NSW GOVERNMENT

NSW Education Standards Authority

2020 **HIGHER SCHOOL CERTIFICATE EXAMINATION**

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks (pages 2–11)

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

Section II – 80 marks (pages 13–36)

- Attempt Questions 21–36
- Allow about 2 hours and 25 minutes for this section

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 What is the function of the magnetic field in a mass spectrometer?

A. It detects the mass of the particles.

B. It deflects the stream of charged particles.

C. It excites electrons to higher energy levels.

D. It produces a stream of electrons that bombards the sample.

2 Which indicator in the table would be best for distinguishing between a face cleanser ($pH = 5.0$) and a soap ($pH = 9.0$)?

	Indicator	*Colour* (low pH – high pH)	*pH range*
A.	Bromophenol blue	Yellow – blue	3.0–4.6
B.	Methyl orange	Red – yellow	3.1–4.4
C.	Phenol red	Yellow – red	6.4–8.0
D.	Thymolphthalein	Colourless – blue	9.4–10.6

3 Which of the following compounds is the most basic?

A. Ethane

B. Ethanol

C. Ethanamine

D. Ethyl ethanoate

4 Which pair of compounds would be difficult to distinguish using infrared spectroscopy?

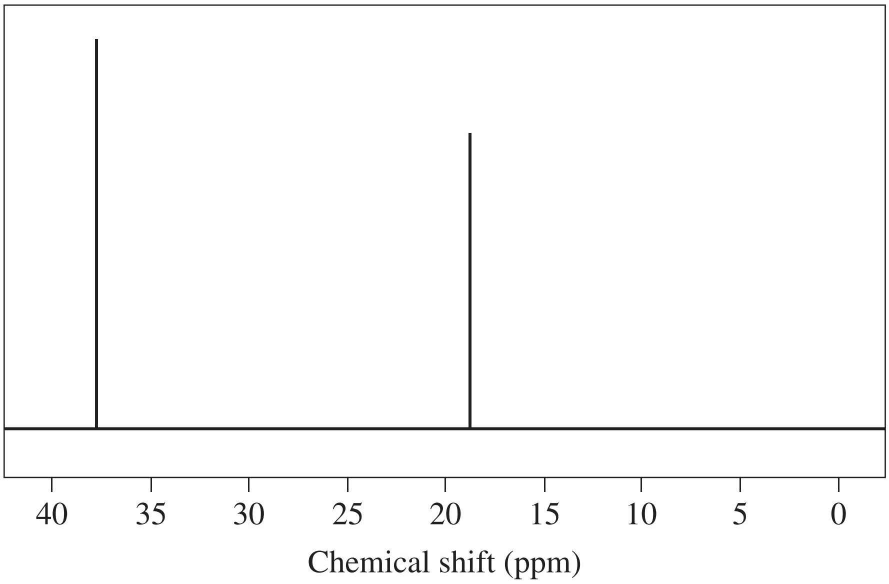
A. Butane and propane

B. Ethane and propan-1-ol

C. Propanol and propanoic acid

D. Methanamine and propanone

5 A ^{13}C NMR spectrum is shown.



Which compound gives rise to this spectrum?

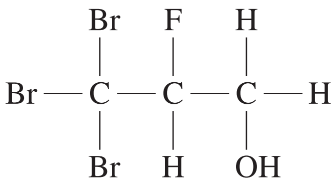
A. chloroethane

B. 1-chloropropane

C. 1,2-dichloroethane

D. 1,2-dichloropropane

6 The structure of a compound is shown.



What is the preferred IUPAC name of this compound?

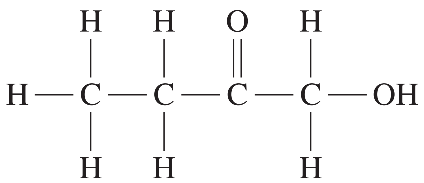
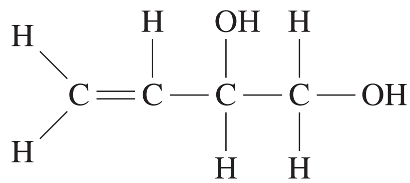
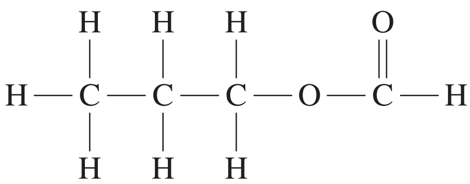
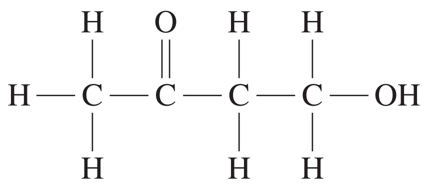
A. 1,1,1-tribromo-2-fluoropropan-3-ol

B. 2-fluoro-3,3,3-tribromopropan-1-ol

C. 2-fluoro-1,1,1-tribromopropan-3-ol

D. 3,3,3-tribromo-2-fluoropropan-1-ol

7 The structures of four isomers are shown.

Compound 1 	Compound 2 
Compound 3 	Compound 4 

Which statement is correct?

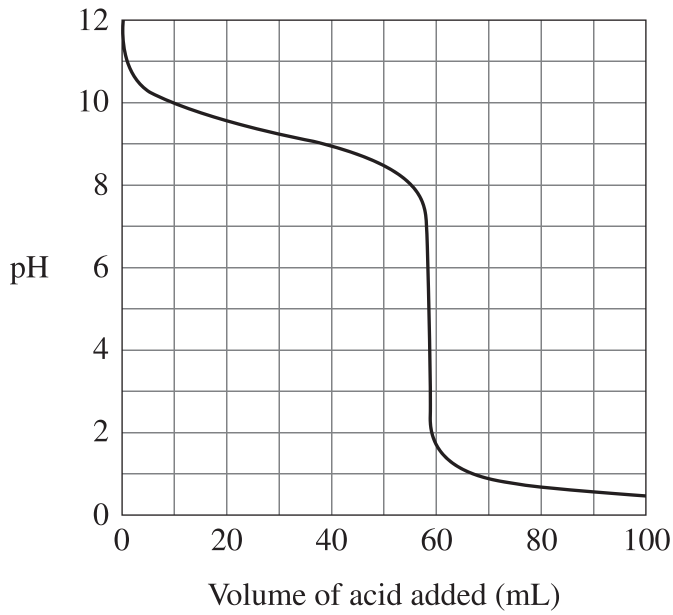
A. Compounds 1 and 2 are chain isomers.

B. Compounds 1 and 4 are chain isomers.

C. Compounds 2 and 3 are functional group isomers.

D. Compounds 2 and 4 are positional isomers.

8 A weak base is titrated with 1.0 mol L^{-1} aqueous HCl. The pH curve is shown.



At which pH value would the solution be most effective as a buffer?

