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**2020**

**BORED OF STUDIES TRIAL EXAMINATION**

12th October

# Chemistry

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**General instructions**

- Reading time – 5 minutes
- Working time – 3 hours
- Write using a black or blue pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A formulae sheet, data sheet and Periodic Table are provided

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

**100**

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

**Section II – 80 marks** (pages 13–37)

- Attempt Questions 21–35
- Allow about 2 hour and 25 minutes for this section

## Section I

**20 marks**

**Attempt Questions 1–20**

**Allow about 35 minutes for this section**

Use the multiple-choice answer sheet provided for Questions 1–20.

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**1** Which of the following pairs of molecules are **functional group** isomers of each other?

- A. Hexane and 2-methylpentane
- B. Butanoic acid and methyl propanoate
- C. Hexanol and cyclohexanol
- D. Butan-1-ol and 2-methylpropan-2-ol

**2** The  $K_{\text{sp}}$  of lead chloride is  $1.70 \times 10^{-5}$  at 25 °C. What is the solubility in g/L?

- A. 4.50 g/L
- B. 1.15 g/L
- C. 0.0162 g/L
- D.  $5.82 \times 10^{-5}$  g/L

**3** Which of the following mixtures of solutions can be used to make a buffer?

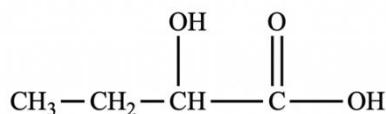
- A. HCl / NaCl
- B.  $\text{H}_3\text{PO}_4$  /  $\text{Na}_2\text{HPO}_4$
- C.  $\text{NaH}_2\text{PO}_4$  /  $\text{Na}_2\text{HPO}_4$
- D.  $\text{H}_2\text{SO}_4$  /  $\text{NaHSO}_4$

- 4 A compound was analysed by a series of chemical tests. The tests and the observations obtained are displayed below:

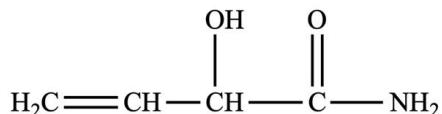
<i>Test</i>	<i>Observation</i>
Add Bromine Water	Orange-brown to colourless
Litmus Paper	Red to blue
Add $\text{H}^+$ / $\text{MnO}_4^-$	Purple to colourless

Which of the following molecules could produce these observations?

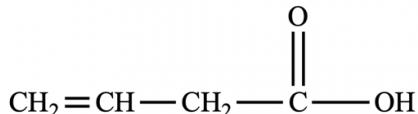
A.



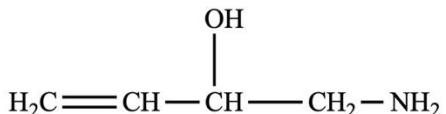
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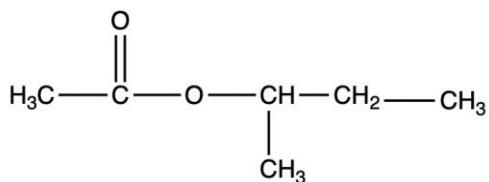
C.



D.

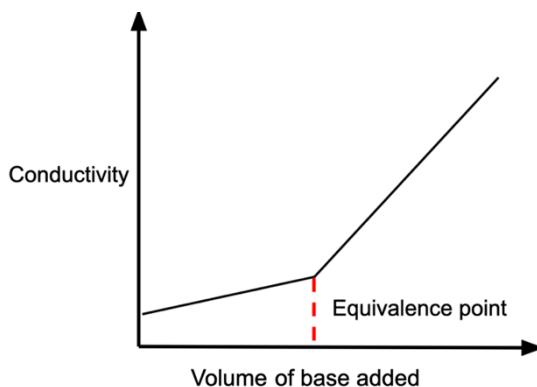


- 5 Which reagents were used to make the following ester?



	<i>Alcohol</i>	<i>Carboxylic acid</i>	<i>Catalyst</i>
A.	Propan-2-ol	Propanoic acid	Dilute. $\text{H}_2\text{SO}_4$
B.	Butan-1-ol	Ethanoic acid	Conc. $\text{H}_2\text{SO}_4$
C.	Butan-2-ol	Ethanoic acid	Conc. $\text{H}_2\text{SO}_4$
D.	Ethanol	Butanoic acid	Dilute. $\text{H}_2\text{SO}_4$

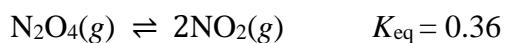
- 6 A titration was performed using a conductivity probe. The following graph was collected.



Which of the following correctly identifies the type of acid and base reacted?

- A. Strong acid and strong base
- B. Weak acid and strong base
- C. Strong acid and weak base
- D. Weak acid and weak base

- 7 At a certain temperature, the  $K_{\text{eq}}$  for the following reaction is 0.36.



0.50 moles of  $\text{NO}_2$  and 0.20 moles of  $\text{N}_2\text{O}_4$  were placed in a 2 L reaction vessel. Which row of the table correctly identifies the direction of the equilibrium shift and the reason?

	<i>Direction favoured</i>	<i>Reason</i>
A.	Left	$Q > K_{\text{eq}}$
B.	Left	$Q < K_{\text{eq}}$
C.	Right	$Q > K_{\text{eq}}$
D.	Right	$Q < K_{\text{eq}}$

- 8** Acetic acid ( $\text{CH}_3\text{COOH}$ ) is a weak monoprotic acid while hydrochloric acid (HCl) is a strong monoprotic acid.

25.00 mL solutions of 1.00 mol/L concentration of each acid were titrated against the same sodium hydroxide standard solution.

Which of the following statements is true about the volume of base required to reach the equivalence point?

- A. The volume of base required cannot be compared for this example.
- B. The acetic acid will require less amount of base than the hydrochloric acid
- C. The acetic acid will require more amount of base than the hydrochloric acid
- D. The acetic acid will require the same amount of base as the hydrochloric acid

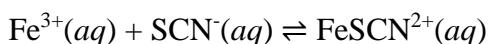
- 9** A series of chemical tests were performed on a soil sample, as recorded below:

<i>Test</i>	<i>Observation</i>
Flame test	Blue-Green
Add $\text{Na}_2\text{SO}_4$	No precipitate
Add $\text{NaCl}$	No precipitate

What compound is present in the soil sample?

- A.  $\text{NaNO}_3$
- B.  $\text{Cu}(\text{NO}_3)_2$
- C.  $\text{Ba}(\text{NO}_3)_2$
- D.  $\text{Pb}(\text{NO}_3)_2$

**10** Consider the exothermic equilibrium reaction:



**Yellow**

**Red**

Which of the following correctly predicts the change in colour for each change?

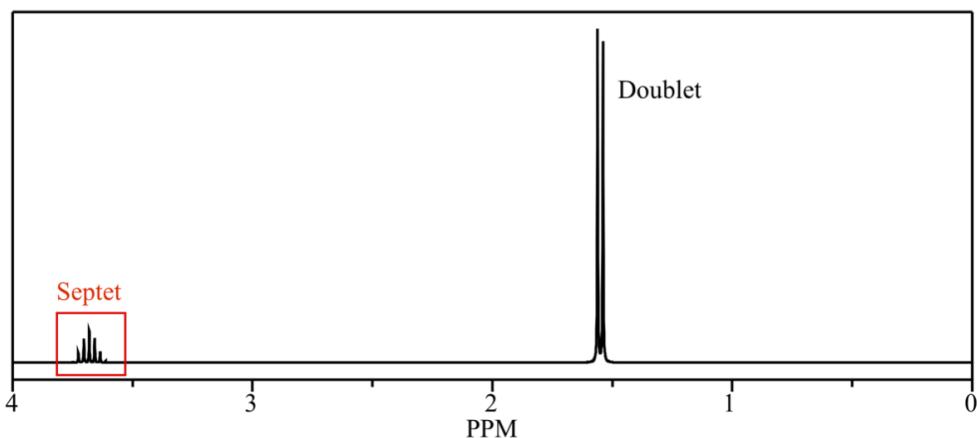
	<i>KSCN(aq) added</i>	<i>Hot water bath</i>	<i>NaOH(aq) added</i>
A.	More yellow	More red	More yellow
B.	More yellow	More red	More red
C.	More red	More yellow	More red
D.	More red	More yellow	More yellow

**11** The molar absorption constant for  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$  is  $2.00 \times 10^3 \text{ L mol}^{-1} \text{ cm}^{-1}$ . A 10.0 mL sample of  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$  was analysed in a 1.00 cm cuvette. A reading of 0.213 was obtained for its absorbance. The molecular mass of  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$  is 163.946 g/mol.

What is the amount in **grams** of  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$  present in the sample?

- A.  $1.75 \times 10^{-4} \text{ g}$
- B.  $1.07 \times 10^{-4} \text{ g}$
- C.  $1.07 \times 10^{-6} \text{ g}$
- D. 4.26 g

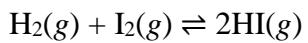
**12** The following data was obtained from the  $^1\text{H-NMR}$  spectrum of a molecule.



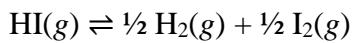
Which of the following molecules could produce this spectrum?

- A. 1-chloropropane
- B. 2-chloropropane
- C. Ethane
- D. Propane

**13** At temperature 720 K, the equilibrium constant for the reaction below is 50.

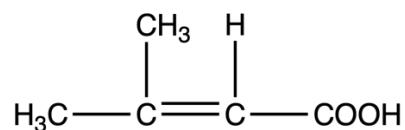


What is the equilibrium constant of the following equilibrium reaction?

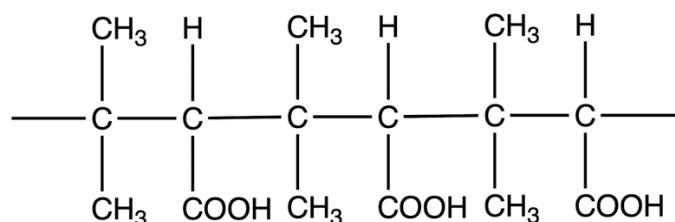


- A. 0.141
- B. 0.02
- C. 50
- D. 7.07

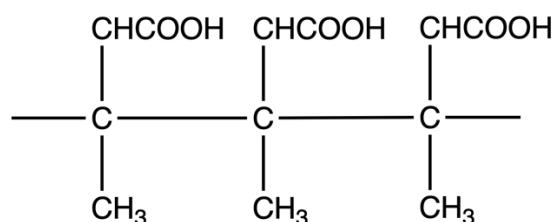
14 Which polymer is made by the polymerisation of the molecule below?



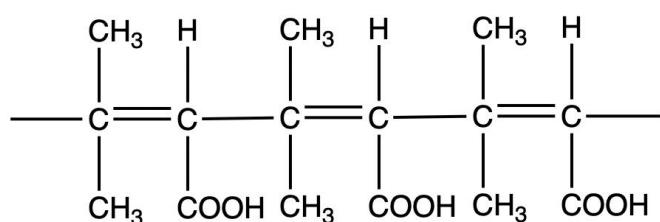
A.



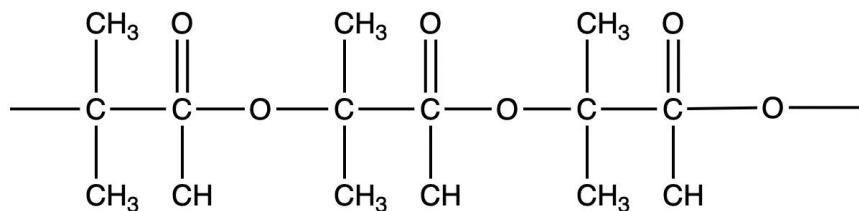
B.



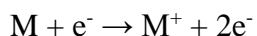
C.



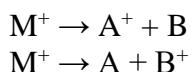
D.



**15** A compound M was analysed by mass spectrometry. The compound M was vaporised and ionised by electron bombardment, forming the molecular ion ( $M^+$ ):



During electron bombardment the molecular ion can undergo fragmentation. For example:



The mass spectrum would show peaks due to which of the following species?

- A.  $M^+$ , A,  $A^+$ , B and  $B^+$
- B.  $M^+$ ,  $A^+$  and  $B^+$  only
- C.  $A^+$  and  $B^+$  only
- D. A and B only

**16** 75.0 mL of 0.040 mol/L calcium hydroxide is added to 25.0 mL of 0.040 mol/L nitric acid.

What is the pH of the final solution?

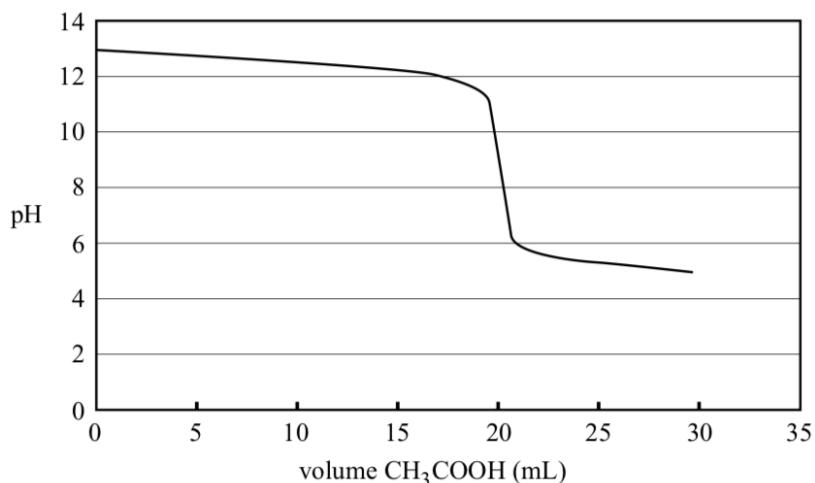
- A. 1.3
- B. 1.7
- C. 12.3
- D. 12.7

**17** Methanoic acid ( $\text{HCOOH}$ ) has a  $pK_a$  of 3.7. Hypochlorous acid ( $\text{HOCl}$ ) has a  $pK_a$  of 7.5. Which of the following solutions will have the highest pH?

- A. 0.2 M  $\text{HCOOH}$
- B. 0.2 M  $\text{NaCHOO}$
- C. 0.2 M  $\text{HOCl}$
- D. 0.2 M  $\text{NaOCl}$

**18** A titration was performed between a 0.10 mol/L acetic acid ( $\text{CH}_3\text{COOH}$ ) and a 10.0 mL sample of a calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ) solution.

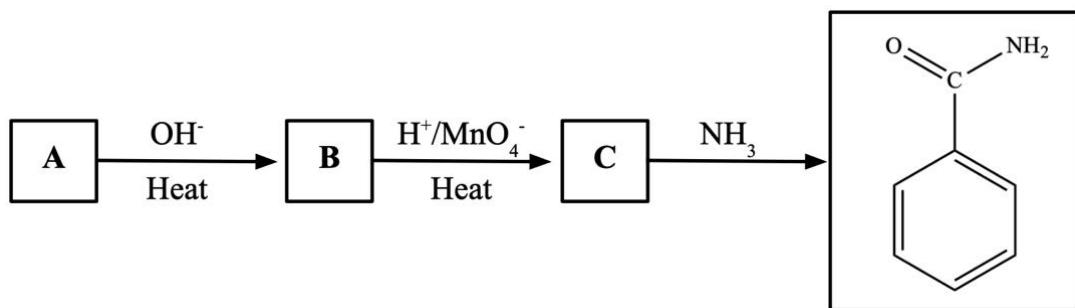
The following titration curve was obtained using a pH probe.



What is the concentration of the calcium hydroxide solution?

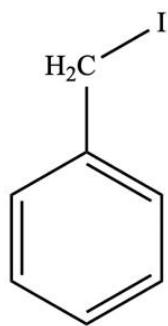
- A. 0.0010 g/L
- B. 0.074 g/L
- C. 7.4 g/L
- D. 0.10 g/L

**19** A compound was produced from a series of chemical reactions. Its synthesis is below:

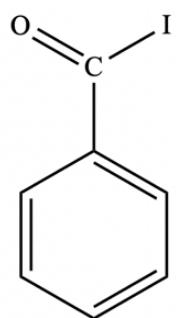


Which of the following is the structure of **Compound B**?

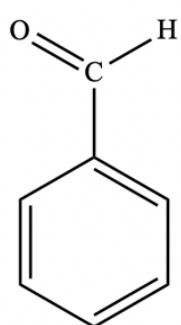
A.



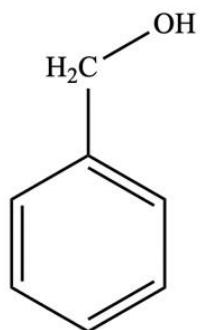
B.



C.



D.

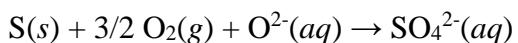


**20** Gravimetric analysis was used to determine the sulfur content in a 15.0 g sample of coal.

The following method was used:

1. The sulfur was converted to sulfur dioxide
2. The sulfur dioxide was converted to sulfur trioxide
3. The sulfur trioxide was dissolved in water producing sulfuric acid

These series of reactions are summarised by the net-ionic equation:



Excess calcium nitrate solution was added to  $\text{SO}_4^{2-}(aq)$  ions. The precipitate that formed from this reaction was filtered, dried and weighed.

The mass of the dried precipitate was 200 mg.

What is the percentage mass of sulfur in the original coal sample?

- A. 0.00980%
- B. 1.33%
- C. 0.141%
- D. 0.314%



Student Number: .....

Username: .....

Name: .....

## **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, username and name on the top right 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.
- If you require extra writing space, please ask for a writing booklet. If you use a writing booklet, clearly indicate which questions you are answering.

