2020 HSC Chemistry
Marking Guidelines

Section I

Multiple-choice Answer Key

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

Section II

Question 21

Criteria	Marks
• Correctly identifies the alkane • Provides a valid justification	2
• Correctly identifies the alkane OR • Shows some understanding of the mass spectrum	1

Sample answer:

The alkane is propane. This can be determined from the mass spectrum as the parent ion has a molecular mass of 44, which is consistent with propane C_3H_8.

Question 22

Criteria	Marks
• Outlines a sequence of suitable tests with expected observations • Includes a balanced chemical equation	5
• Outlines a sequence of suitable tests and most of the expected observations • Includes a substantially correct balanced chemical equation	4
• Provides suitable tests that can identify cation(s) and anion(s) present • Includes some expected observations and/or a balanced chemical equation	3
• Provides one test and observation that can identify a cation OR anion present OR • Provides tests that can identify cations and anions present OR • Provides a balanced chemical equation and one test that can identify a cation OR anion present	2
• Provides some relevant information	1

Sample answer:

Cation

Carry out a flame test

- If pale green → barium
- If brick red → calcium
- No colour → magnesium

Anion

1. Add $Cu(NO_3)_2(aq)$

   If pale blue precipitate forms → OH^- present

2. Add $AgNO_3(aq)$

   - If white ppt forms → Cl^- present
   - If no ppt forms → CH_3COO^- present
   - $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

Answers could include:

Test pH with universal indicator, pH meter

$Cl^- \rightarrow$ neutral

$CH_3COO^- \rightarrow$ slightly basic

$OH^- \rightarrow$ very basic

Question 23

Criteria	Marks
• Explains three relevant factors • Makes specific reference to the flow chart	4
• Explains two relevant factors with some reference to the flow chart OR • Explains one relevant factor and outlines two other relevant factors with some reference to the flow chart OR • Explains three relevant factors without specific reference to the flow chart	3
• Explains one relevant factor OR • Outlines two relevant factors	2
• Provides some relevant information	1

Sample answer:

The use of a catalyst in reactions 1 and 2 allows a faster rate at a lower temperature. This both increases the efficiency of the process and reduces energy consumption that makes the process more economical and ultimately less polluting.

Unused reactant gases are recycled after being separated from the reaction mixture in separator 1. This means that resources are not wasted – making the process more economical as less reactant needs to be purchased from suppliers.

Markets have been accessed for the major product (ethane-1,2-diol) – without a market the industrial process is not economically viable – the location of these markets has been determined and suitable transport arranged – the industrial plant has probably been located near a major port, rail or road network to facilitate economical and rapid transport to markets.

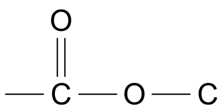
Answers could include:

- By-products are also produced rather than wastes to be disposed of. These by-products are sent to markets, which indicates that all the products of the reaction have a purpose. This makes the entire process more economical and less wasteful (potentially 100% atom economy).
- Access to reactants – the plant would be located so that ethylene and oxygen gases would be easily accessible – perhaps near a petrochemical plant or road/rail network so that these resources could be transported easily and cheaply.

Question 24 (a)

Criteria	Marks
• Correctly identifies the functional group	1

Sample answer:

Ester (or )

Question 24 (b)

Criteria	Marks
• Explains why biodiesel produces less soot than diesel • Supports answer with relevant and correctly balanced chemical equations (states NOT required)	3
• Makes use of at lease one substantially correct balanced equation to provide an explanation OR • Provides two correctly balanced equations	2
• Provides some relevant information	1

Sample answer:

$$C_{18}H_{38} + \frac{55}{2}O_2 \rightarrow 18CO_2 + 19H_2O$$

$$C_{14}H_{30}O_2 + \frac{41}{2}O_2 \rightarrow 14CO_2 + 15H_2O$$

More supplied oxygen is required for the complete combustion of diesel compared to biodiesel. Therefore it is more likely that diesel will combust incompletely, producing soot.

