NSW Education Standards Authority

2019 **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 2–10)

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

Section II – 80 marks (pages 13–32)

- Attempt Questions 21–34
- 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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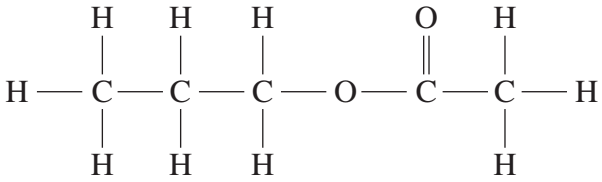
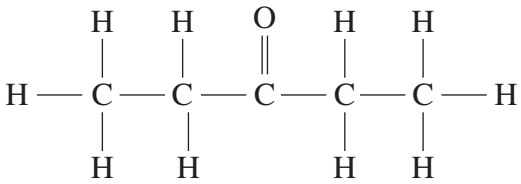
1 Which structural formula represents pentan-2-one?

A.



B.



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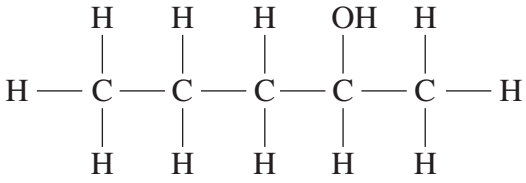

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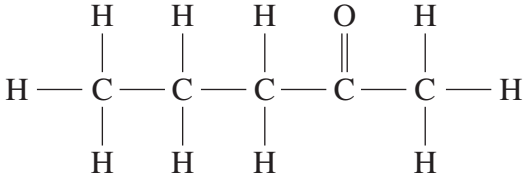


2 Which of the following is an Arrhenius base?

A. Na

B. NaOH

C. Na_2CO_3

D. $NaHCO_3$

3 Which of the following metal carbonates has the highest molar solubility?

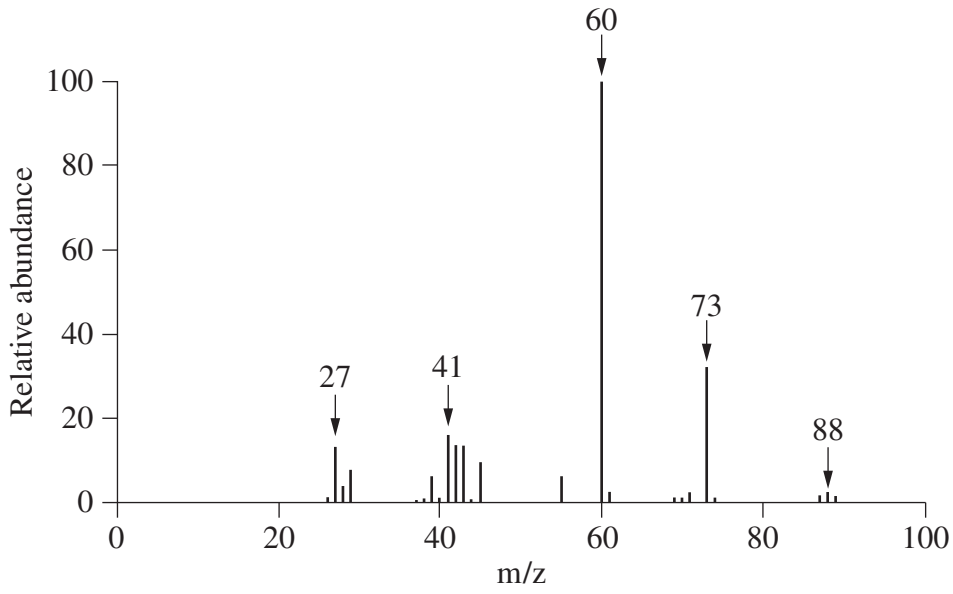
A. Calcium carbonate

B. Copper(II) carbonate

C. Iron(II) carbonate

D. Lead(II) carbonate

4 The diagram shows the mass spectrum of an organic compound.



Which compound was analysed?