**Please turn over**

**Question 21** (6 marks)

A chemical compound A decomposes to produce compound B and C.

The reaction occurs as an equilibrium process as below.



The equilibrium constant ( $K_{eq}$ ) for the above reaction is 4.0 at a certain temperature.

- (a) What does the value of the equilibrium constant ( $K_{eq}$ ) indicate about the position of the equilibrium? 1

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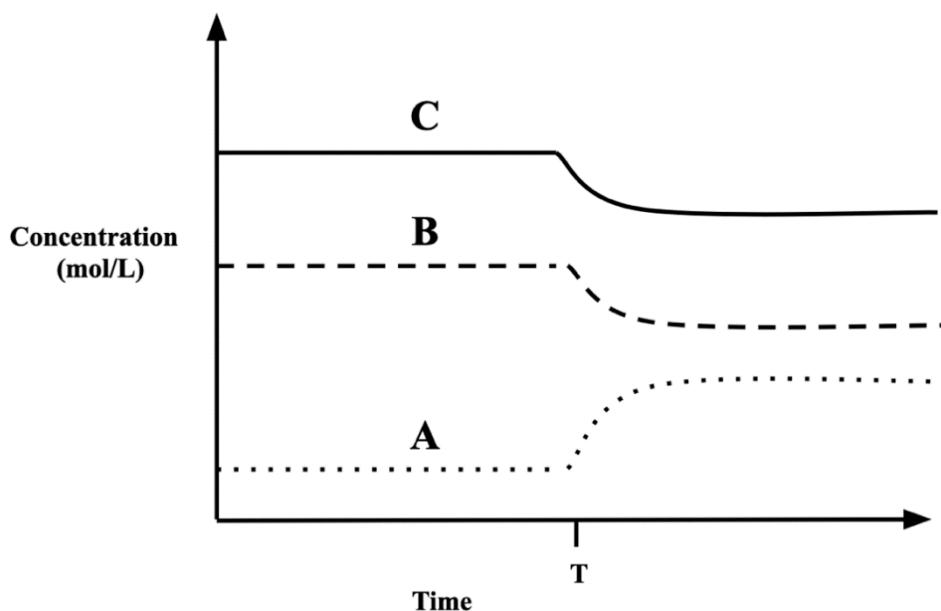
- (b) Initially 5.0 moles of A was added to a sealed 10.0 L container and allowed to come to equilibrium. Calculate the equilibrium concentration of B. 3

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**Question 21 continues on page 15**

Question 21 (continued)

- (c) Below is the concentration-time graph for the system at a certain equilibrium. 2



At time  $T$ , the temperature of the reaction vessel was increased.

Explain with reference to the graph whether the reaction is exothermic or endothermic.



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**End of Question 21**

## **Question 22 (7 marks)**

A student performs three different experiments to investigate solubility equilibria.

In the first experiment, she investigated the solubility of calcium sulfate at 20 °C. She found the solubility of calcium sulfate to be 0.21 g per 100 g of water.

In the second experiment, she combined 100 mL of 0.0010 mol/L  $\text{Ca}(\text{NO}_3)_2$  and 100 mL of 0.0010 mol/L  $\text{Na}_2\text{SO}_4$ . She observed that no precipitate was produced.

- (a) Calculate the  $K_{sp}$  for calcium sulfate from the first experiment. Use this value to explain why no precipitate was formed in the second experiment.

Question 22 (continued)

- (b) In the third experiment, the molar solubility of barium hydroxide in pure water and 0.50 M sodium hydroxide was determined. The results are displayed below.

2

<i>Case</i>	<i>Molar Solubility of Barium hydroxide (M)</i>
Water	0.044
0.50 M NaOH	0.0010

Explain the reason for the large difference in solubility in these cases. Include a chemical equation in your answer.

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**End of Question 22**

**Question 23** (2 marks)

Sodium hydrogen phosphate ( $\text{Na}_2\text{HPO}_4$ ) is an example of an amphiprotic substance. 2

With reference to TWO chemical equations, explain the term amphiprotic and justify the statement that  $\text{Na}_2\text{HPO}_4$  is amphiprotic.

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**Question 24** (3 marks)

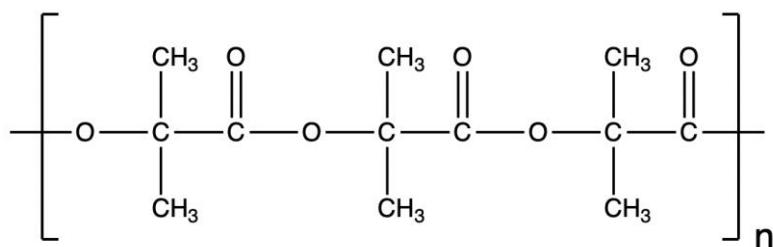
Ethanamine ( $\text{C}_2\text{H}_5\text{NH}_2$ ) is a weak base with a dissociation constant ( $K_b$ ) of  $5.6 \times 10^{-4}$ . 3

Calculate the pH of a 0.10 M solution of ethanamine.

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**Question 25** (4 marks)

A **condensation polymer** was produced from **one monomer**. A section of the polymer is displayed below:



- (a) Draw the structure of the monomer.

1

- (b) How many peaks would the **monomer** show in the <sup>1</sup>H-NMR spectrum?

1

- (c) The molecular weight of the polymer formed was  $1.29 \times 10^5$  g/mol.

2

Using your structure from part (a), determine the number of monomer units required to produce a polymer with this molecular weight.

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**Question 26** (4 marks)

The structure of a soap molecule and cationic detergent are displayed below.

4

<i>Molecule</i>	<i>Structure</i>
Soap	A skeletal structure of a long, zigzag hydrocarbon chain. At the end of the chain is a carbon atom double-bonded to an oxygen atom (top) and single-bonded to another oxygen atom with a negative charge (bottom).
Cationic Detergent	A skeletal structure of a long, zigzag hydrocarbon chain. At the end of the chain is a nitrogen atom with a positive charge (top), single-bonded to three methyl groups (represented by short lines).

Hard water contains a large concentration of  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$  ions.

Compare the cleaning action of the soap molecule and cationic detergent when removing oil from surfaces in hard water. Include a diagram(s) to support your answer.

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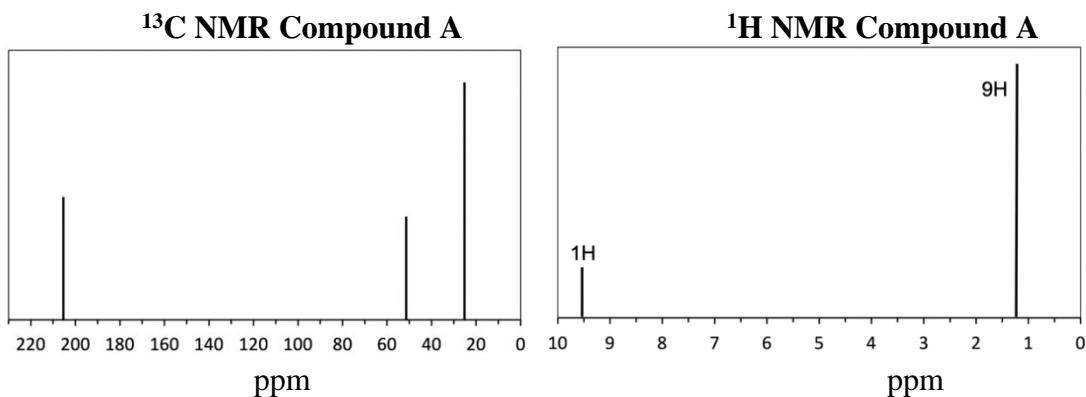
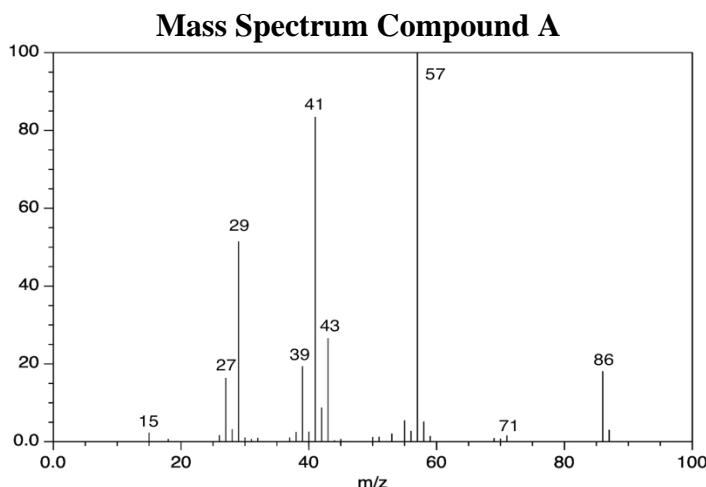
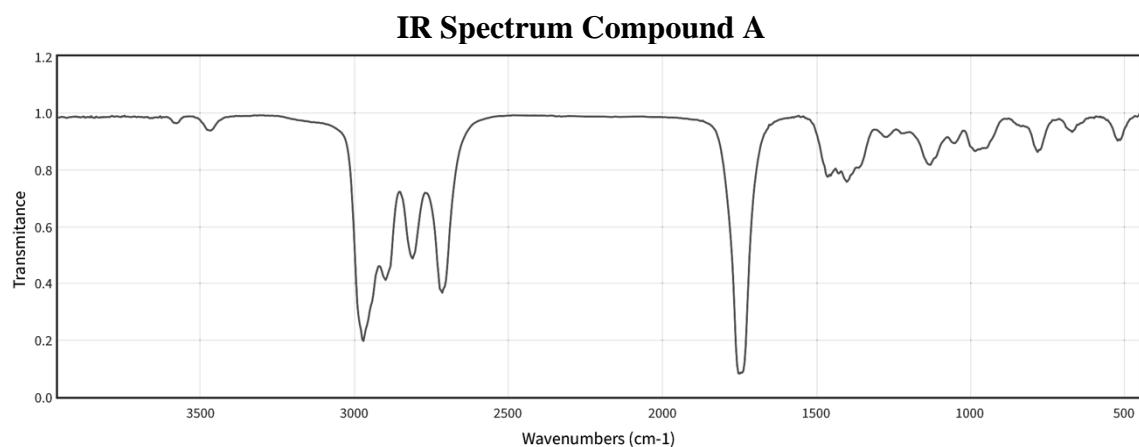
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**Question 27** (5 marks)

The following data were obtained for an unknown **Compound A**.

The compound decolourises acidified permanganate ( $\text{H}^+/\text{MnO}_4^-$ ) from purple to colourless to produce a **Compound B**, that produces bubbles when sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) is added.



**Question 27 continues on page 22**

### Question 27 (continued)

Determine the structures of compound A and B.

5

Justify your answer with reference to the information given on its reactivity and the spectroscopic data provided.

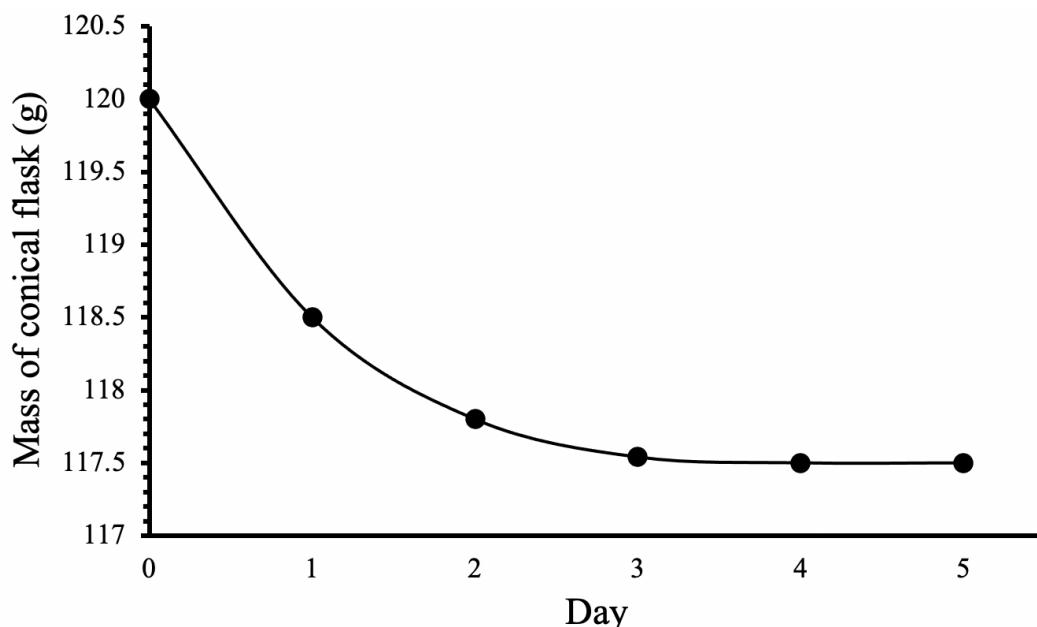
<i>Compound A Structure</i>	<i>Compound B Structure</i>

End of Question 27

**Question 28** (8 marks)

In an experiment glucose was fermented to produce ethanol. The flask was stoppered with cotton wool.

The mass changes were monitored over several days and the graph below was obtained.



- (a) Write a balanced chemical equation for fermentation. 1

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- (b) Identify the reason why the flask must be stoppered. 1

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- (c) Using the graph above, show that the fermentation produced 2.62 g of ethanol. 2

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**Question 28 continues on page 24**

### Question 28 (continued)

- (d) The enthalpy of combustion of ethanol is 1370 kJ/mol. The 2.62 g of ethanol produced was used to heat 200 mL of water in a can from 20.0°C to 29.5°C. 4

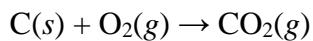
Calculate the percentage of heat lost to the environment.

**End of Question 28**

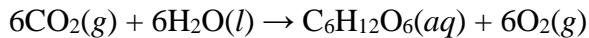
**Question 29** (4 marks)

Solid coal (C) undergoes complete combustion according to the equation:

4



Photosynthesis is a chemical process which produces glucose as shown below:



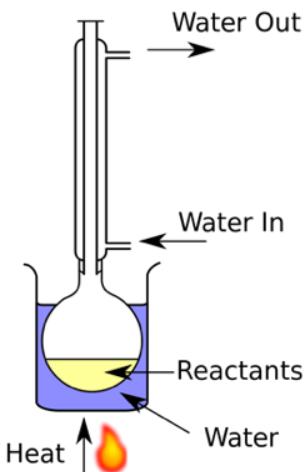
The table below lists the enthalpy and entropy values for the coal combustion and photosynthesis chemical reactions.

	<i>Combustion</i>	<i>Photosynthesis</i>
$\Delta H \text{ (kJ mol}^{-1}\text{)}$	-715	+2803
$\Delta S \text{ (J mol}^{-1} \text{ K}^{-1}\text{)}$	+2.9	-212

Analyse the processes in terms of enthalpy and entropy. By calculating Gibbs Free Energy ( $\Delta G$ ) determine the spontaneity of the reactions at 25 °C.

**Question 30** (7 marks)

Esters are compounds that can be produced from an alcohol and carboxylic acid. During this experiment the following refluxing apparatus is used.



- (a) Explain the purpose of refluxing when producing an ester. 2

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- (b) Safety glasses, a lab coat and gloves are common safety precautions taken during an experiment. 1

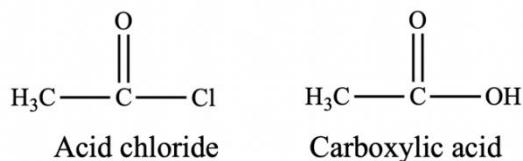
Identify a safety issue with this reflux experiment and a safety precaution that can minimise the risk other than safety glasses, lab coat and gloves.

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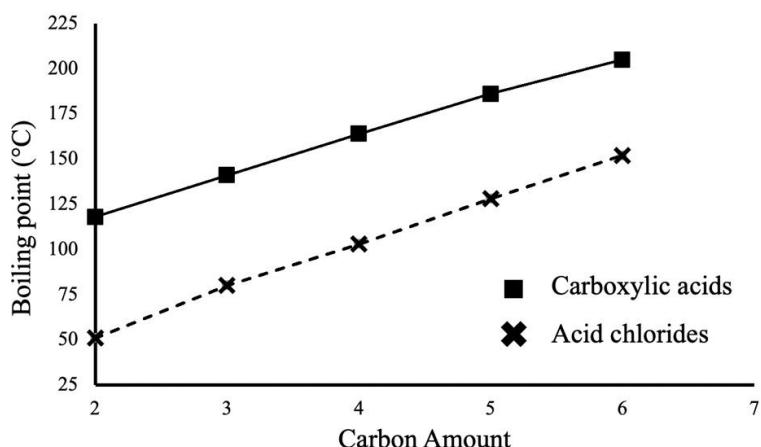
**Question 30 continues on page 27**

Question 30 (continued)

- (c) Acid chlorides are molecules similar to carboxylic acids in structure. They are often used in esterification as a substitute for the carboxylic acid as they are more reactive. As shown below they have a Cl instead of an OH group. 3



The boiling point of straight chain acid chlorides and carboxylic acids is below.



Explain the trends in the boiling points in the above graph. Use diagrams to support your answer.

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**Question 30 continues on page 28**

Question 30 (continued)

- (d) The solubility of the carboxylic acids in water is displayed in the below table. 1

Carbon Amount	Carboxylic acid solubility (g / 100 g water)
2	Miscible
3	Miscible
4	Miscible
5	5
6	1.1

Explain the trend in the solubility of the carboxylic acids.

