BOARD OF STUDIES
NEW SOUTH WALES

2003

HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- A data sheet and a Periodic Table are provided at the back of this paper
- Write your Centre Number and Student Number at the top of pages 13, 17, 21 and 25

Total marks – 100

Section I Pages 2–28

75 marks

This section has two parts, Part A and Part B

Part A – 15 marks

- Attempt Questions 1–15
- Allow about 30 minutes for this part

Part B – 60 marks

- Attempt Questions 16–29
- Allow about 1 hour and 45 minutes for this part

Section II Pages 29–37

25 marks

- Attempt ONE question from Questions 30–34
- Allow about 45 minutes for this section

Section I
75 marks

Part A – 15 marks
Attempt Questions 1–15
Allow about 30 minutes for this part

Use the multiple-choice answer sheet.

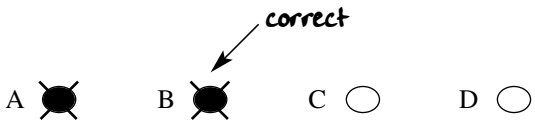
Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.



1 Which of the following is an acid–base indicator?

(A) Methanol

(B) Methyl orange

(C) Methanoic acid

(D) Methyl ethanoate

2 Which of the following is a transuranic element?

(A) Caesium

(B) Cerium

(C) Chromium

(D) Curium

3 Which instrument is used to detect radiation from radioactive isotopes?

(A) pH meter

(B) Geiger counter

(C) Ion-selective electrode

(D) Atomic absorption spectrophotometer (AAS)

4 In which layer of the atmosphere does ozone act as a UV radiation shield?

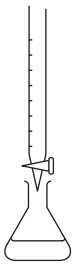
(A) Mesosphere

(B) Stratosphere

(C) Thermosphere

(D) Troposphere

5 Which of the following could be used to determine the total dissolved solids in a sample of muddy river water?



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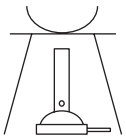
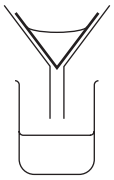


Q

R



S

(A) *P* and *Q*

(B) *R* and *S*

(C) *P* and *R*

(D) *Q* and *S*

6 The table gives the heat of combustion in kJ g^{-1} for a number of different fuels.

Fuel	*Heat of combustion* (kJ g^{-1})
Methanol	22.7
Ethanol	29.6
Propanol	33.6
Petrol (octane)	47.8

The heat of combustion in kJ mol^{-1} for one of the fuels was calculated as 2016 kJ mol^{-1}. What was the fuel?

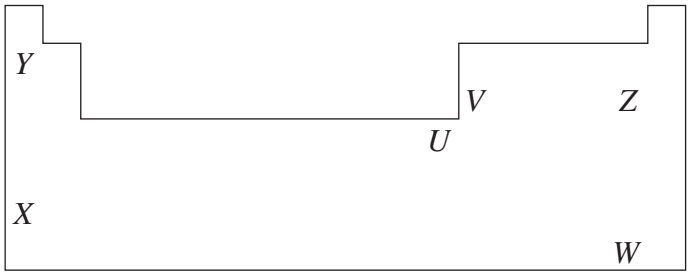
(A) Methanol

(B) Ethanol

(C) Propanol

(D) Petrol

7 The diagram is a representation of the Periodic Table. The positions of six different elements are shown.



What are the reactions of oxides of these elements with acid and with base?

	Oxide reacts with acid	*Oxide reacts with base*	*Oxide reacts with acid and with base*
(A)	*Z*	*X*	*V*
(B)	*Y*	*X*	*U*
(C)	*X*	*Z*	*V*
(D)	*V*	*W*	*Y*

8 A sulfuric acid solution has a concentration of 5×10^{-4} mol L^{-1}.

What is the pH of this solution, assuming the acid is completely ionised?