Eg $C_{18}H_{38} + \frac{41}{2}O_2 \rightarrow 10CO_2 + 2CO + 6C + 19H_2O$

Question 24 (c)

Criteria	Marks
• Correctly calculates the volume of biodiesel	2
• Provides a correct step	1

Sample answer:

Energy density (biodiesel) = 38 MJ kg^{-1}

m (biodiesel) needed = $\frac{2141}{38}$ = 56.3 kg

d (biodiesel) = 0.90 kg L^{-1}

V (biodiesel) = $\frac{56.3}{0.90}$ = 63 L

Question 24 (d)

Criteria	Marks
• Explains TWO advantages and TWO disadvantages of using bioethanol as an alternative to a fossil fuel	4
• Outlines TWO advantages and TWO disadvantages of using bioethanol as an alternative to a fossil fuel • Explains at least TWO of them	3
• Outlines TWO advantages and TWO disadvantages of using bioethanol as an alternative to a fossil fuel OR • Explains TWO advantages or TWO disadvantages of using bioethanol as an alternative to a fossil fuel OR • Explains ONE advantage and ONE disadvantage of using bioethanol as an alternative to a fossil fuel	2
• Provides some relevant information	1

Sample answer:

Bioethanol is produced from renewable resources while petrol is produced from non-renewable crude oil reserves. Thus, ethanol is a sustainable fuel, which may be continually produced while petrol is unsustainable. Combustion of petrol increases greenhouse gas concentrations in the atmosphere. If green energy is used to produce bioethanol, the carbon dioxide released during the combustion may be removed by plants during photosynthesis, resulting in a carbon neutral process. Increased demand for ethanol to replace petrol may cause crops to be grown for fuel rather than food. Food shortages or increased food prices may result. As more crops are grown to produce biofuels, more fertiliser is used. The excess use of fertilisers can result in soil erosion and can lead to land and water pollution.

Answers could include:

Advantages of bioethanol over petrol

- Ethanol produces less particulates, which can be responsible for significant lung disease and may even be associated with the formation of cancer. Reducing airborne pollutants also has the added benefit of reducing the cost of health care in a community.
- Ethanol is biodegradable. Thus, spills pose less of an environmental threat than spills of non-biodegradable petrol, which can cause long-term contamination of soil and water bodies.

Disadvantages of bioethanol

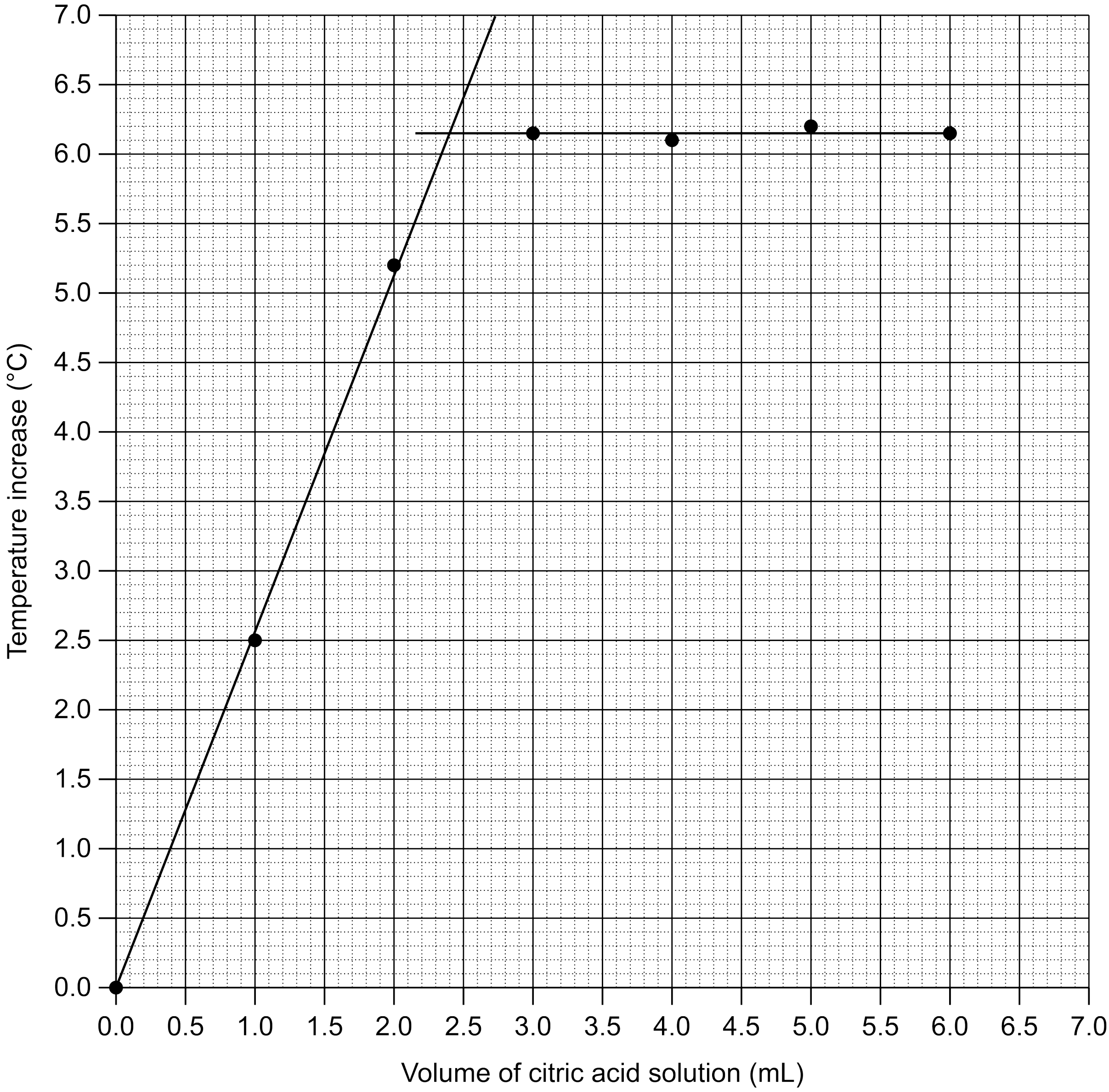
- The use of water to produce more crops to produce bioethanol can put pressure on local water resources. In areas where there is water scarcity, production of crops to be used in making bioethanol compromises water security for this region – possibly leading to health issues due to lack of potable water.
- Energy is needed for the mechanised sowing, fertilising and harvesting of crops. Significant amounts of energy are required for the distillation of ethanol from fermentation mixtures. If fossil fuels are used as the source of this energy then the use of bioethanol as an alternative would not be carbon neutral and would contribute to global warming.

