Neap

Trial Examination 2022

HSC Year 12 Chemistry

General Instructions	
	• Reading time – 5 minutes • Working time – 3 hours • Write using black pen • Draw diagrams using pencil • Calculators approved by NESA may be used • A formulae sheet, data sheet and Periodic Table are provided at the back of this paper
Total Marks: 100	SECTION I – 20 marks (pages 2–8) • Attempt Questions 1–20 • Allow about 35 minutes for this section SECTION II – 80 marks (pages 9–26) • Attempt Questions 21–34 • 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 2022 HSC Year 12 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 ‘An acid is a substance that donates one or more protons.’
This definition of an acid was first given by

A. Arrhenius.

B. Brønsted–Lowry.

C. Lewis.

D. Lavoisier.

2 Which of the following substances would make the best primary standard?

	Substance	*Purity*	*Solubility*	*Formula mass*
A.	P	high	low	low
B.	Q	high	high	high
C.	R	high	low	high
D.	S	high	high	low

3 Which of the following compounds has the highest molar solubility in water at 25°C?

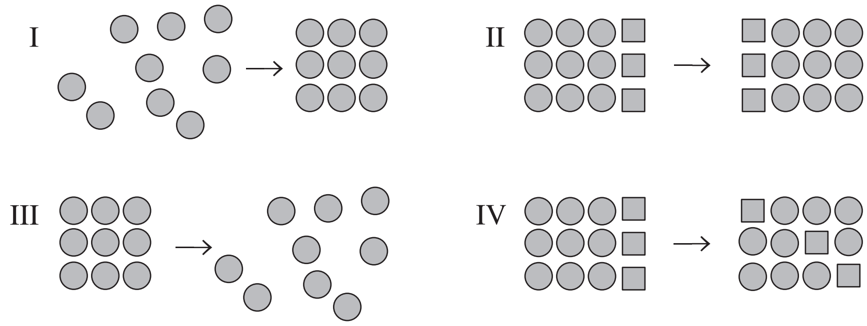
A. $BaCO_3$

B. $Mg_3(PO_4)_2$

C. $Pb(OH)_2$

D. $CaSO_4$

4 The diagram shows four different systems.



Which systems show an increase in entropy?

A. I and II only

B. II and III only

C. III and IV only

D. I and IV only

5 Cloudy ammonia is an ingredient of some household cleaners. It forms an equilibrium mixture when dissolved in water, as shown in the equation.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

Which of the following is the equilibrium expression for the reaction from right to left?

A. $\dfrac{[NH_4^+][OH^-]}{[NH_3]}$

B. $\dfrac{[NH_4]}{[NH_3^+][OH^-]}$

C. $\dfrac{[NH_3][OH^-]}{[NH_4^+]}$

D. $\dfrac{[NH_3]}{[NH_4^+][OH^-]}$

6 Four different equilibrium systems (I–IV) at standard pressure and temperature are shown.

I	$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$	$\Delta H < 0$
II	$2NOBr(g) \rightleftharpoons 2NO(g) + Br_2(g)$	$\Delta H < 0$
III	$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$	$\Delta H > 0$
IV	$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$	$\Delta H > 0$

In each system, the pressure was increased. Later, the temperature was decreased.

In which equilibrium system would BOTH changes result in a product yield increase?

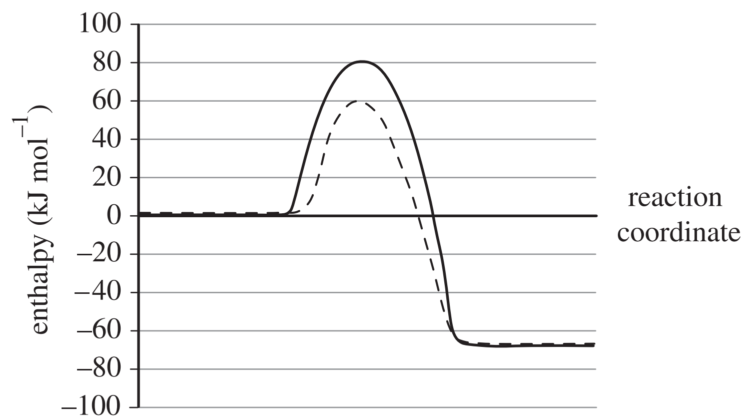
A. I

B. II

C. III

D. IV

7 A particular reaction can occur with or without a catalyst. The energy profiles of this reaction, both catalysed and uncatalysed, are shown.



Which row of the table best matches the reactions as shown by the energy profiles?

	E_a of uncatalysed reaction (kJ mol^{-1})	*ΔH of uncatalysed reaction (kJ mol^{-1})*	*E_a of catalysed reaction (kJ mol^{-1})*	*ΔH of catalysed reaction (kJ mol^{-1})*
A.	–80	70	–60	70
B.	80	–150	80	60
C.	80	–70	60	–70
D.	20	80	150	–80

8 Stomach (gastric) acid is a solution of mainly hydrochloric acid and can vary between 0.01 mol L^{-1} and 0.1 mol L^{-1}. Sometimes, excess acid is secreted in the stomach. Medications can be taken to neutralise the surplus acid.

Which of the following substances would be best suited to safely neutralising this acid?

A. a dilute solution of sodium chloride

B. a dilute suspension of sodium hydrogen carbonate

C. a concentrated solution of sodium hydroxide

D. large quantities of distilled water

9 Citric acid has the formula $H_3C_6H_5O_7$. It is often used as a flavouring and preservative in food and drinks. A solution of citric acid is neutralised by a solution of sodium hydroxide.

Which of the following equations correctly represents this reaction?

A. $3NaOH(s) + H_3C_6H_5O_7(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l)$

B. $3NaOH(aq) + H_3C_6H_5O_7(aq) \rightarrow 3NaC_6H_5O_7(aq) + 3H_2O(l)$

C. $NaOH(aq) + 3H_3C_6H_5O_7(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l)$

D. $3NaOH(aq) + H_3C_6H_5O_7(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l)$

10 Phosphoric acid (H_3PO_4) is a triprotic acid. It dissociates in water in three stages as shown.

Stage 1: $H_3PO_4(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + H_2PO_4^-(aq)$ $\quad K_{a1} = 7.3 \times 10^{-3}$

Stage 2: $H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HPO_4^{2-}(aq)$ $\quad K_{a2} = 6.3 \times 10^{-8}$

Stage 3: $HPO_4^{2-}(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HPO_4^{3-}(aq)$ $\quad K_{a3} = 4 \times 10^{-13}$

A student wants to calculate the approximate pH of a 0.1 mol L^{-1} solution of phosphoric acid.

Which value(s) of the dissociation constants should the student use?

A. K_{a1} only

B. $K_{a1} + K_{a2} + K_{a3}$

C. $K_{a1} - K_{a2} - K_{a3}$

D. $K_{a1} \times K_{a2} \times K_{a3}$

11 Which of the following compounds forms a 0.00100 mol L^{-1} aqueous solution with a pH closest to 7.00?

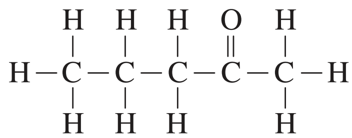
A. sodium ethanoate

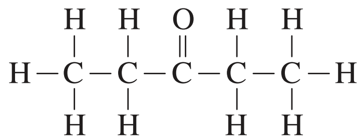
B. ethanol

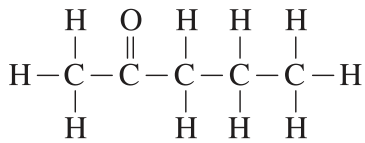
C. ethanamine

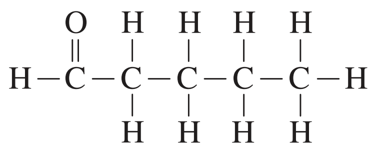
D. 2,3-dihydroxypropanoic acid

12 Which of the following is a functional group isomer of pentan-2-one?

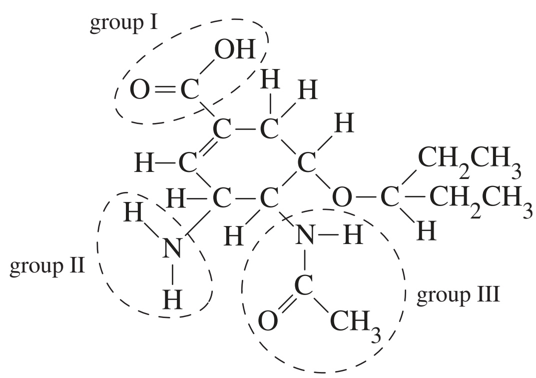
A. 

B. 

C. 

D. 

13 The structure of a compound is shown. It has been suggested that this molecule may be an effective drug for treating seasonal influenza (the flu).



Which row of the table correctly names the functional groups labelled I, II and III?

	Group I	*Group II*	*Group III*
A.	amide	amine	ester
B.	carboxylic acid	amine	amide
C.	ketone	amine	carboxylic acid
D.	alcohol	amide	amine

14 A student performed an experiment in which 250 mL of water was heated by burning methanol in a spirit burner. The enthalpy of combustion of methanol is –726 kJ mol^{-1}. Assume that all heat released by the process is absorbed by the water.

What is the maximum change in temperature of the water when 1.26 g of methanol is completely combusted?

A. 0.434°C

B. 3.66°C

C. 27.3°C

D. 36.3°C

15 An experiment is conducted in which 4-aminobutanoic acid, $H_2N(CH_2)_3COOH$, forms a condensation polymer containing 1000 monomer units.
What is the molar mass of this polymer?