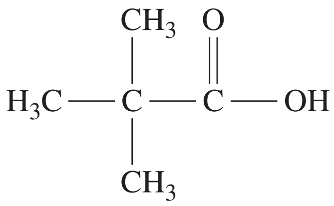
A. 5

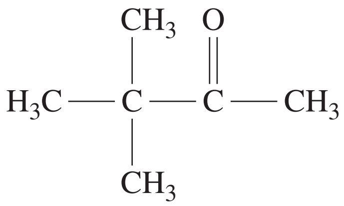
B. 7

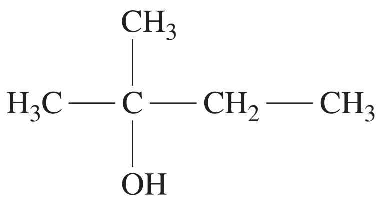
C. 8

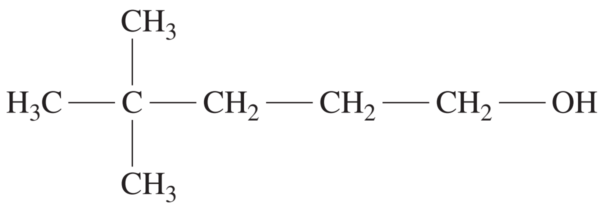
D. 9

9 Which compound reacts readily with sodium hydrogen carbonate?

A. 

B. 

C. 

D. 

10 Equimolar solutions of $NaCl(aq)$, $NH_4Cl(aq)$ and $NaCH_3COO(aq)$ were prepared.

In which of the following are these salt solutions listed from least to most acidic?

A. $NaCl(aq)$, $NH_4Cl(aq)$, $NaCH_3COO(aq)$

B. $NaCl(aq)$, $NaCH_3COO(aq)$, $NH_4Cl(aq)$

C. $NH_4Cl(aq)$, $NaCl(aq)$, $NaCH_3COO(aq)$

D. $NaCH_3COO(aq)$, $NaCl(aq)$, $NH_4Cl(aq)$

11 Equal volumes of two 0.04 mol L^{-1} solutions were mixed together.

Which pair of solutions would give the greatest mass of precipitate?

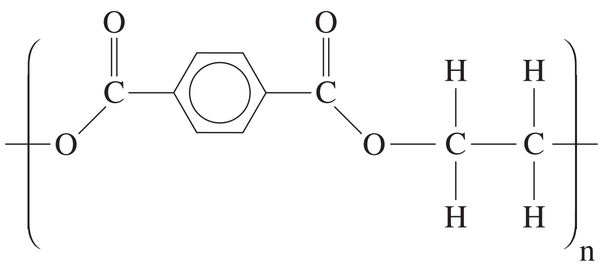
A. $Ba(OH)_2$ and $MgCl_2$

B. $Ba(OH)_2$ and $MgSO_4$

C. $Ba(OH)_2$ and NaCl

D. $Ba(OH)_2$ and Na_2SO_4

12 The structure of part of a polymer chain is shown.



Which statement best explains why plastics made from this polymer require a temperature of approximately 250°C before they begin to soften?

A. The carbon–carbon bonds in the polymer chains are strong.

B. The carbon–hydrogen bonds in the polymer chains are strong.

C. Extensive dipole–dipole and dispersion forces exist between the polymer chains.

D. Extensive hydrogen bonds and dispersion forces exist between the polymer chains.

13 Which of the following conversions results in the formation of a different shape around the carbon atom?

A. Methanoic acid to methanal

B. Methanoic acid to methanol

C. Methanoic acid to methanamide

D. Methanoic acid to sodium methanoate

14 The equation for the autoionisation of water is shown.

$$2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

At 50°C the water ionisation constant, K_w, is 5.5×10^{-14}.

What is the pH of water at 50°C?

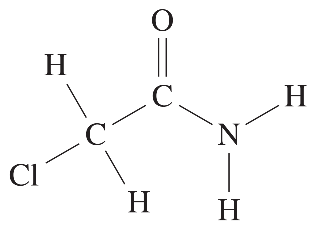
A. 5.50

B. 6.63

C. 6.93

D. 7.00

15 The structure of chloroacetamide is shown.



The common isotopes of chlorine are ^{35}Cl and ^{37}Cl.

The mass spectrum of chloroacetamide contains a peak at m/z = 51.

What is the most likely source of this peak?

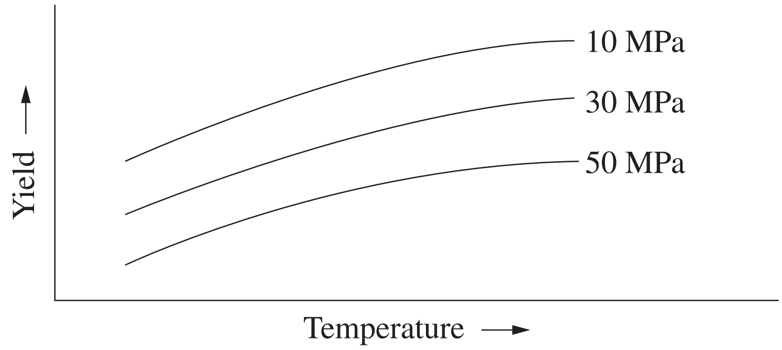
A. $[OCl]$

B. $[NH_2]^+$

C. $[C_4H_3]^+$

D. $[CH_2Cl]^+$

16 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?

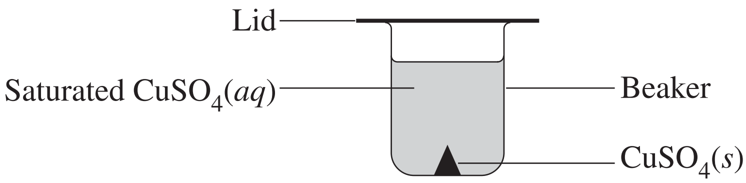
A. $X(g) + 3Y(g) \rightleftharpoons 2Z(g)$ $\Delta H > 0$

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

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

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

17 The following apparatus was set up in a temperature-controlled laboratory.



Excess solid sodium hydroxide is added to the beaker.

Which row of the table correctly identifies the change in the $CuSO_4(s)$ mass and the colour of the solution after several days?

	Solid $CuSO_4$ mass	*Colour of solution*
A.	No change	No change
B.	No change	Blue colour fades
C.	Decreases	Blue colour intensifies
D.	Decreases	Blue colour fades

18 An aqueous solution of sodium hydrogen carbonate has a pH greater than 7.

Which statement best explains this observation?