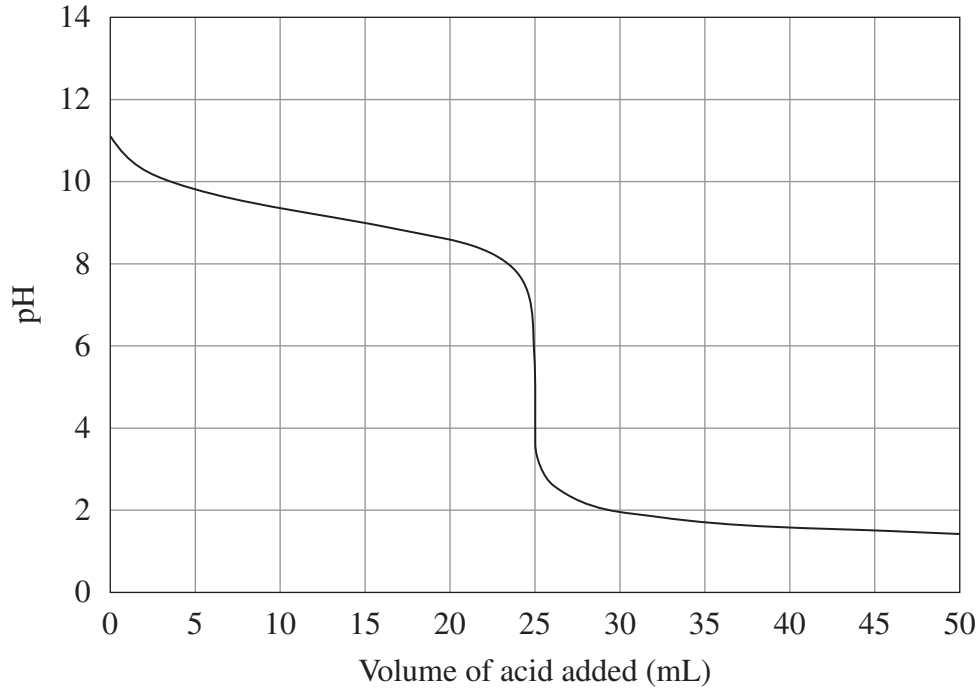
A. Butan-1-amine

B. Butanoic acid

C. Ethanoic acid

D. Iron(II) sulfide

The diagram represents the titration curve for a reaction between a particular acid and a particular base. Use the diagram to answer Questions 5 and 6.



5 Which indicator would be best for this titration?

	Indicator	*Colour change range* (pH)
A.	Martius yellow	2.0 – 3.2
B.	Magdala red	3.0 – 4.0
C.	Isopicramic acid	4.0 – 5.6
D.	Cresol red	7.2 – 8.8

6 Which of the following equations best represents the reaction described by the titration curve?

A. $NH_3(aq) + HCl(aq) \longrightarrow NH_4Cl(aq)$

B. $NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$

C. $NH_3(aq) + CH_3COOH(aq) \longrightarrow CH_3COONH_4(aq)$

D. $NaOH(aq) + CH_3COOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$

7 How does the addition of a catalyst affect a reversible reaction?

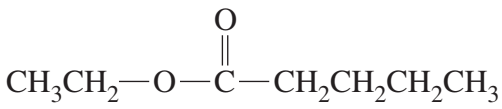
A. It increases the activation energy of the forward reaction only.

B. It decreases the activation energy of the forward reaction only.

C. It increases the activation energy of both the forward and reverse reactions.

D. It decreases the activation energy of both the forward and reverse reactions.

8 The structure of an organic compound is shown.



Which row of the table correctly gives the name of the compound and one of the reactants used to produce it in a one-step reaction?

	Name	*Reactant*
A.	Ethyl pentanoate	Ethanol
B.	Ethyl pentanoate	Pentan-1-ol
C.	Pent-1-yl ethanoate	Ethanol
D.	Pent-1-yl ethanoate	Pentan-1-ol

9 All of the following compounds have similar molar masses.

Which has the highest boiling point?

A. Butane

B. Ethanoic acid

C. Propan-1-ol

D. Propanone

10 Which class of organic compound must contain at least three carbon atoms?

A. Aldehydes

B. Alkenes

C. Carboxylic acids

D. Ketones

11 A saturated solution of barium carbonate was stored in a flask. Solid barium carbonate containing radioactive carbon-14 was added to the solution. The mixture was allowed to stand for several days and was then filtered.

Radioactivity could reasonably be expected to be found in

A. the filtrate only.

B. the residue only.

C. both residue and filtrate.

D. neither residue nor filtrate.

12 Methanol can be produced from the reaction of carbon monoxide and hydrogen, according to the following equation:

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta_r H^{\ominus} = -90 \text{ kJ mol}^{-1}$$

Which set of conditions will produce the maximum yield of methanol?

A. Low pressure and low temperature

B. Low pressure and high temperature

C. High pressure and low temperature

D. High pressure and high temperature

13 A sample of polydifluoroethylene is determined to have an average molar mass of 4.8×10^4 g mol^{-1}.

Approximately how many carbon atoms are there in an average molecule?

