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

1040

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?

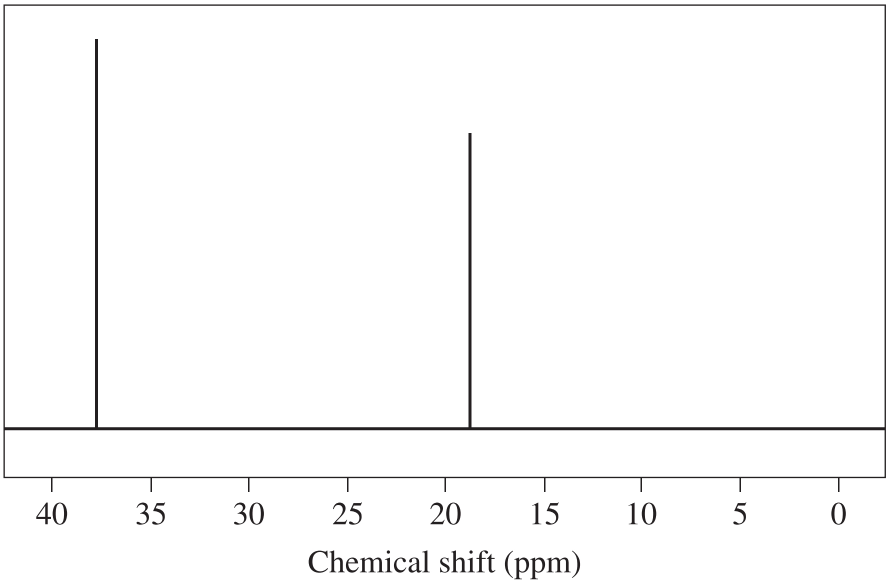
A. Butane and propane

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?

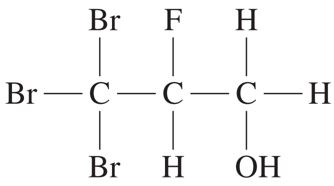
A. chloroethane

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

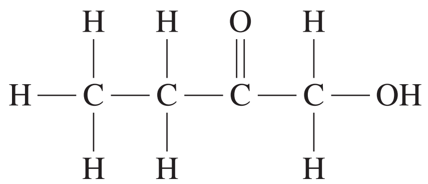
B. 2-fluoro-3,3,3-tribromopropan-1-ol

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

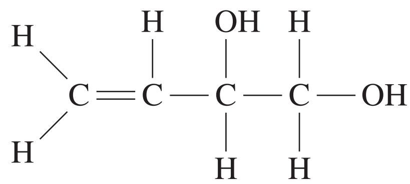
D. 3,3,3-tribromo-2-fluoropropan-1-ol

7 The structures of four isomers are shown.

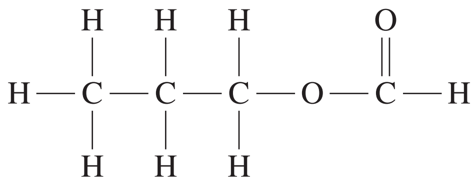
Compound 1



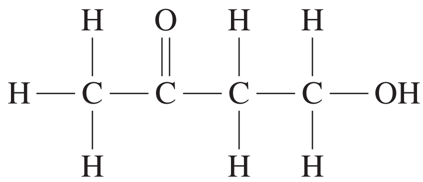
Compound 2



Compound 3



Compound 4



Which statement is correct?

