NSW Education Standards Authority

2018 **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 data sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 75 marks (pages 2–24)

This section has two parts, Part A and Part B

Part A – 20 marks

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

Part B – 55 marks

- Attempt Questions 21–30
- Allow about 1 hour and 40 minutes for this part

Section II – 25 marks (pages 25–32)

- Attempt ONE question from Questions 31–35
- Allow about 45 minutes for this section

Section I
75 marks

Part A – 20 marks
Attempt Questions 1–20
Allow about 35 minutes for this part

Use the multiple-choice answer sheet for Questions 1–20.

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1 Which of the following is an industrial use of ammonia?

A. As a catalyst in the Haber process

B. As a reagent in the production of fertilisers

C. As a catalyst in the manufacture of explosives

D. As a reagent in the treatment of drinking water

2 Which row of the table correctly matches the chemical additive with its main function in a water treatment plant?

	Additive	*Function*
A.	Chlorine	Kills microorganisms
B.	Fluoride	Reduces turbidity
C.	Fe^{3+}	Minimises tooth decay
D.	HCl	Increases the pH of the water

3 An esterification reaction is to be performed.

Which of the following substances, when added, would increase the yield of the product?

A. Water

B. Boiling chips

C. More alkanol

D. Dilute sulfuric acid

4 Which of the following greatly enhanced scientific understanding of the effects of trace elements?

A. Improved filtration techniques

B. The development of atomic absorption spectroscopy

C. The creation of new elements in particle accelerators

D. The work of Le Chatelier in describing chemical equilibrium

5 Cellulose extracted from biomass is able to be used as a raw material in the manufacture of polymers because it

A. is a condensation polymer.

B. is a strong flexible molecule.

C. produces carbon dioxide when burnt.

D. contains a basic carbon-chain structure.

6 Sodium hydrogen carbonate is often used to clean up large spills of acids and alkalis.

Why is it a suitable chemical for this application?

A. It is diprotic and is readily neutralised.

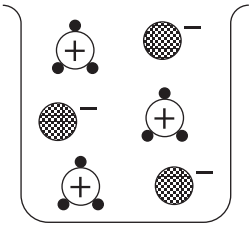
B. It is amphiprotic, stable and easily handled.

C. It is diprotic and easily cleaned up when neutralised.

D. It is amphiprotic and only small quantities are required.

7 Which diagram represents ionisation of a weak acid?

A.



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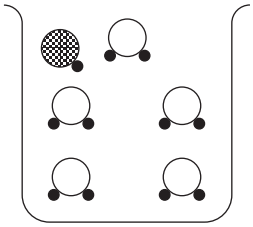

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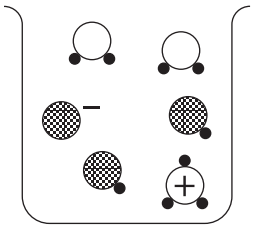

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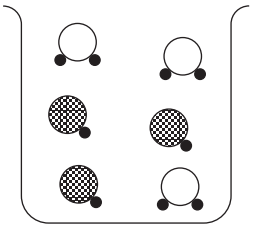


KEY

8 Which row of the table correctly identifies a major source of an acidic oxide in the atmosphere and the chemical equation for the formation of the oxide?

	Source	*Equation*
A.	Volcanoes	$N_2(g) + O_2(g) \longrightarrow 2NO(g)$
B.	Mineral smelting	$2ZnS(s) + 3O_2(g) \longrightarrow 2ZnO(s) + 2SO_2(g)$
C.	Lightning	$4NO(g) + 3O_2(g) + 2H_2O(g) \longrightarrow 4HNO_3(aq)$
D.	Incomplete combustion of fuels	$2C_8H_{18}(l) + 17O_2(g) \longrightarrow 16CO(g) + 18H_2O(g)$

9 Which of the following would NOT have been classified as an acid by Antoine Lavoisier in 1780?

A. Acetic acid

B. Citric acid

C. Sulfuric acid

D. Hydrochloric acid

10 Which row of the table correctly matches the reaction type with the reactant(s), catalyst and product(s)?

	Reaction type	*Reactant(s)*	*Catalyst*	*Product(s)*
A.	Hydration	$C_2H_4 + H_2O$	Dilute acid	C_2H_6
B.	Hydration	C_2H_4	Concentrated acid	C_2H_5OH
C.	Dehydration	C_2H_5OH	Dilute acid	C_2H_4
D.	Dehydration	C_2H_5OH	Concentrated acid	$C_2H_4 + H_2O$

11 Which row of the table correctly matches the polymer with its structural feature and property?

	Polymer	*Structural feature*	*Property*
A.	Polyvinyl chloride	Chlorine side group	Rigid
B.	Low density polyethylene	Tightly packed molecules	Opaque
C.	High density polyethylene	Branched chains	Transparent
D.	Polystyrene	Large side chains	Flexible

12 A silver spoon becomes tarnished over time according to the following reaction.

$$4Ag(s) + O_2(g) + 2H_2S(g) \rightarrow 2Ag_2S(s) + 2H_2O(l)$$

Which row of the table correctly describes this process?

