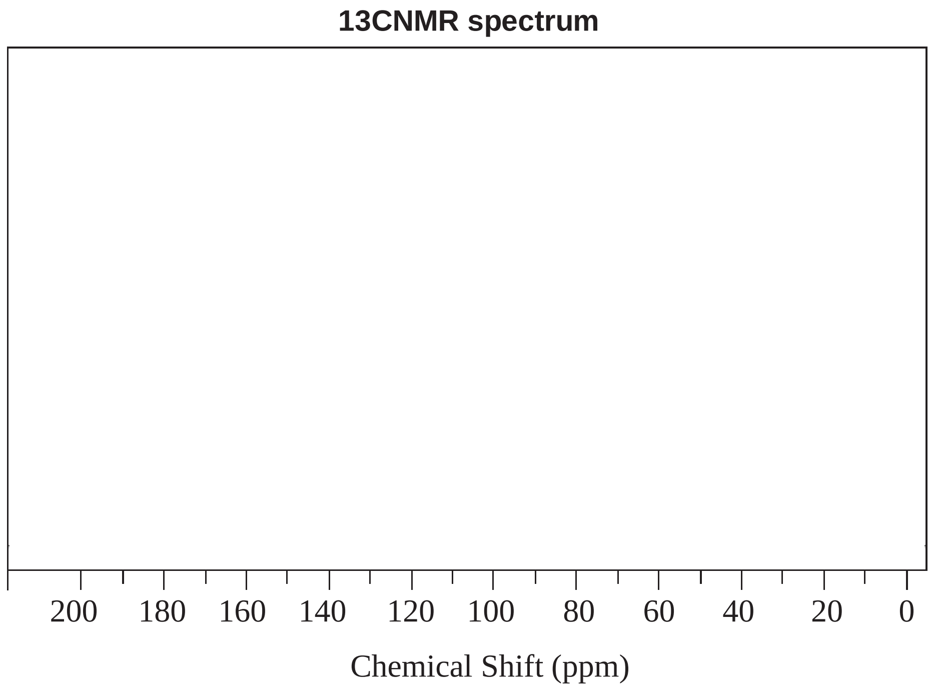
Question 32 (continued)

Figure 2 shows the ^{13}C NMR spectrum for the product, 3-methylbutan-2-one.

***Figure 2**. ^{13}C NMR spectrum of 3-methylbutan-2-one*



On the incomplete ^{13}C NMR spectrum below <u>*sketch the **approximate** locations of the peaks*</u> you would expect to see for **Compound X**.



Question 32 continues on page 31

Question 32 (continued)

For both the IR spectrum and ^{13}C NMR of **Compound X,** justify <u>one</u> similarity and <u>one</u> difference when compared to 3-methylbutan-2-one.

End of Question 32

Question 33 (6 marks)

27.62 g of hydrated sodium carbonate crystals, $Na_2CO_3{\cdot}xH_2O(s)$, was dissolved in water and made up to 1.000 L. 25.00 mL of this solution was neutralised by 24.13 mL of hydrochloric acid of concentration 0.2000 M.

(a) Write an equation for the reaction between sodium carbonate solution and hydrochloric acid. **1**

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(b) Calculate the molar concentration of the sodium carbonate solution neutralised by the hydrochloric acid. **2**

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(c) By calculating the mass of water in the hydrated crystals, find the value of *x*. **3**

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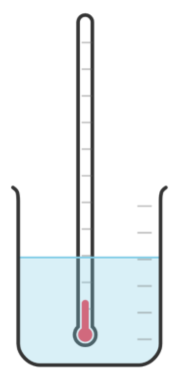
Question 34 (4 marks)

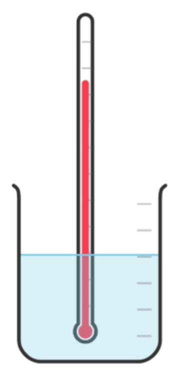
Elsa carried out an experiment to compare the energy changes when solid ionic compounds dissolve in water and to compare their Gibbs free energy. She observed that the temperature fell when potassium chloride dissolved but rose when sodium hydroxide dissolved. **4**

Addition of KCl(s)



Temperature of solution decreases after addition of solid

Addition of NaOH(s)



Temperature of solution increases after addition of solid

Elsa correctly concluded:

The dissolution of both potassium chloride and of sodium hydroxide occur spontaneously.

Justify the conclusion made by Elsa by referring to the changes in enthalpy, entropy and Gibbs free energy.

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Question 35 (8 marks)

Biofuels are becoming an increasingly important alternative to fossil fuels worldwide. However, biofuel production and consumption in Australia remained low in 2022 (Biki & Flake, 2022). **8**

The following data provides a comparison of the properties of petrol and bioethanol (Thakur & Kaviti, 2018).

Property	***Petrol***	***Bioethanol***
Chemical formula	$C_5 – C_{12}$	C_2H_5OH
C : O : H fractions (mass %)	87.4 : 0 : 12.6	52.2 : 34.7 : 13.0
Stoichiometric air-fuel ratio	14.2 – 15.1	8.97
Octane Rating	91 – 100	108.61 – 110
Heat of combustion (kJ mol^{-1})	5460	1370
Density (at 15°C) (g L^{-1})	0.750	0.785
Solubility in water (%)	0	100
Average cost of production (AUD per litre of gasoline equivalent (LGE))	1.17	1.50

Source: Thakur, Amit & Kaviti, Ajay. (2018). Progress in regulated emissions of ethanol-gasoline blends from a spark ignition engine. *Biofuels*. 12. 1-24. 10.1080/17597269.2018.1464875.