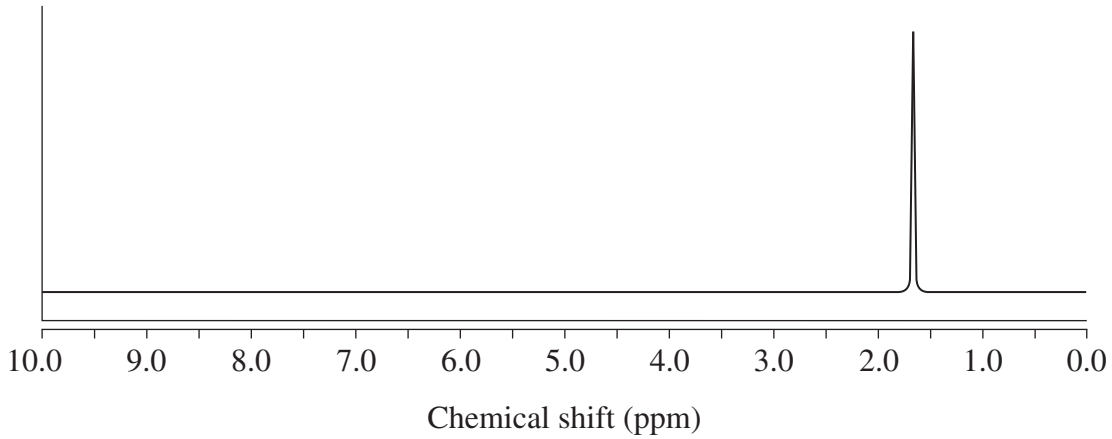
A. 750

B. 1500

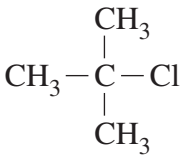
C. 2500

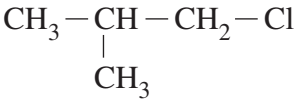
D. 4000

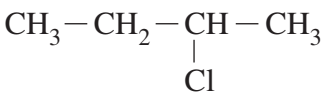
14 A molecule, C_4H_9Cl, is analysed. The ^1H NMR spectrum of this molecule is shown.



What is the structural formula of this molecule?

A. 

B. 

C. 

D. 

15 What is the concentration of hydroxide ions $\left(\text{in mol L}^{-1}\right)$ in a solution that has a pH of 8.53?

A. 3.0×10^{-9}

B. 3.4×10^{-6}

C. 5.5

D. 3.0×10^{5}

16 At equilibrium, a 1.00 L vessel contains 0.0430 mol of H_2, 0.0620 mol of I_2, and 0.358 mol of HI. The system is represented by the following equation:

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

Which of the following is closest to the value of the equilibrium constant, K_{eq}, for this reaction?

A. 0.0208

B. 48.1

C. 134

D. 269

17 A student makes a solution with a final volume of 200 mL by mixing 100 mL of 0.0500 mol L^{-1} barium nitrate solution with 100 mL of 0.100 mol L^{-1} sodium hydroxide solution.

Which row of the table correctly identifies if a precipitate will form under these conditions and the reason?

	Will a precipitate form?	*Reason*
A.	Yes	$Q > K_{sp}$
B.	Yes	$Q < K_{sp}$
C.	No	$Q > K_{sp}$
D.	No	$Q < K_{sp}$

18 Consider the following equilibrium.

$$HF(aq) + CF_3COO^-(aq) \rightleftharpoons F^-(aq) + CF_3COOH(aq) \qquad K_{eq} = 3.80 \times 10^{-4}$$

Which row of the table correctly identifies the strongest acid and the strongest base in this system?

	Strongest acid	*Strongest base*
A.	$CF_3COOH(aq)$	$F^-(aq)$
B.	$CF_3COOH(aq)$	$CF_3COO^-(aq)$
C.	$HF(aq)$	$F^-(aq)$
D.	$HF(aq)$	$CF_3COO^-(aq)$

19 Compound X shows three signals in its ^{13}C NMR spectrum.

Treatment of X with hot acidified potassium permanganate produces a compound Y. Compound Y turns blue litmus red.

Compound X produces compound Z upon reaction with hot concentrated sulfuric acid.

Which of the following correctly identifies compounds X, Y and Z?

	Compound X	*Compound* Y	*Compound* Z
A.	butan-1-ol	butanoic acid	but-1-ene
B.	butan-2-ol	butanone	but-2-ene
C.	methyl ethanoate	methanoic acid	ethene
D.	2-methylpropan-1-ol	2-methylpropanoic acid	2-methylprop-1-ene

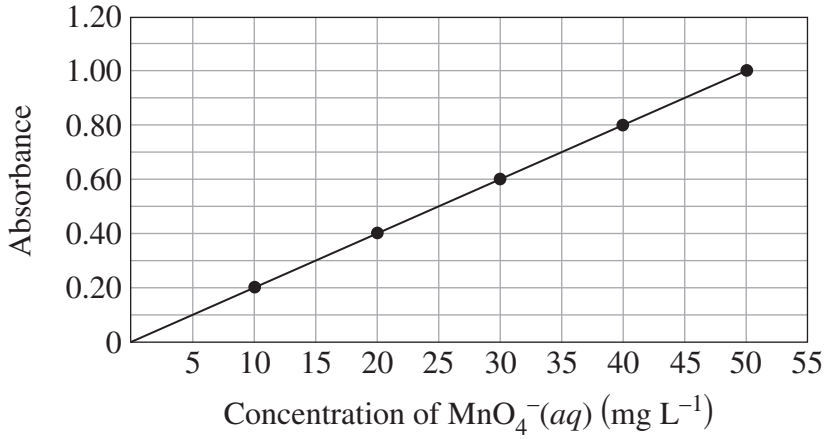
20 The manganese content in a 12.0-gram sample of steel was determined by measuring the absorbance of permanganate (MnO_4^-) using the following process.

The steel sample was dissolved in nitric acid and the $Mn^{2+}(aq)$ ions produced were oxidised to $MnO_4^-(aq)$ by periodate ions, $IO_4^-(aq)$, according to the following equation.

$$2Mn^{2+}(aq) + 5IO_4^-(aq) + 3H_2O(l) \longrightarrow 2MnO_4^-(aq) + 5IO_3^-(aq) + 6H^+(aq)$$

The resulting solution was made up to a volume of 1.00 L, then 20.0 mL of this solution was diluted to 100.0 mL. The absorbance at 525 nm of the resulting solution was 0.50.

