Student Number

2021
YEAR 12 TRIAL EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA-approved calculators may be used
- Three data sheets and a Periodic Table are provided at the back of this paper
- Use the Multiple-Choice Answer Sheet provided
- Write your Student Number at the top of this page, on page 13 and on the Multiple-Choice Answer Sheet

Total marks: 100

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

Section II – 80 marks
- Attempt Questions 21-30
- Allow about 2 hours 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

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample 2 + 4 = A. 2 B. 6 C. 8 D. 9

A B C D

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A B C D

If you have changed your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows:

correct

A B C D

1 Ca^{2+} will form precipitates with solutions of

A. sodium chloride and sodium carbonate.

B. sodium sulfate and sodium carbonate.

C. sodium nitrate and sodium carbonate.

D. sodium chloride and sodium sulfate.

2 A solution containing $Co(H_2O)_6^{2+}$ *(aq)*, $CoCl_4^{2-}$ *(aq)* and Cl^- *(aq)* at equilibrium at room temperature is initially pink. When heated, the solution turns blue. Then, when Ag^+*(aq)* is added, the solution turns back to pink.

Which statements are correct?

I. $Co(H_2O)_6^{2+}$ *(aq)* is pink.
II. Formation of $CoCl_4^{2-}$ *(aq)* from $Co(H_2O)_6^{2+}$ *(aq)* and Cl^-*(aq)* is exothermic.

A. I only

B. II only

C. Both I and II

D. Neither I nor II

3 The normal boiling point of propan-2-ol, $(CH_3)_2CHOH$, is 83ºC, while that of acetone, $(CH_3)_2C{=}O$, is 56ºC.

What is the principal reason for the higher boiling point of propan-2-ol?

A. The O–H bond in propan-2-ol is stronger than the C–H bonds in acetone.

B. Propan-2-ol experiences greater dispersion forces than acetone.

C. Propan-2-ol experiences stronger dipole-dipole interactions than acetone.

D. Propan-2-ol experiences hydrogen bonding while acetone does not.

4 Nitrous acid, HNO_2, has $K_a = 4.5 \times 10^{-4}$.

What is the best description of the species present in a 0.1 M solution of nitrous acid?

A. HNO_2 *(aq)* is the predominant species; much smaller amounts of H^+ *(aq)* and NO_2^- *(aq)* are present.

B. H^+ *(aq)* and NO_2^- *(aq)* are the predominant species; much smaller amounts of HNO_2 *(aq)* are present.

C. Only H^+ *(aq)* and NO_2^- *(aq)* are present in measurable amounts.

D. HNO_2 *(aq)*, H^+ *(aq)* and NO_2^- *(aq)* are all present in comparable amounts.

5 What is the solubility of MgF_2 ($K_{sp} = 6.8 \times 10^{-9}$) in pure water?

A. 6.8×10^{-9} mol L^{-1}

B. 5.8×10^{-5} mol L^{-1}

C. 8.2×10^{-5} mol L^{-1}

D. 1.2×10^{-3} mol L^{-1}

6 Question 6 relates to the endothermic reaction shown below.

$$N_2O_4\,(g) \rightleftharpoons 2NO_2\,(g) \qquad K_{eq} \text{ is } 0.48 \text{ at } 100°C$$

In an experiment it was found that the concentration of N_2O_4*(g)* was 0.20 mol/L. Calculate the concentration of the NO_2*(g)* in this equilibrium mixture.

A. 0.10 mol/L

B. 0.31 mol/L

C. 0.096 mol/L

D. 3.23 mol/L

7 A 1.0 M aqueous solution of which compound has the lowest pH?

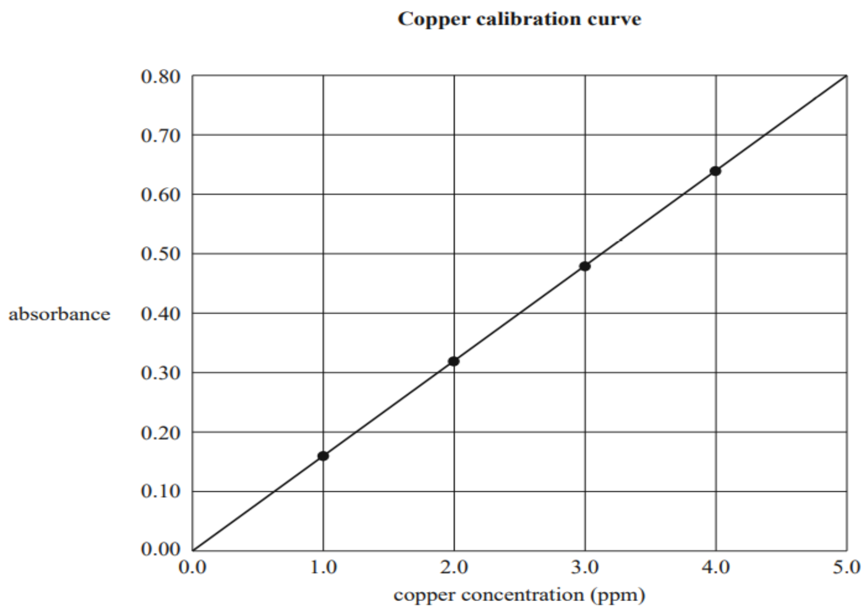
A. CH_3CH_2OH

B. CH_3COOH

C. CH_3CHO

D. CH_3COCH_3

8 An atomic absorption spectrometer can be used to determine the level of copper in soils.
The calibration curve below plots the absorbance of four standard copper solutions against the concentration of copper ions in ppm. The concentrations of copper ions in the standard solutions were 1.0, 2.0, 3.0 and 4.0 mg L^{-1}. (1 mg L^{-1} = 1 ppm)



If the test solution gave an absorbance reading of 0.40, what would be the concentration of copper ions in the solution in mol L^{-1}?

A. 2.5

B. 3.9×10^{-2}

C. 3.9×10^{-5}

D. 2.5×10^{-6}

9 A 60.0 g sample of $CaCO_3$ is heated to 950 K in a 1.00 L evacuated container, where it reacts according to the following equation:

$$CaCO_3\,(s) \rightleftharpoons CaO\,(s) + CO_2\,(g)$$

After equilibrium is attained, the pressure of $CO_2\,(g)$ is 30.0 mm Hg. When the experiment is repeated using 120.0 g $CaCO_3$, what is the equilibrium pressure P?

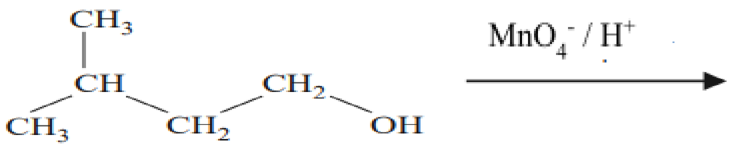
A. 15.0 mm Hg ≤ P < 30.0 mm Hg

B. P = 30.0 mm Hg

C. 30.0 mm Hg < P < 60.0 mm Hg

D. P = 60.0 mm Hg

10 What is the systematic name for the product of the reaction below?



A. 2-methylpentanoic acid

B. 4-methylpentanoic acid

C. 2-methylbutanoic acid

D. 3-methylbutanoic acid

11 and 12 Many industrial processes use the following reaction for the production of hydrogen gas.

$$CO\ (g) + H_2O\ (g) \rightleftharpoons H_2\ (g) + CO_2\ (g) \quad \Delta H = -41 \text{ kJ mol}^{-1}$$

11 Carbon monoxide, water vapour, carbon dioxide and hydrogen were pumped into a sealed container that was maintained at a constant temperature of 200°C.

After 30 seconds, the concentration of gases in the sealed container was found to be $[CO] = 0.1$ M, $[H_2O] = 0.1$ M, $[H_2] = 2.0$ M, $[CO_2] = 2.0$ M.

The equilibrium constant at 200°C for the above reaction is K = 210.

Which one of the following statements about the relative rates of the forward reaction and the reverse reaction at 30 seconds is true?

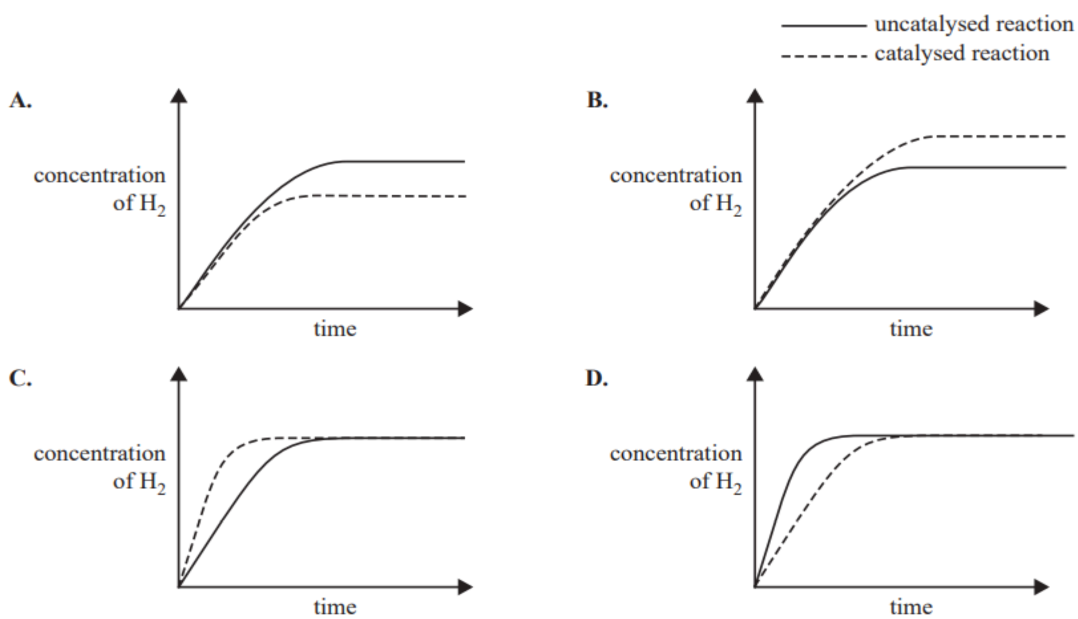
A. The rate of the forward reaction is greater than the rate of the reverse reaction.

B. The rate of the forward reaction is equal to the rate of the reverse reaction.

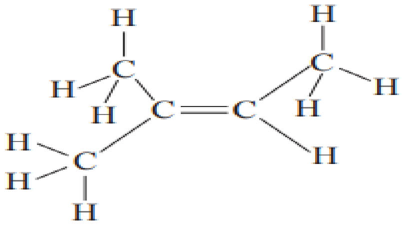
C. The rate of the forward reaction is less than the rate of the reverse reaction.

D. There is insufficient information to allow a statement to be made about the relative rates of the forward and reverse reactions.

12 In trials, the reaction is carried out with and without a catalyst in the sealed container. All other conditions are unchanged. The change in hydrogen concentration with time between an uncatalysed and a catalysed reaction is represented by a graph. Which graph is correct?



13 The molecule with the structural formula shown below reacts with hydrogen bromide, HBr, to form $C_5H_{11}Br$.



The number of different isomers of $C_5H_{11}Br$ which could be formed is(are)

A. 1

B. 2

C. 3

D. 4

14 When 0.10 M solutions of ammonium acetate, barium acetate and sodium acetate are ranked from least basic to most basic, what is the correct ordering?