A. $H_2O(l)$ is a stronger acid than $HCO_3^-(aq)$.

B. $HCO_3^-(aq)$ is a weaker acid than $H_2CO_3(aq)$.

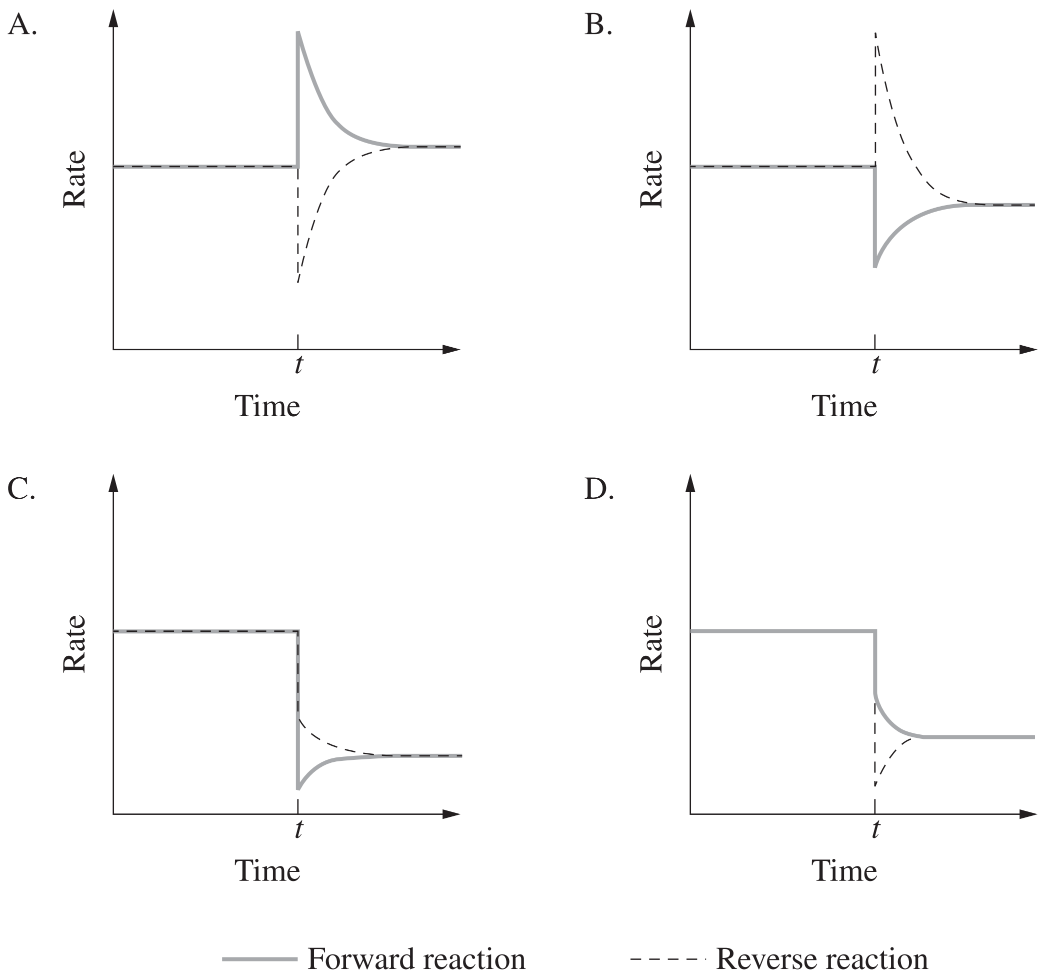
C. $Na^+(aq)$ reacts with water to produce the strong base $NaOH(aq)$.

D. The conjugate acid of $HCO_3^-(aq)$ is a stronger acid than $H_2O(l)$.

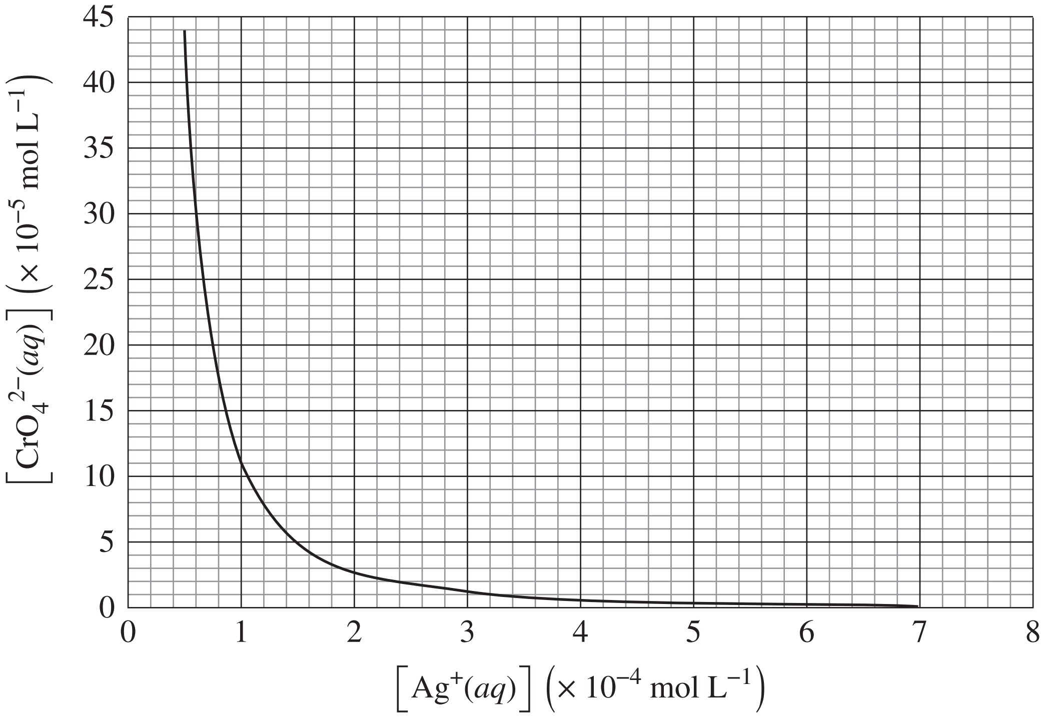
19 Nitrogen dioxide reacts to form dinitrogen tetroxide in a sealed flask according to the following equation.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57.2 \text{ kJ mol}^{-1}$$

Which graph best represents the rates of both the forward and reverse reactions when an equilibrium system containing these gases is cooled at time t?



20 The graph shows the concentration of silver and chromate ions which can exist in a saturated solution of silver chromate.



Based on the information provided, what is the K_{sp} for silver chromate?

A. 1.1×10^{-8}

B. 2.2×10^{-8}

C. 1.1×10^{-12}

D. 4.4×10^{-12}

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2020 HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Student Number

Chemistry

Section II Answer Booklet

80 marks
Attempt Questions 21–36
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

Office Use Only – Do NOT write anything, or make any marks below this line.

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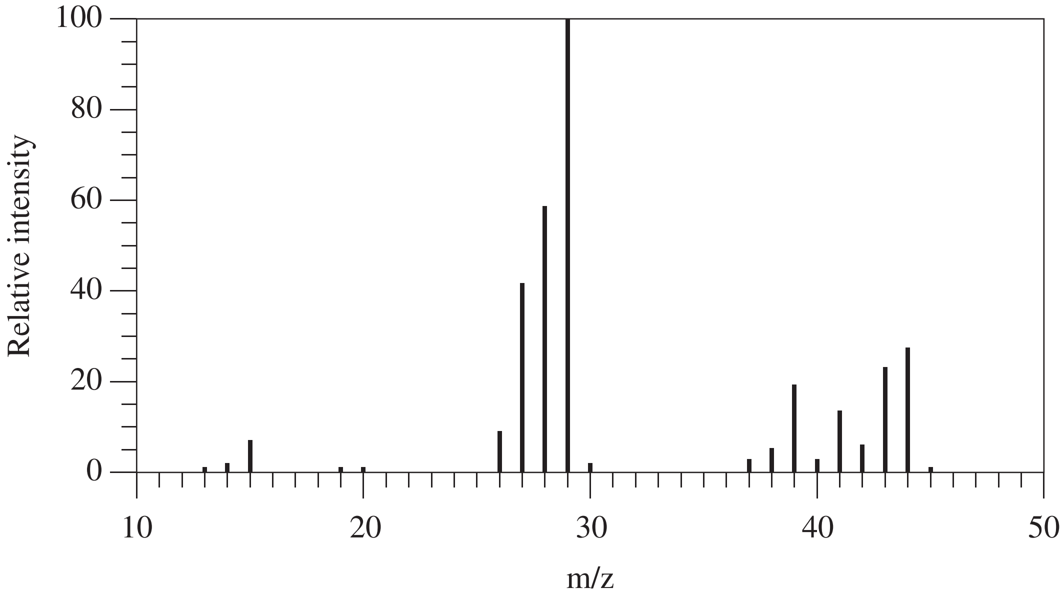
Question 21 (2 marks)

The mass spectrum of an alkane is shown. **2**



Use the information provided to identify the alkane and justify your choice.