Question 25

Criteria	Marks
• Provides graph with – correctly labelled axes including units – appropriate scales – correctly plotted points – correct line(s) of best fit • Correctly calculates the concentration of sodium hydroxide with units	7
• Provides a correct graph and most of the steps for calculating the concentration of sodium hydroxide	6
• Provides a substantially correct graph and at least one step for calculating the concentration of sodium hydroxide	4–5
• Provides a graph with some correct features AND/OR • Provides some steps for calculating the concentration of sodium hydroxide	2–3
• Provides some relevant information	1

Question 25 (continued)

Sample answer:



n(citric acid at equivalence point) = 2.4×10^{-3} L $\times$ 1.0 mol L^{-1} = 2.4×10^{-3} mol

n(sodium hydroxide at equivalence point) = 2.4×10^{-3} mol $\times$ 3 = 7.2×10^{-3} mol

[sodium hydroxide] = 7.2×10^{-3} mol $\div$ 8.0×10^{-3} L = 0.90 mol L^{-1}

Question 26 (a)

Criteria	Marks
• Writes a substantially correct balanced equation, including states	1

Sample answer:

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

Question 26 (b)

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

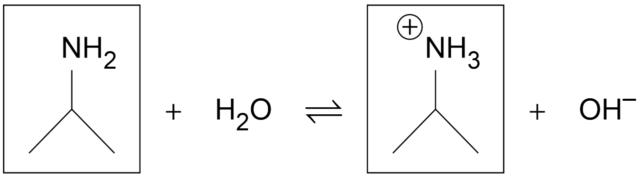
Answers could include:

Reference to the Maxwell–Boltzmann distribution.

Question 27 (a)

Criteria	Marks
• Provides correct structural formula for each organic species	2
• Provides one correct structural formula or shows some understanding of protonation	1

Sample answer:



Question 27 (b)

Criteria	Marks
• Correctly calculates the concentration of hydroxide ions	3
• Provides the main steps of the calculation	2
• Provides some relevant information	1

Sample answer:

	$C_3H_7NH_2$	+ H_2O ⇌	$C_3H_7NH_3^+$	+ OH^-
I	1.00		0	0
C	$-x$		x	x
E	$1.00 - x$		x	x

$$K_b = \frac{[C_3H_7NH_3^+][OH^-]}{[C_3H_7NH_2]} = \frac{x^2}{1.00 - x}$$

Assuming $x \ll 1.00$, $\frac{x^2}{1.00} = 4.37 \times 10^{-4}$

$$x = \sqrt{4.37 \times 10^{-4}} = 0.0207 \text{ mol L}^{-1}$$

$$[OH^-] = x = 0.0207 \text{ mol L}^{-1}$$

Question 28

Criteria	Marks
• Explains why the results produced by the method are not accurate and not reliable	3
• Shows some understanding of why the results produced by the method are not accurate and/or not reliable	2
• Provides some relevant information	1

Sample answer:

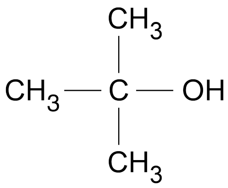
NaOH is used as a primary standard, but it is not a primary standard. Solid NaOH is deliquescent, so the mass obtained by the balance is that of NaOH and water. The mass of NaOH is therefore lower than reported, and the solution made up is therefore lower in concentration than expected, resulting in a titre that is larger than it should be, giving an inaccurate result.