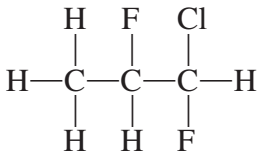
(A) 3.0

(B) 3.3

(C) 3.6

(D) 4.0

9 What is the name of the compound shown?



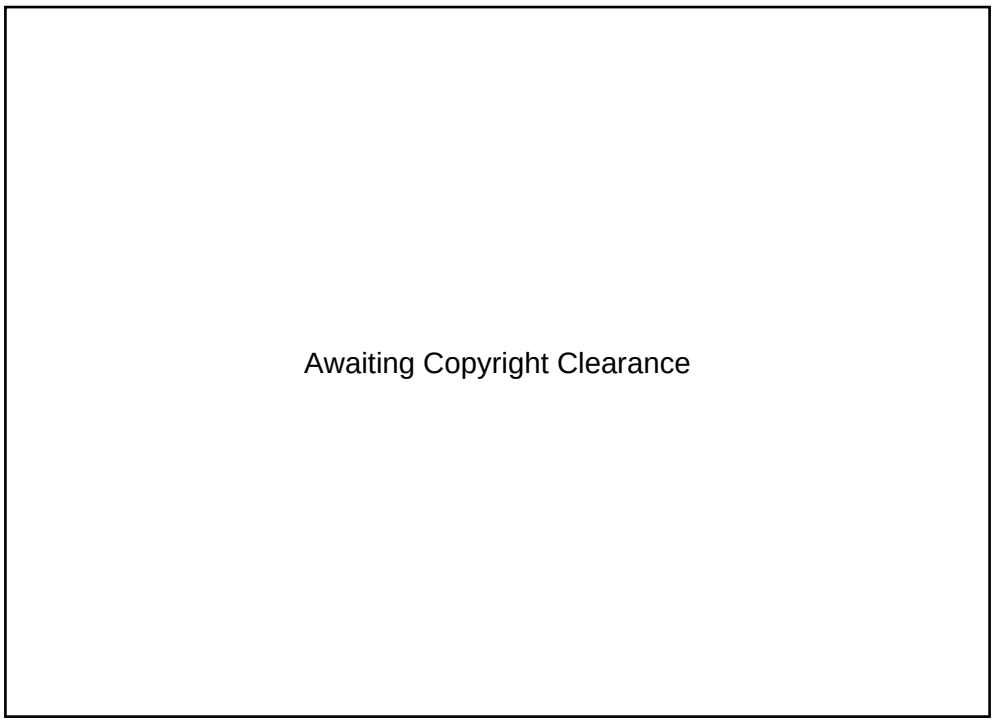
(A) 1-chloro-1,2-difluoropropane

(B) 3-chloro-2,3-difluoropropane

(C) 1,2-difluoro-1-chloropropane

(D) 1-chloro-1,2-difluoropentane

10 The graph shows October ozone concentrations above Halley Bay in Antarctica between 1956 and 1998.



Based on these data alone, which of the following is a valid statement about the concentration of ozone above Halley Bay?

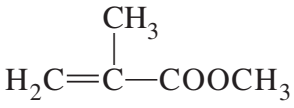
(A) It was greater in 1998 than in 1993.

(B) It will be greater in 2004 than in 1998.

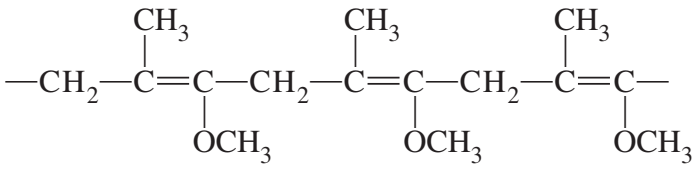
(C) The variation in ozone concentration between 1960 and 1970 was due to changes in atmospheric CFC concentrations.

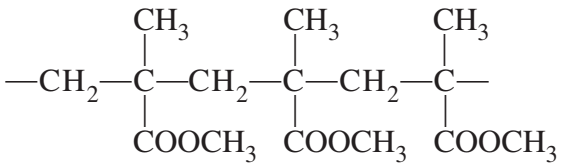
(D) The variation in ozone concentration from one year to the next is due only to changes in atmospheric CFC concentrations.

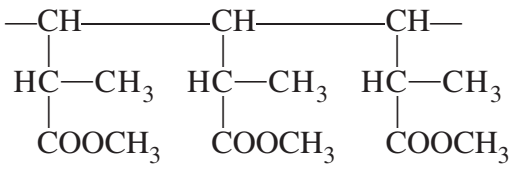
11 Which polymer is made by the polymerisation of methyl methacrylate?

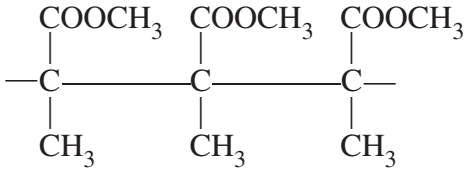


methyl methacrylate

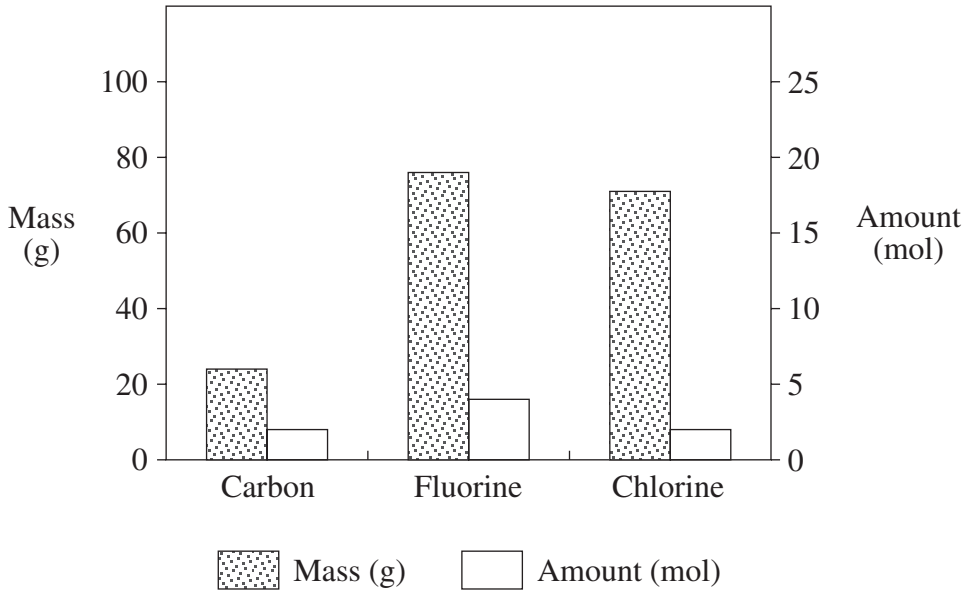
(A) 

(B) 

(C) 

(D) 

12 The graph shows the mass and amount of carbon, fluorine and chlorine atoms in one mole of a compound.



What is the molecular formula for this compound?

