2019 HSC Chemistry Marking Guidelines

Section I

Multiple-choice Answer Key

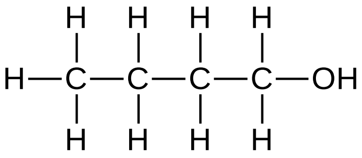
Question	Answer
1	D
2	B
3	A
4	B
5	C
6	A
7	D
8	A
9	B
10	D
11	C
12	C
13	B
14	A
15	B
16	B
17	D
18	A
19	D
20	C

Section II

Question 21 (a)

Criteria	**Marks**
• Provides an acceptable structure and name	2
• Provides some relevant information	1

Sample answer:



$$\begin{array}{ccccccccccc} & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & OH \\ & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & \end{array}$$

butan-1-ol

Answers could include:

Condensed or skeletal formulae. Other unambiguous systematic names are acceptable, eg 1-butanol.

Question 21 (b)

Criteria	**Marks**
• States why the two compounds are classed as functional group isomers	2
• Provides some relevant information	1

Sample answer:

Both compounds have the same molecular formula (C_3H_6O) but have different functional groups.

Question 21 (c)

Criteria	Marks
• Identifies a suitable test • Provides the appropriate observations • Explains the observations	3
• Identifies the observations and the test reagent OR • Explains the observations	2
• Provides some relevant information	1

Sample answer:

Tollens' test could be used to distinguish between Isomer A (ketone) and Isomer B (aldehyde). Aldehydes are readily oxidised to carboxylic acids whereas ketones are not. Isomer B will therefore reduce the silver ions in the Tollens' reagent to form a silver mirror inside the test tube whereas Isomer A will not react.

Answers could include:

Other oxidants that can oxidise Isomer B but not Isomer A, eg $Cr_2O_7^{2-}$, MnO_4^{-}.

I_2/OH^- will give iodoform with Isomer A but not with Isomer B.

The orange dichromate solution will change to green.

The purple permanganate solution will decolourise.

Question 22

Criteria	**Marks**
• Identifies that the observed effect is due to small variation in pH • Explains what occurs when acid and base are added • Includes at least one equation	4
• Identifies that the observed effect is due to small variation in pH • Explains what occurs when acid or base is added • Includes a substantially correct equation	3
• Provides a correct equation • OR • Includes a partially correct equation and shows some understanding of what occurs when acid or base is added	2
• Provides some relevant information	1

Sample answer:

The colour of the universal indicator did not change because the pH did not change very much despite the addition of acid and/or base. This is due to the equilibrium position of the buffer equation shifting in response to the addition of acid and/or base in accordance with Le Chatelier's Principle.

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

If acid is added the equilibrium position will shift left and if base is added the equilibrium position shifts right. In both cases the concentration of H_3O^+ remains nearly constant.

Question 23 (a)

Criteria	Marks
• Correctly calculates $\triangle_c H$ with units • Uses correct significant figures	4
• Provides substantially correct working	3
• Provides some relevant steps	2
• Provides some relevant information	1

Sample answer:

Moles ethanol (n) $= 0.370\text{ g} / (12.01 \times 2 + 1.008 \times 6 + 16.00\text{ g mol}^{-1})$
$= 0.008032\text{ mol}$

$$q = mC\triangle T$$

$$= 105\text{ g} \times 4.18\text{ J g}^{-1}\text{K}^{-1} \times (30 - 18.5)\text{K}$$

$$= 5047.35\text{ J}$$

$$\triangle_c H = -\frac{q}{n} = -\frac{5047.35\text{ J}}{0.008032\text{ mol}}$$

$$= -628405\text{ J mol}^{-1}$$

$$= -628\text{ kJ mol}^{-1} \quad \text{(3 significant figures)}$$

Question 23 (b)

Criteria	Marks
• Provides a change that would improve accuracy • Gives a reason for the low molar enthalpy of combustion related to the change	2
• Provides some relevant information	1

Sample answer:

The experimental value for the molar enthalpy of combustion is low, primarily due to heat loss to the environment.

A change that would reduce heat loss and improve accuracy is moving the spirit burner closer to the beaker.

(There are many other possible improvements that are acceptable.)

Question 24 (a)

Criteria	Marks
• Explains the shape of the titration curve, in terms of ions present, as it falls, at equivalence point and as it rises	3
• Describes the trend in the titration curve and makes an explanation	2
• Provides some relevant information	1

Sample answer:

The curve steadily falls as OH^- ions are added because they react and remove the highly conductive H^+ ions from the solution. At equivalence point, conductivity is lowest because the solution contains only Ba^{2+} and Cl^- ions, which are much less mobile than the H^+ or OH^- ions. The curve then rises as more OH^- ions are added.

