NSW GOVERNMENT

Centre Number

Student Number

NSW Education Standards Authority

This sample HSC examination paper is designed to show one way the Chemistry 11–12 Syllabus (2025) could be examined. It reflects the layout of a formatted HSC examination paper.

Sample **HIGHER SCHOOL CERTIFICATE EXAMINATION**

Chemistry

General Instructions

- Reading time – 10 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
- Write your Centre Number and Student Number at the top of this page

Total marks: 100

Section I – 20 marks (pages 3–14)

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

Section II – 80 marks (pages 15–42)

- Attempt Questions 21–39
- Allow about 2 hours and 25 minutes for this section

The first HSC examination for the Chemistry 11–12 Syllabus (2025) will be held in 2029. The structure of the Chemistry HSC examination is similar to the structure of past Chemistry HSC examinations. Where they are still relevant, past HSC questions have been used to illustrate different types of questions and how the syllabus can be examined.

The Chemistry HSC examination specifications can be found in the assessment information for the Chemistry 11–12 Syllabus (2025).

This sample examination provides examples of some types of questions that may be found in HSC examinations for the Chemistry 11–12 Syllabus (2025). Each question has been mapped to show how the question relates to syllabus outcomes and content.

Answers for the objective-response questions (Section I) and sample answers and marking guidelines for all other questions (Section II) are provided. The marking guidelines indicate the criteria for each mark or mark range in the box.

In the examination, students will record their answers to Section I on a multiple-choice answer sheet and their answers to Section II in the spaces provided in the Section II Answer Booklet.

The sample questions, marking criteria, sample answers, answers could include and annotations provide teachers and students with guidance as to the types of questions to expect and how they may be marked. They are not meant to be prescriptive. Each year the structure of the examination may differ in the number and types of questions, or focus on different syllabus outcomes and content.

Note:

Comments in coloured boxes are annotations that provide information and guidance.

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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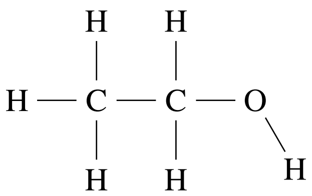
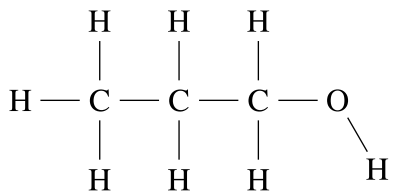
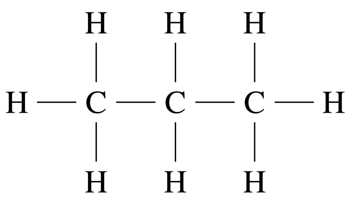
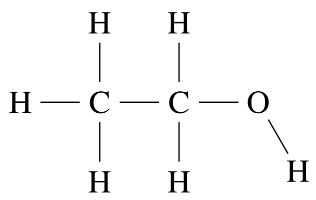
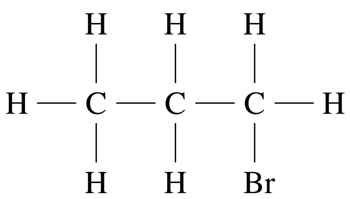
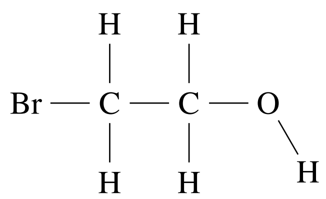
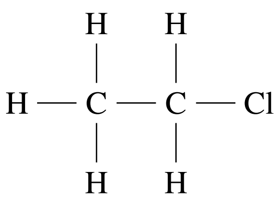
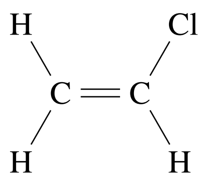
1 Which two substances are members of the same homologous series?

A.  

B.  

C.  

D.  

2 Which of the following compounds can be correctly described as an Arrhenius base when dissolved in water?

A. Sodium nitrate

B. Sodium hydroxide

C. Sodium permanganate

D. Sodium hydrogencarbonate

3 This table contains information on three indicators.

Indicator	*pH range*	*Colour (lower pH – higher pH)*
Methyl orange	3.1–4.4	red – yellow
Methyl red	4.4–6.2	pink – yellow
Phenolphthalein	8.3–10.0	colourless – pink

A substance is tested with each of the indicators and the results are recorded below.

Indicator	*Colour*
Methyl orange	yellow
Methyl red	yellow
Phenolphthalein	colourless

Which of the following substances will produce these results?

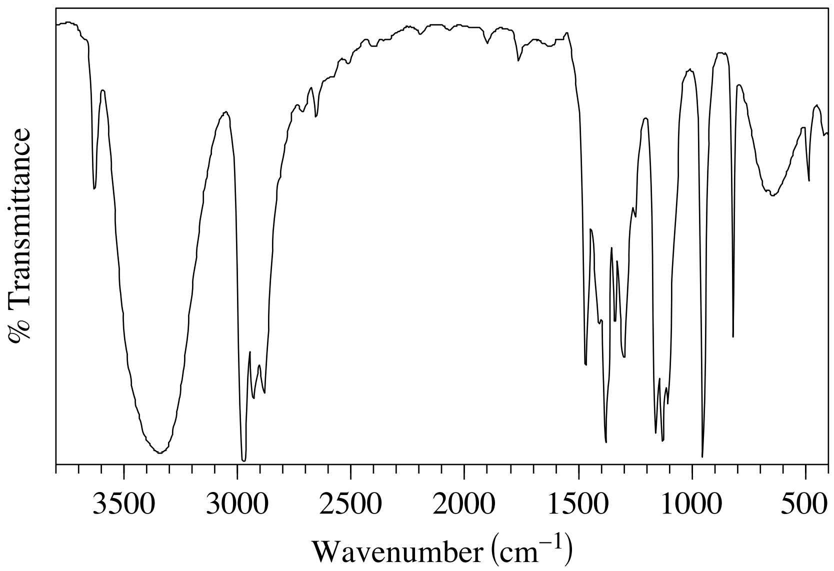
A. Lemonade pH 2.9

B. White wine pH 4.2

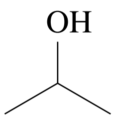
C. Tap water pH 7.2

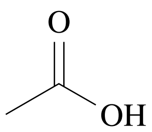
D. Ammonia pH 11.2

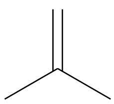
4 An infrared spectrum of an organic compound is shown.

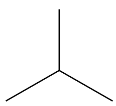


Which of the following compounds would produce the spectrum shown?

A. 

B. 

C. 

D. 

5 Which pair of compounds has the same number of peaks in their ^{13}C NMR spectra?

A. Pentane and heptane

B. Ethanol and propan-2-ol

C. Propan-1-ol and butan-1-ol

D. Propan-1-ol and propan-2-ol

6 Which would be the best reagent to use to determine whether an unknown substance was 2-methylpropan-1-ol or 2-methylpropan-2-ol?

A. Bromine water

B. Potassium nitrate solution

C. Sodium carbonate solution

D. Acidified potassium permanganate solution

7 What is the hydroxide ion concentration of a solution of potassium hydroxide with a pH of 11?

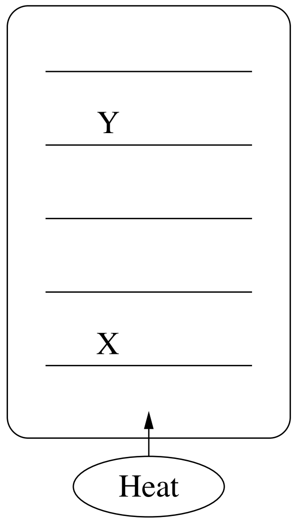
A. 10^{-11} mol L^{-1}

B. 10^{-3} mol L^{-1}

C. 10^{3} mol L^{-1}

D. 10^{11} mol L^{-1}

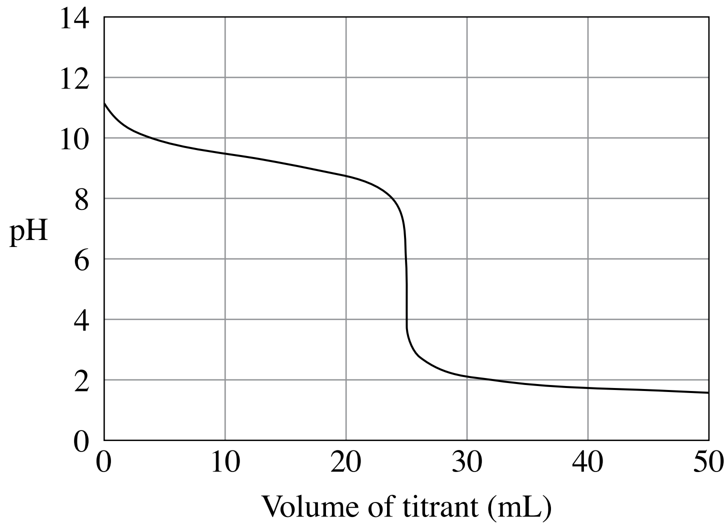
8 Fractional distillation is a separation method where a mixture is heated at the bottom of a tower and the components cool as they rise. The image below represents a simplified fractional distillation column.



Which row of the table correctly compares the boiling point and molecular mass of the components collected at X and Y in the fractional distillation column?

	Boiling point	*Molecular mass*
A.	X higher than Y	X higher than Y
B.	Y higher than X	Y higher than X
C	X higher than Y	Y higher than X
D.	Y higher than X	X higher than Y

9 A titration was performed using two solutions of equal concentration, producing the following titration curve.



Which combination of solutions does the titration curve represent?