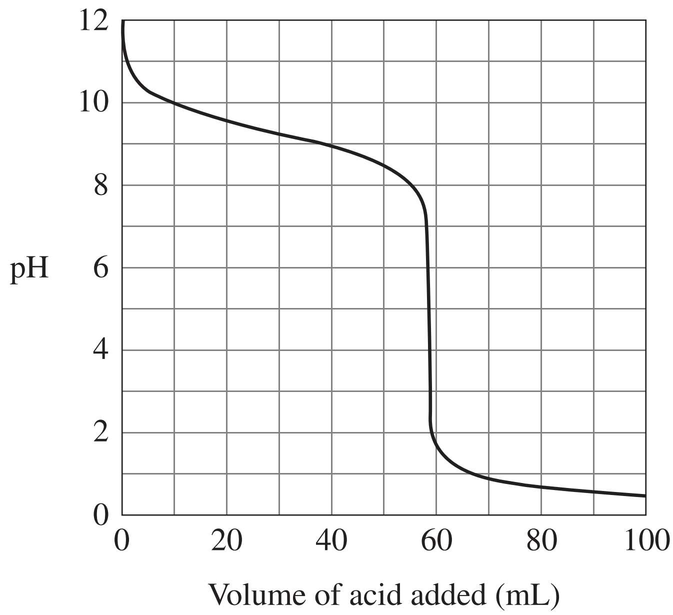
A. Compounds 1 and 2 are chain isomers.

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?

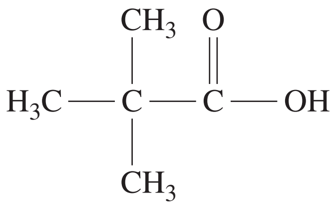
A. 5

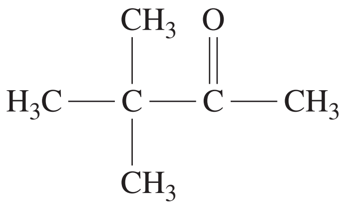
B. 7

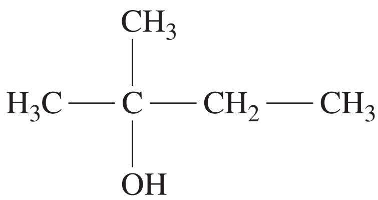
C. 8

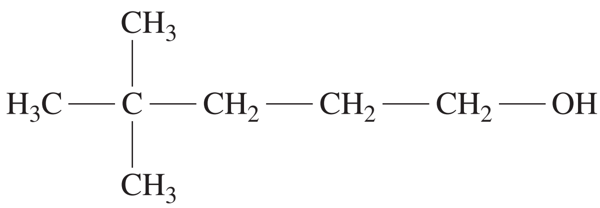
D. 9

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?

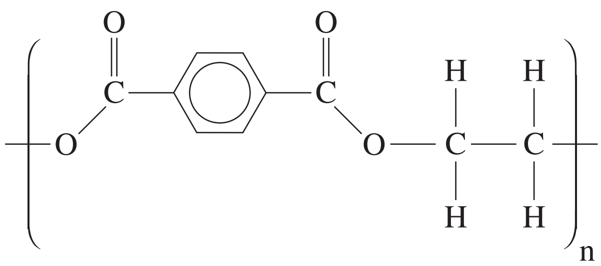
A. $Ba(OH)_2$ and $MgCl_2$

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?

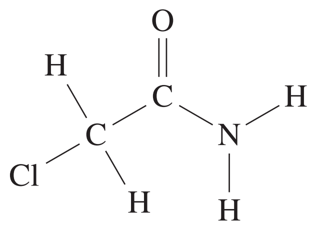
A. 5.50

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?

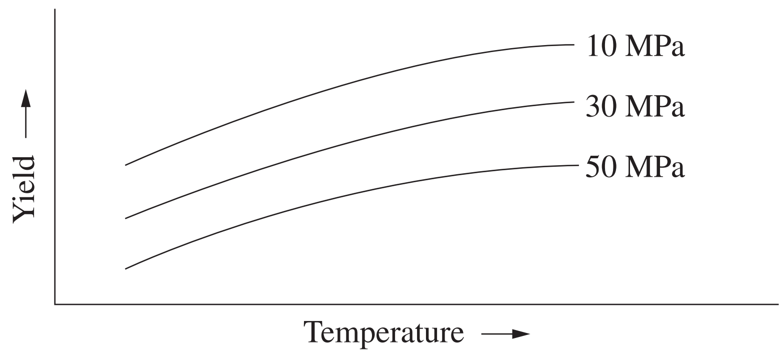
A. $[OCl]$

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?