A. 8.5×10^4 g mol^{-1}

B. 1.0×10^5 g mol^{-1}

C. 1.0×10^3 g mol^{-1}

D. 9.7 g mol^{-1}

16 The structure of a compound is shown. Its carbon atoms are labelled I–IV.

$$\overset{\text{I}}{CH_3} - \overset{\text{II}}{CH_2} - \overset{\text{III}}{CH_2} - \overset{\text{IV}}{CO_2H}$$

Which carbon atom has a trigonal planar arrangement of bonds around it?

A. I

B. II

C. III

D. IV

17 A table of reactions involving organic compounds is shown.

Reaction	*Product*
but-2-ene + hydrogen bromide	1
butanal + acidified potassium dichromate	2
butan-2-ol + ethanoic acid + catalyst	3
butanoic acid + sodium hydrogen carbonate	4

Which row of the table correctly identifies a product from each reaction?

	Product 1	*Product 2*	*Product 3*	*Product 4*
A.	2-bromobutane	butanoic acid	2-butyl ethanoate	sodium butanoate
B.	2-bromobutane	sodium butanoate	butanoic acid	carbon dioxide
C.	butane	butanoic acid	2-butyl ethanoate	carbon dioxide
D.	2-bromobutane	2-butyl ethanoate	butanoic acid	sodium butanoate

18 Which of the following statements best explains the cleaning action of soap?

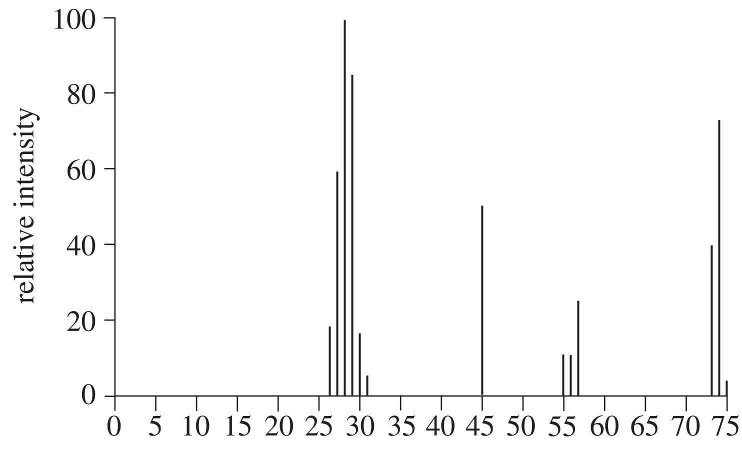
A. The polar head group forms dispersion forces with oils and fats and the non-polar tail group forms hydrogen bonds with water.

B. The non-polar tail group forms dispersion forces with oil and fats, as well as forming dipole–dipole forces with water.

C. The polar head group forms dipole–dipole forces with oil, fats and water.

D. The polar head group forms ion–dipole forces with water and the non-polar tail group forms dispersion forces with oil and fats.

19 The diagram shows a simplified mass spectrum of propanoic acid.



What does the peak at m/z = 45 represent?

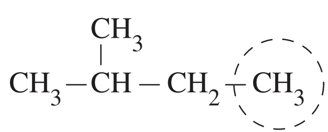
A. $[CH_3CH_2CO]^+$

B. $[CH_3COH_2]^+$

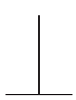
C. $[CO_2H]^+$

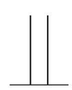
D. the base peak for the mass spectrum

20 The structure of 2-methylbutane is shown. A CH_3 group is circled

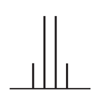


Which of the following splitting patterns would be observed in the ^{1}H NMR spectrum for the CH_3 group circled?

A. 

B. 

C. 

D. 

 HSC Chemistry Yr12 QB_2022

HSC Year 12 Chemistry

Section II Answer Booklet

80 marks
Attempt Questions 21–34
Allow about 2 hours and 25 minutes for this section

Instructions	• 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 at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (4 marks)

Draw a table that compares THREE characteristics of static and dynamic equilibrium systems. **4**

Question 22 (7 marks)

Many reactions involving ionic compounds will only take place when the ionic compounds are in aqueous solutions.

(a) Describe the processes involved in the dissolution of ionic compounds in water. **4**

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(b) Equimolar aqueous solutions of silver nitrate and magnesium chloride are mixed at 25°C. **3**
Write the overall equation AND net ionic equation for any reactions that occur.

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Question 23 (9 marks)

Carbonyl chloride ($COCl_2$) gas can be formed in an equilibrium reaction between carbon monoxide (CO) gas and chlorine (Cl_2) gas. A 10 L vessel containing these gases under standard conditions, but not at equilibrium, was sampled. It was found that there were 0.11 moles of carbon monoxide, 0.63 moles of chlorine and 2.9 moles of carbonyl chloride present in the vessel. The equilibrium constant (K_{eq}) for this reaction, under the conditions used, is 2.62×10^{2} mol L^{-1}.

(a) Write the equilibrium expression for this reaction. **1**

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(b) After sampling, in which direction will the reaction shift in order to reach equilibrium? Justify your answer. **4**

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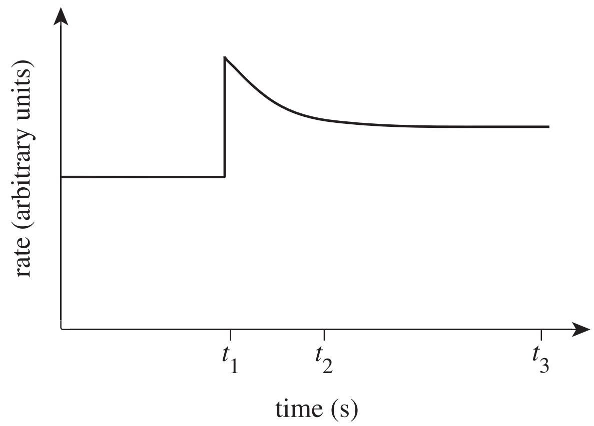
Question 23 continues on page 12

Question 23 (continued)

(c) The mixture of carbon monoxide, chlorine and carbonyl chloride was allowed to come to equilibrium. The rate of reaction was monitored at a constant temperature. The diagram shows the rate of formation of carbonyl chloride over a period of time. At t_1, the volume of the reaction vessel was decreased. **4**



Explain, using collision theory, the shape of the graph over time. Refer to any factors that affect the rate of the reaction in your answer.

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End of Question 23

Question 24 (7 marks)

As part of the Chemistry course, you have carried out an investigation to prepare a buffer and demonstrate its properties. **7**

Describe how you carried out this investigation. Include the conclusions reached and any risk assessments made.

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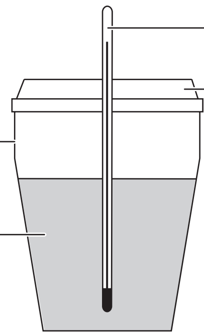
Question 25 (9 marks)

A class carried out an experiment to find the molar enthalpy of neutralisation of the reaction between a solution of sodium hydroxide and a dilute solution of nitric acid. The students were provided with the relevant glassware, a calorimeter and standardised aqueous solutions of sodium hydroxide (2.4 mol L^{-1}) and nitric acid (2.1 mol L^{-1}). The calorimeter provided is shown in the diagram.



The students were asked to calculate the amount of nitric acid required to neutralise 50 mL of the sodium hydroxide solution. The students split into groups. Each group noted the initial temperature of the solution, added the calculated amount of sodium hydroxide to 50 ml of the acid, stirred the mixture and then recorded the change in temperature. An average of the temperatures was obtained and used in later calculations. The results are shown in the table.

Group	*Temperature change (°C)*
A	+9
B	+9
C	+10
D	+9
E	+10

(a) What material should be used for the cup of the calorimeter in the experiment? Justify your answer. **1**

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(b) Calculate the initial pH of the sodium hydroxide solution. Show all relevant working. **2**

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Question 25 continues on page 15

Question 25 (continued)

(c) Calculate the exact volume of nitric acid needed to neutralise the sodium hydroxide solution. Show all relevant working. **2**

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(d) Calculate the molar enthalpy of neutralisation for this reaction. Show all relevant working. **3**

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(e) The accepted value for the molar enthalpy of neutralisation in this reaction is 57.3103 J. **1**

Compare this to the value calculated in part (d) and suggest a reason for any discrepancy between the two values.

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End of Question 25

Question 26 (4 marks)

Some salts display amphiprotic behaviour. **4**

Using a suitable example, explain what is meant by 'amphiprotic'. Support your answer with at least ONE chemical equation.