Assess the potential of ethanol as an alternative fuel and discuss the advantages and disadvantages to support its future increased use in Australia.

Include balanced chemical equations for both the production and use of ethanol and refer to the data provided in your answer.

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Question 35 continues on page 35

Question 35 (continued)

End of Paper

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HSC CHEMISTRY

Assessment Task 4 Trial Examination

Marking Guidelines and Sample Responses

Section I: 20 marks

Multiple-choice Answer Key

Question	Answer	KU/WS
1	A	KU
2	B	KU
3	C	KU
4	D	KU
5	A	KU
6	B	KU
7	D	KU
8	D	KU
9	B	KU
10	C	KU

Question	Answer	KU/WS
11	A	KU
12	D	KU
13	D	KU
14	B	KU
15	B	WS
16	A	KU
17	C	KU
18	C	KU
19	D	KU
20	C	WS

Section II: 80 marks

Question 21 (3 marks) KU **Marker: LD**

Criteria	Marks
• Clear outline of how to make indicator AND how the indicator can be tested with across a range of pH, including neutral	3
• Limited outline of how to prepare and limited outline of how to test the indicator. OR • Clear outline of how to make indicator AND outlines how the indicator can be tested with across a limited range of pH.	2
• Any relevant information on the preparation or testing of an indicator. • Either outlines how to prepare or how to test the indicator	1

Sample response:

To make the indicator grind a few cherries using a mortar and pestle with small volume of distilled water. Use pipette to remove the coloured liquid.
In 5 small test tubes put about 1 mL of solutions of known pH ranging from acidic, neutral to basic. Add 1 drop of the cherry indicator to each test tube, wait a minute, record the colour of the cherry indicator.

Question 22 (3 marks) KU **Marker: LD**

Criteria	**Marks**
• Identifies THREE steps in how an Indigenous food is prepared. • Explains how each step effectively removes the toxins.	3
• Identifies TWO steps in how an Indigenous food is prepared. OR • Outlines three steps OR • explains ONE step.	2
• Some relevant information about food preparation to remove toxins	1

Sample response:

1. Yam roots are ground up or cut up. This increases their surface area so that when placed in water the dissolving process is faster.
2. The yam roots are then soaked in water for a period of time. The toxins (oxalates) are more soluble than other components and leach out. Since the oxalates are soluble in water, an equilibrium is reached where no more oxalates can be dissolved in the water.
3. At this stage the yam roots should be rinsed and placed in fresh water so that more oxalates can be leached out of the yam root.
4. Yams can be cooked which further changes the chemical composition of the toxins, detoxifying them.

Question 23 (3 marks) **Marker: LD**

Criteria	Marks
• Sufficient working shown to correctly calculate Keq • Makes a correct statement about what the Keq indicates	3
• Most working shown to calculate Keq and makes a correct statement about what the Keq indicates OR • Sufficient working shown to correctly calculate Keq but no statement about Keq. OR • One mistake/error in calculation of Keq AND makes a correct statement about Keq.	2
• Provides a correct calculation process or some correct information about Keq	1

Sample response:

Initial concentration of $[H_2]$ = 1 mol / 2.00 L = 0.5 mol/L
Initial concentration of $[I_2]$ = 1 mol / 2.00 L = 0.5 mol/L

	$[H_2]$	$[I_2]$	[HI]
Initial	0.5	0.5	0.0
Change	–0.38	–0.38	+0.76
Equilibrium	0.12	0.12	0.76

Now $K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = (0.76)^2/(0.12) \times (0.12) = 40.1$

This moderately large number indicates that the equilibrium position is on the right side. The products are favoured in this equilibrium reaction.

Question 24(a) (3 marks) Skills **Marker: SN**

Criteria	Marks
• Correctly calculates the enthalpy of combustion of propan-1-ol showing ALL steps, working and reasoning. Correct units shown. ○ Heat of reaction of propan-1-ol correctly calculated using q=mCΔT using correct units ○ Calculation of moles of propan-1-ol shown using n=m/MM ○ Molar heat of combustion of propan-1-ol correctly calculated using -q/n with **correct units**	3
• ONE incorrect calculation OR TWO correct calculation without correct units	2
• At least ONE correct working or calculation/reasoning shown	1

Sample response

1. q= mCΔT
   m= 50 mL/g, ΔT= 12.8°C, C= 4.18 x 10^{-3}J/g/K
   q= 50g x 4.18 x 12.8
   =2675.2 J /1000 = 2.675 kJ.

2. Molar heat of combustion of propan-1-ol = -q/n
   Number of moles of propan-1-ol = m/MM
   MM of propan-1-ol= (12.01 x3) + (1.008x8)+ 16.00 = 60.094
   n(C_3H_7OH) = 0.100g (given)/ 60.094 = 0.001664….