A. $NH_4C_2H_3O_2 < NaC_2H_3O_2 < Ba(C_2H_3O_2)_2$

B. $Ba(C_2H_3O_2)_2 < NH_4C_2H_3O_2 < NaC_2H_3O_2$

C. $NaC_2H_3O_2 < Ba(C_2H_3O_2)_2 < NH_4C_2H_3O_2$

D. $NaC_2H_3O_2 < NH_4C_2H_3O_2 < Ba(C_2H_3O_2)_2$

15 A student mixed 10.0 mL of 0.0400 mol L^{-1} H_2SO_4 with 40.0 mL of 0.35 mol L^{-1} KOH.

What is the pH of the resulting solution?

A. 0.26

B. 0.59

C. 13.42

D. 13.45

16 An organic compound has a molar mass of 72 g mol^{-1}.
The ^{13}C NMR spectrum of the organic compound shows three distinct peaks.
The organic compound is most likely

A. butan-1-ol

B. butanal

C. butanone

D. 2-methylpropanal

17 Precipitation titration can be used to determine the percentage by mass of certain ions in food samples.

The food sample was dissolved in water and the chloride ion was precipitated by adding an excess of silver nitrate solution. The precipitate was washed and dried.

The food sample had a mass of 20.0 g and the final precipitate a mass of 0.376 g.
Assume that the chloride ion in the food was caused by the addition of salt, sodium chloride, during the manufacture of the food product.

What was the percentage by mass of sodium chloride in the food?

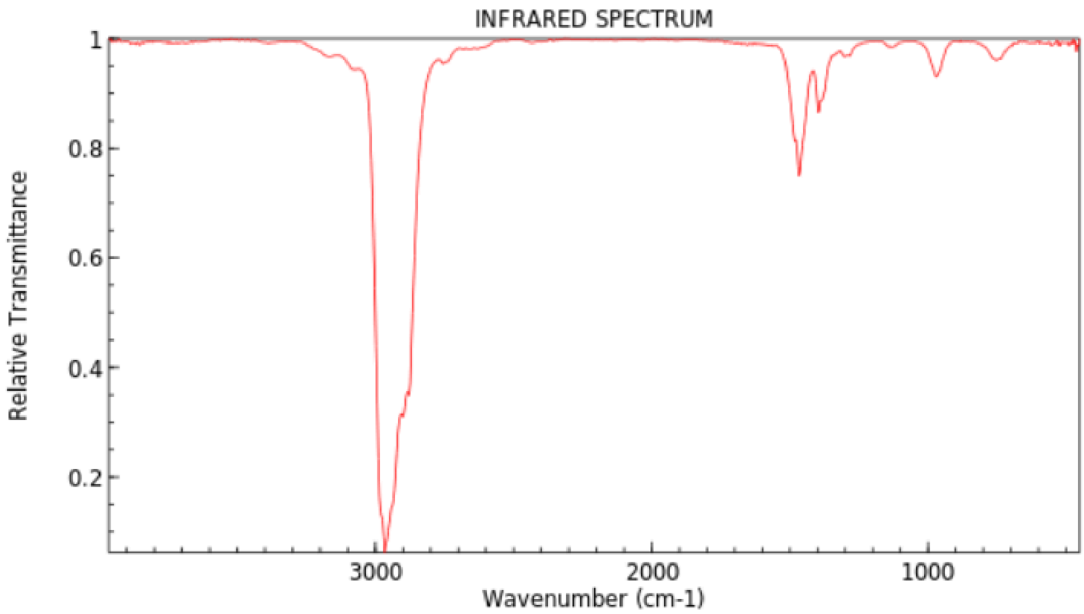
A. 0.220%

B. 0.465%

C. 0.766%

D. 1.88%

18 The infrared spectrum of a pure compound is shown below.



NIST Chemistry WebBook (https://webbook.nist.gov/chemistry)

Which of the following compounds best matches this spectrum?

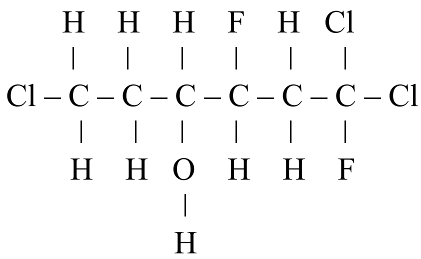
A. butane

B. butan-1-ol

C. ethyl propanoate

D. propanoic acid

19 What is the correct I.U.P.A.C. name for the compound with formula shown below?



A. 1,1,6-trichloro-1,3-difluorohexan-4-ol

B. 1,3-difluoro-1,1,6-trichlorohexan-4-ol

C. 1,6,6-trichloro-4,6-difluorohexan-3-ol

D. 4,6-difluoro-1,6,6-trichlorohexan-3-ol

20 A solution of ammonia, NH_3, has pH = 11.50 at 25°C.
What is the ammonia concentration?
(The pK_a of NH_4^+ is 9.24.)

A. 1.7×10^{-5} M

B. 3.2×10^{-3} M

C. 5.5×10^{-3} M

D. 0.58 M

End of Section I

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2021 YEAR 12 TRIAL EXAMINATION

Chemistry

Student Number

Section II – 80 marks
Attempt Questions 21-30
Allow about 2 hours and 25 minutes for this section.

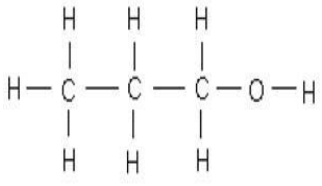
Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

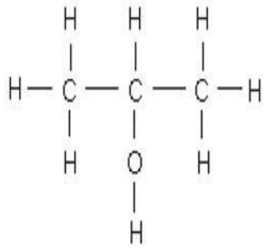
Extra writing space is provided on pages 33 and 34. If you use this space, clearly indicate which question you are answering.

Question 21 (8 marks)

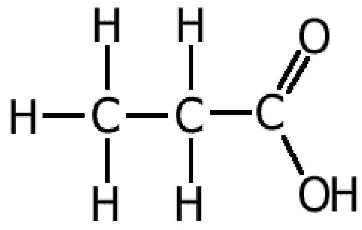
The structures of 3 organic compounds, A, B and C are shown below.



Compound **A**



Compound **B**



Compound **C**

(a) Which of these compounds are isomeric? Explain your response. **2**

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(b) Which of compounds **A** and **B** could be converted into compound **C**? **3**
Name the reagent(s) which would be used and the observations you would make as the reaction proceeded.

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(c) Describe how a scientist could confirm the presence of compound **C** in the reaction mixture. **1**

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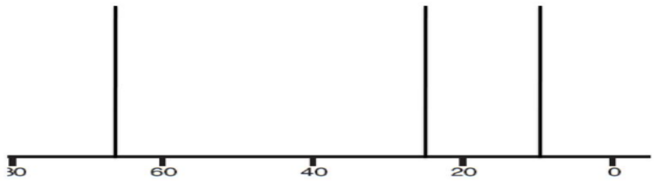
Question 21 continues on the next page

Question 21 (continued)

(d) A student discovered a ^{13}C NMR spectrum, shown below, which claimed to be that of compound **B**. His teacher told him that the claim was incorrect. **2**



Justify why the claim is incorrect and include a diagram to predict the correct ^{13}C NMR spectrum for compound **B**.

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Question 22 (16 marks)

A titration was carried out to determine the concentration of an ethanoic acid solution, using previously standardised 0.105 mol L^{-1} sodium hydroxide solution.

(a) Outline the method used to standardise the sodium hydroxide solution. **2**

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(b) Calculate the concentration of the ethanoic acid solution, if 25.0 mL of this solution reacted completely with 17.6 mL of the sodium hydroxide solution. **1**

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(c) Sketch a pH titration curve for the reaction of ethanoic acid and sodium hydroxide. Ensure that the axes are labelled and the equivalence point clearly indicated. **2**

Question 22 continues on the next page

Question 22 (continued)

(d) Methyl orange is NOT a suitable indicator for use in this titration. Justify this statement. **1**

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(e) CH_3COOH is a weak acid and has an acid dissociation constant of 1.8×10^{-5}. **2**

Write the equation for the ionisation of ethanoic acid in water.

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Write the expression for K_a for ethanoic acid.

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(f) Determine the pH of a 0.01 mol/L solution of ethanoic acid. **2**

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Question 22 continues on the next page

Question 22 (continued)

(g) A student conducted the following experiment using a solution of ethanoic acid and a solution of hydrochloric acid. After measuring the pH, a salt was dissolved into each sample and the pH measured again. The results are summarised in the table below. **4**

	Ethanoic acid	***Hydrochloric acid***
Concentration of acid (mol L^{-1})	1.0	0.0040
Initial pH	2.4	2.4
Substance added	1.0 g solid potassium ethanoate	1.0 g solid potassium chloride
Final pH	2.6	2.4

Use the data in the table to explain all concentration and pH readings recorded during this investigation.

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(h) Explain why ethanoic acid is classified as an acid according BOTH to the Lowry-Brønsted and Arrhenius theories of acids. **2**

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Question 23 (6 marks)

(a) Write an ionic equation for the reaction of solutions of barium nitrate and sodium fluoride to form solid barium fluoride. **1**

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(b) Barium fluoride has $K_{sp} = 1.8 \times 10^{-7}$. **2**
What is the maximum fluoride ion concentration possible in a solution which has $[Ba^{2+}] = 5.0 \times 10^{-4}$ M?

Show all working and reasoning.

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(c) Would a precipitate of barium fluoride form if 50 mL of 2.0×10^{-6} mol/L sodium fluoride were added to a solution of 150 mL of 5.0×10^{-3} mol/L barium nitrate? Show all working and reasoning. **3**

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Question 24 (7 marks)

The Contact process in the industrial production of sulfuric acid involves the conversion of SO_2 *(g)* into SO_3 *(g)*.

0.360 moles of sulfur dioxide and 0.300 moles of oxygen were injected into a 1.00 L vessel and allowed to reach equilibrium at 500°C.

At equilibrium, the concentration of sulfur trioxide was found to be 0.240 mol L^{-1}.

(a) Write a balanced equation for the equilibrium process forming 1 mole of sulfur trioxide. **1**

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(b) Calculate the equilibrium constant for the reaction in part (a) above. **2**

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(c) Use Le Chatelier's principle to predict the change in the concentrations of the 3 gases if the total pressure on the system were increased at 500°C. Explain your reasoning. **2**

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(d) Predict the impact on the equilibrium constant when the pressure was increased in part (c) above. **2**

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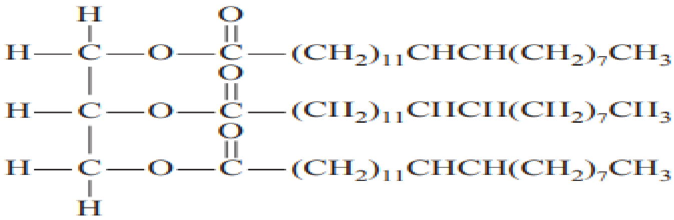
Question 25 (3 marks)

The molecule below can be used as a source of fuel. It is classified as an oil and is found in some plants.



(a) This molecule can be hydrolysed to form glycerol and a long chain acid, erucic acid. Erucic acid will combine with methanol to form an ester, methyl erucate, which can be used as the biofuel known as biodiesel. 1

Draw a structural formula for methyl erucate.

