Neap

Trial Examination 2024

HSC Year 12 Chemistry

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   The diagram shows the initial and final stages of a reaction.
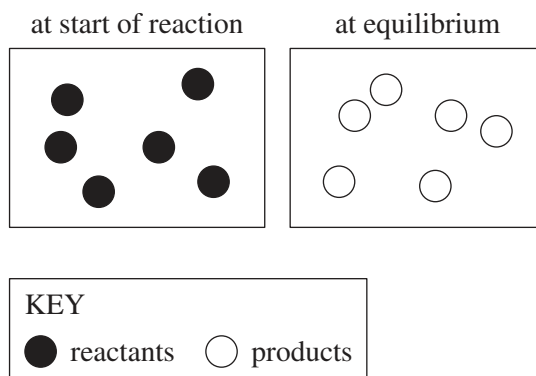
This reaction is an example of

A.   static equilibrium.

B.   a reversible reaction.

C.   dynamic equilibrium.

D.   a reaction that does not react completely.

2   Which row of the table correctly describes open and closed systems?

	Open systems	*Closed systems*
A.	only involve gases	only involve liquids and solids
B.	can exchange energy and matter with surroundings	can only exchange energy with surroundings
C.	can only exchange energy with surroundings	can exchange energy and matter with surroundings
D.	can exchange energy and matter with surroundings	do not have any interaction with surroundings

3 Which of the following equilibrium constants (K_{eq}) is most likely to indicate a reaction where the reactants are most favoured?

    A. $K_{eq} = 2.1 \times 10^{-12}$

    B. $K_{eq} = 3.7 \times 10^{-4}$

    C. $K_{eq} = 5.9 \times 10^{5}$

    D. $K_{eq} = 9.8 \times 10^{13}$

4 A student was supplied with a sample of an unknown powder. The diagram shows the student's treatment of the powder.

Stage I — water vapour — pink — Heat is added.

Stage II — blue — The powder is left to cool.

Stage III — blue — Water is added.

Stage IV — pink
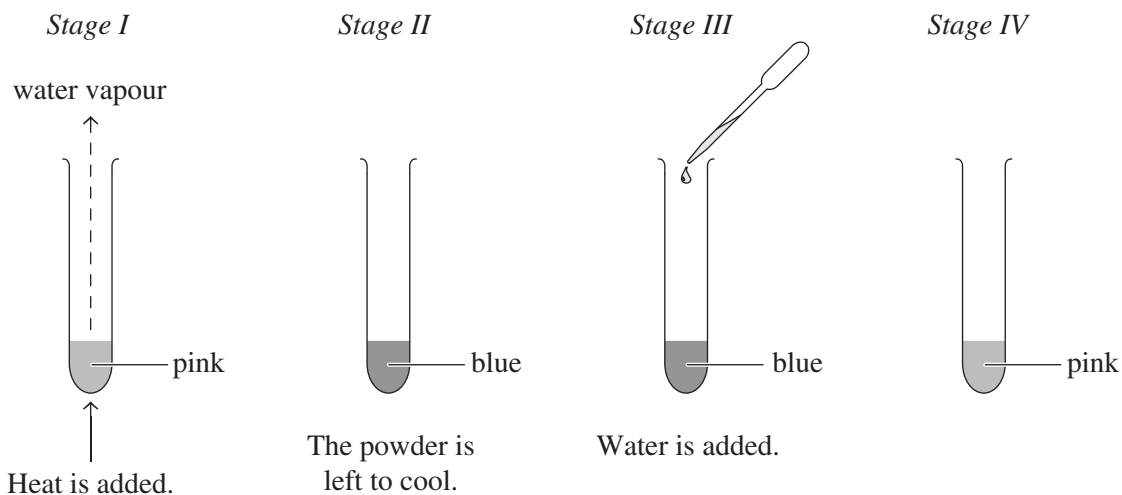
Using the information provided, which of the following conclusions can be made?

    A.   The reaction is exothermic.

    B.   The reaction is endothermic.

    C.   The reaction is reversible.

    D.   There will be no change if the compound at stage IV is heated.

5 Methane and water can be used to form hydrogen according to the following equation.

$$CH_4(g) + 2H_2O(g) \rightleftharpoons 4H_2(g) + CO_2(g)$$
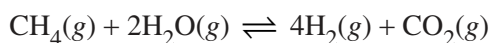
A system containing the substances shown in the equation was allowed to reach equilibrium. The system is kept at a constant volume and temperature.

If carbon dioxide is added to the system, the concentration of hydrogen will

    A.   not change.

    B.   increase.

    C.   decrease.

    D.   initially increase then decrease.

6 Which of the following statements about amphiprotic substances is NOT correct?

A. Water is amphiprotic.

B. They must contain both H^+ and OH^-.

C. They can accept and donate protons.

D. An amphiprotic substance must contain at least one hydrogen atom.

7 A student prepared a solution containing 100 mL of 0.1 mol L^{-1} disodium hydrogen phosphate (Na_2HPO_4) and 100 mL of 0.1 mol L^{-1} sodium dihydrogen phosphate (NaH_2PO_4).

They measured the initial pH of the mixture, then conducted two tests where different substances were added to the mixture and the effect on the pH was measured.

In the first test, the student added a few drops of 0.1 mol L^{-1} sodium hydroxide (NaOH) solution. In the second test, they added a few drops of 0.1 mol L^{-1} hydrochloric acid (HCl).

The tests were repeated using distilled water. The results are shown in the table.

Substance	Initial pH	pH after NaOH added	pH after HCl added
phosphate mixture	7.1	7.2	6.9
distilled water	7.0	10.9	3.1

Which of the following statements is correct?

A. The phosphate mixture acts as a buffer.

B. The phosphate compounds are covalent compounds.

C. The phosphate compounds are insoluble.

D. Distilled water is not affected by the addition of small amounts of acids or bases.

8 A solution of potassium hydroxide (KOH) has a concentration of 0.2 mol L^{-1}.
What is its pH?

A. 0.7

B. 1.6

C. 12.4

D. 13.3

9 The diagram shows a reaction between HX and a water molecule.
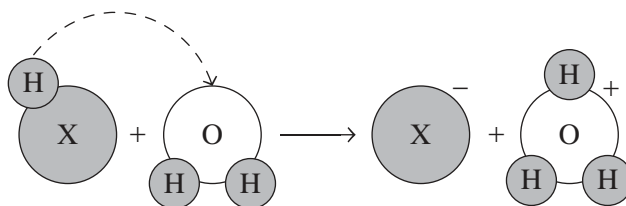
Which of the following statements is correct?

A. The reaction is an acid–base neutralisation.

B. HX is acting as an Arrhenius base.

C. HX is acting as a Brønsted–Lowry acid.

D. HX is acting as a Brønsted–Lowry base.

10 Which of the following equations best represents the reaction between solid magnesium and sulfuric acid?

A. $Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq)$

B. $Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$

C. $2Mg(s) + H_2SO_4(aq) \rightarrow Mg_2SO_4(aq) + H_2(l)$

D. $2Mg(s) + H_2SO_4(aq) \rightarrow Mg_2SO_4(aq) + H_2O(l)$

11 The diagram shows a step in the polymerisation of a free radical.
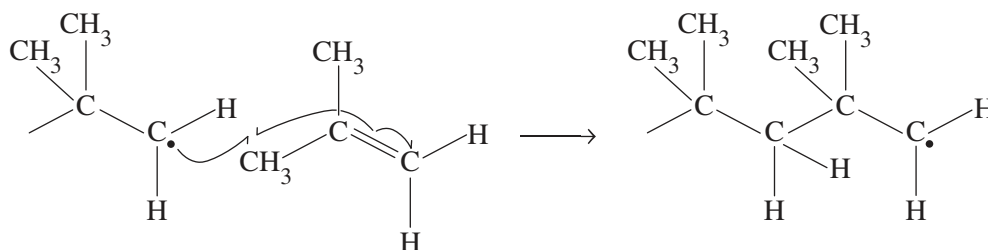
Which step is shown in the diagram?

A. initiation

B. propagation

C. continuation

D. termination

12 The graph shows the boiling points and chain lengths of nine unbranched organic compounds, A–I. Three of the compounds are chain carboxylic acids, three are amines and three are amides.
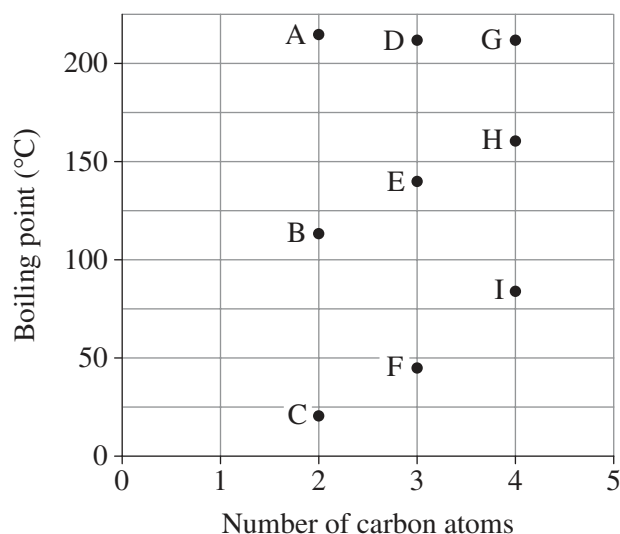
Which row of the table correctly identifies the groups to which compounds A–I belong?

	Carboxylic acid	Amine	Amide
A.	A, B, C	D, E, F	G, H, I
B.	D, E, F	A, B, C	G, H, I
C.	A, D, G	B, E, H	C, F, I
D.	B, E, H	C, F, I	A, D, G

13 Three chemical formulae are shown.

- Compound X: $CH_3(CH_2)_{15}COOK$
- Compound Y: $(CH_3)_3C(CH_2)_3NHCH_3$
- Compound Z: $CH_3(CH_2)_5CHO$

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

	Compound X	Compound Y	Compound Z
A.	soap	amine	alcohol
B.	acid	soap	ketone
C.	soap	amine	aldehyde
D.	ester	amide	acid

14 A stream was suspected to have been polluted by a metal ion. A scientist analysed a sample of water from the polluted stream to identify the pollutant.

The scientist collected a 50.0 mL sample of water from the stream. They diluted the sample with distilled water to reach a final volume of 500.0 mL. A series of tests were performed on the diluted sample. The results of the tests are recorded in the table.

Test	Results
Five drops of dilute HCl solution were added to 2.00 mL of the diluted sample.	No visible reaction occurred.
Five drops of dilute Na_2SO_4 solution were added to 2.00 mL of the diluted sample.	A white precipitate formed.
A flame test was performed on a small amount of the diluted sample.	A pale-green flame formed.

Which of the following is most likely to be the pollutant?