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Question 22 (5 marks)

A 0.1 mol L^{-1} solution of an unknown salt is to be analysed. The cation is one of magnesium, calcium or barium. The anion is one of chloride, acetate or hydroxide. **5**

Outline a sequence of tests that could be performed in a school laboratory to confirm the identity of this salt solution. Include expected observations and a balanced chemical equation in your answer.

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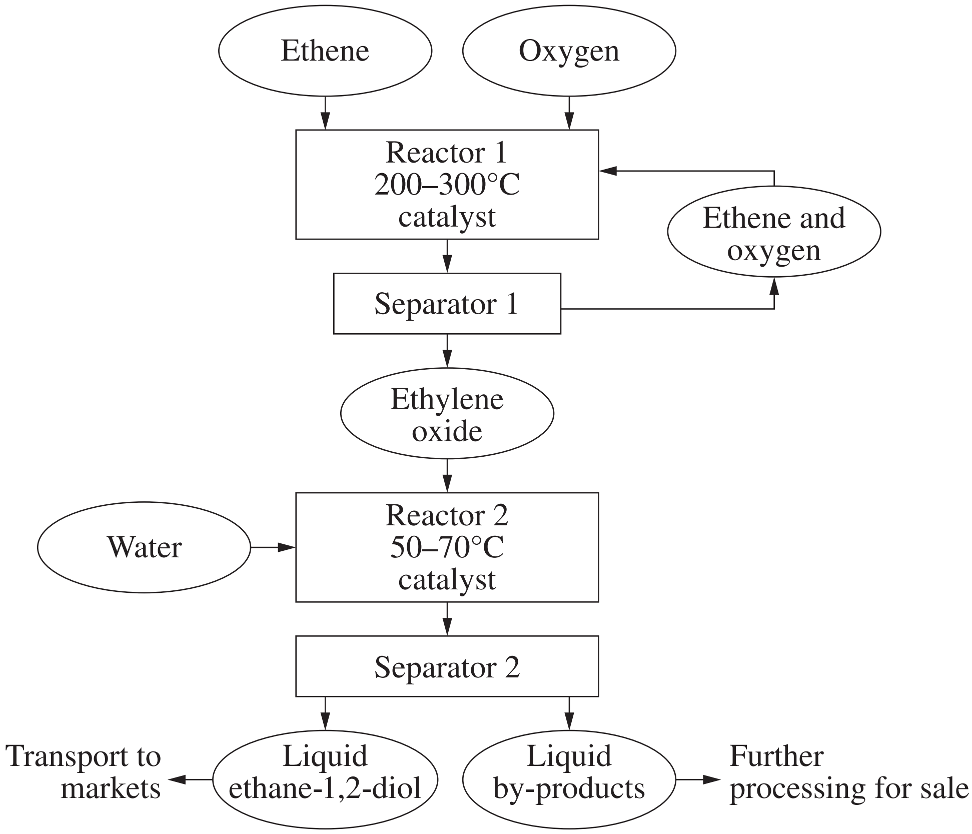
Question 23 (4 marks)

The flow chart summarises an industrial process for the synthesis of ethane-1,2-diol. **4**



Explain THREE factors that may have been considered in the design of this industrial process. Make specific reference to the flow chart.

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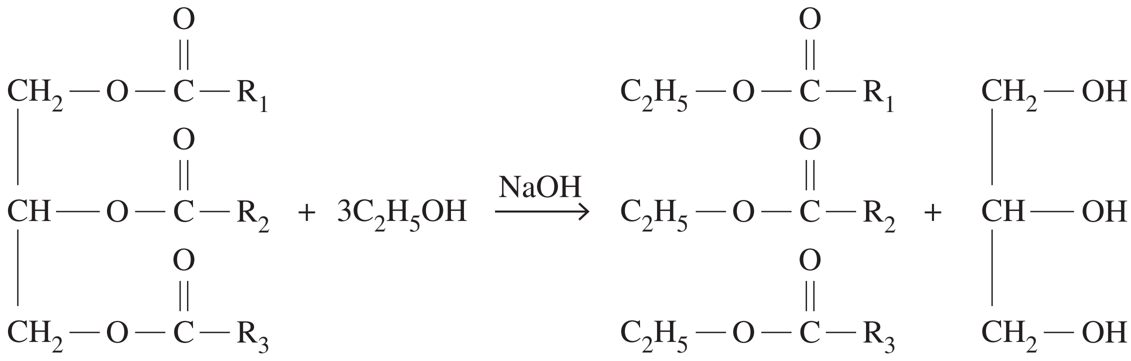
Question 24 (10 marks)

Biodiesel, an alternative fuel to diesel, may be produced from vegetable oil. The chemical reaction which converts oils from biomass into biodiesel is shown. R_1, R_2 and R_3 are alkyl chains which may vary from 10 to 22 carbons in length.



Vegetable oil   Biodiesel   Glycerol

(a) Which functional group is present in both the oil and the biodiesel? **1**

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(b) Explain why biodiesel ($C_{14}H_{30}O_2$) produces less soot than diesel ($C_{18}H_{38}$) when combusted under the same conditions. Support your answer with balanced chemical equations. **3**

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Question 24 continues on page 19

(c) The energy densities of biodiesel and diesel are 38 MJ kg^{-1} and 43 MJ kg^{-1} respectively. The densities of biodiesel and diesel are 0.90 kg L^{-1} and 0.83 kg L^{-1} respectively. **2**

When 60.0 L of diesel is combusted in a typical engine, 2141 MJ of energy is released.

What volume of biodiesel would be required to produce the same amount of energy?

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(d) Explain TWO advantages and TWO disadvantages of using bioethanol (ethanol produced from biomass) as an alternative to a fossil fuel. **4**

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End of Question 24

Question 25 (7 marks)

Citric acid reacts with sodium hydroxide according to the following chemical equation:

$$C_6H_8O_7(aq) + 3NaOH(aq) \longrightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l).$$

Various volumes of 1.0 mol L^{-1} citric acid solution were mixed with 8.0 mL of a sodium hydroxide solution of unknown concentration and sufficient deionised water added to make the total volume of the resulting solution 14.0 mL. The change in temperature of each solution was measured.

The data are given in the table.