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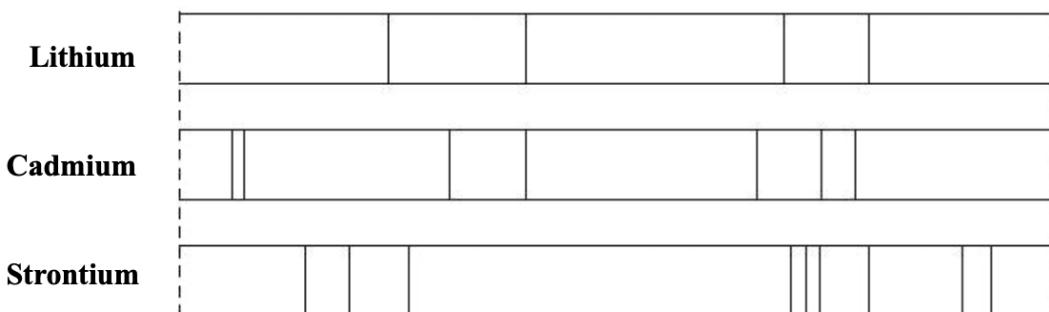
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**End of Question 30**

**Question 31** (7 marks)

The emission spectra of lithium, cadmium and strontium samples were recorded as displayed below.



The emission spectra of the metal ions in a soil sample in a farm was also taken. This is displayed below.



- (a) Explain why the soil sample contains lithium and strontium, but not cadmium. 1

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- (b) The concentration of strontium ( $\text{Sr}^{2+}$ ) in the soil sample was investigated. 2

Explain why AAS would selectively analyse for the  $\text{Sr}^{2+}$  and not the  $\text{Li}^+$  also present in the soil sample.

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**Question 31 continues on page 30**

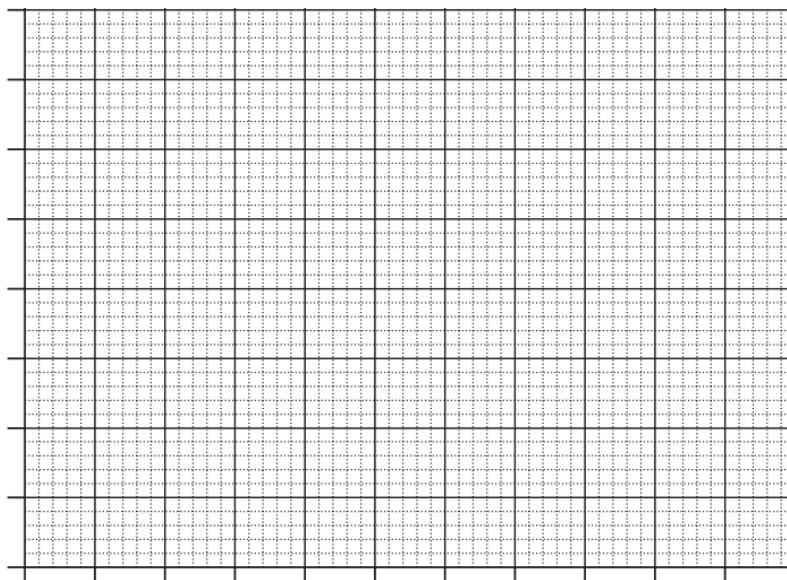
Question 31 (continued)

- (c) The local allowable level for strontium in farming soil is 0.10% by percentage mass. A chemist prepared a series of  $\text{Sr}^{2+}$  standard solutions with varying concentrations. The absorbance of these solutions is displayed below.

2

$\text{Sr}^{2+}$ (mg/L)	20.0	40.0	60.0	80.0	100.0
Absorbance	0.15	0.30	0.46	0.61	0.76

Plot a calibration curve for the standard  $\text{Sr}^{2+}$  solutions on the grid.



- (d) A 12.00 g sample of the soil was dissolved in 250.0 mL of water. 10.0 mL of this solution was further diluted to a final volume of 100.0 mL. The absorbance of the diluted solution was determined to be 0.38. Determine if the level of strontium in the soil sample is within the allowable level.

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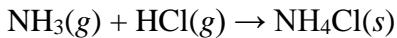
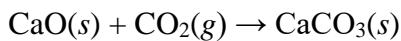
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**End of Question 31**

**Question 32** (2 marks)

Two acid-base reaction processes are displayed below.

2



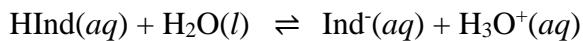
Identify which reaction is a Bronsted-Lowry reaction. Include a reason to justify the selection that you make.

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**Question 33** (3 marks)

Phenolphthalein is an example of an acid-base indicator. The indicator exists in two forms  $\text{HInd}$  and  $\text{Ind}^-$ . The “Ind” refers to indicator. These two forms have different colours as shown in the equilibrium equation below:

3



**Colourless**                    **Pink**

When sodium acetate ( $\text{NaCH}_3\text{COO}$ ) solution is added to the indicator, the colour of the solution turns to pink.

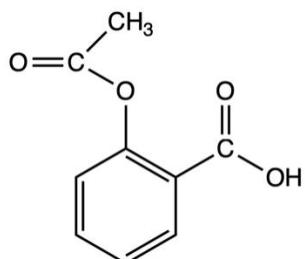
Describe why this colour change occurs. In your answer include a chemical equation(s).

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**Question 34** (10 marks)

An analytical chemistry lab was hired to verify claims regarding suspect aspirin tablets. Consumers who used the tablets experienced negative health effects consistent with heavy metal poisoning.

Legitimate aspirin tablets contain 2-acetoxybenzoic acid as the active ingredient and other harmless fillers such as microcellulose.



2-acetoxybenzoic acid  
C<sub>9</sub>H<sub>8</sub>O<sub>4</sub>

The manufacturer stated that each tablet contained a minimum of 25.0% of 2-acetoxybenzoic acid by percentage mass.

The following procedure was conducted to determine the validity of this claim:

- A 200.0 mg aspirin tablet was crushed and placed in a conical flask.
- 35.0 mL of 0.0150 mol/L standardised sodium hydroxide was added to neutralise all the 2-acetoxybenzoic acid present, leaving an excess of sodium hydroxide.
- The excess sodium hydroxide was titrated with 0.0170 mol/L hydrochloric acid, until the phenol red indicator reached its endpoint. The titres found are below.

<i>Trial run</i>	<i>Titre (mL)</i>
1	24.0
2	22.0
3	22.1
4	21.9

**Question 34 continues on page 33**

Question 34 (continued)

- (a) Write balanced chemical equations for the TWO reactions of sodium hydroxide with 2-acetoxybenzoic acid and hydrochloric acid. 2

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- (b) Determine the number of moles of excess sodium hydroxide. 2

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- (c) Calculate the percentage by mass of 2-acetoxybenzoic acid in the aspirin tablet. 3  
Use this to show the claim by the manufacturer is invalid.

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**Question 34 continues on page 34**

Question 34 (continued)

- (d) Explain why phenol red (pH range: 6.2 - 8.2) was chosen as the pH indicator for the sodium hydroxide and hydrochloric acid titration.

1

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- (e) The aspirin tablets were also analysed by precipitation tests to determine the cause of the heavy metal poisoning in patients.

2

Common heavy metals include:  $Pb^{2+}$ ,  $Ba^{2+}$ ,  $Cu^{2+}$  and  $Ag^+$ .

The results of the precipitation tests are below.

<i>Test</i>	<i>Addition of <math>Cl^-</math></i>	<i>Addition of <math>OH^-</math></i>	<i>Addition of <math>CO_3^{2-}</math></i>	<i>Addition of <math>SO_4^{2-}</math></i>
<b>Observation</b>	No precipitate	Precipitate	Precipitate	No precipitate

Use the results above to determine the identity of the heavy metal present. Include at LEAST one balanced ionic equation in your answer showing the formation of precipitates.

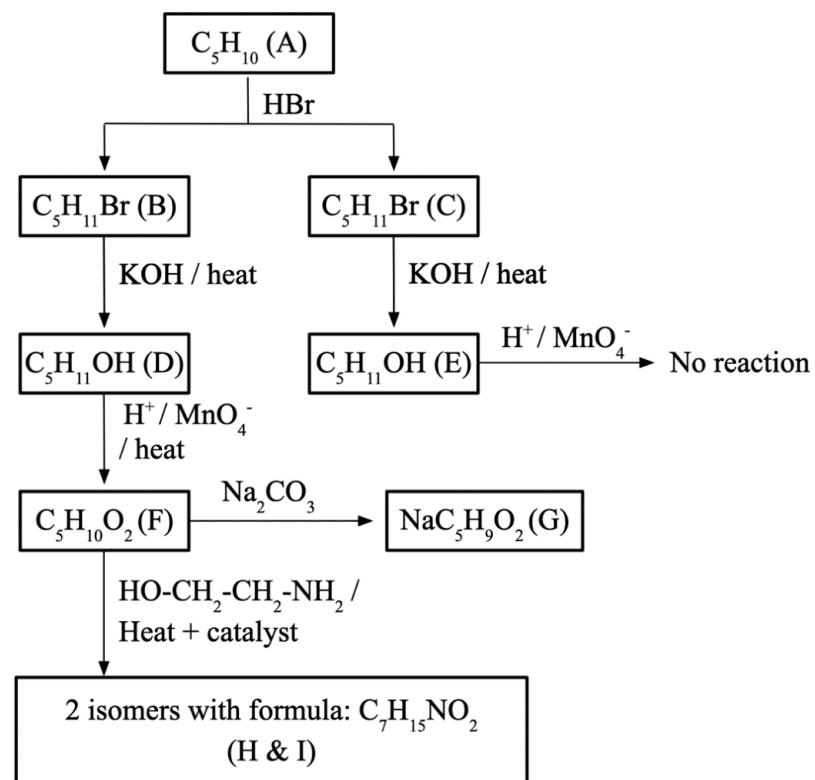
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**End of Question 34**

**Question 35** (8 marks)

Consider the reaction pathway flowchart below.

8



Determine the structure of compounds A-I by filling in the table below (**condensed structures are acceptable**). Provide a **brief** justification for each structure you draw.

	<i>Structure</i>	<i>Justification</i>
A		
B		

Question 35 continues on page 36

Question 35 (continued)

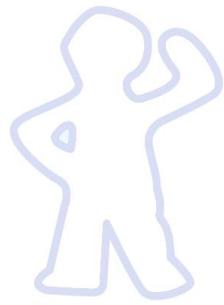
	<i>Structure</i>	<i>Justification</i>
C		
D		
E		
F		

**Question 35 continues on page 37**

Question 35 (continued)

	<i>Structure</i>	<i>Justification</i>
<b>G</b>		
<b>H</b>		
<b>I</b>		

**End of paper**



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**2020**

**BORED OF STUDIES TRIAL EXAMINATION**

# Chemistry

# **Marking Guidelines, Marker's Comments & Exemplar Responses**

## Section I

### Multiple-choice Answer Key

1	2	3	4	5	6	7	8	9	10
B	A	C	D	C	B	A	D	B	D
<b>11</b>	<b>12</b>	<b>13</b>	<b>14</b>	<b>15</b>	<b>16</b>	<b>17</b>	<b>18</b>	<b>19</b>	<b>20</b>
A	B	A	A	B	D	D	C	D	D

### Multiple-choice Explanations

Question	Ans	Explanation
<b>1</b>	B	<p>Functional group isomers have the same chemical formula but come from a different homologous series. Butanoic acid (<math>\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}</math>) has the formula <math>\text{C}_4\text{H}_8\text{O}_2</math> and methyl propanoate (<math>\text{CH}_3\text{O}(\text{CO})\text{CH}_2\text{CH}_3</math>) has the formula <math>\text{C}_4\text{H}_8\text{O}_2</math> as well. Therefore, they are isomers. They are functional group isomers as one is a carboxylic acid and the other is a ketone.</p> <p>In A, the molecules are isomers but are chain isomers (as only the parent length is different). In C, the molecules are not isomers as they have different formulas. In D, the molecules are isomers but are position and chain isomers.</p>
<b>2</b>	A	$\text{PbCl}_2(s) \rightleftharpoons \text{Pb}^{2+}(aq) + 2\text{Cl}^-(aq)$ $K_{sp} = [\text{Pb}^{2+}][\text{Cl}^-]^2$ $1.70 \times 10^{-5} = (x)(2x)^2$ $1.70 \times 10^{-5} = 4x^3$ $x = 0.0162 \text{ mol/L}$ <p>This is needs to be converted to g/L, so multiply by the molecular mass.  Solubility = <math>0.0162 \times (207.2 + 2(35.45)) \text{ g/L} = 4.50 \text{ g/L}</math> (3 sf)</p>
<b>3</b>	C	<p>A buffer is made from a weak acid/base and its conjugate (one <math>\text{H}^+</math> difference). A has a strong acid and D has a strong acid so these are incorrect. B has a weak acid, however they are not conjugates as there are 2 <math>\text{H}^+</math> difference between them. C has a weak acid <math>\text{H}_2\text{PO}_4^-</math> and its conjugate <math>\text{HPO}_4^{2-}</math>.</p>
<b>4</b>	D	<p>Decolourising of bromine water indicates it has a double bond. Therefore, A is incorrect. Litmus paper turns from red to blue indicating a base, this</p>

		means that B and C are incorrect, as B is an amide (neutral) and C is a carboxylic acid (acidic). Therefore, the answer is D. Purple to colourless with $\text{H}^+/\text{MnO}_4^-$ indicates a primary or secondary alcohol. This group is present in D.
5	C	An ester is made from a carboxylic acid and alcohol. The left portion contains the COO which comes from a carboxylic acid with 2 carbon atoms i.e. ethanoic acid. The right portion comes from an alcohol containing 4 carbon atoms. Based on the connection it is butan-2-ol. Butan-1-ol would instead connect through the end as the OH is on a terminal carbon. The catalyst used is concentrated sulfuric acid.
6	B	The curve is for a weak acid + strong base. This is because initially the conductivity of the acid is being measured as it will be in the conical flask. There is a low conductivity in the graph indicating a lower number of ions (consistent with a partially ionised acid). The base is added from the burette. After the equivalence point only excess base is added and as there is a sharp increase in conductivity this indicates a high number of ions (consistent with a fully ionised base).
7	A	$[\text{NO}_2] = \frac{0.50}{2} = 0.25 \text{ mol/L}$ $[\text{N}_2\text{O}_4] = \frac{0.20}{2} = 0.10 \text{ mol/L}$ $Q = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{0.25^2}{0.10} = 0.625$ <p>Therefore, <math>Q &gt; K_{\text{eq}}</math></p> <p><math>Q</math> must approach <math>K_{\text{eq}}</math> to reach equilibrium so <math>Q</math> must decrease. Therefore <math>[\text{N}_2\text{O}_4]</math> must increase and <math>[\text{NO}_2]</math> must also increase.</p> <p>This is consistent with a left shift.</p>
8	D	The amount of base required in a neutralisation reaction is NOT dependent on the strength of the acid. The strength of the acid is linked to the reaction it has with water when ionised. Both reactions go to completion due to NaOH being a strong base. As both acids are monoprotic it means they will require the same amount of base.
9	B	A blue-green flame test indicates either copper or barium. Addition of sodium sulfate produced no precipitate, so it cannot be barium as it forms insoluble barium sulfate, which was not observed. Copper would not form precipitates with sodium sulfate or sodium chloride.

<b>10</b>	D	Adding KSCN increases $[SCN^-]$ shifting the equilibrium right (more red). A hot-water bath will increase the temperature shifting the equilibrium to the left as it is an exothermic reaction (more yellow). NaOH precipitates $Fe^{3+}$ forming insoluble $Fe(OH)_3$ , therefore removing $Fe^{3+}$ shifting equilibrium left (more yellow).
<b>11</b>	A	The scenario being described obeys the Beer-Lambert Law: $A = \epsilon lc$ $0.213 = (2.00 \times 10^3)(1.00)c$ $c = 1.065 \times 10^{-4} \text{ mol/L}$ $n = cv = (1.065 \times 10^{-4})(0.010) = 1.065 \times 10^{-6} \text{ mol}$ $m = (1.065 \times 10^{-6})(55.85 + 6(2(1.008) + 16.00))$ $m = 1.75 \times 10^{-4} \text{ g (3 sf)}$
<b>12</b>	B	There are 2 signals in the $^1\text{H-NMR}$ indicating two hydrogen environments. Therefore 1-chloropropane is not possible (it has 3 hydrogen environments) and ethane is not possible (it has 1 hydrogen environment). Propane and 2-chloropropane both have 2 hydrogen environments.  However, the splitting patterns are different. Propane will have a septet and triplet whereas 2-chloropropane will have a septet and doublet.  Therefore 2-chloropropane is the correct answer.
<b>13</b>	A	For the first equation: $\frac{[HI]^2}{[I_2][H_2]} = 50$ This can be transformed into the second equilibrium constant by taking a reciprocal and square rooting so $\frac{[I_2]^{0.5}[H_2]^{0.5}}{[HI]} = \sqrt{\frac{1}{50}} = 0.141$ <b>Note:</b> You cannot just half the reaction because this wouldn't take into account that the molar ratios are powers and not coefficients in the $K$ constant expression.
<b>14</b>	A	The monomer contains a double bond, which forms an addition polymer by the breaking of the double bond and connection of repeating monomer units.  By moving all bonds not involved in the double to the vertical position and connecting 3 units, the polymer in option A is formed.

