Neap

HSC Trial Examination 2020

Chemistry

General Instructions	• Reading time – 5 minutes • Working time – 3 hours • Write using black pen • Draw diagrams using pencil • Calculators approved by NESA may be used • A formulae sheet, data sheet and Periodic Table are provided at the back of this paper • For questions in Section II, show all relevant working in questions involving calculations
Total marks: 100	**Section I – 20 marks** (pages 2–8) • Attempt Questions 1–20 • Allow about 35 minutes for this section **Section II – 80 marks** (pages 9–26) • Attempt Questions 21–32 • Allow about 2 hours and 25 minutes for this section

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2020 HSC Chemistry Examination.

Section I

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

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

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1. A student carried out an investigation into the behaviour of cobalt(II) chloride when it is heated in an open test tube. The following extract is from the rough notes written by the student:

> *1. A few spatulas of hydrated cobalt(II) chloride were put into a test tube. The cobalt(II) chloride was a pink solid.*
>
> *2. The test tube was heated carefully using a Bunsen burner flame. When heated, the cobalt(II) chloride gave off a vapour.*
>
> *3. The solid was allowed to cool. When cooled, the remaining solid was blue.*
>
> *4. Water was added to the solid. The solid became pink, and the test tube became warm.*

Based on the information given, what should the student conclude?

(A) The procedure shows a reversible reaction.
(B) The procedure shows an equilibrium reaction.
(C) Cobalt(II) chloride is an ionic substance.
(D) Cobalt(II) chloride decomposes when heated.

2. Which one of the following correctly identifies the conjugate acid–base pairs present in the equilibrium mixture shown?

(A) $\underset{\text{acid 1}}{CH_3COOH(l)} + \underset{\text{base 1}}{H_2O(l)} \rightleftharpoons \underset{\text{base 2}}{CH_3COO^-(l)} + \underset{\text{acid 2}}{H_3O^+(aq)}$

(B) $\underset{\text{acid 1}}{CH_3COOH(l)} + \underset{\text{base 2}}{H_2O(l)} \rightleftharpoons \underset{\text{base 1}}{CH_3COO^-(l)} + \underset{\text{acid 2}}{H_3O^+(aq)}$

(C) $\underset{\text{base 1}}{CH_3COOH(l)} + \underset{\text{acid 1}}{H_2O(l)} \rightleftharpoons \underset{\text{acid 2}}{CH_3COO^-(l)} + \underset{\text{base 2}}{H_3O^+(aq)}$

(D) $\underset{\text{acid 2}}{CH_3COOH(l)} + \underset{\text{base 2}}{H_2O(l)} \rightleftharpoons \underset{\text{acid 1}}{CH_3COO^-(l)} + \underset{\text{base 1}}{H_3O^+(aq)}$

3. Separate 25.0 mL samples of 0.10 mol L^{-1} ethanoic acid solution and 0.10 mol L^{-1} hydrochloric acid solution are prepared.

Which one of the following statements about the samples is correct?

(A) Both samples will react with 1.00 g of magnesium ribbon at the same rate.
(B) Both samples have the same electrical conductivity.
(C) The concentration of H_3O^+ ions is greater in the ethanoic acid solution.
(D) Both samples will react completely with 25.0 mL of 0.10 mol L^{-1} sodium hydroxide solution.

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4. Which row of the table correctly identifies the links between changes in entropy and enthalpy for combustion reactions and photosynthesis?

	Entropy change		*Enthalpy change*	
	Combustion	*Photosynthesis*	*Combustion*	*Photosynthesis*
(A)	increases	decreases	endothermic	exothermic
(B)	decreases	increases	exothermic	endothermic
(C)	increases	decreases	exothermic	endothermic
(D)	decreases	increases	endothermic	exothermic

5. Half of a 2 mol sample of hydrogen chloride gas dissociates to form hydrogen and chlorine, as shown in the following equilibrium reaction:

$$2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$$

How many moles of gas are present in the equilibrium mixture in total?

(A) 1
(B) 2
(C) 3
(D) 4

6. Which one of the following statements does NOT apply to static equilibrium?

(A) The rates of the forward and reverse reactions are zero.
(B) There is no exchange between reactants and products.
(C) The rate of exchange between reactants and products is steady.
(D) The concentration of reactants and products does not change.

7. The following table shows the colour changes and pH ranges of three indicators:

Indicator	*Colour change (low pH to high pH)*	*pH range*
bromophenol blue	yellow to blue	3.0–4.5
methyl red	red to yellow	4.5–6.3
alizarin	yellow to red	10.2–12.0

The indicators were used to test a liquid. The following table shows the final colours of the liquid:

Indicator	*Final colour*
bromophenol blue	blue
methyl red	yellow
alizarin	yellow

Which one of the following substances was tested?

(A) vinegar (pH 2.1)
(B) rain water (pH 5.2)
(C) distilled water (pH 7.0)
(D) bleach (pH 12.1)

8. Which one of the following statements about buffers is correct?

(A) Buffers can be made from a weak acid and its salt.
(B) Buffers have a pH very close to 7.
(C) Buffers prevent changes in pH when large amounts of acids or bases are added.
(D) Buffers have equal numbers of hydrogen ions and hydroxide ions.

9. In an aqueous solution, an iron(III) ion (Fe^{3+}) reacts with a thiocyanate anion (SCN^{-}) to form the iron(III) thiocyanate ($Fe(SCN)^{2+}$) complex. This is an equilibrium reaction.

What is the correct equilibrium expression for this reaction?

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

(B) $Fe^{3+}(aq) + SCN^{-}(aq) \rightarrow Fe(SCN)^{2+}(aq)$

(C) $\dfrac{Fe(SCN)^{2+}(aq)}{Fe^{3+}(aq) + SCN^{-}(aq)}$

(D) $\dfrac{[Fe(SCN)^{2+}(aq)]}{[Fe^{3+}(aq)] \times [SCN^{-}(aq)]}$

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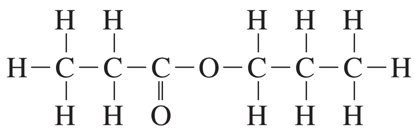
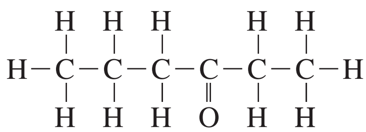
10. 250 mL of 0.1 mol L^{-1} sodium hydroxide is added to 100 mL of 0.4 mol L^{-1} hydrochloric acid.

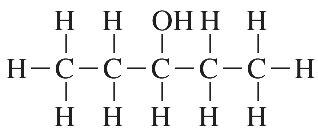
What is the resulting pOH?

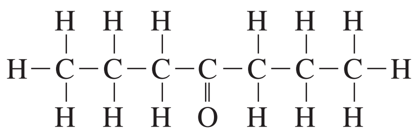
(A) 1.4
(B) 2.3
(C) 11.7
(D) 12.6

11. Which one of the following structural formulae represents hexan-3-one?

(A) 

(B) 

(C) 

(D) 

12. The molar absorptivity for sodium penicillin G at 634 nm is 3.91×10^{3} L mol^{-1} cm^{-1}. A tablet containing penicillin G was dissolved in a 10.0 mL standard flask, and a sample of the resulting solution was placed into a 1.00 cm cuvette. A reading of 0.552 was obtained for its absorbance at 634 nm.

How much sodium penicillin G did the tablet contain?

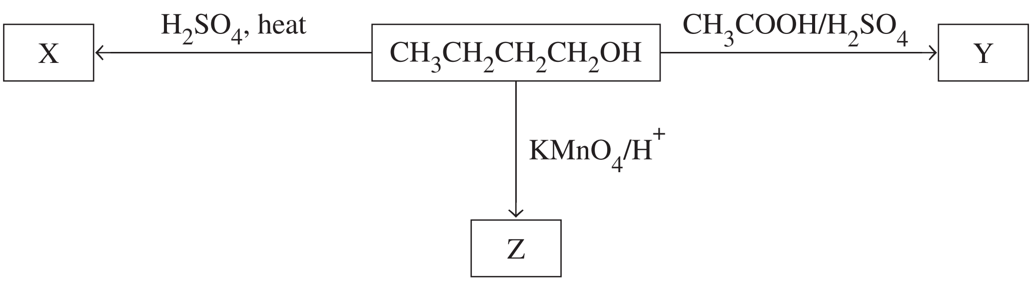
(A) 1.41×10^{-6} mol
(B) 5.63×10^{-3} mol
(C) 8.95×10^{-3} mol
(D) 3.40 mol

13. The molar heat of combustion of $CH_3CH_2CH_2CH_2OH$ is –2670 kJ mol^{-1}.

What is the minimum mass of $CH_3CH_2CH_2CH_2OH$ that, when burnt, would release sufficient heat energy to raise the temperature of 1.000 kg of water from 25.00°C to 100.0°C? Assume no loss of heat to the surroundings.