A. Na^+

B. Ca^{2+}

C. Ba^{2+}

D. Fe^{3+}

15 Which of the following is a functional group isomer of hexanoic acid?

A. hexan-1-ol

B. methyl pentanoate

C. 2-methylpentanoic acid

D. cyclohex-2-ene-1,4-diol

16 The structure of N,N-diethylacetamide is shown.
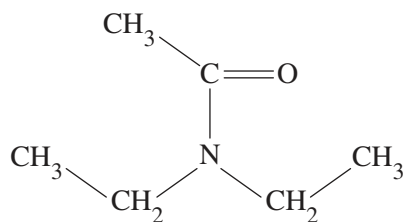
The mass spectrum of N,N-diethylacetamide has a peak at a mass-to-charge ratio (m/z) of 72.

Which formula most likely represents this peak?

A. $[CH_3CH_2]^+$

B. $[CH_3CH_2NCH_2CH_3]^+$

C. $[CH_3CONCH_2CH_3]^+$

D. $[CH_3CON]^+$

17 The ^{13}C NMR spectrum of an organic compound is shown.

Chemical shift (ppm)
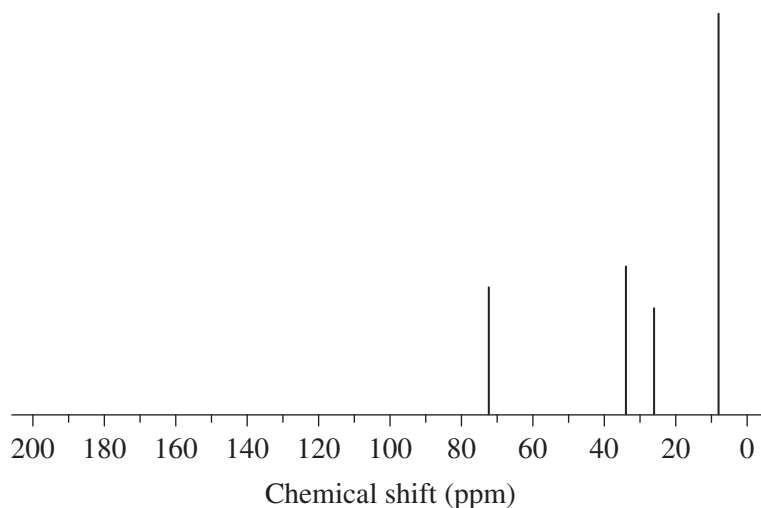
Which of the following compounds would produce this ^{13}C NMR spectrum?

A. 3-methylpentan-3-ol

B. pentan-3-ol

C. butan-2-one

D. 2-methylpropan-1-ol

18 The structural formula of a molecule is shown. The molecule reacts with hydrogen bromide (HBr) to form $C_5H_{11}Br$.
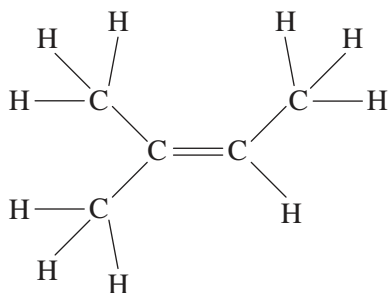
How many different isomers of $C_5H_{11}Br$ could be formed?

A. 1

B. 2

C. 3

D. 4

19 Precipitation titration can be used to determine the percentage by mass of certain ions in food samples. A 200.0 g food sample was chemically dissolved in concentrated nitric acid. The resulting solution was transferred into a standard flask and distilled water was added to give a final volume of 500.0 mL.

An excess of silver nitrate solution was added to a 50.0 mL sample of the diluted solution, which reacted with a chloride ion to form a precipitate of AgCl. The precipitate was washed and dried, producing 0.376 g of dry solid.

Assume that the presence of the chloride ion in the food sample was caused by the addition of sodium chloride (NaCl) during the manufacture of the food product.

What was the percentage by mass of NaCl in the food sample?

A. 0.077%

B. 0.465%

C. 0.766%

D. 1.530%

20 Curcumin ($MM = 368.4$ g mol^{-1}) dissolves in ethanol to form a yellow solution, which can be used as a natural food colouring.

A solution was prepared by dissolving 49.5 µg of curcumin in 10.0 mL of water. The UV-visible spectrum of this solution is shown.
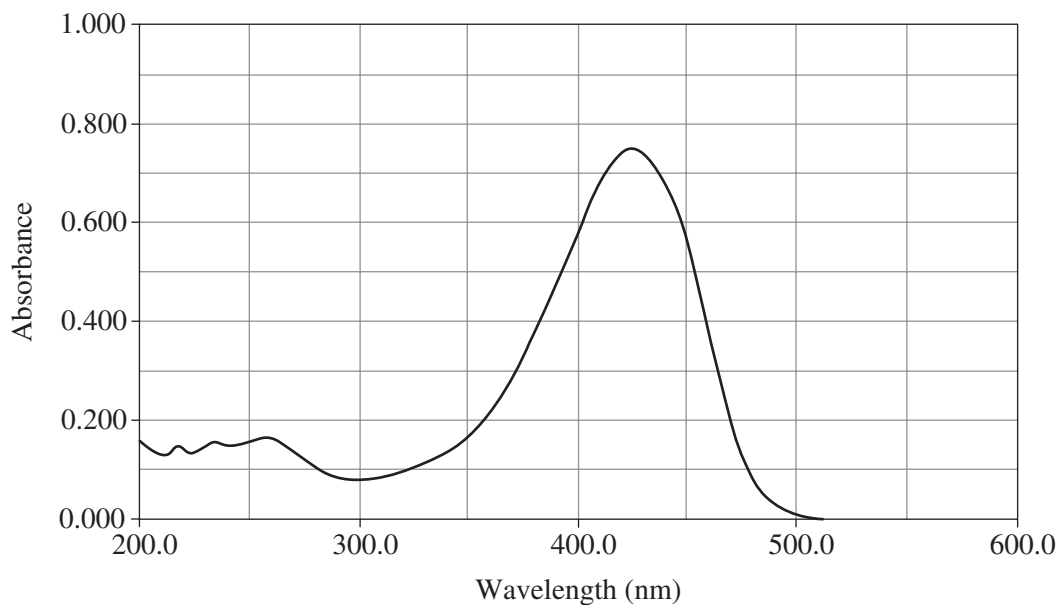
The optical path length of the sample cell used was 1.00 cm.

What is the extinction coefficient, ε, of curcumin at a wavelength of 424 nm?

A.   0.75 mol^{-1} L cm^{-1}

B.   66.0 mol^{-1} L cm^{-1}

C.   559 mol^{-1} L cm^{-1}

D.   55 900 mol^{-1} L cm^{-1}

HSC Year 12 Chemistry

Section II Answer Booklet

80 marks
Attempt Questions 21–33
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 (8 marks)

In an endothermic equilibrium reaction where all substances are gases, nitrosyl chloride (NOCl) forms nitrogen monoxide (NO) and chlorine (Cl_2).

(a)   Write a balanced chemical equation for this reaction.   **1**

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(b)   Write the equilibrium expression, K_{eq}, for this reaction.   **1**

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(c)   If the pressure of the system is kept constant, what is the effect of increasing the temperature of the system?   **2**

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Question 21 continues on page 13

Question 21 (continued)

(d) A student was provided with the graph of the reaction shown. **4**
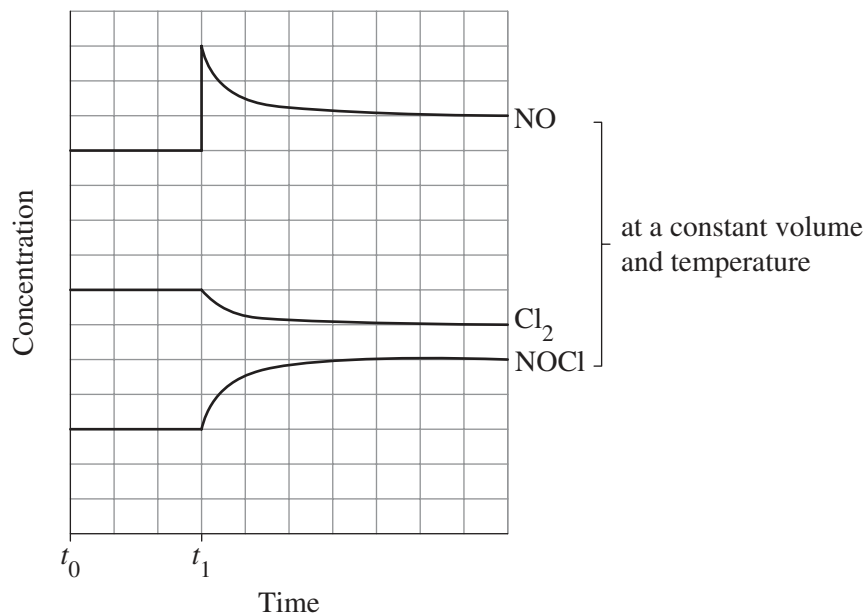
The student was asked to describe the progress of the reaction. They submitted the response shown.

> The reaction is in equilibrium and the concentrations of the reactant and products are steady between t_0 and t_1. At t_1, there is a change to the system and all three concentrations change. This is due to the addition of a catalyst at t_1. After a short time, the concentrations stabilise and the reaction returns to equilibrium, resulting in a new value for the equilibrium constant.

Evaluate the student's description of the reaction.