Volume of 1.0 mol L^{-1} citric acid (aq) (mL)	*Temperature increase* (°C)
0.0	0.00
1.0	2.50
2.0	5.20
3.0	6.15
4.0	6.10
5.0	6.20
6.0	6.15

Question 25 continues on page 21

Question 25 (continued)

By graphing the data in the table and performing relevant calculations, determine the concentration of the sodium hydroxide solution. **7**

End of Question 25

Question 26 (5 marks)

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

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

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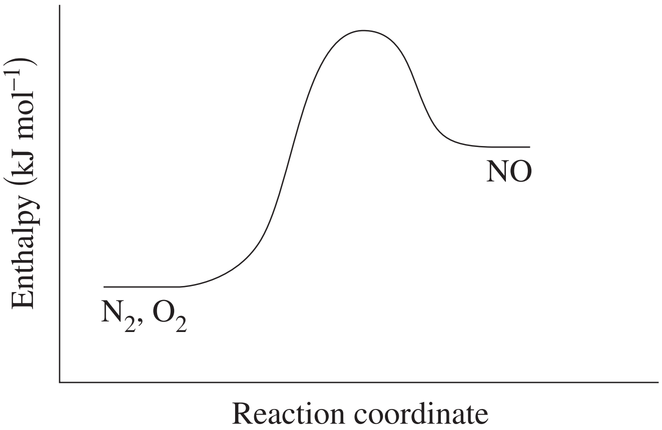
(b) The energy profile diagram for this reaction is shown. **4**



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 27 (5 marks)

A student makes up a solution of propan-2-amine in water with a concentration of 1.00 mol L^{-1}.

(a) Using structural formulae, complete the equation for the reaction of propan-2-amine with water. **2**

$$\boxed{} + H_2O \rightleftharpoons \boxed{} + OH^-$$

(b) The equilibrium constant for the reaction of propan-2-amine with water is 4.37×10^{-4}. **3**

Calculate the concentration of hydroxide ions in this solution.

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Question 28 (3 marks)

A chemist used the following method to determine the concentration of a dilute solution of propanoic acid ($pK_a = 4.88$). **3**

The chemist weighed out 1.000 g of solid NaOH on an electronic balance and then made up the solution in a 250.0 mL volumetric flask.

The chemist then performed titrations, using bromocresol green as the indicator. This indicator is yellow below pH 3.2 and green above pH 5.2.

The results are shown in the table.

Titre	*Volume of NaOH(aq) added* (mL)
1	16.35
2	10.10
3	12.35
4	11.25

Explain why this method produces inaccurate and unreliable results.

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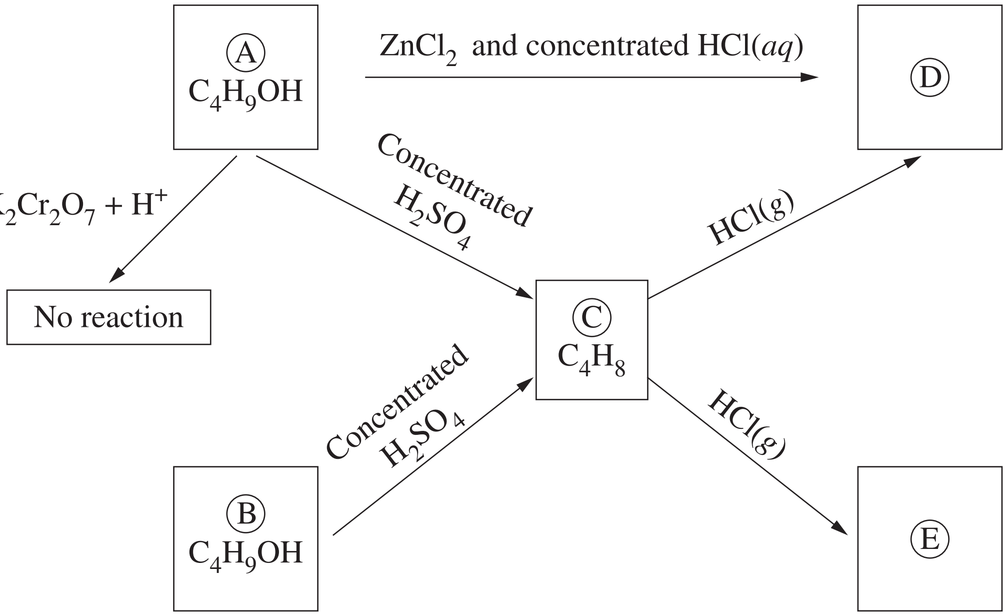
Question 29 (5 marks)

The flow chart shows reactions involving five different organic compounds, A to E. **5**



Draw the structure of each compound A to E in the corresponding space provided.

