2020 **BORED OF STUDIES TRIAL EXAMINATION**

12th October

Chemistry

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

Total marks: 100

Section I – 20 marks (pages 2–12)

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

Section II – 80 marks (pages 13–37)

- 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_{sp} of lead chloride is 1.70×10^{-5} at 25 ^{o}C. What is the solubility in **g/L**?

A. 4.50 g/L

B. 1.15 g/L

C. 0.0162 g/L

D. 5.82×10^{-5} g/L

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

A. HCl / NaCl

B. H_3PO_4 / Na_2HPO_4

C. NaH_2PO_4 / Na_2HPO_4

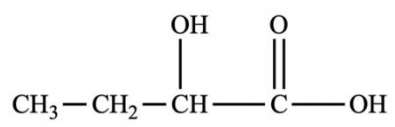
D. H_2SO_4 / $NaHSO_4$

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

Test	***Observation***
Add Bromine Water	Orange-brown to colourless
Litmus Paper	Red to blue
Add H^+ / MnO_4^-	Purple to colourless

Which of the following molecules could produce these observations?

A.



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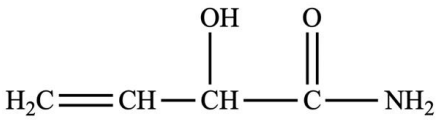

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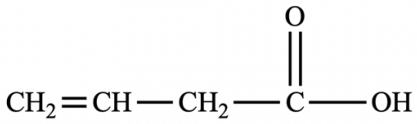

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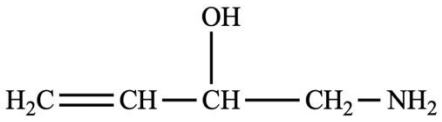
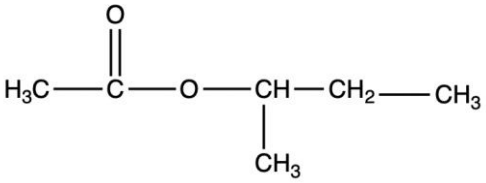
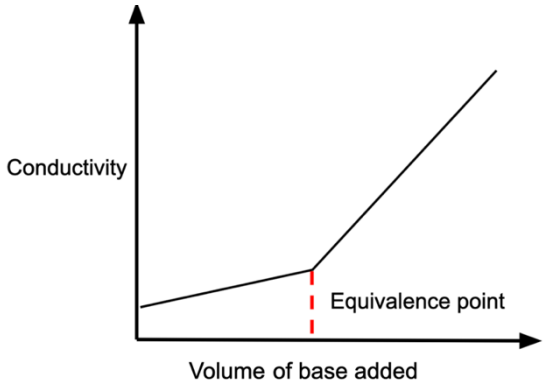


5 Which reagents were used to make the following ester?



	Alcohol	***Carboxylic acid***	***Catalyst***
A.	Propan-2-ol	Propanoic acid	Dilute. H_2SO_4
B.	Butan-1-ol	Ethanoic acid	Conc. H_2SO_4
C.	Butan-2-ol	Ethanoic acid	Conc. H_2SO_4
D.	Ethanol	Butanoic acid	Dilute. H_2SO_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_{eq} for the following reaction is 0.36.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad K_{eq} = 0.36$$

0.50 moles of NO_2 and 0.20 moles of N_2O_4 were placed in a 2 L rection vessel. Which row of the table correctly identifies the direction of the equilibrium shift and the reason?

	Direction favoured	***Reason***
A.	Left	$Q > K_{eq}$
B.	Left	$Q < K_{eq}$
C.	Right	$Q > K_{eq}$
D.	Right	$Q < K_{eq}$

8 Acetic acid (CH_3COOH) 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:

Test	***Observation***
Flame test	Blue-Green
Add Na_2SO_4	No precipitate
Add NaCl	No precipitate

What compound is present in the soil sample?