	Type of reaction of silver	*Change in oxidation state*
A.	Oxidation	From 0 to +1
B.	Oxidation	From 0 to +2
C.	Reduction	From +2 to +1
D.	Reduction	From +4 to +2

13 Pentanol, propyl acetate, pentanoic acid and ethyl propanoate all contain five carbon atoms. These four compounds are mixed in a flask and then separated by fractional distillation.

Which compound would be most likely to remain in the flask?

A. Pentanol

B. Propyl acetate

C. Pentanoic acid

D. Ethyl propanoate

14 How many isomers are there of C_3H_6ClF?

A. 3

B. 4

C. 5

D. 6

15 A solution containing potassium dihydrogen phosphate and potassium hydrogen phosphate is a common laboratory buffer with a pH close to 7.

Which row of the table correctly identifies the chemistry of this buffer?

	Buffer equation	*Equilibrium shift*	
		Acid is added to the solution	*Alkali is added to the solution*
A.	$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$	Right	Left
B.	$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$	Left	Right
C.	$H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$	Right	Left
D.	$H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$	Left	Right

16 An investigation was carried out to determine the calcium ion concentration of a 2.0 L sample of tap water. Excess Na_2CO_3 was added to the sample. The precipitate was filtered, dried and weighed. The mass of the dried precipitate was 400 mg.

What was the concentration of calcium ions in the sample of tap water?

A. 80 mg L^{-1}

B. 160 mg L^{-1}

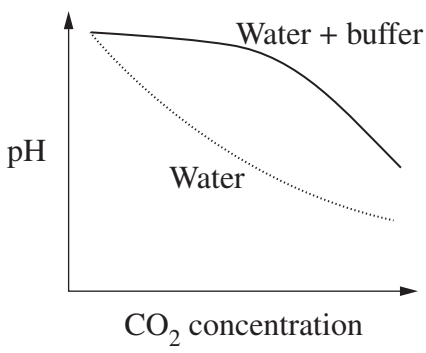
C. 200 mg L^{-1}

D. 400 mg L^{-1}

17 Increasing amounts of carbon dioxide were dissolved in two beakers, one containing water and one a mixture of water and a buffer. The pH in each beaker was measured and the results graphed.

Which graph best represents the results?

A.



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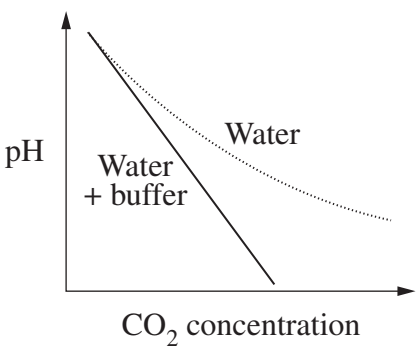

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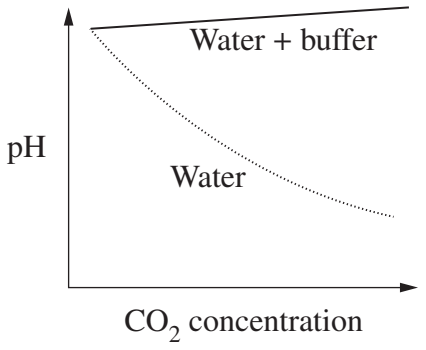

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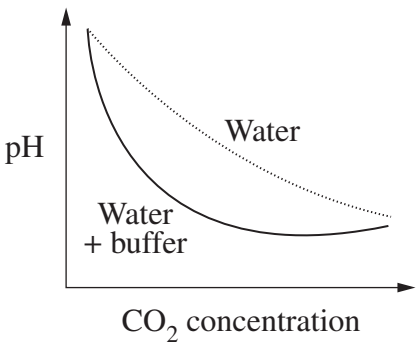


18 The pH of a 0.080 mol L^{-1} solution of acetic acid is 2.9.

What percentage of the acetic acid has dissociated into ions?