(A) 0.176 g
(B) 8.70 g
(C) 74.1 g
(D) 470 g

14. Consider the reaction sequence below.



Which row of the table correctly identifies X, Y and Z?

	X	*Y*	*Z*
(A)	but-1-ene	(1-butyl) ethanoate	butanoic acid
(B)	butane	hexanoic acid	butan-1-ol
(C)	but-2-ene	ethyl butanoate	butanoate
(D)	cyclobutane	butyl acetate	butanal

15. The most appropriate technique to determine levels of the Pb^{2+} ion in blood is

(A) mass spectrometry.
(B) infrared spectroscopy.
(C) atomic absorption spectroscopy.
(D) ultraviolet-visible spectroscopy.

16. It is suspected that a stream is contaminated with metal ions. A sample of water from the stream was analysed. The results are recorded in the table.

Test	*Reaction*
adding dilute HCl solution	There is no visible reaction.
adding Na_2SO_4 solution	A white precipitate forms.
flame test	The flame turns pale orange/red.

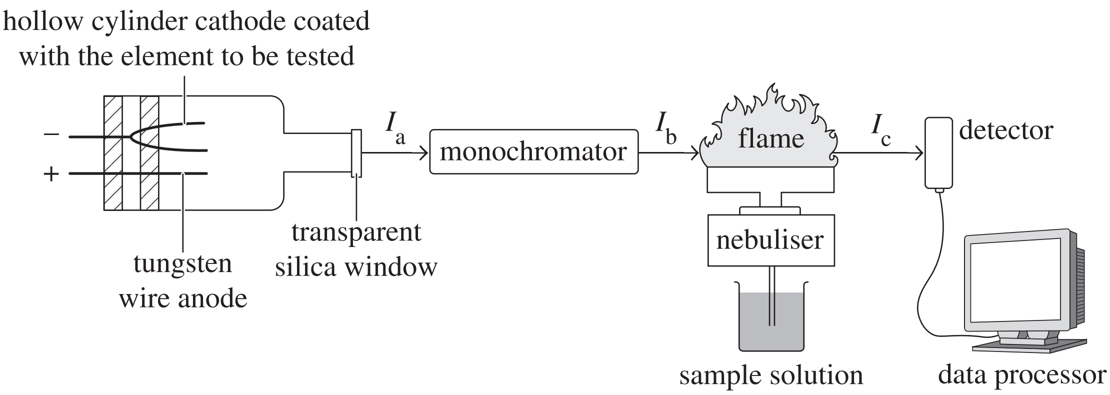
What is the most likely contaminant in the water?

(A) Ba^{2+}
(B) Ca^{2+}
(C) Cu^{2+}
(D) Fe^{2+}

17. The compound with the formula $(CH_3)_3COH$ is a

(A) primary alcohol.
(B) secondary alcohol.
(C) tertiary alcohol.
(D) quaternary alcohol.

18. The following diagram of an atomic absorption spectrophotometer (AAS) shows the intensity of light at various points within the spectrometer.



The absorbance of the sample solution is given by the relationship

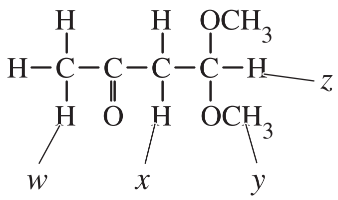
(A) $\frac{I_a}{I_b}$

(B) $\frac{I_b}{I_c}$

(C) $\log\frac{I_b}{I_c}$

(D) $\log\frac{I_a}{I_c}$

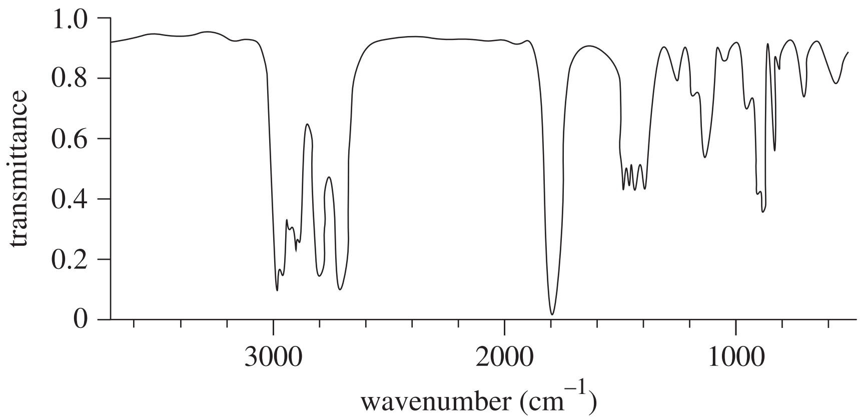
19. Consider the following molecule.



Which one of the labelled hydrogens gives a triplet signal in a ^{1}H NMR spectrum?

(A) hydrogen *w*
(B) hydrogen *x*
(C) hydrogen *y*
(D) hydrogen *z*

20. The infrared spectrum of an unknown sample is shown below.



What is the unknown sample most likely to be?

(A) butanal
(B) butanoic acid
(C) hex-3-ene
(D) propanol

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Section II

80 marks
Attempt Questions 21–32
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.

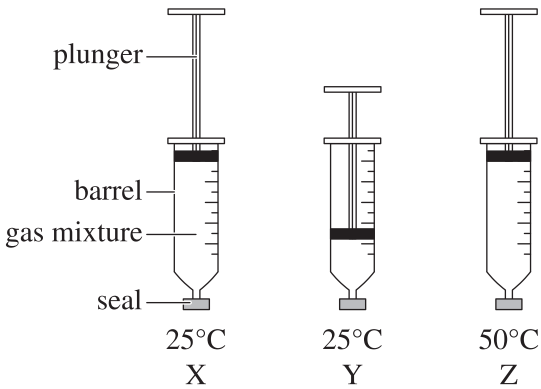
Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Question 21 (6 marks)

Nitrogen dioxide is brown and dinitrogen tetroxide is colourless. They form an equilibrium mixture as shown by the following equation: **6**

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -58 \text{ kJ mol}^{-1}$$

A sealed gas syringe can be used to investigate the properties of a fixed mass of gas. An equimolar mixture of nitrogen oxide and dinitrogen tetroxide was set up as shown in X in the following diagram. The conditions were then varied as shown in Y and Z.



Complete the table by describing the colour of the gas mixtures in X, Y and Z. Include any comparisons to the initial colour of X and justify your answers.

	Colour	*Justification*
X		
Y		
Z		

Question 22 (7 marks)

Bromomethane, CH_3Br, is manufactured by reacting methanol with hydrogen bromide according to the following equilibrium equation:

$$CH_3OH(g) + HBr(g) \rightleftharpoons CH_3Br(g) + H_2O(g)$$

It is a toxic, odourless and colourless gas used as an insecticide.

(a) Predict what would happen to the rate of production of bromomethane (the rate of the forward reaction) if the water was continuously removed. Explain your answer. **2**

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(b) Predict what would happen to the rate of production of bromomethane if the temperature was increased at constant pressure. Justify your answer. **2**

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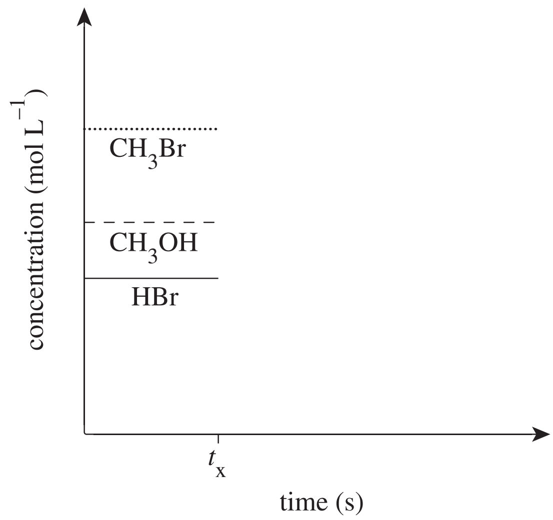
(c) The following graph shows the equilibrium concentrations of three of the compounds involved in the reaction at 298 K. A small amount of methanol was added at time t_x. **3**



Sketch the concentrations of the three compounds after time t_x.