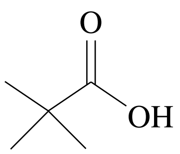
A. Addition of a weak base to a weak acid

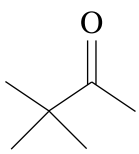
B. Addition of a weak base to a strong acid

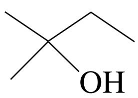
C. Addition of a strong acid to a weak base

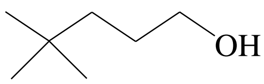
D. Addition of a strong acid to a strong base

10 Which compound reacts readily with sodium hydrogencarbonate?

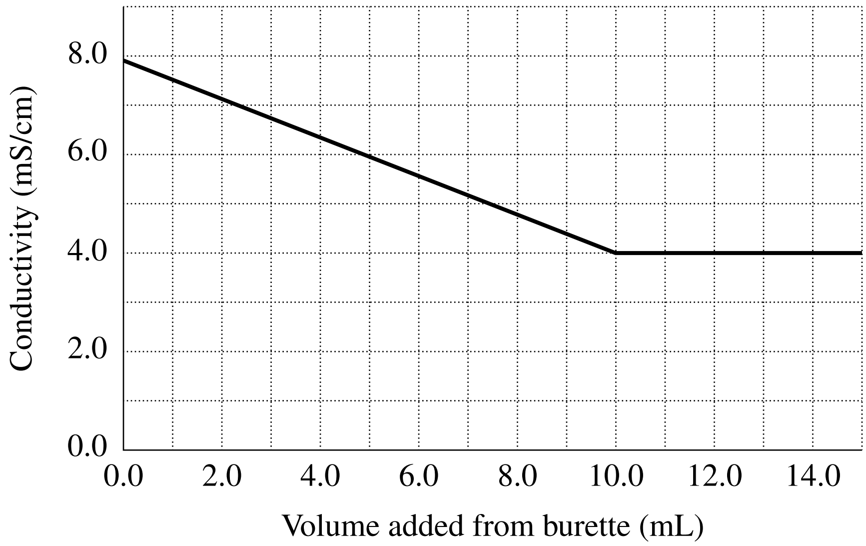
A. 

B. 

C. 

D. 

11 A 25.00 mL sample of 0.1131 mol L^{-1} $HCl(aq)$ was titrated with an aqueous ammonia solution. The conductivity of the solution was measured throughout the titration and the results graphed.



What was the concentration of the ammonia solution?

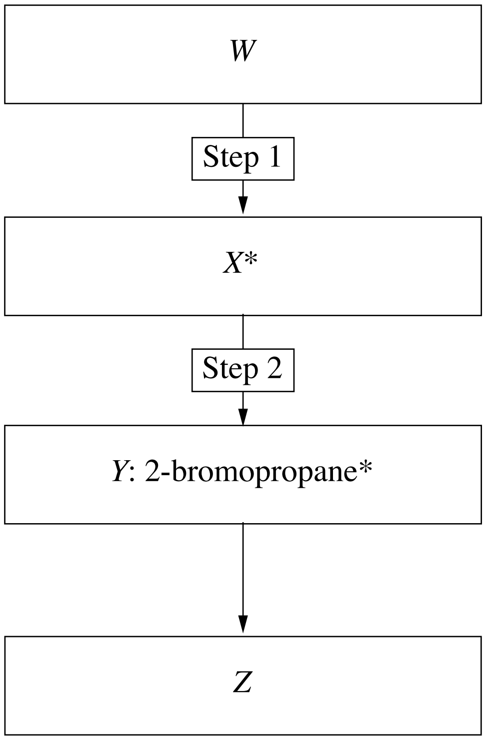
A. 0.0452 mol L^{-1}

B. 0.189 mol L^{-1}

C. 0.283 mol L^{-1}

D. 0.690 mol L^{-1}

12 A sequence of steps was carried out on a liquid alkanol, *W*, producing its position isomer, *Z*.



* purified by distillation

Which row of the table shows the correct reagents for the sequence from compound *W* to compound *Y*?

	Step 1: W to X	*Step 2: X to Y*
A.	Dilute H_2SO_4	HBr
B.	Dilute H_2SO_4	Br_2/H_2O
C.	Concentrated H_2SO_4	HBr
D.	Concentrated H_2SO_4	Br_2/H_2O

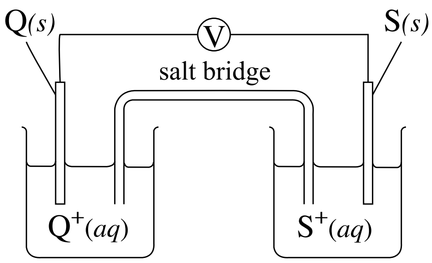
13 Some reactions of the metals Q, R and S are given below.

Metal	*Reaction in air*	*Reaction with steam*	*Reaction with dilute hydrochloric acid*
Q	Burns to form metallic oxide	Hydrogen is formed	Hydrogen is formed
R	Reacts slowly to form metallic oxide	Does not react	Does not react
S	Reacts to form metallic oxide	Does not react	Hydrogen is formed

In a galvanic cell, Q^+ , R^+ and S^+ would represent cations of these metals.

Which galvanic cell will produce the greatest voltage?

A.



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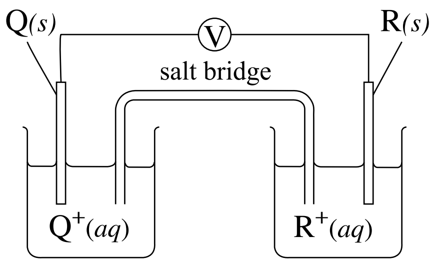
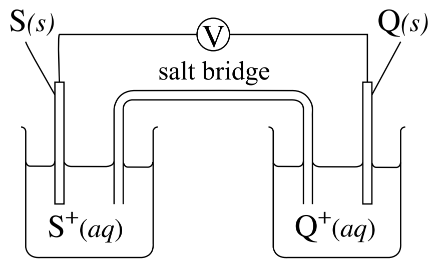
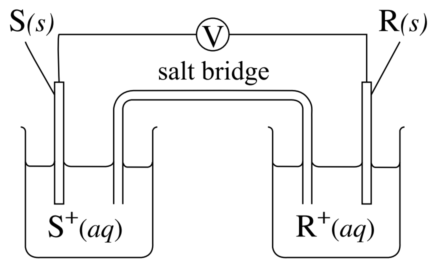


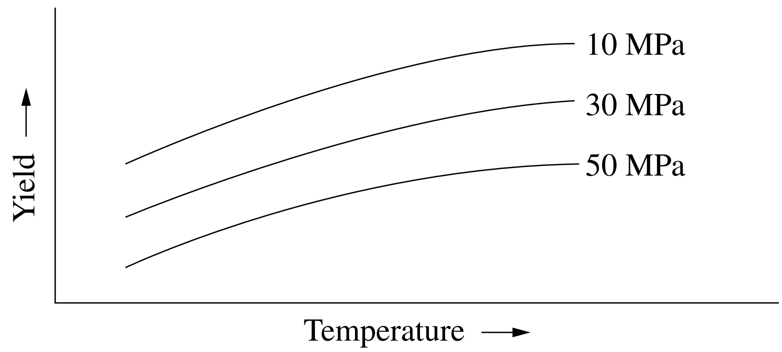
C.



D.



14 Compounds X, Y and Z are in equilibrium. The diagram shows the effects of temperature and pressure on the equilibrium yield of compound Z.



Which equation would be consistent with this data?

A. $X(g) + 3Y(g) \rightleftharpoons 2Z(g)$ $\Delta H > 0$

B. $X(g) + 3Y(g) \rightleftharpoons 2Z(g)$ $\Delta H < 0$

C. $2X(g) \rightleftharpoons 2Y(g) + Z(g)$ $\Delta H > 0$

D. $2X(g) \rightleftharpoons 2Y(g) + Z(g)$ $\Delta H < 0$

15 If s is the solubility (in mol L^{-1}) of barium hydroxide, what is the relationship between its K_{sp} and s?

A. $K_{sp} = s^2$

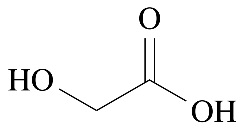
B. $K_{sp} = 2s^2$

C. $K_{sp} = 2s^3$

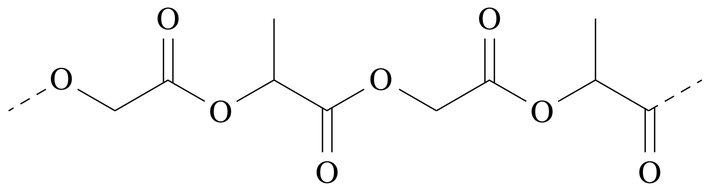
D. $K_{sp} = 4s^3$

16 Glycolic acid can react with itself and another monomer to form the polymer PLGA.

Glycolic acid has the structure:

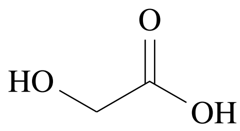


A section of PLGA is shown.

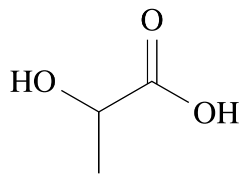


Which monomer could react with glycolic acid to form this section of PLGA?

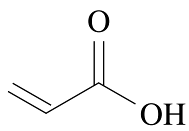
A.



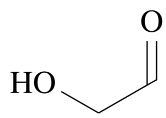
B.



C.



D.



17 A sample was contaminated with sodium phosphate. The sample was dissolved in water and added to an excess of acidified $(NH_4)_2MoO_4$ to produce a precipitate of $(NH_4)_3PO_4{\bullet}12MoO_3$ (MM = 1877 g mol^{-1}).

If 24.21 g of dry $(NH_4)_3PO_4{\bullet}12MoO_3$ was obtained, what was the mass of sodium phosphate in the original sample?

A. 1.225 g

B. 1.521 g

C. 1.818 g

D. 2.115 g

18 When equal volumes of a sodium sulfate solution and a 0.0310 mol L^{-1} calcium nitrate solution are added together, a saturated calcium sulfate solution is produced.

When equal volumes of a silver nitrate solution and the same sodium sulfate solution are added together, a saturated silver sulfate solution is produced.

What is the concentration of the silver nitrate solution?

A. 0.0827 mol L^{-1}

B. 0.0869 mol L^{-1}

C. 0.123 mol L^{-1}

D. 0.174 mol L^{-1}

19 Sulfur dioxide and oxygen gas react to form sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad K_{eq}\ (300°C) = 6.25 \times 10^9$$

Pure sulfur trioxide at a concentration of 1.00 mol L^{-1} is allowed to decompose and reach equilibrium at 300°C.

What will be the concentration of $SO_2(g)$ at equilibrium?

A. 0 mol L^{-1}

B. 2.52×10^{-4} mol L^{-1}

C. 3.42×10^{-4} mol L^{-1}

D. 6.84×10^{-4} mol L^{-1}

20 A redox titration can be used to determine the concentration of Vitamin C (ascorbic acid) with a molar mass of 176.124 g mol^{-1}.

$$C_6H_8O_6\,(aq) + I_2\,(aq) \rightleftharpoons C_6H_6O_6\,(aq) + 2H^+(aq) + 2I^-(aq)$$

Two solutions were analysed by titration with an iodine solution.