A. 1.1%

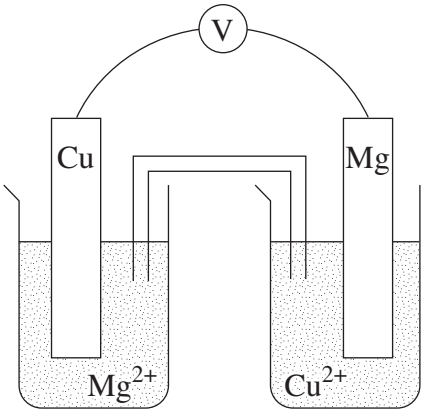
B. 1.3%

C. 1.6%

D. 2.8%

19 Which of the following standard galvanic cells will show the HIGHEST reading on the voltmeter?

A.



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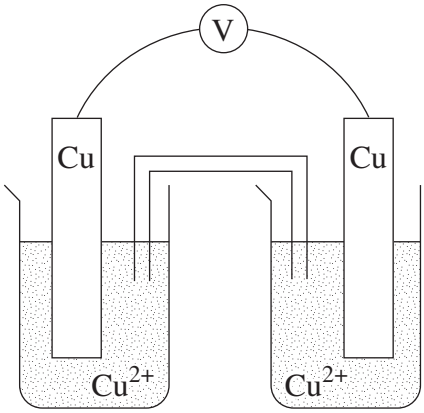

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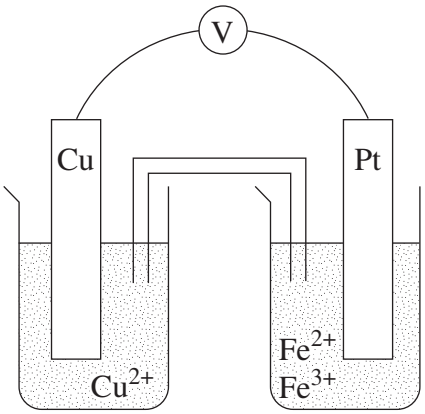

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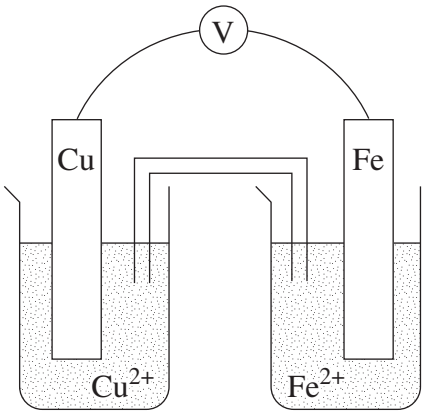

20 The Winkler method is used to determine the amount of dissolved oxygen in a water sample. The procedure involves the following sequence of reactions.

Step 1. $2Mn^{2+}(aq) + O_2(g) + 4OH^-(aq) \longrightarrow 2MnO(OH)_2(s)$

Step 2. $MnO(OH)_2(s) + 2I^-(aq) + 4H^+(aq) \longrightarrow I_2(aq) + Mn^{2+}(aq) + 3H_2O(aq)$

Step 3. $I_2(aq) + 2S_2O_3{}^{2-}(aq) \longrightarrow 2I^-(aq) + S_4O_6{}^{2-}(aq)$

When a 5.00 L sample of water was analysed using the Winkler method, a total of 4.00×10^{-3} mol of thiosulfate $\left(S_2O_3{}^{2-}\right)$ was required in Step 3.

What concentration of oxygen was present in the original sample?

A. 3.20 mg L^{-1}

B. 6.40 mg L^{-1}

C. 12.8 mg L^{-1}

D. 32.0 mg L^{-1}

2018 HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Student Number

Chemistry

Section I Part B
Answer Booklet

55 marks
Attempt Questions 21–30
Allow about 1 hour and 40 minutes for this part

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

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Question 21 (3 marks)

Ethylene can be readily transformed into many useful products.