<b>15</b>	B	<p>The mass spectrometer detector only records species that form ions.</p> <p>Option B contains all the possible ions that could be detected and displayed in the mass spectrum.</p>
<b>16</b>	D	$n(\text{Ca}(\text{OH})_2) = cv = (0.040)(0.075) = 0.003 \text{ mol}$ $n(\text{HNO}_3) = cv = (0.040)(0.025) = 0.001 \text{ mol}$ <p>Since calcium hydroxide has two <math>\text{OH}^-</math> ions and nitric acid has one <math>\text{H}^+</math> then</p> $n(\text{OH}^-) = 0.006 \text{ mol}$ $n(\text{H}^+) = 0.001 \text{ mol}$ <p>Excess <math>n(\text{OH}^-) = 0.006 - 0.001 = 0.005 \text{ mol}</math></p> $c(\text{OH}^-) = \frac{n}{v} = \frac{0.005}{0.100} = 0.05 \text{ mol/L}$ $\text{pOH} = -\log_{10} 0.05 = 1.3$ $\text{pH} = 14 - \text{pOH} = 12.7$
<b>17</b>	D	<p>Highest pH indicates the most basic solution (i.e. the strongest base), so A and C are not possible, as these are acids. Option B and D represent the conjugate bases of the acids in A and C (if we remove the <math>\text{Na}^+</math> spectator ion). The <math>pK_b</math> of the conjugate bases come from: <math>pK_a + pK_b = 14</math></p> <p>For <math>\text{NaCHOO}</math>: <math>pK_b = 14 - 3.7 = 10.3</math></p> <p>For <math>\text{NaOCl}</math>: <math>pK_b = 14 - 7.5 = 6.5</math></p> <p>A lower <math>pK_b</math> corresponds to a stronger base.</p> <p>Therefore, <math>\text{NaOCl}</math> will be the stronger base and have the highest pH.</p>
<b>18</b>	C	$2\text{CH}_3\text{COOH}(aq) + \text{Ca}(\text{OH})_2(aq) \rightarrow \text{Ca}(\text{CH}_3\text{COO})_2(aq) + 2\text{H}_2\text{O}(l)$ <p>From graph equivalence point volume is 20 mL of <math>\text{CH}_3\text{COOH}</math>.</p> $n(\text{CH}_3\text{COOH}) = cv = (0.10)(0.020) = 0.002 \text{ mol}$ $n(\text{Ca}(\text{OH})_2) = 0.5n(\text{CH}_3\text{COOH}) = 0.001 \text{ mol}$ $m(\text{Ca}(\text{OH})_2) = (0.001)(40.008 + 2(16.00 + 1.008)) = 0.074096 \text{ g}$ <p>Concentration in g/L</p> $c(\text{Ca}(\text{OH})_2) = \frac{0.074096}{0.010} = 7.4 \text{ g/L (2 sf)}$

<b>19</b>	D	<p>C is a carboxylic acid, B is a primary alcohol and A is a haloalkane.</p>
<b>20</b>	D	<p><math>\text{Ca}(\text{NO}_3)_2(aq) + \text{SO}_4^{2-}(aq) \rightarrow \text{CaSO}_4(s) + 2\text{NO}_3^-(aq)</math></p> $n(\text{CaSO}_4) = \frac{0.2}{40.08 + 32.07 + 4(16.00)} = 0.00147 \text{ mol}$ $n(\text{SO}_4^{2-}) = n(\text{CaSO}_4) = 0.00146 \text{ mol}$ <p>Given</p> $\text{S}(s) + 3/2 \text{ O}_2(g) + \text{O}^{2-}(aq) \rightarrow \text{SO}_4^{2-}(aq)$ $n(\text{S}) = n(\text{SO}_4^{2-}) = 0.00147$ $m(\text{S}) = (0.00147)(32.07) = 0.0471 \text{ g}$ $\% m(\text{S}) = \frac{0.0471}{15.0} \times 100 = 0.314\%$

## Section II

### Question 21 (a)

Criteria	Marks
• Provides correct comment about equilibrium position	1

*Sample answer:*

$K > 1$  indicating there are more products than reactants, so the equilibrium lies to the right.

*Marker's comments:*

This question was well answered by students. The best responses made a clear link to the equilibrium constant definition.

*Exemplar student answer:*

(a) What does the value of the equilibrium constant ( $K_{eq}$ ) indicate about the position of the equilibrium? 1

The value of  $K_{eq} > 1$ , indicating more products are present than reactants ( $K_{eq} = \frac{[C][D]}{[A][B]}$ ), so equilibrium lies to the right, towards the products.

### Question 21 (b)

Criteria	Marks
<ul style="list-style-type: none"> <li>Correct equilibrium constant expression</li> <li>Correct RICE table or equivalent to find equilibrium concentrations</li> <li>Correctly finds concentration of B</li> </ul>	3
<ul style="list-style-type: none"> <li>Any two of the above</li> </ul>	2
<ul style="list-style-type: none"> <li>One of the above</li> </ul>	1

*Sample answer:*

	2A(g) ⇌ B(g) + C(g)		
	A	B	C
R	2	1	1
I	0.50	0	0
C	-2x	+x	+x
E	0.50 - 2x	x	x

$$K = \frac{[B][C]}{[A]^2}$$

$$4.0 = \frac{x^2}{(0.50 - 2x)^2}$$

$$2.0 = \frac{x}{0.50 - 2x}$$

$$2.0(0.50 - 2x) = x$$

$$1.0 - 4x = x$$

$$5x = 1.0$$

$$x = 0.2 \text{ mol/L (2 sf)}$$

*Marker's comments:*

This question was moderately well answered by students. The best responses used a RICE table in their answer and used a square root instead of expanding and solving a quadratic, although some students were able to arrive at the correct answer using the quadratic.

Many students lost a mark on this question due to simple mathematical errors, such as:

- Incorrectly writing the change for compound A was  $-x$ , when it should be  $-2x$ .
- Solving the quadratic and making substitution errors in the formula or incorrectly assuming that the  $\frac{1}{3}$  mol/L solution was the  $x$  value. In this case the equilibrium concentration of A was  $0.50 - 2x$ . If  $x = \frac{1}{3}$ , the value would be negative.
- Assuming that the approximation of  $0.50 - 2x$  could be made. In this case it cannot, as  $K$  is not a small number at 4.0.

**Exemplar student answer:**

- (b) Initially 5.0 moles of A was added to a sealed 10.0 L container and allowed to come to equilibrium. Calculate the equilibrium concentration of B.

3

	$2A(g)$	$\rightleftharpoons$	$B(g)$	$+ C(g)$	$K_{eq} = \frac{[B][C]}{[A]^2} = 4$
I	0.5		0	0	
C	$-2x$		$+x$	$+x$	$x^2 = 4$
E	$0.5 - 2x$		$x$	$x$	$(0.5 - 2x)^2$

$$\frac{x}{0.5 - 2x} = 4 \quad 2$$

$$x = 2(0.5 - 2x)$$

$$x = 1 - 4x$$

$$5x = 1 \Rightarrow x = \frac{1}{5}$$

Question 21 continues on page 15

$$[B] = 0.2 \text{ mol L}^{-1}$$

$$\approx 0.20 \text{ mol L}^{-1}$$

✓

(2sf)

### Question 21 (c)

Criteria	Marks
<ul style="list-style-type: none"> <li>Determines reaction is exothermic</li> <li>Provides link to graph (i.e. equilibrium shifting left due to an increase in temperature)</li> <li>Links this to either Le Chatelier's Principle or Collision Theory correctly</li> </ul>	2
Any correct statement from the above	1

#### Sample answer:

The graph shows the equilibrium is shifting left due to an increase in temperature. [A] increases, while [B] and [C] decrease. This would be consistent with an exothermic reaction. By increasing the temperature, the equilibrium shifts towards the left (the endothermic side) by Le Chatelier's Principle to minimise the disturbance (i.e. decrease heat). This means that the forward reaction (right side) is exothermic.

#### Marker's comments:

This question was well answered by students. The best responses included a definition of Le Chatelier's Principle in terms of minimising the disturbance and made reference to the graph in explaining their answer.

#### Exemplar student answer:

At time  $T$ , the temperature of the reaction vessel was increased.

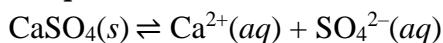
Explain with reference to the graph whether the reaction is exothermic or endothermic.

$$2A(g) \rightleftharpoons B(g) + C(g)$$
*when the temperature of the reaction vessel is increased, Le Chatelier's principle predicts that the heat ~~is~~ absorbing endothermic reaction will be favoured until a new equilibrium is established. The increase in the concentration of the reactants and decrease in the concentration of the products as seen on the graph indicates that the reverse reaction is favoured. Hence, the reverse reaction is endothermic and the forward reaction is exothermic.*

### Question 22 (a)

Criteria	Marks
<ul style="list-style-type: none"> <li>Finds moles of <math>\text{CaSO}_4</math> or concentration</li> <li>Includes a relevant chemical equation</li> <li>Finds <math>K_{\text{sp}}</math> value correctly</li> <li>Finds diluted concentrations</li> <li>Finds <math>Q</math> value correctly AND explains reason for why a precipitate is not formed (i.e. link to saturation has not been reached)</li> </ul>	5
<ul style="list-style-type: none"> <li>Finds all of the above but makes 1 or 2 mistakes</li> </ul>	3-4
<ul style="list-style-type: none"> <li>Finds some of the above points or provides some relevant information</li> </ul>	1-2

**Sample answer:**



$$n(\text{CaSO}_4) = \frac{0.21}{40.08 + 32.07 + 4(16.00)} = 0.00154 \text{ mol}$$

$$c(\text{CaSO}_4) = \frac{n}{v} = \frac{0.00154}{0.100} = 0.0154 \text{ mol/L}$$

$$K = [\text{Ca}^{2+}][\text{SO}_4^{2-}] = (0.0154)(0.0154) = 2.4 \times 10^{-4} \text{ (2 sf)}$$

Both solutions are diluted from 100 mL to 200 mL, therefore the diluted concentrations are:

$$[\text{Ca}(\text{NO}_3)_2] = 0.5 \times 0.0010 = 0.0005 \text{ mol/L}$$

$$[\text{Ca}^{2+}] = [\text{Ca}(\text{NO}_3)_2] = 0.0005 \text{ mol/L}$$

$$[\text{Na}_2\text{SO}_4] = 0.5 \times 0.0010 = 0.0005 \text{ mol/L}$$

$$[\text{SO}_4^{2-}] = [\text{Na}_2\text{SO}_4] = 0.0005 \text{ mol/L}$$

$$Q = [\text{Ca}^{2+}][\text{SO}_4^{2-}] = (0.0005)(0.0005) = 2.5 \times 10^{-7} \text{ (2 sf)}$$

As  $Q < K_{\text{sp}}$  no precipitate forms. The solution has not reached the saturation point as the forward reaction (i.e. dissolution) is still favoured.

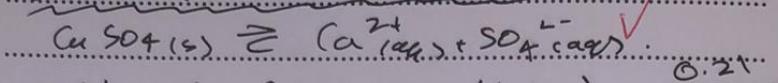
**Marker's comments:**

Most students calculated  $K_{\text{sp}}$  correctly. However, mistakes for the  $Q$  calculation included:

- Not accounting for the dilution factor or only finding moles and not concentration.
- Not explaining the answer  $Q < K_{\text{sp}}$  statement. For a question with the verb ‘predict’ the statement  $Q < K_{\text{sp}}$  is satisfactory. However, this question with the verb ‘explain’ requires the reason behind this. This was the determining factor between exemplar responses and ½ mark answers.

**Exemplar student answer:**

(Consider saturated solution:



$$0.21 \text{ g of } \text{CaSO}_4 \Rightarrow n(\text{CaSO}_4) = \frac{0.21}{136.15}$$

$$\therefore [\text{Ca}^{2+}] = [\text{SO}_4^{2-}] = 0.015424 \text{ M} \quad (\text{as } 1 \text{ mol occupies } 100 \text{ mL})$$

$$\therefore K_{\text{sp}} = [\text{Ca}^{2+}][\text{SO}_4^{2-}] = (0.015424)^2 = 2.379 \times 10^{-4}$$

(In second experiment):

$$[\text{Ca}^{2+}] = \frac{0.1 \times 0.001}{0.2} = 0.0005 \text{ M}$$

$$[\text{SO}_4^{2-}] = \frac{0.1 \times 0.001}{0.2} = 0.0005 \text{ M}$$

$$\therefore Q_{\text{sp}} = [\text{Ca}^{2+}][\text{SO}_4^{2-}] = (0.0005)^2 = 2.5 \times 10^{-7}$$

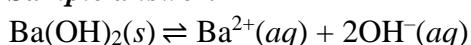
$\therefore$  since  $Q_{\text{sp}} < K_{\text{sp}}$ , the forward reaction is favoured to reach equilibrium and so no ppt will form. as the

Question 22 continues on page 17  
salt will react, explaining  
the results of the experiment

## Question 22 (b)

Criteria	Marks
<ul style="list-style-type: none"> <li>Relevant chemical equation included (this could be slightly different to the sample answer)</li> <li>Provides link to Le Chatelier's Principle or equilibrium shift to explain the lower solubility in NaOH (common ion effect)</li> </ul>	2
• Provides one of the above	1

**Sample answer:**



The solubility in the NaOH solution is lower because the presence of OH<sup>-</sup> ions shifts the equilibrium to the left by Le Chatelier's Principle (when an equilibrium system is disturbed it undergoes a chemical reaction to minimise the disturbance) favouring the reverse reaction. This therefore means a precipitate is formed more easily

**Marker's comments:**

This question was well answered by students. The best responses provided a relevant chemical equation and link to equilibrium shifts when explaining their answer.

Students can improve on the following aspects:

- Reading the question carefully as some students forgot to include a chemical equation.
- Understanding the question is asking for 'explain' the results, rather than to provide the calculation for the results in the table. This would not be required for a 2-mark question.

Highlighting and underlining key parts of the question can also assist.

**Exemplar student answer:**

Explain the reason for the large difference in solubility in these cases. Include a chemical equation in your answer.

$\text{Ba}(\text{OH})_2(s) \rightleftharpoons \text{Ba}^{2+}(aq) + 2\text{OH}^-(aq)$   
 When OH<sup>-</sup> is present, the equilibrium is disturbed ([OH<sup>-</sup>] ↑)  
 and it shifts to the left to remove the extra OH<sup>-</sup> ions.  
 (common ion effect). (according to le chatelier's principle)  
 Thus, more solid Ba(OH)<sub>2</sub> is produced in NaOH  
 compared to water ∵ Ba(OH)<sub>2</sub> is much more soluble in water (0.044M) than NaOH (0.001 M).

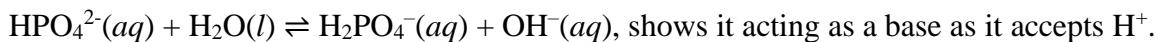
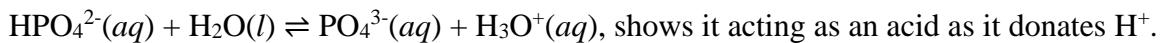
End of Question 22

### Question 23

Criteria	Marks
<ul style="list-style-type: none"> <li>Links amphiprotic property to proton transfer</li> <li>Provides a relevant chemical equation for acidic behaviour</li> <li>Provides a relevant chemical equation for basic behaviour</li> </ul>	2
Any of the above points or partially correct chemical equation	1

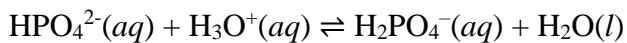
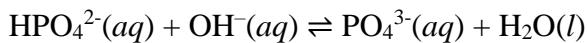
**Sample answer:**

Amphiprotic substances can act as acids ( $H^+$  donor) or bases ( $H^+$  acceptor).



**Answers could include:**

Alternative chemical equations:



**Marker's comments:**

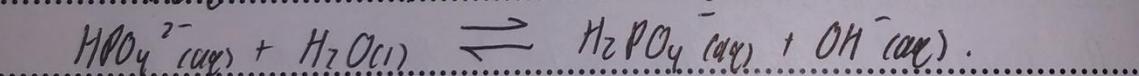
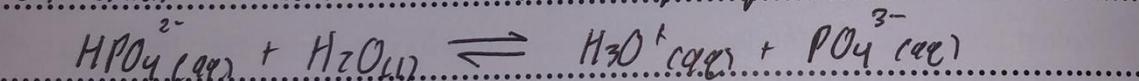
This question was surprisingly poorly answered by a large number of students. The best responses provided a short concise definition of amphiprotic substances and wrote equations without the spectator ion. Students need to recall that  $Na^+$  ions and other ions such as  $K^+$  ions are spectator ions and therefore should not be included in the equation. Instead the equations should only be written with  $HPO_4^{2-}$ . Some responses also had incorrect charges on the ions. Partial marks were awarded in these two cases.

**Exemplar student answer:**

Sodium hydrogen phosphate ( $Na_2HPO_4$ ) is an example of an amphiprotic substance.

With reference to TWO chemical equations, explain the term amphiprotic and justify the statement that  $Na_2HPO_4$  is amphiprotic.

The term.....amphiprotic.....means.....that.....the.....compound.....can.....act.....as.....an.....acid.....and.....a.....base.....It.....can.....donate.....and.....accept.....protons.....( $H^+$ ).



Evident in the chemical equations,  $HPO_4^{2-}$  can accept and donate protons, meaning that it is amphiprotic.