(b) Describe TWO environmental advantages of using biodiesel as a fuel rather than petrodiesel, which is produced from crude oil. 2

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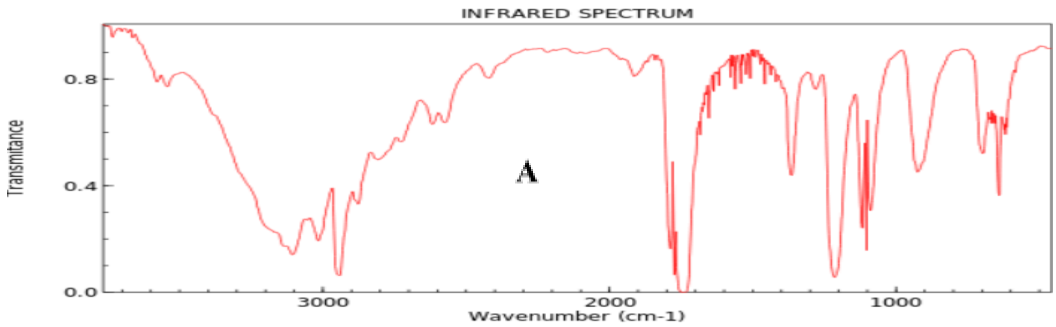
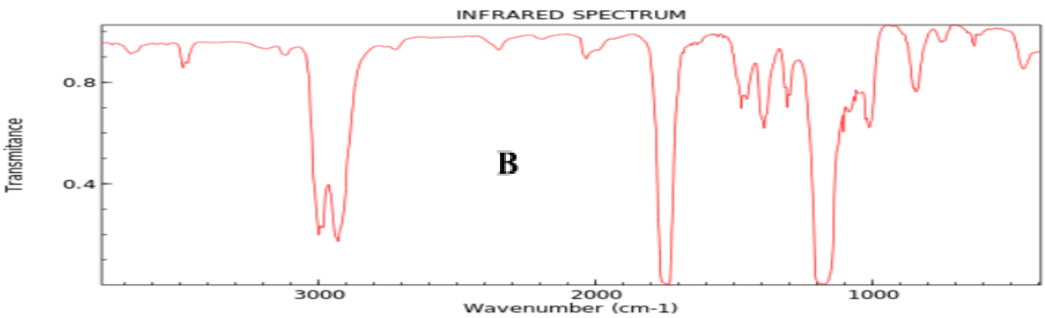
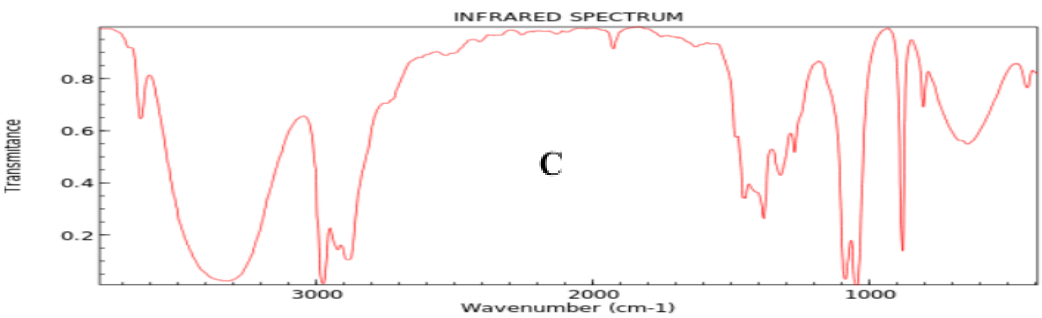
Question 26 (8 marks)

A student prepared the compound ethyl methanoate in a school laboratory using two organic reactants. The infrared (IR) spectra for the two reactants and their product are given below.







(a) Name and draw the structural formula for each of the organic reactants used to produce ethyl methanoate. **2**

Question 26 continues on the next page

Question 26 (continued)

(b) For each of the reactants named in part (a) above and for the product, identify its corresponding IR spectrum from spectra **A** to **C** shown on page 22. Justify your answer using data from the spectrum. **3**

Reactant …………………………. Spectrum……………………………… ….

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Reactant …………………………. Spectrum……………………………… ….

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Product …………………………. Spectrum……………………………… ….

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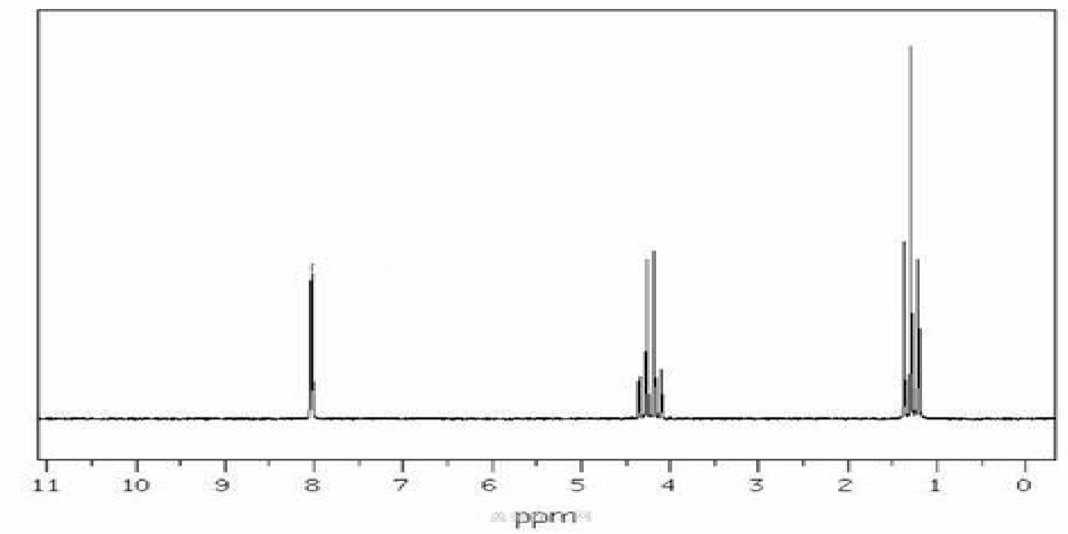
Question 26 (continued)

(c) Two versions of the high-resolution proton NMR spectrum, ^1H NMR, for ethyl methanoate are shown below. **3**



Describe **three** features of this spectrum that confirm it is for ethyl methanoate.

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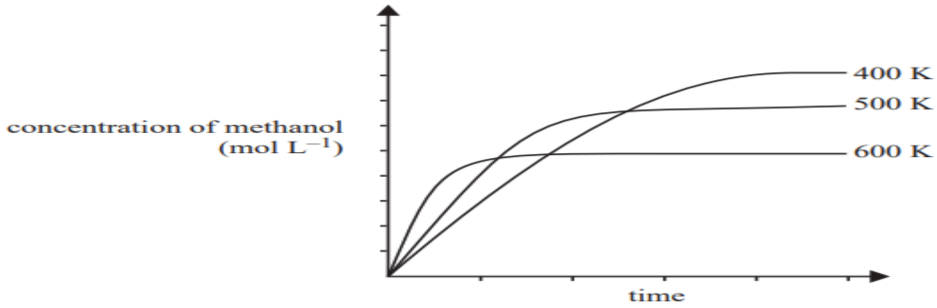
Question 27 (9 marks)

Methanol is produced on an industrial scale by the catalytic conversion of a mixture of hydrogen and carbon monoxide gases at a temperature of 520 K and a pressure of 50 to 100 atmospheres.

The reaction that occurs is:

$$CO\ (g) + 2H_2\ (g) \rightleftharpoons CH_3OH\ (g)$$

Carbon monoxide gas and hydrogen gas were mixed in a reaction vessel and equilibrium was established. The graph below shows how the concentration of methanol in this vessel changes with time at three different temperatures.



(a) Is the reaction endothermic or exothermic? Explain your response. **2**

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(b) Explain, in terms of collision theory and referring to the graphs, why a moderately high temperature is used in this industrial process even though the equilibrium concentration of methanol is higher at low temperatures. **3**

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Question 27 continues on the next page

Question 27 (continued)

(c) A metal alloy catalyst is used in this reaction. Discuss the role of a catalyst in changing the economic viability of an industrial process. **4**

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Question 28 (8 marks)

A scientist wished to determine the presence of metal ions in a sample of water taken from a dam near a mine site. She predicted that copper (II) ions would be found in the dam water.

(a) She initially decided to use chemical tests to see if precipitation reactions could determine whether copper (II) ions were present. **3**

Outline a procedure she might use in the laboratory to confirm the presence of these ions. Include observations for any chemical tests and equations for any reactions described.

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Question 28 continues on the next page

Question 28 (continued)

(b) She then decided to use UV-VIS spectroscopy to see if this could determine the concentration of these ions. Discuss the procedure she could use. **5**

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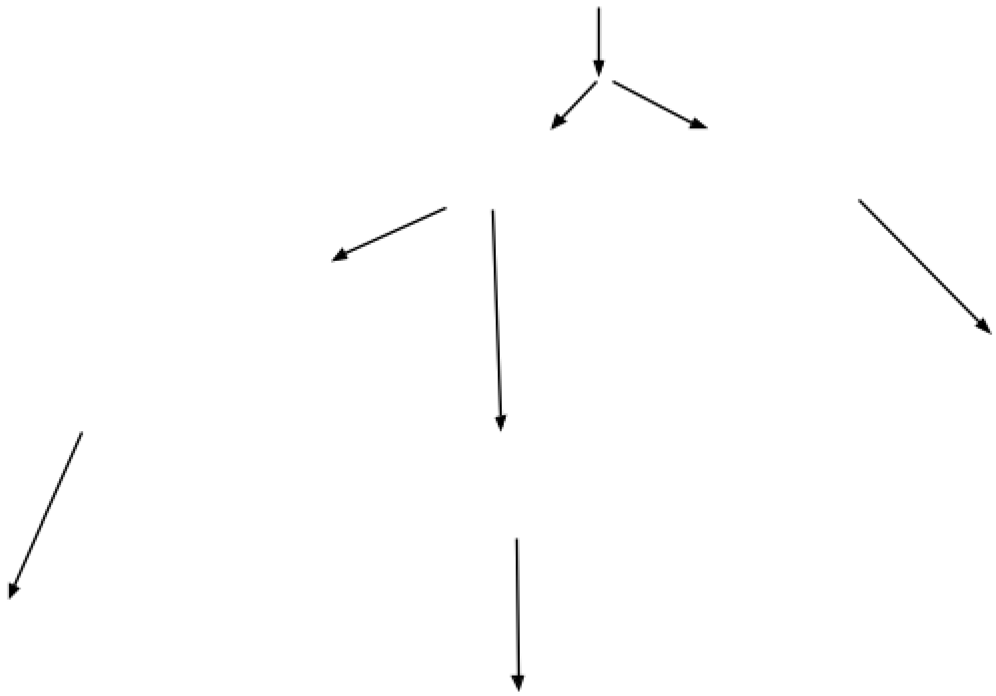
Question 29 (8 marks)

Use the flowchart to answer the questions below:



A = C_4H_8

Add H_2O/H^+

C = C_4H_9O

B = C_4H_9O

Heat with an oxidising agent

F = C_4H_9Cl

G = $C_3H_9NH_2$

D = $C_4H_9O_2$

Add Na_2CO_3 solution

E = C_4H_8O

An alkanone

CO_2 *(g)*

Add HCl

Add NH_3

Heat with an oxidising agent

(a) Compound **A** reacts with dilute acid solution to form 2 different compounds with the same formula, compounds **B** and **C**. **3**

Identify compounds **A**, **B** and **C** by name and drawing structural formulae. Explain how you decided on the structures of **A**, **B** and **C**.