A calibration curve for $MnO_4^-(aq)$ was constructed and is shown below.



What was the percentage by mass of manganese in the steel sample?

A. 0.019%

B. 0.096%

C. 0.48%

D. 1.0%

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2019 HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Student Number

Chemistry

Section II Answer Booklet

80 marks
Attempt Questions 21–34
Allow about 2 hours and 25 minutes for this section

Instructions

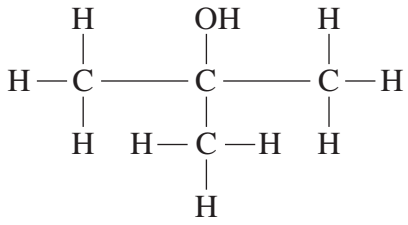
- Write your Centre Number and Student Number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this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

Please turn over

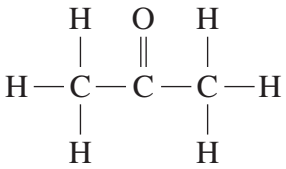
Question 21 (7 marks)

(a) The structural formula for 2-methylpropan-2-ol is shown in the table. **2**

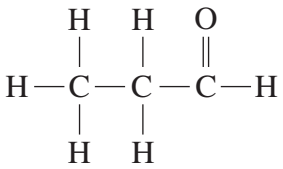
Draw one structural isomer of this alcohol and state its name.

	Alcohol	*Isomer*
Structure		
Name	2-methylpropan-2-ol	

(b) The structural formulae for two compounds are shown below. **2**



Isomer A



Isomer B

Why are these two compounds classed as functional group isomers?

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(c) A chemical test is required to distinguish between the isomers in part (b). **3**

Identify a suitable test and explain the expected observations.

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Question 22 (4 marks)

A buffer was prepared with acetic acid and sodium acetate. A few drops of universal indicator were then added. When small amounts of either 0.1 mol L^{-1} HCl(*aq*) or 0.1 mol L^{-1} NaOH(*aq*) were added, no change in the colour of the solution was observed. **4**

Explain these observations. Support your answer with at least ONE chemical equation.

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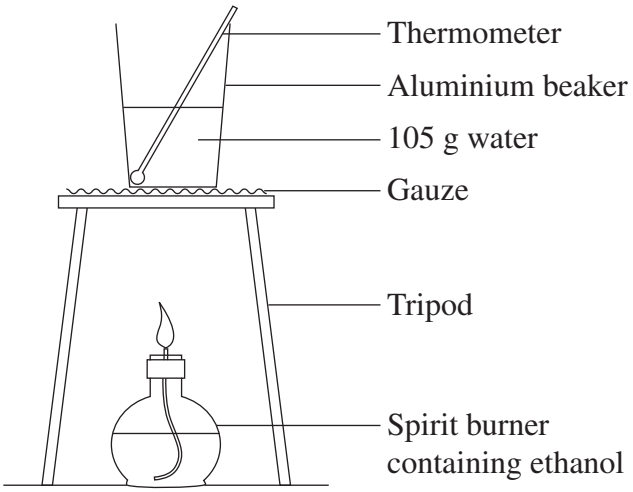
Question 23 (6 marks)

The following apparatus was used in an experiment to determine the molar enthalpy of combustion of ethanol.



(a) Calculate the experimental molar enthalpy of combustion $\left(\Delta_c H\right)$ of ethanol when 0.370 g ethanol was used to raise the water temperature from 18.5°C to 30.0°C. **4**

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Question 23 continues on page 17

(b) Upon replication, the molar enthalpy of combustion obtained in the experiment was consistently much lower than the accepted value. **2**

Explain ONE change that could be made to the experiment that would improve the accuracy of the obtained value.

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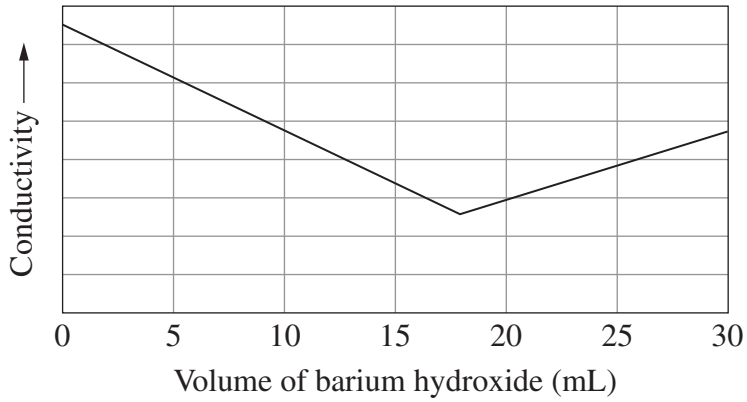
End of Question 23

Please turn over

Question 24 (7 marks)

A conductometric titration was undertaken to determine the concentration of a barium hydroxide solution. The solution was added to 250.0 mL of standardised 1.050×10^{-3} mol L^{-1} hydrochloric acid solution. The results of the titration are shown in the conductivity graph.