Question 24 (b)

Criteria	Marks
• Provides correct calculation, and a balanced equation with states	4
• Provides partially correct calculation and a correct balanced equation OR • Provides substantially correct calculation	3
• Provides some relevant steps	2
• Provides some relevant information	1

Sample answer:

$$2\mathrm{HCl}(aq) + \mathrm{Ba(OH)_2}(aq) \rightarrow \mathrm{BaCl_2}(aq) + 2\mathrm{H_2O}(l)$$

$$n\left(HCl\right) = c \times v = 1.050 \times 10^{-3}\ \mathrm{mol\,L^{-1}} \times 250.0$$

$$n\left(\mathrm{Ba(OH)_2}\right) = n\left(\mathrm{HCl}\right) \times \frac{1}{2} \quad \text{(as reaction ratio is } 2:1\text{)}$$

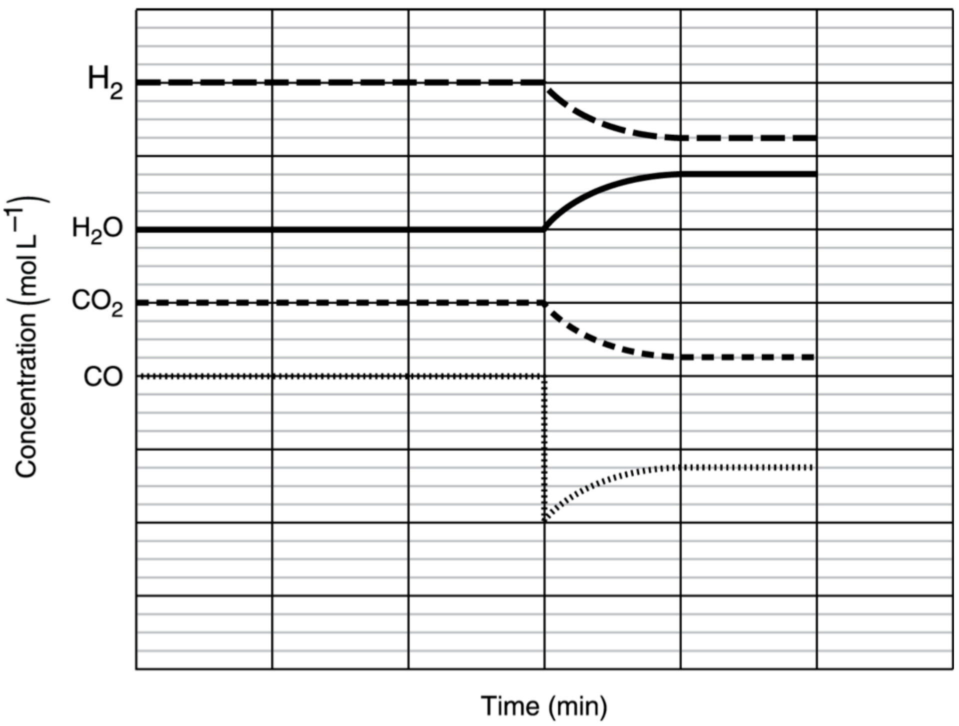
$$\text{Concentration } \mathrm{Ba(OH)_2} = \frac{n}{v} = \frac{1.050 \times 10^{-3} \times 0.2500\ \mathrm{L}}{0.01715 \times 2}$$

$$= 7.653 \times 10^{-3}\ \mathrm{mol\,L^{-1}}$$

Question 25 (a)

Criteria	Marks
• Sketches the concentrations correctly	2
• Provides some correct features	1

Sample answer:



Question 25 (b)

Criteria	Marks
• Provides a thorough explanation of the change in the concentration of CO	3
• Provides some explanation of the change in the concentration of CO	2
• Provides some relevant information	1

Sample answer:

At time *T*, the concentration of CO was decreased.

A decrease in the concentration of CO results in a decrease in the rate of the forward reaction due to fewer collisions between CO and H_2O molecules.

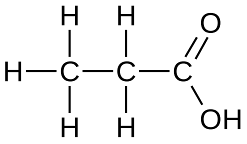
The rate of the reverse reaction is now greater than the forward reaction so the concentrations of $H_2(g)$ and $CO_2(g)$ decrease. As this occurs, the concentrations of $CO(g)$ and $H_2O(g)$ gradually increase.