The indicator chosen is inappropriate. It changes colour in the flat region of the titration curve, prior to the equivalence point. Small titre volume differences will result in big variations in the observed endpoint, explaining the lack of reliability in titres 2, 3 and 4.

Question 29

Criteria	Marks
• Draws correct structural formulae for all five compounds	5
• Draws correct structural formulae for four compounds OR • Draws five correct structural formulae with one minor error	4
• Draws substantially correct structural formulae demonstrating an understanding of most reactions	3
• Draws structural formulae demonstrating an understanding of some different reactions	2
• Draws a substantially correct structural formula	1

Sample answer:

Ⓐ


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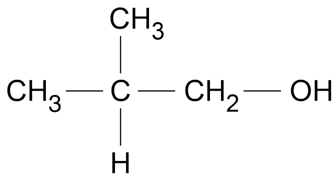

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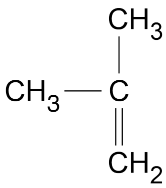

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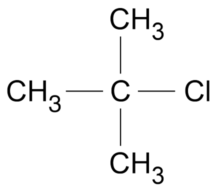

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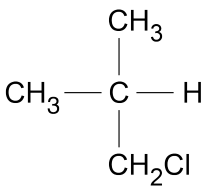
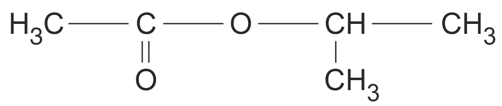


Question 30

Criteria	Marks
• Writes the correct structural formula of propan-2-yl acetate (naming not required) • Justifies the correct structure showing an extensive understanding of the interpretation of spectroscopic data • Refers explicitly to the relevant spectroscopic data	7
• Writes the correct structural formula for an isomer of propan-2-yl acetate (methyl 2-methylpropanoate) (naming not required) • Justifies the structure showing a thorough understanding of the interpretation of spectroscopic data • Refers to relevant spectroscopic data	6
• Shows a sound understanding of the interpretation of spectroscopic data • Uses relevant information presented in the question to justify the structure of the chemical • Provides a structural formula consistent with analysis	4–5
• Shows some understanding of the interpretation of spectroscopic data	2–3
• Provides some relevant information	1

Sample answer:



IR Spectrum:

- The IR spectrum shows a strong absorption at 1750 cm^{-1} which is consistent with a carbonyl group – this group is present in both esters and carboxylic acids
- However, the lack of the broad O–H (acid) absorption band (stretch) at 2500–3300 cm^{-1} means that it is not a carboxylic acid –COOH.

The ^{13}C NMR Spectrum:

- C atom double bonded to an O atom on the ester group: consistent with chemical shift approximately 170
- C atom singly bonded to an O atom in an ester group: consistent with chemical shift approximately 70
- C atom bonded to the C in an alkyl group: consistent with chemical shift approximately 20.

The ^{1}H NMR Spectrum:

- A septet – consistent with six neighbouring H atoms on two CH_3 groups
- A doublet – consistent with one neighbouring H atom
- The septet and doublet combination is consistent with the presence of a $–CH(CH_3)_2$ group
- A singlet – consistent with no neighbouring H atoms which would be produced by the isolated methyl group.

The spectroscopic data suggests that a $CH(CH_3)_2$ group is attached to an O atom of the ester group (that is, $OCH(CH_3)_2$) and a CH_3 group is attached to the C atom of the ester group (that is, CH_3CO).

Answers could include:

Condensed and skeletal formulae.