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End of Question 21

Question 22 (7 marks)

The flowchart shows some chemical interactions involving polymers and their monomers.
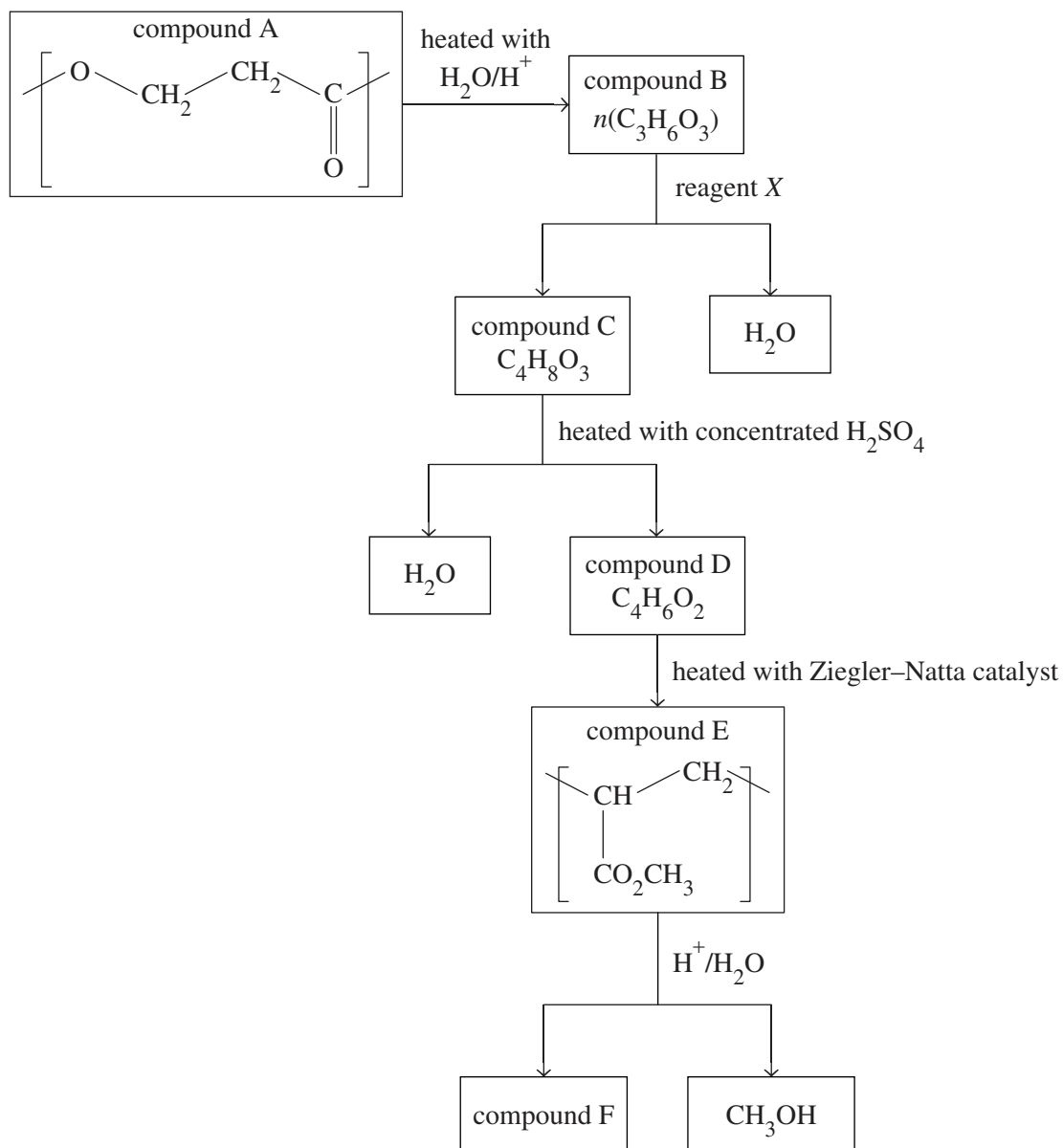
Question 22 continues on page 15

Question 22 (continued)

(a)   Draw the structural formula of the compound in the flowchart that is a monomer for   **1**
      a condensation polymer.

(b)   Using structural formulae, draw a diagram that represents the conversion of compound B   **2**
      into compound C. Include reaction conditions.

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(c)   Complete the table with the names and structural formulae of compounds D and F.   **4**

	Name	*Structural formula*
Compound D		
Compound F		

End of Question 22

Question 23 (6 marks)

Ionic compounds can form saturated solutions in water.

(a) Outline what happens to the solid solute and aqueous ions in a saturated solution.   **2**

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(b) Write the equilibrium expression, K_{sp}, for a saturated solution of lead(II) sulfate.   **1**

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(c) Lead(II) sulfate is an ionic compound used in lead–acid batteries.   **3**

Calculate the solubility of lead(II) sulfate at 25°C, in grams per litre.

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Question 24 (6 marks)

Sodium hypochlorite (NaOCl), commonly known as liquid chlorine, is a widely used disinfectant in swimming pools. When sodium hypochlorite reacts with water, it forms hypochlorite ions (OCl^- (aq)).

Swimming pools require regular monitoring to ensure that the pH of the water remains within the recommended range of 7.1–7.6. The diagram shows four indicators and their colours at various pHs.

Colour range of indicators

bromothymol blue	yellow	blue
methyl orange	red	yellow
bromothymol green	yellow	blue
phenolphthalein	colourless	pink

pH: 1 2 3 4 5 6 7 8 9 10 11 12 13
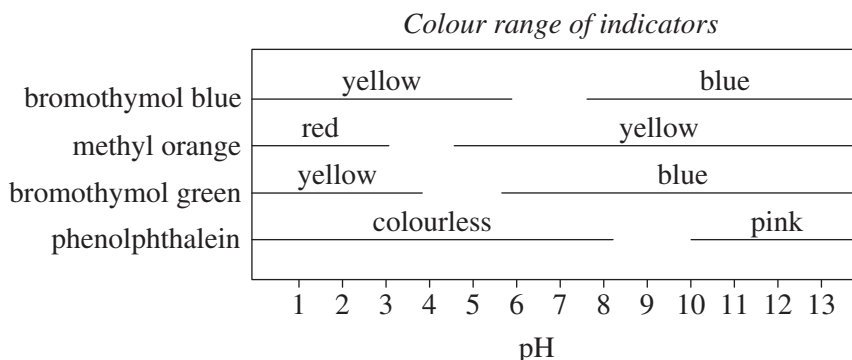
(a) Explain how the hypochlorite ions will affect the pH of water. Support your answer with a relevant net ionic equation. **2**

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(b) Which indicator should be used to monitor the pH of a pool? Justify your answer. **2**

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(c) Under certain conditions, hypochlorous acid (HOCl) can react with water, as shown in the equation. **2**

$$HOCl(aq) + H_2O(l) \rightleftharpoons OCl^-(aq) + H_3O^+$$
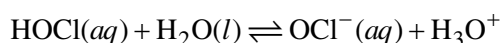
On the equation, label the conjugate acid/base pairs present. Use appropriate scientific notation.

Question 25 (9 marks)

Ethanoic acid (CH_3COOH) can be diluted with water to make vinegar. Most types of vinegar typically require a concentration of 4–8% ethanoic acid.

A commercial producer of vinegar conducted a batch test to check whether their vinegar contained the required concentration of ethanoic acid. The batch of vinegar was sent to a laboratory for analysis, and part of the resulting laboratory report is shown.

> The vinegar was diluted by a factor of 10. A 25.00 mL sample of the diluted vinegar was titrated with 0.12 mol L^{-1} of sodium hydroxide (NaOH), which was added in 2 mL increments. Potentiometric titration was used to find an equivalence point. The conductivity graph of the titration is shown.
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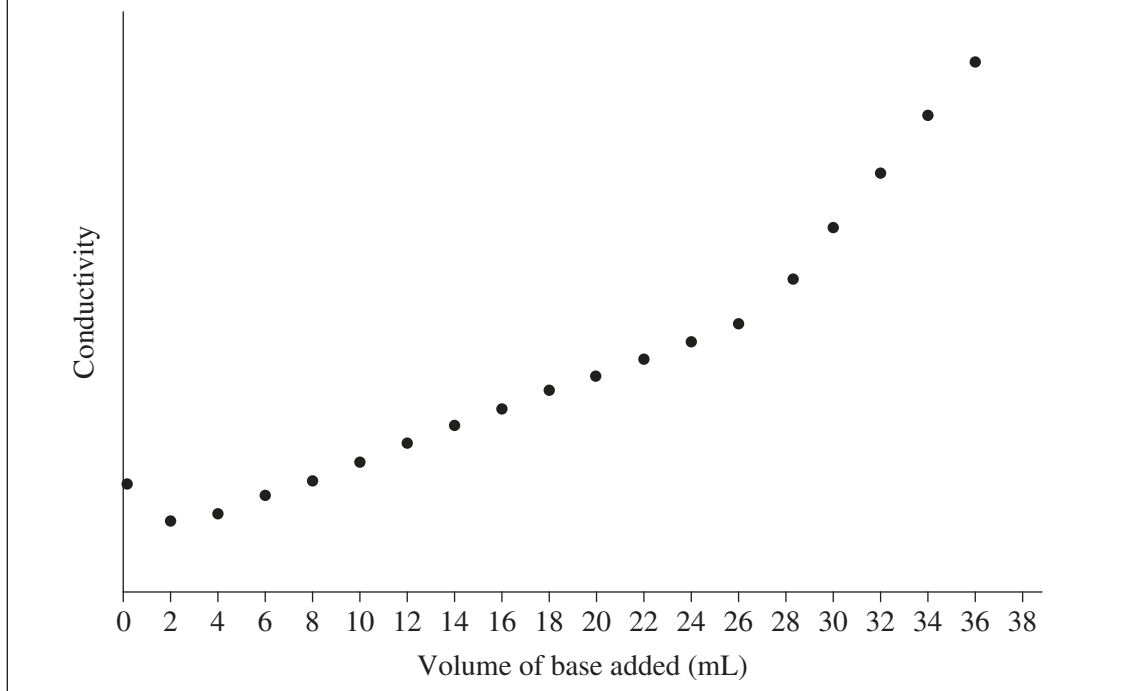
(a)   Using the graph, determine the equivalence point of the reaction.   **2**

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(b)   Write a balanced chemical equation for the neutralisation of ethanoic acid by the sodium hydroxide solution.   **1**

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Question 25 continues on page 19

Question 25 (continued)

(c)   Using the equivalence point obtained in part (a), determine whether the concentration of   **3**
      ethanoic acid in the vinegar is within the required range.

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(d)   A 1.0 mol L^{-1} solution of ethanoic acid has a dissociation constant, K_a, of 1.8×10^{-5}.   **3**
      Calculate the pH of the solution.

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End of Question 25

Question 26 (4 marks)

A group of students conducted an experiment using the calorimeter shown to determine the heat of neutralisation for an acid/base reaction.
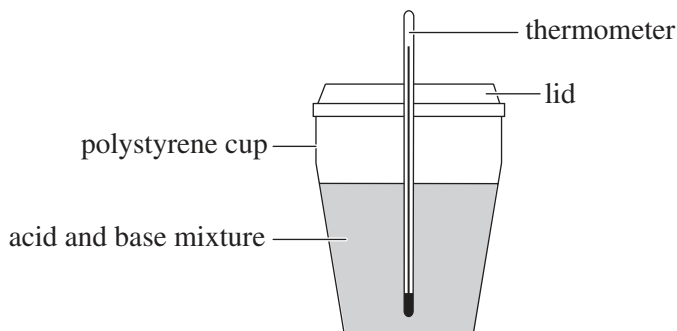
The students added 200 mL of 1.0 mol L^{-1} nitric acid (HNO_3) to 200 mL of 1.0 mol L^{-1} potassium hydroxide (KOH) and stirred the mixture. An initial temperature of 22.7°C and a final temperature of 29.4°C were recorded.

(a) Calculate the molar enthalpy of neutralisation between nitric acid and potassium hydroxide. **3**

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(b) State ONE assumption that you made in your calculations in part (a). **1**

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Question 27 (4 marks)

The following method was used to determine the mass of carbon dioxide in a sample of polluted air. **4**

1. A 20.0 L sample of air was slowly bubbled through 100.0 mL of 0.0200 mol L^{-1} barium hydroxide ($Ba(OH)_2$) solution. The following reaction was observed.

$$Ba(OH)_2(aq) + CO_2(g) \rightarrow BaCO_3(s) + H_2O(l)$$

2. The mixture was filtered to remove the precipitate formed and the filtrate was titrated according to the steps below.

- Three drops of phenolphthalein were added to the filtrate.
- An end point was observed when 27.1 mL of 0.100 mol L^{-1} HCl was added.