(a) Explain the shape of the titration curve. **3**

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(b) The equivalence point was reached when a volume of 17.15 mL of barium hydroxide was added. **4**

Calculate the concentration of barium hydroxide (in mol L^{-1}), and give a relevant chemical equation.

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Question 25 (5 marks)

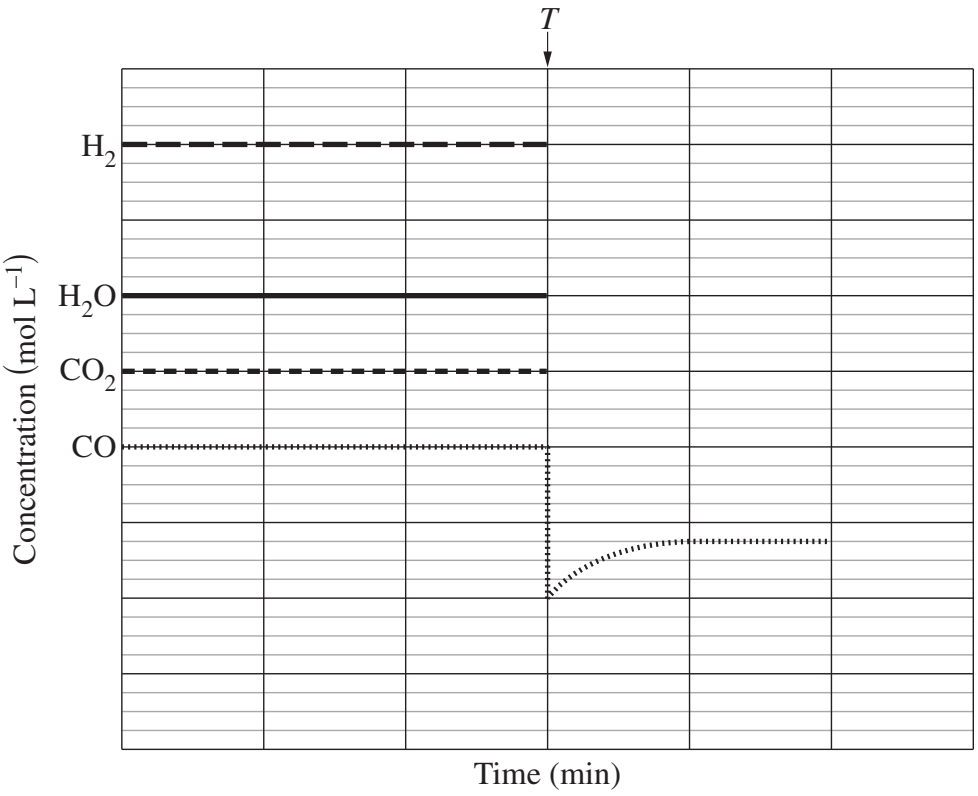
The concentrations of reactants and products as a function of time for the following system were determined.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

At time *T*, some CO(*g*) was removed from the system.

(a) The concentration of CO after time *T* is shown. **2**

Sketch the concentrations after time *T* for the remaining species.



(b) Using collision theory, explain the change in the concentration of CO after time *T*. **3**

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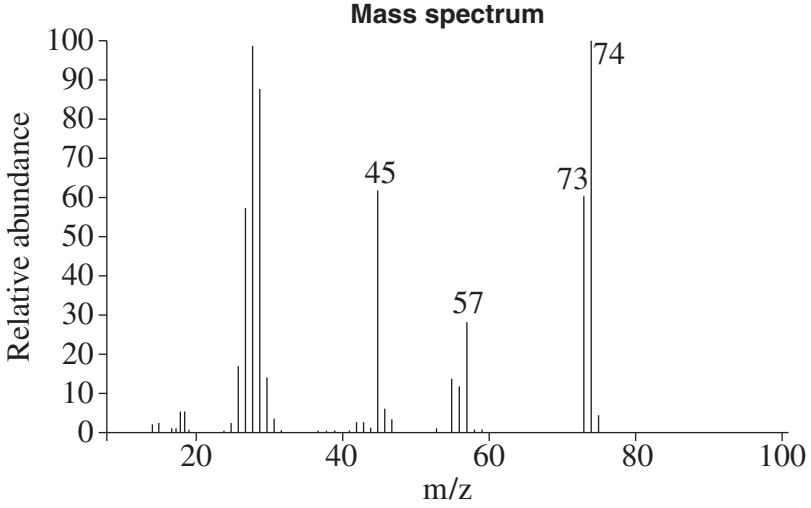
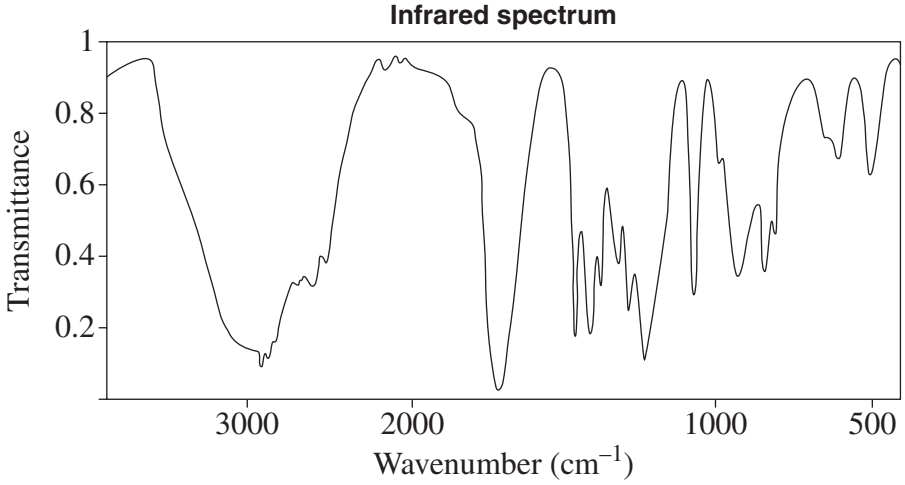
Question 26 (8 marks)