Question 27 (4 marks)

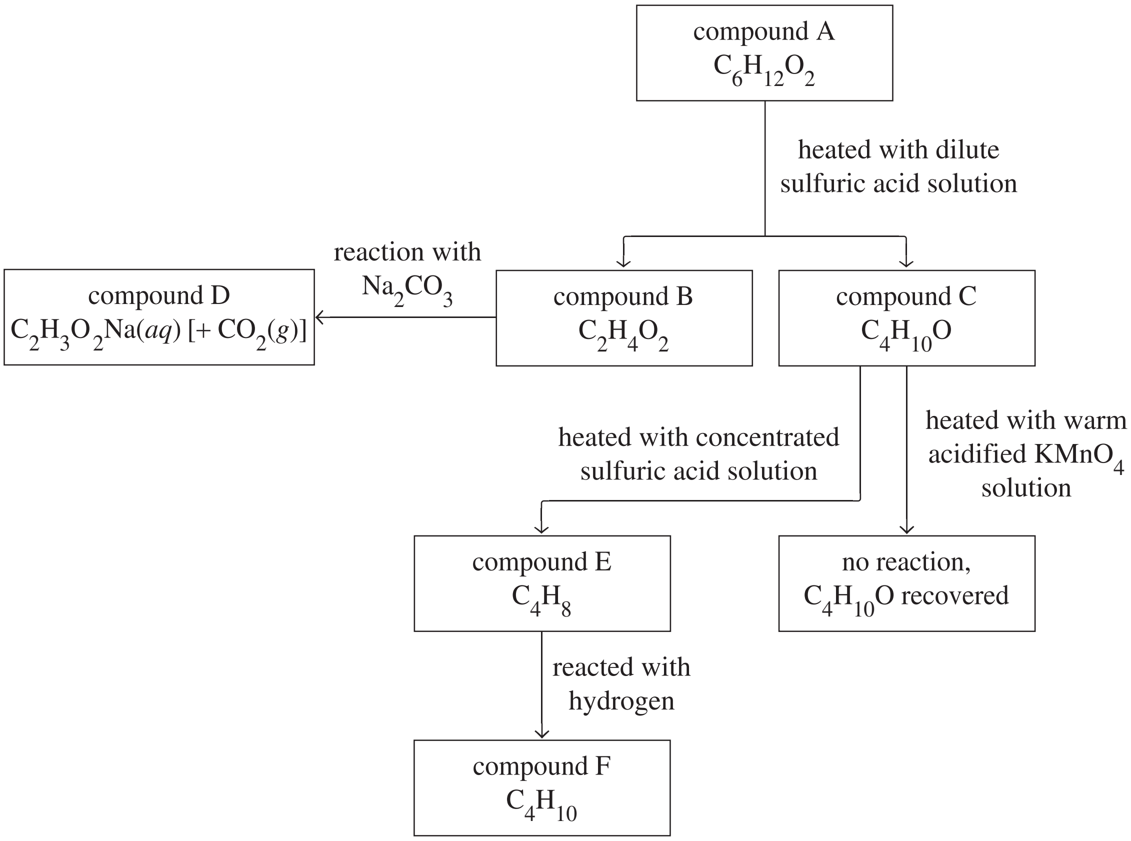
Describe a suitable chemical test that could be used to distinguish between the following pairs of isomeric compounds. Include the expected observations for each test.

(a) propanol and propanone **2**

(b) hex-3-ene and cyclohexane **2**

Question 28 (7 marks)

The flow chart shows reactions involving six different organic compounds, A–F. **7**



Draw the structural formula of compounds A–F and use the information provided to justify your answers.

Compound	*Structural formula*	*Justification*
A		
B		

Question 28 continues on page 18

Question 28 (continued)

C		
D		
E		
F		

End of Question 28

Question 29 (5 marks)

Some properties of but-1-ene, 1-fluoropropane, propan-1-ol and ethanamide are shown in the table. **5**

Compound	*Molar mass (g mol^{-1})*	*Solubility in water*
but-1-ene	56	insoluble
1-fluoropropane	62	slightly soluble
propan-1-ol	60	soluble
ethanamide	59	soluble

Explain the different water solubilities of these compounds. Support your answer with at least ONE labelled diagram.

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Question 30 (4 marks)

A comparison of two different industrial processes for the synthesis of phenol is shown in the table. **4**

	Industrial process A	*Industrial process B*
Chemical equations	$C_6H_6 + Cl_2 \rightarrow C_6H_5Cl + HCl$ $C_6H_5Cl + NaOH \rightarrow C_6H_5OH + NaCl$	$C_6H_6 + C_3H_6 \rightarrow C_6H_5C_3H_7$ $C_6H_5C_3H_7 + O_2 \rightarrow C_6H_5OH + C_3H_6O$
Capital cost	\$1 500 000 000	\$1 900 000 000
Chemical cost	\$270 000 000 per year	\$120 000 000 per year
Energy cost	\$100 000 000 per year	\$25 000 000 per year
Labour cost	\$3 500 000 per year	\$3 500 000 per year
Decommission cost	\$500 000 000	\$100 000 000
Lifetime of plant	15 years	25 years
Yield of C_6H_5OH	150 000 tonnes per year (98.0% pure)	200 000 tonnes per year (99.9% pure)
Other chemical products	HCl (to be stored or disposed) NaCl (to be stored or disposed)	C_3H_6O (sold as solvent)

Which of the two industrial processes is the better investment? Justify your answer with reference to yield and purity, economic costs and environmental impact.

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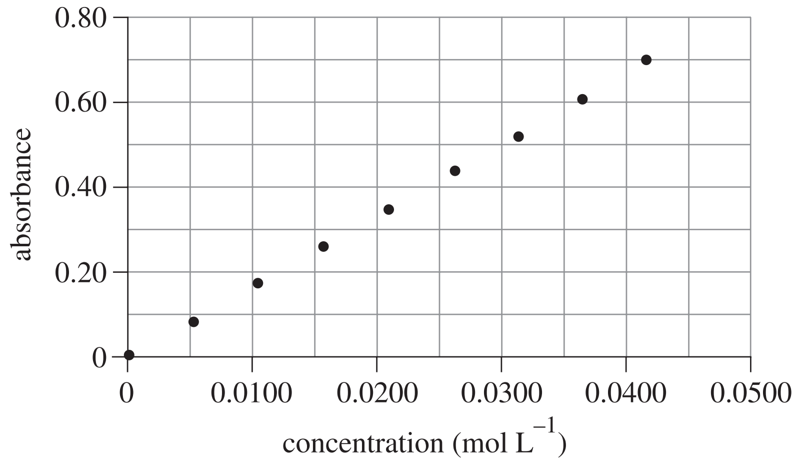
 HSC Chemistry Yr12 QB_2022

Question 31 (4 marks)

A colourimeter with an orange filter was used to analyse the concentration of copper ions in a solution **4**
To calibrate the colourimeter, a distilled water blank and eight standards of Cu^{2+} were prepared. Their absorbances were measured to give the calibration curve shown.



A 20.0 mL sample of a copper solution of unknown concentration was diluted to a total of volume of 80.0 mL. This diluted solution recorded an absorbance of 0.500.

Use the graph to determine the mass of the copper ions contained in the 20.0 mL sample.

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Question 32 (3 marks)

A sample of an unknown metal salt is to be analysed. The cation in the metal salt is known to be one of Ba^{2+}, Ca^{2+}, Mg^{2+} or Cu^{2+} and the anion is known to be one of Cl^{-}, OH^{-}, CO_3^{2-} or SO_4^{2-}. The metal salt is dissolved in water and the resulting colourless solution is divided into four equal samples to be tested, labelled A, B, C and D. The results of the tests are shown in the table. **3**

	Test(s) conducted	*Result*
Sample A	A solution of NaOH is added.	A white precipitate forms.
Sample B	Test 1: A dilute solution of HNO_3 is added.	There is no visible reaction.
	Test 2: A solution of $AgNO_3$ is added.	There is no visible reaction.
Sample C	Test 1: A solution of $BaCl_2$ is added.	A white precipitate forms.
	Test 2: A solution of HCl is added.	There is no visible reaction.
Sample D	A small sample of the solution was heated in the flame of a Bunsen burner.	The flame of the Bunsen burner does not change colour.

Identify the metal salt. Support your answer with at least ONE net ionic equation.

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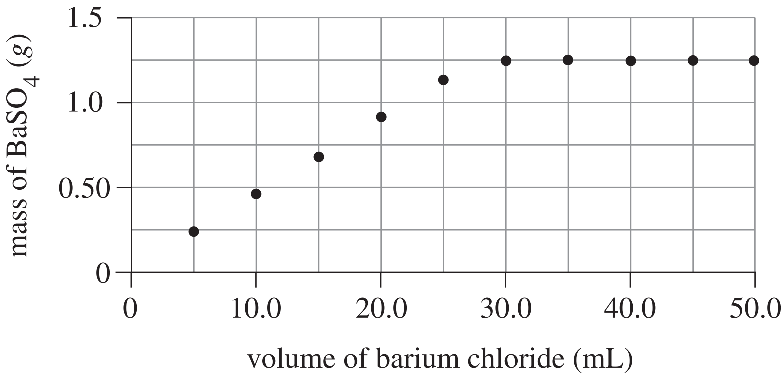
Question 33 (4 marks)

A gravimetric analysis was undertaken to determine the percentage, by mass, of sulfur in a sample of lawn fertiliser. A 10.4 g sample of fertiliser was dissolved into 250.0 mL of distilled water. This solution was then divided into ten equal 25.0 mL sub-samples. **4**

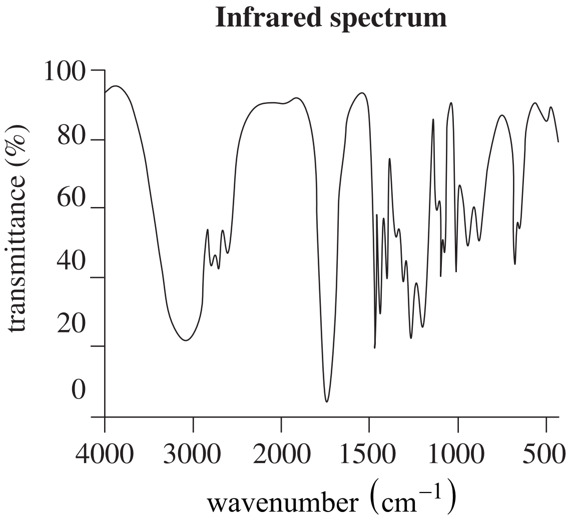
A barium chloride solution was added to each 25.0 mL sub-sample, and the resulting precipitate of barium sulfate was collected by filtration, dried and weighed. The graph shows the results of the gravimetric analysis.