The rate of the forward reaction subsequently increases until at some point the rate of the reverse reaction will be the same as the rate of the forward reaction as equilibrium is established.

Question 26 (a)

Criteria	Marks
• Gives correct structure and justifies using reactivity and at least three spectra	5
• Gives substantially correct structure and justifies using reactivity and at least two spectra OR • Gives a correct structure and justifies using at least three spectra	4
• Gives substantially correct structure and some correct analyses OR • Gives substantially correct analyses with incorrect structure	2–3
• Provides some relevant information	1

Sample answer:



Reaction with sodium carbonate implies that it is an organic acid as shown.

The ^{13}C NMR spectrum has three peaks; the peak at 180 ppm confirms the presence of a COOH group.

The ^{1}H NMR spectrum shows 3 separate proton environments – the splitting and integration indicate a CH_3 group and a CH_2 group.

The mass spectrum has a parent ion at 74, indicating that the compound must have a molar mass of 74 g mol^{-1}.

Answers could include:

Condensed or skeletal formula.

Could use infrared to confirm the presence of a carboxylic acid group.

Question 26 (b)

Criteria	Marks
• Explains why more than one spectroscopic technique should be used • Supports answer with two spectroscopic techniques	3
• Outlines why more than one spectroscopic technique should be used • Supports answer with at least one spectroscopic technique	2
• Provides some relevant information	1

Sample answer:

Different techniques are used in the identification of organic molecules but give different information about structure.

For example, ^1H NMR provides information about the chemical environment and relative number of hydrogen nuclei. This can be used to identify functional groups and distinguish between isomers.

Mass spectrometry gives information about the molecular weight of a molecule and its characteristic fragments.

Question 27 (a)

Criteria	Marks
• Provides correct method for calculating K_b	1

Sample answer:

$$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{3.0 \times 10^{-8}} = 3.3 \times 10^{-7}$$

Question 27 (b)

Criteria	Marks
• Correctly calculates pH, showing all working	4
• Provides substantially correct working	3
• Provides some relevant steps	2
• Provides some relevant information	1

Sample answer:

$$\frac{\left[\text{HOCl}\right]\left[\text{OH}^-\right]}{\left[\text{OCl}^-\right]} = 3.3 \times 10^{-7}$$

Because K_b is very small we can assume that the equilibrium concentration of OCl^- is essentially unchanged.

	$H_2O + OCl^- \rightleftharpoons HOCl + OH^-$		
I	0.20	0	0
C	$-x$	$+x$	$+x$
E	≈ 0.20	x	x

Now, $\left[\text{HOCl}\right] = \left[\text{OH}^-\right]$ at equilibrium

$$\therefore \quad \frac{x^2}{0.20} = 3.3 \times 10^{-7}$$

$$x = \sqrt{\left(3.3 \times 10^{-7}\right) \times 0.20}$$

$$= 2.5690 \times 10^{-4} \text{ mol L}^{-1}$$

$$\therefore \left[\text{OH}^-\right] = 2.5690 \times 10^{-4} \text{ mol L}^{-1}$$

$$\text{pOH} = -\log\left(\left[\text{OH}^-\right]\right) = -\log\left(2.5690 \times 10^{-4}\right)$$

$$= 3.59$$

$$\text{pH} = 14 - \text{pOH}$$

$$= 10.41$$

Question 28

Criteria	Marks
• Makes an informed judgement about the usefulness of the B–L model • Considers an advantage and a limitation of the model • Includes at least TWO relevant equations	5
• Makes a judgement about the usefulness of the B–L model • Considers an advantage and a limitation of the model • Includes at least ONE relevant equation OR • Outlines an advantage and a limitation of the B–L model • Includes at least TWO relevant equations	4
• Outlines an advantage and/or a limitation of the model AND/OR • Includes at least ONE relevant equation	2–3
• Provides some relevant information	1

Sample answer:

The Brønsted–Lowry model describes acids as proton donors and bases as proton acceptors. It was an improvement on the Arrhenius theory as it describes more acid and base behaviour.

For example, in the reaction $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$, ammonia is classified as a Brønsted–Lowry base and hydrogen chloride as a Brønsted–Lowry acid, as a proton has been transferred from the hydrogen chloride to the ammonia. Ammonia is not an Arrhenius base as it does not dissociate to form OH^- ions.