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Question 23 (7 marks)

A student was researching calcium sulfate ($CaSO_4$) and calcium carbonate ($CaCO_3$). Their first step was to look at the solubility constants (K_{sp}) and equilibrium expressions for the two compounds.

(a) Discuss the solubilities of these two compounds at 25°C. **2**

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(b) Derive the equilibrium expression for calcium sulfate and use this to calculate the solubility (in mol L^{-1}) for calcium sulfate. Show your working. **2**

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(c) Outline ONE practice of Aboriginal and Torres Strait Islander Peoples that uses solubility equilibria. **3**

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Question 24 (7 marks)

Neutralisations are common chemical reactions and can be useful in many situations.

(a) A student spilt some hydrochloric acid solution (HCl) and was told to sprinkle powdered sodium carbonate (Na_2CO_3) on the spillage. **1**

Write a balanced equation for the reaction.

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(b) As part of the Chemistry course, you have carried out a practical investigation to measure the enthalpy of neutralisation.

(i) What is meant by the term 'enthalpy of neutralisation'? **1**

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(ii) Describe how you carried out this investigation. **5**

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Question 25 (4 marks)

(a) Outline the principles of the Arrhenius model for classifying acids and bases. Support your answer with at least TWO chemical equations. **3**

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(b) Sodium hydrogen carbonate (bicarbonate) forms the hydrogen carbonate ion in aqueous solution. Consider the following reactions of this ion: **1**

$$HCO_3^-(aq) + NH_4^+(aq) \rightleftharpoons H_2CO_3(aq) + NH_3(aq)$$

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CO_3^{2-}(aq)$$

Identify the behaviour shown by this species.

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Question 26 (9 marks)

The concentration of a sample of nitric acid was determined using 1.01 mol L^{-1} ammonia solution. A 25.0 mL aliquot (portion) of the ammonia solution was added to a conical flask and a few drops of methyl orange were added. The mixture was shaken, giving a pale yellow colour. The end points of four titrations are shown in the table.

Titration number	*Volume of HNO_3 (mL)*
1	37.8
2	36.1
3	36.2
4	36.0

(a) 'Equivalence point' and 'end point' are terms often used regarding titrations. **3**

Using the titrations described above, explain the difference between the two terms.

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(b) Write a balanced equation for the reaction. **1**

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Question 26 continues on page 15

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Question 26 (continued)

(c) Calculate the concentration of the acid. Show your working and explain how you came to a value for the end point. **3**

(d) Using the axes provided, sketch the shape of the expected titration curve for this titration. Label the axes appropriately. **2**

End of Question 26

Question 27 (4 marks)

Explain how the surfactant properties of the sodium salts of long chain fatty acids help to clean grease from dirty dishes. Draw a diagram of a micelle to support your answer. **4**

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Question 28 (4 marks)

Propene can be polymerised in different ways to produce different polymers. Heating propene to a high temperature under high pressure produces polymer A. Using a Zieglar–Natta catalyst, a lower temperature and lower pressure produces polymer B.

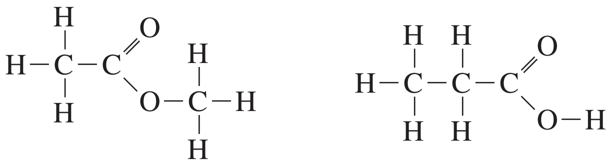
(a) Draw a structural diagram of polypropene. **1**

(b) Complete the table by identifying polymer A and polymer B, and listing TWO of properties of each. **3**

	Polymer A	*Polymer B*
Name		
Properties		

Question 29 (9 marks)

The diagram shows the structural formulae of two compounds.



methyl ethanoate propanoic acid

(a) Why are these two compounds classed as functional group isomers? **2**

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(b) A student designed a procedure to distinguish between methyl ethanoate and propanoic acid. A small sample of methyl ethanoate was placed into a test tube and dissolved in water. In a separate test tube, a similar sized sample of propanoic acid was dissolved in a similar volume of water. A small volume of $NaHCO_3$ solution was added to each test tube. **3**

Describe the expected observations for each test tube. Include relevant net ionic equations.

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Question 29 continues on page 19

Question 29 (continued)

(c) The table lists the boiling points of some straight chain alkanoic acids and their isomeric straight chain methyl esters. **4**

Alkanoic acid	*Boiling point (°C)*	*Methyl ester*	*Boiling point (°C)*	*Difference between boiling points (°C)*
$CH_3(CH_2)_3CO_2H$	186	$CH_3(CH_2)_2CO_2CH_3$	102	186 – 102 = 84
$CH_3(CH_2)_4CO_2H$	205	$CH_3(CH_2)_3CO_2CH_3$	126	205 – 126 = 79
$CH_3(CH_2)_5CO_2H$	223	$CH_3(CH_2)_4CO_2CH_3$	150	223 – 150 = 73
$CH_3(CH_2)_6CO_2H$	239	$CH_3(CH_2)_5CO_2CH_3$	174	239 – 174 = 65
$CH_3(CH_2)_7CO_2H$	253	$CH_3(CH_2)_6CO_2CH_3$	194	253 – 194 = 59

Explain the patterns of boiling points shown in the table.

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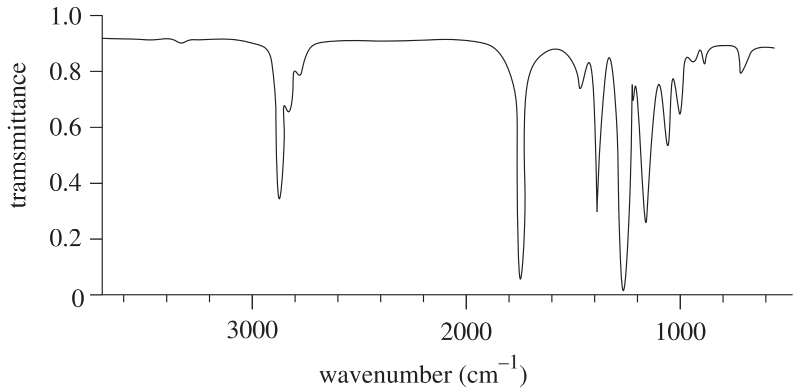
End of Question 29

Question 30 (8 marks)

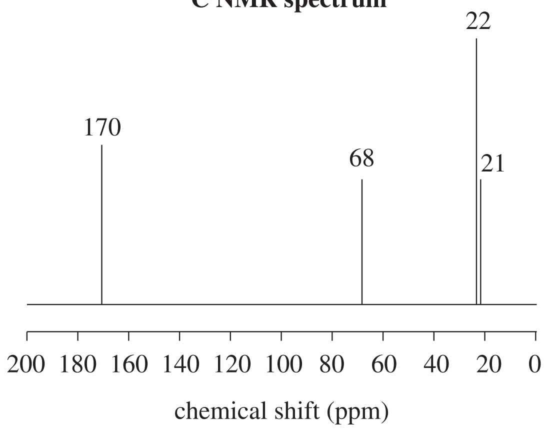
A chemist finds an unlabelled bottle containing a large quantity of compound Y, a colourless liquid. Elemental analysis gives a molecular formula of $C_5H_{10}O_2$. Compound Y does not decolourise bromine water, nor does it produce CO_2 when added to $NaHCO_3$ solution.

To identify the molecular structure of compound Y, a sample is submitted for spectroscopic analysis. The following data were obtained.