A

B

C

D

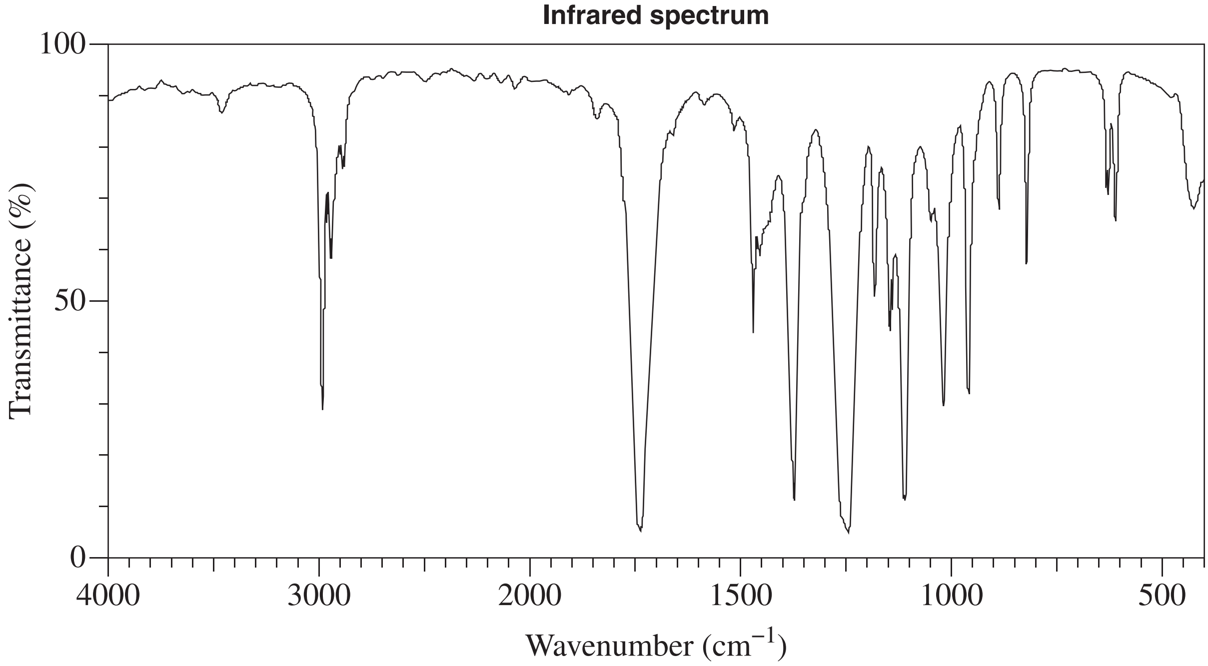
E

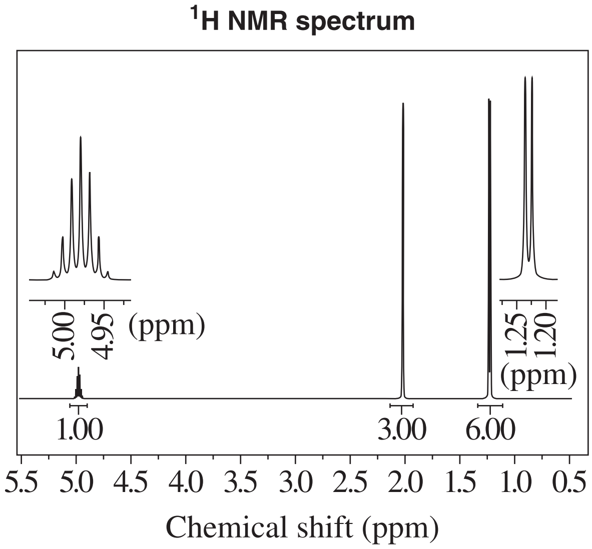
Do NOT write in this area.

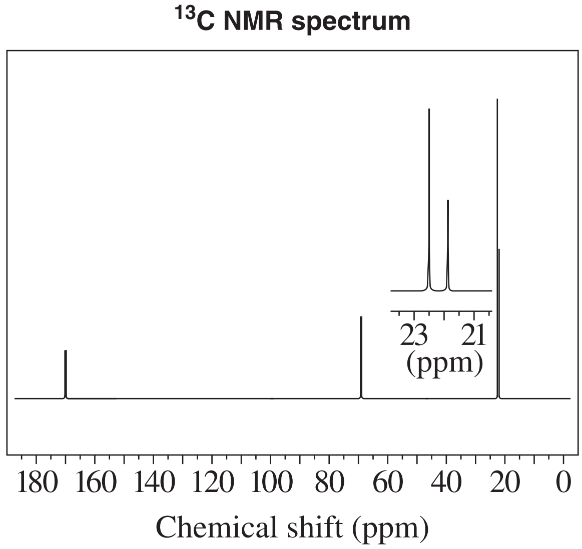
Question 30 (7 marks)

A chemist discovered a bottle simply labelled '$C_5H_{10}O_2$'.

To confirm the molecular structure of the contents of the bottle, a sample was submitted for analysis by infrared spectroscopy and ^1H and ^{13}C NMR spectroscopy. The resulting spectra are shown.







Question 30 continues on page 27

Data from ^{1}H NMR spectrum

Chemical shift	*Relative peak area*	*Splitting pattern*
1.2	6	doublet (2)
2.0	3	singlet (1)
5.0	1	septet (7)

^{1}H NMR chemical shift data

Type of proton		δ/ppm
$Si(C\mathbf{H}_3)_4$	(TMS)	0
$R—C\mathbf{H}_3$		0.7–1.3
$R—C\mathbf{H}_2—R$		1.2–1.5
$R—C\mathbf{H}R_2$		1.5–2.0
$\mathbf{H}_3C—CO—$	(aldehydes, ketones or esters)	2.0–2.5
$—C\mathbf{H}—CO—$	(aldehydes, ketones or esters)	2.1–2.6
$\mathbf{H}_3C—O—$	(alcohols or esters)	3.2–4.0
$—C\mathbf{H}—O—$	(alcohols or esters)	3.3–5.1
$R_2—C\mathbf{H}_2—O—$	(alcohols or esters)	3.5–5.0
$R—O\mathbf{H}$		1–6
$R_2C{=}C\mathbf{H}R$	(alkene)	4.5–7.0
$R—C\mathbf{H}O$	(aldehyde)	9.4–10.0
$R—COO\mathbf{H}$		9.0–13.0

Question 30 continues on page 28

Question 30 (continued)

In the space provided, draw a structural formula for the unknown compound that is consistent with all of the information provided. Justify your answer with reference to the information provided. **7**

End of Question 30

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Question 31 (4 marks)

A water sample was analysed to determine the chloride ion content. 100.0 mL of this water was added to 25.00 mL of 0.100 mol L^{-1} $AgNO_3(aq)$. **4**

The mixture was filtered and the filtrate was titrated against 0.0500 mol L^{-1} $KSCN(aq)$ according to the following reaction.

$$Ag^+(aq) + SCN^-(aq) \longrightarrow AgSCN(s)$$

The titration was repeated three times and the average titre was 28.65 mL.

Calculate the concentration of chloride ions in the water, expressed in mg L^{-1}.

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Question 32 (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 33 (6 marks)

Excess solid calcium hydroxide is added to a beaker containing 0.100 L of 2.00 mol L^{-1} hydrochloric acid and the mixture is allowed to come to equilibrium.

(a) Show that the amount (in mol) of calcium hydroxide that reacts with the hydrochloric acid is 0.100 mol. **2**

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(b) It is valid in this instance to make the simplifying assumption that the amount of calcium ions present at equilibrium is equal to the amount generated in the reaction in part (a). **4**

Calculate the pH of the resulting solution.

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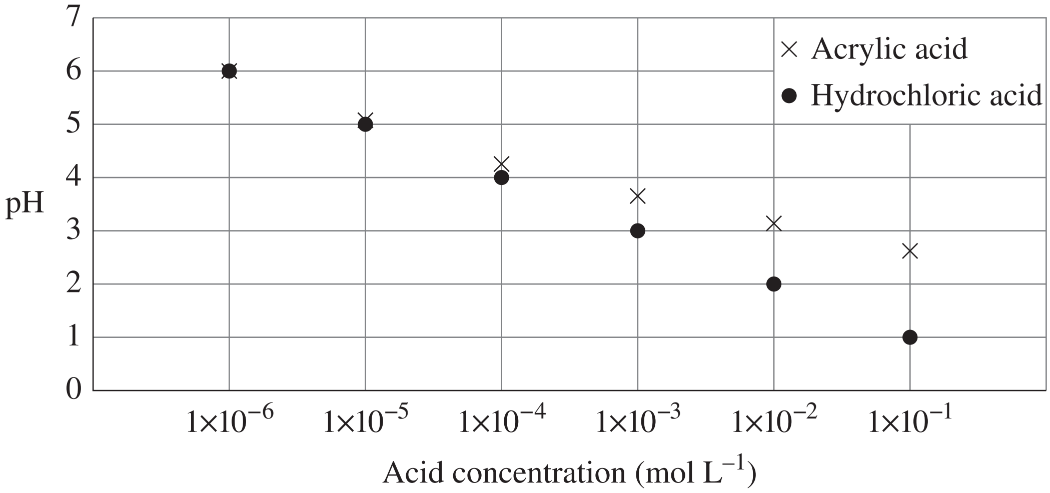
Question 34 (4 marks)

The effect of concentration on the pH of acrylic acid (C_2H_3COOH) and hydrochloric acid (HCl) solutions is shown in the graph. Both of these acids are monoprotic. **4**



Explain the trends in the graph. Include relevant chemical equations in your answer.