- Solution A: an ascorbic acid solution
- Solution B: 25.00 mL of solution A + 50.00 mg of ascorbic acid

Titres for both titrations are given.

Solution	*Iodine solution titre* (mL)
25.00 mL of solution A	22.75
25.00 mL of solution A + 50.00 mg of ascorbic acid	43.10

What is the concentration of ascorbic acid in solution A?

A. 5.362×10^{-3} mol L^{-1}

B. 5.994×10^{-3} mol L^{-1}

C. 1.016×10^{-2} mol L^{-1}

D. 1.269×10^{-2} mol L^{-1}

Sample HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Student Number

Chemistry

Section II Answer Booklet

80 marks
Attempt Questions 21–39
Allow about 2 hours and 25 minutes for this section

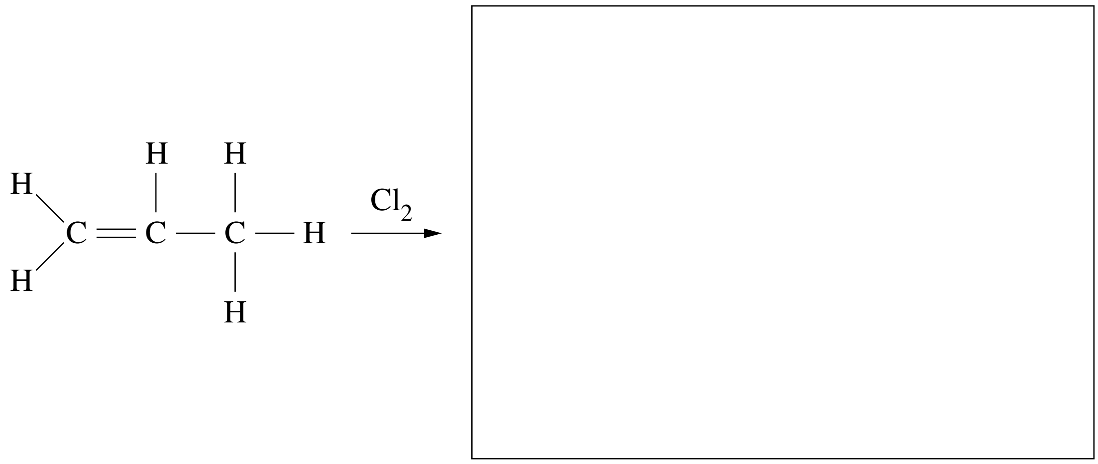
Instructions

- Write your Centre Number and Student Number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (2 marks)

Prop-1-ene reacts with Cl_2 in an addition reaction. In the box given, draw the structural formula of the product of this reaction. **2**



Question 22 (2 marks)

The following equation describes an equilibrium reaction. **2**

$$HF(aq) + PO_4^{3-}(aq) \rightleftharpoons HPO_4^{2-}(aq) + F^-(aq)$$

Identify ONE base and its conjugate acid in the above equation.

Base	*Conjugate acid*

Question 23 (3 marks)

Consider the following equilibrium system. **3**

$$\left[Co\left(H_2O\right)_6\right]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons \left[CoCl_4\right]^{2-}(aq) + 6H_2O(l)$$

$\left[Co\left(H_2O\right)_6\right]^{2+}(aq)$ is pink and $\left[CoCl_4\right]^{2-}(aq)$ is blue. When a solution of these ions and chloride ions is heated, the mixture becomes more blue.

Relate the observed colour change to the change in K_{eq}.

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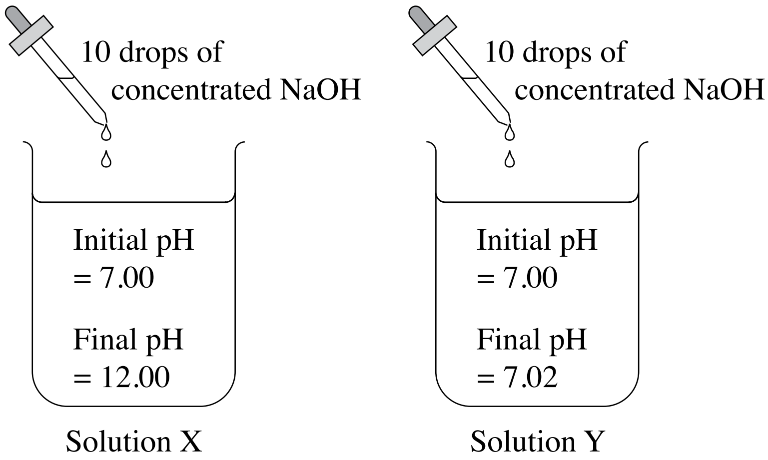
Question 24 (3 marks)

The pH of two solutions, X and Y, were measured before and after 10 drops of concentrated NaOH was added to each. **3**



Explain the pH changes that occurred in solutions X and Y.

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Question 25 (2 marks)

The hydrogenoxalate ion $\left(HC_2O_4^-\right)$ is classified as amphiprotic. **2**

Describe, using chemical equations, how this ion is amphiprotic.

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Question 26 (3 marks)

A half-cell containing an unknown metal, M, was connected to zinc and silver half-cells to form galvanic cells, as described below. The potential difference across the electrodes of each cell was measured under standard conditions. **3**

Cell 1:	$Zn(s) \mid Zn^{2+}(aq) \parallel M^{2+}(aq) \mid M(s)$	$E^{\ominus} = +0.52$ V
Cell 2:	$M(s) \mid M^{2+}(aq) \parallel Ag^{+}(aq) \mid Ag(s)$	$E^{\ominus} = +1.04$ V

Use the cell potentials to write oxidation and reduction half-equations for Cell 1, and the overall equation for Cell 2, identifying the unknown metal, M.

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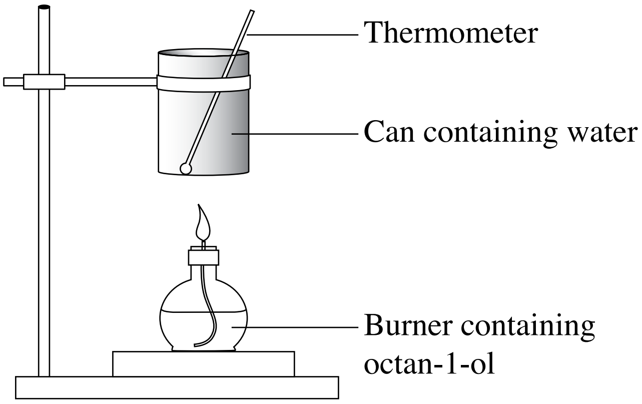
Question 27 (5 marks)

A student used the apparatus shown to investigate the combustion of octan-1-ol.



The following results were obtained by the student.

Mass of water heated	= 205 g
Initial temperature of water	= 23.7°C
Final temperature of water	= 60.4°C

The following data are given.

Molar enthalpy of combustion of octan-1-ol	= -5294 kJ mol^{-1}
Molar mass of octan-1-ol	= 130.22 g mol^{-1}

(a) Assuming that no energy released by this combustion is lost to the surroundings, calculate the mass of octan-1-ol burnt. **3**

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Question 27 continues on page 21

Question 27 (continued)

(b) Explain ONE advantage of using ethanol derived from plants rather than using ethanol derived from crude oil. **2**

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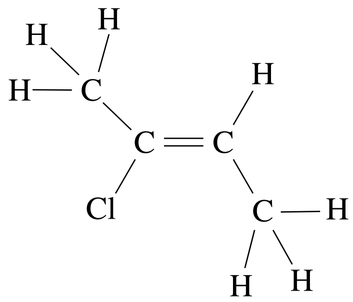
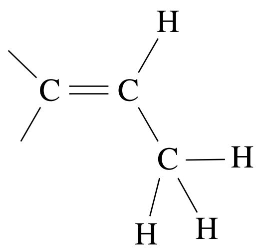
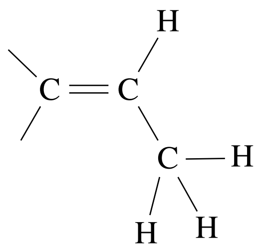
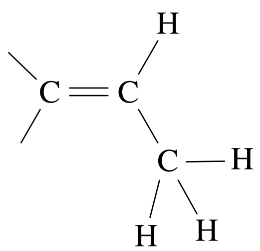
End of Question 27

Question 28 (3 marks)

The structure of (2*Z*)-2-chlorobut-2-ene is shown. **4**



Represent the other possible structures of chlorobut-2-ene by completing the provided structural formulae in the table. In your answer, name the molecules using International Union of Pure and Applied Chemistry (IUPAC) conventions.

Structural formula	*Name*
	
	
	

Question 29 (3 marks)

A 0.2000 mol L^{-1} solution of dichloroacetic acid $(CHCl_2COOH)$ has a pH of 1.107. **3**
Dichloroacetic acid is monoprotic.

Calculate the K_a for dichloroacetic acid.