A. $NaNO_3$

B. $Cu(NO_3)_2$

C. $Ba(NO_3)_2$

D. $Pb(NO_3)_2$

10 Consider the exothermic equilibrium reaction:

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

Yellow **Red**

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

	KSCN(aq) added	***Hot water bath***	***NaOH(aq) added***
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 $[Fe(H_2O)_6]^{2+}$ is 2.00×10^3 L mol^{-1} cm^{-1}. A 10.0 mL sample of $[Fe(H_2O)_6]^{2+}$ was analysed in a 1.00 cm cuvette. A reading of 0.213 was obtained for its absorbance. The molecular mass of $[Fe(H_2O)_6]^{2+}$ is 163.946 g/mol.

What is the amount in **grams** of $[Fe(H_2O)_6]^{2+}$ present in the sample?

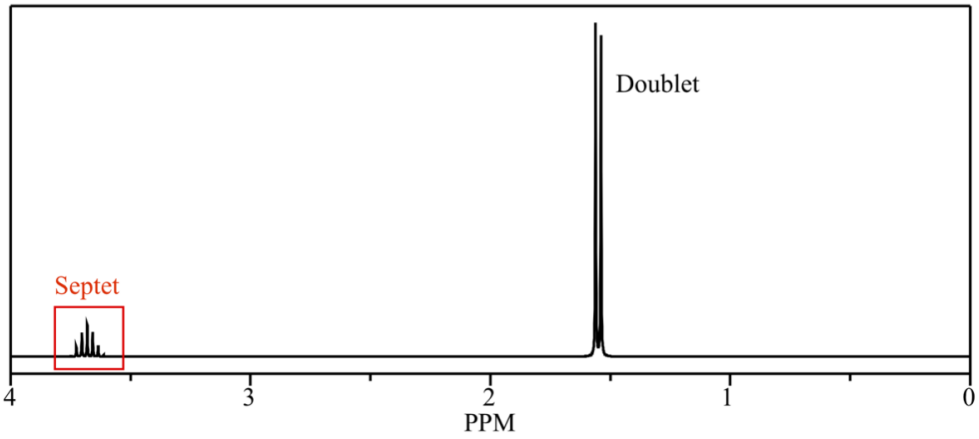
A. 1.75×10^{-4} g

B. 1.07×10^{-4} g

C. 1.07×10^{-6} g

D. 4.26 g

12 The following data was obtained from the ^{1}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.

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

What is the equilibrium constant of the following equilibrium reaction?

$$HI(g) \rightleftharpoons \tfrac{1}{2}\, H_2(g) + \tfrac{1}{2}\, I_2(g)$$

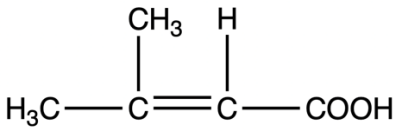
A. 0.141

B. 0.02

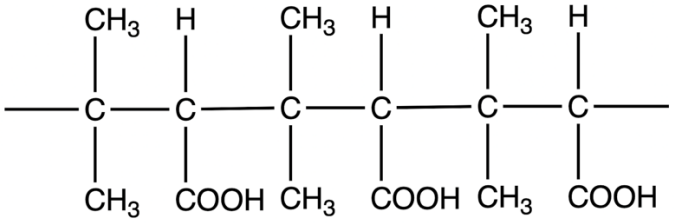
C. 50

D. 7.07

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



A.



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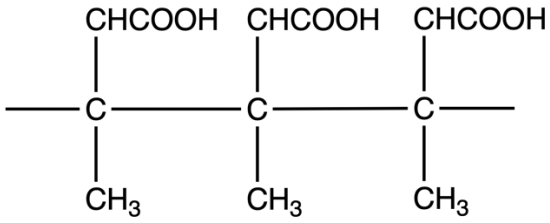

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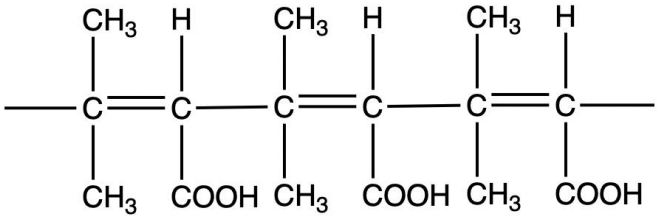
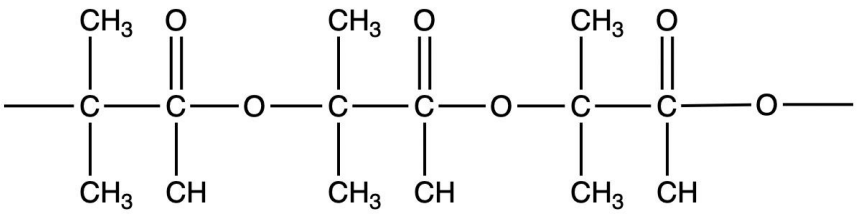


D.