The following data were obtained for an organic compound containing carbon, hydrogen and oxygen. The compound is a colourless liquid that reacts with sodium carbonate powder to produce bubbles.

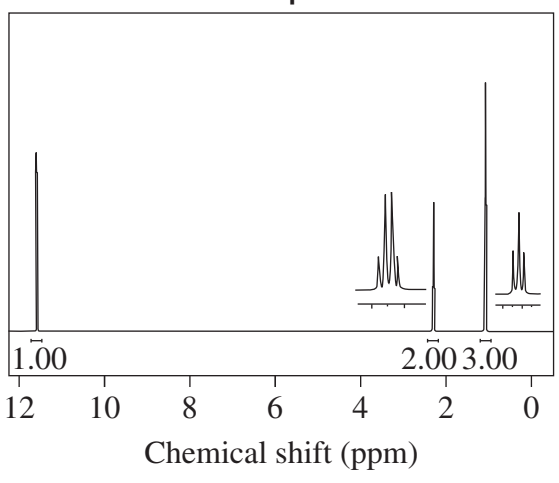
Mass spectrum



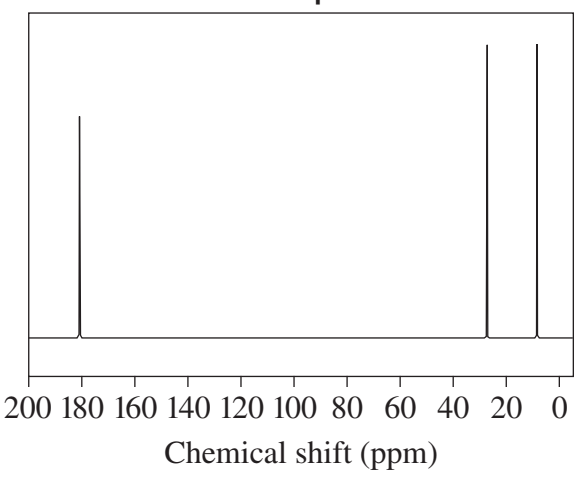
Infrared spectrum



^{1}H NMR spectrum



^{13}C NMR spectrum



Question 26 continues on page 21

Question 26 (continued)

(a) What is the structural formula of this compound? Justify your answer with reference to the information given on its reactivity and to at least THREE of the provided spectra. **5**

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(b) Explain why a chemist should use more than one spectroscopic technique to identify an organic compound. Use TWO spectroscopic techniques to support your answer. **3**

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End of Question 26

Question 27 (5 marks)

The relationship between the acid dissociation constant, K_a, and the corresponding conjugate base dissociation constant, K_b, is given by:

$$K_a \times K_b = K_w$$

Assume that the temperature for part (a) and part (b) is 25°C.

(a) The K_a of hypochlorous acid (HOCl) is 3.0×10^{-8}. **1**

Show that the K_b of the hypochlorite ion, OCl^-, is 3.3×10^{-7}.

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(b) The conjugate base dissociation constant, K_b, is the equilibrium constant for the following equation: **4**

$$OCl^-(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + OH^-(aq)$$

Calculate the pH of a 0.20 mol L^{-1} solution of sodium hypochlorite (NaOCl).

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Question 28 (5 marks)

Assess the usefulness of the Brønsted–Lowry model in classifying acids and bases. Support your answer with at least TWO chemical equations. **5**

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Please turn over

Question 29 (11 marks)

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

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

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

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(c) The data below were obtained after treatment of the stormwater. **7**