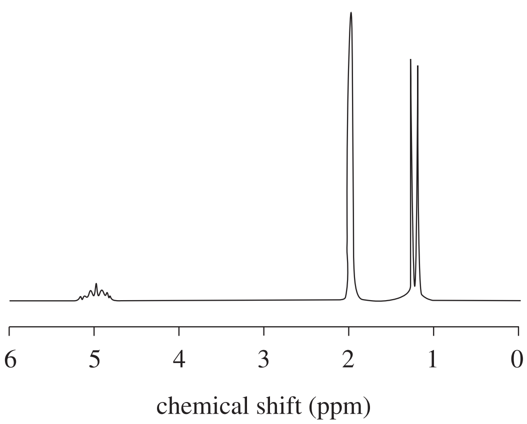
Infrared spectrum



^{13}C NMR spectrum



^{1}H NMR spectrum



^{1}H NMR data		
Chemical shift (ppm)	*Relative peak area*	*Peak splitting*
1.2	6	doublet (2)
2.0	3	singlet (1)
5.0	1	septet (7)

Question 30 continues on page 21

Question 30 (continued)

(a) Draw the structural formula of compound Y. Justify your answer with reference to all THREE of the provided spectra. **6**

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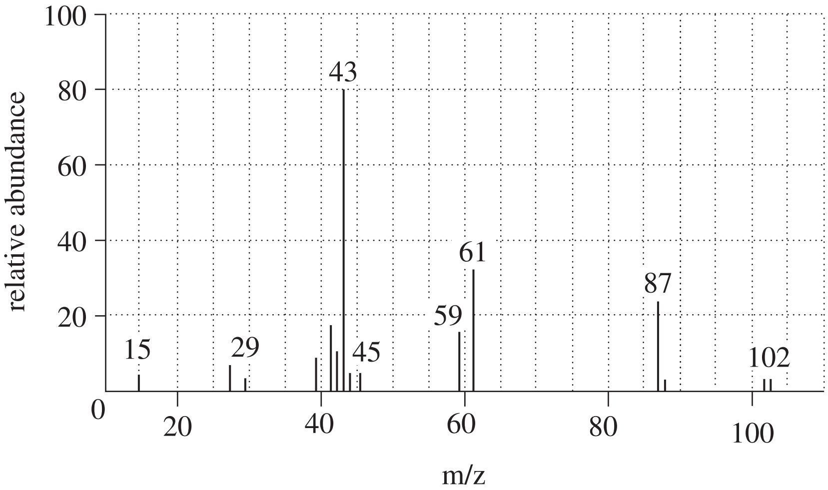
Question 30 continues on page 22

Question 30 (continued)

(b) The diagram shows the mass spectrum of compound Y. **2**



Explain how the molecular ion and mass spectrum splitting pattern can assist with determining the identity of the compound.

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End of Question 30

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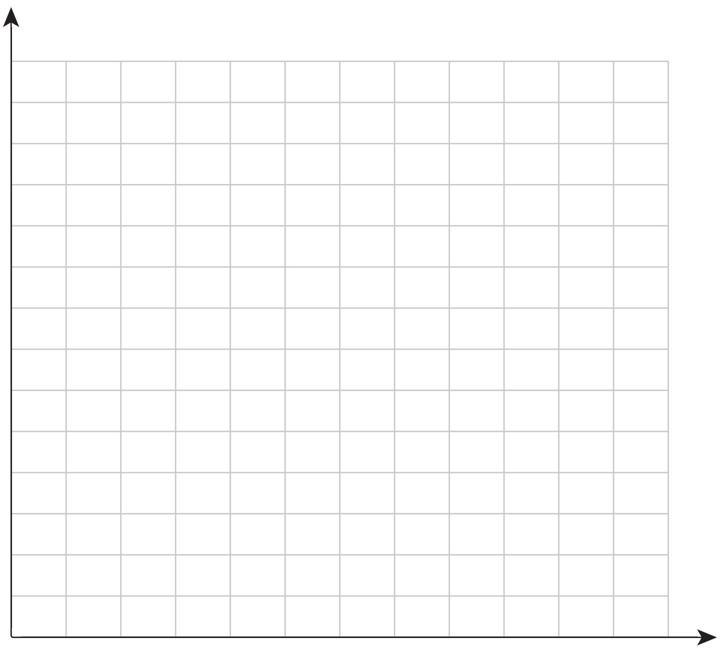
Question 31 (8 marks)

Brass is an alloy of copper and zinc.

To determine the percentage of copper in a particular sample of brass, an analyst prepared a number of standard solutions of copper(II) ions and measured their absorbance using an atomic absorption spectrometer (AAS). The results are given in the table.

Cu^{2+} concentration ($mg\ L^{-1}$)	*Absorbance*
0	0
50.00	0.060
100.0	0.120
200.0	0.240
300.0	0.360
400.0	0.480
500.0	0.600

(a) Draw and label the absorbance versus concentration calibration curve for Cu^{2+}. **3**



Question 31 continues on page 24

Question 31 (continued)

A 19.8 mg sample of the brass was dissolved in acid, and the solution was made up to 100 mL in a volumetric flask. The absorbance of this test solution was found to be 0.150.

(b) Calculate the percentage by mass of copper in the brass sample. **3**

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(c) When using AAS techniques, the presence of Zn^{2+} in the sample does not affect the measurement of Cu^{2+} in the sample. **2**

Explain this observation.

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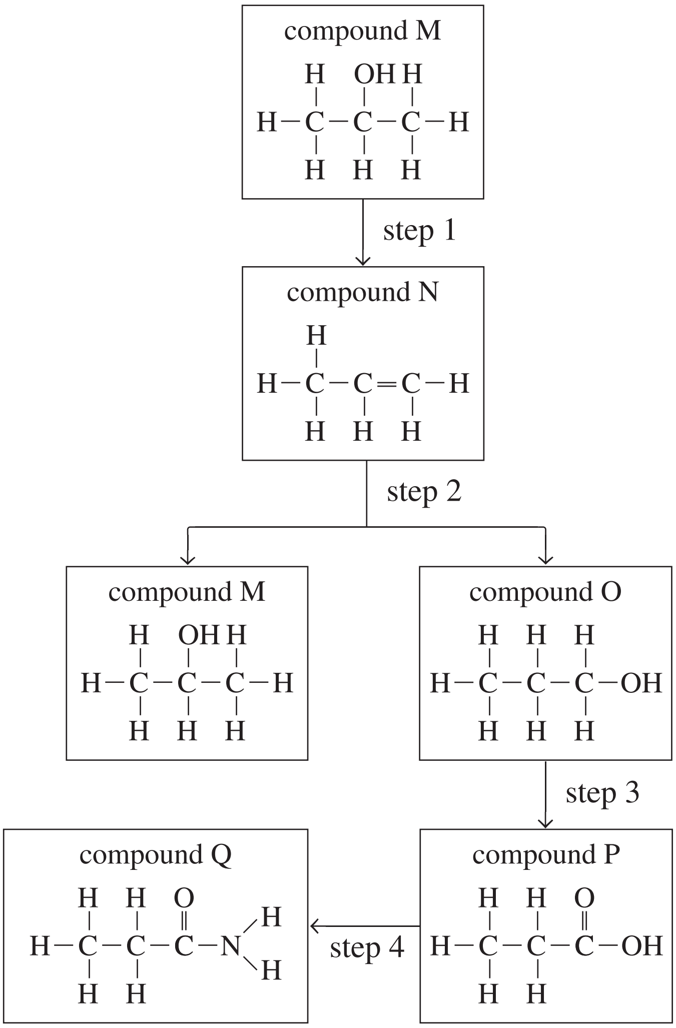
End of Question 31

Question 32 (7 marks)

The diagram shows a reaction scheme that can be used to synthesise propanamide. **7**



Identify the reagents and conditions needed to achieve each step of this synthetic scheme and explain how NMR and mass spectroscopic techniques could be used to identify the isomeric compounds M and O.

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End of paper

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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.

FORMULAE SHEET

$n = \frac{m}{MM}$ $\qquad$ $c = \frac{n}{V}$ $\qquad$ $PV = nRT$

$q = mc\Delta T$ $\qquad$ $\Delta G° = \Delta H° - T\Delta S°$ $\qquad$ $\text{pH} = -\log_{10}[\text{H}^+]$

$pK_a = -\log_{10}[K_a]$ $\qquad$ $A = \varepsilon lc = \log_{10}\frac{I_o}{I}$

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

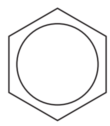
Solubility constants at 25°C

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}

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	112
C—C	135
C═C	162

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

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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

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

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 **Nh** Nehonium	114 **Fl** Flerovium	115 **Mc** Moscovium	116 **Lv** Livermorium	117 **Ts** Tennessine	118 **Og** Oganesson

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 (November 2016 version). The International Union of Pure and Applied Chemistry Periodic Table of the Elements (Febuary 2010 version) is the principal source of all other data. Some data may have been modified.