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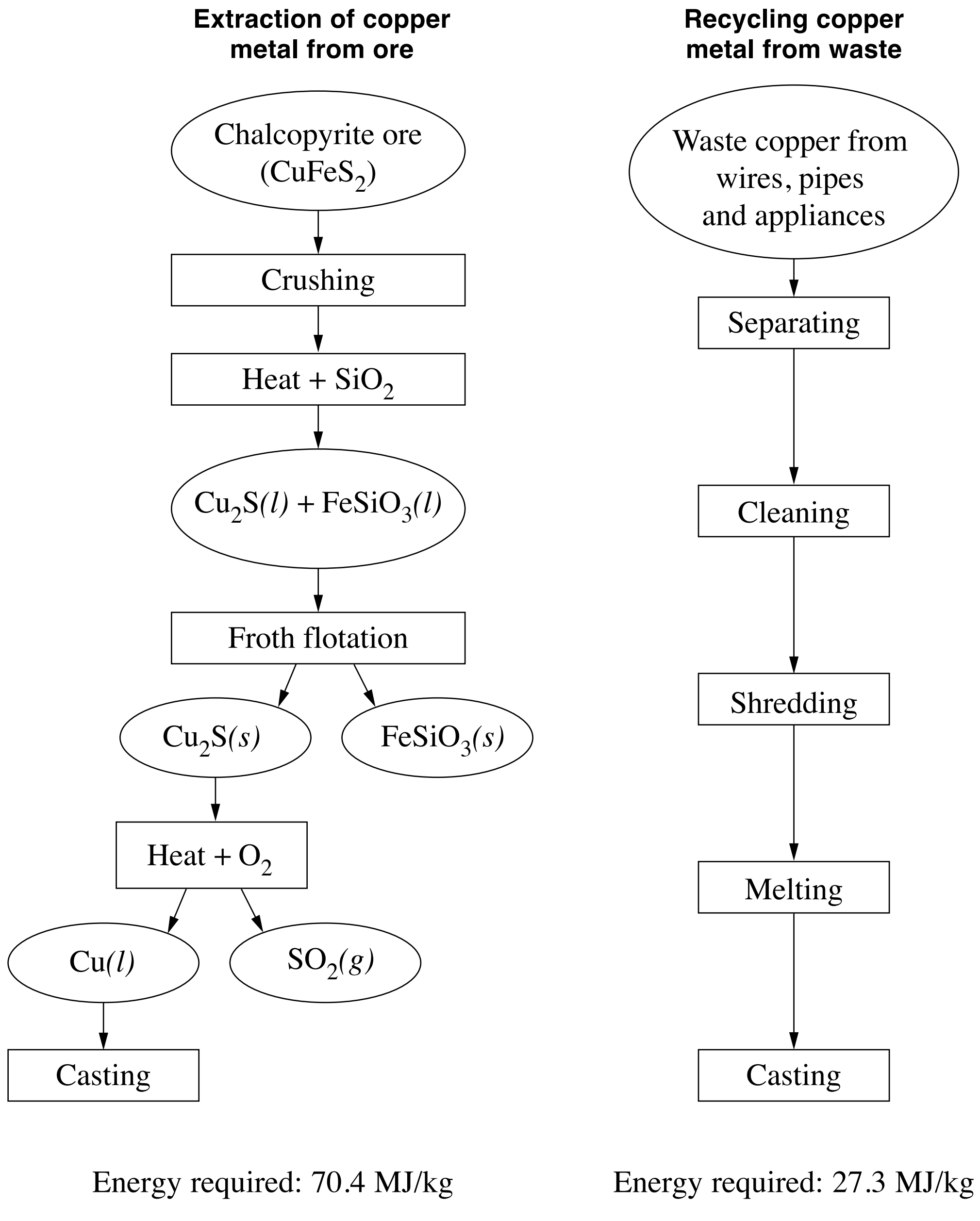
Please turn over

Question 30 (6 marks)

Australia has the second-largest copper reserves globally and is the eighth-largest copper producer. Copper ores, such as chalcopyrite, are mined in several remote locations in Australia. Copper can also be recycled from waste materials. The flow charts below show a simplified version of these processes.



Question 30 continues on page 25

Question 30 (continued)

(a) With reference to the information provided, explain the differences in the energy required to extract copper metal from chalcopyrite ore compared to recycling it from waste. **3**

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(b) One of the final stages in extraction of copper metal from this chalcopyrite ore is to heat Cu_2S in the presence of oxygen. Air contains 21.0% oxygen by volume. If the outside air temperature is 38.0°C and the pressure is 100 kPa, what volume of air (in kL) would need to be pumped into a reactor containing 734 kg of Cu_2S? **3**

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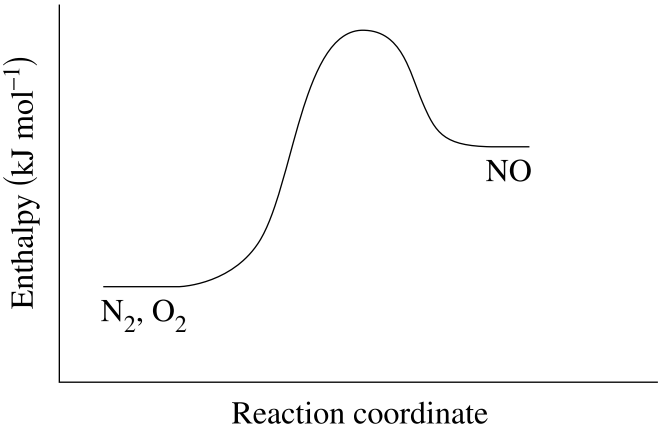
End of Question 30

Question 31 (4 marks)

Nitric oxide gas (NO) can be produced from the direct combination of nitrogen gas and oxygen gas in a reversible reaction, as shown. **4**

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

The energy profile diagram for this reaction is shown.



Explain, using collision theory, how an increase in temperature would affect the value of K_{eq} for this system. Refer to the diagram in your answer.

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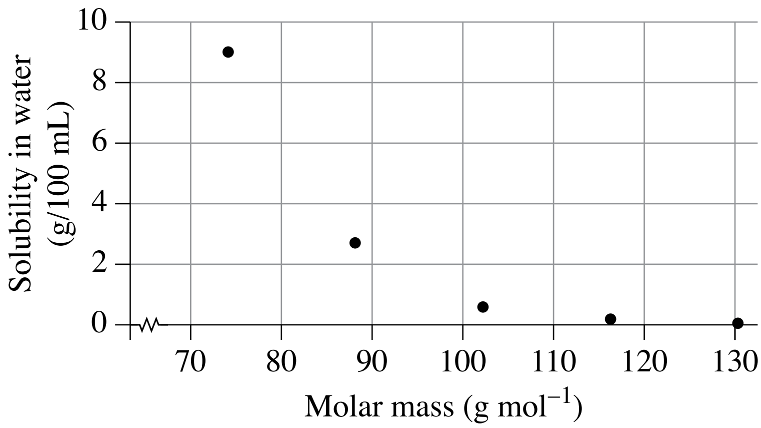
Question 31 shows one way that an item could require the integration of knowledge from more than one syllabus content point.

Question 32 (3 marks)

The following graph shows the solubility of some straight-chained alkan-1-ols in water at 20°C. **3**



Explain the relationship between the trend shown in the graph and the relevant intermolecular forces.

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Question 33 (11 marks)

Stormwater from a mine site has been found to be contaminated with copper(II) and lead(II) ions. The required discharge limit is 1.0 mg L^{-1} for each metal ion. Treatment of the stormwater with solid $Ca(OH)_2$ to remove the metal ions is recommended.

(a) Explain the recommended treatment with reference to solubility. Include a relevant chemical equation. **2**

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(b) Explain why atomic absorption spectroscopy can be used to determine the concentrations of Cu^{2+} and Pb^{2+} ions in a solution containing both species. **2**

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(c) The data below were obtained after treatment of the stormwater.

Data from atomic absorption spectroscopy

Concentration ($\times 10^{-5}$ mol L^{-1}) Cu^{2+} or Pb^{2+}	*Absorbance* Cu^{2+}	*Absorbance* Pb^{2+}
0.0	0.000	0.000
1.0	0.140	0.090
2.0	0.310	0.180
4.0	0.520	0.390
6.0	0.840	0.530
Water sample before treatment	0.820	0.440
Water sample after treatment	0.040	0.080

Question 33 continues on page 29

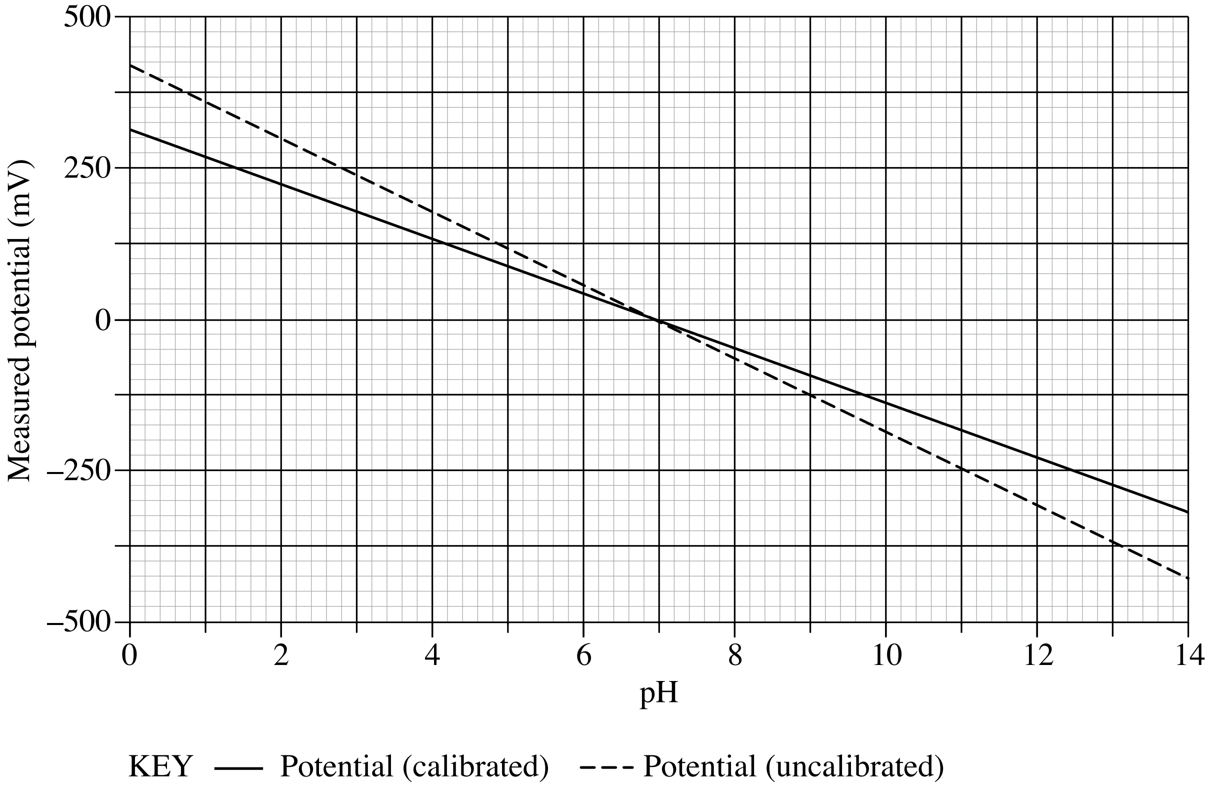
To what extent is the treatment effective in meeting the required discharge limit of 1.0 mg L^{-1} for each metal ion? Support your conclusion with calibration curves and calculations. **7**

Question 33 (c) shows one way an item could assess Working scientifically outcomes and content.

End of Question 33

Question 34 (5 marks)

Household pH probes measure a cell potential when immersed in a solution. The graph below shows the relationship between the measured potential and the pH for both an uncalibrated household pH probe and a calibrated pH probe.