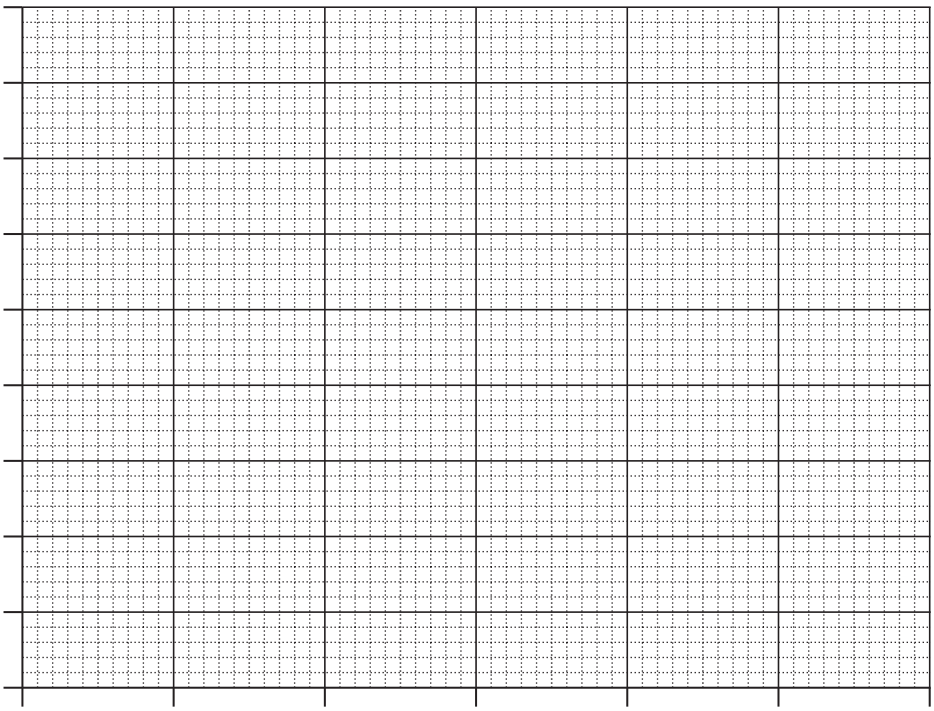
Data from atomic absorption spectroscopy

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

Question 29 continues on page 25

Question 29 (continued)

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



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End of Question 29

Question 30 (3 marks)

The following data apply to magnesium fluoride and magnesium chloride dissolving in water at 298 K. **3**

	Magnesium fluoride	*Magnesium chloride*
$\Delta_{sol}H^{\ominus}$ (kJ mol^{-1})	−7.81	−160
$\Delta_{sol}S^{\ominus}$ (J K^{-1} mol^{-1})	−223	−115
$T\Delta_{sol}S^{\ominus}$ (kJ mol^{-1})	−66.4	−34.2
$\Delta_{sol}G^{\ominus}$ (kJ mol^{-1})	+58.6	−125

Compare the effects of enthalpy and entropy on the solubility of these salts.

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Question 31 (4 marks)

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

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

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

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

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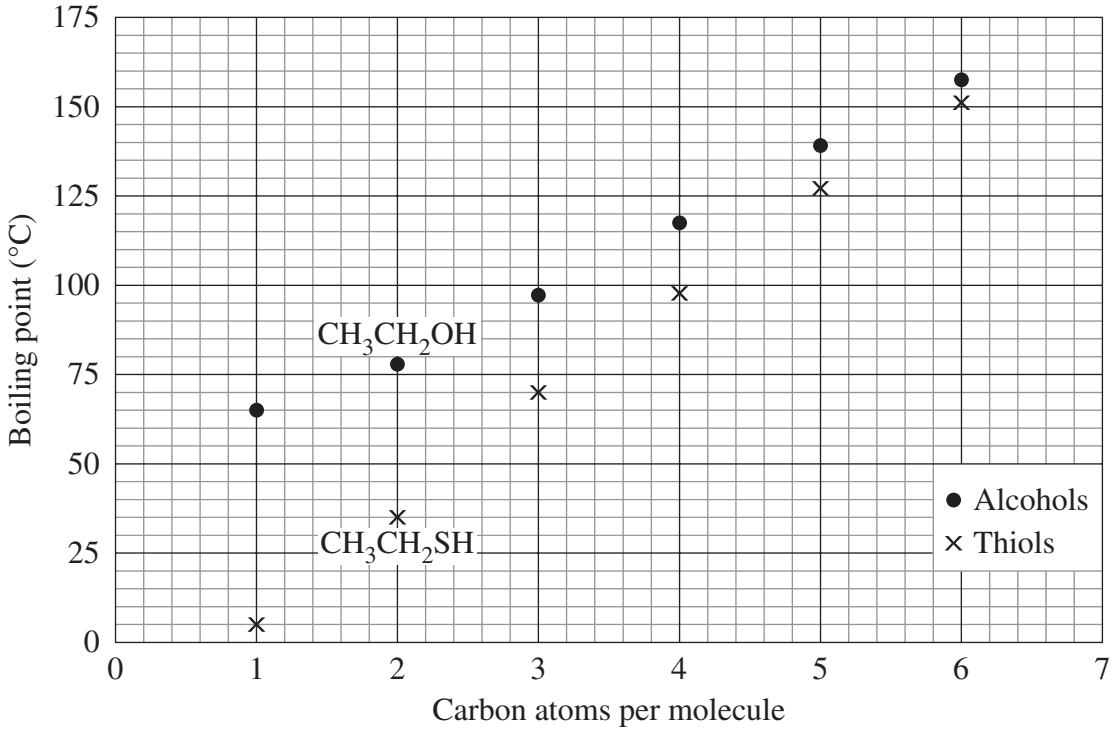
Question 32 (4 marks)

Thiols are the sulfur analogues of alcohols in that the oxygen atom of the alcohol is replaced by a sulfur atom. For example, methanethiol (CH_3SH) is the analogue of methanol (CH_3OH). The boiling points of some straight chain alcohols and thiols are given in the following graph. **4**



Explain the patterns of the boiling points shown in the graph.