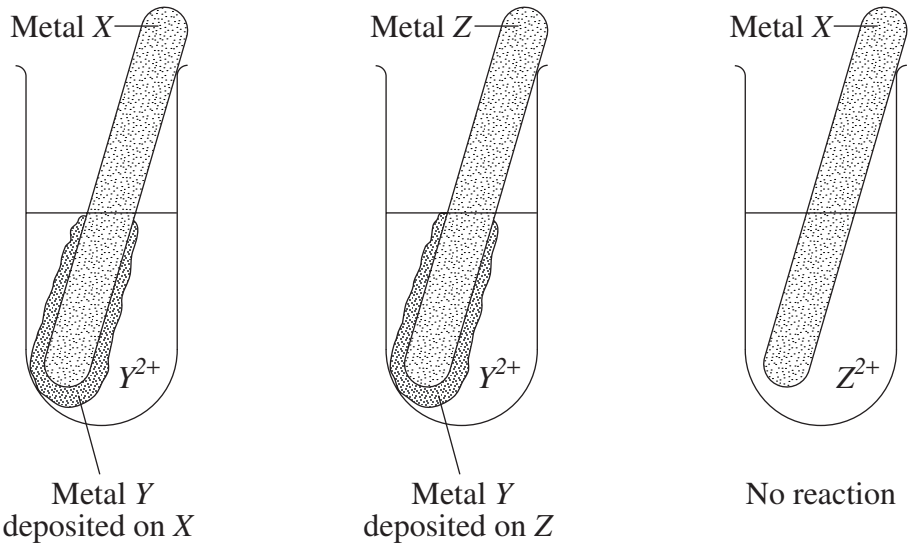
(A) CF_2Cl

(B) CF_2Cl_2

(C) $C_2F_3Cl_3$

(D) $C_2F_4Cl_2$

13 A student performed three tests to investigate the relative activity of metals. In each test a metal strip was placed in a solution containing ions of a different metal. The results are shown in the diagrams.



What is the order of activity of the metals, based on these results?

(A) $X > Z > Y$

(B) $Y > X > Z$

(C) $Z > Y > X$

(D) $Z > X > Y$

14 In a titration of a strong base with a strong acid, the following procedure was used:

1. A burette was rinsed with water and then filled with the standard acid.
2. A pipette was rinsed with some base solution.
3. A conical flask was rinsed with some base solution.
4. A pipette was used to transfer a measured volume of base solution into the conical flask.
5. Indicator was added to the base sample and it was titrated to the endpoint with the acid.

Which statement is correct?

(A) The calculated base concentration will be correct.

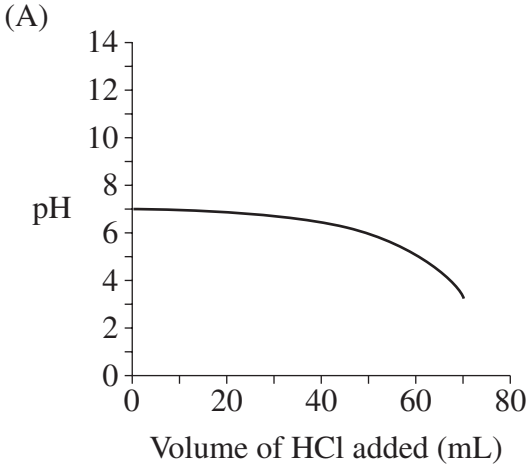
(B) The calculated base concentration will be too low.

(C) The calculated base concentration will be too high.

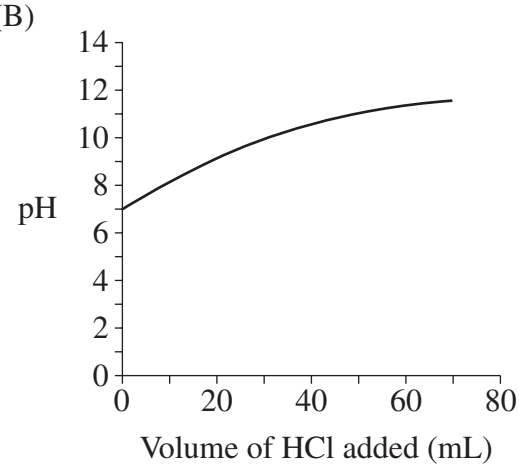
(D) No definite conclusion can be reached about the base concentration.

15 Which of the following graphs shows how pH will vary when dilute HCl is added to 100 mL of dilute natural buffer solution with an initial pH of 7.0?