Neap

HSC Trial Examination 2020

Chemistry

Solutions and marking guidelines

Section I

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 1 **A** The procedure shows a reversible reaction, as loss of water can be reversed. It is not an equilibrium reaction because it is an open system, so **B** is incorrect. There is no information given about bonding, so **C** is incorrect. As there is no decomposition occurring, **D** is also incorrect.	Mod 5 Static and Dynamic Equilibrium CH12–5, CH12–12 Bands 2–3
Question 2 **B** Conjugate acid–base pairs only differ by a proton (H^+). In the reaction going left to right: CH_3COOH (ethanoic acid) has donated a proton to H_2O (water), so ethanoic acid is an acid and water is a base. In the reaction going right to left: H_3O^+ (the hydronium ion) is an acid because it has donated a proton to CH_3COO^- (the ethanoate ion). CH_3COOH and CH_3COO^- are a conjugate acid–base pair, acid 1 and base 1 respectively. The other conjugate acid–base pair is H_3O^+/H_2O, acid 2 and base 2 respectively.	Mod 6 Using Brønsted–Lowry Theory CH12–6, CH12–12 Bands 3–4
Question 3 **D** Ethanoic acid is a weak acid, and hydrochloric acid is a strong acid. Hydrochloric acid is more dissociated than ethanoic acid; hence, it will have a greater concentration of H_3O^+ ions, so **C** is incorrect. Because of this, hydrochloric acid will react faster with magnesium ribbon and will also have a higher conductivity; **A** and **B** are incorrect. Each solution has the same number of moles of acid needed for neutralisation: $\frac{25}{1000} \times 0.1$	Mod 6 Using Brønsted–Lowry Theory CH12–5, CH12–12 Bands 3–4
Question 4 **C** Entropy can be thought of as randomness or disorder. In combustion reactions, a system becomes more disordered; hence, entropy increases. In photosynthesis, a system becomes more ordered; hence, entropy decreases. Enthalpy is the heat content of a system. If a system loses/gives out heat, it is described as exothermic. If a system gains/takes in heat, it is endothermic. Combustion causes an increase in entropy and is exothermic. Photosynthesis causes a decrease in entropy and is endothermic.	Mod 5 Static and Dynamic Equilibrium CH12–12 Bands 3–4
Question 5 **B** The ratios in the equation mean that 0.5 mol of hydrogen and 0.5 mol of chlorine will be formed, and 1 mol of hydrogen chloride will remain. Therefore, 2 moles of gas are present in the equilibrium mixture in total.	Mod 5 Calculating the Equilibrium Constant CH12–12 Bands 3–4
Question 6 **C** The statement 'the rate of exchange between reactants and products is steady' only applies to dynamic equilibrium reactions.	Mod 5 Static and Dynamic Equilibrium CH12–12 Band 3
Question 7 **C** As the bromophenol blue turned blue, the pH is 4.5 or higher. Methyl red turned yellow, so the pH is 6.3 or higher. The alizarin is yellow, so the pH is 10.2 or lower. Distilled water is the only option with a pH between 6.3 and 10.2.	Mod 6 Properties of Acids and Bases CH12–6, CH12–13 Band 4

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 8 **A** Buffers can be made from a weak acid and its salt or a weak base and its salt. Buffer solutions are not necessarily neutral; they can be formulated to a wide variety of pHs. Buffer solutions resist changes in pH when small amounts of acids (H^+) or bases (OH^-) are added.	Mod 6 Quantitative Analysis CH12–13 Band 3
Question 9 **D** The equilibrium expression is a mathematical ratio that shows the concentrations (in moles per litre) of the products over the reactants at equilibrium, all raised to their stoichiometric powers. The balanced equation described in the question is $Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons Fe(SCN)^{2+}(aq)$. The resulting equilibrium constant is $\frac{[Fe(SCN)^{2+}(aq)]}{[Fe^{3+}(aq)] \times [SCN^-(aq)]}$.	Mod 5 Calculating the Equilibrium Constant CH12–16, CH12–12 Bands 3–4
Question 10 **D** $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$ mol of OH^- added: $\frac{250}{1000} \times 0.1 = 0.025$ mol of H^+ added: $\frac{100}{1000} \times 0.4 = 0.04$ Hence, there is 0.040 – 0.025 = 0.015 mol of H^+ in excess. There is 350 mL of solution in total. molarity: $\frac{0.015}{350} \times 1000 = 0.043$ $pH = -\log_{10}[0.43]$ $= 1.4$ pOH = 14 – 1.4 = 12.6	Mod 6 Using Brønsted–Lowry Theory CH12–6, CH12–13 Band 6
Question 11 **B** Hexan-3-one contains six carbons and a carbonyl group (C=O) on the third carbon from the end, as in **B**. The structural formula in **C** represents pentan-3-ol. The structural formula in **A** represents 1-propyl propanoate. The structural formula in **D** represents heptan-4-one.	Mod 7 Nomenclature CH12–7, CH12–14 Bands 2–3

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 12 **A** The Beer–Lambert law relates absorbance and concentration: $A = \varepsilon l c$ $c = \frac{A}{\varepsilon l}$ $= \frac{0.552}{(3.91 \times 10^3 \times 1)}$ $= 1.41 \times 10^{-4}$ mol L^{-1} The tablet was dissolved into 10.0 mL, so there was $1.41 \times 10^{-4} \times 0.0100 = 1.41 \times 10^{-6}$ mol of sodium penicillin G in the tablet.	Mod 8 Analysis of Inorganic Substances CH12–17 Band 3
Question 13 **B** $CH_3CH_2CH_2CH_2OH$ is butan-1-ol. molar mass of butan-1-ol: $4 \times 12.01 + 10 \times 1.008 + 16.00 = 74.12$ $\Delta T = 100.0 - 25.00 = 75.0°C$ $q_{\text{water}} = mC\Delta T$ $= 1.00 \times 4.18 \times 10^3 \times (75.0)$ $= 313\ 500$ J $n_{\text{butan-1-ol}} = -\frac{q}{\Delta H}$ $= \frac{-313\ 500 \text{ J}}{-2670 \times 10^3 \text{ J mol}^{-1}}$ $= 0.1174$ mol mass of butan-1-ol = 0.1174×74.12 $= 8.70$ g	Mod 7 Alcohols CH12–5, CH12–4 Bands 5–6
Question 14 **A** $CH_3CH_2CH_2CH_2OH$ is butan-1-ol. Acid-catalysed dehydration of butan-1-ol yields but-1-ene, X. Esterification of butan-1-ol with acetic acid yields the ester (1-butyl) ethanoate (also named butyl acetate), Y. Oxidation of primary alcohols with acidified permanganate yields acids, so Z is butanoic acid.	Mod 7 Reactions of Organic Acids and Bases CH12–5, 6, 7, 14 Bands 5–6
Question 15 **C** Atomic absorption spectroscopy allows the analysis of many metal ions in complex mixtures with minimal interference from other metal ions or organic compounds.	Mod 8 Analysis of Inorganic Substances CH12–4, 5, 6, 7, 14 Band 4
Question 16 **B** A precipitate with sulfate ion is likely for calcium or barium ions. Barium gives a green flame, and calcium gives an orange/red flame.	Mod 8 Analysis of Inorganic Substances CH12–3, CH12–5, CH12–6 Band 3

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 17 **C** Tertiary alcohols are alcohols in which the OH functional group is attached to a carbon that is directly attached to three other carbon atoms.	Mod 7 Alcohols CH12–5, CH12–15 Bands 2–3
Question 18 **C** $A = \log \frac{I_o}{I}$ where I_o is the intensity of the incident radiation at the measured wavelength (I_b in the diagram) and I is the intensity of the transmitted radiation through the flame (I_c in the diagram).	Mod 7 Polymers CH12–6, CH12–15 Bands 3–4
Question 19 **D** The number of peaks in a signal equals $n + 1$ where n is the number of hydrogens on adjacent carbons. Protons for z (CH_2–**CH**–$(OCH_3)_2$) have two hydrogens on the adjacent carbon and will appear as a triplet. **D** is correct. Protons for w (**CH_3**–C=O) have no hydrogens on the adjacent carbons and will appear as a singlet. **A** is incorrect. Protons for x (O=C–**CH_2**–CH) have a single hydrogen on the adjacent carbons and will appear as a doublet. **B** is incorrect. Protons for y (**CH_3**–O) have no hydrogens on adjacent carbons and will appear as a singlet. **C** is incorrect.	Mod 8 Analysis of Organic Substances CH12–4, CH12–7, CH12–15 Bands 3–4
Question 20 **A** The strong peak at 1780 indicates the presence of a carbonyl group; hence, the unknown sample is most likely either butanoic acid or butanal. The lack of a broad OH absorbance between 3200–3500 cm^{-1} rules out butanoic acid, leaving butanal as the only option that would fit this IR spectrum.	Mod 8 Analysis of Organic Substances CH12–6, CH12–15 Bands 4–5

Section II

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide

Question 21

	Colour	*Justification*
X	light brown	A mixture of colourless N_2O_4 and brown NO_2 gives a light brown equilibrium mixture.
Y	lighter brown (lighter than *X*)	The system has shifted to the right (fewer gas molecules), decreasing the amount of brown NO_2 in the resulting equilibrium mixture (Le Châtelier's principle).
Z	brown (darker than *X*)	The forward reaction is exothermic. Increasing temperature shifts the reaction to the left, increasing the amount of brown NO_2 in the resulting equilibrium mixture.