Calculate the mass of barium carbonate ($BaCO_3$) precipitated in step 1.

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Question 28 (5 marks)

The Haber process is used to make ammonia according to the reaction shown. **5**

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -90 \text{ kJ mol}^{-1}$$
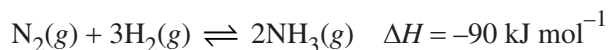
The flow chart shows the formation of ammonia by the Haber process, including the conditions used in the reaction.

nitrogen from air

nitrogen and hydrogen 1 : 3 by volume

thick-walled reactor vessel
400–450°C
200 atm
mixed iron oxide catalyst

hydrogen from fossil fuels

unreacted gases recycled

gases cooled in refrigeration tower

liquid ammonia forms

purified liquid ammonia forms
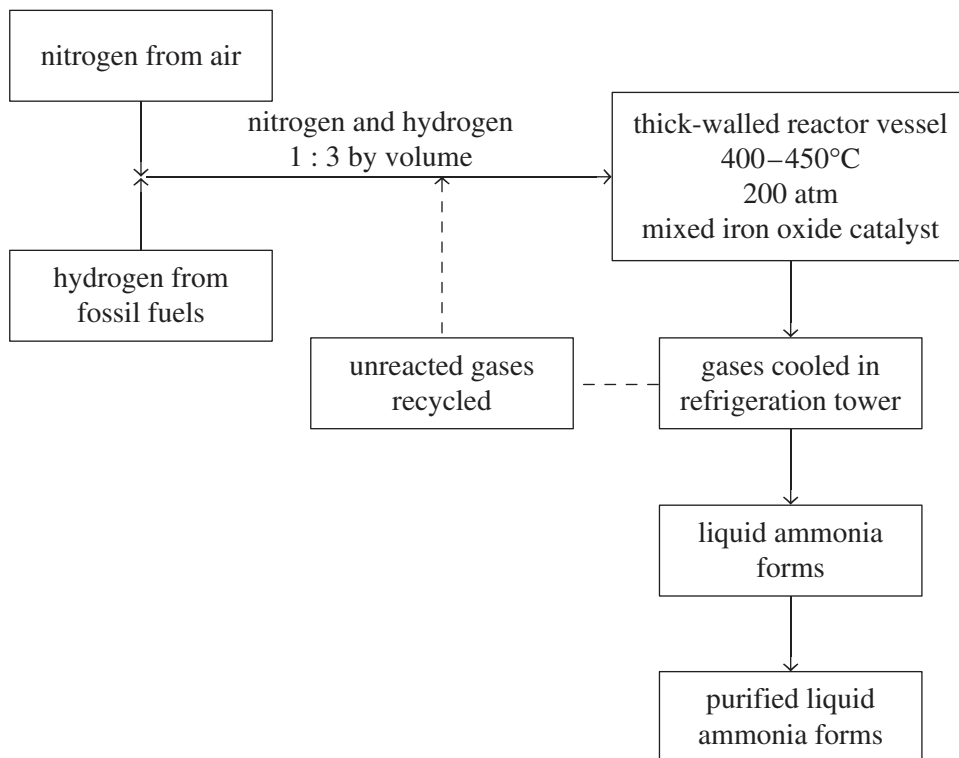
Justify the conditions used in the Haber process.

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Question 29 (3 marks)

Propan-1-amine has a boiling point of 47°C, while N,N-dimethylmethanamine has a boiling point of only 3°C. The structural formulae for the two compounds are shown.

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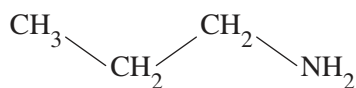
propan-1-amine
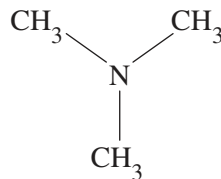
N,N-dimethylmethanamine

Explain why the boiling points of these two compounds are different.

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Question 30 (5 marks)

(a)   Draw the structural formula of an anionic detergent.   **1**

(b)   Compare the properties of soaps and anionic detergents.   **2**

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(c)   Using appropriately labelled diagrams, explain how surfactants clean grease from a dirty surface.   **2**

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Question 31 (7 marks)

As part of the Chemistry course, you have carried out an investigation to determine solubility rules. **7**

Explain how you carried out your investigation. In your answer, refer to:

- drawbacks to your method, and relevant improvements that could be made

- safety precautions taken.

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Question 32 (7 marks)

A bottle contains one of the two isomers of methylpropanol.

(a)   Draw the structural formulae of the isomers of methylpropanol.   **2**

Isomer A	*Isomer B*

(b)   Describe how ^{1}H NMR spectroscopy could be used to identify which isomer of methylpropanol   **3**
is in the bottle.

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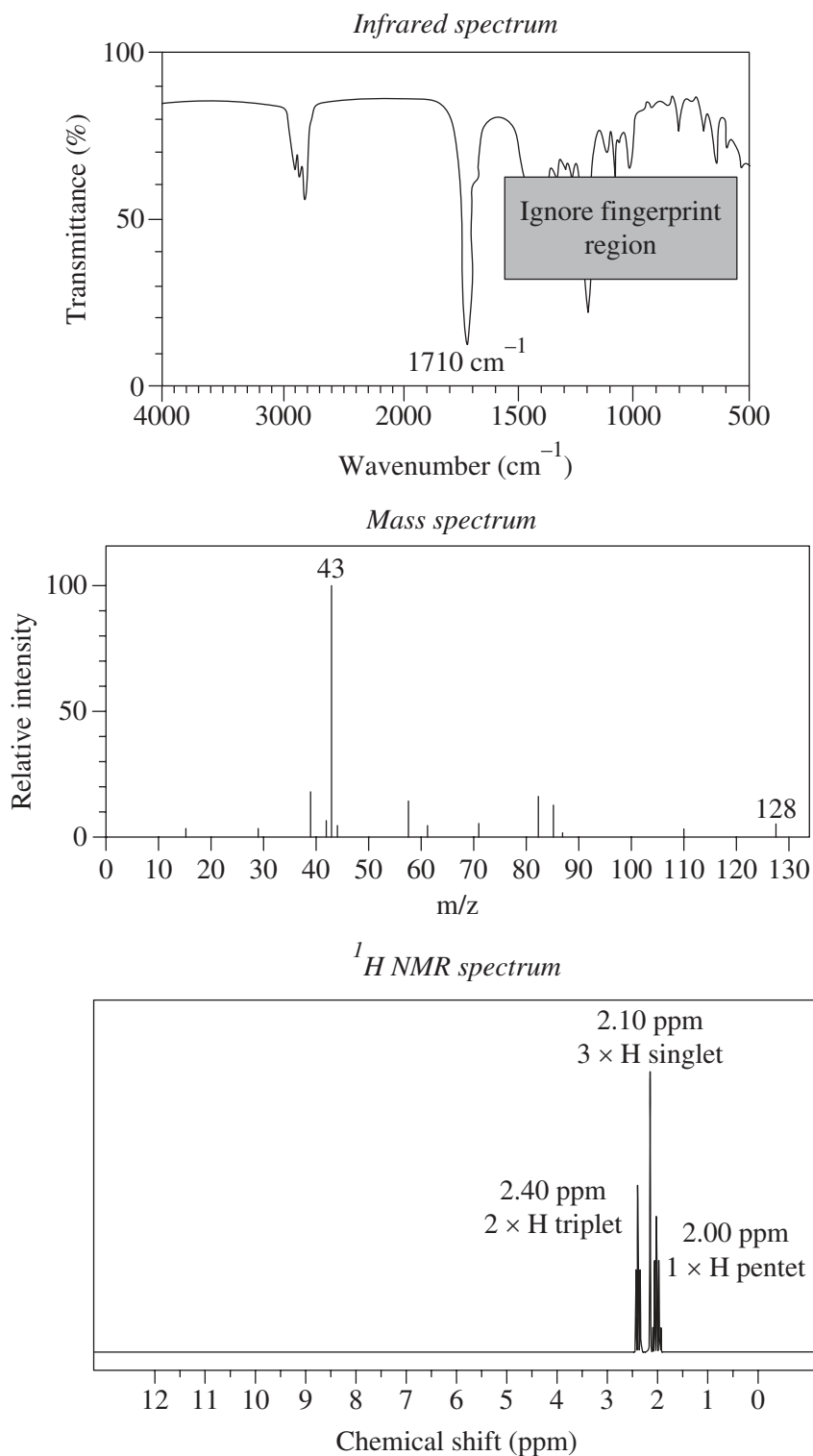……………………………………………………………………………………………..

(c)   Using structural formulae, write the equation for the complete oxidation of the isomer   **2**
of methylpropanol that is a primary alcohol. Include reaction conditions.

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Question 33 (9 marks)

The following spectra were obtained for an unknown organic compound.

Infrared spectrum

Mass spectrum

^{1}H NMR spectrum

Question 33 continues on page 28

Question 33 (continued)

^{13}C NMR spectrum

Chemical shift (ppm)
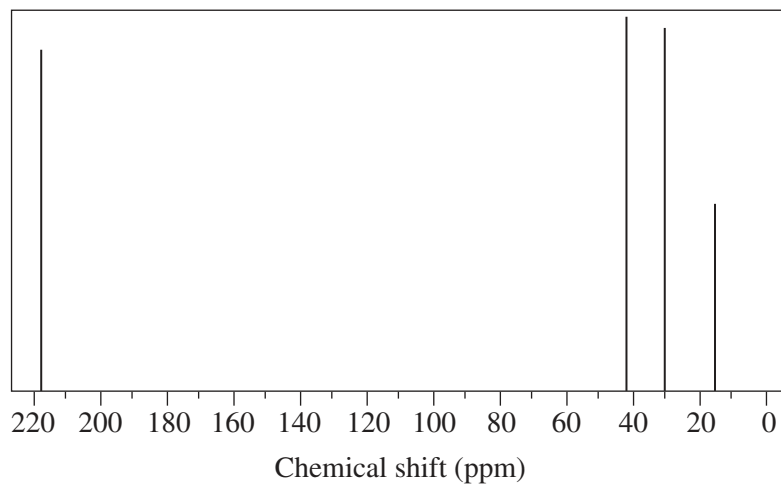
(a)   Elemental analysis showed that the compound contained 65.6% carbon, 9.4% hydrogen   **2**
       and 25.0% oxygen.

Determine the empirical formula of the compound.

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Question 33 continues on page 29

Question 33 (continued)

(b) Name and draw the structure of the unknown compound. Justify your answer with reference   **7**
to the information provided.