3. Molar heat of combustion of C_3H_7OH = -q/n = 2.675 kJ/0.001664….
   = -1607.57 kJmol^{-1} = -1610 kJmol^{-1} (3 sf)

Question 24(b) (2 marks) Skills **Marker: SN**

Criteria	Marks
• Identifies the effect of using a draught shield on accuracy by stating the effect on change in temperature and therefore the effect on delta H.	2
• Improvement in accuracy without explanation or explanation does not link to the question	1

Sample response

Using a draught shield while carrying out the experiment will improve accuracy of the experiment as it would decrease heat loss to the surrounding by directing the heat of the flame towards the calorimeter. The temperature rise of water will more accurately reflect the heat energy released when the alcohol is burnt.

Question 25(a) (1 mark) **Marker: SN**

Criteria	Marks
• Correctly provides molecular formula of citronellol.	1

Sample response:

$C_{10}H_{20}O$ and accepted $C_{10}H_{19}OH$

Question 25(b) (1 marks) **Marker: SN**

Criteria	Marks
• Correctly identifies the TWO main functional groups found in citronellol.	1

Sample response:

The two main functional groups within citronellol are the alcohol and alkene functional groups.

Question 25(c) (3 marks) **Marker: SN**

Criteria	Marks
• Identifies that the alcohol group has capacity for H-bonding enabling solubility with water. • Identifies that the long non-polar alkyl chain hinders solubility with water, a polar molecule. • Correctly predicts that citronellol is slightly soluble in water.	3
• Identifies that citronellol is insoluble in water/ completely soluble in water. • Provides correct justification of prediction with reference to the structure of the molecule and its inability/capacity to form intermolecular forces.	2
• Provides some relevant information.	1

Sample response:

The hydroxyl group (–OH) is polar due to the large difference in electronegativity between the oxygen and hydrogen atom. This allows the hydroxyl group in the molecule to interact with polar water molecules forming hydrogen bonds.

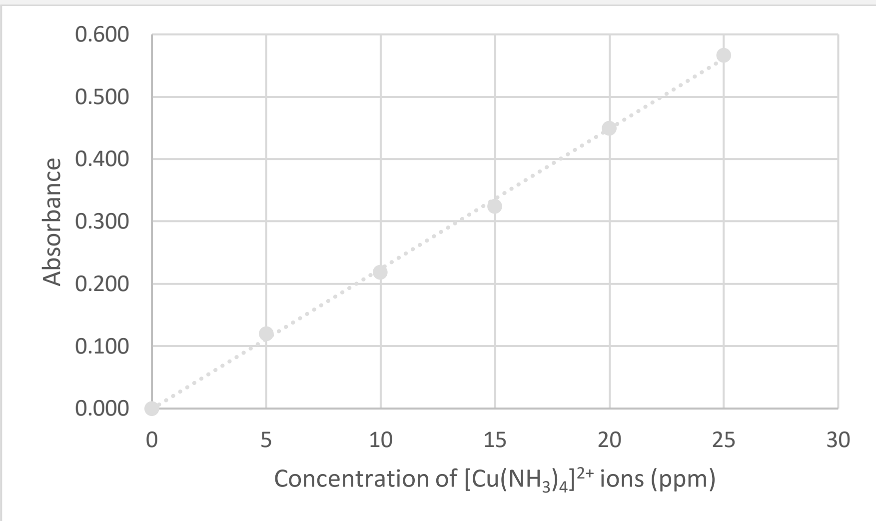
The large, non-polar alkyl chain causes the solubility of the molecule to decrease. The large surface area of the non-polar alkyl chain hinders polar water molecules from forming sufficient H-bonds to aid solubility.

The large size of the non-polar alkyl chain means that the hydrophobic part of the molecule will dominate the interactions, leading to a molecule that is only very slightly soluble in water. [Actual solubility is 31 mg/mL]

Question 26(a) (3 marks) **Marker:**

Criteria	**Marks**
• Graph is correct, including ○ correctly labelled axes including units on x axis ○ appropriate scales ○ correctly plotted points ○ correct line of best fit	3
• Three correct aspects of graph	2
• Two correct aspects of graph	1

Sample response:



Question 26(b) (3 marks) **Marker:**

Criteria	Marks
• Correctly calculates the absorbance of the sample solution • Uses data from the graph to calculate the correct concentration of the original solution in mol L^{-1}	3
• Correctly calculates the absorbance of the sample solution AND but omission or mistake in calculating concentration of the original solution. OR • Incorrectly calculates the absorbance of the sample solution AND Uses data from the graph to calculate the correct concentration of the original solution in mol L	2
• One correct and relevant step	1

Sample response:

Given an initial intensity of 100% and an intensity after passing though the solution of 42.6%, we can calculate the absorbance, *A*.

$$\begin{aligned} A &= \log\frac{I_0}{I} \\ &= \log\left(\frac{100\%}{42.6\%}\right) \\ &= 0.371 \end{aligned}$$

From the graph, this absorbance would correspond to a $[Cu(NH_3)_4{}^{2+}(aq)]$ = 16.5 ppm, this is equivalent to $[Cu(NH_3)_4{}^{2+}(aq)]$ = 16.5 mg/L.