(a) Calculate the percentage error in the measured potential when the uncalibrated household pH probe is placed in a solution for which the calibrated pH probe records a pH of 2. **2**

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Question 34 continues on page 31

Question 34 (continued)

(b) A solution of sodium hydroxide was used to clean a drain and there was excess solution to dispose of. The uncalibrated household pH probe was used to determine the pH of the sodium hydroxide solution and a value of 12.00 was recorded. This value was used to determine the amount of acetic acid required to neutralise 1.0 L of the sodium hydroxide solution. **3**

Assess the effectiveness of this strategy.

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End of Question 34

Question 35 (4 marks)

The following reaction occurs in an aqueous solution. **4**

$$HgCl_4^{2-}(aq) + Cu^{2+}(aq) \rightleftharpoons CuCl_4^{2-}(aq) + Hg^{2+}(aq) \qquad K_{eq} = 4.55 \times 10^{-11}$$

A solution containing a mixture of $HgCl_4^{2-}(aq)$ and $Cu^{2+}(aq)$ ions is prepared. The initial concentration of each ion is 0.100 mol L^{-1}, and there are no other ions present.

Calculate the concentration of $Hg^{2+}(aq)$ ions once the system has reached equilibrium.

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Question 36 (4 marks)

The table shows three compounds and their boiling points. **4**

Compound	*Boiling point* (°C)
Methanol	64.7
Propanoic acid	141.2
Methyl propanoate	79.8

An ester does not always have a lower boiling point than both the alcohol and the alkanoic acid from which it is produced.

Using the information in the table, account for this observation.

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Question 37 (5 marks)

The ammonium ion content of mixtures can be determined by boiling the mixture with a known excess of sodium hydroxide. This converts the ammonium ions into gaseous ammonia, which is removed from the system.

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

The excess sodium hydroxide can then be titrated with an acid solution of known concentration.

A fertiliser containing ammonium ions was analysed as follows.

- A sample of fertiliser was treated with 50.00 mL of 1.124 mol L^{-1} sodium hydroxide solution and the solution boiled.
- After all of the ammonia was removed, the resulting solution was transferred to a 250.0 mL volumetric flask and made up to the mark with deionised water.
- 20.00 mL aliquots of this solution were titrated with 0.1102 mol L^{-1} hydrochloric acid, giving the following results.

Titration	*Volume HCl* (mL)
1	22.65
2	22.05
3	22.00
4	21.95

Question 37 continues on page 35

Question 37 (continued)

Calculate the mass of ammonium ions in the sample of fertiliser. **5**

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End of Question 37

Question 38 (5 marks)

When performing industrial reductions with $CO(g)$, the following equilibrium is of great importance.

$$2CO(g) \rightleftharpoons CO_2(g) + C(s) \qquad K_{eq} = 10.00 \text{ at } 1095\text{ K}$$

A 1.00 L sealed vessel at a temperature of 1095 K contains $CO(g)$ at a concentration of 1.10×10^{-2} mol L^{-1}, $CO_2(g)$ at a concentration of 1.21×10^{-3} mol L^{-1}, and excess solid carbon.

(a) Is the system at equilibrium? Support your answer with calculations. **2**

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(b) Carbon dioxide gas is added to the system above and the mixture comes to equilibrium. The equilibrium concentrations of $CO(g)$ and $CO_2(g)$ are equal. Excess solid carbon is present and the temperature remains at 1095 K. **3**

Calculate the amount (in mol) of carbon dioxide added to the system.

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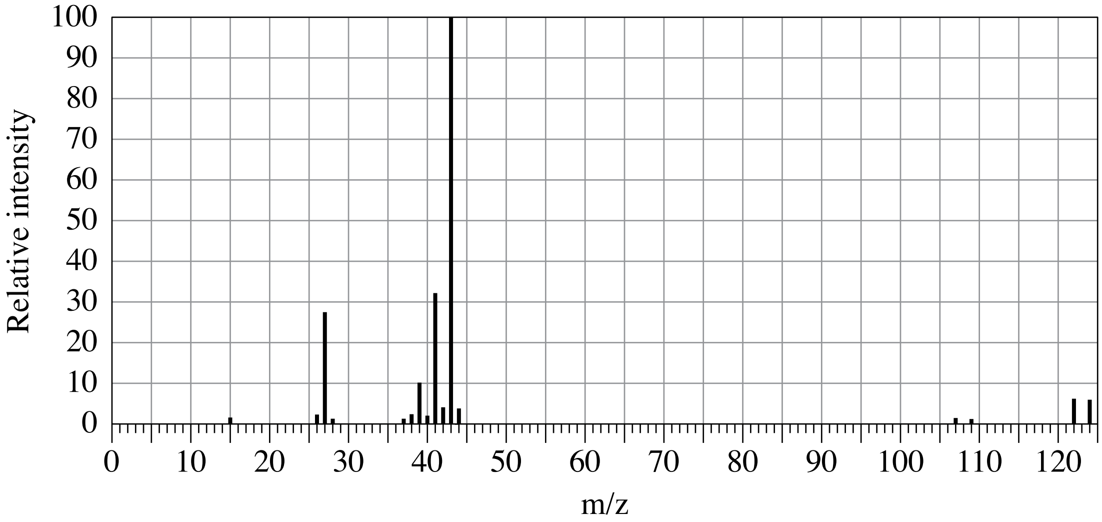
Question 39 (7 marks)

Compounds A and B are isomers with formula C_3H_7X, where X is a halogen. The mass spectrum for compound A is shown.



Compounds A and B undergo substitution reactions in the presence of hydroxide ions, producing alcohols C and D. Compound D can be oxidised to a ketone; compound C can also be oxidised, but does not produce a ketone.

$$\text{A} \xrightarrow{OH^-} \text{C}$$

$$\text{B} \xrightarrow{OH^-} \text{D} \xrightarrow{\text{oxidation}} \text{ketone}$$

Compound E can be produced by refluxing 3-methylbutanoic acid, with one of the alcohols C or D, in the presence of a catalyst.

The ^{1}H NMR spectrum for compound E contains the following features.

^{1}H NMR spectrum data for compound E

Chemical shift (ppm)	*Integration*	*Peak splitting*
0.95	3	Triplet
0.96	6	Doublet
1.7	2	Multiplet
2.1	1	Multiplet
2.2	2	Doublet
4.0	2	Triplet

Question 39 is an example of a past HSC question that has been used in this sample HSC examination. The proton ^{1}H NMR chemical shift data appears on the data sheet.

Question 39 continues on page 38

Question 39 (continued)

Draw the structure of compounds A, B and E. Explain your answer with reference to the information provided. **7**

Compound A
Compound B
Compound E

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Question 39 continues on page 39

Question 39 (continued)

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Question 39 shows one way that an item could require the integration of knowledge from more than one syllabus focus area.

End of paper

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NSW GOVERNMENT

NSW Education Standards Authority

Sample 2029 **HIGHER SCHOOL CERTIFICATE EXAMINATION**

Chemistry

The Chemistry formulae sheet and data sheet have been updated. Additions and changes have been highlighted in red boxes below.

FORMULAE SHEET

$n = \dfrac{m}{MM}$ $\quad C = \dfrac{n}{V}$ $\quad PV = nRT$

$q = mc\Delta T$ $\quad \boxed{C_1V_1 = C_2V_2}$ $\quad \boxed{\mathrm{pH} = -\log_{10}[\mathrm{H_3O^+}]}$

$\boxed{\Delta H = \dfrac{-q}{n}}$

Avogadro constant, N_A .... $6.022 \times 10^{23}\ \mathrm{mol^{-1}}$

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 .... $8.314\ \mathrm{J\ mol^{-1}\ K^{-1}}$

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

Specific heat capacity of water .... $4.18 \times 10^{3}\ \mathrm{J\ kg^{-1}\ K^{-1}}$

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}

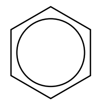
Compound	K_{sp}
Lead(II) bromide	6.60×10^{-6}
Lead(II) chloride	1.70×10^{-5}
Lead(II) iodide	9.8×10^{-9}
Lead(II) carbonate	7.40×10^{-14}
Lead(II) hydroxide	1.43×10^{-15}
Lead(II) phosphate	8.0×10^{-43}
Lead(II) sulfate	2.53×10^{-8}
Magnesium carbonate	6.82×10^{-6}
Magnesium hydroxide	5.61×10^{-12}
Magnesium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

^{1}H NMR chemical shift data

Type of proton	δ/ppm
$\mathrm{R-}\mathbf{CH_3}$	0.9–1.0
$\mathrm{R-}\mathbf{CH_2}\mathrm{-R}$	1.3–1.4
$\mathrm{R_3-}\mathbf{CH}$	1.4–1.8
$\mathrm{R-CH{=}CH-}\mathbf{CH_3}$	1.6–1.9
$\mathrm{R-O-C({=}O)-}\mathbf{CH_3}$	2.0–2.7
$\mathrm{R-C({=}O)-}\mathbf{CH_3}$	2.1–2.7
$\mathrm{R-}\mathbf{CH_2}\mathrm{-X}$ (X is F, Cl, Br or I)	3.0–4.5
$\mathrm{R-}\mathbf{CH_2}\mathrm{-OH}$	3.3–4.5
$\mathrm{R_2-}\mathbf{CH}\mathrm{-OH}$	3.3–4.5
$\mathrm{R-O-}\mathbf{CH_3}$ or $\mathrm{R-O-}\mathbf{CH_2}\mathrm{R}$	3.3–3.7
$\mathrm{R-O-C({=}O)-O-}\mathbf{CH_2}\mathrm{-R}$	3.7–4.8
$\mathrm{R-O-}\mathbf{H}$	1–6 (varies considerably under different conditions)
$\mathrm{R-HC{=}}\mathbf{CH}\mathrm{-R}$	4.5–7.0
$\mathrm{R-C({=}O)-}\mathbf{H}$	9.4–10.0
$\mathrm{R-C({=}O)-O-}\mathbf{H}$	9.0–13.0

Typical proton chemical shift values relative to TMS = 0. These can differ slightly in different solvents. The shift refers to the proton environment that is indicated in bold letters **(H)** in the formula.