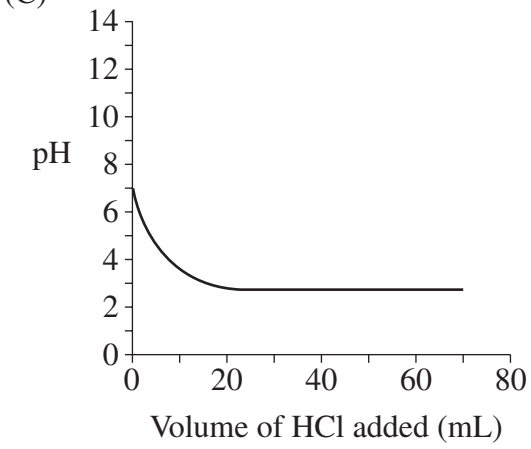
(A)



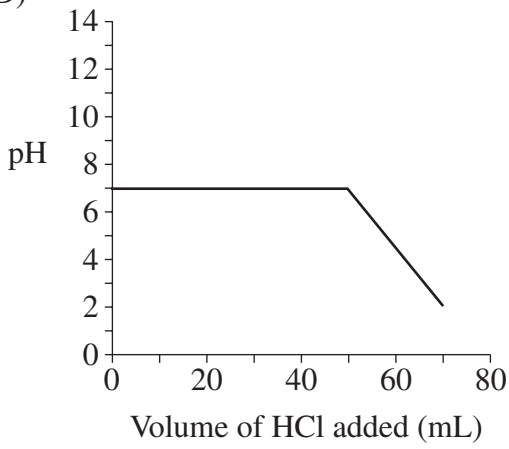
(B)



(C)



(D)



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Chemistry

Centre Number

Student Number

Section I (continued)

Part B – 60 marks
Attempt Questions 16–29
Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Marks

Question 16 (3 marks)

You performed a first-hand investigation that monitored mass changes during the fermentation of glucose to ethanol.

(a) Outline the procedure you used. **2**

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

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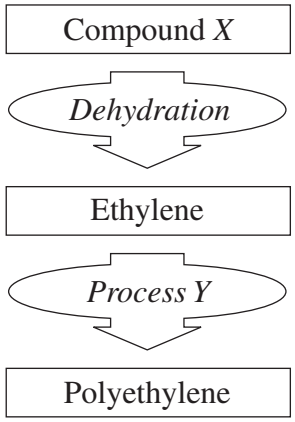
Marks

Question 17 (5 marks)

The flowchart shows the production of polyethylene.



(a) Identify Compound *X*. **1**

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(b) Describe *Process Y*. **3**

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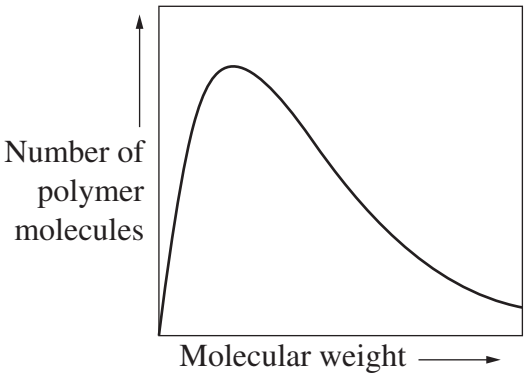
Question 17 continues on page 15

Marks

Question 17 (continued)

A sample of polyethylene was produced by *Process Y*. The following graph shows the distribution of molecular weights of polymer molecules in the sample.



(c) Why is a range of molecular weights observed? **1**

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End of Question 17

Please turn over

Marks

Question 18 (4 marks)

Describe how commercial radioisotopes are produced, and how transuranic elements are produced. **4**

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Chemistry

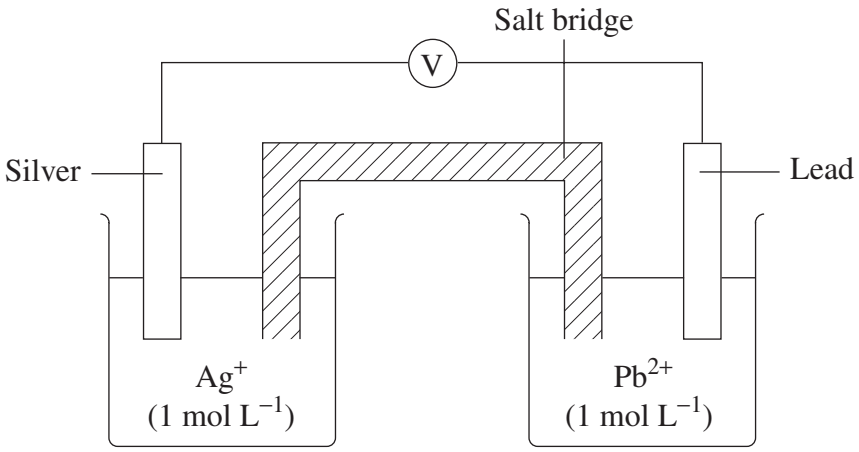
Centre Number

Section I — Part B (continued)

Student Number

Marks

Question 19 (3 marks)



(a) Identify the cathode in this diagram. **1**

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(b) Write the net redox equation for the cell reaction, and calculate the cell potential ($E^{\ominus}$). **2**

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Marks

Question 20 (5 marks)

Assess the suitability of biomass as a future source of energy and chemicals for industry. **5**

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Marks

Question 21 (5 marks)

You performed a first-hand investigation to prepare an ester by reflux.

(a) Identify the products formed when propanoic acid and butanol are refluxed with acid catalyst. **1**

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(b) Draw a fully labelled diagram of the equipment assembled for use. **2**

(c) Outline the advantages of using reflux to prepare the ester. **2**

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Marks

Question 22 (3 marks)

(a) Write a balanced chemical equation for the complete combustion of ethanol. **1**

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(b) A mass of 72.5 g of ethanol was burnt completely in air. Calculate the volume of carbon dioxide that was produced at 25°C and 100 kPa. **2**

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Marks

Question 23 (4 marks)

25.0 mL of 0.12 mol L^{-1} standard barium hydroxide solution was titrated with nitric acid. The results are recorded in the table.