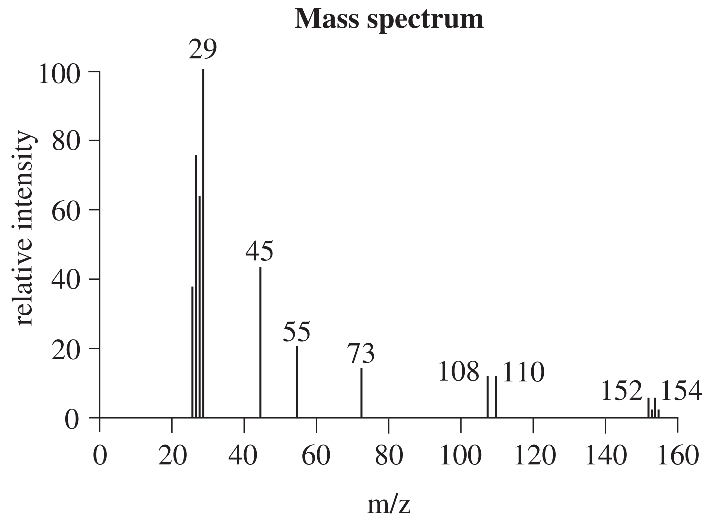


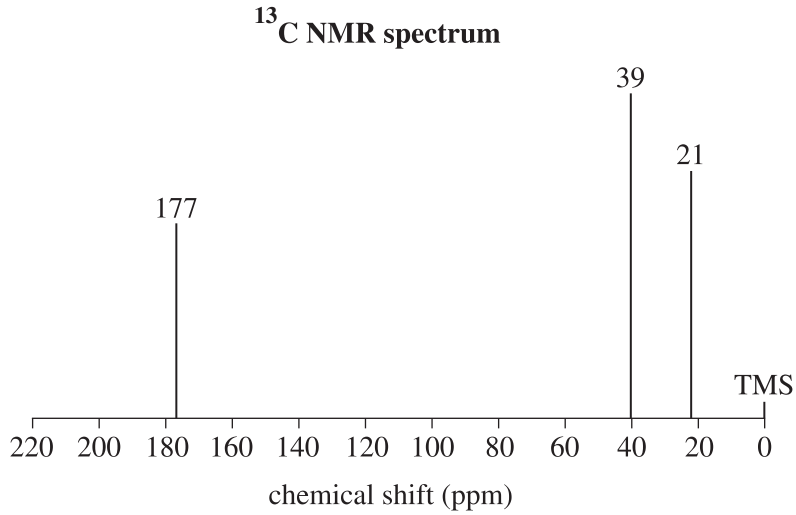
Determine the percentage of sulfur, by mass, in the original sample of lawn fertiliser. Show all relevant working.

Question 34 (9 marks)

A series of preliminary tests on a small, water-soluble organic molecule revealed that it contained a halogen. The mass, infrared, ^{1}H NMR and ^{13}C NMR spectra of the unknown molecule are shown. **9**

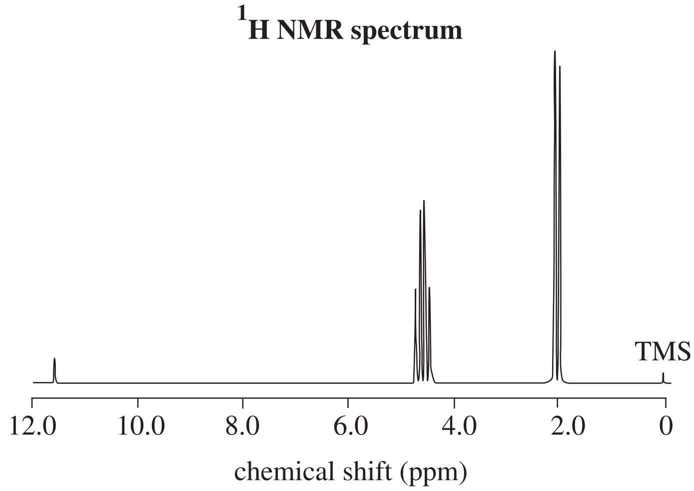






Question 34 is continued on page 25

Question 34 (continued)



Chemical shift (ppm)	*Peak splitting*	*Relative peak area*
1.9	doublet	3
4.4	quartet	1
11.5	singlet	1

In the space provided, draw a structural formula for the unknown molecule that is consistent with all of the information provided. Justify your answer with reference to the information provided.

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End of paper

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Section II extra writing space

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

FORMULAE SHEET

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

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

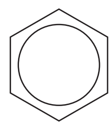
Compound	K_{sp}
Barium carbonate	2.58×10^{-9}
Barium hydroxide	2.55×10^{-4}
Barium phosphate	1.3×10^{-29}
Barium sulfate	1.08×10^{-10}
Calcium carbonate	3.36×10^{-9}
Calcium hydroxide	5.02×10^{-6}
Calcium phosphate	2.07×10^{-29}
Calcium sulfate	4.93×10^{-5}
Copper(II) carbonate	1.4×10^{-10}
Copper(II) hydroxide	2.2×10^{-20}
Copper(II) phosphate	1.40×10^{-37}
Iron(II) carbonate	3.13×10^{-11}
Iron(II) hydroxide	4.87×10^{-17}
Iron(III) hydroxide	2.79×10^{-39}
Iron(III) phosphate	9.91×10^{-16}

Compound	K_{sp}
Lead(II) bromide	6.60×10^{-6}
Lead(II) chloride	1.70×10^{-5}
Lead(II) iodide	9.8×10^{-9}
Lead(II) carbonate	7.40×10^{-14}
Lead(II) hydroxide	1.43×10^{-15}
Lead(II) phosphate	8.0×10^{-43}
Lead(II) sulfate	2.53×10^{-8}
Magnesium carbonate	6.82×10^{-6}
Magnesium hydroxide	5.61×10^{-12}
Magnesium phosphate	1.04×10^{-24}
Silver bromide	5.35×10^{-13}
Silver chloride	1.77×10^{-10}
Silver carbonate	8.46×10^{-12}
Silver hydroxide	2.0×10^{-8}
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

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** nihonium	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 (February 2010 version) is the principal source of all other data. Some data may have been modified.

Neap

Trial Examination 2022

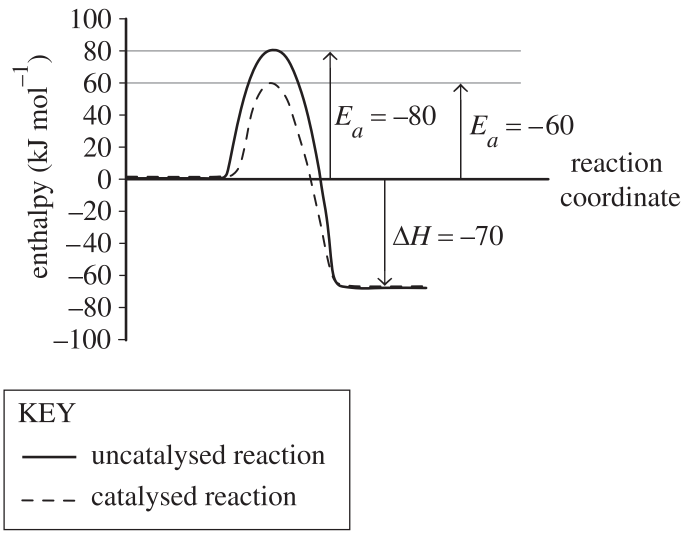
HSC Year 12 Chemistry

Solutions and Marking Guidelines

SECTION I

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 1 **B** **B** is correct. Brønsted and Lowry independently proposed the proton theory of acids and bases. In this theory, acids donate protons and bases accept protons. **A** is incorrect. Arrhenius stated that an acid dissociates in a solution to give hydrogen ions. **C** is incorrect. Lewis defined acids as electron pair acceptors. **D** is incorrect. Lavoisier thought that acidic properties were derived from the presence of oxygen.	Mod 6 Using Brønsted–Lowry Theory CH12–13 Band 2
Question 2 **B** **B** is correct. A primary standard is a substance that is available in a high purity (such as 99.9% pure) and may be easily dissolved in a known volume of solvent, usually water. The substance should also have a high formula mass to reduce error from mass measurements. Only substance Q matches these criteria. **A**, **C** and **D** are incorrect. These substances do not match the criteria for a primary standard.	Mod 6 Properties of Acids and Bases Mod 6 Quantitative Analysis CH12–13 Band 3
Question 3 **D** **D** is correct. This compound is calcium sulfate, which has a K_{sp} of 4.93×10^{-5}. The compound with the highest solubility constant has the greatest solubility. Thus, $CaSO_4$ has the highest molar solubility. **A** is incorrect. This compound is barium carbonate, which has a K_{sp} of 2.58×10^{-9}. **B** is incorrect. This compound is magnesium phosphate, which has a K_{sp} of 1.04×10^{-24}. **C** is incorrect. This compound is lead (II) hydroxide, which has a K_{sp} of 1.43×10^{-15}. *Note: The data sheet contains the table of solubility constants.*	Mod 5 Solution Equilibria CH12–4, 12–13 Band 2
Question 4 **C** **C** is correct. Entropy is a measure of randomness or disorder. Systems III and IV are the only systems in the diagram in which entropy increases. **A**, **B** and **D** are incorrect. System I shows a decrease in entropy and system II shows no change in entropy.	Mod 5 Static and Dynamic Equilibrium CH12–6, 12–13 Band 3