(a) What is the name of the industrial process by which ethylene is obtained from long chain alkanes? **1**

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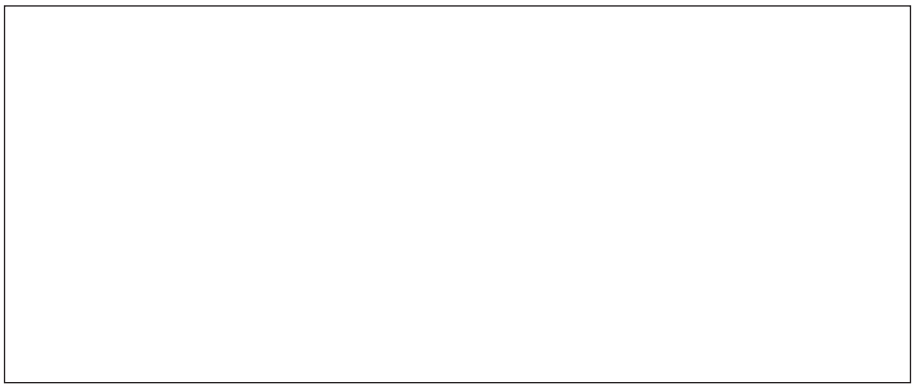
(b) Ethylene can be converted into vinyl chloride. **2**

Draw structural formulae for vinyl chloride and its polymer, polyvinyl chloride.

Vinyl chloride



Polyvinyl chloride

Question 22 (4 marks)

A bottle of solution is missing its label. It is either $Pb(NO_3)_2$, $Ba(NO_3)_2$ or $Fe(NO_3)_2$. **4**

Using only HCl, NaOH and H_2SO_4 solutions, outline a sequence of steps that could be followed to confirm the identity of the solution in the bottle. Include observed results and ionic equations in your answer.

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Question 23 (6 marks)

A student makes an ester in the school laboratory using methanol and butanoic acid.

(a) Using structural formulae, write an equation for this reaction. **2**

(b) Explain the conditions needed to efficiently and safely carry out this reaction in the school laboratory. **4**

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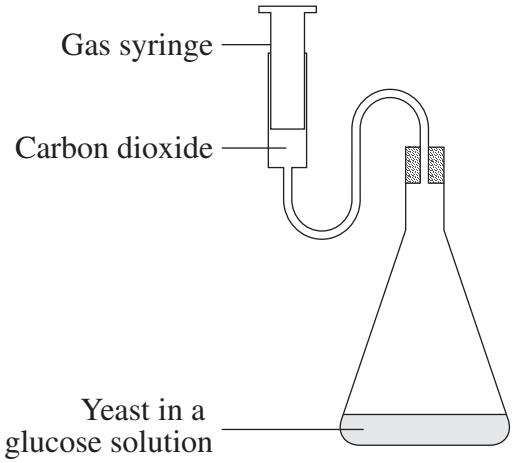
Question 24 (4 marks)

The following apparatus was set up to test the reaction rate of fermentation of glucose at different temperatures.



(a) Write a balanced equation for the fermentation of glucose. **1**

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(b) After 24 hours, 5.5 mL of gas was collected at 25°C and 100 kPa. **3**

Calculate the mass of glucose that would have been reacted.

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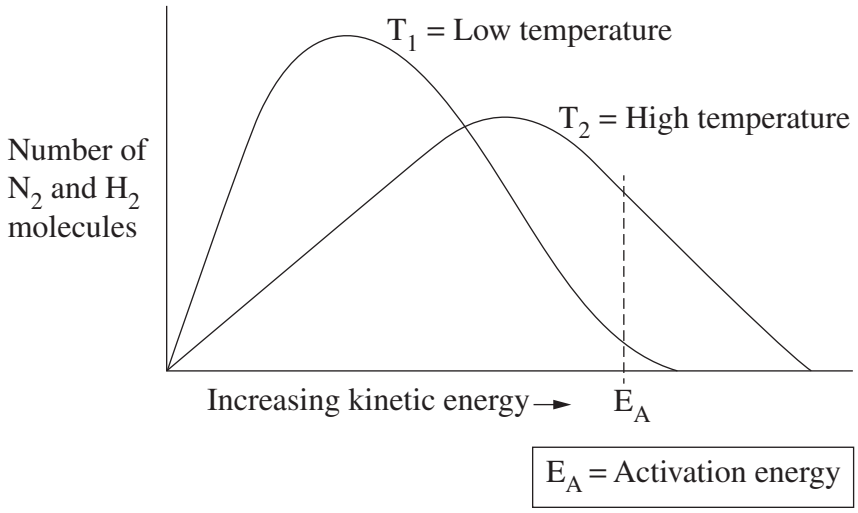
Question 25 (4 marks)

The graph shows the number of molecules of N_2 and H_2 that possess a certain kinetic energy at two different temperatures. **4**



With reference to the graph, explain why changing the temperature and adding a catalyst would change the rate of production of ammonia.