However, the Brønsted–Lowry model does not explain the acidity of acidic oxides such as SO_2 and SO_3 and their reaction with basic oxides such as CaO. For example, in the reaction $CaO(s) + SO_3(g) \rightarrow CaSO_4(s)$ there is no proton transfer, so Brønsted–Lowry theory cannot be used to explain this as an acid–base reaction.

The Brønsted–Lowry model is useful to explain many acid–base reactions but has its limitations.

Answers could include

Descriptions of Lewis acid–base reactions.

Question 29 (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 $Cu(OH)_2(s) \rightleftharpoons Cu^{2+}(aq) + 2OH^-(aq)$

Answers could include:

Alternative chemical equations:
$Pb(OH)_2(s) \rightleftharpoons Pb^{2+}(aq) + 2OH^-(aq)$
$M(OH)_n(s) \rightleftharpoons M^{n+}(aq) + nOH^-(aq)$

Question 29 (b)

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

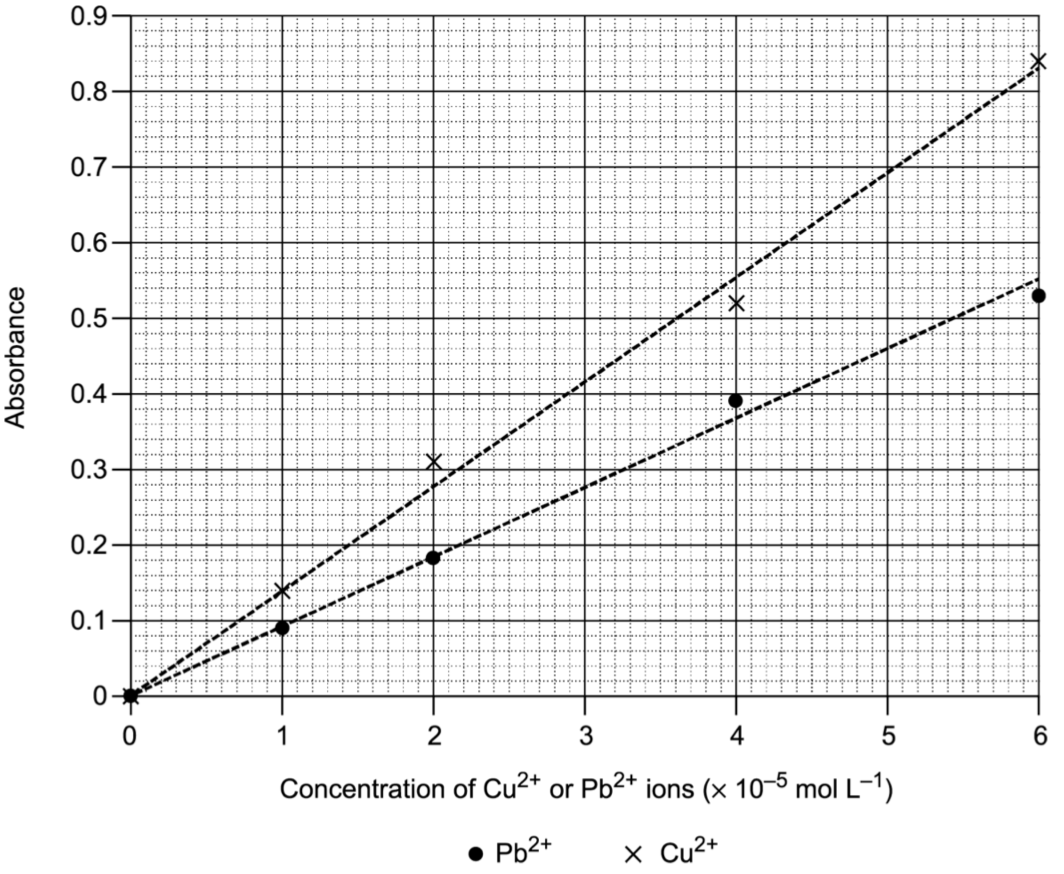
Sample answer:

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 29 (c)

Criteria	Marks
• Provides correct graph – 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 a substantially correct answer with a minor error	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 metals ions in mol L^{-1}

Sample	$Cu^{2+} \times 10^{-5}$ mol L^{-1}	$Pb^{2+} \times 10^{-5}$ 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}

Conclusion: 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 30

Criteria	Marks
• Compares the effects of enthalpy and entropy in relation to the solubility of both salts	3
• Compares enthalpy and entropy values for both salts • Identifies the solubility of both salts	2
• Provides some relevant information	1

Sample answer:

Magnesium chloride has a negative $\triangle_{\text{sol}}G^{\ominus}$ (−125 kJ mol^{-1}) and hence dissolves in water spontaneously, whereas the corresponding value for magnesium fluoride is +58.6 kJ mol^{-1}, so magnesium fluoride does not dissolve in water spontaneously.