## Question 24

Criteria	Marks
<ul style="list-style-type: none"> <li>Correct chemical equation for the dissociation of the base</li> <li>Correct equilibrium constant expression</li> <li>Finds the <math>[\text{OH}^-]</math> concentration</li> <li>Finds pOH</li> <li>Finds pH</li> </ul>	3
<ul style="list-style-type: none"> <li>Any 3 or 4 of the above</li> </ul>	2
<ul style="list-style-type: none"> <li>Any 1 or 2 of the above</li> </ul>	1

*Sample answer:*

	$\text{C}_2\text{H}_5\text{NH}_2(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{C}_2\text{H}_5\text{NH}_3^+(aq) + \text{OH}^-(aq)$		
	$\text{C}_2\text{H}_5\text{NH}_2$	$\text{C}_2\text{H}_5\text{NH}_3^+$	$\text{OH}^-$
R	1	1	1
I	0.10	0	0
C	$-x$	$+x$	$+x$
E	$0.10 - x$	$x$	$x$

$$K = \frac{[\text{C}_2\text{H}_5\text{NH}_3^+][\text{OH}^-]}{[\text{C}_2\text{H}_5\text{NH}_2]}$$

$$5.6 \times 10^{-4} = \frac{x^2}{0.10 - x}$$

As  $K$  is small, can use the approximation  $0.10 - x \approx 0.10$

$$5.6 \times 10^{-4} = \frac{x^2}{0.10}$$

$$x^2 = 5.6 \times 10^{-5}$$

$$x = 0.00748 \text{ mol/L}$$

$$\text{pOH} = -\log_{10} 0.00748 = 2.126$$

$$\text{pH} = 14 - \text{pOH} = 11.87 \text{ (2 dp)}$$

**Marker's comments:**

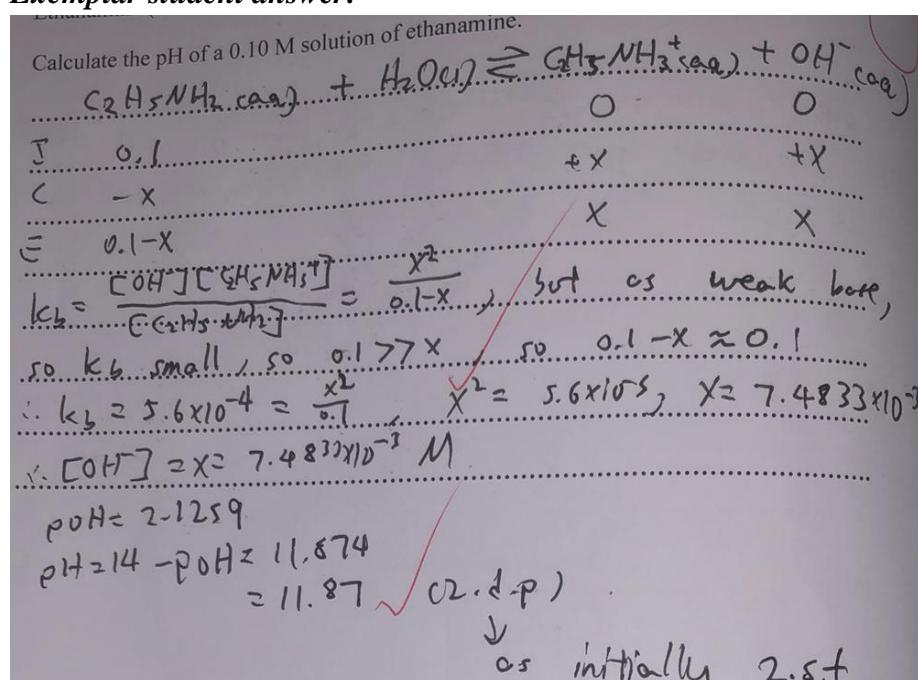
Those students who were able to correctly write the equation and equilibrium expression were in most cases able to correctly arrive at the answer. The better responses made use of a RICE table.

Students can improve on:

- Justifying why they made an approximation if the quadratic formula wasn't used.
- Rounding their final answer to decimal places instead of significant figures. For calculations involving logarithms the rounding is after the decimal place, so in this case 2 decimal places.

Although no marks were deducted in this instance for these two aspects if the question was 4 marks deductions would have been made for these things.

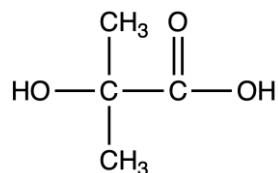
**Exemplar student answer:**



### Question 25 (a)

Criteria	Marks
• Provides correct structure of the monomer	1

*Sample answer:*



*Marker's comments:*

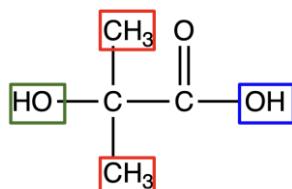
This question was well answered by students. Some students can improve their answer by recalling for a condensation polymer, water needs to be added back into the monomer unit.

### Question 25 (b)

Criteria	Marks
• Identifies correct number of peaks	1

*Sample answer:*

There are 3 hydrogen environments therefore 3 peaks, as labelled below:



*Marker's comments:*

This question was well answered by most students.

### Question 25 (c)

Criteria	Marks
<ul style="list-style-type: none"> <li>Finds molar mass of monomer with OR without water</li> <li>Correctly finds number of monomer units</li> </ul>	2
<ul style="list-style-type: none"> <li>One of the above correctly completed or finds number of monomer units without the removal of water</li> </ul>	1

#### Sample answer:

A condensation polymerisation follows:  $N$  monomer  $\rightarrow$  Polymer +  $(N - 1)$  Water

This is because for a polymer made up of  $N$  monomers, there are  $N - 1$  linkages between these monomers. Since each linkage created releases water in the polymerisation process then there are also  $N - 1$  water molecules. The monomer chemical formula is C<sub>4</sub>H<sub>8</sub>O<sub>3</sub>

$$\text{Molar mass of monomer} = 4(12.01) + 8(1.008) + 3(16.00) = 104.104 \text{ g/mol}$$

$$\text{Molar mass of water} = 2(1.008) + 16.00 = 18.016 \text{ g/mol}$$

$$N \times \text{Molar mass of monomer} = \text{Molar mass of polymer} + (N - 1) \times \text{Molar mass of water}$$

$$104.104N = 1.29 \times 10^5 + (N - 1)18.016$$

$$104.104N = 1.29 \times 10^5 + 18.016N - 18.016$$

$$86.088N = 1.2898 \times 10^5$$

$$N = 1498.26 = 1500 \text{ (3 sf)}$$

#### Marker's comments:

This question was fairly well answered by students. Some students lost marks on not accounting for the water loss or making simple mathematical errors in rearranging equations. Some students used other approaches to the question which were awarded the full marks provided the correct answer was found.

#### Exemplar student answer:

(c) The molecular weight of the polymer formed was  $1.29 \times 10^5$  g/mol. (2)

Using your structure from part (a), determine the number of monomer units required to produce a polymer with this molecular weight.

mm (monomer) = 104.104 g/mol

mm (H<sub>2</sub>O) = 18.016 g/mol

when forming polymer with  $k$  monomers you lose  $k-1$  H<sub>2</sub>O molecule

$\therefore 1.29 \times 10^5 = 104.104 \times k - 18.016(k-1)$

$128981.984 = 86.088k$

$k = 1498.2574$

$\therefore$  we need 1499 such monomers (round up as 1498 would not be sufficient)

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## Question 26

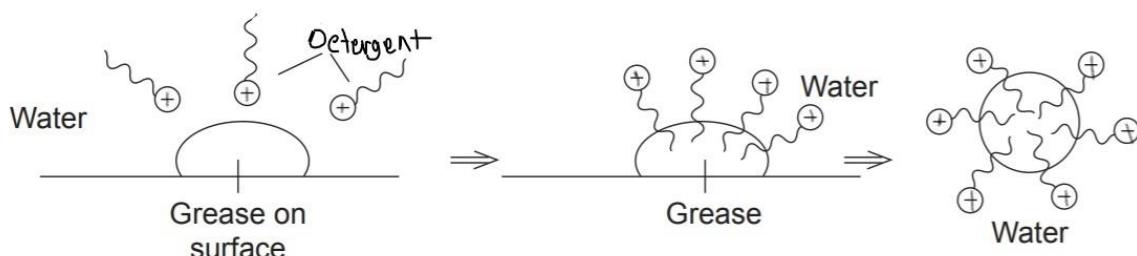
Criteria	Marks
<ul style="list-style-type: none"> <li>Explains why soap is ineffective in hard water (precipitates) while cationic detergent is still effective</li> <li>Explains cleaning action with reference to the hydrophobic and hydrophilic parts of soap and how they bind to oil and water</li> <li>Mentions the intermolecular force(s)</li> <li>Provides labelled relevant diagram(s)</li> </ul>	4
All of the above but missing one point	3
Missing two points (or missing a point and wrong statement given)	2
One relevant piece of information or point from the above	1

**Sample answer:**

Soap is ineffective in hard water as it makes a precipitate. This stops their cleaning ability as they are unable to form micelles:



The cationic detergent cannot make precipitates in hard water as the head group is positively charged so will repel  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions. Therefore, it is still effective in hard water. The hydrophobic hydrocarbon tail forms dispersion forces with oil molecules and the hydrophilic head forms ion-dipole forces with water molecules. These forces lead to the formation of a micelle and stable emulsion. A scrubbing action then removes oil off from the surface and leaves the object clean.



Source: [NESA 2019 Additional Questions](#)

### **Marker's comments:**

This question was fairly well answered by students with most receiving ¾ or all marks.

The key distinctions between these responses with those scores were:

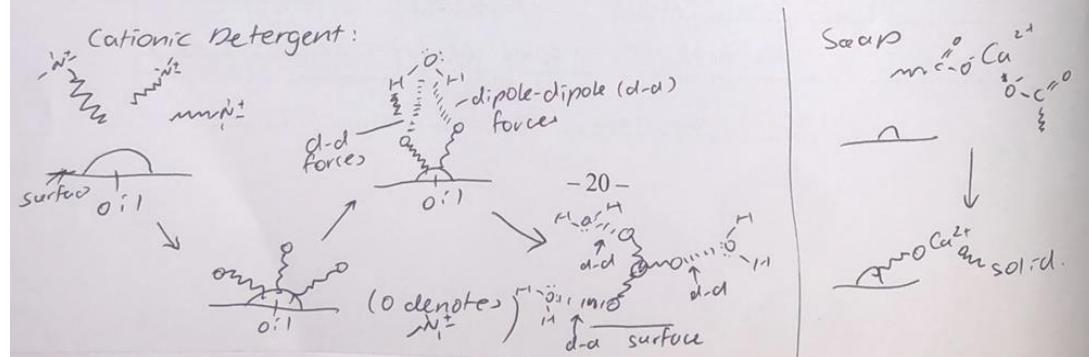
- No diagram(s) included. Students need to remember to read the question carefully to not miss important details. Stronger responses included these diagram(s) and they were well labelled in most cases and assisted in supporting their response.
- Including a chemical equation. This was not required for the full marks, but students who included this were able to better justify the poor cleaning action of soap.
- Stronger responses made reference to the intermolecular forces (dispersion and/or ion-dipole forces). This was the main reason students did not get full marks. Mentioning these forces is important as it is what leads to the tail binding to oil and the head group binding to water.

Another general comment is that students should be more concise. The exemplar response shown below shows how this can be achieved. Some responses which received full marks wrote almost double compared to this with the same information. This highlights an inefficient allocation of exam time and how the choice of words can impact the length of a response.

### **Exemplar student answer:**

Compare the cleaning action of the soap molecule and cationic detergent when removing oil from surfaces in hard water. Include a diagram(s) to support your answer.

Both soaps and cationic detergents have a hydrophobic, non-polar, hydrocarbon tail that forms dispersion forces with the oil molecules. They both act as surfactants, reducing the surface tension of water so it spreads more on the surface. The cationic detergent's quaternary ammonium ion head will form dipole-dipole forces with the hard water, causing a micelle to be formed as a suspension in water. However, the soap molecule will form insoluble salts in hard water, causing the soap to form calcium precipitates. This causes the soap to be unable to act as a bridge between the oil and water, causing it to be unable to clean grease off surfaces.

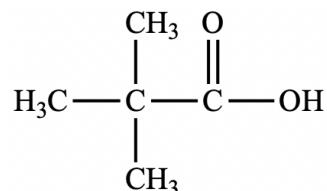
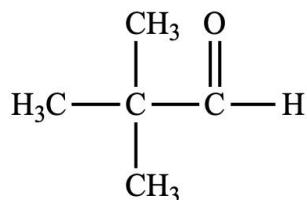


## Question 27

Criteria	Marks
<ul style="list-style-type: none"> <li>Analysis of IR spectrum</li> <li>Analysis of mass spectrum</li> <li>References the reactivity in their answer</li> <li>Analysis of <math>^1\text{H-NMR}</math> (must reference to all of signal amount, integration and splitting/multiplicity)</li> <li>Analysis of <math>^{13}\text{C-NMR}</math> (comments on signal amount, needs to make at least one assignment of a certain chemical shift)</li> <li>Structure of A correctly drawn</li> <li>Structure of B correctly drawn</li> </ul>	5
<ul style="list-style-type: none"> <li>Missing one or two of the above OR incomplete analysis OR partially incorrect structure(s)</li> </ul>	4
<ul style="list-style-type: none"> <li>Makes reference to at LEAST 3 of the above with partially correct structures</li> </ul>	2-3
<ul style="list-style-type: none"> <li>Provides one of the above pieces of relevant information</li> </ul>	1

**Sample answer:**

Compound A (left), Compound B (right)



**Reactivity:** Compound A is an aldehyde or primary alcohol as it oxidises to produce Compound B a carboxylic acid as it gives off bubbles when  $\text{Na}_2\text{CO}_3$  is added.

**IR:** Strong sharp peak at  $1700 \text{ cm}^{-1}$  ( $\text{C=O}$ ) and collection of strong sharp peaks at  $2600-2950 \text{ cm}^{-1}$  ( $\text{C-H}$ ). The IR indicates Compound A is an aldehyde.

**MS:** 86 m/z molecular ion peak, consistent with  $\text{C}_5\text{H}_{10}\text{O}$  as  
 $\text{Molar mass} = 5 \times 12.01 + 10 \times 1.008 + 16.00 = 86.13$

**$^{13}\text{C-NMR}$ :** Has 3 peaks indicating 3 carbon environments. 208 ppm is  $\text{C=O}$  in an aldehyde, 52 ppm is  $\text{C-C=O}$  and 28 ppm is  $\text{C-C}$ .

**$^1\text{H-NMR}$ :** Has 2 peaks indicating 2 hydrogen environments. 1.3 ppm - singlet with 9H integration ( $3 \times \text{CH}_3$  with no hydrogen neighbours), 9.6 ppm - singlet with 1H integration ( $\text{CH}$  with no hydrogen neighbours).

**Marker's comments:**

This was well answered by most students who received a  $\frac{4}{5}$  or all marks. The best responses were concise (e.g. used headings) and made reference to all of the features on the spectra.

The main distinction between the responses receiving those marks was the discussion of the  $^{13}\text{C}$ -NMR and  $^1\text{H}$ -NMR. Very few students made an assignment of peaks in the  $^{13}\text{C}$ -NMR and reference to the multiplicity and integration in the  $^1\text{H}$ -NMR in justifying their structures.

**Exemplar student answer:**

27 Compound A

Compound B

Since compound A oxidises to form compound B, evident in the decolorisation of acidified potassium permanganate, it must be a primary alcohol, a secondary alcohol or an aldehyde. Since compound B produces bubbles when in the presence of sodium carbonate, it must be a carboxylic acid, undergoing a neutralisation reaction. Hence, compound A must be a primary alcohol or an aldehyde. The absence of an absorption at  $3100\text{ cm}^{-1}$  in compound A's IR spectrum indicates that no hydroxyl (-OH) functional group is present. Hence, compound A must be an aldehyde.\* The molecular ion peak in its mass spectrum indicates that it has a molecular mass of  $86\text{ g mol}^{-1}$ , meaning that it must be an isomer of pentanal.

*continued on  
extra paper*

End of Question 27

\* This is reinforced by the absorption at  $\approx 1700\text{ cm}^{-1}$ , corresponding to a carbonyl ( $\text{C=O}$ ) functional group.

The  $^{13}\text{C}$  NMR spectrum displays three peaks indicating that there will be identical carbon environments. The tall peak at 25 ppm corresponds to the three terminating methyl groups of the aldehyde, reinforced by the 9H integration of the peak at 1.3 ppm on the  $^1\text{H}$  NMR spectrum. The peak at 90.7 ppm on the  $^{13}\text{C}$  NMR spectrum refers to the carbon environment containing the  $-\text{CON}$  aldehyde functional group. This is the singlet on the  $^1\text{H}$  NMR spectrum, with a significantly larger chemical shift due to its close proximity with the oxygen atom. As a result, the only structure that compound A can take is 2,2-dimethylpropanal. Compound B is the carboxylic acid formed from oxidising B and hence, can only have the structure as seen above.

### Question 28 (a)

Criteria	Marks
• Provides a balanced chemical equation with states AND catalyst	1

**Sample answer:**



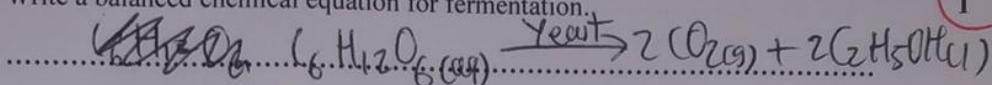
**Marker's comments:**

This was surprisingly a question that more than 50% of students lost a mark on. Students need to remember to include the catalyst for certain reactions in the Module 7 Organic Chemistry section. In this case of fermentation, the catalyst yeast must be specified on the arrow, as the reaction will not occur without this important condition.