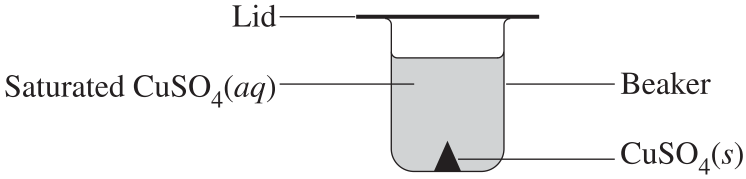
A. $X(g) + 3Y(g) \rightleftharpoons 2Z(g)$ $\Delta H > 0$

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 $H_2CO_3(aq)$.

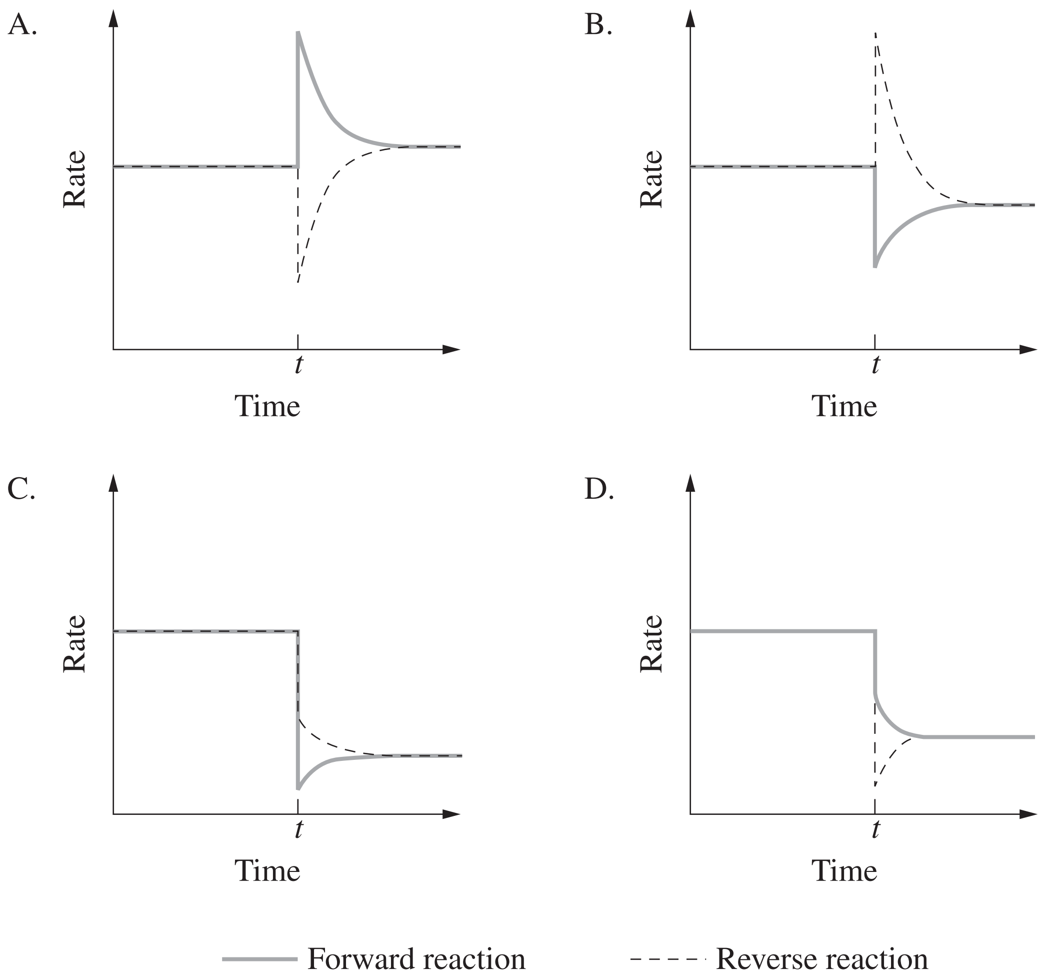
C. $Na^+(aq)$ reacts with water to produce the strong base $NaOH(aq)$.