$$\begin{aligned} [\mathrm{Cu(NH_3)_4}^{2+}(aq)] &= 16.5\ \mathrm{mg/L} \\ &= \frac{16.5\times10^{-3}}{63.55+4(14.01+3\times1.008)}\ \mathrm{mol\ L^{-1}} \\ &= 1.25\times10^{-4}\ \mathrm{molL^{-1}} \end{aligned}$$

Using the mole ratio of $Cu^{2+}(aq)$: $Cu(NH_3)_4{}^{2+}(aq)$ = 1:1 we can now find the $[Cu^{2+}(aq)]$ in solution.

$$[\mathrm{Cu}^{2+}(aq)] = [\mathrm{Cu(NH_3)_4}^{2+}(aq)] = 1.25\times10^{-4}\ \mathrm{molL^{-1}}$$

Question 26(c) (2 marks) **Marker:**

Criteria	Marks
• Outlines TWO features of a named suitable alternative to colorimetry	2
• Outlines ONE feature of a named suitable alternative to colorimetry	1

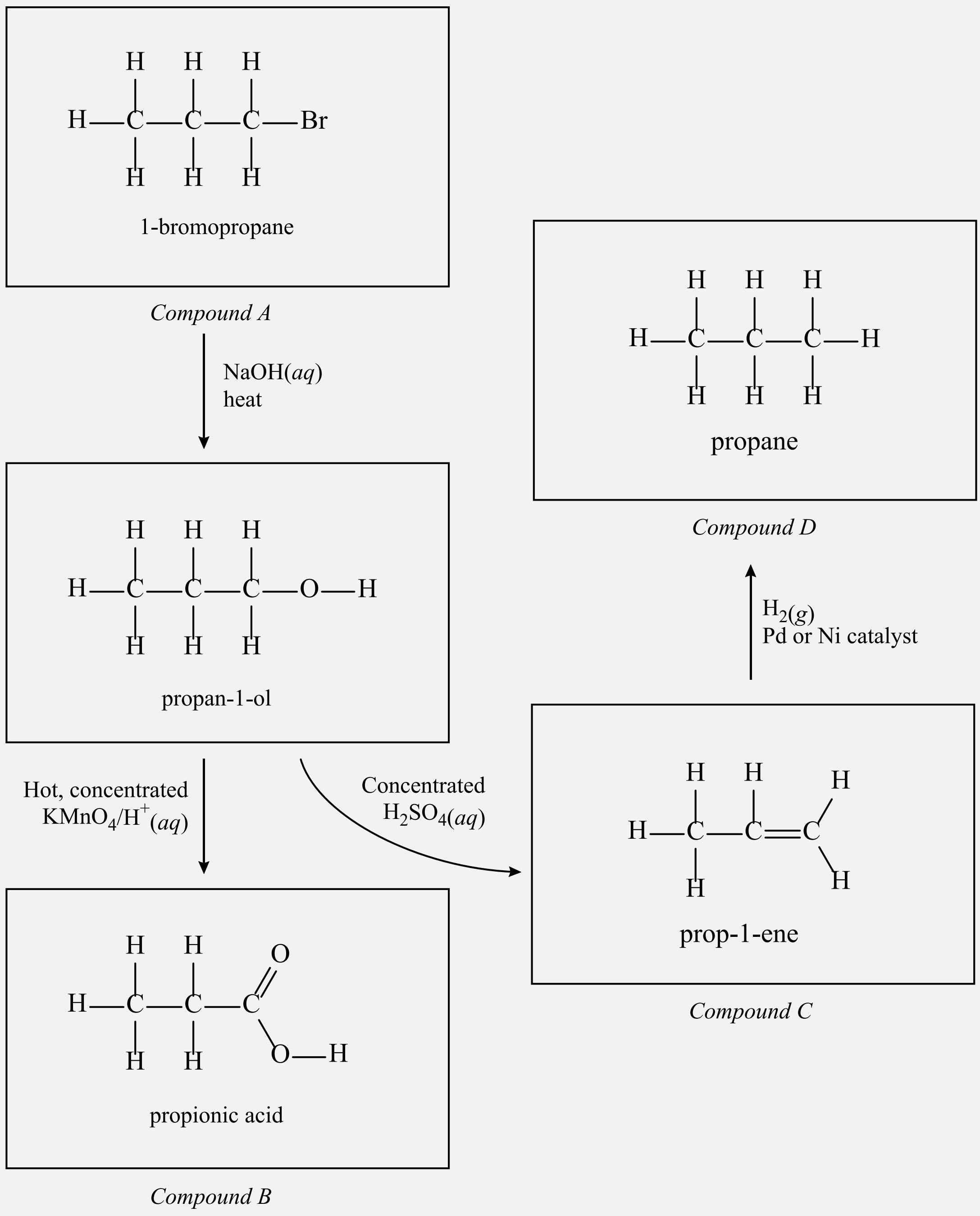
Sample response:

Sample answer: Using atomic absorption spectrometry (AAS) a sample solution containing an element is vaporised in a hot flame. Radiation from a cathode lamp of a particular wavelength is absorbed by the atom's electrons. Unabsorbed light is passed through a wavelength selector and a detector. A computer determines the amount of absorbance as a measure of the concentration of the metal ions present in the sample.