Name ....

Structure ....

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Section II extra writing space

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Section II extra writing space

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FORMULAE SHEET

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

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

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

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}
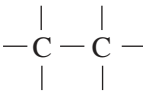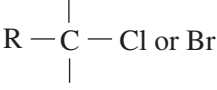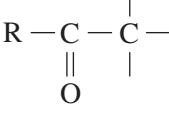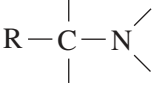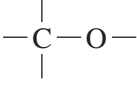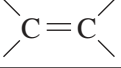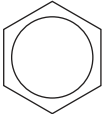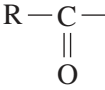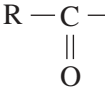
Infrared absorption data

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—C— (with =O)	20–50
R—C—N	25–60
—C—O— alcohols, ethers or esters	50–90
C=C	90–150
R—C≡N	110–125
(benzene ring)	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)	Chromophore	λ_{max} (nm)
C—H	122	C≡C	173 178 196 222
C—C	135	C—Cl	173
C=C	162	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

79	
Au	atomic number
197.0	symbol
gold	standard atomic weight
	name

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 2024

HSC Year 12 Chemistry

Solutions and Marking Guidelines

SECTION I

Question 1   A

A is correct. When the reaction in the diagram reaches equilibrium, there are only products present. In static equilibrium, the rates of the forward and reverse reactions are zero, and there is no change in the concentration of reactants or products.

B, **C** and **D** are incorrect. These options would show a mixture of products and reactants.

Mod 5 Equilibrium and Acid Reactions (CH12–12)	Bands 1–2

Question 2   B

Open systems can exchange energy and matter with their surroundings. Closed systems can only exchange energy with their surroundings. Both systems can involve solids, liquids and gases. Thus, only option **B** is correct.

Mod 5 Equilibrium and Acid Reactions (CH12–4)	Bands 2–3

Question 3   A

A greater equilibrium constant (K_{eq}) indicates that there are greater amounts of products present when the reaction reaches equilibrium. A lower K_{eq} means that there are greater amounts of reactants present when the reaction reaches equilibrium. As option **A** is the lowest K_{eq}, it is likely to indicate that there are greater amounts of reactants at equilibrium.

Mod 5 Equilibrium and Acid Reactions (CH12–6, 12–12)	Bands 3–4

Question 4   C

C is correct. The powder changes from pink to blue when it is heated, and changes from blue to pink when water is added. Thus, the reaction is reversible.

A and **B** are incorrect. There is no information to indicate whether this is an exothermic or endothermic reaction.

D is incorrect. If the solid is heated at stage IV, it will turn blue.

Mod 5 Equilibrium and Acid Reactions (CH12–6)	Bands 3–4

Question 5   C

Le Châtelier's principle states that when a product is added (in this case, carbon dioxide), the reaction will shift to minimise the effect of adding the product. Hence, the reverse reaction will be favoured and the concentration of the products will decrease. As hydrogen is a product of the reaction, its concentration will decrease.

Mod 5 Equilibrium and Acid Reactions (CH12–12)	Bands 3–4

Question 6   **B**

B is an incorrect statement and is therefore the required response. Amphiprotic species can both donate and accept protons, meaning that they can act as a Brønsted–Lowry acid and base. However, amphiprotic species do not necessarily contain both H^+ and OH^-.

A, **C** and **D** are correct statements and are therefore not the required response.

Mod 6 Acid/Base Reactions (CH12–13)	Bands 3–4

Question 7   **A**

A is correct. A buffer is a solution that resists pH changes when small amounts of acids and/or bases are added. As the pH of the phosphate mixture only changed slightly after the addition of NaOH and HCl, it acts as a buffer.

B is incorrect. The phosphate compounds are mixtures of either weak acids and their salts or weak bases and their salts. Thus, the compounds form ionic solutions.

C is incorrect. According to solubility rules (salts of Group I metals), the compounds are soluble.

D is incorrect. The addition of an acid or a base will cause a significant change in the pH of water.

Mod 6 Acid/Base Reactions (CH12–6, 12–12)	Bands 2–3

Question 8   **D**

$$pOH = -\log_{10}(0.2)$$
$$= 0.6989\ldots$$

Hence:

$$pH + pOH = 14$$
$$pH + 0.6989\ldots = 14$$
$$pH = 14 - 0.6989\ldots$$
$$= 13.3$$

Mod 6 Acid/Base Reactions (CH12–6, 12–13)	Bands 4–5

Question 9   **C**

C is correct. In the reaction, HX donates a proton to H_2O (water). Therefore, it is acting as a Brønsted–Lowry acid.

A is incorrect. The reaction is not an acid–base neutralisation as no salt has formed.

B is incorrect. An Arrhenius base would increase the OH^- ion concentration in an aqueous solution; in this case, HX is increasing the H^+ concentration.

D is incorrect. A Brønsted–Lowry base is a substance that accepts a H^+ ion (proton). HX is donating a H^+ ion; therefore, it is a Brønsted–Lowry acid.

Mod 6 Acid/Base Reactions (CH12–6, 12–12)	Bands 3–4

Question 10   **B**

B is correct. Solid magnesium and sulfuric acid react to form magnesium sulfate and hydrogen. Equation **B** uses the correct formulae and states for the reactants and products of the reaction.

A is incorrect. This option does not include hydrogen as a product of the reaction.

C and **D** are incorrect. These options do not show the correct ratio of solid magnesium or use the correct formula for magnesium sulfate. Option **D** also shows water, not hydrogen, as a product of the reaction.

Mod 6 Acid/Base Reactions (CH12–6, 12–12)	Band 5

Question 11   **B**

B is correct. Propagation refers to the addition of a monomer unit to a growing polymer chain.

A is incorrect. Initiation refers to the addition of a free radical to a monomer unit.

C is incorrect. Continuation is not a term used to describe a step in the polymerisation of a free radical.

D is incorrect. Termination refers to the free radical on a growing polymer chain reacting with a second free radical.

Mod 7 Organic Chemistry (CH12–7, 12–14)	Band 3

Question 12   **D**

The boiling point of a compound is related to the total intermolecular force. For small compounds, the dispersion force will be small, meaning that the boiling point is largely determined by the dipole–dipole and hydrogen bonds. As the electronegativity of nitrogen is lower than that of oxygen, amines will be less polar than amides or carboxylic acids. Hence, amines will have weaker dipole–dipole and hydrogen bonds, leading to low boiling points. In the graph, compounds C, F and I have the lowest boiling points and are therefore amines.

Carboxylic acids and amides both contain oxygen atoms and thus will form stronger dipole–dipole forces than amines. Amides have two hydrogen atoms attached to an electronegative nitrogen atom. This means amides can form extensive hydrogen bond networks that cause them to have higher boiling points than carboxylic acids. Reading from the graph, compounds A, D and G have the highest boiling points and are therefore amides. Compounds B, E and H are carboxylic acids.

Mod 7 Organic Chemistry (CH12–5, 12–7, 12–14)	Band 5

Question 13   **C**

Soaps are long chain fatty acid salts ($R–CO_2^-K^+$ or $R_2CO_2^-Na^+$); therefore, compound *X* is a soap. Amines contain nitrogen atoms; therefore, compound *Y* is an amine. Aldehydes contain a RCHO group; therefore, compound *Z* is an aldehyde.

Mod 7 Organic Chemistry (CH12–7, 12–14)	Band 3

Question 14   C

C is correct and **B** is incorrect. The formation of a precipitate after exposure to sulfate ions indicates the presence of either lead or barium ions (both insoluble carbonates) or calcium or silver ions (both slightly soluble carbonates). However, the pale-green flame produced during the flame test indicates that barium ions are the pollutant.

A and **D** are incorrect. Na^+ and Fe^{3+} do not form a precipitate when exposed to sulfate ions.

Mod 8 Applying Chemical Ideas (CH12–5, 12–15)	Band 5

Question 15   B

B is correct and **C** is incorrect. Functional group isomers refer to substances that have the same molecular formula but have different functional groups. Hexanoic acid has the molecular formula of $C_6H_{12}O_2$. Both 2–methylpentanoic acid and methyl pentanoate have the molecular formula of $C_6H_{12}O_2$. However, 2–methylpentanoic acid is a chain isomer of hexanoic acid and methyl pentanoate is a functional group isomer of hexanoic acid.

A and **D** are incorrect. These options are not isomers of hexanoic acid. The molecular formula of hexan-1-ol is $C_6H_{14}O$ and the molecular formula of cyclohex-2-ene-1,4-diol is $C_6H_{10}O_2$.

Mod 7 Organic Chemistry (CH12–7, 12–14)	Bands 5–6

Question 16   B

B is correct. The peak for $[CH_3CH_2NCH_2CH_3]^+$ occurs at an m/z of 72.

A is incorrect. The peak for $[CH_3CH_2]^+$ occurs at an m/z of 29.

C is incorrect. The peak for $[CH_3CONCH_2CH_3]^+$ occurs at an m/z of 86.

D is incorrect. The peak for $[CH_3CON]^+$ occurs at an m/z of 57.

Mod 8 Applying Chemical Ideas (CH12–5, 12–6, 12–15)	Bands 4–5

Question 17   A

A is correct. The ^{13}C NMR spectrum has four peaks, meaning that the organic compound has four unique chemical environments. The highest chemical shift occurs at 72 ppm, which would indicate an alcohol carbon. Therefore, the ^{13}C NMR spectrum represents 3-methylpentan-3-ol.

B and **D** are incorrect. Pentan-3-ol and 2-methylpropan-1-ol both have three unique chemical environments, meaning that their ^{13}C NMR spectrums would have three peaks.

C is incorrect. While butan-2-one has four unique chemical environments (and thus four peaks in its ^{13}C NMR spectrum), the highest chemical shift in its spectrum would occur between 180–200 ppm and indicate a carbonyl carbon.

Mod 8 Applying Chemical Ideas (CH12–4, 12–6, 12–15)	Band 5

Question 18   B

The molecule in the diagram is an alkene; thus, the reaction of HBr with the molecule is an addition reaction. The hydrogen of HBr could be added to either end of the alkene's double bond, meaning that two isomeric alkyl halides could be formed.