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

$$M + e^- \rightarrow M^+ + 2e^-$$

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

$$M^+ \rightarrow A^+ + B$$
$$M^+ \rightarrow A + B^+$$

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 (HCOOH) has a pK_a of 3.7. Hypochlorous acid (HOCl) has a pK_a of 7.5. Which of the following solutions will have the highest pH?

A. 0.2 M HCOOH

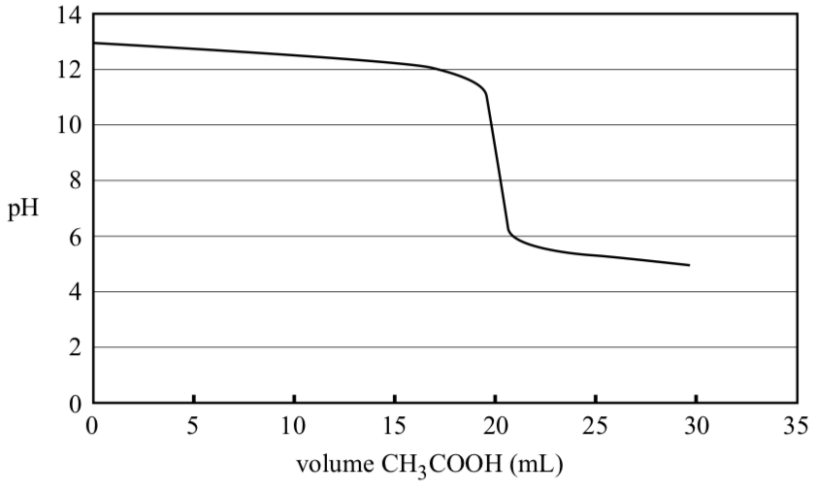
B. 0.2 M NaCHOO

C. 0.2 M HOCl

D. 0.2 M NaOCl

18 A titration was performed between a 0.10 mol/L acetic acid (CH_3COOH) and a 10.0 mL sample of a calcium hydroxide ($Ca(OH)_2$) solution.

The following titration curve was obtained using a pH probe.



What is the concentration of the calcium hydroxide solution?

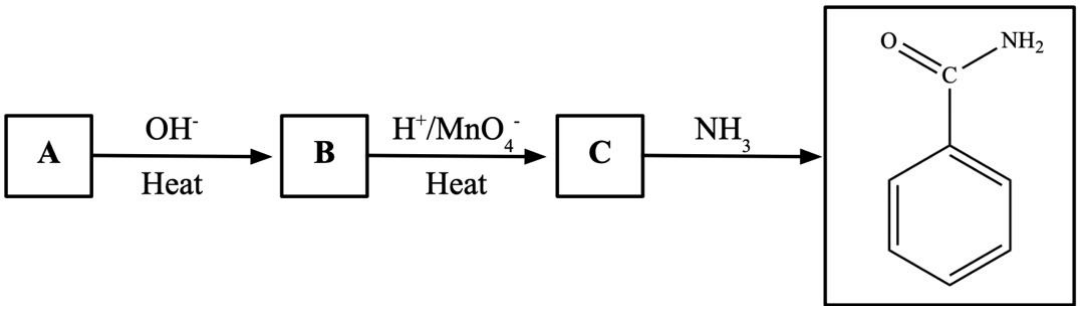
A. 0.0010 g/L

B. 0.074 g/L

C. 7.4 g/L

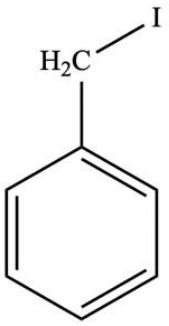
D. 0.10 g/L

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.