Question 27(a) (4 marks) **Marker: SN**

Criteria	Marks
• Provides the correct structure of all FOUR compounds.	4
• Provides the correct structure of THREE compounds.	3
• Provides the correct structure of TWO compounds.	2
• Provides the correct structure of ONE compound.	1

Sample response:



Note: Names are not necessary. Any correct structural representation is permissible.

Question 27(b) (2 marks) **Marker:**

Criteria	**Marks**
• Bromine water test described AND observation mentioned	2
• ONLY test described OR some relevant information pertaining to test or observation	1

Sample response:

Test for alkenes (unsaturation): Add a few drops of bromine water (1 mark) to compound C in a test tube and shake. If the bromine water is immediately decolourised or colour disappears (1 mark), the organic solution contains a double bond and is an alkene.

Question 28 (4 marks) **Marker:**

Criteria	Marks
• Explains two correct trends in the graph. • Includes two relevant chemical equations.	4
• Explains a trend in graph and outlines a second trend • Includes at least one relevant chemical equation.	3
• Identifies some trends/features from the graph OR • Outlines a trend/feature of the graph	2
• Some relevant information	1

Sample response:

The trend for both acids is for pH to decrease with increasing concentration as [H+] increases. The strong acid, HCl, shows a linear trend with pH (the log of [HCl]). This is because HCl fully ionises at all concentrations, and therefore the [H+] equals [HCl].

$$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

However, propanoic acid is a weak acid. The degree of ionisation is dependent on the concentration of the acid. We can see that the trend of the propanoic acid is not linear. It bends up at higher concentrations. This reflects the proportionally lower fraction of ionisation. This is because it is an equilibrium system given by the equation:

$$C_2H_5COOH(aq) + H_2O(l) \leftrightharpoons H_3O^+(aq) + C_2H_5COO^-(aq)$$

As the solution becomes more dilute (more water added), the equilibrium shifts to the right and ionises more, hence the degree of ionisation is higher for lower concentrations. The opposite is true for more concentrated solutions of propanoic acid, and the degree of ionisation is lower when compared with the same concentration of HCl. Hence lower H^+ therefore proportionally higher pH than HCl at same concentration.

Question 29(a) (1 marks) **Marker:**

Criteria	Marks
• Correctly states the common ion effect.	1

Sample response

The solubility of a salt is reduced by the presence of one of its constituent ions (the common ion) already in the solution. The presence the common ion drives the equilibrium towards precipitation through Le Châtelier's principle.

Question 29(b) (3 marks) **Marker:**

Criteria	Marks
• States that there is no common ion in water, so has the highest solubility. • Identifies that the concentration of Br^{-}(*aq*) is greater in aluminium bromide than in sodium bromide, thus explaining the reduced molar solubility. • Describes the effect of increased Br^{-}(*aq*) on the equilibrium by referring to LCP, or rate of precipitation / rate of dissolution.	3
• TWO of the above.	2
• Provides ONE piece of relevant information.	1

Sample response

In distilled water, there are no bromide ions present in solution. As such, the molar solubility should be highest in this solution, as there is no common ion present.

In 0.1 M NaBr(*aq*), there is 0.1 M Br^{-}(*aq*) ions present in solution. This should see a decrease in the molar solubility as the common ion supresses the solubility. The data shows this as the molar solubility in 0.1 M NaBr(*aq*) (2.1×10^{-4} M) is lower than in water (8.1×10^{-3}). In 0.1 M aluminium bromide, the [Br^{-}(*aq*)] is three times greater than in the 0.1 M NaBr(*aq*) solution. As such, the molar solubility in this solution will be the lowest as the concentration of bromide ions is the greatest.

This effect is observed because as the concentration of Br^{-}(*aq*) ions present in solution increases, the equilibrium for the solubility of $PbBr_2$ shifts to the left, increasing the rate of precipitation, and thus decreasing the rate of dissolution, so reducing concentration of $PbBr_2$(*aq*) in solution. The molar solubility of $PbBr_2$(*aq*) should then decrease as [Br^{-}(*aq*)] increases, as predicted by the common ion effect.

Question 30 (a) (5 marks) **Marker:**

Criteria	**Marks**
• Correctly calculates moles of NaOH to find moles of excess HCl, including showing molar ratio from equation AND • Uses this and initial moles of HCl to determine moles of HCl that reacted with eggshell AND • Uses mole ratio from balanced chemical equation of eggshell reacting with HCl to find moles of $CaCO_3$ • Determines the mass of $CaCO_3$ in eggshell then % by mass in the eggshell • Makes a statement to answer question. • Answer is to the correct number of significant figures (3 sf)	5
• Four steps correct	4
• Three steps correct	3
• Two steps correct	2
• One step correct	1

Sample response:

From titration, $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

- Sig fig 5

$n(NaOH) = cV = 0.598 \times 0.01255 = 0.0075049\ldots$ mol
from equation, 1 mol NaOH reacts with 1 mol HCl.
Therefore $n(NaOH) = n(HCl)$ in excess $= 0.0075049\ldots$ mol

Initial $n(HCl) = cV = 0.971 \times 0.02500 = 0.024275$ mol

1

Therefore n(HCl) that reacted with eggshell
= initial n(HCl) – excess n(HCl)
$= 0.024275 - 0.0075049 = 0.0167701$ mol HCl that reacted with eggshell