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Question 35 (4 marks)

In aqueous solution, iodide ions (I^-) react rapidly with iodine (I_2) to form triiodide ions (I_3^-), making the equilibrium system shown in the chemical equation: **4**

$$I^-(aq) + I_2(aq) \rightleftharpoons I_3^-(aq)$$

The following relationships can be derived from the reaction mechanism:

$$[I^-]_{eq} = 2[I_2]_{eq}$$

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

where '*initial*' designates the initial concentration and '*eq*' designates the equilibrium concentration.

The absorbance of the solution in the UV–Vis spectrum is given by:

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

Determine the value of the equilibrium constant, given that $A = 0.745$ at equilibrium and $[I^-]_{initial} = 7.00 \times 10^{-4}$ mol L^{-1}.

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Please turn over

Question 36 (5 marks)

100.00 mL of 2.00 mol L^{-1} $HCl(aq)$ was initially at a temperature of 22.5°C. The mass of this solution was 103 g. **5**

10.0 g of solid NaOH was added to the acid. The specific heat capacity of the resulting solution was 3.99 J g^{-1} K^{-1}.

Assuming no energy loss to the environment, calculate the maximum temperature reached by the solution.

Use the following information in your calculations.

$$NaOH(s) \longrightarrow Na^{+}(aq) + OH^{-}(aq) \qquad \Delta H = -44.5 \text{ kJ mol}^{-1}$$

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l) \qquad \Delta H = -56.1 \text{ kJ mol}^{-1}$$

End of paper

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Section II extra writing space

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

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Section II extra writing space

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

Chemistry

FORMULAE SHEET

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

Avogadro constant, N_A .... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and
at 0°C (273.15 K) .... 22.71 L
at 25°C (298.15 K) .... 24.79 L

Gas constant .... 8.314 J mol^{-1} K^{-1}

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

Specific heat capacity of water .... 4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

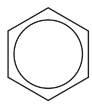
Solubility constants at 25°C

Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	Lead(II) hydroxide	1.43×10^{-15}
Calcium hydroxide	5.02×10^{-6}	Lead(II) phosphate	8.0×10^{-43}
Calcium phosphate	2.07×10^{-29}	Lead(II) sulfate	2.53×10^{-8}
Calcium sulfate	4.93×10^{-5}	Magnesium carbonate	6.82×10^{-6}
Copper(II) carbonate	1.4×10^{-10}	Magnesium hydroxide	5.61×10^{-12}
Copper(II) hydroxide	2.2×10^{-20}	Magnesium phosphate	1.04×10^{-24}
Copper(II) phosphate	1.40×10^{-37}	Silver bromide	5.35×10^{-13}
Iron(II) carbonate	3.13×10^{-11}	Silver chloride	1.77×10^{-10}
Iron(II) hydroxide	4.87×10^{-17}	Silver carbonate	8.46×10^{-12}
Iron(III) hydroxide	2.79×10^{-39}	Silver hydroxide	2.0×10^{-8}
Iron(III) phosphate	9.91×10^{-16}	Silver iodide	8.52×10^{-17}
		Silver phosphate	8.89×10^{-17}
		Silver sulfate	1.20×10^{-5}

Infrared absorption data

Bond	Wavenumber/cm^{-1}
N—H (amines)	3300–3500
O—H (alcohols)	3230–3550 (broad)
C—H	2850–3300
O—H (acids)	2500–3000 (very broad)
C≡N	2220–2260
C=O	1680–1750
C=C	1620–1680
C—O	1000–1300
C—C	750–1100

^{13}C NMR chemical shift data

Type of carbon		δ/ppm
—C—C—		5–40
R—C—Cl or Br		10–70
R—C(=O)—C—		20–50
R—C—N<		25–60
—C—O—	alcohols, ethers or esters	50–90
>C=C<		90–150
R—C≡N		110–125
		110–160
R—C(=O)—	esters or acids	160–185
R—C(=O)—	aldehydes or ketones	190–220

UV absorption

(This is not a definitive list and is approximate.)

Chromophore	λ_{max} (nm)
C—H	122
C—C	135
C=C	162

Chromophore	λ_{max} (nm)
C≡C	173 178 196 222
C—Cl	173
C—Br	208

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4{}^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7{}^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4{}^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for the standard potentials. Some data may have been modified for examination purposes.

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

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.

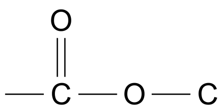
Answers could include:

- 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 = $\dfrac{2141}{38} = 56.3$ kg

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

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

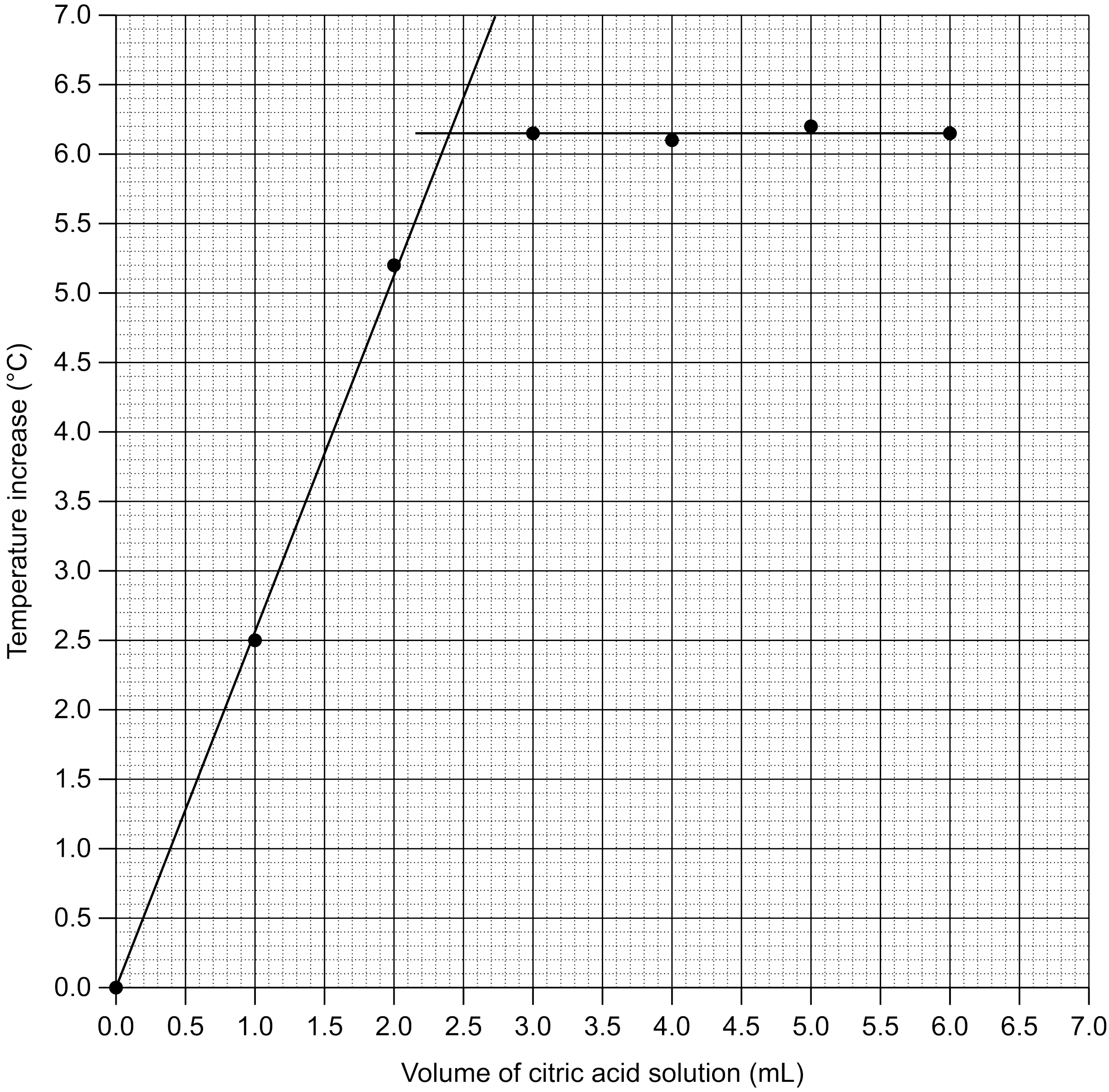
- The use of water to produce more crops to produce bioethanol can put pressure on local water resources. In areas where there is water scarcity, production of crops to be used in making bioethanol compromises water security for this region – possibly leading to health issues due to lack of potable water.
- 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.