Titration	*Volume of nitric acid used* (mL)
1	20.4
2	18.1
3	18.2
4	18.1

(a) Write a balanced chemical equation for the reaction of barium hydroxide with nitric acid. **1**

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(b) Calculate the concentration of the nitric acid. **3**

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Marks

Question 24 (4 marks)

Discuss factors that must be considered when using neutralisation reactions to safely minimise damage in chemical spills. **4**

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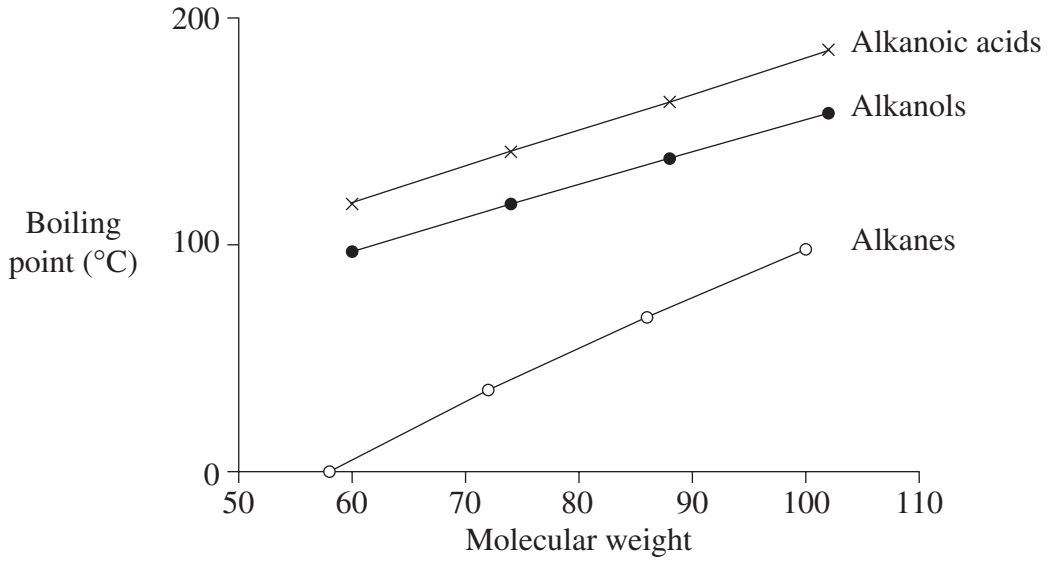
Marks

Question 25 (4 marks)

Explain the trends in boiling points shown in the graph. **4**



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Marks

Question 26 (4 marks)

Describe the process of eutrophication, and assess the suitability of water quality tests used to monitor it. **4**

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Chemistry

Centre Number

Student Number

Section I — Part B (continued)

Marks

Question 27 (5 marks)

A student carried out an investigation to analyse the sulfate content of lawn fertiliser. The student weighed out 1.0 g of fertiliser and dissolved it in water. 50 mL of 0.25 mol L^{-1} barium chloride solution was then added. A white precipitate of barium sulfate formed, which weighed 1.8 g.

(a) Calculate the percentage by mass of sulfate in the fertiliser. **2**

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(b) Evaluate the reliability of the experimental procedure used. **3**

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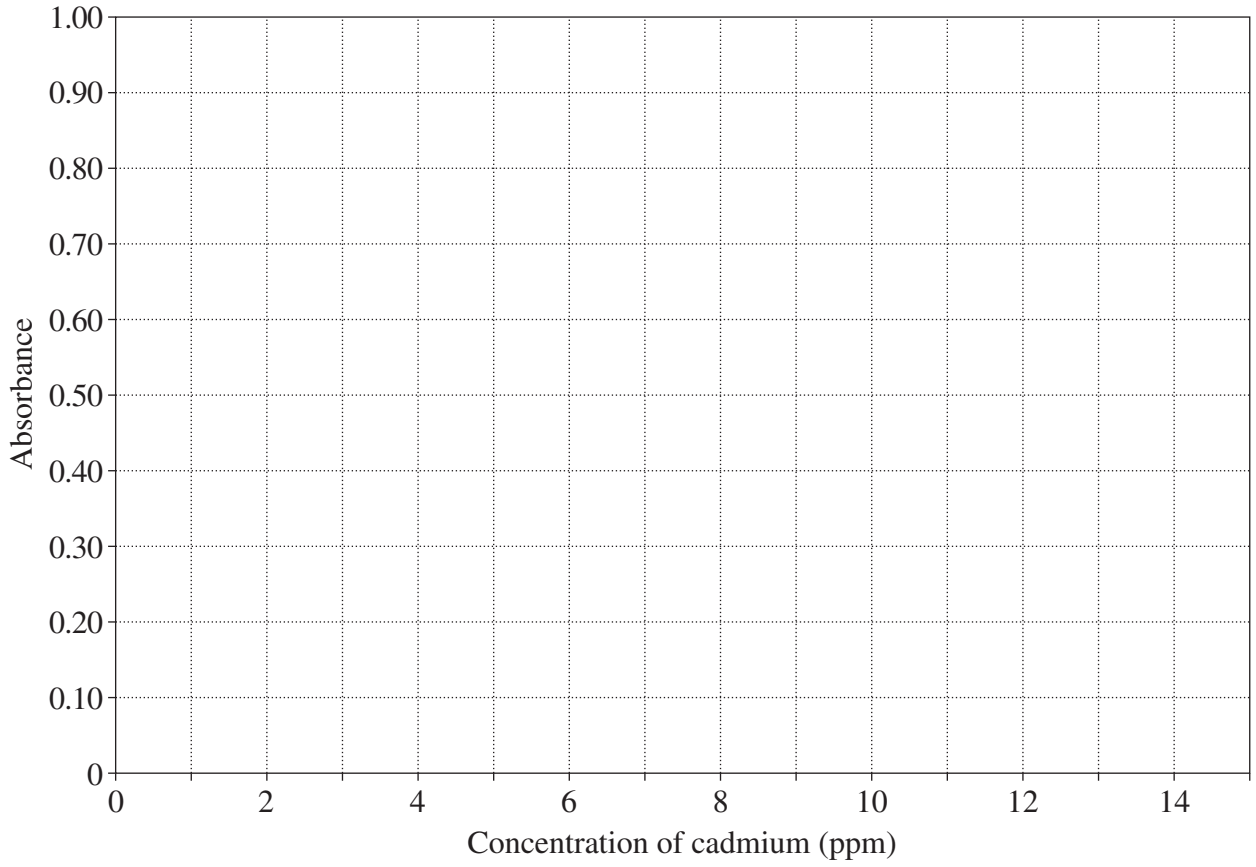
Marks