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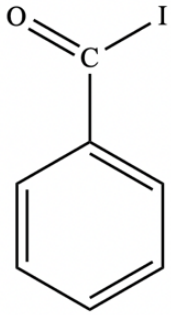
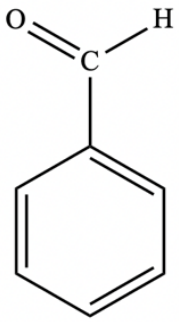
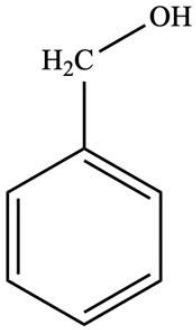


C.



D.



20 Gravmetric 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:

$$S(s) + 3/2\ O_2(g) + O^{2-}(aq) \rightarrow SO_4^{2-}(aq)$$

Excess calcium nitrate solution was added to $SO_4^{2-}(aq)$ 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.

$$2A(g) \rightleftharpoons B(g) + C(g) \qquad K_{eq} = 4.0$$

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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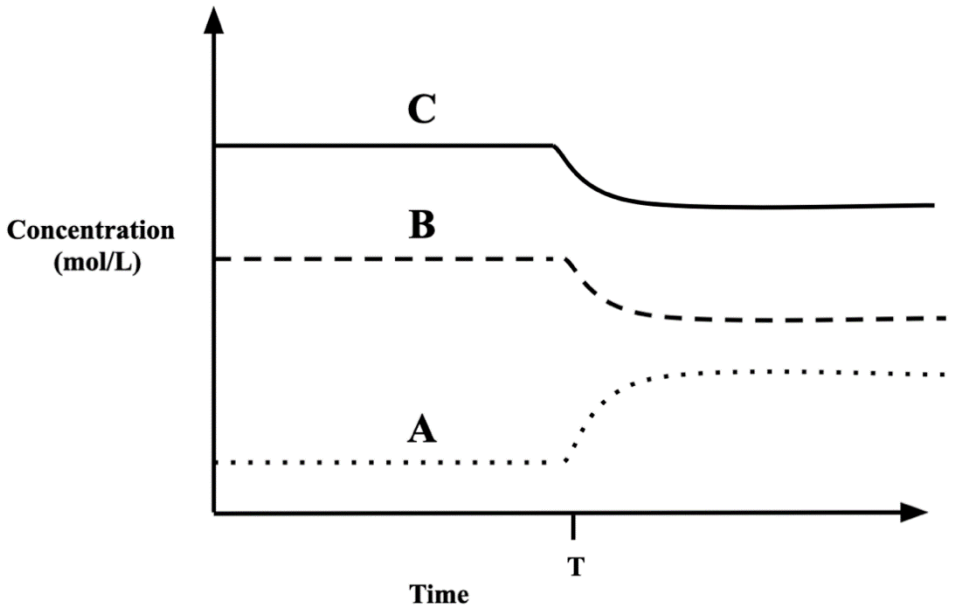
Question 21 continues on page 15

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.

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

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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 ^{o}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 $Ca(NO_3)_2$ and 100 mL of 0.0010 mol/L Na_2SO_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. **5**

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Question 22 continues on page 17

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**

Case	***Molar Solubility of Barium hydroxide (M)***
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 (Na_2HPO_4) is an example of an amphiprotic substance. **2**

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

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Question 24 (3 marks)

Ethanamine ($C_2H_5NH_2$) is a weak base with a dissociation constant (K_b) of 5.6×10^{-4}. **3**

Calculate the pH of a 0.10 M solution of ethanamine.

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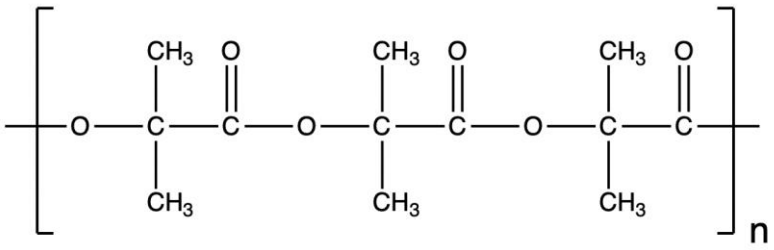
Question 25 (4 marks)