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

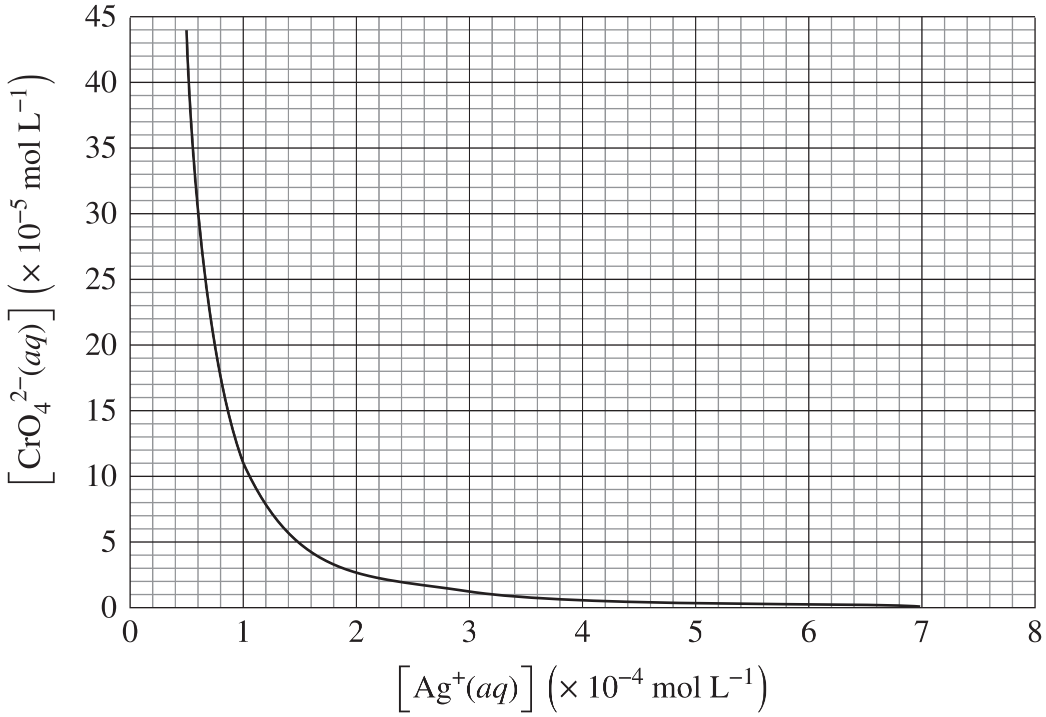
19 Nitrogen dioxide reacts to form dinitrogen tetroxide in a sealed flask according to the following equation.

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

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.