Mod 7 Organic Chemistry (CH12–7, 12–14)	Bands 4–5

Question 19   C

Finding the mass of NaCl in the 50.0 mL sample of the diluted solution gives:

$$n(\text{AgCl}) = \frac{m}{MM}$$

$$= \frac{0.376}{107.9 + 35.45}$$

$$= 0.0026\ldots \text{ mol}$$

$$n(\text{NaCl}) = n(\text{AgCl})$$

$$\frac{m(\text{NaCl})}{MM(\text{NaCl})} = 0.0026\ldots$$

$$\frac{m(\text{NaCl})}{22.99 + 35.45} = 0.0026\ldots$$

$$m(\text{NaCl}) = 0.1532\ldots \text{ g}$$

Finding the percentage by mass of NaCl in the 200 g food sample gives:

$$m(\text{NaCl}) = \frac{0.1532\ldots \times 500.0}{50.0}$$

$$= 1.532\ldots \text{ g}$$

$$\%(\text{NaCl}) = \frac{1.532\ldots}{200} \times 100$$

$$= 0.766\%$$

Mod 7 Organic Chemistry (CH12–7, 12–14)	Band 5

Question 20   **D**

$$n(\text{curcumin}) = \frac{m}{MM}$$

$$= \frac{49.5 \times 10^{-6}}{368.4}$$

$$= 1.34 \times 10^{-7} \text{ mol}$$

$$c(\text{curcumin}) = \frac{n}{V}$$

$$= \frac{1.34 \times 10^{-7}}{0.0100}$$

$$= 1.34 \times 10^{-5} \text{ mol L}^{-1}$$

Reading from the spectrum, at 424 nm, $A = 0.750$.

Therefore:

$$A = \varepsilon c l$$

$$0.750 = \varepsilon \times (1.34 \times 10^{-5}) \times 1.00$$

$$\varepsilon = \frac{0.750}{(1.34 \times 10^{-5}) \times 1.00}$$

$$= 55\,900 \text{ mol}^{-1} \text{ L cm}^{-1}$$

Mod 8 Applying Chemical Ideas (CH 12–4, 12–7)	Bands 5–6

SECTION II

Question 21

(a)　　$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$
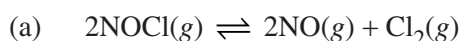
Mod 5 Equilibrium and Acid Reactions (CH12–6, 12–12)	Bands 1–2

- Provides the correct equation 1

(b)　　$K_{eq} = \dfrac{[NO]^2 [Cl]}{[NOCl]^2}$

*Note: Consequential on answer to **Question 21(a)**.*

Mod 5 Equilibrium and Acid Reactions (CH12–6, 12–12)	Bands 2–3

- Provides the correct equilibrium expression 1

(c)　　According to Le Châtelier's principle, since the forward reaction is endothermic, increasing the temperature would favour the forward reaction. In turn, this would increase the concentration of products and reduce the concentration of reactants. Hence, K_{eq} would increase.

Mod 5 Equilibrium and Acid Reactions (CH12–12)	Bands 3–4

- Explains the effect of increasing the temperature.
  AND
- Refers to Le Châtelier's principle 2

- Provides some relevant information 1

(d)　　The student was correct about the reaction being in equilibrium and the concentrations being steady between t_0 and t_1. They were also correct about the concentrations stabilising over time. However, the student incorrectly stated that the concentrations change at t_1 due to the addition of a catalyst. The changes in concentration were caused by the addition of NO; a catalyst would have no effect on a system at equilibrium. The student was also incorrect about the new equilibrium constant; only a change in temperature can change the equilibrium constant.

Overall, the student showed an incomplete understanding of how changes to equilibrium systems occur.

Mod 5 Equilibrium and Acid Reactions (CH12–5, 12–12)	Bands 5–6

- Provides at least FOUR points that evaluate how well the student described the reaction.
  AND
- Provides a judgement of the student's description 4

- Provides at least THREE points that evaluate how well the student described the reaction.
  AND
- Provides a judgement of the student's description 3

- Provides TWO points that evaluate how well the student described the reaction. 2

- Provides some relevant information 1

Question 22

(a)
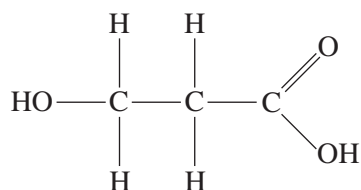
Mod 7 Organic Chemistry (CH12–4, 12–7, 12–14)	Band 3

- Draws the structural formula of the compound 1

(b)
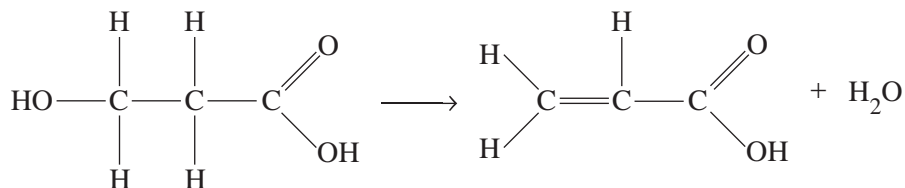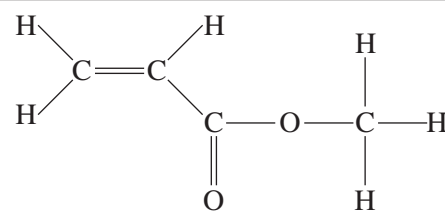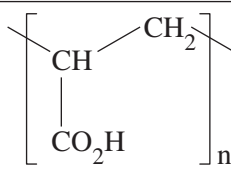
The reaction conditions are heat with an acid catalyst, such as H_3PO_4 or H_2SO_4.

Mod 7 Organic Chemistry (CH12–4, 12–7, 12–14)	Band 3

- Provides the correct balanced equation.
  AND
- Identifies the reaction conditions. 2

- Provides some relevant information 1

(c)

	Name	Structural formula
Compound D	methylpropenoate	
Compound F	polypropenoic acid (polyacrylic acid)	

Mod 7 Organic Chemistry (CH12–4, 12–7, 12–14)	Band 4

- Identifies methylpropenoate.
  AND
- Draws the structural formula of methylpropenoate.
  AND
- Identifies polypropenoic acid.
  AND
- Draws the structural formula of polypropenoic acid. 4

- Any THREE of the above points. 3

- Any TWO of the above points. 2

- Any ONE of the above points 1

Question 23

(a)   A saturated solution is at equilibrium. The rate of dissolution (which forms the aqueous ions) and the rate of reforming the solid solute are equal. Thus, the concentrations of the solid solute and the aqueous ions remain constant.

Mod 5 Equilibrium and Acid Reactions (CH12–12)	Bands 2–3

- Outlines what happens to the solid solute and aqueous ions in a saturated solution.
  AND
- Refers to equilibrium. 2

- Provides some relevant information 1

(b)   The equilibrium reaction for a saturated solution of lead(II) sulfate is:

$PbSO_4(s) \rightleftharpoons Pb^{2+}(aq) + SO_4^{2-}(aq)$.
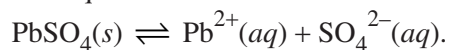
Hence, $K_{sp} = [Pb^{2+}][SO_4^{2-}]$.

Mod 5 Equilibrium and Acid Reactions (CH12–12)	Bands 2–3

- Provides the correct equilibrium expression 1

(c)   Reading from the data sheet, K_{sp} of $PbSO_4 = 2.53 \times 10^{-8}$.

Using stoichiometry, the concentration of $Pb^{2+}(aq)$ and $SO_4^{2-}(aq)$ are equal.

Letting the concentration be c gives:

$$K_{sp} = [c][c]$$
$$= c^2$$
$$c = \sqrt{K_{sp}}$$
$$= \sqrt{2.53 \times 10^{-8}}$$
$$= 1.59 \times 10^{-4} \text{ mol L}^{-1}$$

Converting from moles per litre to grams per litre gives:

$$MM(PbSO_4) = 207.20 + 32.07 + (4 \times 16.00)$$
$$= 303.27$$

$$m(PbSO_4) = MM \times n$$
$$= 303.27 \times (1.59 \times 10^{-4})$$
$$= 482.20 \times 10^{-4} \text{ OR } 0.0482 \text{ g L}^{-1}$$

Note: Award follow-through marks for calculations that use an incorrect value of K_{sp}.

Mod 5 Equilibrium and Acid Reactions (CH12–6, 12–12)	Bands 5–6

- Calculates the solubility of lead(II) sulfate.
  AND
- Shows all relevant working 3

- Calculates the solubility of lead(II) sulfate.
  AND
- Shows some relevant working. 2

- Shows some relevant working. 1

Question 24

(a)   The pH will increase because the hypochlorite ions will hydrolyse to produce hydroxide ions, as shown in the equation.

$$OCl^-(aq) + H_2O(l) \rightarrow HOCl(aq) + OH^-(aq)$$
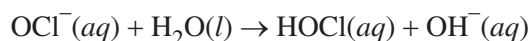
Mod 6 Acid/Base Reactions (CH 12–6, 12–13)	Bands 3–4

• Explains how the hypochlorite ions will affect the pH. AND • Provides the correct net ionic equation 2	
• Explains how the hypochlorite ions will affect the pH. OR • Provides the correct net ionic equation 1	

(b)   Bromothymol blue would be the most appropriate indicator to use.

Bromothymol blue changes colour over the range of 6–7.6 and is the only indicator that covers the desired range of 7.1–7.6. It is blue at higher pHs and yellow at lower pHs. Therefore, bromothymol blue can show whether the pH is within the correct range or whether it is too high or too low.

Mod 6 Acid/Base Reactions (CH12–6)	Bands 4–5

• Identifies bromothymol blue as the most appropriate indicator. AND • Provides appropriate justification 2	
• Identifies bromothymol blue as the most appropriate indicator 1	

(c)

$$HOCl(aq) + H_2O(l) \rightleftharpoons OCl^-(aq) + H_3O^+$$

conjugate   conjugate   conjugate   conjugate
 acid 1   base 2   base 1   acid 2
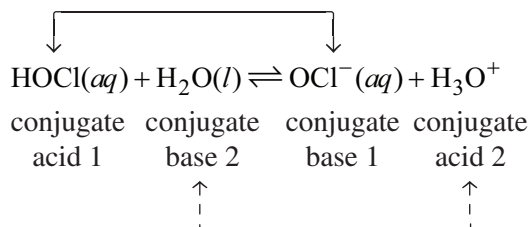
Mod 6 Acid/Base Reactions (CH12–6, 12–12)	Bands 3–4

• Labels BOTH conjugate acid/base pairs 2	
• Labels ONE conjugate acid/base pair 1	

Question 25

(a)   The equivalence point can be found by drawing two lines of best fit through the points in the conductivity graph, which finds the point of intersection. Drawing another line down from the point of intersection to the *x*-axis indicates the equivalence point.
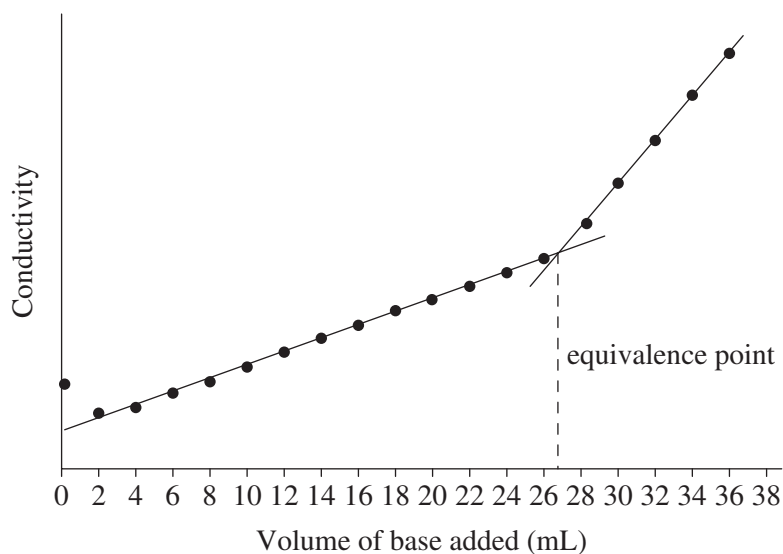
Therefore, the equivalence point is approximately 26.8 mL.