Equation for reaction of HCl with eggshell:
$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

2

From this equation, 1 mol $CaCO_3$ reacts with 2 moles HCl
So $n(CaCO_3) = n(HCl) / 2 = 0.0167701 \text{ mol} / 2 = 0.00838505..$ mol

$MM(CaCO_3) = 40.08 + 12.01 + (16.00 \times 3) = 100.09$ gmol^{-}

$m(CaCO_3) = 0.00838505..\text{ mol} \times 100.09 = 0.8392596\ldots\ldots$g

3

% of $CaCO_3$ in eggshell = 0.8392596/1.25 x 100% = 67.1% (3 sig fig)

Since 67.1% is less than the 85% of a normal eggshell, Snow White has a good reason to be concerned.

4

Question 30(b) (2 marks) **Marker:**

Criteria	Marks
• Explains, using LCP and all chemical equations, why eggshells are thinner in warm weather	2
• Uses some information to explain why eggshells are thinner in warm weather.	1

Sample response:

When the weather is warmer, chickens pant more, which means they breathe out more $CO_2(g)$. By LCP, this shifts the equilibrium in Equation 1 to the left, to replace the lost $CO_2(g)$. In turn this reduces $[CO_2(aq)]$, which shifts Equation 2 to left. This reduces $[H_2CO_3]$, shifting equation 3 to left. This reduces $[CO_3^{2-}]$ shifting equation 4 to left, which reduces the amount of $CaCO_3$ formed, which makes the shells thinner.

Question 31(a) (4 marks) **Marker: ER**

Criteria	Marks
• Correct equation (state symbols not needed). • Extensive knowledge showing cause and effect for initial and final colours of the solution linked to the equation and Le Chateliers Principle.	4
• Initial and final colour explained without correct equation • OR correct equation given with limited explanation of colours	3
• Two relevant pieces of information • OR correct equation and one piece of information.	2
• Any piece of relevant information.	1

Sample response

Relevant equation $CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$

Buffers are solutions in which the pH remains relatively constant when small amounts of acid or base are added. The buffer in the question comprises equal amounts of a weak B-L base (carbonate ion) with its conjugate acid (hydrogen carbonate) in water. Initially the solution contains carbonate and hydrogen carbonate ions with enough hydroxide ions to make the solution alkaline (pH 10.0) and therefore the indicator to be blue.

When sodium hydroxide is added this increases the concentration of hydroxide and in accordance with Le Chatelier's Principle the equilibrium will shift to counteract this change and therefore the equilibrium would shift to the left. As there is a large concentration of hydrogen carbonate ions available these are able to react with and therefore remove the added hydroxide ions. The pH remains largely unaltered as the concentrations is high and this reacts with water to produce hydrogencarbonate and the ratio of the ions remains largely unaltered and the colour remains blue.

Question 31(b) (3 marks) **Marker: ER**

Criteria	Marks
• Correctly calculates the mass of sodium acetate	3
• Substantially correct calculation	2
• Any correct step in the calculation.	1

Sample response

Start with $K_a = 1.76 \times 10^{-5} = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$

$pH = 5.00 \therefore [H_3O^+] = 10^{-5.00} = 1 \times 10^{-5}$ M.

Note: In the buffer soln $[CH_3COO^-] \neq [H_3O^+]$

so $[CH_3COO^-] = \frac{(1.76 \times 10^{-5}) \times 0.100}{1.0 \times 10^{-5}}$

$= 0.176$ M

using $n = cV$ $n = 0.176 \times 0.100$
$= 0.0176$ mol

MM = 22.99
24.02
32.00
3.024
82.034

$m = nMM$
$= 0.0176 \times 82.034$
$= 1.44$ g $NaCH_3COO$ should be added.

Common mistakes were:

MM of acetate rather than sodium acetate produced final mass of 1.04g.

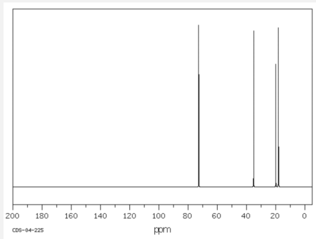
Using [acetate] = [hydronium] and from there solving as if to determine hydronium to get to pH results in mass of 0.0109g.

Question 32 (7 marks) **Marker: ER**

Criteria	Marks
• Compound X named as 3-methylbutan-2-ol and correctly drawn. • Extensive understanding of interpretation of spectra with appropriate terminology throughout response to justify a similarity and difference in each of the spectra. • IR sketched to show broad O-H around 3000 and C-H stretch in approximately the region of 3000. • C NMR sketch to show 4 peaks with one low field for the C-O-H carbon compared to the other 3. The low field to be around 70 when compared to the C=O. • IR similarity could include that there will be CH stretch or similar fingerprint region. Difference to be either that the C=O is not present in X OR that the broad O-H has been gained in X compared to the ketone. • C NMR similarity is that there are still 4 environments with link to the structures as both the molecules have 5 C with one a lower field compared to the others. Key difference is the C on the OH is not as low field as a carbonyl group carbon. • Clear use of the structure for supporting argument (opposed to a list of features).	7
• As above with one mistake	6
• X named and drawn correctly with sound understanding but incomplete/limited justification or error in a sketch. OR • X named/drawn incorrectly with thorough understanding and justification of the given molecule and corresponding spectra for X compared to the ketone.	5-4
• Two or three correct and relevant pieces of information.	3-2
• Any one piece of relevant information.	1