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 ^{1}H-NMR spectrum? **1**

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(c) The molecular weight of the polymer formed was 1.29×10^{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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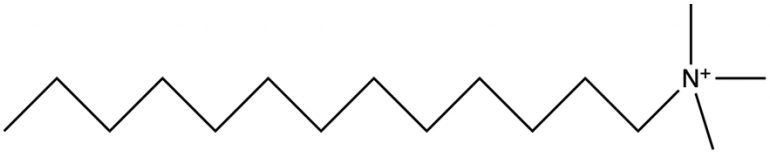
Question 26 (4 marks)

The structure of a soap molecule and cationic detergent are displayed below. **4**

Molecule	***Structure***
Soap	
Cationic Detergent	

Hard water contains a large concentration of Mg^{2+} and 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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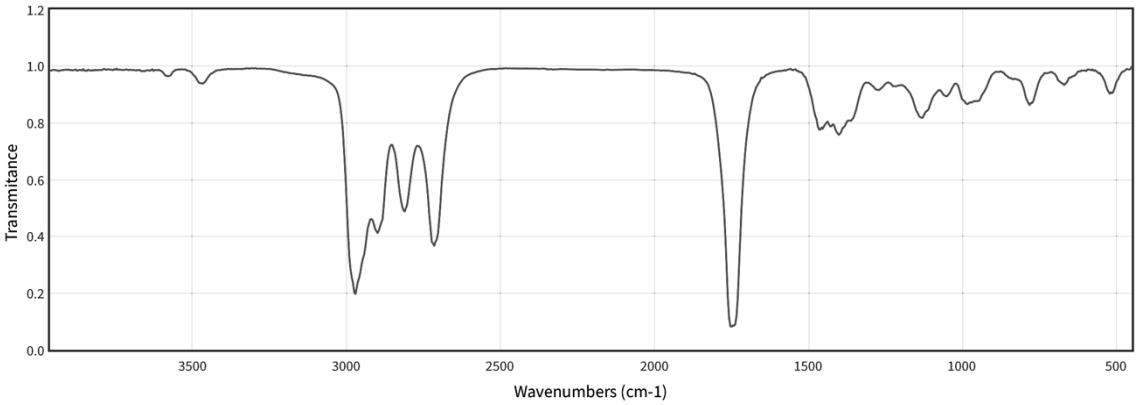
Question 27 (5 marks)

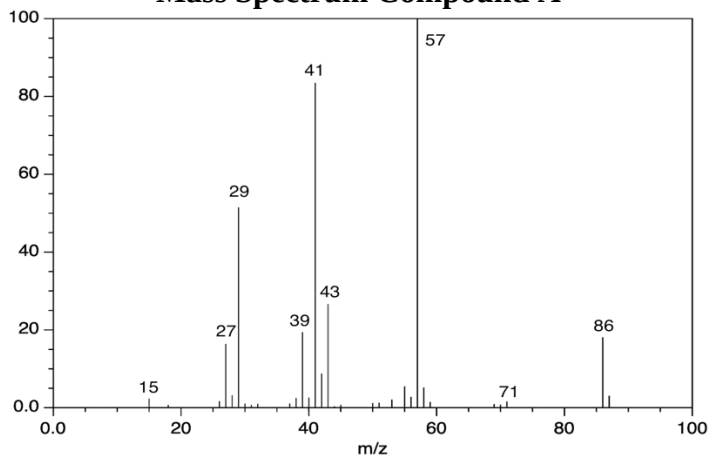
The following data were obtained for an unknown **Compound A**.

The compound decolourises acidified permanganate (H^+/MnO_4^-) from purple to colourless to produce a **Compound B**, that produces bubbles when sodium carbonate (Na_2CO_3) is added.