Mod 5 Factors that Affect Equilibrium
CH12–5, CH12–6, CH12–12 Band 5

- Correctly completes all SIX cells of the table 6
- Correctly completes FIVE cells of the table 5
- Correctly completes FOUR cells of the table 4
- Correctly completes THREE cells of the table. 3
- Correctly completes TWO cells of the table 2
- Correctly completes ONE cell of the table 1

Question 22

(a) The rate of production of bromomethane would increase. The system would compensate for the removal of product by increasing the forward reaction (production of CH_3Br), as in Le Châtelier's principle.

Mod 5 Factors that Affect Equilibrium
CH12–6, CH12–12 Bands 3 – 4

- Gives the correct prediction.

AND

- Gives a suitable justification. 2

- Gives the correct prediction 1

(b) The rate of production of bromomethane would increase. Collision theory tells us that increasing the temperature increases the average kinetic energy of reactant molecules. This results in more collisions that have energy greater than the activation energy needed, so the proportion of collisions that are successful increases.

Mod 5 Static and Dynamic Equilibrium
Mod 5 Factors that Affect Equilibrium
CH12–12 Bands 3 – 4

- Gives the correct prediction.

AND

- Gives a suitable explanation using collision theory 2

- Gives the correct prediction 1

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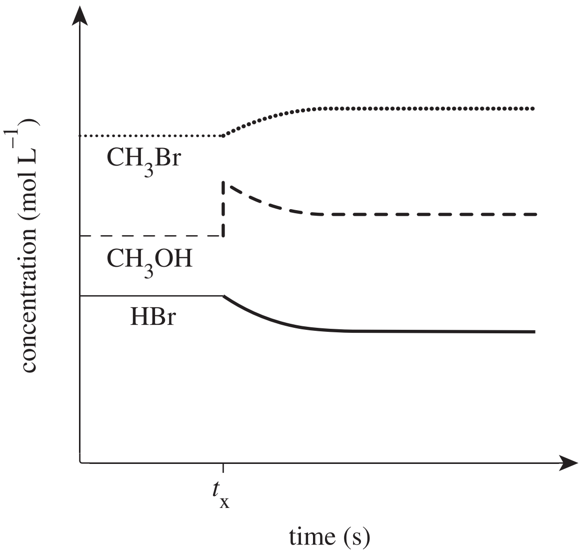
Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(c)  *Note: All three lines should level out at the same time, and the three concentration changes should be the same. The CH_3Br line should rise gradually and level out. The CH_3OH line should rise sharply vertically, fall gradually, then level out higher than its original concentration. The HBr line should fall gradually and level out.*	Mod 5 Factors that Affect Equilibrium CH12–6, CH12–12 Bands 4–5 • Correctly shows changes over time for all THREE species . . . . 3 • Correctly shows changes over time for TWO species . . . . 2 • Correctly shows changes over time for ONE species. 1
Question 23	
(a) The two compounds are relatively insoluble (low solubility constants). The solubility constant for calcium sulfate is related to its molar solubility by the following equation: $K_{sp} = [Ca^{2+}][SO_4^{\ 2-}]$ $= 4.93 \times 10^{-5}$ The solubility constant for calcium carbonate is related to its molar solubility by the following equation: $K_{sp} = [Ca^{2+}][SO_4^{\ 2-}]$ $= 3.39 \times 10^{-9}$ It therefore follows that calcium sulfate is more soluble because it has a higher solubility constant than calcium carbonate.	Mod 5 Calculating the Equilibrium Constant CH12–5, CH12–12 Band 3 • Discusses the solubilities of each compound. AND • Links the discussion to the solubility constant . . . . 2 • Gives details of solubilities 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(b) $CaSO_4(s) \underset{}{\overset{H_2O}{\rightleftharpoons}} Ca^{2+}(aq) + SO_4^{2-}(aq)$ $K_{sp} = [Ca^{2+}][SO_4^{2-}]$ $= 4.93 \times 10^{-5}$ $\sqrt{K_{sp}} = \sqrt{4.93 \times 10^{-5}}$ $= 7.02 \times 10^{-3}$ mol L^{-1}	Mod 5 Calculating the Equilibrium Constant CH12–6, CH12–12 Bands 4–5 • Derives correct equilibrium expression. AND • Calculates solubility . . . . 2 • Derives correct equilibrium expression . . 1
(c) Some Aboriginal and Torres Strait Islander groups in northern Australia use the seeds of cycad plants as a food source. These seeds contain toxins and are poisonous if eaten untreated. The solubility of these toxins in water is much greater than the solubility of the nutriments in the cycad seeds. Prolonged soaking of the cycad seeds in water leaches (removes) the toxins. This process depends upon the toxins being more soluble than the non-toxic nutriments.	Mod 5 Solution Equilibria CH12–3, CH12–12 Band 4 • Gives an appropriate example. AND • Gives an outline with at least THREE relevant points. . . . . 3 • Gives an appropriate example. AND • Gives an outline with at least TWO relevant points . . . . 2 • Gives an outline with some relevant information 1
Question 24	
(a) $Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$	Mod 6 Properties of Acids and Bases CH12–3, CH12–12 Band 5 • Gives correct balanced equation with states 1
(b) (i) The enthalpy of neutralisation is the enthalpy change (ΔH_n) that occurs when an acid and a base undergo a neutralisation reaction to form water and a salt. Values are usually given per mole of water formed.	Mod 6 Properties of Acids and Bases CH12–13 Band 3 • Gives an appropriate definition 1

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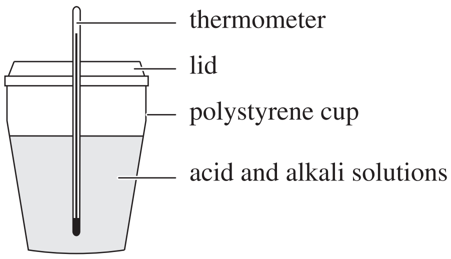
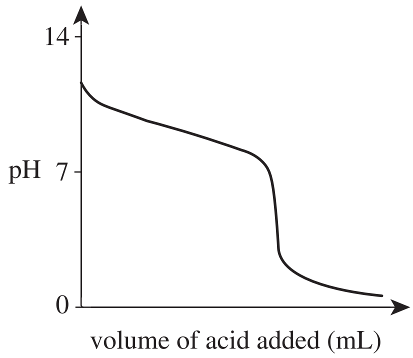
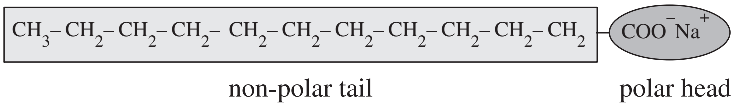
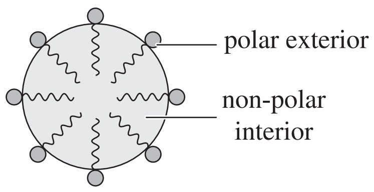
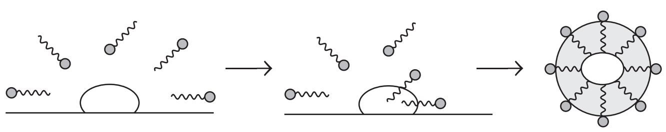
Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(ii) Select appropriate acid and alkali solutions – for example, hydrochloric acid and sodium hydroxide. $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$ There is a 1 : 1 mol ratio. Measure the initial temperature of these solutions. In this example, there is 50 mL of 1.0 mol L^{-1} hydrochloric acid solution and 50 mL of 1.0 mol L^{-1} sodium hydroxide solution. Place the solutions in a calorimeter, such as a polystyrene cup with a lid, and measure the increase in temperature.  Calculate the enthalpy change involved in this reaction using the equation $\Delta H = mCp\Delta T$, where ΔH is the enthalpy change (in J), m is the mass of the mixture (in kg), Cp is the specific heat of the mixture (in J kg^{-1}) and ΔT is the temperature change (in K). Then calculate the enthalpy of neutralisation per mol for the reaction between hydrochloric acid and sodium hydroxide. *Note: Responses do not require a diagram.*	Mod 6 Properties of Acids and Bases CH12–3, CH12–7, CH12–13 Band 6 • Gives a clear description in the correct sequence. AND • Includes the materials used. AND • States equation/calculations . . . . 5 • Gives a clear description in the correct sequence. AND • Includes the materials used. AND • Outlines equation/calculations . . . . 4 • Gives a clear description in the correct sequence. AND • Includes the materials used OR outlines equation/calculations . . . . 3 • Gives a clear description in the correct sequence. . . . . 2 • Gives a description with some details . . . 1
Question 25	
(a) To account for the characteristic properties of acids and bases, Arrhenius suggested that all aqueous solutions of acids contain an excess of H^+ ions and all aqueous solutions of bases (alkalis) contain an excess of hydroxide (hydroxyl) OH^- ions. His proposals were: • Acidic properties are those associated with the H^+ ion. • Basic properties are those associated with the OH^- ion. • H^+ and OH^- ions are formed when an acid or base ionises as it dissolves in water. For nitric acid and sodium hydroxide: $HNO_3(l) \rightarrow H^+(aq) + NO_3^-(aq)$ $NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$ *Note: We now know that the H^+ ion (a proton) cannot exist by itself in aqueous solution, but is always combined with a molecule of water to form the hydronium (H_3O^+) ion.*	Mod 6 Properties of Acids and Bases CH12–13 Bands 4–5 • Gives the principles of the Arrhenius model. AND • Gives TWO appropriate equations . . . . . 3 • Gives the principles of the Arrhenius model. AND • Gives ONE appropriate equation. . . . . . . 2 • Gives the principles of the Arrhenius model. 1
(b) amphiprotic	Mod 6 Using Brønsted–Lowry Theory CH12–13 Band 3 • Gives the appropriate term. 1