^{13}C NMR chemical shift data

Type of carbon		δ/ppm
$\mathrm{-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-}$		5–40
$\mathrm{R-\overset{|}{\underset{|}{C}}-}$Cl or Br		10–70
$\mathrm{R-C({=}O)-\overset{|}{\underset{|}{\mathbf{C}}}-}$		20–50
$\mathrm{-\overset{|}{\underset{|}{C}}-O-}$	alcohols or esters	50–90
$\mathrm{>C{=}C<}$		90–150
		110–160
$\mathrm{R-C({=}O)-}$	esters or acids	160–185
$\mathrm{R-C({=}O)-}$	aldehydes or ketones	190–220

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=O	1680–1750
C=C	1620–1680

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 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.

HSC Chemistry Sample Examination Marking Guidelines

Section I

Multiple-choice Answer Key

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

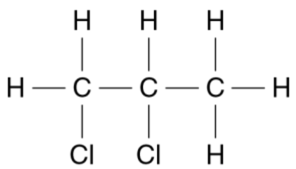
Section II

Sample answers are provided for each question in Section II. Sample answers show one way a student may answer a question and there may be alternative responses that are correct. Sample answers show one way maximum marks may be achieved for that question.

Question 21

Criteria	Marks
• Provides the correct structure	2
• Structure drawn with an addition of at least one chlorine atom	1

Sample answer:



Question 22

Criteria	Marks
• Provides a correct base and its conjugate acid	2
• Provides a correct base or conjugate acid from the reaction	1

Sample answer:

Base	*Conjugate acid*
PO_4^{3-}	HPO_4^{2-}

OR

Base	*Conjugate acid*
F^-	HF

Question 23

Criteria	Marks
• Provides a sound relationship between the observed colour change and K_{eq}	3
• Provides some information about changes in concentration of reactants and/or products	2
• Provides some relevant information	1

Sample answer:

The mixture becomes more blue as temperature is increased, which suggests that the concentration of $8CoCl_4B^{2-}$ is increasing. This means that an increase in temperature favours the forward reaction. This response will result in a larger value of K_{eq} as

$$K_{eq} = \frac{\left[\left[CoCl_4\right]^{2-}\right]}{\left[\left[Co(H_2O)_6\right]^{2+}\right]\left[Cl^-\right]^4}$$

Question 24

Criteria	Marks
• Provides a sound explanation of the pH changes that occur in both solutions	3
• Provides an explanation of the pH change in one of the solutions	2
• Provides some relevant information	1

Sample answer:

The pH of solution X changed significantly when base was added, while the pH of solution Y showed only a small change in pH. This indicates that solution Y contains a buffer while solution X does not.

When NaOH was added to solution X, the addition of OH^- ions from the base caused the increase in pH (as pH = $-\log_{10}[H_3O^+]$).

In solution Y, these OH^- ions reacted with the buffer solution, which minimised the change in $[H_3O^+]$ and therefore pH.

Question 25

Criteria	Marks
• Demonstrates $HC_2O_4^-$ is able to accept and donate protons • Includes correct chemical equations	2
• Provides some relevant information	1

Sample answer:

$HC_2O_4^-$ can either accept or donate H^+, as illustrated in the equations below:

$$HC_2O_4^-(aq) + H^+(aq) \rightleftharpoons H_2C_2O_4(aq)$$

$$HC_2O_4^-(aq) + OH^-(aq) \rightleftharpoons H_2O(l) + C_2O_4^{2-}(aq)$$

As it can either accept or donate H^+, $HC_2O_4^-$ can be described as amphiprotic.

Question 26

Criteria	Marks
• Identifies M as Ni • Provides all relevant half-equations, overall equation and cell potentials	3
• Provides the main steps	2
• Provides some relevant information	1

Sample answer:

M is nickel.

Cell 1:

Oxidation: $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$ $E^\circ = +0.76$ V

Reduction: $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ $E^\circ = -0.24$ V

Cell 2:

$Ni(s) + 2Ag^+(aq) \rightarrow Ni^{2+}(aq) + 2Ag(s)$ $E^\circ = 0.24 + 0.80 \text{ V} = 1.04 \text{ V}$

Question 27 (a)

Criteria	Marks
• Calculates the mass of octan-1-ol burnt	3
• Provides some correct steps of the calculation	2
• Provides some relevant information	1

Sample answer:

Heat absorbed by water = mass of water × c × ΔT

q = 205 g × 4.18 J K^{-1} g^{-1} × 36.7 K

q = 31 448 J

q = 31.448 kJ

$$n(\text{octan-1-ol}) = \frac{-31.448 \text{ kJ}}{-5294 \text{ kJ mol}^{-1}} = 5.94 \times 10^{-3} \text{ mol}$$

m(octan-1-ol) = 5.94×10^{-3} mol × 130.22 g mol^{-1} = 0.774 g

Question 27 (b)

Criteria	Marks
• Explains ONE advantage of using ethanol derived from plants	2
• Provides some relevant information	1

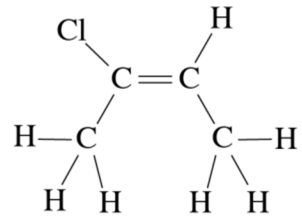
Sample answer:

Combustion of ethanol derived from plants will have a lower greenhouse impact as the carbon dioxide released during combustion will replace that consumed during recent photosynthesis, unlike ethanol derived from crude oil.

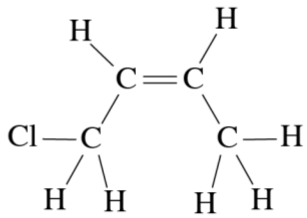
Question 28

Criteria	Marks
• Provides THREE correct structural formulae with correct names	3
• Provides THREE correct structural formulae with at least ONE correct name OR • Provides TWO correct structural formulae with at least TWO correct names	2
• Provides some relevant information	1

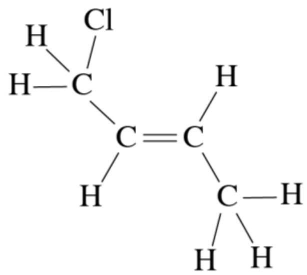
Sample answer:



(2*E*)-2-chlorobut-2-ene



(2*Z*)-1-chlorobut-2-ene
OR
cis-1-chlorobut-2-ene



(2*E*)-1-chlorobut-2-ene
OR
trans-1-chlorobut-2-ene

Question 29

Criteria	Marks
• Calculates the K_a	3
• Provides some steps for calculating the K_a	2
• Provides some relevant information	1

Sample answer:

$[H^+] = 10^{-pH} = 10^{-1.107} = 0.0782 \text{ mol L}^{-1}$

	$CHCl_2COOH(aq)$	$\rightleftharpoons$	$H^+(aq)$	$CHCl_2COO^-(aq)$
Initial	0.2000		0	0
Change	–0.0782		+0.0782	+0.0782
Equilibrium	0.1218		0.0782	0.0782

$$K_a = \frac{[H^+][CHCl_2COO^-]}{[CHCl_2COOH]}$$

$$= \frac{[0.0782][0.0782]}{[0.1218]}$$

$$= 0.0501$$

Question 30 (a)

Criteria	Marks
• Explains the differences in energy required, using the information provided	3
• Explains a difference in energy required, using the information provided OR • Describes differences in energy required, using the information provided	2
• Provides some relevant information	1

Sample answer:

Mining copper uses 43.1 MJ/kg more energy than recycling copper from waste (70.4 MJ/kg vs 27.3 MJ/kg).

Mining, crushing and heating all require a large amount of energy. Waste products, such as $FeSiO_3$ and SO_2 must either be disposed of or further reacted to produce useful substances, which also requires energy for transportation and/or processing.

Recycling copper involves the physical processes of collecting, sorting, shredding and melting. This requires less energy because the copper is already in metallic form and does not need to be chemically separated from other the mixtures and compounds present in the copper ore.

Question 30 (b)

Criteria	Marks
• Calculates the volume of air • Provides some correct steps of the calculation	3
• Completes most relevant information	2
• Provides some relevant information	1

Sample answer:

$$n(\mathrm{Cu_2S}) = m\,/\,MM = \frac{734\ 000\ \mathrm{g}}{(2 \times 63.55 + 32.07)\ \mathrm{g\ mol^{-1}}} = 4611\ \mathrm{mol}$$

$$\mathrm{Cu_2S}(s) + \mathrm{O_2}(g) \rightarrow 2\ \mathrm{Cu}(s) + \mathrm{SO_2}(g)$$

$n(\mathrm{Cu_2S}) : n(\mathrm{O_2})$ = 1:1, therefore 4611 mol O_2 required

$$PV = nRT$$

$$V(\mathrm{O_2}) = nRT\,/\,P = 4611 \times 8.314 \times (38.0 + 273.15)\,/\,100 = 119 \times 10^3\ \mathrm{L} = 119\ \mathrm{kL}$$

$$V(\mathrm{air}) = 119\ \mathrm{kL} \times \frac{100}{21} = 568\ \mathrm{kL}$$

Question 31

Criteria	Marks
• Provides an explanation, using collision theory • Refers to the diagram	4
• Shows a sound understanding of how increasing temperature favours an endothermic process, with reference to some aspects of the collision theory	3
• Shows understanding of the effect of increasing temperature	2
• Provides some relevant information	1

Sample answer:

The forward reaction is endothermic. For the reaction to proceed the reacting molecules must possess the activation energy to result in successful collisions. The activation energy for the forward reaction is greater than that of the reverse, exothermic reaction. An increase in temperature will increase the average kinetic energy of all molecules, resulting in more effective collisions increasing the reaction rate for both the forward and reverse reactions. However, the added temperature will have a greater impact on the forward reaction and the rate of this reaction will be higher than that of the reverse reaction.

As a result, the forward reaction is favoured.

As $K_{eq} = \frac{[NO]^2}{[N_2][O_2]}$, a shift to the right will result in an increase in K_{eq}.

Question 32

Criteria	Marks
• Provides a thorough explanation of the relationship between the trend and named intermolecular forces	3
• Provides a sound explanation of the relationship	2
• Provides some relevant information	1

Sample answer:

As the molar mass increases within this homologous series, the chain length increases. As the chain length increases, the solubility of alkan-1-ols in water decreases. Shorter chain alcohols dissolve in water due to the formation of hydrogen bonds between the hydroxyl group of the alcohol and water molecules. However, as the chain length increases, the dispersion forces between the alkyl groups become more significant which decreases the solubility of alkan-1-ols in water.