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Question 26 (7 marks)

(a) Outline ONE method that is used to detect radiation to ensure the safety of workers that use radioisotopes. **2**

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(b) Analyse the impact on society of the use of ONE named radioisotope, with reference to its properties. **5**

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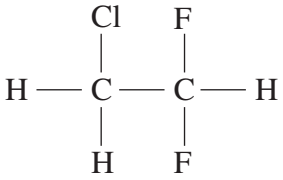
Question 27 (5 marks)

(a) Identify the systematic name of the compound shown. **1**



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(b) Assess the suitability of the compound shown in part (a) as a replacement for chlorofluorocarbons (CFCs) in aerosols. **4**

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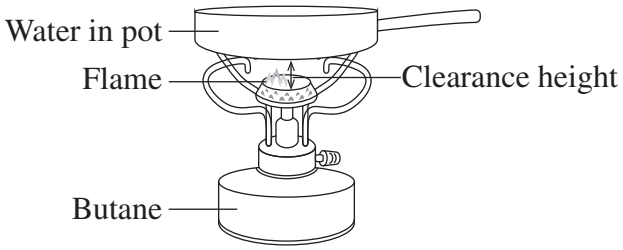
Question 28 (8 marks)

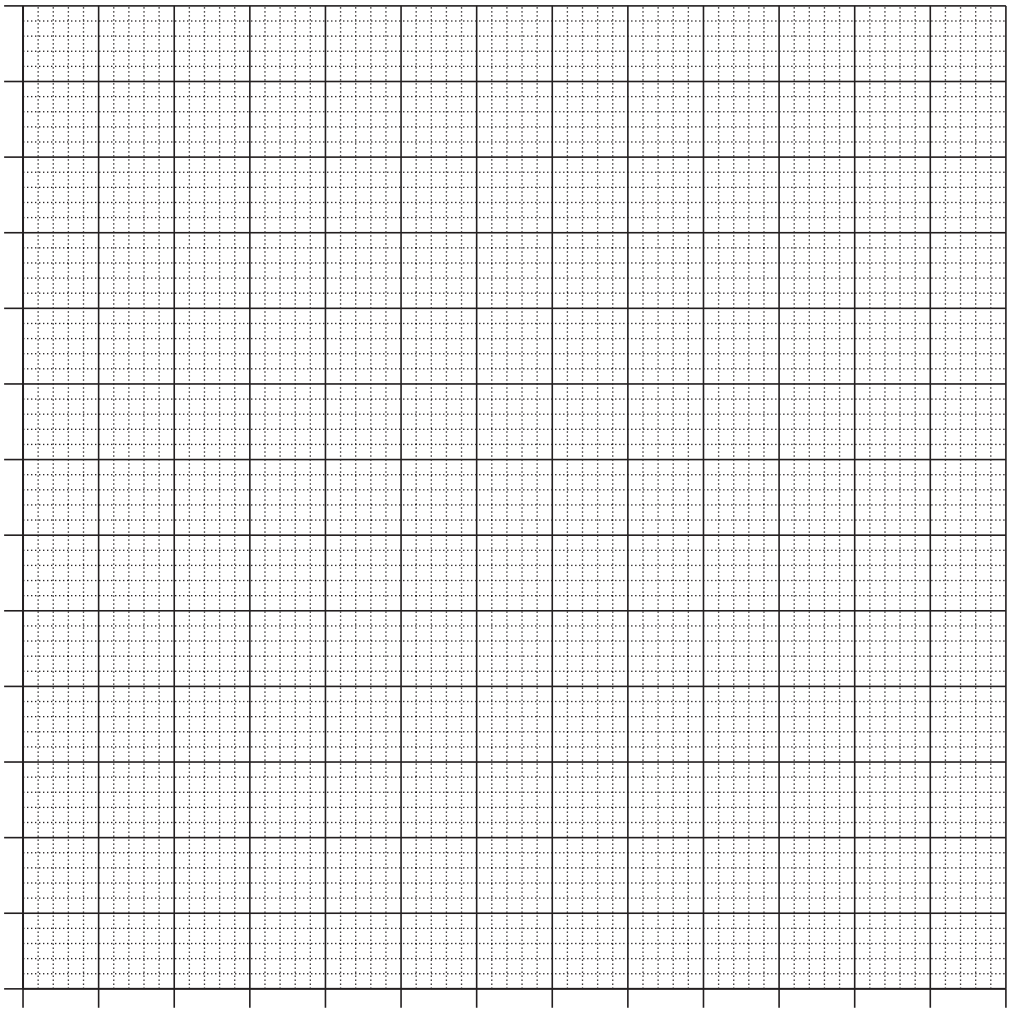
A camp stove using butane as a fuel was used to heat a pot of water inside a small tent. Poisonous carbon monoxide (CO) gas can be released from these stoves.