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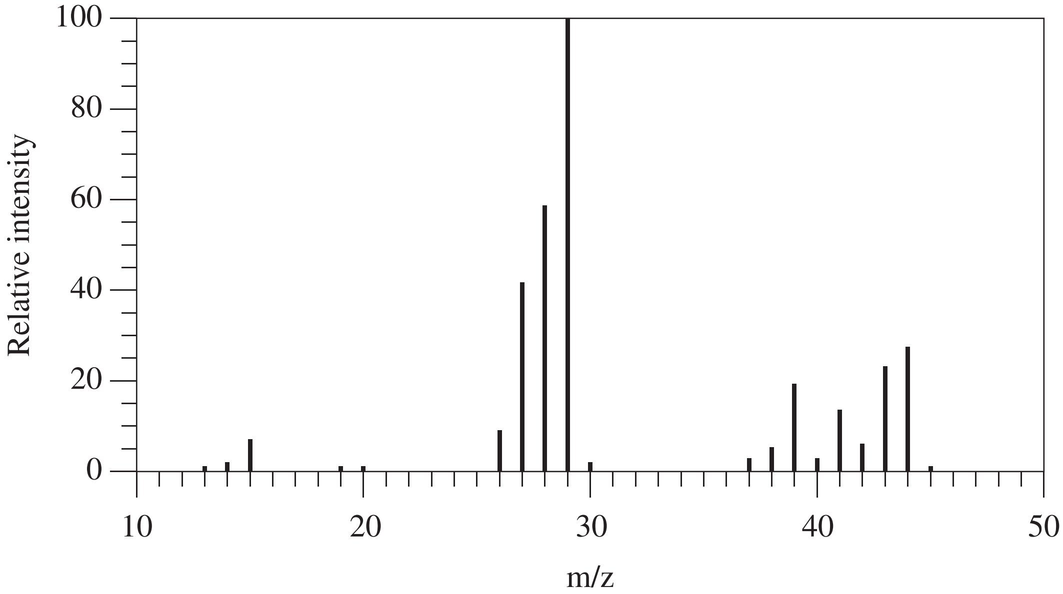
Question 21 (2 marks)

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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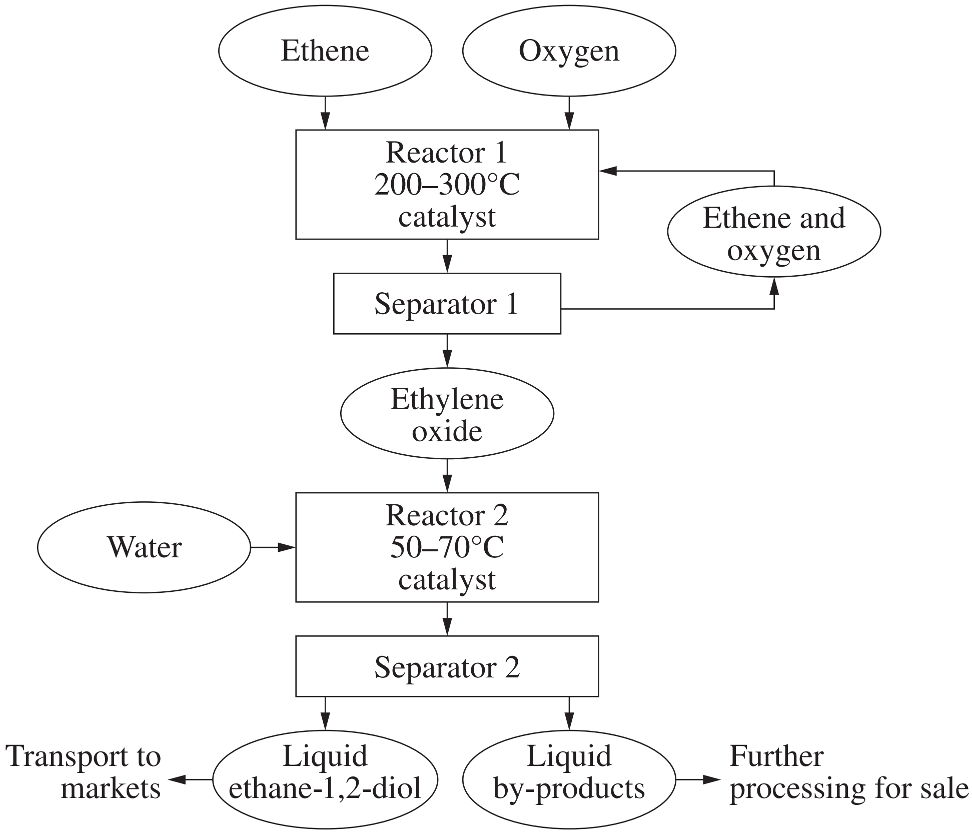
Question 23 (4 marks)