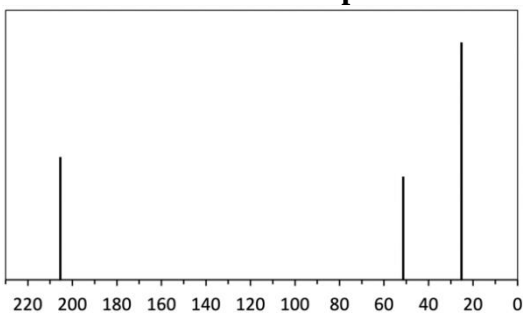
IR Spectrum Compound A



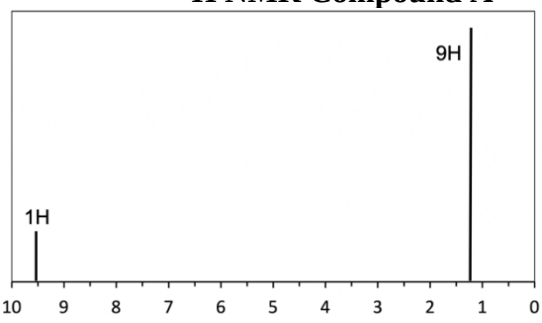
Mass Spectrum Compound A



^{13}C NMR Compound A



^{1}H NMR Compound A



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.

Compound A Structure	***Compound B Structure***

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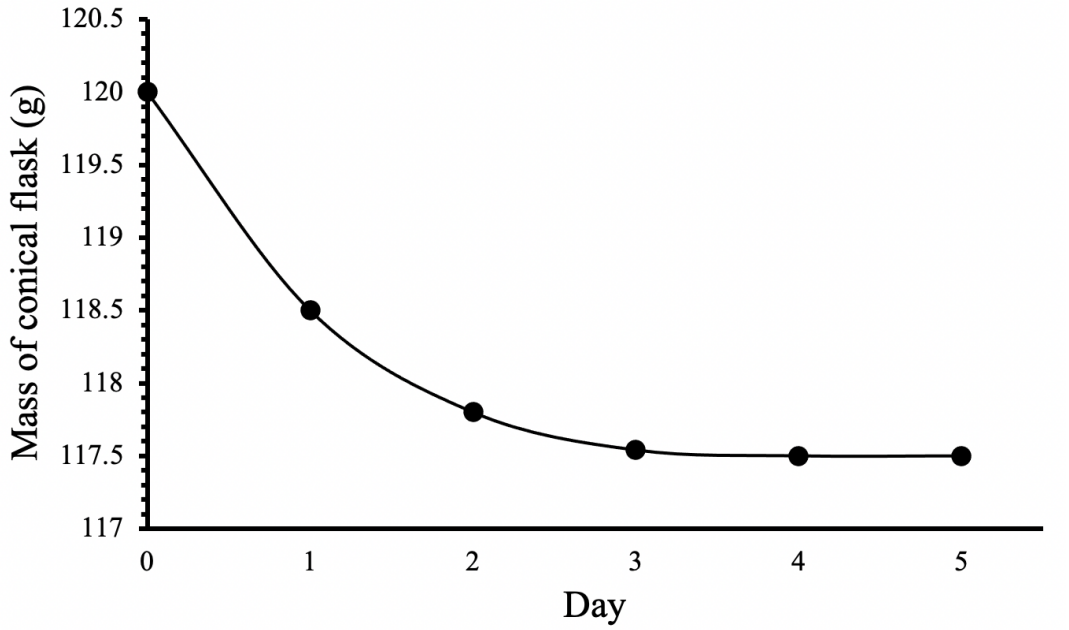
End of Question 27

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 20.0ºC to 29.5ºC. **4**

Calculate the percentage of heat lost to the environment.

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End of Question 28

Question 29 (4 marks)

Solid coal (C) undergoes complete combustion according to the equation: **4**

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

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

$$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$$

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

	Combustion	***Photosynthesis***
ΔH (kJ mol^{-1})	-715	+2803
ΔS (J mol^{-1} K^{-1})	+2.9	-212

Analyse the processes in terms of enthalpy and entropy. By calculating Gibbs Free Energy (**ΔG**) determine the spontaneity of the reactions at 25 ^{o}C.