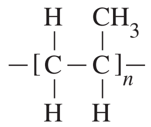
Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 26	
(a) The 'equivalence point' occurs when the reaction has reached a specific stoichiometric ratio of reactants. In acids and bases the equivalence point is reached when the number of H^+ ions equals the number of OH^- ions (equal mole ratio). The 'end point' is when a physical change can be detected. In this case, it is when the indicator changes colour. The end point is not necessarily exactly the same as the equivalence point. In this case, the end point (colour change) for titration 1 does not match with the end points for the other titrations, suggesting that the end point for titration 1 does not occur at the equivalence point. In an accurate titration, the indicator should change colour as close to the equivalence point as possible.	Mod 6 Quantitative Analysis CH12–13 Band 3 • Clearly explains the difference between the two terms. AND • Uses the titration as an example . . . . 3 • Clearly explains the difference between the two terms . . . . 2 • Gives some useful information. 1
(b) $HNO_3(aq) + NH_3(aq) \rightarrow NH_4NO_3(aq)$	Mod 6 Quantitative Analysis CH12–13 Band 3 • Gives correct equation with states 1
(c) Ignoring titration 1 (rough), the average of titrations 2–4 is 36.1 mL. Stoichiometry is 1 : 1 (acid : base). Hence the number of moles of acid equals the number of moles of base. $n = cV$, where n = number of moles (mol), c = concentration (mol L^{-1}) and V = volume (L). $n = 1.01 \times \frac{25.0}{1000}$ $= 0.02525$ mol For the concentration of the acid: $0.02525 = x \times \frac{36.1}{1000}$ $x = \frac{0.02525}{36.1} \times 1000$ $= 0.699$ mol L^{-1} **OR** $c_1V_1 = c_2V_2$ $1.01 \times 25.0 = c_2 \times 36.1$ $c_2 = 1.01 \times \frac{25}{36.1}$ $= 0.699$ mol L^{-1}	Mod 6 Quantitative Analysis CH12– 4, CH12–6, CH12–13 Bands 5–6 • Obtains correct value for the end point. AND • Explains how the value was obtained. AND • Correctly calculates the concentration. AND • Shows working . . . . .3 • Any THREE of the above points . . . . 2 • Any TWO of the above points 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(d)  *Note: The initial pH of the 1.01 M NH_3 solution should be less than 14. The pH of the equivalence point and the pH of the final solution should be less than 7.*	Mod 6 Quantitative Analysis CH12–3, CH12–13 Band 4 • Draws an appropriate graph showing the correct shape AND • Labels axes appropriately . . . . 2 • Draws an appropriate graph showing some relevant details 1
Question 27	
The sodium salts of long chain fatty acids consist of two parts: a non-polar hydrophobic 'tail' consisting of fatty acids; and a polar, hydrophilic, charged 'head' consisting of the sodium salt of the alkanoic acid, as shown below.   simplified representation A micelle forms when sodium salts assemble so that the long hydrophobic tails all point inwards and the polar heads all sit on the outside of the micelle.  micelle The hydrophobic tails embed themselves in the grease. The hydrophilic heads are attracted to the water and lift the grease off the dirty dishes to reform a micelle that then remains suspended in water.  *Note: While the question requires a diagram of only a single micelle, diagrams of micelle formation or action such as those above may help to develop high-quality responses.*	Mod 7 Reactions of Organic Acids and Bases CH12–6, CH12–7, CH12–13 Band 4 • Provides a detailed explanation of the surfactant properties of the sodium salts of long chained fatty acids. AND • Includes a detailed diagram of a micelle . . . . 3–4 • Provides an explanation of the surfactant properties of the sodium salts of long chain fatty acids. AND • Includes a diagram of a micelle . . . . 2 • Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide

Question 28

(a)



Mod 7 Polymers
CH12–7, CH12–14 Band 4

- Draws structural formula of polypropene 1

(b)

	Polymer A	*Polymer B*
Name	low-density polypropylene (LDPP)	high-density polypropylene (HDPP)
Properties	*Any two of:* • amorphous polymer • lots of side chains • flexible • lower melting point • weaker • cheaper	*Any two of:* • crystalline polymer • fewer side chains • rigid • higher melting point • stronger • more expensive

Mod 7 Polymers
CH12–7, CH12–14 Band 4

- Correctly identifies polymer A as low-density polypropylene and polymer B as high-density polypropene.

AND

- Lists at least TWO properties of each polymer 3

- Correctly identifies polymer A as low-density polypropylene and polymer B as high-density polypropene.

OR

- Lists at least TWO properties of each polymer 2

- Provides some relevant information 1

Question 29

(a) Propanoic acid and methyl ethanoate have the same molecular formula but different structural formulae and are therefore isomeric. The isomers differ in their functional group (one being an acid and the other an ester). These are their functional group isomers.

Mod 7 Nomenclature
CH12–5, CH12–7, CH12–15 Bands 2–3

- Identifies isomers as having the same molecular formula but different structural formulae.

AND

- Identifies the TWO functional groups represented by the two isomers 2

- Any ONE of the above points. 1

(b) There will be no visible change when sodium bicarbonate is added to the solution of methyl ethanoate.
Adding sodium bicarbonate to the test tube containing the solution of propanoic acid will produce bubbles of gas.

$$CH_3CH_2COOH(aq) + HCO_3^-(aq) \rightarrow CH_3CH_2COO^-(aq) + CO_2(g) + H_2O(l)$$

Mod 7 Reactions of Organic Acids and Bases
Mod 8 Analysis of Organic Substances
CH12–2, 3, 7, 14 Bands 3–4

- Describes the observations expected for the methyl ethanoate test tube.

AND

- Describes the observations expected for the propanoic acid test tube.