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 5 **A** **A** is correct. The equilibrium expression is usually written as the product of the concentrations of the reactants (the left-hand side of the equation) divided by the product of the concentrations of the products (the right-hand side of the equation). However, the question asks for the reaction going from right to left. This means that the expression should show the ammonium ion and the hydroxide ion on the upper part of the expression and the ammonia molecule on the lower part of the expression; that is, $\frac{[NH_4^+][OH^-]}{[NH_3]}$. **B** is incorrect. This expression uses the incorrect formulae. **C** is incorrect. This expression may be reached by mixing up the species. **D** is incorrect. This expression shows the reaction from left to right.	Mod 5 Calculating the Equilibrium Constant (K_{eq}) CH12–13 Band 3
Question 6 **A** **A** is correct. An increase in pressure will only increase the product yield if the forward (left to right) reaction results in a decrease in the number of particles. A decrease in temperature will only increase the product yield if the forward reaction is exothermic (such as $\Delta H < 0$). Thus, the reaction must both decrease the number of particles and be exothermic to result in a product yield increase. Only the reaction in equilibrium system I satisfies these criteria. **B** is incorrect. The reaction in equilibrium system II increases the number of particles and is exothermic. **C** and **D** are incorrect. The reactions in equilibrium systems III and IV increase the number of particles and are endothermic.	Mod 5 Factors that Affect Equilibrium CH12–13 Band 6

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 7 **C** **C** is correct. The energy profile for the uncatalysed reaction is shown with a solid line and the catalysed reaction is shown with a dotted line. The E_a for the uncatalysed reaction is 80 kJ mol^{-1}, the E_a for the catalysed reaction is 60 kJ mol^{-1} and the ΔH for both the uncatalysed and catalysed reactions is –70 kJ mol^{-1}.  **A**, **B** and **D** are incorrect. These options do not match the energy profiles.	Mod 5 Static and Dynamic Equilibrium CH12–6, 12–12 Band 5
Question 8 **B** **B** is correct. To neutralise the acid, a base is needed. To do this safely, it is best to use a dilute weak base, such as a suspension of sodium hydrogen carbonate. **A** is incorrect. This substance is a salt and will not neutralise the acid. **C** is incorrect. Sodium hydroxide is a strong base and is corrosive, especially when concentrated. **D** is incorrect. Water is neutral and will only dilute the acid, not neutralise it.	Mod 6 Properties of Acids and Bases Mod 6 Quantitative Analysis CH12–13 Band 3
Question 9 **D** **D** is correct. A solution of sodium hydroxide reacts with a solution of citric acid in a 3 : 1 ratio, forming sodium citrate ($Na_3C_6H_5O_7$) and 3 moles of water. **A** is incorrect. This equation shows sodium hydroxide as a solid, not an aqueous solution. **B** is incorrect. This equation shows the wrong ratio of sodium citrate to citric acid and gives the wrong formula. **C** is incorrect. This equation shows the wrong ratio of sodium hydroxide to citric acid.	Mod 6 Quantitative Analysis CH12–13 Band 3

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 10 **A** **A** is correct. The K_{a1} value for the first ionisation of $H_3PO_4(aq)$ is many times larger (by 10^5) than the K_{a2} value for the second ionisation, which is also far greater (by 10^5) than the K_{a3} value for the third ionisation. The first ionisation value will, therefore, make the greatest contribution to the hydrogen ion concentration and should be used by the student. **B**, **C** and **D** are incorrect. The contributions by K_{a2} and K_{a3} are negligible.	Mod 6 Quantitative Analysis CH12–4, 12–13 Band 5
Question 11 **B** **B** is correct. Ethanol is a covalent substance and does not dissociate in water. Ethanol forms a neutral solution when dissolved in water. **A** is incorrect. Sodium ethanoate is the conjugate base of ethanoic acid and will form an aqueous solution with a pH greater than 7.00 due to the formation of hydroxide ions through hydrolysis. **C** is incorrect. Ethanamine is basic and will form an aqueous solution with a pH greater than 7.00 due to the formation of hydroxide ions through hydrolysis. **D** is incorrect. Due to the formation of hydrogen ions through hydrolysis, 2,3-dihydroxypropanoic acid will have a pH less than 7.00.	Mod 7 Reactions of Organic Acids and Bases CH12–5, 12–14 Band 4
Question 12 **D** **D** is correct. This option represents pentanal, which contains the aldehyde functional group (a functional group isomer of ketones). **A** and **C** are incorrect. These options represent pentan-2-one. **B** is incorrect. This option represents pentan-3-one, which is a positional isomer that contains the same functional group as pentan-2-one.	Mod 7 Nomenclature CH12–5, 12–7, 12–14 Band 4

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 13 **B** **B** is correct. Functional group I is a carboxylic acid, functional group II is an amine and functional group III is an amide. **A** is incorrect. The molecule does not include an ester functional group. The ester functional group is shown below. $\mathrm{C{-}\overset{\overset{\large O}{\Vert}}{C}{-}O{-}C}$ **C** is incorrect. The molecule does not include a ketone functional group. The ketone functional group is shown below. $\mathrm{C{-}\overset{\overset{\large O}{\Vert}}{C}{-}C}$ **D** is incorrect. The molecule does not include an alcohol functional group. The alcohol functional group is C–OH.	Mod 7 Nomenclature CH12–7, 12–14 Bands 2–3
Question 14 **C** molar mass of $CH_3OH = 12.01 + 4 \times 1.008 + 16.00$ $= 32.042\ \text{g mol}^{-1}$ moles of $CH_3OH = \dfrac{1.26}{32.042}$ $= 0.0393$ mol heat released $= 0.0393 \times 726$ $= 28.5$ kJ $= 28\ 500$ J $\Delta T = \dfrac{28\ 500}{(0.250 \times 4.18 \times 10^3)}$ $= 27.3°C$	Mod 7 Alcohols CH12–5, 12–6, 12–7 Bands 5–6
Question 15 **A** molar mass of $H_2N(CH_2)_3COOH = 4 \times 12.01 + 9 \times 1.008 +$ $2 \times 16.00 + 14.01$ $= 103.12\ \text{g mol}^{-1}$ $1000H_2N(CH_2)_3COOH \rightarrow H_2N(CH_2)_3CO[HN(CH_2)_3CO]_{98}$ $HN(CH_2)_3COOH + 999H_2O$ molar mass of the polymer $= 1000 \times 103.12 - 999 \times 18.016$ $= 8.5 \times 10^4\ \text{g mol}^{-1}$	Mod 7 Polymers CH12–5, 12–6, 12–14 Band 6
Question 16 **D** **D** is correct. This carbon atom is only attached to three other atoms, resulting in a trigonal planar arrangement. **A**, **B** and **C** are incorrect. These carbons are each attached to four other atoms, resulting in a tetrahedral arrangement around the central carbon.	Mod 7 Hydrocarbons CH12–7, 12–14 Bands 4–5

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 17 A **A** is correct. The reactions can be represented by the following word equations. • but-2-ene + hydrogen bromide $\rightarrow$ 2-bromobutane • butanal + acidifed potassium dichromate $\rightarrow$ butanoic acid + chromium (III) salts • butan-2-ol + ethanoic acid $\rightarrow$ 2-butyl ethanoate + water (sulfuric acid as catalyst) • butanoic acid + sodium hydrogen carbonate $\rightarrow$ sodium butanoate + carbon dioxide **B**, **C** and **D** are incorrect. These options do not identify one of the products from each reaction.	Mod 7 Hydrocarbons Mod 7 Reactions of Organic Acids and Bases CH12–6, 12–14 Band 6
Question 18 D **D** is correct. When soap dissolves in water, the polar head group interacts with water and the non-polar tail group interacts with oils and grease to form micelles. This leads to the cleaning action of soap. **A** is incorrect. A non-polar tail group does not form hydrogen bonds with water. **B** is incorrect. A non-polar tail group does not form dipole–dipole forces with water. **C** is incorrect. The polar head group does not form dipole–dipole forces with oils or fats.	Mod 7 Reactions of Organic Acids and Bases CH12–7, 12–14 Bands 4–5
Question 19 C **C** is correct. $[CO_2H]^+$ is an expected fragment from propanoic acid and has m/z = 45. **A** is incorrect. $[CH_3CH_2CO]^+$ has m/z = 57. **B** is incorrect. Propanoic acid ($CH_3CH_3CO_2H$) does not fragment to produce $[CH_3COH_2]^+$ ions. **D** is incorrect. The base peak is the most intense peak in the spectrum, which, in this spectrum, occurs at m/z = 28.	Mod 8 Analysis of Organic Substances CH12–4, 12–7 Band 6
Question 20 C **C** is correct. The circled CH_3 group is adjacent to a CH_2 group. The *n* + 1 rule predicts that this CH_3 group will be split into a group of three peaks. **A**, **B** and **D** are incorrect. These options do not correctly apply the *n* + 1 rule.	Mod 8 Analysis of Organic Substances CH12–4, 12–7 Bands 4–5

SECTION II

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 21	

Static equilibrium	*Dynamic equilibrium*
no visible change	no visible change
irreversible	reversible
forward and backward reaction rates are zero	forward and backward reactions occur at the same rate
No further chemical reactions occur.	The reactants and the products are still participating in chemical reactions.
can occur in open and closed systems	can only occur in closed systems

Note: Only three comparisons are required.

Mod 5 Static and Dynamic Equilibrium
CH12–13 Band 4

- Draws an appropriate table.

AND

- Makes THREE comparisons 4

- Draws an appropriate table.