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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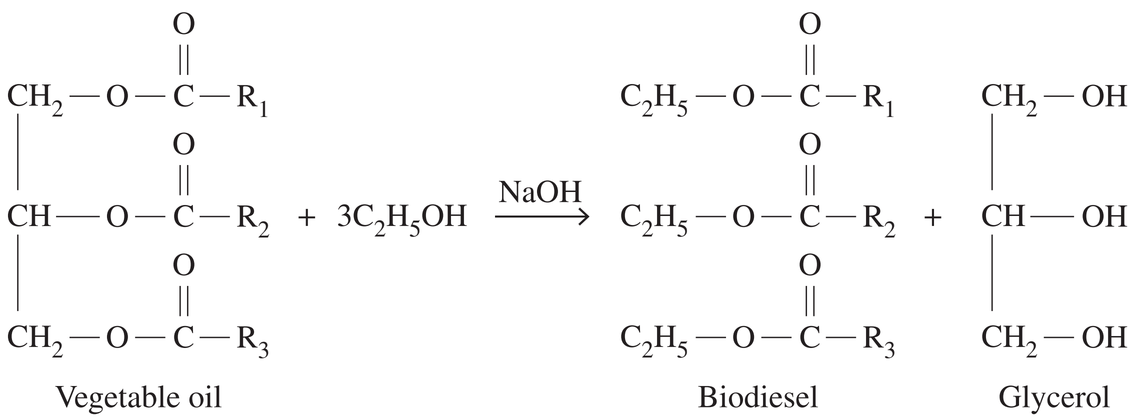
Question 24 (10 marks)

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.



(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

Question 24 (continued)

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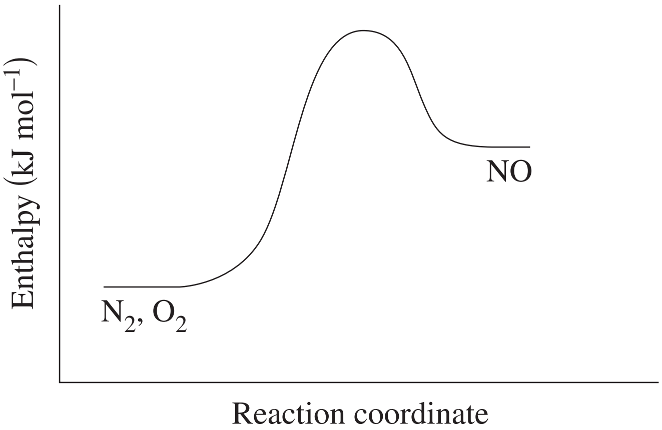
(b) The energy profile diagram for this reaction is shown. **4**



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**

[ ] $+ H_2O \rightleftharpoons$ [ ] $+ OH^-$

(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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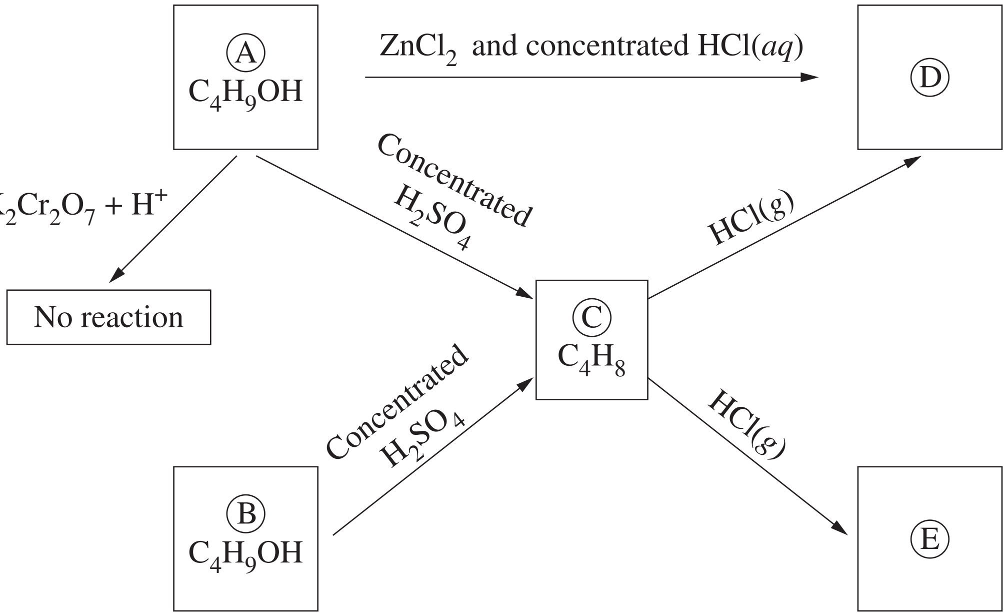
Question 29 (5 marks)