Question 33 (a)

Criteria	Marks
• Explains the treatment, with reference to solubility • Provides a correct chemical equation	2
• Provides some relevant information	1

Sample answer:

Calcium hydroxide, $Ca(OH)_2$, is slightly soluble in water. Copper(II) hydroxide and lead(II) hydroxide are both very insoluble in water shown by their small K_{sp} values, which will result in most of the metal ions precipitating.

A chemical equation: $Cu(OH)_2(s) \rightleftharpoons Cu^{2+}(aq) + 2OH^-(aq)$

Question 33 (b)

Criteria	Marks
• Provides a valid explanation	2
• Provides some relevant information	1

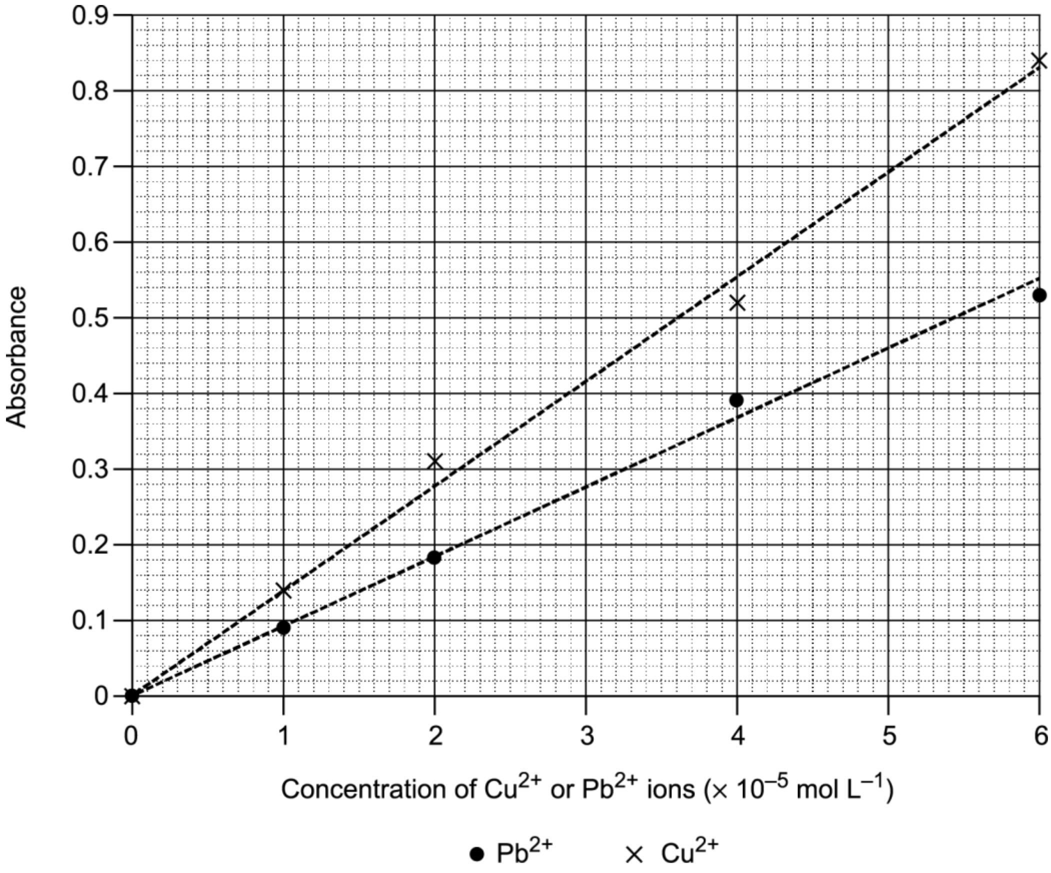
Sample answer:

AAS determines the concentration of metal ions by measuring the absorbance of light at different characteristic wavelengths for each metal. This allows the determination of the concentration of one metal without interference from the other metal.

Question 33 (c)

Criteria	Marks
• Provides correct graph including: – Labels axes correctly, including units – Uses appropriate scale – Plots both sets of data – Draws two lines of best fit – Provides a key • Provides correct concentration values • Converts concentration data from mol L^{-1} to mg L^{-1} • Compares to discharge limit and makes correct judgement of treatment success	7
• Provides correct graph, concentration values and applies conversion with minor errors • Provides some judgement of treatment success	6
• Provides correct graph, provides correct concentration values and applies conversion OR • Provides a substantially correct graph, provides concentration values, applies conversion and attempts judgement	5
• Provides correct graph and provides correct concentration values OR • Provides a graph with some correct features, provides concentration values and applies conversion	4
• Provides correct graph OR • Provides a graph with some correct features and provides some concentration values	3
• Provides a substantially correct graph OR • Provides a graph with two correct features and extracts some relevant sample data OR • Provides a graph with one correct feature, extracts some relevant sample data and attempts a relevant conversion	2
• Provides some relevant information	1

Sample answer:



Concentrations of metal ions in mol L^{-1}

Sample	Cu^{2+} × 10^{-5} mol L^{-1}	Pb^{2+} × 10^{-5} mol L^{-1}
Water sample pre-treatment	5.95	4.75
Water sample post-treatment	0.25	0.85

The copper and lead concentrations have both been lowered by the treatment. To compare the post treatment concentrations to the discharge standard, the sample concentrations need to be converted to mg L^{-1}.

Cu^{2+}: 5.95×10^{-5} mol $L^{-1} \times 63.55$ g $mol^{-1} \times 1000$ mg g^{-1} = 3.78 mg L^{-1}
0.25×10^{-5} mol $L^{-1} \times 63.55$ g $mol^{-1} \times 1000$ mg g^{-1} = 0.20 mg L^{-1}

Pb^{2+}: 4.75×10^{-5} mol $L^{-1} \times 207.2$ g $mol^{-1} \times 1000$ mg g^{-1} = 9.84 mg L^{-1}
0.85×10^{-5} mol $L^{-1} \times 207.2$ g $mol^{-1} \times 1000$ mg g^{-1} = 1.8 mg L^{-1}

The copper ion concentration has been successfully lowered to less than the discharge limit. However, the lead ion concentration, although reduced, remains above the discharge limit. The treatment is only partially successful.

Question 34 (a)

Criteria	Marks
• Calculates the percentage error correctly showing all steps	2
• Provides some relevant information	1

Sample answer:

At pH 2, potential (calibrated) = 225 mV and potential (uncalibrated) = 300 mV.

$$\% \text{ error} = \frac{300 \text{ mV} - 225 \text{ mV}}{225 \text{ mV}} \times 100 = 33\%$$

Question 34 (b)

Criteria	Marks
• Assesses the effectiveness of the strategy	3
• Shows understanding of the effect of calibration	2
• Provides some relevant information	1

Sample answer:

At pH 12, potential (uncalibrated) = –310 mV. This corresponds to a pH of 13.7, as read by the calibrated pH probe. Accordingly, less acetic acid will be added than required to neutralise the NaOH, so this strategy is ineffective.

Question 35

Criteria	Marks
• Calculates the concentration of Hg^{2+} ions, showing all working	4
• Provides substantially correct working	3
• Provides some correct steps	2
• Provides some relevant information	1

Sample answer:

$$K_{eq} = \frac{\left[CuCl_4^{\ 2-}\right]\left[Hg^{2+}\right]}{\left[HgCl_4^{\ 2-}\right]\left[Cu^{2+}\right]}$$

	$\left[HgCl_4^{\ 2-}\right]$	$\left[Cu^{2+}\right]$	$\left[CuCl_4^{\ 2-}\right]$	$\left[Hg^{2+}\right]$
I	0.100	0.100	0	0
C	$-x$	$-x$	$+x$	$+x$
E	$0.100 - x$	$0.100 - x$	x	x

$$K = \frac{x^2}{(0.100 - x)^2} = 4.55 \quad 10^{-11}$$

Solving for x (take square root OR assume that $x \ll 0.100$ OR use the quadratic formula),

$x = 6.75 \times 10^{-7}$ mol L^{-1}

So $\left[Hg^{2+}\right] = 6.75 \times 10^{-7}$ mol L^{-1}

Question 36

Criteria	Marks
• Accounts for the observation using the information provided	4
• Outlines reasons for the observation using some of the information provided	3
• Outlines a reason for the observation OR • Identifies reasons for the observation	2
• Provides some relevant information	1

Sample answer:

The boiling points of all three compounds are determined by the intermolecular forces between their molecules. Both methanol and propanoic acid have hydrogen bonding between their molecules, while the ester (methyl propanoate) does not. As hydrogen bonding is the strongest type of intermolecular force it might be assumed that this would give the ester a lower boiling point. However, all three compounds also have dispersion forces between molecules. These increase with the number of electrons per molecule. The dispersion forces between the ester molecules are larger than the combined effect of dispersion forces and hydrogen bonding in the alcohol, so the ester has a higher boiling point than methanol.

Question 37

Criteria	Marks
• Calculates the mass of ammonium ions in the sample to four significant figures	5
• Provides a substantially correct calculation	4
• Provides main steps in the calculation	3
• Provides some relevant steps in the calculation	2
• Provides some relevant information	1

Sample answer:

$V(\text{HCl, average}) = \dfrac{22.05 + 22.00 + 21.95}{3} = 22.00 \text{ mL} = 0.02200 \text{ L}$

$n(\text{HCl}) = 0.02200 \text{ L} \times 0.1102 \text{ mol L}^{-1} = 2.424 \times 10^{-3} \text{ mol}$

$n(\text{NaOH, excess, in 20 mL aliquot}) = 2.424 \times 10^{-3} \text{ mol}$

$n(\text{NaOH, excess, in 250.0 mL flask}) = \dfrac{250.00 \text{ mL}}{20.00 \text{ mL}} \times 2.424 \times 10^{-3} \text{ mol} = 3.031 \times 10^{-2} \text{ mol}$

$n(\text{NaOH, total}) = 0.0500 \text{ L} \times 1.124 \text{ mol L}^{-1} = 5.620 \times 10^{-2} \text{ mol}$

$n(\text{NaOH reacting with } NH_4^+) = 5.620 \times 10^{-2} \text{ mol} - 3.031 \times 10^{-2} \text{ mol} = 2.590 \times 10^{-2} \text{ mol}$

$n(NH_4^+) = 2.590 \times 10^{-2} \text{ mol}$

$MM(NH_4^+) = 14.01 + 4 \times 1.008 = 18.042 \text{ g mol}^{-1}$

$m(NH_4^+) = 2.590 \times 10^{-2} \text{ mol} \times 18.042 \text{ g mol}^{-1} = 0.4672 \text{ g}$

Question 38 (a)

Criteria	Marks
• Calculates Q and compares to K_{eq} to determine whether the system is in equilibrium	2
• Provides some relevant information	1

Sample answer:

$$K_{eq} = \frac{[CO_2]}{[CO]^2}$$

$$Q = \frac{1.21 \times 10^{-3}}{(1.10 \times 10^{-2})^2} = 10.0 = K_{eq}$$

Since $Q = K_{eq}$, the system is at equilibrium.