An investigation was carried out to determine the carbon monoxide concentration in the tent when the clearance height of the pot above the flame was altered. The results are shown in the table.

Clearance height (mm)	35	40	45	50
CO concentration (ppm)	120	87	50	18

(a) Construct a graph of the data on the grid. **3**



Question 28 continues on page 19

Question 28 (continued)

(b) Air containing a CO concentration above 30 ppm is considered unsafe to breathe. **1**

What is the minimum clearance height at which the pot should be placed?

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(c) Increasing the clearance height decreases the efficiency of the stove according to the following table. **4**

Clearance height (mm)	35	40	45	50
Efficiency (%)	90	70	50	30

A bushwalker only has 15.0 g of butane with which to heat 1.0 L of water with a starting temperature of 20°C.

Calculate the highest temperature of the water that could safely be achieved in the tent. (Molar heat of combustion of butane: $\Delta H_c = 2877$ kJ mol^{-1})

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End of Question 28

Question 29 (7 marks)

The concentration of hydrochloric acid in a solution was determined by an acid base titration using a standard solution of sodium carbonate.

(a) Explain why sodium carbonate is a suitable compound for preparation of a standard solution. **2**

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(b) A 25.00 mL sample of 0.1050 mol L^{-1} sodium carbonate solution was added to a conical flask and three drops of methyl orange indicator added. The mixture was titrated with the hydrochloric acid and the following readings were recorded. **3**

Initial burette reading (mL)	*Final burette reading* (mL)	*Titre* (mL)
0.00	22.00	22.00
22.00	43.65	21.65
0.00	21.70	21.70
21.70	43.30	21.60

Using the data from the table, calculate the concentration of the hydrochloric acid.

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Question 29 continues on page 21

Question 29 (continued)

(c) Explain the effect on the calculated concentration of hydrochloric acid if phenolphthalein is used as the indicator instead of methyl orange. **2**

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End of Question 29

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Question 30 (7 marks)

Over the last 50 years, scientists have recorded increases in the following: **7**

- the amount of fossil fuels burnt
- atmospheric carbon dioxide levels
- average global air temperature and ocean temperature
- the volume of carbon dioxide dissolved in the oceans.

Analyse the factors that affect the equilibrium between carbon dioxide in the air and carbon dioxide in the oceans. In your answer, make reference to the scientists' observations and include relevant equations.

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Question 30 continues on page 23

Question 30 (continued)

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End of Question 30

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Section I Part B extra writing space

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

Chemistry

Section II

25 marks
Attempt ONE question from Questions 31–35
Allow about 45 minutes for this section

Answer parts (a)–(d) of one question in the Section II Writing Booklet. Extra writing booklets are available.

Show all relevant working in questions involving calculations.

Question 31 — Industrial Chemistry (25 marks)

Answer parts (a) and (b) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) Use a labelled diagram to show the structure of a soap molecule. **2**

(ii) Explain how soap acts as a cleaning agent. **3**

(b) Sulfuric acid is an important industrial chemical.

(i) Relate a property of sulfuric acid to a condition necessary for its safe transport and storage. **2**

(ii) Two first-hand investigations are carried out. One demonstrates the use of sulfuric acid as an oxidising agent and the other demonstrates the use of sulfuric acid as a dehydrating agent. **4**

Explain the observations that could be made in these investigations. Include relevant equations in your answer.

Answer parts (c) and (d) of the question on pages 5–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(c) (i) Consider the following equilibrium reaction, which is endothermic. **3**

$$[Co(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CoCl_4]^{2-} + 6H_2O(l)$$

Pink solution *Blue solution*

Justify TWO conditions that could change the colour of the solution from pink to blue.