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)

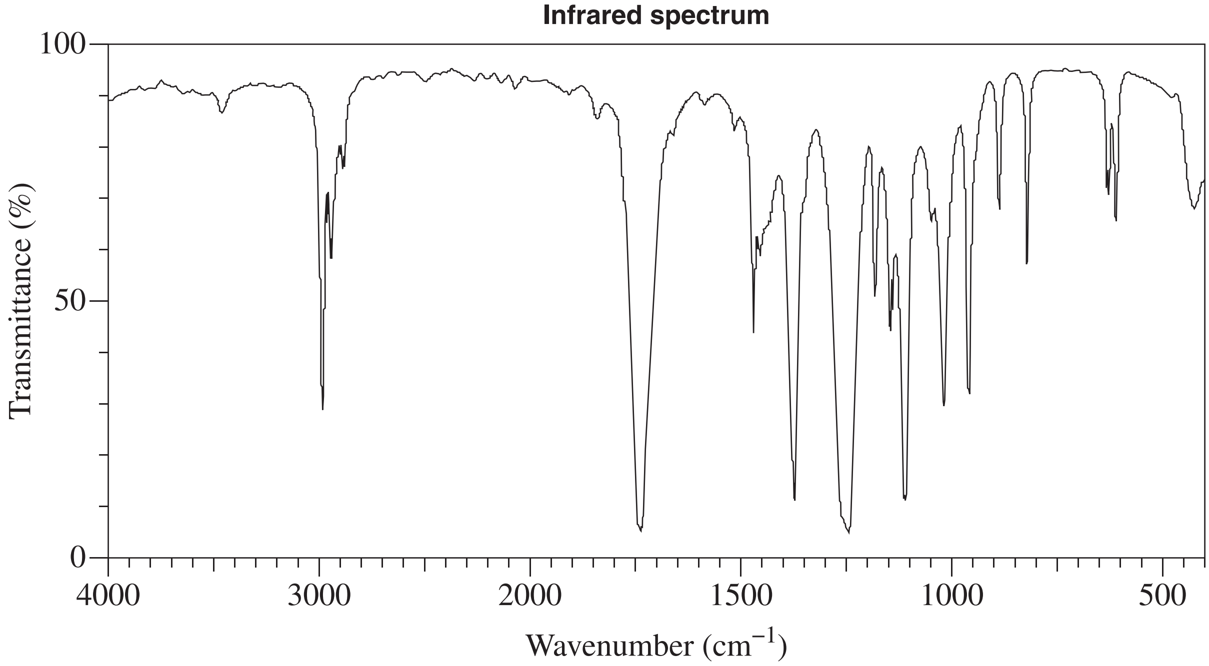
(D)