Question 38 (b)

Criteria	Marks
• Calculates the amount of CO_2 added to the system	3
• Provides some relevant steps in the calculation	2
• Provides some relevant information	1

Sample answer:

$$K_{eq} = \frac{[CO_2]}{[CO]^2}$$

Since $[CO] = [CO_2]$, $K_{eq} = \frac{[CO]}{[CO]^2} = \frac{1}{[CO]} = 10.00$

So $[CO] = \frac{1}{10.00} = 0.1000 \text{ mol L}^{-1} = [CO_2]$

	$2CO(g)$	$\rightleftharpoons$	$CO_2(g)$	+	$C(s)$
Initial	1.10×10^{-2}		1.21×10^{-3}		
Change	+0.0890		+0.0988		
Equilibrium	0.1000		0.1000		

Since 1 mol of CO_2 gives 2 mol of CO:

$n(CO_2)$ required to be added to increase $[CO_2]$ = 0.0988 mol

$n(CO_2)$ total = 0.0988 mol + $n(CO_2$ required to make CO)

$n(CO_2)$ required to be added to increase [CO] = $\frac{0.0890}{2}$ = 0.0445 mol

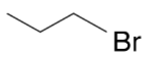
Total $n(CO_2)$ added = 0.0445 + 0.0988 = 0.143 mol

Question 39

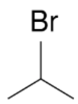
Criteria	Marks
• Draws the correct structure of compounds A, B and E • Explains the correct structures showing an extensive understanding of the interpretation of spectroscopic data and reaction pathways • Refers to relevant spectroscopic data	7
• Draws the correct structure of compounds A, B and E • Explains the correct structures showing a thorough understanding of the interpretation of spectroscopic data and reaction pathways • Refers to most relevant spectroscopic data	6
• Shows a sound understand of the interpretation of spectroscopic data and reaction pathways • Uses relevant information presented in the question to explain structures • Draws structures for compounds A and B with halogen location correct AND/OR • Draws correct structure for compound E	4–5
• Demonstrates some understanding of the different reactions AND/OR • Demonstrates some understanding of the interpretation of spectroscopic data	2–3
• Provides some relevant information	1

Sample answer:

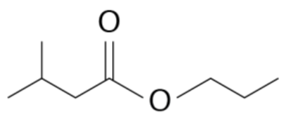
Compound A



Compound B



Compound E



From the mass spectrum of A, the two peaks at m/z 122/124 indicate the presence of a Br atom (two isotopes of approximately equal abundance) – halogen X in C_3H_7X is Br.

The peak at m/z 43 is due to the loss of Br.

There are two isomers of C_3H_7Br: 1-bromopropane and 2-bromopropane. These will produce propan-1-ol and propan-2-ol respectively after substitution with hydroxide. Only propan-2-ol will produce a ketone upon oxidation, so B must be 2-bromopropane and A must be 1-bromopropane.

E is an ester formed from the reaction of 3-methylbutanoic acid with either C (propan-1-ol) or D (propan-2-ol).

> The chemical shift for the CH_2 multiplet at 1.7 ppm is slightly higher than the range on the data sheet (1.3–1.4) due to the proximity of the electronegative O atom. The same is true for the CH multiplet at 2.1 ppm, due to the proximity of the C=O group.

The ^{1}H NMR data gives the following information:

- The peak at δ 4.0 ppm is a CH_2 group bonded to an oxygen atom (hence the high chemical shift). This tells us that E is a propyl ester, $—OCH_2CH_2CH_3$.
- The rest of the propyl group gives rise to a CH_2 multiplet (present at δ 1.7 ppm) and a CH_3 triplet (present at δ 0.95 ppm).
- The peak at δ 2.2 ppm is a CH_2 group attached to a carbonyl (C═O) group.
- The remaining peaks integrate for 6 (δ 0.95 ppm doublet) and 1 (δ 2.1 ppm multiplet), which indicates an isopropyl group attached to the CH_2 group, giving the structure for E.

This mapping grid shows how the Chemistry Sample HSC Examination allows for appropriate differentiation of student performance at each band on the performance scale. An examination committee uses a mapping grid to ensure the examination is appropriately mapped to the course's syllabus and performance standards.

HSC Chemistry Sample Examination Mapping Grid

An examination committee uses the 'targeted syllabus outcomes' column of the mapping grid to ensure there is a representative sample of a **range of syllabus outcomes** throughout the examination.

The 'targeted performance bands' column of the mapping grid shows how questions in this sample HSC examination are targeted to **levels of performance** that are described in the bands on the performance scale.

Section I

Question	Marks	Content	Targeted syllabus outcomes	Targeted performance bands
1	1	Organic chemistry – Hydrocarbons	CH-12-03	2–3
2	1	Acid-base reactions – Properties of acids and bases	CH-12-02	2–3
3	1	Acid-base reactions – Properties of acids and bases	CH-12-02, CH-12-WS-06	2–3
4	1	Applying chemical ideas – Analysis and uses of organic substances	CH-12-04, CH-12-WS-04	2–3
5	1	Applying chemical ideas – Analysis and uses of organic substances	CH-12-04	3–4
6	1	Organic chemistry – Alcohols	CH-12-03, CH-12-WS-02	3–4
7	1	Acid-base reactions – Using Brønsted–Lowry theory	CH-12-02, CH-12-WS-07	3–4
8	1	Applying chemical ideas – Analysis and uses of organic substances	CH-12-04, CH-12-WS-06	3–4
9	1	Acid-base reactions – Quantitative analysis	CH-12-02, CH-12-WS-05	3–4
10	1	Organic chemistry – Organic acids	CH-12-03	3–4
11	1	Acid-base reactions – Quantitative analysis	CH-12-02, CH-12-WS-04	4–5
12	1	Organic chemistry – Hydrocarbons Organic chemistry – Alcohols	CH-12-03, CH-12-WS-06	4–5
13	1	Applying chemical ideas – Analysis and uses of inorganic substances	CH-12-04, CH-12-WS-05	4–5
14	1	Equilibrium – Factors that affect equilibrium	CH-12-01, CH-12-WS-06	4–5

Question	Marks	Content	Targeted syllabus outcomes	Targeted performance bands
15	1	Equilibrium – Solution equilibria	CH-12-01, CH-12-WS-05	4–5
16	1	Organic chemistry – Esters	CH-12-03, CH-12-WS-04	4–5
17	1	Equilibrium – Solution equilibria	CH-12-01, CH-12-WS-06	5–6
18	1	Equilibrium – Solution equilibria	CH-12-01, CH-12-WS-04	5–6
19	1	Equilibrium – Calculating the equilibrium constant	CH-12-01, CH-12-WS-07	5–6
20	1	Applying chemical ideas – Analysis and uses of inorganic substances	CH-12-04, CH-12-WS-04	5–6

Section II

Question	Marks	Content	Targeted syllabus outcomes	Targeted performance bands
21	2	Organic chemistry – Hydrocarbons	CH-12-03, CH-12-WS-07	2–3
22	2	Acid-base reactions – Using Brønsted–Lowry theory	CH-12-02	2–3
23	3	Equilibrium – Factors that affect equilibrium	CH-12-01, CH-12-WS-05	2–4
24	3	Acid-base reactions – Using Brønsted–Lowry theory	CH-12-02, CH-12-WS-05	3–5
25	2	Acid-base reactions – Using Brønsted–Lowry theory	CH-12-02, CH-12-WS-05, CH-12-WS-06	4–5
26	3	Applying chemical ideas – Analysis and uses of inorganic substances	CH-12-04, CH-12-WS-05	3–5
27 (a)	3	Organic chemistry – Alcohols	CH-12-03, CH-12-WS-04	3–5
27 (b)	2	Organic chemistry – Alcohols Applying chemical ideas – Analysis and uses of organic substances	CH-12-03, CH-12-04	3–4
28	3	Organic chemistry – Hydrocarbons	CH-12-03, CH-12-WS-07	3–5
29	3	Acid-base reactions – Using Brønsted–Lowry theory	CH-12-02, CH-12-WS-04	3–5
30 (a)	3	Applying chemical ideas – Analysis and uses of inorganic substances	CH-12-04, CH-12-WS-04	3–5
30 (b)	3	Applying chemical ideas – Analysis and uses of inorganic substances	CH-12-04, CH-12-WS-06	3–5
31	4	Equilibrium – Factors that affect equilibrium and Equilibrium – Calculating the equilibrium constant	CH-12-01, CH-12-WS-05	3–6
32	3	Organic chemistry – Alcohols	CH-12-03, CH-12-WS-05	3–5

Question	Marks	Content	Targeted syllabus outcomes	Targeted performance bands
33 (a)	2	Equilibrium – Solution equilibria	CH-12-01, CH-12-WS-04	3–4
33 (b)	2	Applying chemical ideas – Analysis and uses of inorganic substances	CH-12-04	3–4
33 (c)	7	Applying chemical ideas – Analysis and uses of inorganic substances	CH-12-04, CH-12-WS-04, CH-12-WS-07	2–6
34 (a)	2	Acid-base reactions – Quantitative analysis	CH-12-02, CH-12-WS-05	4–5
34 (b)	3	Acid-base reactions – Quantitative analysis	CH-12-02 CH-12-WS-05	4–6
35	4	Equilibrium – Calculating the equilibrium constant	CH-12-01, CH-12-WS-04	3–6
36	4	Organic chemistry – Esters	CH-12-03, CH-12-WS-05	3–6
37	5	Acid-base reactions – Quantitative analysis	CH-12-02, CH-12-WS-04, CH-12-WS-05	2–6
38 (a)	2	Equilibrium – Calculating the equilibrium constant	CH-12-01, CH-12-WS-05	4–5
38 (b)	3	Equilibrium – Calculating the equilibrium constant	CH-12-01, CH-12-WS-05	4–6
39	7	Applying chemical ideas – Analysis and uses of organic substances Organic chemistry – Alcohols Organic chemistry – Esters	CH-12-04, CH-12-03, CH-12-WS-04, CH-12-WS-06	2–6