AND

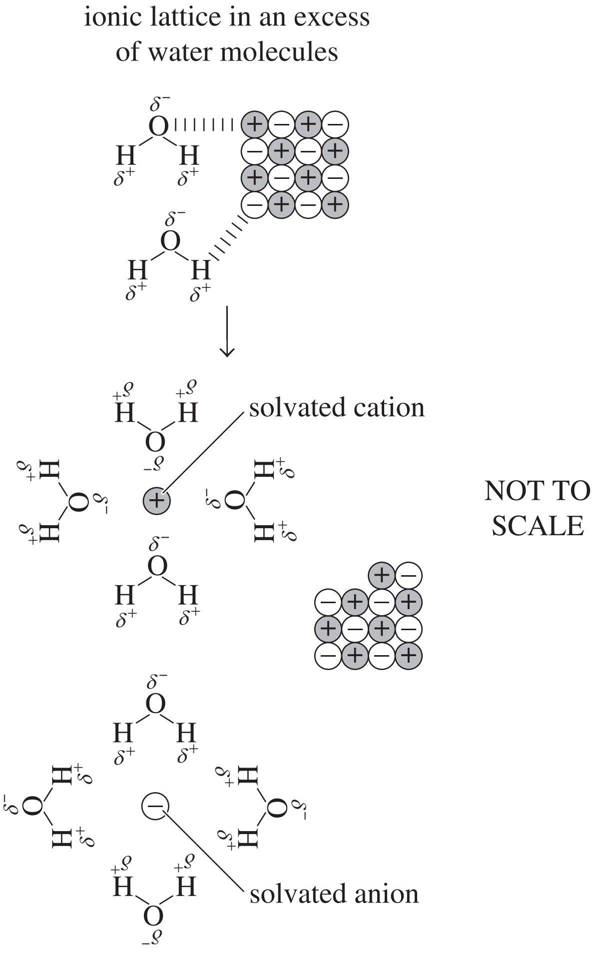
- Makes TWO comparisons 3

- Draws an appropriate table.

AND

- Makes ONE comparison 2

- Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 22	
(a) In dissolution, a solution is formed by dissolving a solute in a solvent (in this case, water). Ionic compounds in a solid form exist in three-dimensional lattices made up of oppositely charged (positive and negative) ions. The relatively positive (δ^+) hydrogen ions of the water molecules form bonds (ion–dipole interactions) with the negative ions. The relatively negative (δ^-) oxygen ions of the water molecules form similar bonds with the positive ions. The ions are pulled away from the solid lattice and form hydrated anions (negative) and hydrated cations (positive). For dissolution to happen, there must be a decrease in Gibbs free energy (G) overall when ionic bonds in the lattice are broken and new ion/water bonds are formed.  *Note: A diagram is not required for full marks, but one may be used to help develop the response.*	Mod 5 Solution Equilibria CH12–7, 12–12 Band 5 • Gives a detailed description. AND • Describes ALL bonds present . . . . .4 • Gives a description. AND • Describes some bonds present. . . . .3 • Gives a description. AND • Outlines bonding . . . . .2 • Gives a description. OR • Outlines bonding 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(b) The possible products of this reaction are silver chloride (insoluble) and magnesium nitrate (soluble). Hence, the word equation is: silver nitrate + magnesium chloride $\rightarrow$ silver chloride + magnesium nitrate The overall equation is: $2AgNO_3(aq) + MgCl_2(aq) \rightarrow 2AgCl(s) + Mg(NO_3)_2(aq)$ OR $2Ag^+(aq) + 2NO_3^-(aq) + Mg^{2+}(aq) + 2Cl^-(aq) \rightarrow 2AgCl(s) + Mg^{2+}(aq) + 2NO_3^-(aq)$ The net ionic equation removes the 'spectator ions' from the overall equation, which gives: $2Ag^+(aq) + 2Cl^-(aq) \rightarrow 2AgCl(s)$ *Note: Consider solubility rules for this question. The data sheet contains the table of solubility constants.*	Mod 5 Solution Equilibria CH12–6, 12–12 Band 5 • Writes the overall equation. AND • Writes the net ionic equation . . . . . .3 • Writes the overall equation with minor errors. AND • Writes the net ionic equation with minor errors . . . . .2 • Writes the overall equation with minor errors. OR • Writes the net ionic equation with minor errors 1
Question 23	
(a) The equation of the reaction is: $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$ Therefore, the equilibrium expression of the reaction is: $\frac{[COCl_2]}{[CO][Cl_2]}$	Mod 5 Factors that Affect Equilibrium CH12–12 Band 2 • Writes the correct equilibrium expression 1
(b) Finding the reaction quotient (Q) gives: $Q = \frac{[COCl_2]}{[CO][Cl_2]}$ $= \frac{[0.29]}{[0.011][0.063]}$ $= 418.47$ $\approx 4.2 \times 10^2$ (to two significant figures) This is not the same as the value quoted for the equilibrium constant (2.62×10^2), so the system is not at equilibrium. $Q > K_{eq}$ and Q will have to decrease. This will occur if the products decrease and reactants increase. Therefore, the direction of the reaction will shift from right to left, favouring products going to reactants. *Note: To use molar concentrations per litre, the values of reactants and products need to be divided by 10 because the container is 10 L.*	Mod 5 Calculating the Equilibrium Constant CH12–6, 12–12 Band 6 • Calculates Q. AND • Compares Q to the equilibrium constant. AND • Identifies the direction of the reaction. AND • Gives an appropriate justification . . . . .4 • Any THREE of the above points. . .3 • Any TWO of the above points. . . . .2 • Provides some relevant information 1

	Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(c)	The rate of formation (reaction rate) of carbonyl chloride is dependent on the frequency of successful collisions between the reactant (CO and Cl_2) particles. The greater the number of collisions, the greater the rate of reaction. The system is at equilibrium from t_0 to t_1, so the number of collisions of reactants will be steady, as shown by the horizontal line on the graph. At t_1, the volume decreases suddenly; particles will be closer together and collide more frequently. Additionally, molar concentrations of the reactants [CO] and [Cl_2] increase. The rate of the reaction is proportional to the concentration of the reactants, and an increase in concentration leads to a sudden increase in the rate of reaction. This is shown by the vertical line on the graph. From t_1 to t_2, the system compensates for the pressure increase caused by the volume decrease. It does this by moving the position of equilibrium to the side with fewer particles (the right-hand side, $COCl_2$). As the reactants are consumed by the forward reaction, the rate of the forward reaction gradually decreases until a new equilibrium position is reached. The new rate of reaction is still higher than before the volume decreased because the system has only partially compensated for this change. This is because the final concentrations of the reactants [CO] and [Cl_2] are higher than the concentrations at the original equilibrium.	Mod 5 Static and Dynamic Equilibrium Mod 5 Factors that Affect Equilibrium CH12–6, 12–12 Band 6 • Gives a detailed explanation. AND • Refers to specific points on the graph. AND • Uses collision theory appropriately. AND • Refers to concentration OR pressure .4 • Gives an explanation. AND • Refers to specific points on the graph. AND • Uses collision theory appropriately. OR • Refers to concentration OR pressure .3 • Gives an explanation. AND • Refers to the graph OR collision theory. OR • Mentions concentration OR pressure .2 • Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 24	

For example:

Buffers are mixtures of aqueous solutions containing a weak acid and its conjugate base or a weak base and its conjugate acid. In this investigation, a weak acid, acetic (ethanoic) acid, and its conjugate base, sodium acetate (ethanoate), were used.

The reagents used in the investigation were:

- a solution of 0.2 mol L^{-1} ethanoic acid
- a solution of 0.2 mol L^{-1} sodium ethanoate
- a solution of 0.1 mol L^{-1} sodium hydroxide
- a solution of 0.1 mol L^{-1} hydrochloric acid
- distilled water.

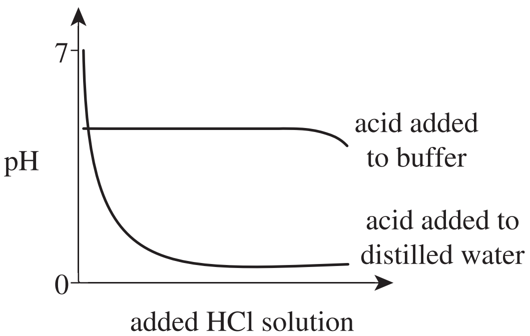
Procedure:

20 mL of ethanoic acid was mixed with 80 mL of sodium ethanoate. 50 mL portions of this mixture were placed into two 250 mL beakers. 50 mL portions of distilled water were placed in similarly sized beakers.

The initial pHs of the ethanoic acid/sodium ethanoate (buffer) mixture and distilled water were measured using a calibrated pH meter. A total of 100 mL of the sodium hydroxide (base) solution was added, 1 mL at a time, to the buffer solution, mixing after each addition, and the pH was recorded. This process was repeated, adding 100 mL of the hydrochloric acid (acid) solution to 50 mL of the buffer solution, then adding 100 mL of the base solution to 50 mL of water and, finally, adding 100 mL of the acid solution to 50 mL of water. The changes of pH in the buffer solution and the water were compared.

Results:

The pH of the buffer solution remained stable with the addition of both basic and acidic solutions until near the end of the additions. The pH of the distilled water changed rapidly with the addition of both the base and acid.



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Mod 6 Quantitative Analysis
CH12–3, 12–7, 12–13 Band 6

- Describes in detail the chemicals used to make a buffer.

AND

- Describes all SIX of the following points:
  - how the buffer is prepared
  - how the buffer is tested
  - how the buffer reacts
  - how the water reacts
  - the conclusions reached
  - the safety aspects 6–7

- Describes the chemicals used to make a buffer.