Question 31

Criteria	Marks
• Correctly calculates the concentration of chloride ions	4
• Provides the main steps of the calculation	3
• Provides some relevant steps of the calculation	2
• Provides some relevant information	1

Sample answer:

Mole ratio $Ag^+ : SCN^- = 1 : 1$

Amount SCN^- used in second titration $= cV = 0.0500 \text{ mol L}^{-1} \times 0.02865 \text{ L} = 0.0014325 \text{ mol}$

$\therefore$ Amount Ag^+ in excess = 0.0014325 mol

Total amount Ag^+ added at beginning $= cV = 0.02500 \text{ mol L}^{-1} \times 0.100 \text{ L} = 0.00250 \text{ mol}$

$\therefore$ Amount Ag^+ reacting with $Cl^- = 0.00250 \text{ mol} - 0.0014325 \text{ mol} = 0.0010675 \text{ mol}$

$\therefore$ Amount $Cl^- = 0.0010675$ mol

Concentration Cl^- in water: $c = n/V = 0.0010675 \text{ mol} \div 0.1000 \text{ L} = 0.010675 \text{ mol L}^{-1}$

Chloride $MM = 35.45 \text{ g mol}^{-1}$

$$\begin{aligned}\text{Concentration } Cl^- \text{ in water } &= 35.45 \text{ g mol}^{-1} \times 0.010675 \text{ mol L}^{-1} \\ &= 0.378429 \text{ g L}^{-1} \\ &= 378 \text{ mg L}^{-1}\end{aligned}$$

Question 32

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 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.

Question 33 (a)

Criteria	Marks
• Correctly shows that the amount of calcium hydroxide is 0.100 mol	2
• Provides some relevant information	1

Sample answer:

$$Ca(OH)_2(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(\ell)$$

$$n(HCl) = 2.00 \text{ mol L}^{-1} \times 0.100 \text{ L} = 0.200 \text{ mol}$$

$$n\left(Ca(OH)_2\right) = \frac{n(HCl)}{2}$$

$$= \frac{0.200 \text{ mol}}{2}$$

$$= 0.100 \text{ mol}$$

Question 33 (b)

Criteria	Marks
• Correctly calculates the pH, showing relevant working	4
• Provides most of the steps of the calculations	3
• Provides some steps of the calculations	2
• Provides some relevant information	1

Sample answer:

$$\left[Ca^{2+}\right] = \frac{0.100 \text{ mol}}{0.100 \text{ L}} = 1.00 \text{ mol L}^{-1}$$

$$K = 5.02 \times 10^{-6} = \left[Ca^{2+}\right]\left[OH^{-}\right]^2$$

Let $\left[OH^{-}\right] = x \text{ mol L}^{-1}$

$$\therefore \quad 1.00 \times x^2 = 5.02 \times 10^{-6}$$

$$x = \sqrt{5.02 \times 10^{-6}}$$

$$= 2.24 \times 10^{-3} \text{ mol L}^{-1}$$

$$\therefore \quad \left[OH^{-}\right] = 2.24 \times 10^{-3} \text{ mol L}^{-1}$$

$$\text{pOH} = -\log_{10}\left(2.24 \times 10^{-3}\right)$$

$$= 2.650$$

$$\text{pH} = 14.00 - 2.650$$

$$= 11.35$$

Question 34

Criteria	Marks
• Explains trends in the graph • Includes relevant chemical equations	4
• Explains a trend in the graph and outlines a second trend in the graph • Includes at least one relevant chemical equation	3
• Identifies some trends/features from the graph OR • Outlines a trend/feature of the graph	2
• Provides some relevant information	1

Sample answer:

The trend for both acids is for pH to decrease with increasing concentration as [H^+] increases. The strong acid, HCl, shows a linear trend with pH (the log of [HCl]). This is because HCl fully dissociates at all concentrations, and therefore the [H^+] equals [HCl]. However, acrylic acid is a weak acid. The degree of dissociation is dependent on the concentration of the acid. We can see that the trend of the acrylic acid is not linear. It bends up at higher concentrations. This reflects the proportionally lower fraction of dissociation. This is given by the following equilibrium expression.

$$C_2H_3COOH \rightleftharpoons C_2H_3COO^- + H^+$$

$$K_a = \frac{\left[C_2H_3COO^-\right]\left[H^+\right]}{\left[C_2H_3COOH\right]}$$

$$\left[H^+\right] = \frac{K_a\left[C_2H_3COOH\right]}{\left[C_2H_3COO^-\right]}$$

Answers could include:

- Increasing concentration decreases pH for both acids
- The pH of the HCl is lower than that of the C_2H_3COOH
- For C_2H_3COOH the degree of ionisation increases as concentration decreases.