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Question 29 continues on the next page

Question 29 (continued)

(b) Write the balanced equation for the reaction of **D** with sodium carbonate solution. **1**

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(c) Write the equation for the reaction of **B** to form **F**. Draw the structural formula and name the organic product formed. **2**

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(d) Name and draw the structural formula for compound **G**. Into which homologous series of compounds is compound **G** classified? **2**

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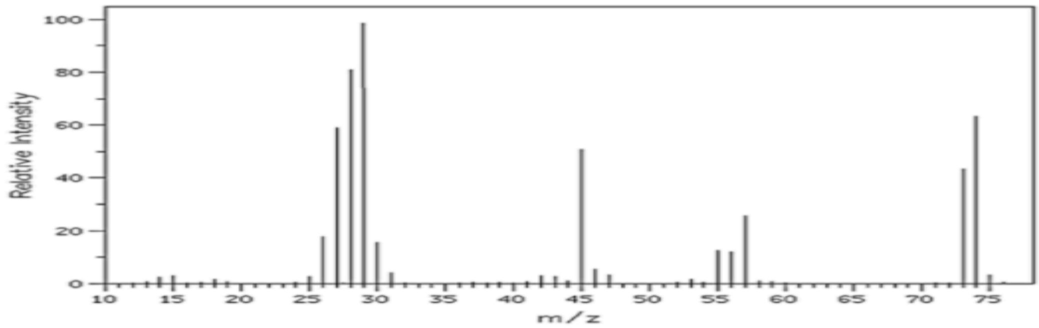
Question 30 (7 marks)

The mass spectrum below was produced by an organic molecule of formula $C_3H_6O_2$.



(a) Identify the base peak and the molecular ion peak. **2**

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(b) Draw 2 possible structures for molecules of formula $C_3H_6O_2$ which belong to different homologous series. **2**

(c) Identify the molecular mass fragments which could correspond to the peaks at m/z = 29 and 45. **2**

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(d) On the basis of this fragmentation pattern, justify which of the structures you have drawn in part (b) above is likely to be the source of the mass spectrum? **1**

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Section II - Extra writing space

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Section II - Extra writing space

If you use this space, clearly indicate which question you are answering.

Student Number

CHEMISTRY – MULTIPLE-CHOICE ANSWER SHEET

ATTEMPT ALL QUESTIONS

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

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FORMULAE SHEET

$n = \dfrac{m}{MM}$	$c = \dfrac{n}{V}$	$PV = nRT$
$q = mc\Delta T$	$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$	$\text{pH} = -\log_{10}\left[\text{H}^+\right]$
$pK_a = -\log_{10}\left[K_a\right]$	$A = \varepsilon lc = \log_{10}\dfrac{I_o}{I}$	

Avogadro constant, N_A .... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and
at 0°C (273.15 K) .... 22.71 L
at 25°C (298.15 K) .... 24.79 L

Gas constant .... 8.314 J mol^{-1} K^{-1}

Ionisation constant for water at 25°C (298.15 K), K_w .... 1.0×10^{-14}

Specific heat capacity of water .... 4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

Solubility constants at 25°C

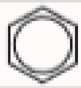
Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	Lead(II) hydroxide	1.43×10^{-15}
Calcium hydroxide	5.02×10^{-6}	Lead(II) phosphate	8.0×10^{-43}
Calcium phosphate	2.07×10^{-29}	Lead(II) sulfate	2.53×10^{-8}
Calcium sulfate	4.93×10^{-5}	Magnesium carbonate	6.82×10^{-6}
Copper(II) carbonate	1.4×10^{-10}	Magnesium hydroxide	5.61×10^{-12}
Copper(II) hydroxide	2.2×10^{-20}	Magnesium phosphate	1.04×10^{-24}
Copper(II) phosphate	1.40×10^{-37}	Silver bromide	5.35×10^{-13}
Iron(II) carbonate	3.13×10^{-11}	Silver chloride	1.77×10^{-10}
Iron(II) hydroxide	4.87×10^{-17}	Silver carbonate	8.46×10^{-12}
Iron(III) hydroxide	2.79×10^{-39}	Silver hydroxide	2.0×10^{-8}
Iron(III) phosphate	9.91×10^{-16}	Silver iodide	8.52×10^{-17}
		Silver phosphate	8.89×10^{-17}
		Silver sulfate	1.20×10^{-5}

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for this examination paper. Some data may have been modified for examination purposes.

Infrared absorption data

Bond	Wavenumber/cm^{-1}
N—H (amines)	3300–3500
O—H (alcohols)	3230–3550 (broad)
C—H	2850–3300
O—H (acids)	2500–3000 (very broad)
C≡N	2220–2260
C=O	1680–1750
C=C	1620–1680
C—O	1000–1300
C—C	750–1100

^{13}C NMR chemical shift data

Type of carbon		δ/ppm
—C—C—		5–40
R—C—Cl or Br		10–70
R—C(=O)—C—		20–50
R—C—N		25–60
—C—O—	alcohols, ethers or esters	50–90
C=C		90–150
R—C≡N		110–125
		110–160
R—C(=O)—	esters or acids	160–185
R—C(=O)—	aldehydes or ketones	190–220

UV absorption

(This is not a definitive list and is approximate.)

Chromophore	λ_{max} (nm)
C—H	122
C—C	135
C=C	162

Chromophore	λ_{max} (nm)
C≡C	173 178 196 222
C—Cl	173
C—Br	208

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Uut Ununtrium	114 Fl Flerovium	115 Uup Ununpentium	116 Lv Livermorium	117 Uus Ununseptium	118 Uuo Ununoctium

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (January 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

2021 YEAR 12 TRIAL EXAMINATION

CHEMISTRY – MAPPING GRID

Exam Section	Question	Marks	Content	Syllabus Outcomes	Targeted Performance Bands	Answer
Section I	1	1	Mod 8: Analysis of Inorganic Substances	CH12–6, CH12–15	2-3	B
	2	1	Mod 5: Factors that Affect Equilibrium	CH12–5, CH12–12	3-4	A
	3	1	Mod 8: Analysis of Organic Substances	CH12–5, CH12–15	3-4	D
	4	1	Mod 6: Quantitative Analysis	CH12–6, CH12–13	3-4	A
	5	1	Mod 5: Solubility Equilibria	CH12–5, CH12–13	3-4	D
	6	1	Mod 5: Calculating the Equilibrium Constant	CH12–6, CH12–13	3-4	B
	7	1	Mod 7: Reactions of Organic Acids and Bases	CH12–5, CH12–14	3-4	B
	8	1	Mod 8: Analysis of Inorganic Substances	CH12–5, CH12–15	3-4	C
	9	1	Mod 5: Factors that Affect Equilibrium	CH12–5, CH12–12	3-4	B
	10	1	Mod 7: Nomenclature, Alcohols	CH12–5, CH12–14	3-4	D
	11	1	Mod 5: Calculating the Equilibrium Constant	CH12–6, CH12–12	3-4	C
	12	1	Mod 5: Static and Dynamic Equilibrium	CH12–5, CH12–12	3-4	C
	13	1	Mod 7: Hydrocarbons	CH12–5, CH12–14	3-4	B
	14	1	Mod 6: Using Brønsted-Lowry Theory	CH12–5, CH12–13	3-4	A
	15	1	Mod 6: Quantitative Analysis	CH12–6, CH12–13	4-5	C
	16	1	Mod 8: Analysis of Organic Substances	CH12–5, CH12–15	4-5	D
	17	1	Mod 8: Analysis of Inorganic Substances	CH12–5, CH12–15	4-5	C
	18	1	Mod 8: Analysis of Organic Substances	CH12–5, CH12–15	4-5	A
	19	1	Mod 7: Nomenclature	CH12–6, CH12–15	4-5	C
	20	1	Mod 6: Quantitative Analysis	CH12–6, CH12–13	4-5	D

Explanations for Multiple-Choice	
1	**B** Ca^{2+} forms precipitates with sulfate and carbonate ions but not with chloride or nitrate ions. Calcium chloride and calcium nitrate are classified as soluble in water.
2	**A** The equilibrium involved is: $Co(H_2O)_6^{2+}$ *(aq)* + $4Cl^-$ *(aq)* $\rightleftharpoons$ $CoCl_4^{2-}$ *(aq)* + $6H_2O$ *(l)* The addition of Ag^+ removes Cl^- and the equilibrium moves to the left. Hence $Co(H_2O)_6^{2+}$ *(aq)* must be pink. On heating the mixture turns blue, so the product $CoCl_4^{2-}$ *(aq)* must be blue and the reaction as written in the equation must be endothermic (as increasing the temperature favours the endothermic reaction). So only alternative I is correct.
3	**D** Propan-2-ol has hydrogen bonding between molecules while acetone has only dipole-dipole interactions (no hydrogen atoms directly bonded to oxygen atoms). A is wrong as covalent bonds are not broken when boiling occurs.
4	**A** Nitrous acid is weak (small K_a value) so only a small proportion of the acid molecules ionise to form H^+ *(aq)* and NO_2^- *(aq)*.
5	**D** K_{sp} MgF_2 = 6.8×10^{-9} Let x moles MgF_2 dissolve to form a saturated solution. K_{sp} MgF_2 = $6.8 \times 10^{-9} = (x)(2x)^2 = 4x^3$ $x^3 = 1.7 \times 10^{-9}$ $x = 1.2 \times 10^{-3}$ mol L^{-1}
6	**B** $K_{eq} = 0.48 = [NO_2]^2 / [N_2O_4] = [NO_2]^2 / 0.20$ Hence $[NO_2]^2 = 0.48 \times 0.20 = 0.096$ $[NO_2] = \sqrt{0.096} = 0.31$ mol/L
7	**B** Only CH_3COOH is an acid. A is ethanol, C is ethanal, D is propanone. These 3 compounds are not classified as acids. The acid will have lowest pH by producing hydronium ions in aqueous solution.
8	**C** From the graph, if absorbance is 0.40, then copper concentration is 2.5 ppm. This is the same as 2.5 mg/L or $2.5 \times 10^{-3}/63.55$ mol/L = 0.039×10^{-3} = 3.9×10^{-5} mol/L

9	**B** The equilibrium vapour pressure depends on the temperature. When more solid $CaCO_3$ is added, at the same temperature, no extra solid will react to form CO_2 as the maximum no. of particles of CO_2 that can exist as a gas at that temperature is already in the container.
10	**D** The primary alcohol, 3-methylbutan-1-ol will be oxidised to 3-methylbutanoic acid.
11	**C** At 30 seconds, the quotient Q = $[CO_2][H_2] \div [CO][H_2O] = (2.0 \times 2.0) \div (0.1 \times 0.1) = 400$ Since Q is greater than K_{eq} (210), the system is moving to decrease the quotient and reach equilibrium. Hence, the amounts of products must be decreasing and the amounts of reactants increasing. This means the reverse reaction is favoured and this requires that the rate of the forward reaction is less than the rate of the reverse reaction.
12	**C** A catalyst increases the rate of reaction; hence the graph for the catalysed reaction is initially steeper. A catalyst has no effect on the yield/position of equilibrium, so both graphs level off at the same concentration of H_2.
13	**B** H–Br adds across the double bond. The 2 isomers are 2-bromo-2-methylbutane and 2-bromo-3-methylbutane. The preferred isomer is 2-bromo-2-methylbutane, by Markovnikov's rule.
14	**A** The ammonium ion is acidic (donates protons to water), so ammonium acetate will be least basic. Neither the barium nor sodium ion will impact on the pH. Since there are more basic acetate ions in a 0.1 M solution of barium acetate than in the same concentration solution of sodium acetate, barium acetate will be the most basic.
15	**C** No. of moles of H^+ = (10/1000) x 0.0400 x 2 = 0.0008 mol H^+ No of moles of OH^- = (40/1000) x 0.35 = 0.014 mol OH^- After mixing and neutralisation, there are excess moles of OH^-. Moles of OH^- in excess = 0.014 – 0.0008 = 0.0132 mol $[OH^-]$ = 0.0132 mol /0.050 L = 0.264 mol/L pOH = $-\log_{10}$ (0.1233) = 0.578 pH = 14.000 – 0.578 = 13.42 (Since the data given was only accurate to 2 s.f., the pH should be expressed to 2 d.p.) Answer D is incorrect as it is based on only 0.0004 moles of H^+ from the H_2SO_4.