Both salts have a negative $\triangle_{\text{sol}}S^{\ominus}$; both result in a positive $-T\triangle_{\text{sol}}S^{\ominus}$ contribution to $\triangle_{\text{sol}}G^{\ominus}$.

Both salts have a negative $\triangle_{\text{sol}}H^{\ominus}$, however magnesium chloride has a significantly negative $\triangle_{\text{sol}}H^{\ominus}$ (−160 kJ mol^{-1}) which is greater than the $-T\triangle_{\text{sol}}S^{\ominus}$ contribution (+34.2 kJ mol^{-1}), resulting in a negative $\triangle_{\text{sol}}G^{\ominus}$. On the other hand, magnesium fluoride has a relatively small negative $\triangle_{\text{sol}}H^{\ominus}$ (−7.81 kJ mol^{-1}) which is smaller than the $-T\triangle_{\text{sol}}S^{\ominus}$ contribution (+66.4 kJ mol^{-1}), resulting in a positive $\triangle_{\text{sol}}G^{\ominus}$.

Question 31

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

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

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

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

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

Question 32

Criteria	Marks
• Explains patterns in the boiling points	4
• Explains most of the patterns in the boiling points	3
• Describes the patterns in the boiling point OR • Explains a pattern in the boiling points	2
• Provides some relevant information	1

Sample answer:

Boiling points for both series increase with increasing number of carbon atoms. This is due to dispersion forces increasing with increasing chain length.

The boiling point of the alcohol is always higher than the analogous thiol. This is due to hydrogen bonding between alcohols being stronger than the dispersion forces between thiols.

The difference between the boiling points of analogous alcohols and thiols decreases with increasing chain length. This is due to the hydrogen bonding having a smaller and smaller contribution to total intermolecular forces as chain length increases.

Question 33

Criteria	Marks
• Calculates pH correctly showing all working	4
• Provides substantially correct working	3
• Provides some correct steps	2
• Provides some relevant information	1

Sample answer:

$$\mathrm{Al(OH)_3}(s) + \mathrm{3HCl}(aq) \rightarrow \mathrm{AlCl_3}(aq) + \mathrm{3H_2O}(l)$$

$$n\left(\mathrm{Al(OH)_3}\right) = \frac{1.17\ \mathrm{g}}{78.004\ \mathrm{g\ mol^{-1}}} = 0.0150\ \mathrm{mol}$$

$$n(\mathrm{HCl}) = 0.500\ \mathrm{L} \times 0.100\ \mathrm{mol\ L^{-1}} = 0.0500\ \mathrm{mol}$$

$$n(\mathrm{HCl\ reacting\ with\ Al(OH)_3}) = 3 \times 0.150\ \mathrm{mol\ L^{-1}} = 0.0450\ \mathrm{mol}$$

$$n(\mathrm{HCl\ in\ excess}) = 0.0500\ \mathrm{mol} - 0.0450\ \mathrm{mol} = 0.0050\ \mathrm{mol}$$

$$[\mathrm{HCl}] = \frac{0.0050\ \mathrm{mol}}{0.500\ \mathrm{L}} = 0.010\ \mathrm{mol\ L^{-1}}$$

$$\mathrm{pH} = -\log_{10}(0.010) = 2.00$$

Question 34

Criteria	Marks
• Outlines the appropriate reagents and conditions • Outlines differences in chemical reactivity or spectroscopic data for products of all three steps	7
• Outlines the appropriate reagents and conditions • Outlines differences in chemical reactivity or spectroscopic data for products of two steps	6
• Outlines some appropriate reagents and conditions • Outlines chemical reactivity or spectroscopic data for the products of some steps	4–5
• Outlines an appropriate reagent and/or condition AND/OR • Outlines chemical reactivity or spectroscopic data for the products	2–3
• Provides some relevant information	1

Sample answer:

In step 1, chloroethane (A) can be converted to ethanol (B) by heating with dilute aqueous potassium hydroxide. The mass spectrum of ethanol will have a single molecular ion peak at m/z = 46, whereas chloroethane will give two peaks at m/z 64 and 66.