Writing zymase on the arrow was also accepted (as the enzyme in yeast).

**Exemplar student answer:**

- (a) Write a balanced chemical equation for fermentation.



### Question 28 (b)

Criteria	Marks
• Provides the reason that anaerobic conditions are needed	1

**Sample answer:**

Fermentation is a chemical process that requires an anaerobic (low oxygen) environment. The use of the cotton wool provides a partial seal to the flask decreasing the amount of oxygen flowing in.

**Marker's comments:**

This was another question many students lost a mark on. Common wrong answers included, it is to prevent carbon dioxide loss or ethanol evaporation. The key point that many students missed is anaerobic conditions doesn't mean absence of oxygen, rather a low oxygen amount, so the cotton wool will be a satisfactory seal to keep out the large majority of inflowing oxygen.

**Exemplar student answer:**

- (b) Identify the reason why the flask must be stoppered.

...Fermentation requires an anaerobic environment  
environment or respiration will occur. The cotton  
wool helps to keep a low oxygen environment

- (c) Using the graph above, show that the fermentation produced 2.62 g of ethanol.

### Question 28 (c)

Criteria	Marks
<ul style="list-style-type: none"> <li>Calculates moles of carbon dioxide from the graph</li> <li>Correctly shows mass of ethanol formed is 2.62 g</li> </ul>	2
<ul style="list-style-type: none"> <li>One of the above included</li> </ul>	1

**Sample answer:**

The mass loss is due to CO<sub>2</sub> being lost

$$m(\text{CO}_2) = 120.0 - 117.5 = 2.5\text{g}$$

$$n(\text{CO}_2) = \frac{2.5}{12.01 + 2(16.00)} = 0.0568 \text{ mol}$$

$$n(\text{C}_2\text{H}_5\text{OH}) = n(\text{CO}_2) = 0.0568 \text{ mol}$$

$$m(\text{C}_2\text{H}_5\text{OH}) = 0.0568 \times (2(12.01) + 6(1.008) + 16.00) = 2.62 \text{ g (3 sf)}$$

**Marker's comments:**

This question was mostly well answered by students. Some students did not understand why the mass was being lost and incorrectly made assumptions such as it was due to ethanol being made. Students need to recall that the Law of Conservation of Mass means that during a chemical reaction the mass does not change, so therefore the mass lost cannot be due to a substance being made, but rather in this case loss of carbon dioxide from the system into the environment.

**Exemplar student answer:**

(c) Using the graph above, show that the fermentation produced 2.62 g of ethanol. 2

..... m(CO<sub>2</sub>) lost from graph = 120 - 117.5 = 2.5g

..... n(CO<sub>2</sub>) = m / MM = 2.5 / 44.01 = 0.056... mole

..... n(C<sub>2</sub>H<sub>5</sub>OH) = n(CO<sub>2</sub>) (1:1 ratio)

..... n(C<sub>2</sub>H<sub>5</sub>OH) = 0.056... moles

..... M(C<sub>2</sub>H<sub>5</sub>OH) = n × MM = (0.056...) (12.01 × 2 + 6 × 1.008 + 16)

..... M(C<sub>2</sub>H<sub>5</sub>OH) = 2.62g (3sf)

Question 28 continues on page 24

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### Question 28 (d)

Criteria	Marks
• Finds $\Delta H$	
• Finds moles of ethanol	4
• Finds molar heat of combustion	
• Finds percentage heat lost	
• All of the above but missing one point	3
• Two of the above correctly found	2
• One of the above correctly found	1

**Sample answer:**

$$\Delta H = mC\Delta T = (0.200)(4.18)(29.5 - 20.0) = 7.942 \text{ kJ}$$

$$n(\text{C}_2\text{H}_5\text{OH}) = \frac{2.62}{2(12.01) + 6(1.008) + 16.00} = 0.0568 \text{ mol} \text{ (or taken from part (c))}$$

To calculate heat absorbed by the can of water per mole of ethanol

$$\Delta H_{\circ c} = \frac{7.942}{0.0568} = 139.8 \text{ kJ/mol}$$

The proportion of heat absorbed by the can of water is

$$\% \text{ Heat absorbed} = \frac{139.8}{1370} \times 100 = 10.21\%$$

$$\% \text{ Heat lost} = 100\% - 10.21\% = 89.8\% \text{ (3 sf)}$$

**Marker's comments:**

Most students were able to correctly find the percentage of heat lost. Some students incorrectly stopped at 10.2% for heat lost. This would instead be the heat absorbed as it has contributed to increasing the temperature of the water.

**Exemplar student answer:**

Question 28 (continued)

(d) The enthalpy of combustion of ethanol is 1370 kJ/mol. The 2.62 g of ethanol produced was used to heat 200 mL of water in a can from 20.0°C to 29.5°C. 4

Calculate the percentage of heat lost to the environment.

$\Delta H = \frac{mC\Delta T}{n}$ ,  $n = \frac{m}{M}$ ,  $M = 2.62$ ,  $M = 2(12.01) + 6(1.008) + 16 = 0.0568 \text{ mol}$ .

$mC\Delta T = (0.2)(4.18)(29.5 - 20)$

$= 7.942 \text{ kJ}$

$\therefore \Delta H = \frac{7.942}{0.0568} = 13.9 \text{ kJ mol}^{-1} \text{ (3 sf)}$

$\% \text{ loss} = \frac{1370 - 13.9}{1370} \times 100 = 89.8\% \text{ (3 sf)}$

## Question 29

Criteria	Marks
<ul style="list-style-type: none"> <li>Analyses enthalpy of the two reactions correctly</li> <li>Analyses entropy changes in terms of disorder and justifies changes</li> <li>Calculates Gibbs Free Energy correctly</li> <li>Links spontaneity to sign of Gibbs Free Energy</li> </ul>	4
<ul style="list-style-type: none"> <li>All of the above but missing one point OR incomplete analysis of the entropy and enthalpy</li> </ul>	3
<ul style="list-style-type: none"> <li>Two of the above points included</li> </ul>	2
<ul style="list-style-type: none"> <li>One of the above points included</li> </ul>	1

**Sample answer:**

**Combustion:** exothermic process as heat is released (-715 kJ/mol). Entropy is a measure of disorder in a system. The entropy change for combustion is positive which indicates that disorder is increasing. This is because the C is changing from solid to CO<sub>2</sub> gas.

$$\Delta G = \Delta H - T\Delta S = (-715) - (25 + 273)(0.0029) = -716 \text{ kJ/mol (3 sf)}$$

Since  $\Delta G < 0$  then the reaction does not require input energy and is spontaneous.

**Photosynthesis:** endothermic process which absorbs heat (+2803 kJ/mol). Entropy decreases as the entropy change is negative. This is because 12 particles become 7 particles in the reaction.

$$\Delta G = \Delta H - T\Delta S = (2803) - (25 + 273)(-0.212) = 2870 \text{ kJ/mol (3 sf)}$$

Since  $\Delta G > 0$  then the reaction requires input energy and is non-spontaneous.

**Marker's comments:**

This question was moderately well answered. Some common mistakes by students included:

- Not ‘analysing’ the data provided in terms of the equations and the table. Most students were able to recognise the meaning of a positive entropy or negative entropy in terms of disorder from the table. However, they did not explicitly explain the reason which involved referencing the chemical equations – for example commenting on the change in state in equation 1 and change in particle number in equation 2. This is necessary as the question is asking for an analysis which means you need to give in depth reasoning for the values.
- In the calculation two common mistakes were to not change the 25 °C to 298 K and secondly to not change the entropy value from J to kJ before using the formula for Gibbs Free Energy (i.e. divide it by 1000).
- Some responses just calculated Gibbs Free energy but did not actually analyse the entropy and enthalpy. This highlights not all parts of the question were read carefully.

**Exemplar student answer:**

Analyse the processes in terms of enthalpy and entropy. By calculating Gibbs Free Energy ( $\Delta G$ ) determine the spontaneity of the reactions at 25 °C.

combustion of coal has a negative  $\Delta H$ , which means it is exothermic (heat is produced); photosynthesis has a positive  $\Delta H$ , meaning it is endothermic (absorbs heat from the environment). combustion of coal has a  $\Delta S$ , which is due to solid coal having less freedom of movement than  $\text{CO}_2$ , thus entropy increases (as product side is less ordered); photosynthesis has a  $\Delta S$ , due to glucose being a larger molecule and there being less moles on the product side than the reactant side.

$$\Delta G_{\text{combustion}} = -715 - 298.15 \times \left( \frac{2.9}{1000} \right) < 0 = -715.86463$$

∴ combustion of coal is spontaneous at 25 °C

$$\begin{aligned}\Delta G_{\text{photosynthesis}} &= 2803 - 298.15 \times \left( \frac{-212}{1000} \right) \\ &= 2866.2078 > 0\end{aligned}$$

∴ photosynthesis is not spontaneous at 25 °C

### Question 30 (a)

Criteria	Marks
• Provides purpose in terms of heating and rate of reaction • Provides purpose in terms of cooling and preventing loss of volatiles	2
• Provides one of the above points	1

#### Sample answer:

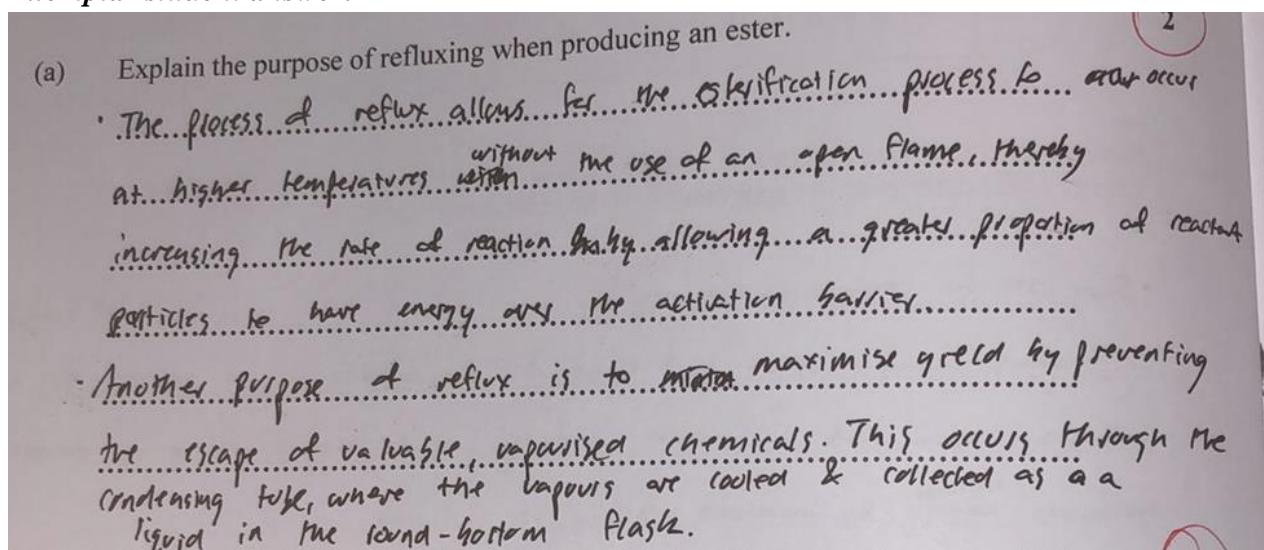
Esterification is a slow reaction. Therefore, by gently heating the reaction mixture the reaction rate is increased as more molecules have a greater collisional energy. Cooling using a condenser is used to prevent the evaporation of volatiles produced by the heating process.

#### Marker's comments:

Better responses were concise and clearly stated the two main reasons. Most responses were able to mention the purpose of the cooling condenser in refluxing in preventing loss of volatiles. However, many students were not able to make the link between why this is required in the first place. If the key purpose of refluxing is to prevent loss of volatiles the materials would not be heated. The main purpose of refluxing is to allow for a way to increase reaction rate by heating the reaction vessel (which is why volatiles are produced and then need to be recaptured as a secondary purpose of refluxing).

Some responses although they obtained the marks wrote 10-12 lines for a 2-mark question. Students should remember that the number of lines provided and the marks amount is a guide to how detailed the answer needs to be. Roughly speaking if a question is 2 marks you need to do 2 different things. Writing more does not always indicate that you are providing more detail, which was a common aspect throughout some responses to this question. Although, this did not lead to any mark losses, it is an inefficient allocation of exam time to a certain question.

#### Exemplar student answer:



### Question 30 (b)

Criteria	Marks
• Correct safety issue and a relevant safety precaution	1

#### **Sample answer:**

Examples can include, but are not limited to:

- Fumes are made in the experiment that can be toxic if inhaled, so use a fume cupboard or well-ventilated area
- Using a heating mantle or water bath instead of an open flame as the materials being used are flammable
- Spitting of reaction mixture when being heated, so use a stirrer bar or boiling chips to help prevent this
- Heating a volatile compound can lead to pressure build up, so an open top should be used

#### **Marker's comments:**

This was a well answered question by all students.

#### **Exemplar student answer:**

Identify a safety issue with this reflux experiment and a safety precaution that can minimise the risk other than safety glasses, lab coat and gloves.

Potentially hazardous (volatile reactants and products being released into air (either alcohol, acid), thus perform experiment in well ventilated room or under fume hood.

### Question 30 (c)

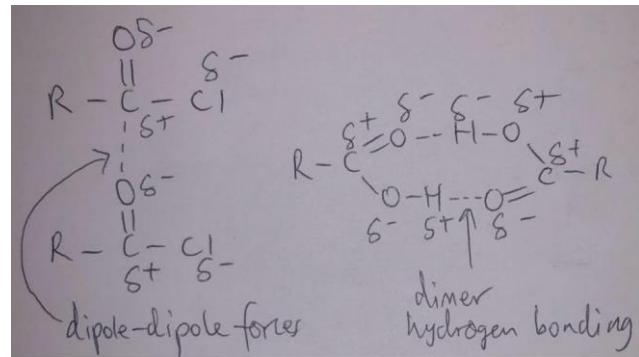
Criteria	Marks
<ul style="list-style-type: none"> <li>Explains trend of why carboxylic acid is higher than acid chloride</li> <li>Explains trend relating carbon amount and boiling point</li> <li>Includes diagram(s) in answer showing the intermolecular forces</li> </ul>	3
<ul style="list-style-type: none"> <li>Missing one of the above points</li> </ul>	2
<ul style="list-style-type: none"> <li>Provides one relevant point from the above</li> </ul>	1

**Sample answer:**

Boiling point is a measure of the intermolecular forces present and how much energy is needed to overcome them. Trends:

1) The carboxylic acid of the same carbon amount as the acid chloride always has a higher boiling point. This is because carboxylic acids are polar molecules which contain moderately strong dipole-dipole interactions and strong dimer ( $2\times$ ) hydrogen bonding. Acid chlorides are polar but only have dipole-dipole interactions. Therefore, carboxylic acids have stronger intermolecular forces and a higher boiling point.

2) In both graphs as carbon amount increases the boiling point also increases. This is because of an increase in dispersion forces from a larger number of electrons present, hence a higher boiling point.



**Marker's comments:**

Students need to remember to read the question carefully. Some students missed the part of the question where it asks for “diagrams to support your answer” or only mentioned 1 trend. See the plural of trends in the question indicating you need to give more than 1 trend. Better responses included these diagrams and made explicit reference to the trends in the graphs and intermolecular forces used to explain them.

Another trend some students were able to identify is that as carbon amounts increased the two graphs converged as dispersion forces became the dominant intermolecular force. This was originally in the marking criteria however due to the graph only showing this change slightly it was decided that it should not negatively impact students who did not include it. If the gradient change was more prominent this trend should also be included.

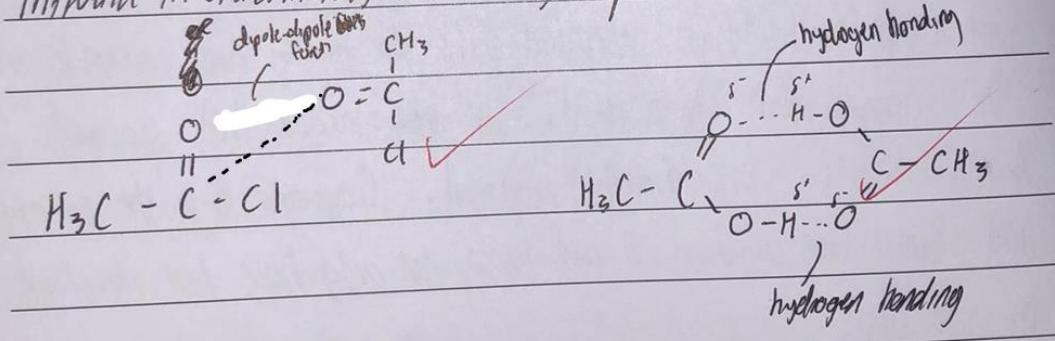
**Exemplar student answer:**

Explain the trends in the boiling points in the above graph. Use diagrams to support your answer.

Both compounds are polar and hence, will experience dipole-dipole attraction forces between their molecules. However, the hydroxyl (-OH) functional group in carboxylic acids facilitates hydrogen bonding, a stronger intermolecular force that requires more energy input to break, resulting in higher boiling points. Hence, carboxylic acids have higher boiling points. As the molar mass increases, the strength ...

30c) ... of the dispersion forces increase due to increased frequency of unequal electron distribution resulting from the increased number of electrons present. This will increase the boiling points for both homologous series as the <sup>strength of the</sup> intermolecular forces present increase for both.

As molar mass increases, the boiling points ~~for~~ for the two homologous series converge as the compounds become increasingly non-polar. The dispersion force attractions become the primary intermolecular force and the hydrogen bonding in carboxylic acids has less of an influence in determining the boiling points of carboxylic acids.