Mod 6 Acid/Base Reactions (CH12–6, 12–13)	Bands 3–4

- Draws two lines of best fit.
  AND
- Determines the equivalence point 2

- Draws two lines of best fit.
  OR
- Determines the equivalence point 1

(b) $CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(aq)$

Mod 6 Acid/Base Reactions (CH12–6, 12–13)	Bands 1–2

- Writes the balanced equation. 1

(c) The number of moles of CH_3COOH is equal to number of moles of NaOH added.

$n(\text{NaOH}) = cV$

$$= \frac{0.12 \times 26.8}{1000}$$

$$= 3.216 \times 10^{-3} \text{ mol}$$

Hence, $n(CH_3COOH) = 3.216 \times 10^{-3}$ mol.

Finding the concentration of CH_3COOH in the 25 mL sample gives:

$c(CH_3COOH) = \dfrac{n}{V}$

$$= \frac{3.216 \times 10^{-3}}{0.025}$$

$$= 0.1286 \text{ mol L}^{-1}$$

As the 25 mL sample was diluted by a factor of 10, the original concentration of CH_3COOH is:

$c(CH_3COOH) = 0.1286 \times 10$

$$= 1.286 \text{ mol L}^{-1}$$

$MM(CH_3COOH) = (2 \times 12.01) + (4 \times 1.008) + (2 \times 16.00)$

$$= 60.052 \text{ g}$$

$c(CH_3COOH) = 60.052 \times 1.286$

$$= 77.23 \text{ g L}^{-1}$$

$$= 7.7\%$$

Hence, the concentration of CH_3COOH is within the required range of 4–8%.

*Note: Consequential on answer to **Question 25(a)**.*

Mod 6 Acid/Base Reactions (CH12–6, 12–13)	Bands 5–6

• Calculates the number of moles of CH_3COOH.   AND   • Calculates the concentration of CH_3COOH in the sample.   AND   • Determines that the concentration of CH_3COOH in the vinegar is within the required range 3
• Calculates the number of moles of CH_3COOH.   AND   • Calculates the concentration of CH_3COOH in the sample 2
• Shows some relevant working. 1

(d) $CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$
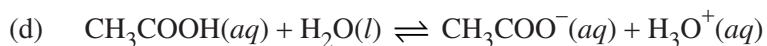
$$K_a = \frac{\left[CH_3COO^-\right]\left[H_3O^+\right]}{\left[CH_3COOH\right]}$$

$$\frac{[c][c]}{[1.0]} = 1.8 \times 10^{-5}$$

$$c^2 = 1.8 \times 10^{-5}$$

$$c = \sqrt{1.8 \times 10^{-5}}$$

$$= 4.24 \times 10^{-3}$$

$$pH = -\log\left(H_3O^+\right)$$

$$= -\log\left(4.24 \times 10^{-3}\right)$$

$$= 2.37$$

Note: Award follow-through marks for calculations that use an incorrect expression for K_a.

Mod 6 Acid/Base Reactions (CH12–4, 12–13)	Bands 4–5

- Provides the correct expression for K_a.
  AND
- Calculates the concentration.
  AND
- Calculates the pH. 3

- Provides the correct expression for K_a.
  AND
- Calculates the concentration.
  OR
- Shows some relevant working.
  AND
- Calculates the pH. 2

- Provides some relevant information 1

Question 26

(a) $\Delta T = 29.4 - 22.7$

$\qquad = 6.7°C$

From the data sheet, $c = 4.18 \times 10^3$ J kg^{-1} K^{-1}

$q = mc\Delta T$

$\qquad = 0.400 \times (4.18 \times 10^3) \times 6.7$

$\qquad = 1.120 \times 10^3$ J

$HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(l)$
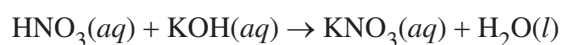
stoichiometry = 1 : 1 : 1 : 1

$n(H_2O) = \dfrac{200}{1000} \times 1.0$

$\qquad\quad = 0.2$

Hence:

molar enthalpy of neutralisation $= \dfrac{1.120 \times 10^3}{0.2}$

$\qquad\qquad\qquad\qquad\qquad\qquad\quad = -56.012 \times 10^3$ J mol^{-1} OR -56.012 kJ mol^{-1}

Mod 6 Acid/Base Reactions (CH12–6, 12–13)	Bands 4–5

- Uses an appropriate formula.
  AND
- Shows relevant working.
  AND
- Calculates the molar enthalpy of neutralisation 3

- Uses an appropriate formula.
  AND
- Shows some relevant working. 2

- Provides some relevant information 1

(b)   *Any one of:*

- The specific heat capacity (c) of all solutions is the same as water (4.18×10^3 J kg^{-1} K^{-1}).
- The density of the solutions is the same as water (1 g mL^{-1}).
- No heat is absorbed by the calorimeter or thermometer.
- No heat is lost to the surroundings.

Mod 6 Acid/Base Reactions (CH12–5, 12–13)	Bands 3–4

- Provides a relevant assumption 1

Question 27

This is an example of back titration.

total moles of OH^- added = moles of OH^- reacting with HCl + moles of OH^- reacting with CO_2

$$n\left(Ba(OH)_2\right) \text{ added} = 0.100 \times 0.0200$$
$$= 0.00200 \text{ mol}$$

$$n(OH^-) \text{ added} = 2 \times 0.00200$$
$$= 0.00400 \text{ mol}$$

$$HCl + NaOH \rightarrow NaCl + H_2O$$
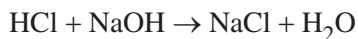
$$n(OH^-) \text{ reacting with HCl} = 0.1 \times 0.0271$$
$$= 0.00271 \text{ mol}$$

$$n(OH^-) \text{ reacting with } CO_2 = 0.004 - 0.00271$$
$$= 0.00129 \text{ mol}$$

$$Ba(OH)_2 + CO_2 \rightarrow BaCO_3 + H_2O$$
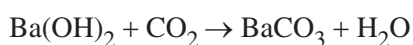
$$n(BaCO_3) = \frac{1}{2} \times 0.00129$$
$$= 0.000645 \text{ mol}$$

$$MM(BaCO_3) = 137.3 + 12.01 + 48.0 = 197.3 \text{ g mol}^{-1}$$

$$m(BaCO_3) = 0.000645 \times 197.3$$
$$= 0.127 \text{ g}$$

Mod 6 Acid/Base Reactions	
Mod 8 Applying Chemical Ideas (CH12–4, 12–6, 12–13)	Band 6

• Determines the mass of $BaCO_3$. AND • Calculates the moles of $Ba(OH)_2$ added. AND • Calculates the moles of HCl added. AND • Calculates moles of $BaCO_3$ precipitated 4
• Determines the mass of $BaCO_3$. AND • Calculates the moles of $Ba(OH)_2$ added. AND • Calculates the moles of HCl added 3
• Determines the mass of $BaCO_3$. AND • Calculates the moles of $Ba(OH)_2$ added 2
• Provides some relevant working 1

Question 28

A catalyst is used to increase the rate of reaction at the compromise temperature (400–450°C) to ensure that the rate of the reaction is fast enough for the process to be profitable. Mixed iron oxide catalysts are used as they are effective, cheap and chemically stable.

The unreacted gases are recycled to be reused in the reaction, as hydrogen is an expensive reagent and the economic success of the Haber process depends on all the hydrogen reacting. Nitrogen is less important, as it is cheaply available from air.

Low temperatures maximise the equilibrium yield because the reaction is exothermic. In addition, Le Châtelier's principle states that low temperatures will favour the formation of ammonia. However, high temperatures are needed for the reaction to occur at a rate fast enough for commercial success. A compromise temperature (400–450°C) balances the yield considerations against the rate requirements.

High pressures maximise yield because there are more reactant gas molecules than product gas molecules; according to Le Châtelier's principle, high pressures will favour ammonia formation. However, high pressures are dangerous and it can be expensive to build a reaction vessel capable of withstanding very high pressures. A compromise pressure (200 atm) balances yield considerations against cost and safety.

Mod 8 Applying Chemical Ideas (CH12–5, 12–6, 12–7, 12–15)	Bands 4–5

- Justifies the conditions used in the Haber process with reference to all FOUR of:
  - catalysts
  - recycling unused gases
  - temperature
  - pressure 5

- Justifies the conditions used in the Haber process with reference to THREE of the above points 4

- Justifies the conditions used in the Haber process with reference to TWO of the above points 3

- Justifies the conditions used in the Haber process with reference to ONE of the above points 2

- Provides some relevant information 1

Question 29

Both molecules are small in size, meaning that dispersion forces will be less significant than dipole–dipole forces or hydrogen bonding in both molecules.

Both molecules will have dipole–dipole forces because the C–N bonds in both molecules are polar, meaning that the dipoles will not cancel. However, only propan-1-amine has a N–H bond, which leads to hydrogen bonding between molecules.

The total intermolecular force acting between propan-1-amine molecules (dispersion, dipole–dipole and hydrogen bonding) is stronger than the total intermolecular force acting between N,N–dimethylmethanamine molecules (dispersion and dipole–dipole). Hence, more energy is required to break the intermolecular force between propan-1-amine molecules, leading to a higher boiling point.

Mod 7 Organic Chemistry (CH12–7, 12–14)	Bands 3–4

- Explains the intermolecular forces in propan-1-amine and N,N–dimethylmethanamine.
    AND
- Explains how the intermolecular forces lead to different boiling points. 3

- Outlines the intermolecular forces in propan-1-amine and N,N–dimethylmethanamine.
    AND
- Outlines how the intermolecular forces lead to different boiling points 2

- Provides some relevant information 1

Question 30

(a)   *For example (linear alkyl benzene sulfonate):*

$$CH_3(CH_2)_{10}CH_2 - \langle\bigcirc\rangle - SO_3^- Na^+$$
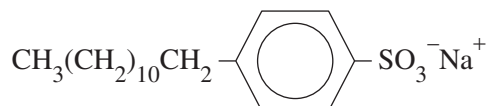
Mod 7 Organic Chemistry (CH12–4, 12–7)	Bands 4–5

- Provides the correct structural formula 1

(b)   Both soaps and anionic detergents contain a long, non-polar tail containing only C and H atoms and a polar head group (a negatively charged ionic group containing oxygen atoms).

non-polar tail   polar head
group
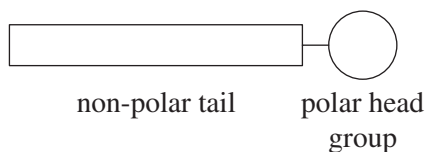
Soaps are cheap, biodegradable and do not remove natural oils and fats from skin, making them safe for use in personal hygiene products. However, soaps form insoluble scums with magnesium and calcium salts, and so cannot be used in hard water.