16	**D** B, C and D all have molar mass of 72 g mol^{-1} Of these only 2-methylpropanal has 3 different carbon atom environments. Butanal and butanone have 4 different carbon environments.
17	**C** Mass AgCl precipitate formed = 0.376 g Moles of AgCl = 0.376/143.35 = 0.002623 Mol AgCl = mol NaCl in original food sample Mass NaCl = 0.002623 x 58.44 g = 0.1533 g Hence % of NaCl by mass = (0.1533/20) x 100 = 0.766%
18	**A** The absence of any broad bands between 3000 and 3500 cm^{-1} rules out acids or alcohols. The absence of absorbance at 1725 cm^{-1}indicates that a carbonyl group (C=O) is not present. Hence options B, C and D are wrong.
19	**C** The compound is an alkanol so the –OH group must have the lowest number. The molecule is numbered from the left. Chlorine atoms are listed before fluorine (alphabetical).
20	**D** If pH = 11.50, pOH = 2.50 Since pK_a NH_4^+ = 9.24, then pK_b NH_3 = 4.76 ($pK_a + pK_b$ of the conjugate acid-base pair = 14) $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ $[OH^-] = [NH_4^+] = 10^{-2.50}$ $K_b\,NH_3 = 10^{-4.76} = [NH_4^+]\,[OH^-] / [NH_3]$ Hence $[NH_3] = (10^{-2.50})\,(10^{-2.50}) / 10^{-4.76} =$ 0.58 M

2021 YEAR 12 TRIAL EXAMINATION

CHEMISTRY – MAPPING GRID

Exam Section	Question	Marks	Content	Syllabus Outcomes	Targeted Performance Bands
Section II	21 (a)	2	Mod 7: Nomenclature and Alcohols	CH12–7, CH12–14	2-3
	21 (b)	3	Mod 7: Alcohols	CH12–7, CH12–14	2-4
	21 (c)	1	Mod 8: Analysis of Organic substances	CH12–7, CH12–15	2-3
	21 (d)	2	Mod 8: Analysis of Organic substances	CH12–5, CH12–7, CH12–15	3-6
	22 (a)	2	Mod 6: Quantitative Analysis	CH12–3, CH12–13	3-5
	22 (b)	1	Mod 6: Quantitative Analysis	CH12–5, CH12–13	3-4
	22 (c)	2	Mod 6: Quantitative Analysis	CH12–7, CH12–13	3-4
	22 (d)	1	Mod 6: Quantitative Analysis	CH12–5, CH12–13	3-4
	22 (e)	2	Mod 6: Quantitative Analysis	CH12–4, CH12–7, CH12–13	2-4
	22 (f)	2	Mod 6: Quantitative Analysis	CH12–5, CH12–13	3-5
	22 (g)	4	Mod 6: Quantitative Analysis	CH12–4, CH12–6, CH12–7, CH12–13	3-6
	22 (h)	2	Mod 6: Using Brønsted-Lowry Theory	CH12–7, CH12–13	2-4
	23 (a)	1	Mod 5: Solution Equilibria	CH12–7, CH12–12	2-3
	23 (b)	2	Mod 5: Solution Equilibria	CH12–6, CH12–12	4-6
	23 (c)	3	Mod 5: Solution Equilibria	CH12–6, CH12–12	4-6
	24 (a)	1	Mod 5: Calculating the Equilibrium Constant	CH12–7, CH12–12	3-4
	24 (b)	2	Mod 5: Calculating the Equilibrium Constant	CH12-5, CH12–12	3-6
	24 (c)	2	Mod 5: Factors that Affect Equilibrium	CH12–6, CH12–12	3-4
	24 (d)	2	Mod 5: Factors that Affect Equilibrium	CH12–7, CH12–12	3-4
	25 (a)	1	Mod 7: Reactions of Organic Acids and Bases	CH12–4, CH12–7, CH12–14	2-3
	25 (b)	2	Mod 7: Reactions of Organic Acids and Bases	CH12–7, CH12–14	3-5
	26 (a)	2	Mod 7: Nomenclature	CH12–7, CH12–14	3-4
	26 (b)	3	Mod 8: Analysis of Organic Substances	CH12–5, CH12–7, CH12–15	3-5
	26 (c)	3	Mod 8: Analysis of Organic Substances	CH12–5, CH12–7, CH12–15	3-5
	27 (a)	2	Mod 5: Factors that Affect Equilibrium	CH12–4, CH12–7, CH12–12	2-4
	27 (b)	3	Mod 5: Factors that Affect Equilibrium	CH12–4, CH12–7, CH12–12, CH12–15	2-5
	27 (c)	4	Mod 5: Factors that Affect Equilibrium. Mod 8: Chemical Synthesis and Design	CH12–7, CH12–15	2-5

	28 (a)	3	Mod 8: Analysis of Inorganic Substances	CH12–3, CH12–7, CH12–15	2-5
	28 (b)	5	Mod 8: Analysis of Inorganic Substances	CH12–3, CH12–7, CH12–15	2-6
	29 (a)	3	Mod 8: Analysis of Organic Substances	CH12–4, CH12–7, CH12–15	2-5
	29 (b)	1	Mod 8: Analysis of Organic Substances	CH12–7, CH12–15	3-4
	29 (c)	2	Mod 8: Analysis of Organic Substances	CH12–7, CH12–15	2-4
	29 (d)	2	Mod 8: Analysis of Organic Substances	CH12–7, CH12–15	2-4
	30 (a)	2	Mod 8: Analysis of Organic Substances	CH12-5, CH12–7, CH12–15	2-4
	30 (b)	2	Mod 8: Analysis of Organic Substances	CH12-5, CH12–7, CH12–15	3-5
	30 (c)	2	Mod 8: Analysis of Organic Substances	CH12-5, CH12–7, CH12–15	3-5
	30 (d)	1	Mod 8: Analysis of Organic Substances	CH12-5, CH12–7, CH12–15	4-6

2021 YEAR 12 TRIAL EXAMINATION

CHEMISTRY – MARKING GUIDELINES

Section II – 80 marks

Question 21 (8 marks)
21 (a) (2 marks)
Outcomes Assessed: CH12–7, CH12–14
Targeted Performance Bands: 2-3

Criteria	Marks
● Identifies Compounds **A** and **B** as isomers AND ● Explains the response by defining isomers	2
● Identifies Compounds **A** and **B** as isomers OR ● Correctly defines isomers	1

Sample answer
Compounds **A** (propan-1-ol) and **B** (propan-2-ol) are isomers as they have the same molecular formula (C_3H_8O) but different structural formulae / different arrangement of atoms.

21 (b) (3 marks)
Outcomes Assessed: CH12–7, CH12–14
Targeted Performance Bands: 2-4

Criteria	Marks
● Identifies **A** (propan-1-ol) as being able to be converted into Compound **C** (propanoic acid) whereas compound **B** is oxidised to propanone ● Names an oxidising agent as the reagent ● States the appropriate observations	3
● TWO of the ABOVE	2
● ONE of the ABOVE	1

Sample answer
Compound **A** or propan-1-ol (by name or correct formula).
The reagent needed would be an oxidising agent such as acidified potassium permanganate or acidified potassium dichromate.
When the coloured oxidising agent (purple for the permanganate ion and orange for the dichromate ion) is added to the colourless alcohol and the mixture heated, a colour change will occur from purple to very pale pink when the acidified permanganate ion has been used OR orange to green when the acidified dichromate ion has been used. Compound **B** can also be oxidised but cannot be converted into propanoic acid.

21 (c) (1 mark)
Outcomes Assessed: CH12–7, CH12–15
Targeted Performance Bands: 2-3

Criteria	Mark
• Spectroscopy or isolation of the pure product and testing with moist pH indicator paper)	1

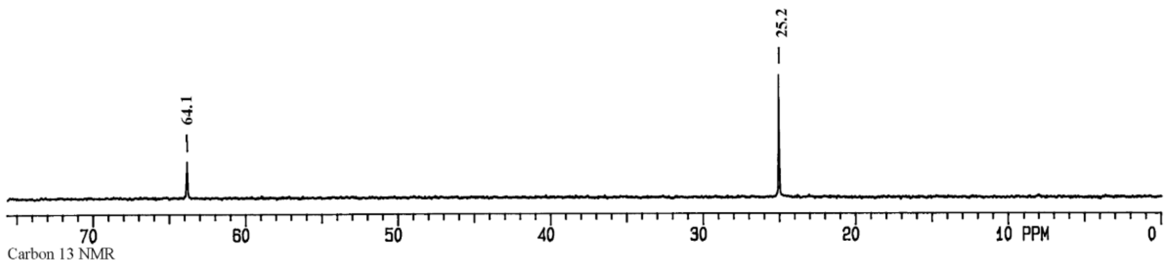
Sample answer
The presence of the carboxylic acid in the mixture would best be identified by IR spectroscopy.
(The use of an indicator to measure pH will not be appropriate as acid has been added as part of the reactant oxidising agent.)
If the product is isolated from the reactants a pure sample could be tested by indicator paper. This isolation could be achieved by fractional distillation.

21 (d) (2 marks)
Outcomes Assessed: CH12–5, CH12–7, CH12–15
Targeted Performance Bands: 3-6

Criteria	Marks
• Justifies that the spectrum cannot be that of compound **B** on the basis that compound **B** has only 2 different carbon environments and the spectrum shows 3 lines, indicating 3 different carbon environments AND • Includes a diagram which shows only 2 lines on the spectrum	2
• Justifies that the spectrum cannot be that of compound **B** on the basis that compound **B** has only 2 different carbon environments and the spectrum shows 3 lines, indicating 3 different carbon environments OR • Includes a diagram which shows only 2 lines on the spectrum	1

Sample answer
The spectrum cannot be that of compound **B** on the basis that compound **B** has only 2 different carbon environments as the 2 terminal carbons have the same environment. The spectrum shows 3 lines, indicating 3 different carbon environments.

Note for teachers: Only requires a rough sketch showing 2 lines, 1 in higher shift range, 1 in lower shift range.