### Question 30 (d)

Criteria	Marks
• Explains trend in solubility of carboxylic acids	1

#### Sample answer:

The solubility of carboxylic acids decreases as the carbon chain length increases. An increase in dispersion forces means the molecule becomes more non-polar like. As water is polar it is unable to dissolve the longer chain alcohols, which cannot be dissolved by hydrogen bonding and dipole-dipole interactions.

#### Marker's comments:

This was a well answered question by the majority of students.

#### Exemplar student answer:

Explain the trend in the solubility of the carboxylic acids.

As chain length increases dispersion force.....  
Strength increases but strength of  
hydrogen bonding remains the same.....  
So the molecule becomes more <sup>non</sup>polar  
as and the non polar section can't be solvated  
by polar water

End of Question 30

leading to a lower solubility

### Question 31 (a)

Criteria	Marks
• Links lines in spectra to being a signature for the elements	1

#### Sample answer:

The lines in the emission spectra from the metals show lithium and strontium are present as these spectral lines are present. Cadmium is missing many spectral lines so is not present.

#### Marker's comments:

This was a well answered question by all students.

#### Exemplar student answer:

(a) Explain why AAS would selectively analyse for the Sr<sup>2+</sup> and not the Li<sup>+</sup> also present in the soil sample.  
The emission spectra of the soil sample contains the absorption lines of both lithium and strontium, but not of cadmium. Thus, the soil must contain both lithium and strontium, but not cadmium. The concentration of strontium (Sr<sup>2+</sup>) in the soil sample was investigated. 2

### Question 31 (b)

Criteria	Marks
• Identifies it is due to the lamp containing the element to be analysed • Links this to specific wavelengths of light emitted by lamp	1

#### Sample answer:

The lamp in AAS contains the element to be analysed. In this case it contains strontium. The lamp therefore produces specific wavelengths of light that can only be absorbed by strontium ions in the sample. Therefore, other metals such as lithium do not interfere with the measurement that is obtained as they do not absorb light at these wavelengths.

#### Marker's comments:

Mostly well answered. The best answers made links between the lamp and wavelength.

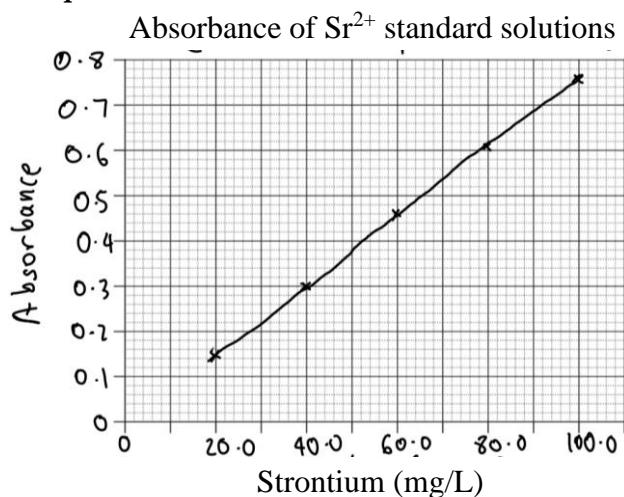
#### Exemplar student answer:

Explain why AAS would selectively analyse for the Sr<sup>2+</sup> and not the Li<sup>+</sup> also present in the soil sample.  
AAS utilises hollow cathode lamps made of the same element (Sr), which emits wavelengths specific to Sr<sup>2+</sup> (and not Li<sup>+</sup>). Li<sup>+</sup> cannot absorb the same wavelengths ∴ will not interfere with the investigation.

### Question 31 (c)

Criteria	Marks
<ul style="list-style-type: none"> <li>Plots data points and draws line of best fit only inside data values</li> <li>Labelled axes, title included and suitable scale</li> </ul>	2
<ul style="list-style-type: none"> <li>One of the above included</li> </ul>	1

**Sample answer:**

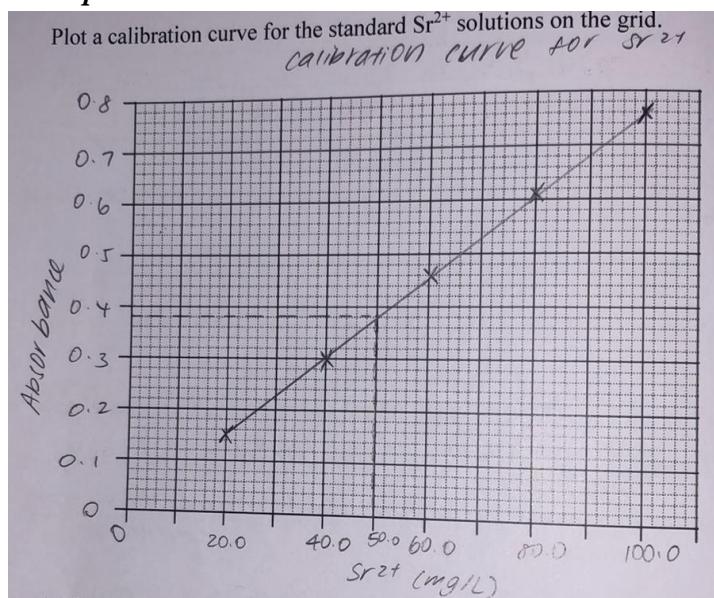


**Marker's comments:**

A fair portion of students did not get full marks. Weaker responses included:

- Not including a title or axis labels with units
- Drawing outside the calibration curve data points, for example connecting it to 0. Students need to remember that when drawing graphs, we can ONLY draw inside the data range as it is not guaranteed that the same relationship continues outside it.

**Exemplar student answer:**



### Question 31 (d)

Criteria	Marks
<ul style="list-style-type: none"> <li>• Uses graph to find <math>\text{Sr}^{2+}</math> concentration</li> <li>• Finds undiluted concentration or mass in the original sample</li> <li>• Finds percentage mass of strontium in the original sample</li> <li>• Makes comment on allowable level</li> </ul>	2
<ul style="list-style-type: none"> <li>• Uses graph to find concentration of <math>\text{Sr}^{2+}</math> AND/OR finds percentage mass in a diluted form AND/OR doesn't make a comment on level</li> </ul>	1

**Sample answer:**

From graph 0.38 absorbance is 50.0 mg/L of  $\text{Sr}^{2+}$  in the diluted solution.  
 10.0 mL has been diluted to 100.0 mL so with a dilution factor of 10 there are  
 $50.0 \times 10 = 500$  mg/L of  $\text{Sr}^{2+}$

The volume is 250 mL so there are

$$500 \times 0.250 = 125 \text{ mg} = 0.125\text{g of } \text{Sr}^{2+}$$

$$\% m(\text{Sr}^{2+}) = \frac{0.125}{12.00} \times 100 = 1.0\% \text{ (2 sf)}$$

This is above the limit

**Marker's comments:**

Well answered overall. However, some responses forgot to account for the dilution factor and therefore came to the incorrect conclusion. Better responses made a clear indication on the graph in part (c) to show the value they used in their calculation for part (d) and had a clear and easy to follow calculation structure.

**Exemplar student answer:**

- (d) A 12.00 g sample of the soil was dissolved in 250.0 mL of water. 10.0 mL of this solution was further diluted to a final volume of 100.0 mL. The absorbance of the diluted solution was determined to be 0.38. Determine if the level of strontium in the soil sample is within the allowable level.

$[\text{Sr}^{2+}] = 50 \text{ mg/L (from graph)}$

$[\text{Sr}^{2+}]_{\text{undiluted}} \sim 500 \text{ mg/L}$

$m(\text{Sr}^{2+}) = 500 \times 0.25$

$\therefore 125 \text{ mg}$

$\% \text{ by mass} = \frac{125 \times 10^{-3}}{12} \times 100\%$

$\sim 1.04\% \text{ (3sf)} \therefore \text{The level of strontium in the soil}$

~~sample is not within the allowable level~~

C2

## Question 32

Criteria	Marks
<ul style="list-style-type: none"><li>Identifies reaction (2) is the Bronsted-Lowry process</li><li>Provides justification in terms of both reactions i.e. why the first reaction is not a Bronsted-Lowry process and the second one is.</li></ul>	2
<ul style="list-style-type: none"><li>One of the above is provided</li></ul>	1

### Sample answer:

In the Bronsted-Lowry theory, acids donate protons to bases. Therefore the 2<sup>nd</sup> reaction is a Bronsted-Lowry acid-base reaction as a proton is transferred from hydrogen chloride to ammonia. There is no proton transfer in the 1<sup>st</sup> reaction so it is not a Bronsted-Lowry process.

### Marker's comments:

This was an all-around well answered question by the majority of students. One aspect that could be improved by students is when given a verb such as "justify" to ensure that in providing their reasoning they explain why the answer they did not select is incorrect. The better responses provided some form of a definition for the Bronsted-Lowry acid-base reactions and used this in supporting their justification.

### Exemplar student answer:

Identify which reaction is a Bronsted-Lowry reaction. Include a reason to justify the selection that you make.

A Bronsted & Lowry reaction must involve a proton transfer.

In reaction 2, NH<sub>3</sub> accepts a proton to become NH<sub>4</sub><sup>+</sup>, while HCl donates a proton to become Cl<sup>-</sup> thus, a proton transfer occurs, so (2) is a Bronsted - Lowry reaction.

No proton transfer occurs in (1), (no proton transfer occurs in (1). so it is not a Bronsted - Lowry reaction).

Question 33 (3 marks)

### Question 33

Criteria	Marks
<ul style="list-style-type: none"> <li>Includes a relevant chemical equation in the answer</li> <li>Identifies sodium acetate is a basic salt (or base)</li> <li>Links equilibrium shift to decreasing hydronium ions using Le Chatelier's principle to explain the colour</li> </ul>	3
<ul style="list-style-type: none"> <li>Provides 2 of the above points</li> </ul>	2
<ul style="list-style-type: none"> <li>Provides 1 of the above points</li> </ul>	1

#### Sample answer:

Sodium acetate ( $\text{NaCH}_3\text{COO}$ ) is a basic salt. The  $\text{Na}^+$  ion is a weak conjugate acid so is unable to react with water. The  $\text{CH}_3\text{COO}^-$  is a moderately strong conjugate base so when added to water produces  $\text{OH}^-$  ions:  $\text{CH}_3\text{COO}^-(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{CH}_3\text{COOH}(aq) + \text{OH}^-(aq)$ . These  $\text{OH}^-$  ions react with  $\text{H}_3\text{O}^+$  so that  $\text{OH}^-(aq) + \text{H}_3\text{O}^+(aq) \rightarrow 2\text{H}_2\text{O}(l)$ . This decreases the  $[\text{H}_3\text{O}^+]$ , therefore the equilibrium is disturbed. By Le Chatelier's principle the equilibrium shifts right to minimise disturbance. This increases the  $[\text{Ind}^-]$ , therefore explaining the colour change to pink.

#### Marker's comments:

Note that both equations are not required (but there should at least be one) but a stronger answer should be aiming to show both of them. Better responses showed a correct chemical equation and used this along with Le Chatelier's Principle to explain the observations.

#### Exemplar student answer:

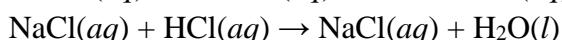
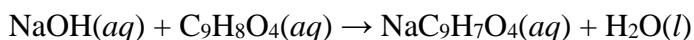
Describe why this colour change occurs. In your answer include a chemical equation(s).

Sodium acetate dissociates to produce  $\text{CH}_3\text{COO}^-$  by  
 $\text{NaCH}_3\text{COO}_{(s)} \rightleftharpoons \text{Na}^+ + \text{CH}_3\text{COO}^-_{(aq)}$   
 $\text{CH}_3\text{COO}^-$  is a weak base, that will react in water to produce hydroxide ions:  
 $\text{CH}_3\text{COO}^- + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COOM}^- + \text{OH}^-_{(aq)}$   
These hydroxide ions then react with  $\text{H}_3\text{O}^+$  to produce  $\text{H}_2\text{O}$   
 $\text{OH}^- + \text{H}_3\text{O}^+ \rightarrow 2\text{H}_2\text{O}_{(l)}$ . Thus,  $[\text{H}_3\text{O}^+]$  decreases while the quantity of water increases. As per Le Chatelier's principle predicts that the indicator system will thus shift to the right to increase  $[\text{OH}^-]$ , so the solution becomes pink.  $[\text{Ind}^-]$  increases, thus turning the solution pink as observed.

### Question 34 (a)

Criteria	Marks
• Provides 2 balanced chemical equations	2
• Provides 1 balanced chemical equation	1

**Sample answer:**



**Marker's comments:**

This question was well answered by most students. The most common mistakes were to forget to include states and incorrectly removing an oxygen atom from the carboxylic acid.

### Question 34 (b)

Criteria	Marks
• Finds average titre without outlier	2
• Finds excess moles of NaOH	
• One of the above OR does not remove outlier in calculation	1

**Sample answer:**

Average volume of HCl titre, noting that 24.0 mL is an outlier

$$\bar{v}(\text{HCl}) = \frac{22.0 + 22.1 + 21.9}{3} = 22.0 \text{ mL}$$

$$n(\text{HCl}) = cv = (0.0170)(0.022) = 3.74 \times 10^{-4} \text{ mol}$$

$$\text{Excess } n(\text{NaOH}) = n(\text{HCl}) = 3.74 \times 10^{-4} \text{ mol (3 sf)}$$

**Marker's comments:**

This question was well answered by most students.

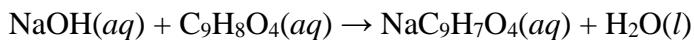
### Question 34 (c)

Criteria	Marks
<ul style="list-style-type: none"> <li>Finds initial moles of NaOH</li> <li>Finds moles of 2-acetoxybenzoic acid</li> <li>Finds percentage mass of 2-acetoxybenzoic acid</li> <li>Proves manufacturer's claim is invalid</li> </ul>	3
<ul style="list-style-type: none"> <li>All but one of the above missing</li> </ul>	2
<ul style="list-style-type: none"> <li>One or two of the above included</li> </ul>	1

**Sample answer:**

$$\text{Initial } n(\text{NaOH}) = cv = (0.0150)(0.035) = 5.25 \times 10^{-4} \text{ mol}$$

$$n(\text{NaOH}) \text{ reacted with C}_9\text{H}_8\text{O}_4 = 5.25 \times 10^{-4} - 3.74 \times 10^{-4} = 1.51 \times 10^{-4} \text{ mol}$$



$$n(\text{C}_9\text{H}_8\text{O}_4) = n(\text{NaOH}) \text{ reacted with C}_9\text{H}_8\text{O}_4 = 1.51 \times 10^{-4} \text{ mol}$$

$$m(\text{C}_9\text{H}_8\text{O}_4) = 1.51 \times 10^{-4} \times (9(12.01) + 8(1.008) + 4(16.00)) = 2.72 \times 10^{-2} \text{ g}$$

Since the tablet is 200 mg then

$$\%m(\text{C}_9\text{H}_8\text{O}_4) = \frac{2.72 \times 10^{-2}}{0.200} \times 100 = 13.6\% \text{ (3 sf)}$$

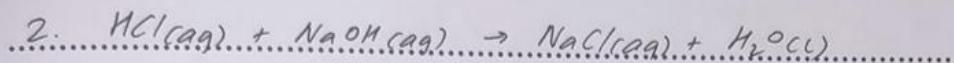
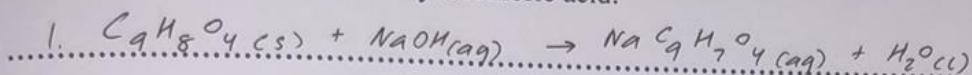
Since this is less than 25% then the claim is invalid.

**Marker's comments:**

This question was fairly well answered. The best responses had a well-structured method in their working out such as labelling of the different types of mole (excess, initial, reacted) involved in this back-titration question.

**Exemplar student answer:** for (a) to (c)

- (a) Write balanced chemical equations for the TWO reactions of sodium hydroxide with 2-acetoxybenzoic acid and hydrochloric acid.



- (b) Determine the number of moles of excess sodium hydroxide.

$$V_{\text{HCl titre}} = \frac{22.0 + 22.1 + 21.9}{3} = 22 \text{ ml} \quad (\text{discarding rough titre})$$

$$n_{\text{HCl}} = CV = 0.017 \text{ M} \times 22 \times 10^{-3} \text{ L} = 3.74 \times 10^{-4} \text{ mol}$$

$$\therefore n_{\text{NaOH excess}} = n_{\text{HCl}} = 3.74 \times 10^{-4} \text{ mol. (3.s.f.)}$$

(1:1 molar ratio, from (a).)

- (c) Calculate the percentage by mass of 2-acetoxybenzoic acid in the aspirin tablet.  
Use this to show the claim by the manufacturer is invalid.

$$n_{\text{NaOH total}} = CV = 0.015 \text{ M} \times 35 \times 10^{-3} \text{ L} = 5.25 \times 10^{-4} \text{ mol}$$

$$n_{\text{NaOH reacted}} = n_{\text{NaOH total}} - n_{\text{NaOH excess}} \\ = 5.25 \times 10^{-4} \text{ mol} - 3.74 \times 10^{-4} \text{ mol} = 1.51 \times 10^{-4} \text{ mol}$$

$$n_{\text{C}_9\text{H}_8\text{O}_4} = n_{\text{NaOH reacted}} \quad (1:1 \text{ molar ratio, from (a.)}) \\ = 1.51 \times 10^{-4} \text{ mol}$$

$$m_{\text{C}_9\text{H}_8\text{O}_4} = n \times MM = 1.51 \times 10^{-4} \times (9 \times 12.01 + 8 \times 1.008 + 4 \times 16) \\ = 27.2 \text{ mg. (3.s.f.)}$$

$$\therefore \% \text{ by mass of C}_9\text{H}_8\text{O}_4 \text{ in tablet.} = \frac{m_{\text{C}_9\text{H}_8\text{O}_4}}{m_{\text{tablet}}} \times 100\% \\ = \frac{27.2 \text{ mg}}{200 \text{ mg}} \times 100\% \\ = 13.6\% \quad (3.s.f.) < 25\%$$

$\therefore$  manufacturer's claim is invalid.