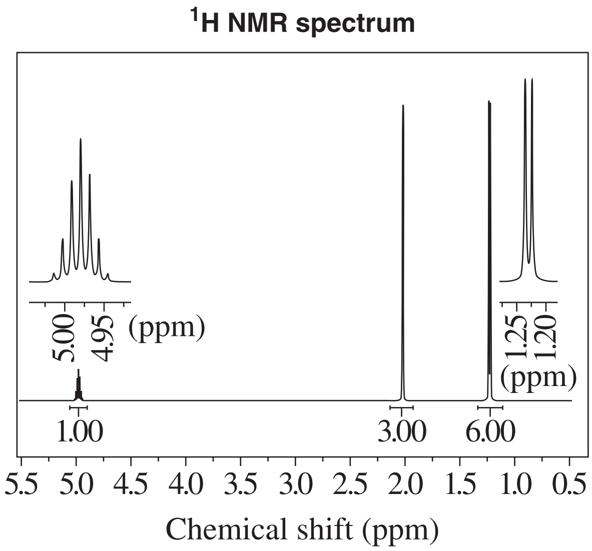
(E)

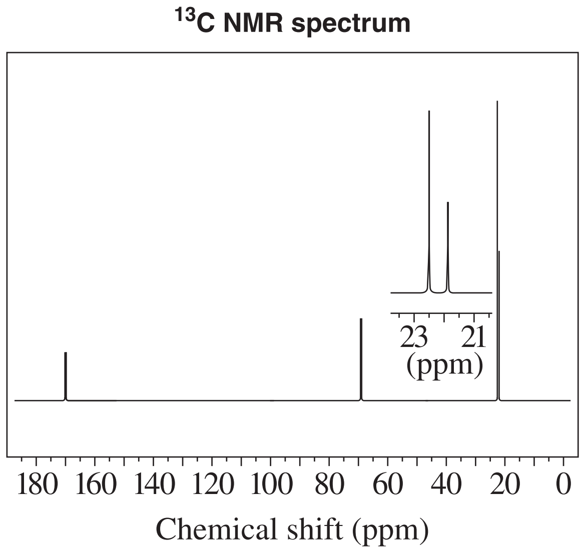
Question 30 (7 marks)

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 ^{1}H and ^{13}C NMR spectroscopy. The resulting spectra are shown.







Question 30 continues on page 27

Question 30 (continued)

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

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

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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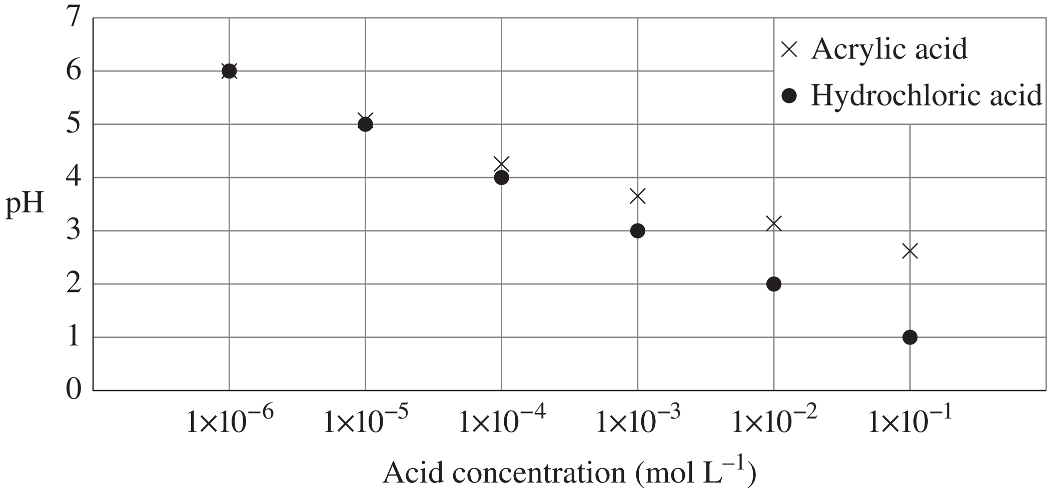
Question 34 (4 marks)

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.

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

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

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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.

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Chemistry

FORMULAE SHEET

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

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

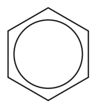
Solubility constants at 25°C

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

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.