Sample response

Marks – X is 3-methylbutan-2-ol

spectrum	similarity	difference
IR	CH stretch around 3000 as both molecules contain C – H bonds in their structures.	Ketone contains C=O peak around 1700 which is not present in X which has the broad O-H around 3000.
Carbon nmr	Using the structures indicate 4 peaks for the 4 environments in both molecules although both have 5 C in their molecules. Both molecules have a peak lower field than the others. Both molecules have C in the high field region (linked to the molecule).	Ketone has peak at 210ppm due to C=O. This is not present in X so the peak is not as pronounced and around 90ppm. 

Question 33(a) (1 marks) **Marker:**

Criteria	Marks
• Provides correct balanced chemical equation with states	1

Sample response:

$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$

Question 33(b) (2 marks) **Marker:**

Criteria	Marks
• Calculates the correct molar concentration.	2
• ONE incorrect step in calculation.	1

Sample response:

Using the titration data we can calculate the number of moles of acid that reacted with the carbonate in solution.

$$\begin{aligned} n_{\mathrm{HCl}} &= c_{\mathrm{HCl}} V_{\mathrm{HCl}} \\ &= 0.2000 \text{ mol L}^{-1} \times 24.13 \times 10^{-3} \text{ L} \\ &= 0.004826 \text{ mol} \end{aligned}$$

By considering the reaction stoichiometry, we can calculate the number of moles of sodium carbonate.

$$\begin{aligned} \frac{n_{\mathrm{Na_2CO_3}}}{n_{\mathrm{HCl}}} &= \frac{1}{2} \\ n_{\mathrm{Na_2CO_3}} &= \tfrac{1}{2} \times n_{\mathrm{HCl}} \\ &= \tfrac{1}{2} \times 0.004826 \text{ mol} \\ &= 0.002413 \text{ mol} \end{aligned}$$

Since a 25.00 mL aliquot of this solution was used in the titration, the molar concentration of the sodium carbonate solution can be determined.

$$\begin{aligned} c_{\mathrm{Na_2CO_3}} &= \frac{n_{\mathrm{Na_2CO_3}}}{V_{\mathrm{solution}}} \\ &= \frac{0.002413 \text{ mol}}{25.00 \times 10^{-3} \text{ L}} \\ &= \underline{\underline{0.09652 \text{ M } \mathrm{Na_2CO_3}}} \end{aligned}$$

Question 33(c) (3 marks) **Marker:**

Criteria	**Marks**
• Finds the mass of anhydrous sodium carbonate in 1 L of solution. • Determines the mass of water in the hydrated solid. • Correctly calculates the value of *x*.	3
• TWO of the above steps correctly shown.	2
• ONE correct step in calculation.	1

Sample response:

From part (b), we know that we have 0.09652 M Na_2CO_3. Therefore we can calculate the mass of Na_2CO_3 present in the 1.0 L solution.

$$\begin{aligned} m_{Na_2CO_3} &= n_{Na_2CO_3} \times MM_{Na_2CO_3} \\ &= 0.09652 \text{ mol} \times (2\times 22.99 + 12.01 + 3\times 16.00) \text{ g mol}^{-1} \\ &= 10.23 \text{ g } Na_2CO_3 \end{aligned}$$

We can now calculate the mass of water, present within the hydrated solid.

$$\begin{aligned} m_{H_2O} &= 27.62 \text{ g} - 10.23 \text{ g} \\ &= 17.39 \text{ g} \end{aligned}$$

From this, we determine the number of moles of water present within the hydrated solid.

$$\begin{aligned} n_{H_2O} &= \frac{m_{H_2O}}{MM_{H_2O}} \\ &= \frac{17.39 \text{ g}}{(2\times 1.008 + 16.00) \text{ g mol}^{-1}} \\ &= 0.9652 \text{ mol} \end{aligned}$$

By considering, the ratio of number of moles of Na_2CO_3 to H_2O present within the solid (i.e. present within 1.00 L of solution), we get the value of *x*.

$$\begin{gathered} n_{Na_2CO_3} : n_{H_2O} \\ 0.09652 : 0.9652 \\ 1 : 10 \end{gathered}$$

Thus, the number of waters of crystallisation, $\underline{\underline{x = 10}}$

Question 34 (4 marks) **Marker: SN**

Criteria	Marks
• Justifies the conclusion by referring to enthalpy, entropy and Gibbs Free Energy of BOTH solutions. o For a reaction to occur spontaneously, ΔG must be negative ($\Delta G = \Delta H - T\Delta S$). o Dissolution of KCl – entropy increases, temperature decreases hence enthalpy is endothermic o Dissolution of KOH – entropy increases, temperature increases hence enthalpy is exothermic o Links the observations back to conclusion	4
• One information above missing (no mention of enthalpy OR entropy OR Gibbs free of a reaction	3
• Two or more information missing	2
• Provides some relevant information about enthalpy, entropy and Gibbs of both reactions	1

Sample response:

Dissolution of KCl – when solid becomes aqueous solution, entropy increases so ΔS is positive. As temperature decreased when KCl was dissolved, energy was absorbed from the surrounding and therefore net ΔH must also have been positive. However, when the increase in entropy is large, $T\Delta S$ overcomes the positive ΔH and this must be the case as the KCl dissolved and the dissolution is spontaneous.
Dissolution of KOH – when solid becomes aqueous solution, entropy increases so ΔS is positive. Temperature increases, so ΔH is negative. Overall when KOH solid dissolves, entropy or ΔS increases. Therefore, overall ΔG is negative.
Hence, as both solids dissolve spontaneously the conclusion is correct.