(ii) 0.20 moles of hydrogen gas and 0.20 moles of iodine gas were placed in a 1.0 L container and allowed to come to equilibrium. **4**

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

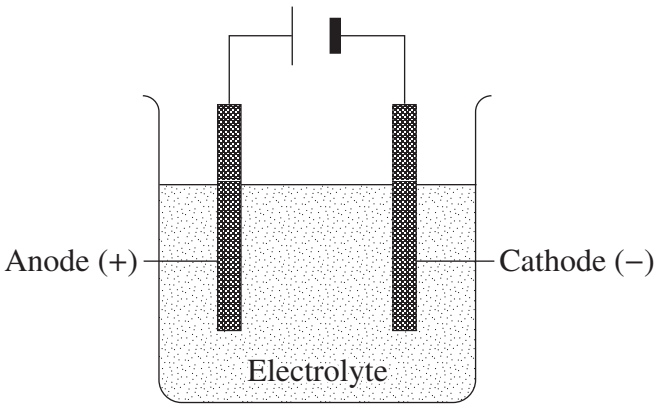
Determine the equilibrium concentration of HI for this reaction, given that the equilibrium constant, K, is 64.

(d) Explain how the environmental issues associated with the industrial production of sodium hydroxide and sodium carbonate can be addressed. Include chemical equations in your answer. **7**

Question 32 — Shipwrecks, Corrosion and Conservation (25 marks)

Answer parts (a) and (b) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) The diagram shows an electrolytic cell.



(i) The equipment shown is being used to investigate the effect of changing the concentration of the electrolyte on the rate of reaction in electrolysis. **2**

Identify THREE variables that should be kept constant.

(ii) Calculate the minimum voltage to drive this cell if the electrolyte is 1.0 mol L^{-1} sodium bromide, assuming the electrodes are inert. **3**

(b) A first-hand investigation is to be carried out to compare the rates of corrosion of iron and a form of steel.

(i) Outline a suitable procedure for this investigation. **2**

(ii) Explain the process of rusting. Include relevant half equations in your answer. **4**

Question 32 continues on page 28

Question 32 (continued)

Answer parts (c) and (d) of the question on pages 5–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(c) In 1912, the ship *Titanic* sank in water over 3 km deep. The wreck was discovered in 1985. It was badly corroded and covered in rusticles. On analysis, the rusticles were found to be composed of iron(II) sulfide, iron(II) hydroxide and other related compounds. Silver coins were also found on the shipwreck and were covered in silver sulfide.

(i) Explain how the rusticles were formed. Include relevant half equations in your answer. **3**

(ii) Compare TWO methods for restoring the silver coins. Refer to the underlying chemistry in your answer. **4**

(d) Explain how advances in chemistry have led to improvements in the protection of steel ships from corrosion in marine environments. Include a relevant equation in your answer. **7**

End of Question 32

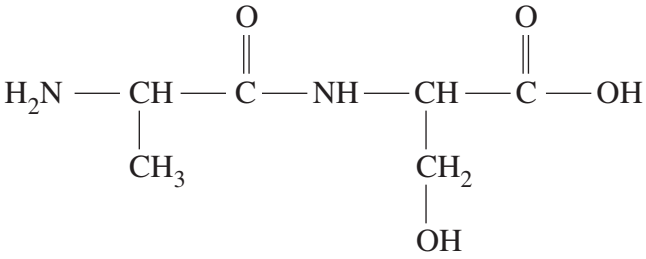
Question 33 — The Biochemistry of Movement (25 marks)

Answer parts (a) and (b) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) Identify TWO main stages of cellular respiration and the location in the cell where each occurs. **2**

(ii) Describe the first stage of cellular respiration. **3**

(b) The structure of a dipeptide is shown.



(i) Draw the structural formulae of the TWO amino acids from which this dipeptide was made. **2**

(ii) Explain how both forces and bonding are responsible for the tertiary structure of a protein. **4**

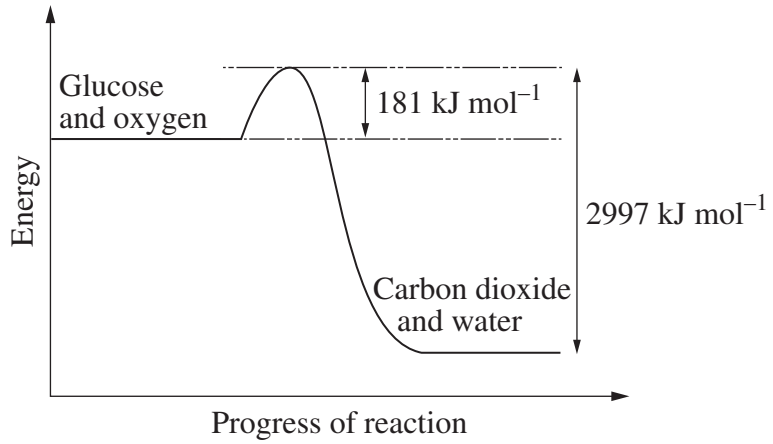
Question 33 continues on page 30

Question 33 (continued)

Answer parts (c) and (d) of the question on pages 5–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(c) (i) Describe how glucose monomers combine to form a branched glycogen polymer. **3**

(ii) The energy profile in the graph shows the combustion of glucose during cellular respiration. **4**



At 25°C and 100 kPa, a running animal consumes a maximum of 3.5 L of oxygen per minute. For a 5-minute run the animal has adequate glucose available from the blood, some of which is mobilised from glycogen stores.