Question 28 (4 marks)

The results of analysis of a set of standard cadmium solutions are presented in the table.

Concentration of cadmium standard solution (ppm)	*Absorbance*
0	0.00
3	0.22
6	0.38
9	0.62
12	0.83

(a) Draw an appropriate graph of the data. **2**

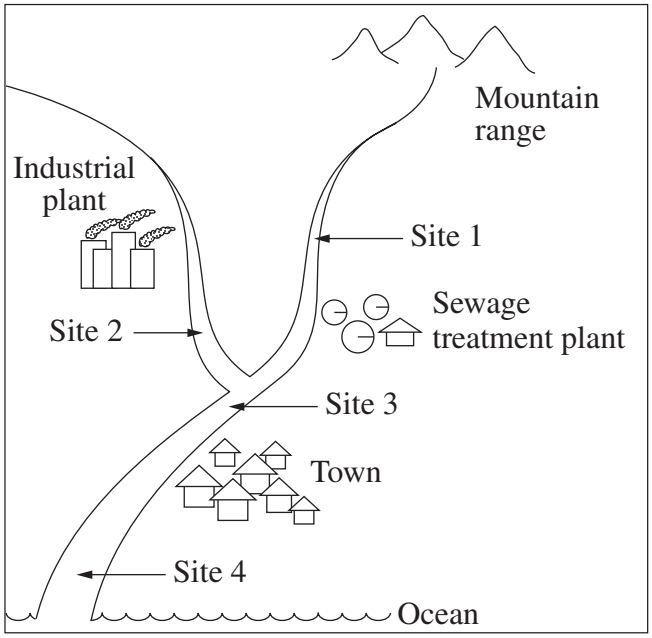


Question 28 continues on page 27

Marks

Question 28 (continued)

The map shows a catchment area. There is an industrial plant, a sewage treatment plant and a small town, all of which discharge water into the river. Water samples were collected at four sites.



The results of analysis of cadmium levels from these four sites are given in the table.

Sample site	*Absorbance*
Site 1	0.08
Site 2	0.15
Site 3	0.55
Site 4	0.40

(b) Justify your conclusion about the most likely source of cadmium pollution. **2**

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End of Question 28

Marks

Question 29 (7 marks)

Evaluate the importance of monitoring and managing the conditions used in the Haber process. **7**

Chemistry

Section II

25 marks
Attempt ONE question from Questions 30–34
Allow about 45 minutes for this section

Answer the question in a writing booklet. Extra writing booklets are available.

Show all relevant working in questions involving calculations.

Marks

Question 30 — Industrial Chemistry (25 marks)

(a) (i) Identify ONE use of sulfuric acid in industry. **1**

(ii) One of the starting materials used for preparing sulfuric acid is sulfur. Describe the process used to extract sulfur from mineral deposits. **3**

(b) During your practical work you performed a first-hand investigation to identify the products of electrolysis of sodium chloride.

(i) Describe ONE precaution you took to minimise hazards, or to dispose of reactants and products safely. **1**

(ii) Outline the procedure you used to identify the products of electrolysis of sodium chloride. **3**

(c) Analyse how an understanding of the structure and cleaning action of soaps led to the development of synthetic detergents. **5**

(d) The Ostwald process is used for making nitric acid from ammonia, and involves several equilibrium steps.

(i) Identify the only factor that changes the value of an equilibrium constant. **1**

(ii) One step in the process produces nitrogen dioxide according to the equation: **2**

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g).$$

This reaction is exothermic. Describe TWO methods that could be used to increase the yield of nitrogen dioxide.

(iii) A 1 L reaction vessel initially contained 0.25 mol NO and 0.12 mol O_2. After equilibrium was established there was only 0.05 mol NO. **3**

Calculate the equilibrium constant for the reaction. Show all relevant working.

(e) Assess how environmental issues have been addressed in an industrial method of production of an acid, and an industrial method of production of a base. **6**

Marks

Question 31 — Shipwrecks, Corrosion and Conservation (25 marks)

(a) (i) Identify ONE passivating metal. **1**

(ii) Account for the differences in corrosion of active and passivating metals. Include a relevant balanced chemical equation in your answer. **3**

(b) During your practical work you performed a first-hand investigation to identify the factors that affect the rate of an electrolysis reaction.