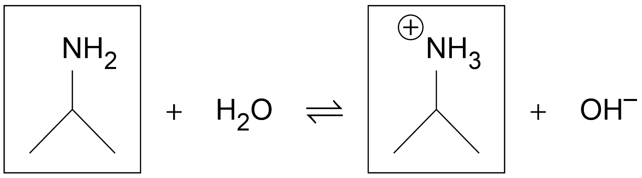
Answers could include:

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:

$$\begin{array}{lcccccccc} & C_3H_7NH_2 & + & H_2O & \rightleftharpoons & C_3H_7NH_3^{\ +} & + & OH^- \\ \text{I} & 1.00 & & & & 0 & & 0 \\ \text{C} & -x & & & & x & & x \\ \text{E} & 1.00 - x & & & & x & & x \end{array}$$

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

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

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

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

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.

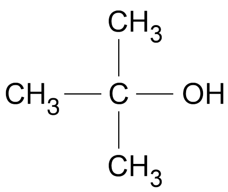
The indicator chosen is inappropriate. It changes colour in the flat region of the titration curve, prior to the equivalence point. Small titre volume differences will result in big variations in the observed endpoint, explaining the lack of reliability in titres 2, 3 and 4.

Question 29

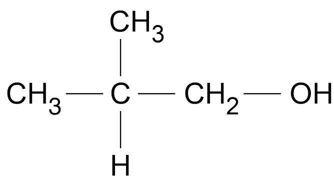
Criteria	Marks
• Draws correct structural formulae for all five compounds	5
• Draws correct structural formulae for four compounds OR • Draws five correct structural formulae with one minor error	4
• Draws substantially correct structural formulae demonstrating an understanding of most reactions	3
•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

Sample answer:

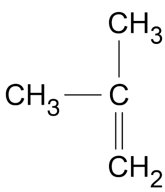
A



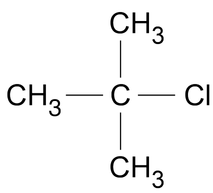
B



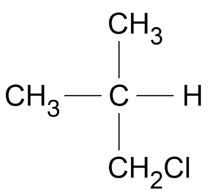
C



D



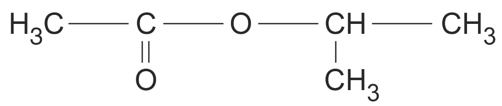
E



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:

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

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

$$\begin{aligned} n\left(\mathrm{Ca(OH)_2}\right) &= \frac{n(\mathrm{HCl})}{2} \\ &= \frac{0.200\ \mathrm{mol}}{2} \\ &= 0.100\ \mathrm{mol} \end{aligned}$$

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:

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

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

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

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

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

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

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

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

$$= 2.650$$

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

$$= 11.35$$

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:

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

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

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

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

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

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

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

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

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

$$= 564$$

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*)

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

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

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

$$q = mc\Delta T$$

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

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

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

2020 HSC Chemistry Mapping Grid

Section I

Question	Marks	Content	Syllabus outcomes
1	1	Mod 8 Analysis of organic substances	12-6, 12-15
2	1	Mod 6 Properties of acids and bases	12-5, 12-13
3	1	Mod 7 Reactions of organic acids and bases	12-4, 12-14
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
8	1	Mod 6 Quantitative analysis	12-5, 12-13
9	1	Mod 7 Reactions of organic acids and bases	12-5, 12-14
10	1	Mod 6 Properties of acids and bases	12-5, 12-13
11	1	Mod 5 Solution equilibria	12-2, 12-12
12	1	Mod 7 Polymers	12-5, 12-14
13	1	Mod 7 Hydrocarbons	12-5, 12-14
14	1	Mod 5 Calculating the equilibrium constant Mod 6 Using Brønsted–Lowry theory	12-2, 12-12, 12-13
15	1	Mod 8 Analysis of organic substances	12-6, 12-15
16	1	Mod 5 Factors that affect equilibrium	12-6, 12-12
17	1	Mod 5 Solution equilibria	12-6, 12-12
18	1	Mod 6 Using Brønsted–Lowry theory	12-5, 12-13
19	1	Mod 5 Factors that affect equilibrium	12-4, 12-12
20	1	Mod 5 Solution equilibria	12-4, 12-12

Section II

Question	Marks	Content	Syllabus outcomes
21	2	Mod 8 Analysis of organic substances	12-6, 12-15
22	5	Mod 5 Factors that affect equilibrium Mod 8 Analysis of inorganic substances	12-6, 12-12, 12-15
23	4	Mod 8 Chemical synthesis and design	12-5, 12-7, 12-15
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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
26 (a)	1	Mod 5 Factors that affect equilibrium	12-6, 12-12
26 (b)	4	Mod 5 Static and dynamic equilibrium	12-4, 12-6, 12-12

Question	Marks	Content	Syllabus outcomes
27 (a)	2	Mod 6 Using Brønsted–Lowry theory Mod 7 Reactions of organic acids and bases	12-5, 12-13, 12-14
27 (b)	3	Mod 5 Calculating the equilibrium constant	12-6, 12-12
28	3	Mod 6 Quantitative analysis	12-2, 12-3, 12-5, 12-13
29	5	Mod 7 Alcohols	12-5, 12-6, 12-7, 12-14
30	7	Mod 8 Analysis of organic substances	12-1, 12-6, 12-7, 12-15
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32	4	Mod 7 Nomenclature Mod 7 Reactions of organic acids and bases	12-5, 12-6, 12-14
33 (a)	2	Mod 6 Using Brønsted–Lowry theory	12-6, 12-13
33 (b)	4	Mod 5 Calculating the equilibrium constant Mod 6 Using Brønsted–Lowry theory	12-6, 12-12, 12-13
34	4	Mod 6 Using Brønsted–Lowry theory Mod 6 Properties of acids and bases	12-2, 12-6, 12-13,
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