### Question 34 (d)

Criteria	Marks
<ul style="list-style-type: none"><li>• Links to equivalence point (pH 7)</li><li>• How it lies within the range of the indicator being used</li></ul>	1

#### **Sample answer:**

The titration is between a strong base and strong acid so has a pH 7 equivalence point. Therefore, phenol red would be suitable as it changes colour in this range.

#### **Marker's comments:**

This question was well answered by most students. The best responses clearly stated that the colour change of the indicator (endpoint) was directly related to approximately the equivalence point for the titration reaction.

#### **Exemplar student answer:**

- (d) Explain why phenol red (pH range: 6.2 - 8.2) was chosen as the pH indicator for the sodium hydroxide and hydrochloric acid titration.

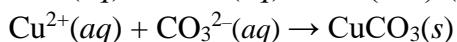
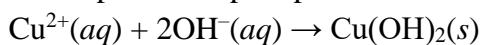
.....because as NaOH is a strong base and HCl is a strong acid  
.....the equivalence point of their neutralisation reaction is around  
.....pH=7, in phenol red's working range.

### Question 34 (e)

Criteria	Marks
<ul style="list-style-type: none"> <li>• Correct identification of copper</li> <li>• Includes chemical equation(s) showing precipitates being made</li> <li>• Provides reasoning for the answer and why other metals aren't present</li> </ul>	2
• One of the above points is included	1

**Sample answer:**

$\text{Cu}^{2+}$  is the ion present.  $\text{Pb}^{2+}$  and  $\text{Ag}^+$  would produce precipitates with all the solutions as no precipitate was made when chloride is added and sulfate is added these are not present.  $\text{Ba}^{2+}$  would produce a precipitate with sulfate as well. The equations for the  $\text{Cu}^{2+}$  precipitates are:



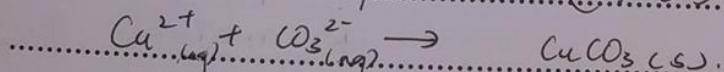
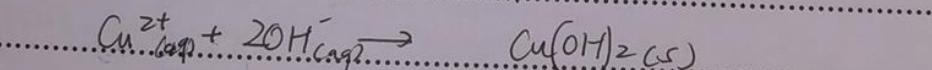
**Marker's comments:**

This question was well answered by most students. The better responses were concise and provided a chemical equation. Some answers, whilst still receiving full marks, wrote additional information irrelevant to the question.

**Exemplar student answer:**

Use the results above to determine the identity of the heavy metal present.  
Include at LEAST one balanced ionic equation in your answer showing the formation of precipitates.

Copper ion ( $\text{Cu}^{2+}$ ) as it doesn't form precipitate with  $\text{Cl}^-$  ions,  
it's neither  $\text{Pb}^{2+}$  nor  $\text{Ag}^+$ ; as it doesn't form precipitate  
with  $\text{SO}_4^{2-}$ , it's not  $\text{Ba}^{2+}$ . therefore it's copper.



### Question 35

Criteria	Marks
<ul style="list-style-type: none"> <li>All correct structures with correct bonding type e.g. Compound G has positive on sodium and negative on oxygen and not a covalent bond</li> <li>Names reaction types in their justification</li> <li>Adequate justification and reasoning for the structures to distinguish other possible structures that could have been used (e.g. Compound F is a tertiary alcohol as it is not oxidised)</li> </ul>	8
<ul style="list-style-type: none"> <li>One incorrect structure and adequate justification OR all correct structures but inadequate justification for some structures</li> </ul>	6-7
<ul style="list-style-type: none"> <li>Same as above but 2-3 incorrect structures</li> </ul>	4-5
<ul style="list-style-type: none"> <li>Some information and/or structures provided that are correct</li> </ul>	2-3
<ul style="list-style-type: none"> <li>Identifies some information that is relevant</li> </ul>	1

*Sample answer:*

	Structure	Justification
A	$\begin{array}{ccccc} & \text{CH}_3 & & & \\ &   & & & \\ \text{H}_2\text{C} & = & \text{C} & - & \text{CH}_2 - \text{CH}_3 \\ & &   & & \\ & & \text{CH}_3 & & \end{array}$	Alkene that needs to have a methyl group as E is a tertiary alcohol and have the C=C on the end to make a primary alcohol (D) as well.
B	$\begin{array}{ccccc} & \text{CH}_3 & & & \\ &   & & & \\ \text{H}_2\text{C} & - & \text{C} & - & \text{CH}_2 - \text{CH}_3 \\   & &   & & \\ \text{Br} & & \text{H} & & \end{array}$	Forms from the addition of HBr. It is the isomer that makes the carboxylic acid in the next step so has to have Br on the terminal carbon.
C	$\begin{array}{ccccc} & \text{CH}_3 & & & \\ &   & & & \\ \text{H}_2\text{C} & - & \text{C} & - & \text{CH}_2 - \text{CH}_3 \\   & &   & & \\ \text{H} & & \text{Br} & & \end{array}$	The other isomer of HBr addition. Makes the tertiary alcohol in the next step so needs to be on the second carbon.

<b>D</b>	$\begin{array}{c} \text{CH}_3 \\   \\ \text{HO} - \text{H}_2\text{C} - \text{C} - \text{CH}_2 - \text{CH}_3 \\   \\ \text{H} \end{array}$	Substitution reaction of OH for Br. Came from B so OH goes on the end. It is a primary alcohol as it makes a carboxylic acid in the next step.
<b>E</b>	$\begin{array}{c} \text{CH}_3 \\   \\ \text{CH}_3 - \text{C} - \text{CH}_2 - \text{CH}_3 \\   \\ \text{OH} \end{array}$	Substitution reaction of OH for Br. Came from C so Br goes on the middle carbon. Tertiary alcohol as not oxidised.
<b>F</b>	$\begin{array}{c} \text{O} & \text{CH}_3 \\    &   \\ \text{HO} - \text{C} - \text{C} - \text{CH}_2 - \text{CH}_3 \\   \\ \text{H} \end{array}$	Carboxylic acid as made from oxidation of a primary alcohol. Also, produces carbon dioxide gas when sodium carbonate is added.
<b>G</b>	$\begin{array}{c} \text{O} & \text{CH}_3 \\    &   \\ \text{Na}^+ \cdot \text{O} - \text{C} - \text{C} - \text{CH}_2 - \text{CH}_3 \\   \\ \text{H} \end{array}$	A carboxylic acid + metal carbonate produces carbon dioxide, water and a salt. G is the salt.
<b>H &amp; I</b>	$\begin{array}{c} \text{H}_2\text{N} - \text{CH}_2 - \text{CH}_2 - \text{O} - \text{C} - \text{C} - \text{CH}_2 - \text{CH}_3 \\   \\ \text{H} \end{array}$ <p style="text-align: center;">AND</p> $\begin{array}{c} \text{H} & \text{O} & \text{CH}_3 \\   &    &   \\ \text{HO} - \text{CH}_2 - \text{CH}_2 - \text{N} - \text{C} - \text{C} - \text{CH}_2 - \text{CH}_3 \\   \\ \text{H} \end{array}$	<p>The two isomers form because the carboxylic acid F can react with either functional group in the HO-CH<sub>2</sub> - CH<sub>2</sub>-NH<sub>2</sub>.</p> <p>If it reacts through the alcohol (OH) group it produces the top product. If it reacts through the amine (NH<sub>2</sub>) group it makes the bottom product.</p>

**Marker's comments:**

There were varying levels of answers provided to this question by students. The better responses provided the structures with the correct bonding (covalent or ionic) and in justifying their answer made specific reference to the chemical processes occurring such as using terms like oxidation, hydrohalogenation and condensation (or esterification and acidification). They also used specific terminology such as primary alcohol and tertiary alcohol to explain certain chemical observations.

Some students provided the names of each compound. This was not required for the question and no marks were awarded for doing this. Students should remember to read the question carefully to ensure the information they provide is relevant to what the question requires.

Some common mistakes made by some students in answering the question included:

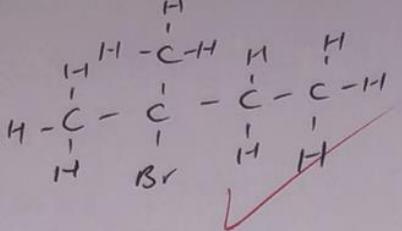
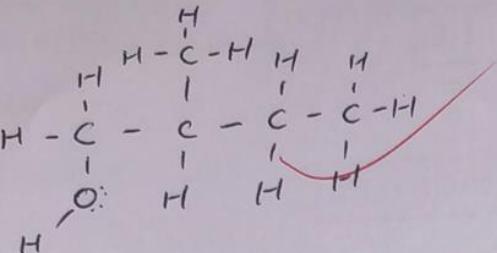
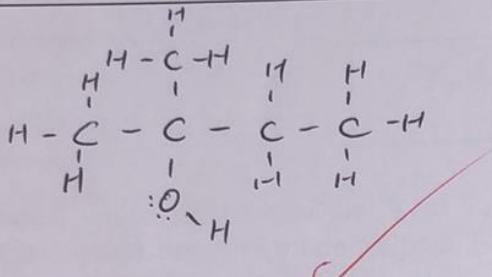
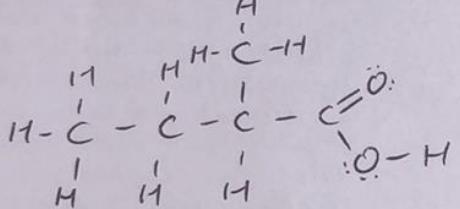
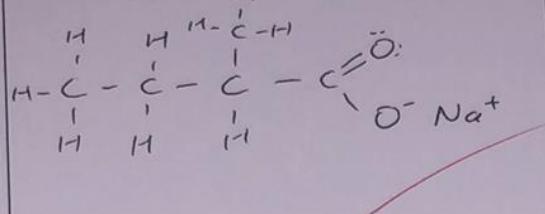
- Correctly determining that Compound E was a tertiary alcohol with a branched structure and then proceeding to use a linear carbon backbone for other structures such as the carboxylic acid. Students should note that in the HSC syllabus there is no reaction that can rearrange carbon atoms and therefore these students should have continued using the same branched carbon structure for the other molecules.
- Forgetting to include hydrogen atoms. Some students left carbon atoms without any hydrogens drawn or labelled as CH<sub>3</sub> or CH<sub>2</sub>. If a student did this once no marks were deducted, but if this occurred more than once a mark was deducted for this error.
- Incorrectly drawing a bond between oxygen and sodium in Compound G. This is an ionic compound. The line bond is only applicable for covalent bonds.
- Forgetting to provide reaction names in their justification. For example, a statement like “it came from compound B” is not an adequate justification for a structure.

**Exemplar student answer:** 2 different exemplars are provided for this long response question

**Student 1:**

	<i>Structure</i>	<i>Justification</i>
A	$  \begin{array}{c}  & \text{H} \\  &   \\  \text{H} - \text{C} = \text{C} - \text{C} - \text{C} - \text{H} \\  &   \quad   \quad   \\  & \text{H} \quad \text{H} \quad \text{H}  \end{array}  $	<p>-General formula of an alkene which undergoes hydrohalogenation to form 2 different products, one of which can form an alcohol that doesn't oxidise.      The other alcohol is primary, indicating branching and double bond is close together</p>
B	$  \begin{array}{c}  & \text{H} \\  &   \\  \text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H} \\  &   \quad   \quad   \\  & \text{Br} \quad \text{H} \quad \text{H} \quad \text{H}  \end{array}  $	<p>Position of Br must allow for primary alcohol to be formed, so Br must be on the end.</p>

Question 55 (continued)

	Structure	Justification
C		Position of Br must allow for tertiary alcohol to be formed, so must be on carbon with extra methyl group
D		Oxidises to form a carboxylic acid, primary alcohol due to reaction with sodium carbonate
E		Doesn't oxidise in presence of $\text{H}^+/\text{MnO}_4^-$ , tertiary alcohol
F		Product of oxidation of <del>primary</del> Oxidation product which reacts with sodium carbonate, must be a carboxylic acid (indicated by salt formation)
G		Sodium carboxylate salt formed after neutralisation of carboxylic acid with sodium carbonate

H	$  \begin{array}{c}  & \text{H} \\  &   \\  \text{H}-\text{C} & -\text{C}-\text{C}-\text{C}-\ddot{\text{N}} & -\text{C}-\text{C}-\ddot{\text{O}}: \\    &   &    &   \\  \text{H} & \text{H} & \text{H} & \text{H} \\  & & &   \\  & & & \text{H}  \end{array}  $	<p>Two products formed from condensation reaction, let H1 be formed due to reaction of amino and acid group. forms an amide linkage</p>
I	$  \begin{array}{c}  & \text{H} \\  &   \\  \text{H}-\text{C} & -\text{C}-\text{C}-\text{C}-\ddot{\text{O}}: & -\text{C}-\text{C}-\ddot{\text{N}}: \\    &   &    &   \\  \text{H} & \text{H} & \text{H} & \text{H} \\  & & &   \\  & & & \text{H}  \end{array}  $	<p>let I be formed due to reaction of <del>alcohol</del> hydroxyl and acid group, forms an ester linkage.</p>

### Student 2:

	Structure	Justification
A	$  \begin{array}{c}  & \text{CH}_3 & \text{H} & \text{H} \\  &   &   &   \\  \text{H}-\text{C} = \text{C} & -\text{C}-\text{C}-\text{H} \\  &   &   &   \\  & \text{H} & \text{H} & \text{H}  \end{array}  $	<p>The carbon-carbon double bond must be in a position where <del>hydrohalogenation</del> a primary and <del>tertiary</del> a primary and tertiary alcohol can be produced via a hydrohalogenation reaction.</p>
B	$  \begin{array}{c}  & \text{CH}_3 & \text{H} & \text{H} \\  &   &   &   \\  \text{Br}-\text{C} & -\text{C}-\text{C}-\text{C}-\text{H} \\  &   &   &   \\  & \text{H} & \text{H} & \text{H}  \end{array}  $	<p>This will later form <del>a</del> a primary alcohol that can be oxidised to a carboxylic acid. Hence, the Br substituent must be on a terminating carbon.</p>

	Structure	Justification
C	$  \begin{array}{c}  & \text{CH}_3 & \text{H} & \text{H} \\  &   &   &   \\  \text{H}-\text{C} & -\text{C}-\text{C}-\text{C}-\text{H} \\    &   &   &   \\  \text{H} & \text{Br} & \text{H} & \text{H}  \end{array}  $	<p>The Br substituent must be in a position where substitution with an OH<sup>-</sup> substituent will produce a tertiary alcohol.</p>

D	$  \begin{array}{ccccccc}  & H & & CH_3 & H & & H \\  &   & &   &   & &   \\  HO - C & - C & - C & - C & - C & - H \\  &   & &   & & &   \\  & H & & H & & & H  \end{array}  $	<p>This must be a primary alcohol as it oxidises to a carboxylic acid. We know the Br substituent in compound B is substituted for a hydroxyl group.</p>
E	$  \begin{array}{ccccccc}  & H & & CH_3 & H & & H \\  &   & &   &   & &   \\  H - C & - C & - C & - C & - C & - H \\  &   & &   & & &   \\  & H & & OH & H & & H  \end{array}  $	<p>This <del>does</del> not oxidise and hence, must be a tertiary alcohol.</p>
F	$  \begin{array}{ccccccc}  & O & & CH_3 & H & & H \\  & \parallel & &   &   & &   \\  HO - C & - C & - C & - C & - C & - H \\  &   & &   & & &   \\  & H & & H & & & H  \end{array}  $	<p>This reacts with sodium carbonate, a base, and hence it must be a carboxylic acid.</p>
G	$  \begin{array}{ccccccc}  & O & & CH_3 & H & & H \\  & \parallel & &   &   & &   \\  Na^+ O^- & C & - C & - C & - C & - H \\  &   & &   & & &   \\  & H & & H & & & H  \end{array}  $	<p>This is the salt formed from the neutralisation reaction between compound F and <math>Na_2CO_3</math>.</p>
H	$  \begin{array}{ccccccc}  & H & & H & & O & & CH_3 & H & H \\  &   & &   & & \parallel & &   &   &   \\  HO - C & - C & - N & - C & - C & - C & - C & - H \\  &   & &   & &   & & H & H & H  \end{array}  $	<p>This is the product of <del>is</del> a condensation reaction. The -OH functional group is taken from compound F and one of the hydrogens from the amine functional group is taken.</p>
I	$  \begin{array}{ccccccc}  & H & & H & & O & & CH_3 & H & H \\  & \backslash & & / & & \parallel & &   &   &   \\  H & & N & - C & - C & - O & - C & - C & - C & - H \\  & & &   & & &   & & &   \\  & & & H & & & H & & & H  \end{array}  $	<p>This is the product of a condensation reaction. The OH functional group is taken from the added reagent and one hydrogen is taken from compound F's hydroxyl group.</p>