The animal needs 300 kJ of energy to maintain the run aerobically for 5 minutes.

Calculate whether the animal has an adequate supply of oxygen for the run, using data from the energy profile. Support your answer with an equation for cellular respiration.

(d) Explain how the structure of muscle cells relates to the function it performs in both gentle exercise and in sprints. **7**

End of Question 33

Question 34 — The Chemistry of Art (25 marks)

Answer parts (a) and (b) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) The electron configuration of an atom may be represented by using arrows to indicate electrons and boxes to indicate orbitals. For example, the electron configuration of boron would be represented as shown. **2**

Draw a similar representation for the electron configuration of sodium.

(ii) Explain why some sub-shells in the fourth shell of an atom are filled before the third shell is complete. **3**

(b) A first-hand investigation was carried out to demonstrate the oxidising strength of potassium permanganate.

(i) Outline a procedure to determine the oxidising strength of potassium permanganate. **2**

(ii) Justify ONE conclusion about the oxidising strength of potassium permanganate using observed results from the procedure. Include half equations in your answer. **4**

Answer parts (c) and (d) of the question on pages 5–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(c) (i) How do an absorption spectrum and an emission spectrum differ? **3**

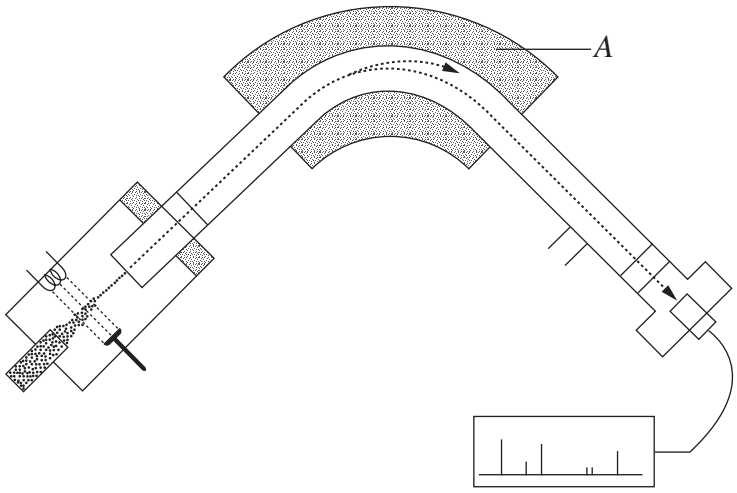
(ii) Explain how both infrared light and ultraviolet light are used to determine the chemical composition and concentration of pigments. **4**

(d) Explain the procedures used by Aboriginal people and an ancient culture to prepare and attach pigments to surfaces. Include the chemical composition of specific pigments in your answer. **7**

Question 35 — Forensic Chemistry (25 marks)

Answer parts (a) and (b) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) The diagram is a schematic representation of a mass spectrometer.



(i) Name and outline the function of the part labelled *A* in the diagram. **2**

(ii) Outline the advantages of using mass spectrometry for analysis of a compound. **3**

(b) (i) A first-hand investigation was carried out to distinguish between reducing and non-reducing sugars. **2**

Outline a chemical test to distinguish between a reducing sugar and a non-reducing sugar.

(ii) Explain the observed results in part (i) with reference to the structural differences between reducing sugars and non-reducing sugars. Include a relevant chemical equation in your answer. **4**

Answer parts (c) and (d) of the question on pages 5–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(c) (i) How can differences in the structure of DNA molecules between individuals be used in forensic investigations? **3**

(ii) Explain how DNA fragments can be separated by electrophoresis to produce a DNA profile that connects an individual to an evidence sample. **4**

(d) Compare emission spectroscopy and chromatography in the analysis of small samples in forensic investigations. **7**

End of paper

Chemistry

DATA SHEET

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

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}

Some useful formulae

$$\text{pH} = -\log_{10}[\text{H}^+] \qquad \Delta H = -mC\Delta T$$

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 this examination paper. 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.