In step 2, ethanol (B) can be converted to ethanoic acid (C) using a strong oxidant, for example: acidified potassium permanganate. A C=O peak will appear in the IR spectrum (1680–1750 cm^{-1}) or in the ^{13}C NMR spectrum (160–185 ppm); ethanol will show neither peak.

In step 3, ethyl ethanoate (D) can be synthesised by heating a mixture of ethanol, ethanoic acid and concentrated sulfuric acid under reflux. The ^{1}H NMR spectrum of ethyl ethanoate will have 3 signals, whereas both ethanol and ethanoic acid will have 2.

Answers could include:

Ethanol (B) can be identified in a number of ways, for example:

- Reactivity tests eg turns acidified potassium dichromate solution from orange to green, or decolourises acidified potassium permanganate solution from purple. Also gives a red colour with ceric ammonium nitrate, or gives hydrogen gas with sodium. Chloroethane reacts with none of these reagents.
- An O−H peak will appear in the IR spectrum (broad peak at 3230–3550 cm^{-1}) and in the ^{1}H NMR spectrum (variable chemical shift, 1–6 ppm, concentration-dependent); the IR spectrum of chloroethane will not contain this peak.
- The ^{1}H NMR spectrum of ethanol will have 3 signals, whereas that of chloroethane will have 2.
- The mass spectrum of ethanol will have a single molecular ion peak at m/z = 46, whereas chloroethane will give two peaks at m/z 64 and 66.

In step 2, ethanol (B) can be converted to ethanoic acid (C) using a strong oxidant, for example: Jones' reagent (CrO_3 in H_2SO_4), and many others.

Ethanoic acid (C) can be identified in a number of ways, for example:

- Indicators (eg blue litmus turning red), carbon dioxide given off when reacted with sodium carbonate or sodium hydrogencarbonate. Ethanol will do neither.
- C=O peak will appear in the IR spectrum (1680–1750 cm^{-1}) and in the ^{13}C NMR spectrum (160 – 185 ppm); ethanol will show neither peak.
- The ^1H NMR spectrum of ethanoic acid will not have a peak in 3.3–4.8 ppm range; the ^{13}C NMR spectrum will not have a peak in the 50–90 ppm range. Ethanol will have a peak in both ranges due to the CH_2 group.
- The ^1H NMR spectrum of ethanoic acid will have 2 signals, whereas that of ethanol will have 3.
- The mass spectrum of ethanoic acid will have a molecular ion peak at m/z = 60, whereas that of ethanol is at m/z 46.

Ethyl ethanoate (D) can be identified in a number of ways, for example:

- Ethyl ethanoate will have no O−H peaks in the IR spectrum (broad peak at 3230–3550 cm^{-1}) and the ^1H NMR spectrum (variable chemical shift, 1–6 ppm, concentration-dependent). These peaks are present in the spectra of ethanol and ethanoic acid.
- The mass spectrum of ethyl ethanoate will have a molecular ion peak at m/z = 102; ethanoic acid will have a molecular ion peak at m/z = 60 and ethanol at m/z 46.
- Ethyl ethanoate has a distinct smell.

2019 HSC Chemistry Mapping Grid

Section I

Question	Marks	Content	Syllabus outcomes
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3	1	Mod 5 Solution equilibria	12-5, 12-6, 12-12
4	1	Mod 8 Analysis of organic substances	12-5, 12-6, 12-7, 12-15
5	1	Mod 6 Properties of acids and bases Mod 6 Quantitative analysis	12-4, 12-13
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15	1	Mod 6 Using Brønsted–Lowry theory	12-4, 12-5, 12-6, 12-13
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17	1	Mod 5 Calculating the equilibrium constant	12-4, 12-5, 12-6, 12-7, 12-12
18	1	Mod 5 Solution equilibria	12-4, 12-5, 12-6, 12-12
19	1	Mod 8 Analysis of organic substances	12-4, 12-5, 12-6, 12-7, 12-15
20	1	Mod 8 Analysis of inorganic substances	12-4, 12-5, 12-6, 12-15

Section II

Question	Marks	Content	Syllabus outcomes
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Question	Marks	Content	Syllabus outcomes
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27 (a)	1	Mod 5 Calculating the equilibrium constant Mod 6 Using Brønsted–Lowry theory Mod 6 Quantitative analysis	12-5, 12-6, 12-12, 12-13
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29 (a)	2	Mod 5 Solution equilibria Mod 8 Analysis of inorganic substances	12-5, 12-6, 12-12, 12-15
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