Anionic detergents are also relatively cheap, and they are more stable and resistant to biodegradation than soaps. Anionic detergents are much more effective surfactants and can be used in hard water.

Note: Responses do not need to include a diagram to obtain full marks.

Mod 7 Organic Chemistry (CH12–4, 12–7)	Bands 4–5

• Compares the properties of soaps and anionic detergents 2
• Provides some relevant information 1

(c)   The non-polar tail in a surfactant can form dispersion forces with greases and oils. The polar head group can form ion–dipole forces with water, which facilitate the formation of micelle and thus the removal of grease from a surface.
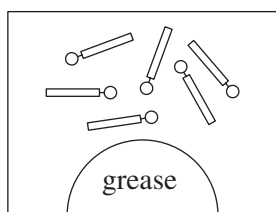
grease stuck to the surface   surfactant's non-polar tail   micelle forms and removes
of the surfactant in water   dissolves into the grease   the grease from the surface

Mod 7 Organic Chemistry (CH12–7, 12–14)	Bands 5–6

• Explains how surfactants clean grease. AND • Provides appropriately labelled diagrams 2
• Provides some relevant information 1

Question 31

For example:

The equipment used included a spatula, distilled water and test tubes with stoppers.

A range of powdered solids were obtained. The test tubes were filled with distilled water until they were three-quarters full. A spatula tip of each powdered solid was added to the test tubes, which were then stoppered and shaken vigorously. The mixtures were examined to determine whether the amount of solid had decreased, and whether the solids could be classified as soluble or insoluble. If the amount of solid remained unchanged, the solid was classified as insoluble. If the solid had dissolved, the mixture was shaken again and left to the side for later examination.

The major drawback was how to classify solids that might have been sparingly soluble. This was a qualitative assessment, using sight to determine if a substance was soluble. The investigation may have been more accurate if a quantitative method was used. This could involve weighing the initial samples of solid before adding them to the test tubes, then filtering the mixtures after shaking and weighing the (dried) filtrate to see if the mass of the samples had changed.

Safety precautions taken included wearing safety goggles, avoiding any skin contact with chemicals, and ensuring that no glassware had broken or sharp edges.

Mod 5 Equilibrium and Acid Reactions (CH12–3, 12–12)	Bands 5–6

- Explains the investigation in detail.
  AND
- Describes any drawbacks to the method AND the improvements that could be made.
  AND
- Refers to any safety precautions taken 6–7

- Explains the investigation.
  AND
- Outlines any drawbacks to the method AND the improvements that could be made.
  AND
- Refers to any safety precautions taken 4–5

- Describes the investigation with limited detail.
  AND
- Outlines any drawbacks to the method OR the improvements that could be made.
  AND
- Refers to at least ONE safety precaution taken 2–3

- Provides some relevant information 1

Question 32

(a)

Isomer A	*Isomer B*
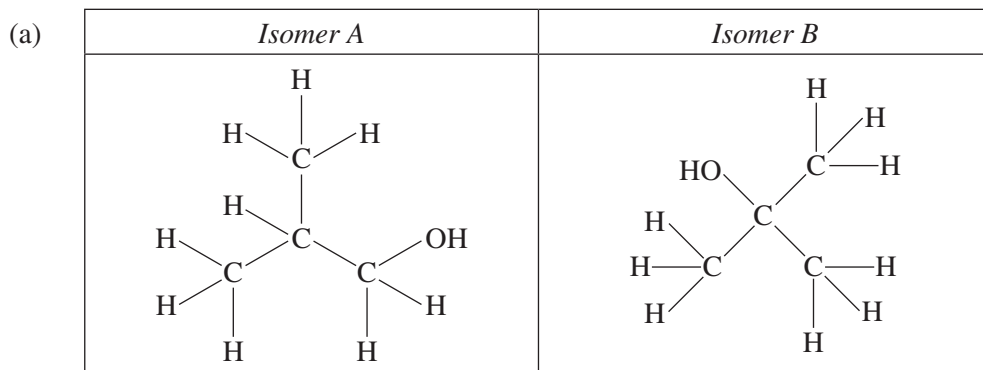
Note: Methylpropan-1-ol is an acceptable variant of the name methylpropanol. Accept responses that draw condensed structural formulae.

Mod 7 Organic Chemistry (CH12–7, 12–14)	Band 3

- Draws the structural formula of 2-methylpropan-1-ol AND 2-methyl-propan-2-ol 2

- Draws the structural formula of 2-methylpropan-1-ol OR 2-methyl-propan-2-ol 1

(b) The isomer can be identified by observing the peaks, splitting patterns and peak areas in the ^{1}H NMR spectrum.

If the ^{1}H NMR spectrum shows a $9 \times H$ singlet (three CH_3 groups) and a broad $1 \times H$ singlet (OH), then the compound is 2-methylpropan-2-ol. If the ^{1}H NMR spectrum shows a $6 \times H$ doublet (two CH_3 groups), a $1 \times H$ nonet (CH group), a $2 \times H$ doublet (CH_2 group) and a broad $1 \times H$ singlet (OH group), then the compound is 2-methylpropan-1-ol.

Mod 8 Applying Chemical Ideas (CH12–4, 12–6, 12–14, 12–15)	Band 6

- Describes the proton NMR spectrum of 2-methylpropan-1-ol and 2-methyl-propan-2-ol 3

- Describes some aspects of the proton NMR spectrum of 2-methylpropan-1-ol and 2-methyl-propan-2-ol. . .2

- Provides some relevant information 1

(c)
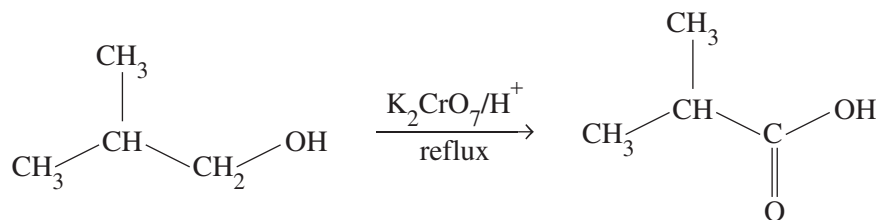
Mod 7 Organic Chemistry (CH12–15)	Band 3

- Provides the correct equation.
  AND
- Includes reaction conditions 2

- Provides the correct equation.
  OR
- Includes reaction conditions 1

Question 33

(a)   Finding the number of moles of each element gives:

$$C = \frac{65.6}{12.01}$$
$$= 5.462 \text{ mol}$$

$$H = \frac{9.4}{1.008}$$
$$= 9.325 \text{ mol}$$

$$O = \frac{25.0}{16.00}$$
$$= 1.563 \text{ mol}$$

Finding the ratio of each element gives:

$$C = \frac{5.462}{1.563}$$
$$= 3.495$$

$$H = \frac{9.325}{1.563}$$
$$= 5.966$$

$$O = \frac{1.563}{1.563}$$
$$= 1.000$$

Simple integer ratio:

C = 7, H =12, O = 2

Therefore, the empirical formula is $C_7H_{12}O_2$.

Mod 8 Applying Chemical Ideas (CH12–6)	Band 3

• Determines the mole ratios of the elements. AND
• Provides the correct empirical formula 2
• Provides some relevant information 1

(b) **Name:** heptane-2,6-dione

Structure:
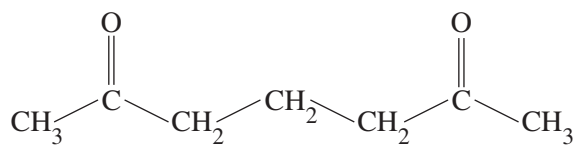
Infrared spectrum:

- The infrared spectrum shows a strong absorption at 1710 cm^{-1}, which is consistent with a carbonyl group.
- The absence of a broad OH stretches between 2500–3000 cm^{-1}.
- Possible functional groups are esters, aldehydes and ketones.

Mass spectrum:

- The parent, or molecular ion, at m/z = 128 is correct for a molecular formula of $C_7H_{12}O_2$. Hence, the molecular formula is the same as the empirical formula.
- The base peak at m/z = 43 is consistent with fragmentation that is adjacent to a methyl ketone, CH_3CO^+.
- Both the infrared and mass spectra suggest the partial structure of $CH_3C=O$ (a methyl ketone).

^{13}C *NMR spectrum:*

- The molecular formula contains seven carbons; however, there are only four peaks in the ^{13}C NMR spectrum, so three carbons must be in chemically equivalent environments.
- The peak at 218 ppm is consistent with a carbonyl group.
- The peaks between 15–42 ppm are consistent with CH_3 and CH_2 groups.
- The absence of a peak between 50–90 ppm eliminates a C–O bond, ruling out the presence of an ester.
- Given that the compound contains two oxygen atoms, it is likely to contain two $CH_3C=O$ groups.

^1H *NMR spectrum:*

- There are three distinct hydrogen environments, showing a total of six H atoms. However, since there are 12 H atoms in the molecular formula, the compound is likely to be symmetrical. This suggests a 2 × H pentet, 6 × H singlet and a 4 × H triplet.
- The 2 × H pentet is consistent with a CH_2 group adjacent to two CH_2 groups ($CH_2CH_2CH_2$).
- The 4 × H triplet is consistent with two equivalent CH_2 groups adjacent to a single CH_2 group ($CH_2CH_2CH_2$).
- The 6 × H singlet is consistent with two methyl groups with no hydrogen on adjacent carbons, which is consistent with two $CH_3C=O$ groups.

Note: Consequential on answer to **Question 33(a)**.

(continues on next page)

(continued)

Mod 8 Applying Chemical Ideas (CH12–5, 12–6, 12–7, 12–15)	Band 6

- Names the compound.
  AND
- Draws the structural formula.
  AND
- Justifies the response by providing a sophisticated interpretation of all FOUR spectra.
  AND
- Refers to specific and relevant evidence from the spectra 6–7

- Names the compound.
  AND
- Draws the structural formula.
  AND
- Justifies the response by providing a sophisticated interpretation of all FOUR spectra.
  AND
- Refers to some evidence from the spectra. 4–5

- Provides the name OR structural formula for a compound.
  AND
- Attempts to justify the response by interpreting the spectra 2–3

- Attempts to interpret the spectra 1