AND

- Outlines all SIX of the following points:
  - how the buffer is prepared
  - how the buffer is tested
  - how the buffer reacts
  - how the water reacts
  - the conclusions reached
  - the safety aspects 5

- Outlines all SIX of the following points:
  - how the buffer is prepared
  - how the buffer is tested
  - how the buffer reacts
  - how the water reacts
  - the conclusions reached
  - the safety aspects 4

- Any THREE of the above points. . .3

- Any TWO of the above points. 2

- Provides some relevant information 1

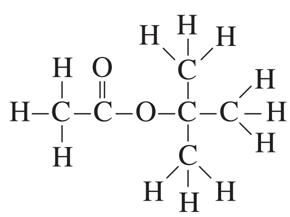
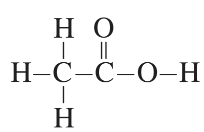
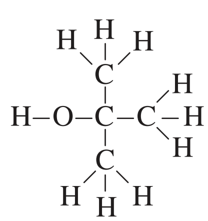
Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(continued) *Conclusion:* A buffer solution resists changes in pH when either a base or an acid is added to it, whereas water does not resist changes in pH. *Safety:* Wear leather shoes with fully enclosed uppers, safety glasses and a lab coat. Avoid contact with chemicals. If the pH meter is mains-powered, check that it is safety tagged. *Note: This buffer is not neutral, it is slightly acidic. There are a range of acceptable responses, including an alkaline buffer (for example, using ammonium hydroxide and ammonium chloride solutions). A graph is not required, but may be used to help develop the response.*	
Question 25	
(a) The cup should be made of polystyrene. Polystyrene is a good insulator and does not react with acids or bases.	Mod 6 Properties of Acids and Bases CH12–13 Band 3 • Names a suitable material. AND • Names at least ONE relevant property 1
(b) $[OH^-] = 2.4$ mol L^{-1} $pOH = -\log 2.4$ $= -0.3802$ $pH + pOH = 14$ $pH = 14 - (-0.3802)$ $= 14 + 0.3802$ $= 14.38$ *Note: Sodium hydroxide is a strong base, so it can be assumed that it is completely ionised.*	Mod 6 Using Brønsted–Lowry Theory CH12–6, 12–13 Band 4 • Shows appropriate calculations. AND • Provides the correct answer . . . . . . .2 ——— • Shows appropriate calculations 1
(c) $HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$ Hence, the acid : base ratio is 1 : 1. The number of moles of the base is equal to the number of moles of the acid, so $v_1 \times c_1 = v_2 \times c_2$ can be used. $v_1 \times c_1 = v_2 \times c_2$ $50 \times 2.4 = v_2 \times 2.1$ $v_2 = \frac{50 \times 2.4}{2.1}$ $= 57$ mL	Mod 6 Properties of Acids and Bases CH12–6, 12–13 Band 4 • Shows appropriate calculations. AND • Provides the correct answer . . . . . . .2 ——— • Shows appropriate calculations 1

	Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(d)	The enthalpy of neutralisation of a strong acid/base is calculated using $q = mc\Delta T$, where q is measured in kJ, m is the mass of the solution in kg, c is the specific heat capacity of water (4.18×10^3 J kg^{-1} K^{-1}) and ΔT is the change in temperature. $\text{mass of water} = 50\text{ g} + 57\text{ g} = 107\text{ g} = 0.107\text{ kg}$ ΔT is equal to the average of the temperature changes. $\Delta T = \left(\frac{9+9+10+9+10}{5}\right) = 9.4\text{ K}$ $q = 0.107 \times 4.18 \times 10^3 \times 9.4 = 4.204 \times 10^3\text{ J}$ To get enthalpy change per mole: $\text{number of moles} = \left(\frac{50}{1000} \times 2.4\right) = 0.12\text{ mol}$ $\text{molar enthalpy of neutralisation} = \frac{4.204 \times 10^3}{0.12} = 35.04 \times 10^3\text{ J} \approx -35 \times 10^3\text{ J}$ *Note: ΔH is negative as the reaction is exothermic.*	Mod 6 Properties of Acids and Bases CH12–6, 12–13 Band 6 • Uses the appropriate equation. AND • Shows appropriate calculations. AND • Provides the correct answer . . . . . . .3 • Uses the appropriate equation. AND • Shows appropriate calculations. OR • Provides the correct answer . . . . . . .2 • Uses the appropriate equation. OR • Shows appropriate calculations 1
(e)	The experimental value obtained is much lower than the accepted value. Heat may have been lost to the surrounding environment through the calorimeter.	Mod 6 Properties of Acids and Bases CH12–5, 12–13 Band 3 • Gives a valid reason. 1

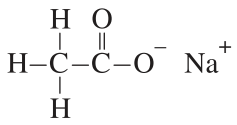
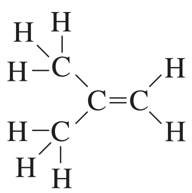
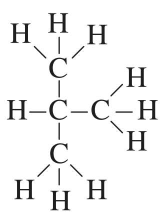
Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 26	
A substance is amphiprotic if it can, in the right circumstances, lose a proton (hydrogen ion) to act as a Brønsted–Lowry acid and gain a proton to act as a Brønsted–Lowry base. An example of an amphiprotic substance is sodium hydrogen carbonate, commonly known as bicarbonate of soda. The following reaction occurs when sodium hydrogen carbonate acts as an acid. $HCO_3^-(aq) + OH^-(aq) \rightleftharpoons CO_3^{2-}(aq) + H_2O(l)$ The following reaction occurs when sodium hydrogren carbonate acts as a base. $HCO_3^-(aq) + H_3O(aq) \rightleftharpoons H_2CO_3(aq) + H_2O(l)$	Mod 6 Using Brønsted–Lowry Theory CH12–7, 12–13 Band 4 • Uses a suitable example. AND • Provides at least ONE suitable equation. AND • Gives a detailed explanation . . . . . .4 • Uses a suitable example. AND • Provides at least ONE suitable equation. AND • Gives an explanation . . . . .3 • Uses a suitable example. AND • Provides at least ONE suitable equation. OR • Gives an explanation . . . . .2 • Provides some relevant information 1
Question 27	
(a) A few drops of the compound to be tested is added to an acidified solution of potassium dichromate and the resulting mixture is warmed in a water bath for a few minutes. Propanal will cause the original orange colour (due to dichromate) of the solution to change to a blue/green colour (due to chromium (III) ions). Propanone does not react with acidified dichromate solutions, so no colour change will occur.	Mod 7 Alcohols Mod 7 Reactions of Organic Acids and Bases CH12–5, 12–6, 12–14 Bands 5–6 • Describes a suitable test. AND • Describes the expected observations . . . . .2 • Provides some relevant information 1

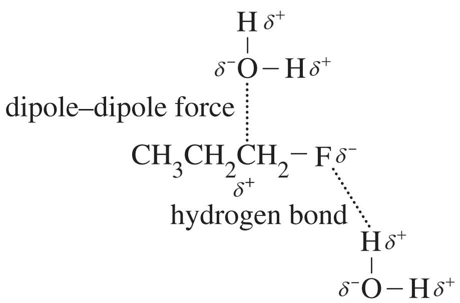
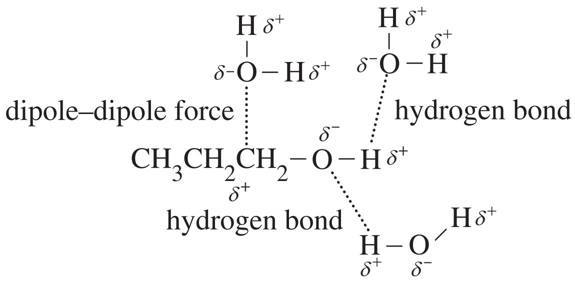
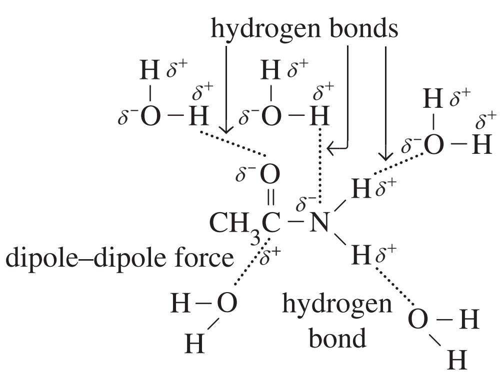
<table>
<tr><th>Sample answer</th><th>Syllabus content, outcomes, targeted performance bands and marking guide</th></tr>
<tr><td>(b) A few drops of the compound to be tested is added to a solution of bromine water.

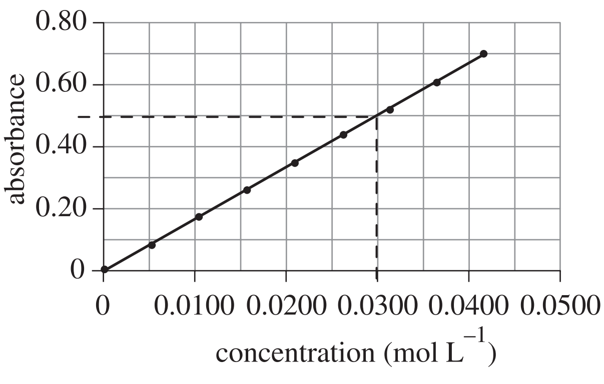
Hex-3-ene will cause the original orange/red colour (due to bromine) of the solution to rapidly fade, leaving a colourless mixture.