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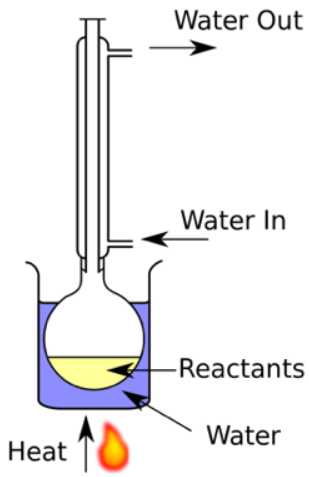
Question 30 (7 marks)

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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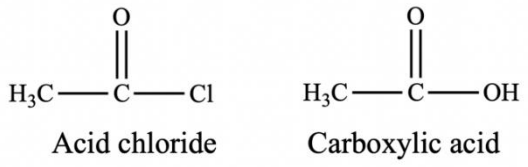
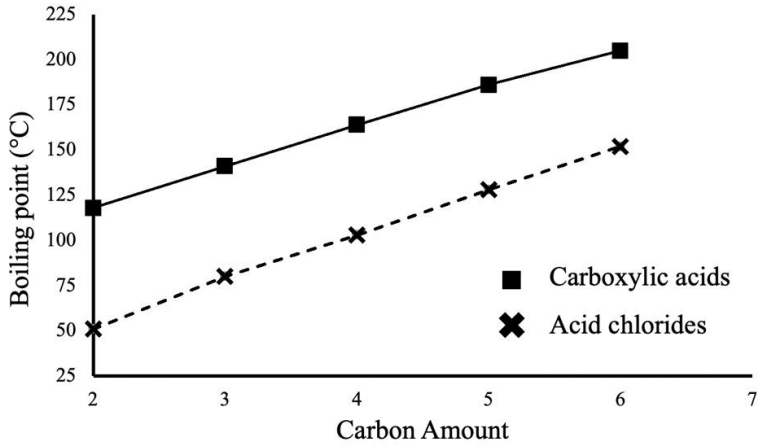
Question 30 continues on page 27

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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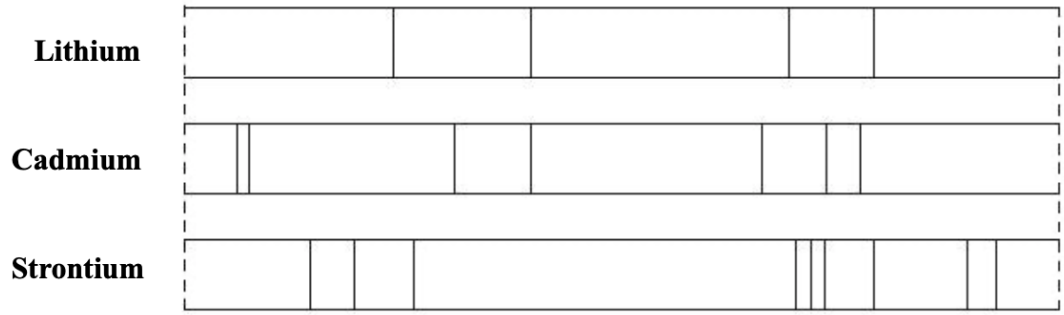
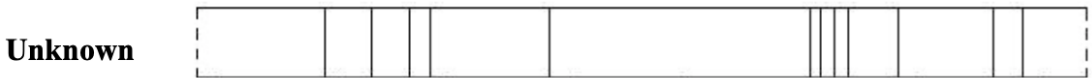
End of Question 30

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 (Sr^{2+}) in the soil sample was investigated. **2**

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

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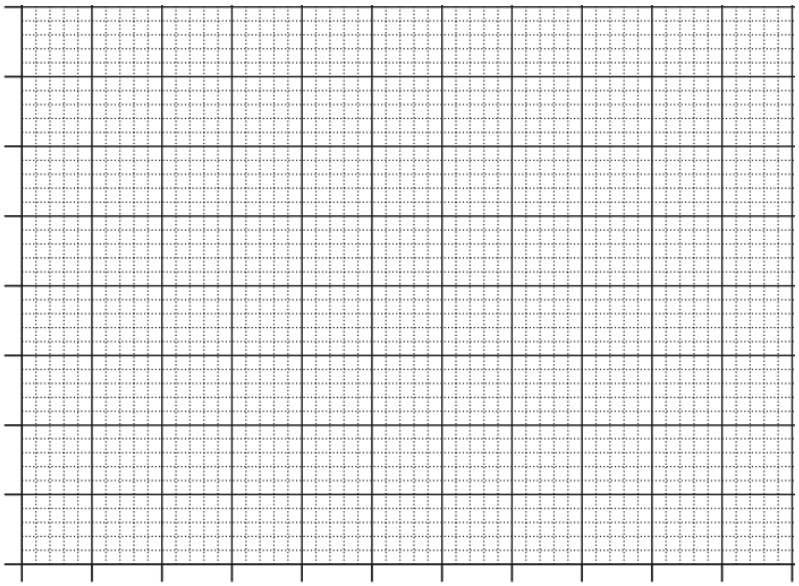
Question 31 continues on page 30