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Question 22 (16 marks)

22 (a) (2 marks)

Outcomes Assessed: CH12–3, CH12–13

Targeted Performance Bands: 3-5

Criteria	Marks
● Outlines an appropriate method by reacting the sodium hydroxide solution with an acid that is a primary standard / (i.e. of exactly known concentration)	2
● Outlines some correct information about standardisation	1

Sample answer

Since sodium hydroxide cannot be weighed out accurately, as it absorbs water and carbon dioxide from the atmosphere, it must be standardised by reacting it with an acid which has a concentration that can be accurately determined by weighing. Oxalic acid is a primary standard as it can be weighed out accurately. The concentration of an oxalic acid solution is determined by calculation (moles/volume). The oxalic acid can then be titrated against the sodium hydroxide. 25.0 mL of the sodium hydroxide solution is pipetted into a conical flask and the oxalic acid titrated from the burette until the phenolphthalein indicator changes from pink to colourless. Oxalic acid is diprotic, so 2 moles of NaOH are needed for 1 mole of oxalic acid.

The concentration of the NaOH is determined by calculation.

22 (b) (1 mark)

Outcomes Assessed: CH12–5, CH12–13

Targeted Performance Bands: 3-4

Criteria	Mark
● Correctly calculates the concentration of ethanoic acid	1

Sample answer

Moles NaOH added = cV = 0.105 x 0.0176 = 0.001848 mol

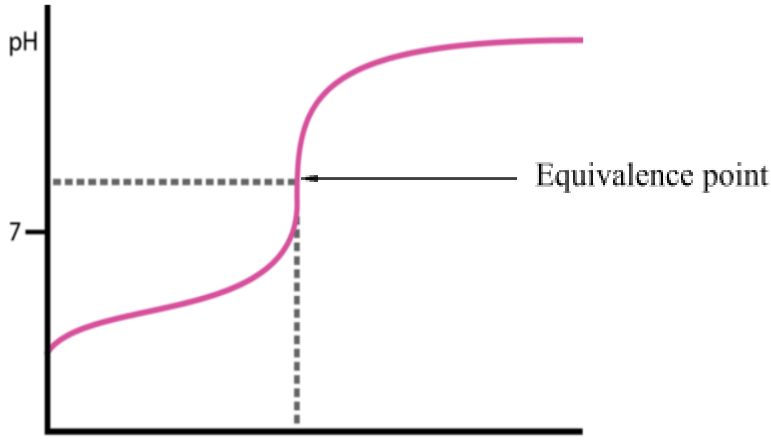
Moles CH_3COOH = 0.001848 mol (same as NaOH as react in 1:1 ratio)

Concentration of CH_3COOH = n/V = 0.001848/0.0250 = 0.07392 M = 0.0739 M

22 (c) (2 marks)
Outcomes Assessed: CH12–7, CH12–13
Targeted Performance Bands: 3-4

Criteria	Marks
• Sketches an appropriate pH titration curve with labelled axes • Indicates the equivalence point	2
• Sketches an appropriate pH titration curve with labelled axes	1

Sample answer



Titration curve of a weak acid (CH_3COOH)
with a strong base (NaOH)

22 (d) (1 mark)
Outcomes Assessed: CH12–5, CH12–13
Targeted Performance Bands: 3-4

Criteria	Mark
• Justifies why methyl orange is NOT a suitable indicator in terms of the pH at the equivalence point	1

Sample answer
The equivalence point for the strong base/weak acid titration (as in part (b) above) is at pH = 9. An indicator which changes colour close to pH 9 is needed. Methyl orange changes colour between pH 3 and 5, so its colour change would not accurately indicate the point where the correct no. of moles of base had been added to neutralise the moles of acid in the flask.

22 (e) (2 marks)
Outcomes Assessed: CH12–4, CH12–7, CH12–13
Targeted Performance Bands: 2-4

Criteria	Marks
• Writes a correct equation, including reversible arrows AND • Writes a correct expression for K_a for ethanoic acid	2
• Writes a correct equation, including reversible arrows OR • Writes a correct expression for K_a for ethanoic acid	1

Sample answer
$CH_3COOH\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + CH_3COO^-\ (aq)$

$$K_a\ CH_3COOH = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]} = 1.8 \times 10^{-5}$$

22 (f) (2 marks)
Outcomes Assessed: CH12–5, CH12–13
Targeted Performance Bands: 3-5

Criteria	Marks
• Determines the pH (to 2 d.p. = 2 s.f.)	2
• Determines the $[H^+]$	1

Sample answer
Let x mol/L ethanoic acid dissociate to form x mol/L H^+ and x mol/L of ethanoate ion

$$K_a\ CH_3COOH = \frac{[x][x]}{[CH_3COOH - x]} = 1.8 \times 10^{-5}$$

$$K_a\ CH_3COOH = \frac{[x][x]}{[0.01 - x]} = 1.8 \times 10^{-5}$$

Assume x is small by comparison with 0.01 mol/L
$x^2 = (1.8 \times 10^{-5})(0.01) = 1.8 \times 10^{-7}$
x = 0.000424 mol/L = 4.24×10^{-4} mol/L
$[H^+] = 4.24 \times 10^{-4}$ mol/L

pH = 3.37 (to 2 s.f.)

Note for teachers: In mathematical terms, the number to the left of the decimal point in a logarithm is called the characteristic and the number to the right of the decimal point is called the mantissa. The mantissa has as many significant figures as the number from which the logarithm was determined. Hence $[H^+] = 4.24 \times 10^{-4}$, pH 3.37

22 (g) (4 marks)
Outcomes Assessed: CH12–4, CH12–6, CH12–7, CH12–13
Targeted Performance Bands: 3-6

Criteria	Marks
● Analyses and explains all concentrations and pH readings, demonstrating a thorough knowledge of pH, equilibrium, acid strength and the related degree of ionisation	4
● Analyses and explains all concentrations and pH readings, demonstrating a sound knowledge of pH, equilibrium, acid strength and the related degree of ionisation	3
● Explains some aspects of concentrations AND pH readings	2
● Relates a feature in the table to equilibrium or acid strength	1

Sample answer:
Despite having the same initial pH of 2.4, which indicates the $[H^+]$ in both were equal, the actual concentrations of the acids were very different.

This reflects the different strengths of the two acids. Hydrochloric acid is strong and totally ionises whereas ethanoic acid is weak and only ionises partially. Therefore, despite the ethanoic acid having a much higher acid concentration of 1.0 mol L^{-1}, the $[H^+]$ in ethanoic acid must be only 0.0040 mol L^{-1}.

After addition of the salts the hydrochloric acid pH remained the same whilst the ethanoic acid pH rose to 2.6, indicating a drop in $[H^+]$.

As ethanoic acid is a weak acid it only partially ionises according to the following equilibrium:
$CH_3COOH\ (aq) + H_2O\ (l) \rightleftharpoons CH_3COO^-\ (aq) + H_3O^+\ (aq)$

The addition of potassium ethanoate increases the concentration of ethanoate ions.

Le Chatelier's Principle states:
If a chemical system at equilibrium experiences a change in concentration, temperature, volume or pressure, then the equilibrium shifts to counteract the imposed change.

According to this principle, the equilibrium shown in the above equation would shift to the left to reduce the concentration of acetate ions.

This would reduce the concentration of H_3O^+ and hence would raise the pH.

As hydrochloric acid is a strong acid it ionises completely:
$HCl\ (aq) + H_2O\ (l) \rightarrow H_3O^+\ (aq) + Cl^-(aq)$

The addition of potassium chloride ions will produce more chloride ions. As there is no equilibrium, the addition of these ions will have no effect. The pH will remain unchanged.

22 (h) (2 marks)
Outcomes Assessed: CH12–7, CH12–13
Targeted Performance Bands: 2-4

Criteria	Marks
• Explains the classification of ethanoic acid BOTH by Lowry-Brønsted and Arrhenius theories of acids	2
• Explains the classification of ethanoic acid by ONE of Lowry-Brønsted and Arrhenius theories of acids	1

Sample answer
Ethanoic acid is classified as an acid by the Arrhenius theory of acids because it forms hydrogen (hydronium) ions in aqueous solution as the only positive ions.

Ethanoic acid is classified as an acid by the Lowry-Brønsted theory because ethanoic acid is capable of donating a proton (H^+) to a base. This definition is independent of state; water does not need to be present.

Question 23 (6 marks)
23 (a) (1 mark)
Outcomes Assessed: CH12–7, CH12–12
Targeted Performance Bands: 2-3

Criteria	Mark
● Correct answer (showing correct states)	1

Sample answer
Ba^{2+} *(aq)* + $2F^-$ *(aq)* → BaF_2 *(s)*

23 (b) (2 marks)
Outcomes Assessed: CH12–6, CH12–12
Targeted Performance Bands: 4-6

Criteria	Marks
● Correct answer, with correct reasoning and full working	2
● Some evidence of correct understanding of how to determine the $[F^-]$	1

Sample answer
Let the solubility of BaF_2 be s.
K_{sp} $BaF_2 = [Ba^{2+}]\ [F]^2 = 1.8 \times 10^{-7}$
If $[Ba^{2+}] = 5.0 \times 10^{-4}$
$[F^-]^2 = 1.8 \times 10^{-7} / 5.0 \times 10^{-4} = 0.00036$
$[F^-] = \sqrt{}0.00036 = 1.9 \times 10^{-2}$ mol/L

23 (c) (3 marks)
Outcomes Assessed: CH12–6, CH12–12
Targeted Performance Bands: 4-6

Criteria	Marks
● Correct answer, with correct reasoning and full working	3
● Some evidence of a comparison between the product of the concentration of the ions and the K_{sp} value	2
● Some evidence of correct understanding of how to determine the product of the concentration of the ions	1

Sample answer
No. of moles NaF = $2 \times 10^{-6} \times (50/1000) = 1.0 \times 10^{-7}$
No. of moles $Ba(NO_3)_2 = 5 \times 10^{-3} \times (150/1000) = 7.5 \times 10^{-4}$
Total volume of solution = 200 mL
$[F^-] = 1 \times 10^{-7} / 0.200 = 5 \times 10^{-7}$ mol/L
$[Ba^{2+}] = 7.5 \times 10^{-4} / 0.200 = 3.75 \times 10^{-3}$ mol/L

The product of the concentration of the ions (Q) is
$Q = [Ba^{2+}]\ [F^-]^2 = 3.75 \times 10^{-3} \times (5 \times 10^{-7})^2 = 9.4 \times 10^{-16}$
Since this product is less than K_{sp} (1.8×10^{-7}), a precipitate will not form.