(i) Describe ONE precaution you took to minimise hazards, or to dispose of reactants and products safely. **1**

(ii) Outline the procedure you used to show how ONE factor affects the rate of an electrolysis reaction. **3**

(c) The Titanic struck an iceberg in 1912 and sank to a depth of more than three kilometres. **5**

Analyse how theories about corrosion at great ocean depth have changed since the recent discovery of extensive corrosion on wrecks such as the Titanic.

(d) Fishermen face a problem of limiting corrosion of their steel fish hooks. A fisherman has the choice of storing his steel fish hooks in a plastic, copper or aluminium container.

(i) What is the main metal in steel? **1**

(ii) Compare the effectiveness of these containers in limiting corrosion of steel fish hooks. **5**

(e) Assess how an understanding of electrolysis has contributed to the development of methods for cleaning and restoring marine artefacts. **6**

Marks

Question 32 — The Biochemistry of Movement (25 marks)

(a) (i) Identify the role of glycogen in human muscle and liver. **1**

(ii) Describe the process of bond formation when glucose molecules react to form glycogen. **3**

(b) During your practical work you performed a first-hand investigation to compare the structures of fatty acids and glycerol.

(i) Describe the results of your investigation. **2**

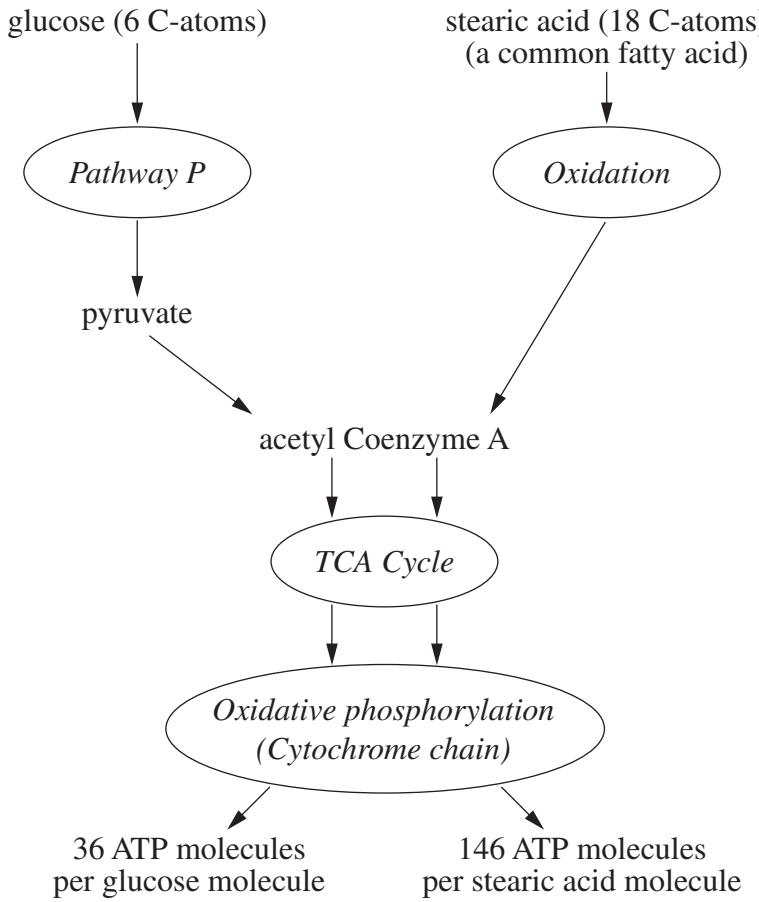
(ii) Outline why glycerol is more soluble in water than are fatty acids that are commonly found in the body. **2**

(c) Analyse how an understanding of the composition and structure of proteins led to the current theory of muscle contraction. **5**

Question 32 continues on page 33

Question 32 (continued)

(d) The flowchart summarises the production of ATP from glucose and stearic acid.



(i) Identify *Pathway P.* **1**

(ii) Construct a word-equation that summarises the formation of products in *Pathway P*, when one molecule of glucose is metabolised. **2**

(iii) Explain why fats can produce more energy per carbon atom than carbohydrates. **3**

(e) Evaluate the importance of the chemistry of ATP in metabolic processes. **6**

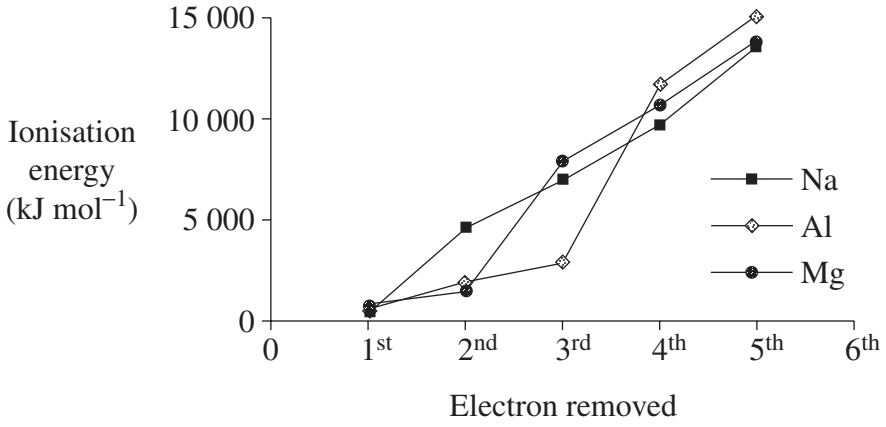
End of Question 32

Marks

Question 33 — The Chemistry of Art (25 marks)

(a) (i) What is the maximum number of electrons found in an atomic orbital? **1**

(ii) The graph shows the first five ionisation energies for sodium, aluminium and magnesium. **3**



C E Housecroft & E C Constable, 2002, *Chemistry,* 2nd edn, reproduced woth permission of Prentice Hall, Harlow, England.