Cyclohexane does not rapidly react with bromine, so the original orange/red colour will not fade.</td><td>Mod 7 Alcohols
Mod 7 Reactions of Involving Hydrocarbons
CH12–5, 12–6, 12–14 Bands 5–6
• Describes a suitable test.
AND
• Describes the expected observations 2
<hr>• Provides some relevant information . . . . .1</td></tr>
<tr><td>Question 28</td><td></td></tr>
<tr><td>
<table>
<tr><th colspan="2">Compound A</th></tr>
<tr><td>Structural formula</td><td>Justification</td></tr>
<tr><td></td><td>Compound A is the ester 2-methyl-2-propyl ethanoate, as this will hydrolyse to yield ethanoic acid and 2-methylpropan-2-ol.</td></tr>
<tr><th colspan="2">Compound B</th></tr>
<tr><td>Structural formula</td><td>Justification</td></tr>
<tr><td></td><td>Compound B reacts with Na_2CO_3 to give a sodium salt plus carbon dioxide gas. This is consistent with the compound being ethanoic acid.</td></tr>
<tr><th colspan="2">Compound C</th></tr>
<tr><td>Structural formula</td><td>Justification</td></tr>
<tr><td></td><td>Alkene E was formed from the dehydration of compound C, suggesting that compound C is an alkanol. Compound C resists oxidation with an acidified permanganate solution, indicating that compound C is a four-carbon tertiary alkanol. The only possible four-carbon tertiary alkanol is 2-methylpropan-2-ol.</td></tr>
</table>
(continues on next page)
</td><td>Mod 7 Reactions of Organic Acids and Bases
CH12–5, 12–6, 12–14 Bands 5–6
• Draws the structural formulae for all SIX compounds.
AND
• Provides a justification for all SIX compounds. 7
<hr>• Draws the structural formulae for most compounds with relevant justifications. 6
<hr>• Draws the structural formulae for some compounds with relevant justifications.
OR
• Draws the structural formulae for all SIX compounds without justification 4–5
<hr>• Identifies some of the compounds.
OR
• Draws the structural formulae for some compounds 2–3
<hr>• Provides some relevant information . . . . .1</td></tr>
</table>

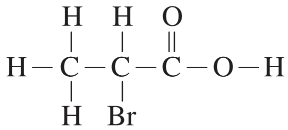
Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(continued)	

Compound D	
Structural formula	*Justification*
	Compound D, sodium ethanoate, is the sodium salt of compound B, ethanoic acid.
Compound E	
Structural formula	*Justification*
	Alkene E was formed from the dehydration of compound C, so it must have the same branched carbon backbone as the tertiary alkanol.
Compound F	
Structural formula	*Justification*
	Compound F is an alkane that results from the hydrogenation of alkene E.

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 29	
Water can form hydrogen bonds and dipole–dipole forces with neutral molecules. All four compounds are neutral molecules that, being similar in size, form similarly sized dispersion forces. • But-1-ene is non-polar and cannot form hydrogen bonds with water. Therefore, but-1-ene is insoluble in water. • 1-fluoropropane is very polar and can form both dipole–dipole forces and one hydrogen bond with water. Therefore, it is slightly soluble in water. • Both propan-1-ol and ethanamide are very polar and can form dipole–dipole forces and hydrogen bonds with water. Both can form many more hydrogen bonds with water than 1-fluoropropane, resulting in both compounds being much more water-soluble than 1-flouropropane.   	Mod 8 Reactions of Organic Acids and Bases CH12–4, 12–5, 12–7 Bands 4–5 • Explains the different water solubilities of all FOUR compounds. AND • Provides at least ONE appropriate, fully labelled diagram . . . . .5 --- • Explains the different water solubilities of at least TWO compounds. AND • Provides at least ONE diagram. . . . . 3–4 --- • Explains the different water solubilities of at least ONE compound. OR • Outlines some intermolecular forces associated with functional groups . . . . .2 --- • Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 30	
Based on the information given in the table, industrial process B is the better investment. *Yield and purity:* Industrial process B has higher annual yields and yields a product of greater purity. Based on these criteria, industrial process B is the better investment. *Economic costs:* The capital cost for industrial process A is \$1 500 000 000 for a plant that has a 15-year lifetime. This gives a capital cost of \$100 000 000 per year. The capital cost for industrial process B is \$1 900 000 000 for a plant with a 25-year lifetime. This gives a capital cost of \$76 000 000 per year. Both chemical costs and energy costs for industrial process B are much less than those for industrial process A. In summary, the economic costs associated with industrial process B over its lifetime are much less than the economic costs associated with industrial process A. On an economic basis, industrial process B is the better investment. *Environmental impact:* Industrial process A produces waste products including HCl (a toxic environmental product that must be stored) and NaCl (not toxic, but an environmental hazard if it enters freshwater systems). Industrial process B produces a side product of commercial value and has a much lower environmental impact. Based on this criterion, industrial process B is the better investment.	Mod 8 Chemical Synthesis and Design CH12–4, 12–7, 12–15 Bands 4–5 • Names industrial process B as the better investment. AND • Refers to yield and purity, economic costs and environmental impacts using information from the table to support the choice of industrial process B . . . . 3–4 • Names industrial process B as the better investment. AND • Refers to information in the table to support the choice of industrial process B . . . . 2 • Provides some relevant information 1
Question 31	
 From the graph, [Cu^{2+}] = 0.0300 mol L^{-1} for the diluted solution. $n(Cu^{2+}) = 0.0300 \times 0.0800 = 0.00240$ mol (contained within 20.0 mL original solution) mass of $Cu^{2+} = 0.00240 \times 63.55 = 0.153$ g	Mod 8 Analysis of Inorganic Substances CH12–4, 12–7 Bands 3–4 • Shows on graph how the initial figure is obtained. AND • Determines the mass. AND • Shows all relevant working . . . . 4 • Determines the mass. AND • Shows all relevant working . . . . 3 • Shows substantially correct working . . . . 2 • Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 32	
The metal salt is magnesium sulfate. The metal salt is colourless and, therefore, cannot be a copper salt. Calcium salts will give a positive red flame test and barium compounds will give a positive green flame test. Therefore, the flame test eliminates these two cations, leaving magnesium as the only remaining option. Magnesium hydroxide is insoluble; therefore, as the metal salt is soluble, it cannot be magnesium hydroxide. The failure of sample B to give a precipitate eliminates magnesium chloride as a possibility. The precipitate formed by sample A is magnesium hydroxide: $Mg^{2+}(aq) + 2OH^{-}(aq) \rightarrow Mg(OH)_2(s)$ The precipitate formed by sample C is barium sulfate: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ The compound is not a carbonate as sample C does not produce bubbles of gas when HCl is added. Therefore, the metal salt must be magnesium sulfate.	Mod 8 Analysis of Inorganic Substances CH12–4, 12–7 Bands 3–4 • Identifies the metal salt. AND • Includes ONE relevant net ionic equation. . . . . .3 • Identifies either the anion OR cation in the metal salt. AND • Includes ONE relevant net ionic equation. . . . . .2 • Provides some relevant information .1
Question 33	
The mass of fertiliser in each 25.0 mL sub-sample is 1.04 g. From the graph, the maximum mass of $BaSO_4$ is 1.25 g. $\text{molar mass of } BaSO_4 = 137.3 + 32.07 + 4 \times 16.00 = 233.4 \text{ g mol}^{-1}$ $n(BaSO_4) = \frac{1.25}{233.4} = 0.00536 \text{ mol}$ $\text{mass of sulfur} = 0.00536 \times 32.07 = 0.172 \text{ g}$ $\text{percentage of sulfur} = \frac{0.172}{1.04} \times 100 = 16.5\%$	Mod 8 Analysis of Inorganic Substances CH12–2, 12–4, 12–7 Band 4 • Determines the percentage of sulfur. AND • Shows all relevant working . . . . . . .4 • Shows substantially correct working . . . . .2–3 • Provides some relevant steps of the calculation 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 34	
 *Infrared spectrum:* • The infrared spectrum shows a strong, broad absorption with a maximum at about 3000 cm^{-1}, which is consistent with an OH group. • The strong absorbance at approximately 1730 cm^{-1} is consistent with a carbonyl group. • The presence of these two absorbances suggest the presence of a carboxylic acid (–COOH) functional group. *Mass spectrum:* • The molecular ion appears as a doublet of two peaks of equal intensity at m/z = 152 and 154. This suggests the presence of a bromine atom in the molecule, thus identifying the halogen indicated in the preliminary tests. • The peaks at m/z = 108 and 110 represent a cleavage from the parent ion of 44, indicating the loss of CO_2. This suggests an acid functional group. • The peak at m/z = 45 is consistent with fragmentation leading to the formation of the $[COOH]^+$ ion, again suggesting a carboxylic acid. *^1H NMR spectrum:* • The ^1H NMR spectrum indicates that there are five hydrogen atoms in the molecule. • The ^1H NMR spectrum indicates the partial structure of CH_3–CH–Y. The splitting pattern is in accord with the *n* + 1 rule, where *n* is the number of hydrogens on the adjacent carbon. The CH_3 will be split into a doublet by the single hydrogen on the adjacent carbon. The CH will be split into a quartet by the three hydrogens on their adjacent carbon. (continues on next page)	Mod 8 Analysis of organic Substances CH12–4, 12–7 Band 5–6 • Draws the correct structural formula of $CH_3CHBrCOOH$. AND • Justifies the structual formula showing an extensive understanding of the interpretation of spectroscopic data. AND • Refers explicitly to the relevant spectroscopic data . . . . .8–9 • Draws the correct structural formula of $CH_3CHBrCOOH$. AND • Justifies the structural formula showing a thorough understanding of the interpretation of spectroscopic data. AND • Refers to the relevant spectroscopic data . . . . .6–7 • Draws the correct structural formula for an isomer of $CH_3CHBrCOOH$. AND • Justifies the structural formula showing an understanding of the interpretation of spectroscopic data. AND • Refers to the relevant spectroscopic data . . . . .4–5 • Determines a functional group or groups present within the molecule OR appropriate partial structures. AND • Shows some understanding of the interpretation of spectroscopic data . . . . .2–3 • Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(continued) *^{13}C NMR spectrum:* • The ^{13}C NMR spectrum indicates that there are three unique carbon atoms in the molecule. • The peak at 177 ppm is consistent with a carboxylic group (COOH). • The peak at 21 ppm is consistent with a carbon attached to an alkyl group. • The peak at 39 ppm is consistent with a halo alkane carbon or a carbon adjacent to a carbonyl group. *In summary:* The compound contains three carbon atoms and five hydrogen atoms (including a partial structure of CH_3CH). The halogen identified in the preliminary tests is identified as a bromine atom. The molecule contains a carboxylic acid functional group. The sub-structure elements are thus CH_3CH, Br and COOH, resulting in $CH_3CHBrCOOH$ as the most likely structure.	