Question 35 (8 marks)

Criteria	Marks
• Provides correct and relevant chemical equations with states for production of ethanol from biomass or glucose AND for the combustion of ethanol. AND • Shows an extensive understanding of the advantages and disadvantages of the increased use of ethanol as a fuel. AND • Provides a thorough judgement statement as to whether we should see future increased use of bioethanol in Australia. AND • Refers extensively to the data provided.	8
• As for 8, but one error/omission/mistake	7
• Provides one OR two substantially correct and relevant chemical equations with states for production of ethanol from biomass or glucose AND for the combustion of ethanol. AND • Shows a thorough understanding of the advantages and disadvantages of the increased use of ethanol as a fuel. AND • Provides a judgement statement as to whether we should see future increased use of bioethanol in Australia. AND • Refers to the data provided.	6
• Provides one attempt at a relevant equation. AND • Shows a sound understanding of some of the advantages and disadvantages of the increased use of ethanol as a fuel. AND • Provides a judgement statement as to whether we should see future increased use of bioethanol in Australia. OR • Refers to the data provided.	5
• No equations or incorrect equations • Shows a limited understanding of the advantages and disadvantages of the increased use of ethanol as a fuel. • Provides a judgement statement as to whether we should see future increased use of bioethanol in Australia. OR • Refers to the data provided.	4
• Provides ONE - THREE pieces of relevant information.	1 – 3

Sample response

ANY of the following advantages of using ethanol:

	Advantages	*Disadvantages*
Production	• Renewable because made by fermenting carbohydrate biomass. • $\underset{\text{glucose}}{C_6H_{12}O_6(aq)} \xrightarrow{\text{yeast / }E.Coli} \underset{\text{ethanol}}{2C_2H_5OH(aq)} + \underset{\text{carbon dioxide}}{2CO_2(g)}$ • Technology is being developed to use waste cellulosic feedstocks. • Local production of bioethanol could reduce the amount of petrol we need to import.	• To grow feedstocks, large areas of land are needed which could otherwise be used to grow food crops. • Waste products of cellulose fermentation are difficult to dispose of. • A lot of water is used in growing crops for ethanol. • High production costs (1.50 AUD/LGE as opposed to 1.17 for petrol), e.g. for distillation or membrane separation and also to remove water from ethanol. At present ethanol cannot be produced at a competitive cost or in the volume required to replace petrol.
Emissions	• Ethanol molecule contains a higher fraction of oxygen - 34.7% (w/w) compare to 0% (w/w) for petrol, so combustion is more complete. • Ethanol burns more cleanly as it has a lower air-fuel ratio (ethanol is 8.97 compared to 14.2 – 15.1 of petrol) producing less carbon monoxide and carbon particles when burnt under the same conditions as petrol. • $\underset{\text{ethanol}}{C_2H_5OH(l)} + \underset{\text{oxygen}}{3O_2(g)} \rightarrow \underset{\text{carbon dioxide}}{2CO_2(g)} + \underset{\text{water}}{3H_2O(g)}$ • Ethanol has a lower greenhouse impact than petrol because there are fewer carbons in the molecule than for petrol (data: C_5-C_{12} compared with C_2H_5OH).However, emissions benefits of ethanol depend on fuel blend used, vehicle type and age, engine calibration and maintenance.	• Biofuels such as bioethanol produced from biomass are not greenhouse neutral. Greenhouse gases are released during its production, e.g. during cultivation of crops, production of fertilisers, distillation of fermented sugars and waste disposal. This reduces its ecological effectiveness.
Additives	• No high octane additives are needed as ethanol has a higher octane rating than	• Other additives are added, e.g. corrosion inhibitors.

	petrol (108-110 for ethanol compared to 91-100 for petrol).	• Ethanol can cause corrosion of metals and deterioration of some rubber engine components.
Spills of fuels	• Spills biodegrade more readily and can more easily be diluted to non-toxic levels.	• Spills are difficult to contain and recover as the hydroxyl group (OH) bonds with water (petrol is not soluble in water whereas ethanol is 100% soluble in water) and thus the fuel cannot be skimmed off the top of water like petrol (since its density is < 1.00 g/L).
Fuel economy	•	• Ethanol (1370 kJ mol^{-1}) has a lower ΔH than petrol (5460 kJ mol^{-1}). • This means that ethanol has lower fuel economy than petrol so higher fuel consumption – you use more ethanol than petrol to go the same distance .

Students could argue for or against the increased use of ethanol, but they must provide a judgement statement supported by a coherent discussion of the advantages and disadvantages.