Explain how the data can be used to provide information about the arrangement of electrons around the atoms.

(b) During your practical work you performed a first-hand investigation to observe the flame colour of different metal ions.

(i) Explain the precautions you took during your investigation. **2**

(ii) Outline the procedure you used to observe the flame colour of different metal ions. **2**

(c) Analyse the relationship between the chemical composition and properties, including colour, of pigments used in traditional art by Aboriginal people. **5**

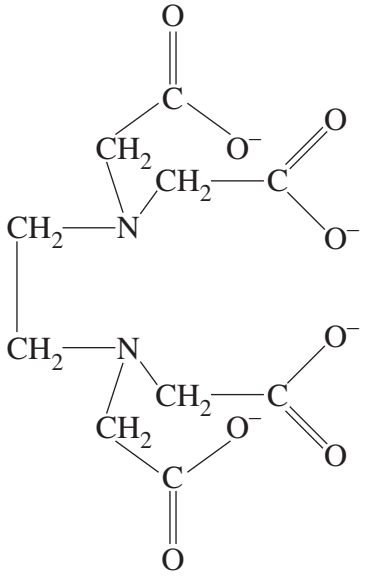
Question 33 continues on page 35

Question 33 (continued)

(d) In the early 1900s, many Australian children were diagnosed as having Pink disease.

The symptoms included pain, loss of teeth, and the presence of a pink colour on fingers and toes.

The first indication that Pink disease was due to mercury poisoning came from the successful treatment of the children using EDTA.



EDTA

(i) Identify the block in the Periodic Table in which mercury is present. **1**

(ii) Explain why transition metals such as mercury may have more than one oxidation state. **2**

(iii) Explain why chelating ligands such as EDTA are often used to treat poisoning by heavy metals. **3**

(e) Evaluate the usefulness of the range of technologies used by chemists to identify pigments. **6**

End of Question 33

Marks

Question 34 — Forensic Chemistry (25 marks)

(a) (i) Identify the general class of compounds represented by the formula $C_x(H_2O)_y$. **1**

(ii) Describe TWO tests that can be used to distinguish between some of the following classes of organic compounds: alkanes, alkenes, alkanols and alkanoic acids. **3**

(b) During your practical work you performed a first-hand investigation to distinguish between reducing and non-reducing sugars.

(i) Describe ONE precaution you took to minimise hazards, or to dispose of reactants and products safely. **1**

(ii) Outline the procedure you used to distinguish between reducing and non-reducing sugars. **3**

(c) Analyse how emission spectra of elements assist in the identification of the origins of a mixture. **5**

Question 34 continues on page 37

Question 34 (continued)

(d) The diagram shows the results of an investigation to identify the parents of a child. The DNA fingerprints from the mother (M) and child (C) are labelled. Also shown are the DNA fingerprints from two possible fathers (F1) and (F2).

(i) Identify the more probable father. **1**

(ii) Outline the structure and composition of DNA. **2**

(iii) Describe how DNA fingerprints are produced, and explain why they can be used to show that two people belong to the same family. **3**

(e) Evaluate how the development of chromatographic methods has advanced forensic science. **6**

End of paper

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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	Symbol of element	Name of element
79	Au	Gold
Atomic Weight	197.0	

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 65.39 Zinc	31 Ga 69.72 Gallium	32 Ge 72.61 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 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [98.91] 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 Lanthanides	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 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 [210.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223.0] Francium	88 Ra [226.0] Radium	89–103 Actinides	104 Rf [261.1] Rutherfordium	105 Db [262.1] Dubnium	106 Sg [263.1] Seaborgium	107 Bh [264.1] Bohrium	108 Hs [265.1] Hassium	109 Mt [268] Meitnerium	110 Uun — Ununnilium	111 Uuu — Unununium	112 Uub — Ununbium	113	114 Uuq — Ununquadium	115	116 Uuh — Ununhexium	117	118 Uuo — Ununoctium

Lanthanides

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [146.9] 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 173.0 Ytterbium	71 Lu 175.0 Lutetium

Actinides

89 Ac [227.0] Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np [237.0] Neptunium	94 Pu [239.1] Plutonium	95 Am [241.1] Americium	96 Cm [244.1] Curium	97 Bk [249.1] Berkelium	98 Cf [252.1] Californium	99 Es [252.1] Einsteinium	100 Fm [257.1] Fermium	101 Md [258.1] Mendelevium	102 No [259.1] Nobelium	103 Lr [262.1] Lawrencium

Where the atomic weight is not known, the relative atomic mass of the most common radioactive isotope is shown in brackets.
The atomic weights of Np and Tc are given for the isotopes ^{237}Np and ^{99}Tc.