AND

- Provides a net ionic equation 3

- Any TWO of the above points 2

- Any ONE of the above points. 1

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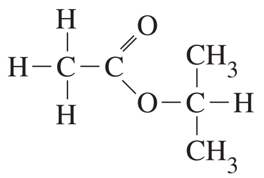
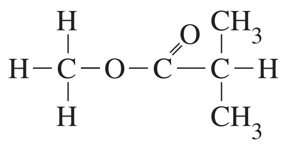
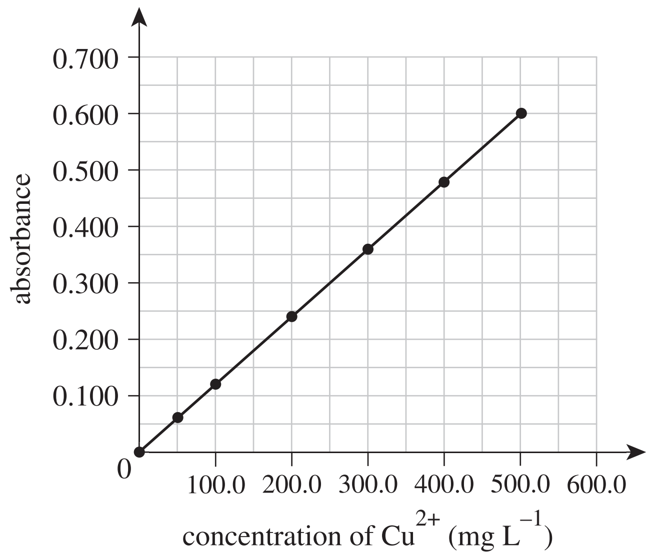
Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(c) Boiling points for both alkanoic acids and their isomeric methyl esters increase with the increasing number of carbon atoms. This is the result of dispersion forces (which act between all molecules) increasing with increasing chain length. Both alkanoic acids and their isomeric methyl esters are polar compounds, and dipole–dipole forces act between these molecules (in addition to dispersion forces). However, only alkanoic acids can form hydrogen bonds (H bonds). The presence of the additional strong intermolecular H bonds means the boiling points of alkanoic acids are always higher than their isomeric methyl esters. The difference between the boiling points of alkanoic acids and their isomeric methyl esters decreases as the chain length (number of carbons in the molecule) increases. This is the result of the dispersion forces (present in both isomers) increasing as the chain length increases.	Mod 7 Reactions of Organic Acids and Bases CH12–5, 6, 7, 14 Bands 5–6 • Comprehensively explains the trends of the boiling points . . . . 4 • Explains most of the trends of the boiling points . . . . 3 • Describes most of the trends of the boiling points. OR • Explains ONE pattern of the boiling points . . . . 2 • Provides some relevant information 1
Question 30	
(a)  **OR**  The infrared spectrum shows a strong carbonyl (C=O) band at 1780 cm^{-1}. The absence of a broad OH band between 2500–3300 cm^{-1} indicates that the compound is not an acid, but could be an aldehyde, ketone or ester. The ^{13}C NMR shows four different carbon environments, and the peak at 170 ppm confirms the presence of a carbonyl group. The peak at 68 ppm suggests a carbon attached to oxygen or nitrogen, providing evidence of an ester. The ^{1}H NMR shows a 1H septet, consistent with six neighbouring H atoms ($CH_3\mathbf{CH}CH_3$). The 6H doublet is consistent with one neighbouring H atom ($\mathbf{CH_3}CH\mathbf{CH_3}$). The final ^{1}H NMR signal is a 3H singlet ($\mathbf{CH_3}C$). A chemical shift of around 5.0 ppm for the septet suggests the signal is for a H atom on a carbon bonded to an oxygen atom. The singlet at 2.0 for 3H suggests CH_3 adjacent to a carbonyl group. The ^{1}H NMR suggests 10 H atoms.	Mod 8 Analysis of Organic Substances CH12–4, 5, 6, 7, 15 Bands 4–6 • Draws a correct structure. AND • Identifies functional group information provided by the IR spectra to justify the chosen structure. AND • Analyses chemical shift data from BOTH the ^{13}C and ^{1}H NMR spectra to justify chosen structure. AND • Analyses the splitting pattern of the ^{1}H NMR spectra to justify the chosen structure . . . . 6 • Draws a correct structure AND justifies the structure using the chemical reactivity AND refers to BOTH spectra. OR • Draws a correct structure AND justifies using some spectroscopic data . . . . 4–5 • Draws a substantially correct structure AND some give correct analysis. OR • Gives a substantially correct analysis . . . . 2–3 • Provides some relevant information. 1

	Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(b)	The molecular (parent) ion occurs at m/z = 102, in agreement with the formula of $C_5H_{10}O_2$. The splitting pattern provides further evidence of structure: • The peak at M-15 = 87 suggests loss of a methyl group. • The peak at M-41 = 59 suggests loss of a CH_3CO_2 group. • The peak base, m/z = 43, is consistent with a CH_3CHCH_3 group.	Mod 8 Analysis of Organic Substances CH12–2, 6, 15 Bands 3 • Identifies the molecular ion. AND • Explains how the splitting pattern provides supporting evidence for structure determination 2
		• Identifies the molecular ion. OR • Provides some relevant information regarding the splitting pattern. 1
Question 31		
(a)		Mod 8 Analysis of Inorganic Substances CH12–1, 4, 5, 6, 7, 15 Bands 3–4 • Plots points. AND • Labels graph. AND • Draws line of best fit 3
		• Plots points. AND • Labels graph OR draws line of best fit. 2
		• Plots points. OR • Labels graph 1
(b)	From the graph, an absorbance of 0.150 gives a concentration of 120 mg L^{-1}. *Note: Accept responses in the 110–130 range.* The brass sample was dissolved in 100 mL; hence, it contains 12.0 mg of Cu^{2+}. $\% \text{ of Cu} = \frac{\text{mass of Cu}}{\text{mass of the sample}} \times 100$ $= \frac{12.0}{19.8} \times 100$ $= 60.6\%$ *Note: Accept responses in the 55–66% range.*	Mod 8 Analysis of Inorganic Substances CH12–1, 4, 5, 6, 7, 15 Band 3 • Accurately reads the graph. AND • Correctly determines the mass of Cu in the sample. AND • Correctly determines the percentage of Cu in the sample. 3
		• Determines the mass of Cu in the sample based on an incorrect reading of the graph. 2
		• Provides some relevant calculations. 1
(c)	The hollow cathode lamp that is used in the atomic absorption spectrometer (AAS) analysis of copper contains a copper cathode that produces wavelengths of light uniquely characteristic for copper. Zinc does not absorb light at the same wavelengths as copper.	Mod 8 Analysis of Inorganic Substances CH12–2, 4, 6, 15 Bands 4–5 • Provides a detailed explanation 2
		• Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 32	
Step 1: Propan-2-ol can be dehydrated to propene when heated with concentrated sulfuric acid as a catalyst. Step 2: Addition of water using dilute sulfuric acid will yield a mixture of isomeric propanols. Step 3: Propan-1-ol can be oxidised using acidified potassium dichromate. Step 4: Propanamide can be obtained through an elimination reaction by heating ammonia and propanoic acid together. The ^{13}C NMR spectrum for propan-2-ol (compound M) will show two peaks for its two carbon environments. Propan-1-ol (compound O) will show three peaks for its three carbon environments. The ^{1}H NMR spectrum for each isomeric alcohol will show a broad exchangeable peak for the OH hydrogen. The ^{1}H NMR for propan-2-ol will show a doublet integrating to 6H for the two methyl groups and a heptet integrating to 1H for the CH hydrogen. The ^{1}H NMR for propan-2-ol will show a triplet integrating to 3H for the methyl group (at around δ1.00 ppm), a hextet integrating to 2H for one of the CH_2 groups (at about δ2.00 ppm) and a triplet integrating to 2H for the CH_2OH group (at around δ3.50 ppm). The mass spectra for both alcohols will have the same molecular ion (at m/z = 60.0), but the splitting patterns will be different. Propan-2-ol, $CH_3CHOHCH_3$, will show a strong peak at M^+–15 for the loss of a CH_3 group. Propan-1-ol, $CH_3CH_2CH_3OH$, would be expected to show a strong peak at M^+–15 for the loss of a CH_3CH_2 group.	Mod 7 Products of Reactions Involving Hydrocarbons Mod 7 Alcohols Mod 7 Reactions of Organic Acids and Bases Mod 8 Analysis of Organic Substances CH12–4, 5, 6, 7, 14, 15 Bands 4–6 • Provides a detailed discussion of the appropriate reagents and conditions. AND • Provides a detailed explanation of how NMR AND mass spectroscopic techniques could be used for identification 7
	• Outlines the appropriate reagents and conditions. AND • Provides a detailed explanation of how NMR OR mass spectroscopic techniques could be used for identification 5–6
	• Outlines the appropriate reagents and conditions. AND • Explains some relevant spectroscopic data 3–4
	• Outlines the appropriate reagents and conditions. OR • Outlines some relevant spectroscopic data 2
	• Provides some relevant information 1