Question 35

Criteria	Marks
• Correctly calculates the equilibrium constant, showing relevant working	4
• Provides the main steps	3
• Provides some relevant steps	2
• Provides some relevant information	1

Sample answer:

$A = [I_3^-] \times 2.76 \times 10^4$

$[I_3^-] = \dfrac{A}{2.76 \times 10^4} = \dfrac{0.745}{2.76 \times 10^4} = 2.70 \times 10^{-5}$ mol L^{-1}

$[I^-]_{initial} = 4[I_2]_{eq} + 3[I_3^-]_{eq}$

7.00×10^{-4} mol L^{-1} $= 4[I_2]_{eq} + 3 \times 2.70 \times 10^{-5}$ mol L^{-1}

$[I_2]_{eq} = \dfrac{7.00 \times 10^{-4} \text{ mol L}^{-1} - 3 \times 2.70 \times 10^{-5} \text{ mol L}^{-1}}{4}$

$= 1.55 \times 10^{-4}$ mol L^{-1}

$\therefore \quad [I^-] = 2 \times 1.55 \times 10^{-4}$ mol L^{-1}

$= 3.10 \times 10^{-4}$ mol L^{-1}

$\therefore \quad K_{eq} = \dfrac{[I_3^-]}{[I^-][I_2]} = \dfrac{2.70 \times 10^{-5}}{3.10 \times 10^{-4} \times 1.55 \times 10^{-4}}$

$= 564$

Question 36

Criteria	Marks
• Correctly calculates the maximum temperature reached, showing relevant working	5
• Provides substantially correct working	4
• Provides the main steps	3
• Provides some relevant steps	2
• Provides some relevant information	1

Sample answer:

1. Dissolution of NaOH(*s*)

$$n_{NaOH} = \frac{m}{MM} = \frac{10.0}{39.991} = 0.2500 \text{ mol}$$

$$q_2 = -\Delta H \times n = 44.5 \times 0.25 = 11.127 \text{ kJ}$$

2. Reaction between NaOH(*aq*) and HCl(*aq*)

NaOH	+	HCl
		$V = 100.00 \times 10^{-3}$ L
		$c = 2.00$ mol L^{-1}
$n = 0.2500$ mol		$\therefore\ n = c \times V = 0.200$ mol
		$\therefore$ HCl is limiting reagent

$$q_2 = -\Delta H \times n = 56.1 \times 0.200 = 11.22 \text{ kJ}$$

3. Total heat supplied $= q_1 + q_2 = 22.347$ kJ

4. Change in temperature of solution

$$q = mc\Delta T$$

$$22.347 \times 10^3 \text{ J} = (10.0 + 103) \text{ g} \times 3.99 \text{ J g}^{-1} \text{ K}^{-1} \times \Delta T$$

$$\therefore \quad \Delta T = 49.564°\text{C}$$

$$\therefore \ T_{final} = T_{initial} + 49.564°\text{C} = 72.1°\text{C (to 1 decimal place)}$$

2020 HSC Chemistry Mapping Grid

Section I

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4	1	Mod 8 Analysis of organic substances	12-5, 12-15
5	1	Mod 7 Nomenclature Mod 8 Analysis of organic substances	12-14, 12-15
6	1	Mod 7 Nomenclature	12-5, 12-14
7	1	Mod 7 Nomenclature	12-5, 12-14
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10	1	Mod 6 Properties of acids and bases	12-5, 12-13
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13	1	Mod 7 Hydrocarbons	12-5, 12-14
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15	1	Mod 8 Analysis of organic substances	12-6, 12-15
16	1	Mod 5 Factors that affect equilibrium	12-6, 12-12
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18	1	Mod 6 Using Brønsted–Lowry theory	12-5, 12-13
19	1	Mod 5 Factors that affect equilibrium	12-4, 12-12
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Section II

Question	Marks	Content	Syllabus outcomes
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24 (b)	3	Mod 7 Products of reactions involving hydrocarbons	12-6, 12-14
24 (c)	2	Mod 7 Alcohols	12-5, 12-14
24 (d)	4	Mod 7 Alcohols	12-5, 12-14
25	7	Mod 6 Properties of acids and bases	12-6, 12-7, 12-13
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Question	Marks	Content	Syllabus outcomes
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28	3	Mod 6 Quantitative analysis	12-2, 12-3, 12-5, 12-13
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35	4	Mod 5 Solution equilibria Mod 5 Calculating the equilibrium constant	12-6, 12-7, 12-12
36	5	Mod 6 Properties of acids and bases	12-6, 12-7, 12-13