Question 24 (7 marks)
24 (a) (1 mark)
Outcomes Assessed: CH12–7, CH12–12
Targeted Performance Bands: 3-4

Criteria	Mark
● Writes a correctly balanced equation for formation of 1 mole of sulfur trioxide	1

Sample answer
$SO_2\,(aq) + \frac{1}{2}O_2\,(g) \rightleftharpoons SO_3\,(g)$

24 (b) (2 marks)
Outcomes Assessed: CH12–5, CH12–12
Targeted Performance Bands: 3-6

Criteria	Marks
● Calculates equilibrium constant for the reaction as written in part (a) above	2
● Uses a correct method but with mathematical error	1

Sample answer

$$K_{eq} = \frac{[SO_3\,(g)]}{[SO_2\,(g)]\;[O_2\,(g)]^{\frac{1}{2}}}$$

	SO_2	O_2	SO_3
Initially	0.360 mol	0.300 mol	0.000 mol
Change	-0.240 mol	-0.120 mol	+0.240 mol
At equilibrium	0.120 mol	0.180 mol	0.240 mol

In 1 L vessel:

$$K_{eq} = \frac{[SO_3\,(g)]}{[SO_2\,(g)]\;[O_2\,(g)]^{\frac{1}{2}}} = \frac{(0.240)}{(0.120)\,(0.180)^{\frac{1}{2}}} = \frac{0.240}{(0.120)\,(0.424)} = 4.72$$

24 (c) (2 marks)
Outcomes Assessed: CH12–6, CH12–12
Targeted Performance Bands: 3-4

Criteria	Marks
• Predicts that [SO_3] will increase and [O_2] and [SO_2] will decrease AND • Explains the prediction in terms of Le Chatelier's principle	2
• Predicts that [SO_3] will increase and [O_2] and [SO_2] will decrease	1

Sample answer
Le Chatelier's principle states that if a system is at equilibrium and the conditions are changed by increasing the pressure, volume or temperature of the system, then the equilibrium will shift to compensate for the applied change.

Here, since the pressure only is increased, the equilibrium will shift to the right, to the side which has fewer molecules (1 mole of SO_3 by comparison with a total of 1.5 moles of gas on the LHS).

Hence the [SO_3] will increase and [O_2] and [SO_2] will decrease

24 (d) (2 marks)
Outcomes Assessed: CH12–7, CH12–12
Targeted Performance Bands: 3-4

Criteria	Marks
• Predicts that the equilibrium constant will not change because the temperature has remained constant	2
• Predicts that the equilibrium constant will not change	1

Sample answer
The equilibrium constant does not change unless the temperature changes.

Question 25 (3 marks)
25 (a) (1 mark)
Outcomes Assessed: CH12–4, CH12-7, CH12–14
Targeted Performance Bands: 2-3

Criteria	Mark
● Draws the correct structural formula for methyl erucate	1

Sample answer
$CH_3(CH_2)_7CHCH(CH_2)_{11}COOCH_3$

25 (b) (2 marks)
Outcomes Assessed: CH12–7, CH12–14
Targeted Performance Bands: 3-5

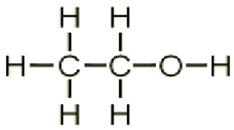
Criteria	Marks
● Describes TWO environmental advantages of using biodiesel rather than petrodiesel AND ● Contrasts each advantage with a disadvantage of using petrodiesel	2
● Describes ONE environmental advantage of using biodiesel rather than petrodiesel AND ● Contrasts that advantage with a disadvantage of using petrodiesel	1

Sample answer (a range of answers possible but must be contrasted with use of petrodiesel)
There is a lower environmental impact of plant growth for biodiesel production compared to crude oil extraction (oil spills) and refining for petrodiesel production.
Biodiesel combustion releases recently extracted CO_2 back into the atmosphere, whereas petrodiesel adds to current atmospheric CO_2 levels.
Biodiesel production is less harmful to marine life that is affected by oil spills during extraction and transport of crude oil for the production of petrodiesel.

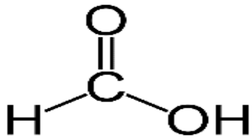
Question 26 (8 marks)
26 (a) (2 marks)
Outcomes Assessed: CH12–7, CH12–14
Targeted Performance Bands: 3-4

Criteria	Marks
● Names AND draws structural formulae for ethanol and methanoic acid	2
● Draws 2 correct formulae OR 2 correct names OR ● 1 correct formula AND 1 correct name	1

Sample answer



ethanol



methanoic acid

26 (b) (3 marks)
Outcomes Assessed: CH12–5, CH12–7, CH12–15
Targeted Performance Bands: 3-5

Criteria	Marks
● Identifies ethanol as Spectrum C ● Identifies methanoic acid as Spectrum A ● Identifies ethyl methanoate as Spectrum B ● Justifies the selections using data from the spectra and data provided on data pages	3
● Identifies 2 of the 3 spectra AND ● Justifies the selection using data from the spectra and data provided on data pages	2
● Identifies 1 of the 3 spectra AND ● Justifies the selection using data from the spectra and data provided on data pages	1

Sample answer
Reactant: ethanol, Spectrum C
The broad O–H absorption band at 3200–3600 cm^{-1} corresponds to an –OH in an alcohol and there is no C=O absorption band in 1680–1750 cm^{-1}. Alcohols do not have a carbonyl group.

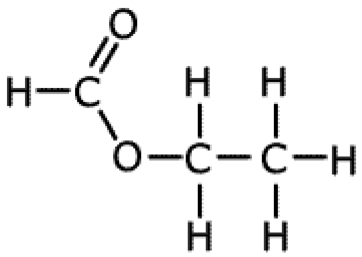
Reactant: methanoic acid, Spectrum A
The very broad O–H absorption band at 2500-3500 cm^{-1} indicates an –OH group in an acid; the C=O absorption band at 1700 cm^{-1} (1680–1750 cm^{-1}) indicates a C=O in an acid.

Product: Ethyl methanoate, Spectrum B
There is no O–H absorption in the 2500-3600 region (so it is not an acid or an alcohol). There is absorption in the 1680-1750 cm^{-1} range which indicates a carbonyl group as is present in an ester.

26 (c) (3 marks)
Outcomes Assessed: CH12–5, CH12–7, CH12–15
Targeted Performance Bands: 3-5

Criteria	Marks
• Describes THREE features of the spectrum which confirm that the compound is ethyl methanoate	3
• Describes TWO features of the spectrum which confirm that the compound is ethyl methanoate	2
• Describes ONE feature of the spectrum which confirms that the compound is ethyl methanoate	1

Sample answer
Ethyl methanoate has the following structure:



Three peaks on the NMR spectrum indicate three hydrogen environments consistent with the above structure.

The combination of a quartet at the shift of 4.2 ppm (with 2 hydrogen atoms) and a triplet at the shift of 1.2 ppm (with 3 hydrogen atoms) is consistent with the presence of CH_3CH_2– (an ethyl group).

The singlet at the shift of 8 ppm is consistent with a single hydrogen on a C atom with no neighbouring hydrogens (as the hydrogen on the C of the C=O group in the ester linkage). The high shift (when compared to the other hydrogens in the molecule) indicates it is close to the 2 electronegative oxygen atoms.

Question 27 (9 marks)
27 (a) (2 marks)
Outcomes Assessed: CH12–4, CH12–7, CH12–12
Targeted Performance Bands: 2-4

Criteria	Marks
● Identifies the reaction as exothermic AND ● Explains the response using data from the graph and Le Chatelier's principle	2
● Identifies the reaction as exothermic OR ● Shows evidence of correctly interpreting the graphs	1

Sample answer
The graphs show that the concentration of the product methanol is greatest at the lowest temperature. This means that an increase in temperature is favouring the reverse reaction. The reverse reaction must be endothermic. Hence the forward reaction, as written in the equation, must be exothermic.

27 (b) (3 marks)
Outcomes Assessed: CH12–4, CH12–7, CH12–12, CH12–15
Targeted Performance Bands: 2-5

Criteria	Marks
● Explains why a moderate temperature is used as a compromise between extent and rate of reaction in an industrial process ● Refers to the graph to support the greater rate of reaction at higher temperature ● Explains this higher rate in terms of the kinetic theory	3
● TWO of the ABOVE	2
● ONE of the ABOVE	1

Sample answer
In this industrial process, as shown by the 3 graphs, the highest temperature produces the smallest yield of methanol. The graphs also show (by the slopes of the graphs before equilibrium is reached), that the rate of reaction is greatest at the highest temperature.

The collision theory explains this greater rate at higher temperatures as at higher temperatures the reacting gas particles have greater kinetic energy and the collisions have a greater probability of being successful.

Hence in this industrial process a compromise, moderate temperature is used so that a viable yield is achieved at a viable rate. Economic viability depends not only on the amount produced but also on the time taken to produce this amount.

27 (c) (4 marks)
Outcomes Assessed: CH12-7, CH12-15
Targeted Performance Bands: 2-5

Criteria	Marks
• Discusses thoroughly the role of a catalyst in the economic viability of an industrial process in terms of maximising the rate of reaction AND in minimising the heat energy input • Includes explanation of how a catalyst changes the reaction rate • Includes explanation which identifies the metal alloy as a surface catalyst	4
• Discusses soundly the role of a catalyst in the economic viability of an industrial process in terms of maximising the rate of reaction AND in minimising the heat energy input • Includes explanation of how a catalyst changes the reaction rate • Includes explanation which identifies the metal alloy as a surface catalyst	3
• Explains how a catalyst changes the reaction rate AND • Explains how use of a catalyst minimises the heat energy input	2
• Includes some correct information about the role of a catalyst	1

Sample answer
Catalysts are chemical substances which, when present in a reaction mixture, increase the rate of reaction by lowering the activation energy for the reaction. The presence of the catalyst allows a different reaction mechanism, with lower energy required for the particles to reach the intermediate state. This means the presence of the catalyst ensures that the reaction can proceed at a lower temperature (hence saving energy) and at a faster rate (as a greater proportion of molecules will have the lower required activation energy for the reaction). The catalyst is not consumed.

In gaseous reactions such as the production of methanol from carbon monoxide and hydrogen, the catalyst is a metal alloy. The reaction occurs on the surface of this catalyst. In the presence of this catalyst, less energy is required to break the bonds in the gaseous molecules to form individual atoms than would be required if the catalyst were not present.

Since the formation of methanol is an exothermic reaction, the yield of methanol would be higher at low temperatures. However, a low temperature would mean a slow rate of reaction, so scientists manage the temperature conditions to keep a moderate, compromise temperature to achieve an optimal yield at an acceptable rate. The rate is enhanced at this moderate temperature by the use of the inert catalytic surface. The use of the catalyst makes the industrial process cost and energy efficient.

Question 28 (8 marks)
28 (a) (3 marks)
Outcomes Assessed: CH12–3, CH12–7, CH12–15
Targeted Performance Bands: 2-5

Criteria	Marks
• Outlines a suitable laboratory procedure to confirm the presence of copper (II) ions by precipitation • Includes observations • Writes an appropriate equation	3
• Outlines a suitable laboratory procedure to confirm the presence of copper (II) ions by precipitation • Includes observations OR • Writes an appropriate equation	2
• Outlines a suitable laboratory procedure to confirm the presence of copper (II) ions by precipitation	1

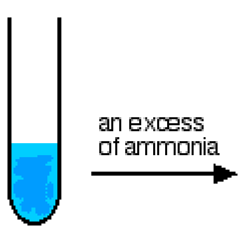
Sample answer
A sample of the water could be filtered to remove any solid impurities.
Sodium hydroxide solution could then be added to the sample.
If a gelatinous blue precipitate forms and a flame test gives a positive result, with a blue-green flame, then copper (II) ions are most likely to be present.

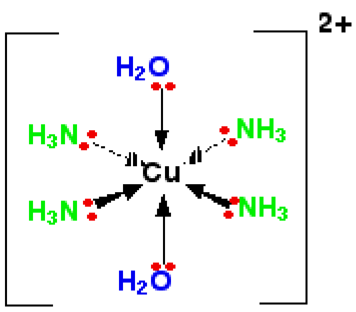
This could be confirmed by the addition of ammonia solution to the mixture containing the precipitate. If the precipitate dissolves and a deep purple/blue solution forms, then copper (II) ions are present. This last step is necessary as several transition metals form blue/green solutions. However, only copper ions form the very deep blue copper tetraammine complex ion.