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 Sr^{2+} standard solutions with varying concentrations. The absorbance of these solutions is displayed below. **2**

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 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. **2**

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End of Question 31

Question 32 (2 marks)

Two acid-base reaction processes are displayed below. **2**

$$CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$$

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$

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 HInd and Ind^-. The "Ind" refers to indicator. These two forms have different colours as shown in the equilibrium equation below: **3**

$$HInd(aq) + H_2O(l) \rightleftharpoons Ind^-(aq) + H_3O^+(aq)$$

Colourless **Pink**

When sodium acetate ($NaCH_3COO$) 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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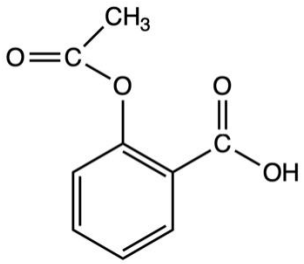
Question 34 (10 marks)

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
$C_9H_8O_4$

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.

Trial run	***Titre (mL)***
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. Use this to show the claim by the manufacturer is invalid. **3**

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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.

Test	***Addition of Cl^-***	***Addition of OH^-***	***Addition of CO_3^{2-}***	***Addition of SO_4^{2-}***
Observation	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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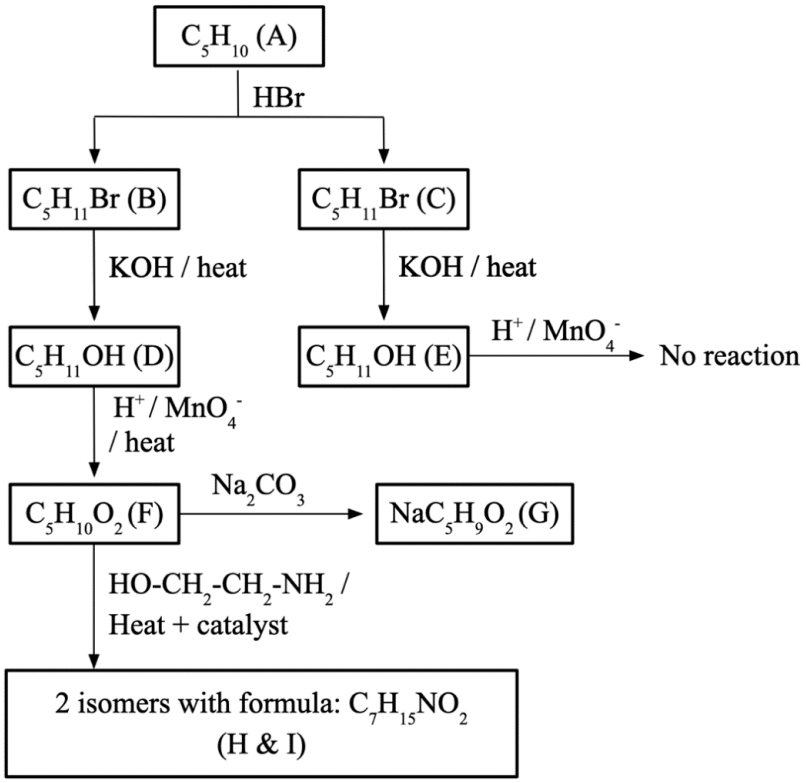
End of Question 34

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.

	Structure	***Justification***
A		
B		

Question 35 continues on page 36

Question 35 (continued)

	Structure	***Justification***
C		
D		
E		
F		

Question 35 continues on page 37

Question 35 (continued)

	Structure	***Justification***
G		
H		
I		

End of paper