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Question 33 (4 marks)

A student adds 1.17 g of $Al(OH)_3(s)$ to 0.500 L of 0.100 mol L^{-1} $HCl(aq)$. **4**

Calculate the pH of the resulting solution. Assume that the volume of the resulting solution is 0.500 L.

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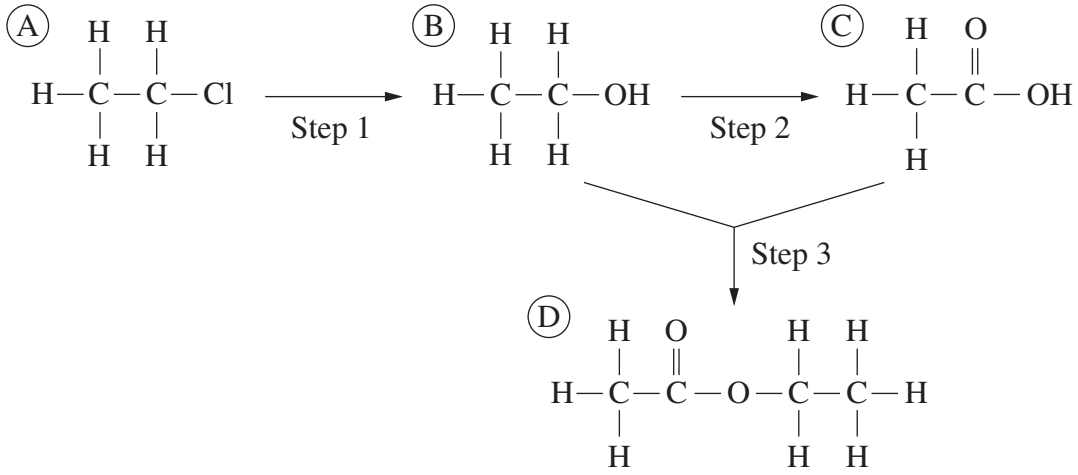
Please turn over

Question 34 (7 marks)

The following reaction scheme can be used to synthesise ethyl ethanoate. **7**



Outline the reagents and conditions required for each step and how the product of each step could be identified.

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Chemistry

FORMULAE SHEET

$$n = \frac{m}{MM} \qquad c = \frac{n}{V} \qquad PV = nRT$$

$$q = mc\Delta T \qquad \Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \qquad \text{pH} = -\log_{10}[\text{H}^+]$$

$$pK_a = -\log_{10}[K_a] \qquad A = \varepsilon lc = \log_{10}\frac{I_o}{I}$$

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

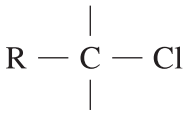
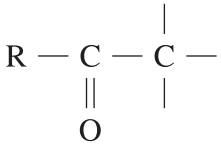
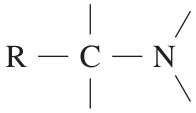
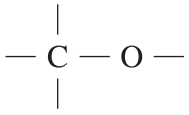
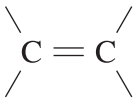
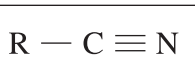
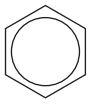
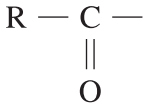
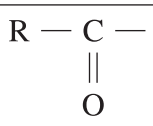
Compound	K_{sp}
Barium carbonate	2.58×10^{-9}
Barium hydroxide	2.55×10^{-4}
Barium phosphate	1.3×10^{-29}
Barium sulfate	1.08×10^{-10}
Calcium carbonate	3.36×10^{-9}
Calcium hydroxide	5.02×10^{-6}
Calcium phosphate	2.07×10^{-29}
Calcium sulfate	4.93×10^{-5}
Copper(II) carbonate	1.4×10^{-10}
Copper(II) 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}

Compound	K_{sp}
Lead(II) bromide	6.60×10^{-6}
Lead(II) chloride	1.70×10^{-5}
Lead(II) iodide	9.8×10^{-9}
Lead(II) carbonate	7.40×10^{-14}
Lead(II) hydroxide	1.43×10^{-15}
Lead(II) phosphate	8.0×10^{-43}
Lead(II) sulfate	2.53×10^{-8}
Magnesium carbonate	6.82×10^{-6}
Magnesium hydroxide	5.61×10^{-12}
Magnesium phosphate	1.04×10^{-24}
Silver bromide	5.35×10^{-13}
Silver chloride	1.77×10^{-10}
Silver carbonate	8.46×10^{-12}
Silver hydroxide	2.0×10^{-8}
Silver iodide	8.52×10^{-17}
Silver phosphate	8.89×10^{-17}
Silver sulfate	1.20×10^{-5}

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
		5–40
		10–70
		20–50
		25–60
	alcohols, ethers or esters	50–90
		90–150
		110–125
		110–160
	esters or acids	160–185
	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.