$Cu^{2+}\,(aq) + 2OH^-\,(aq) \rightarrow Cu(OH)_2\,(s)$ (blue)

$Cu(OH)_2\,(s) + 4NH_3\,(aq) \rightarrow [Cu(NH_3)_4]^{2+}\,(aq) + 2OH^-\,(aq)$

The blue precipitate dissolves in ammonia to produce a solution of purple/blue complex ion, tetraamminediaquacopper (II) ion.





the tetraamminediaquacopper(II) ion

28 (b) (5 marks)
Outcomes Assessed: CH12–3, CH12–7, CH12–15
Targeted Performance Bands: 2-6

Criteria	Marks

● Discusses thoroughly a procedure to determine the concentration of copper (II) ions by use of UV-VIS spectroscopy
● Explains that the absorbance of light at a frequency absorbed by copper (II) ions is proportional to the concentration of the copper (II) ions
● Includes details of
  ● setting up the spectrometer
  ● developing a calibration curve using solutions of known copper (II) concentration
  ● determination of the absorbance of the sample using the calibration curve
	5

● Discusses soundly a procedure to determine the concentration of copper II ions by use of UV-VIS spectroscopy
● Explains that the absorbance of light at a frequency absorbed by copper (II) ions is proportional to the concentration of the copper (II) ions
● Includes some details of
  ● setting up the spectrometer
  ● developing a calibration curve using solutions of known copper (II) concentration
  ● determination of the absorbance of the sample using the calibration curve
	4

● Explains that the absorbance of light at a frequency absorbed by copper (II) ions is proportional to the concentration of the copper (II) ions
● Outlines some aspects of the following
  ● setting up the spectrometer
  ● developing a calibration curve using solutions of known copper (II) concentration
  ● determination of the absorbance of the sample using the calibration curve
	3

● Outlines some aspects of TWO of the following
  ● setting up the spectrometer
  ● developing a calibration curve using solutions of known copper (II) concentration
  ● determination of the absorbance of the sample using the calibration curve
	2

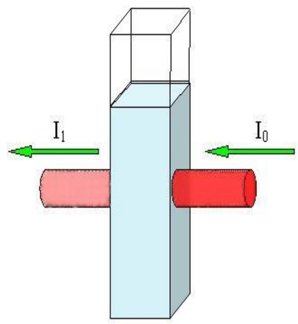
● Outlines some aspect of
  ● setting up the spectrometer
OR
  ● developing a calibration curve using solutions of known copper (II) concentration
OR
  ● determination of the absorbance of the sample using the calibration curve
	1

Sample answer

A spectrophotometer is an instrument that can pass light of a single wavelength through a solution and measure the amount that passes through (is transmitted) and hence the amount of light absorbed (the absorbance).

Copper (II) ions are known to have a maximum absorbance at a particular wavelength of light.

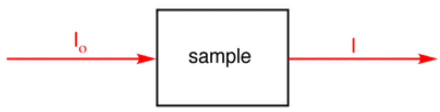
To measure absorbance, a beam of light with intensity I_0 is aimed at the tested solution placed in a cuvette. The intensities of the entering beam (I_0) and the emerging beam (I) are measured, and the absorbance (A) is calculated from the ratio of the two.



$$A = \log\left(\frac{I_o}{I}\right)$$

I_o = intensity of the light entering the sample

I = intensity of the light leaving the sample



The absorbance *(A)* is determined by Beer's Law (given on the data page)

$$A = \varepsilon l c = \log_{10}\frac{I_o}{I}$$

The relationship tells us that the amount of radiation absorbed is:

- proportional to the concentration of the solution being tested (a linear relationship).
- proportional to the pathlength of light through the sample (the greater the distance the light moves through the sample, the greater the energy absorbed).
- a function of the difference in intensities of light entering (I_0) and leaving (I) the sample.

The spectrophotometer must be zeroed by passing light of the appropriate wavelength (600 nm for example) through a blank container (cuvette) containing only the solvent. Then, the same wavelength of light is passed through the solution in the same cuvette. The amount of light at 600 nm that is absorbed by the solution is called the absorbance at 600 nm and is abbreviated A_{600}.

A series of solutions containing known concentrations of copper (II) ions would then be placed in turn in the spectrometer and the absorbance measured.

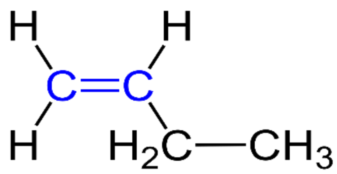
A calibration curve would then be drawn. This would show a straight line, passing through zero. The straight line indicated that the absorbance is proportional to the concentration of copper (II) ions in the standards used for calibration.

The sample would then be tested using the same spectrometer and the absorbance measured. The calibration curve would then be used to determine the concentration of copper (II) ions in the unknown water sample.

Question 29 (8 marks)
29 (a) (3 marks)
Outcomes Assessed: CH12–4, CH12–7, CH12–15
Targeted Performance Bands: 2-5

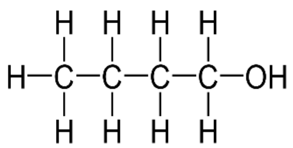
Criteria	Marks
• Identifies ALL of **A**, **B** and **C** by name and structural formula • Explains how the structures of **A**, **B** and **C** were determined	3
• Identifies TWO of **A**, **B** and **C** by name and structural formula • Explains how the structures of TWO of **A**, **B** and **C** were determined	2
• Identifies ONE of **A**, **B** and **C** by name and structural formula • Identifies some correct information about the structures of **A**, **B** or **C**	1

Sample answer
A is but-1-ene.



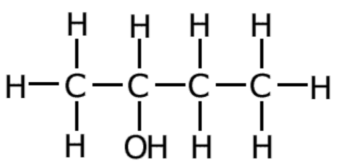
It cannot be but-2-ene as but-2-ene is symmetrical and would only form 1 alcohol on addition of water.

B is butan-1-ol.



Butan-1-ol is a primary alcohol and can be oxidised to form an acid (here **D**).

C is butan-2-ol.



Butan-2-ol can be oxidised to form an alkanone, C_4H_8O

29 (b) (1 mark)
Outcomes Assessed: CH12–7, CH12–15
Targeted Performance Bands: 3-4

Criteria	Mark
● Writes the correct equation for the reaction of **D** with sodium carbonate solution.	1

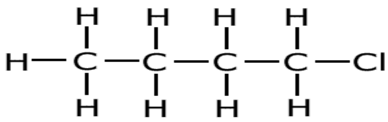
Sample answer
$2CH_3CH_2CH_2COOH\ (aq)\ +\ CO_3^{2-}\ (aq)\ \rightarrow\ CO_2\ (g)\ +\ H_2O\ (l)\ +\ 2CH_3CH_2CH_2COO^-\ (aq)$

29 (c) (2 marks)
Outcomes Assessed: CH12–7, CH12–15
Targeted Performance Bands: 2-4

Criteria	Marks
● Writes the correct equation for the reaction of **B** (butan-1-ol) with HCl AND ● Names the organic product and draws its structure	2
● Writes the correct equation for the reaction of **B** (butan-1-ol) with HCl OR ● Names the organic product and draws its structure	1

Sample answer
$CH_3CH_2CH_2CH_2OH\ (l)\ +\ HCl\ (aq)\ \rightarrow\ CH_3CH_2CH_2CH_2Cl\ (l)\ +\ H_2O\ (l)$

1-chlorobutane is formed.



29 (d) (2 marks)
Outcomes Assessed: CH12–7, CH12–15
Targeted Performance Bands: 2-4

Criteria	Marks
● Names the compound **G** and draws its structure ● Classifies **G** as an amine	2
● Names **G** correctly OR correctly draws its structural formula OR identifies it as an amine.	1

Sample answer
G is butan-1-amine (1-aminobutane).

$CH_3CH_2CH_2CH_2NH_2$

It is classified as an amine (or as an aminoalkane).

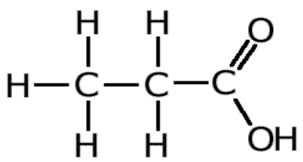
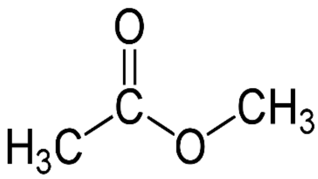
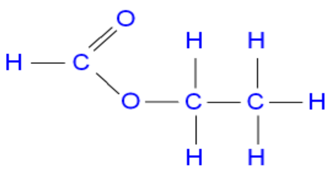
Question 30 (7 marks)
30 (a) (2 marks)
Outcomes Assessed: CH12–5, CH12–7, CH12–15
<u>Targeted Performance Bands: 2-4</u>

Criteria	Marks
• Identifies the base peak AND the molecular ion peak	2
• Identifies the base peak OR the molecular ion peak	1

Sample answer
The base peak is at m/z = 29.
The molecular ion peak is at m/z = 74

30 (b) (2 marks)
Outcomes Assessed: CH12–5, CH12–7, CH12–15
<u>Targeted Performance Bands: 3-5</u>

Criteria	Marks
• Draws structural formulae of 2 isomers of $C_3H_6O_2$ which are members of different homologous series	2
• Draws structural formulae of 2 isomers of $C_3H_6O_2$ which are members of the same homologous series	1

Sample answer


OR


30 (c) (2 marks)
Outcomes Assessed: CH12–5, CH12–7, CH12–15
<u>Targeted Performance Bands: 3-5</u>

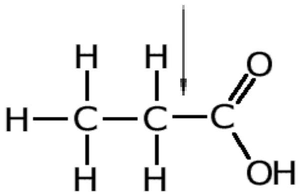
Criteria	Marks
• Identifies 2 molecular fragments which could correspond to the peaks at m/z = 29 and m/z = 45	2
• Identifies 1 molecular fragment which could correspond to the peaks at m/z = 29 OR m/z = 45	1

Sample answer
A $–COOH^+$ fragment would form a base peak at m/z = 45 and a fragment $–C_2H_5^+$ would have a peak at m/z = 29.

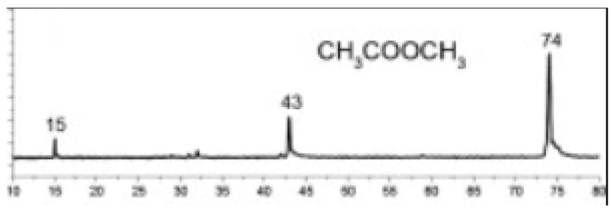
30 (d) (1 mark)
Outcomes Assessed: CH12–5, CH12–7, CH12–15
Targeted Performance Bands: 4-6

Criteria	Mark
• Justifies that the molecule is propanoic acid on the basis of the fragmentation	1

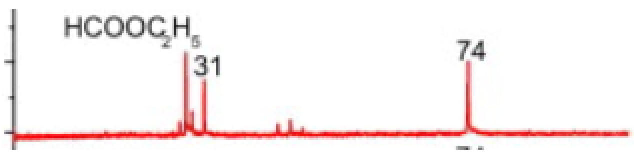
Sample answer
Propanoic acid can fragment as indicated below to form peaks at the m/z values on the graph. If the molecule were an ester, these peaks would not be seen.
The molecule fragments here



(For teachers: fragmentation pattern for the 2 possible esters is below.)



Methyl ethanoate



Ethyl methanoate