Marking Scheme and Outcomes

Chemistry

The Chemical Earth and Metals Modules Test • 2003

General Instructions

- Reading time – 5 minutes
- Working time – 55 minutes
- 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 Student Number at the top of this page

Total Marks – 47

Part A – 12 marks
- Attempt Questions 1 – 12
- Allow about 10 minutes for this part

Part B – 35 marks
- Attempt Questions 13 – 23
- Allow about 45 minutes for this part

Part A – 12 marks
Attempt Questions 1–12
Allow about 10 minutes for this part

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

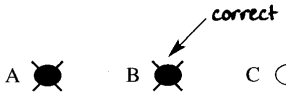
Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

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.

A ● B ⊗ C ○ D ○

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.



Answer Box for Questions 1–12

	OUTCOMES				
1	P 6	A ○	B ○	C ◎	D ○
2	P 1, 4	A ○	B ◎	C ○	D ○
3	P 6	A ○	B ○	C ◎	D ○
4	P 6	A ○	B ○	C ○	D ◎
5	P 6	A ○	B ○	C ○	D ◎
6	P 6	A ○	B ◎	C ○	D ○
7	P 6	A ○	B ○	C ◎	D ○
8	P 6	A ◎	B ○	C ○	D ○
9	P 6	A ○	B ◎	C ○	D ○
10	P 3	A ◎	B ○	C ○	D ○
11	P 4	A ◎	B ○	C ○	D ○
12	P 6	A ○	B ○	C ○	D ◎

Mark your answers for Questions 1 – 12 in the Answer Box on page 2.

1 Which of the following describes the atomic number of an element?

(A) the number of protons plus neutrons in a neutral atom of the element
(B) the number of neutrons in a neutral atom of the element
(C) the number of protons in a neutral atom of the element
(D) the weighted mean of the isotopic masses of the element

2 Which of the following was the first alloy to be used by man?

(A) brass
(B) bronze
(C) solder
(D) steel

3 Which of the following describes the periodic trend in the first ionisation energy of the elements?

(A) decreases across a period
(B) increases as elements become more metallic
(C) decreases down a group
(D) increases with an increase in atomic number

4 Which of the following sets is composed exclusively of covalently bonded compounds?

(A) Na_2O, N_2O_5, NO
(B) Li_2O, Al_2O_3, P_4O_{10}
(C) NO_2, N_2O_5, MgO
(D) NO_2, SiO_2, P_4O_{10}

5 The forces holding together atoms in solid xenon would be most similar to which of these?

(A) the forces between the ions in NaCl
(B) the forces between the atoms in Cl_2
(C) the forces between the atoms in graphite
(D) the forces between the molecules of Br_2

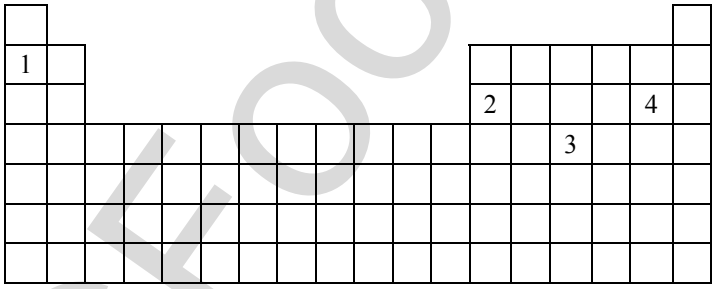
6 The table shows the physical properties of three elements designated as 'X', 'Y' and 'Z'. Note that these are not the periodic table symbols of the elements.

PHYSICAL PROPERTY	X	Y	Z
melting point (^{o}C)	114	660	2370
electrical conductivity	nil	excellent	poor
ductile and malleable	nil	excellent	nil
metallic lustre	nil	yes	nil
density (g cm $^{-3}$)	4.90	2.69	2.30

Which classification of these elements given below is correct?

	X	Y	Z
(A)	non-metal	semi-metal	metal
(B)	non-metal	metal	semi-metal
(C)	semi-metal	metal	semi-metal
(D)	semi-metal	semi-metal	metal

7 The diagram represents the periodic table. The numbers represent certain elements and are not the atomic numbers for any of the elements.



Which numbers represent an element that is a semi-metal and an element that is a gas at 25^{o}C and normal atmosphere pressure?

	Semi-metal	Gas at 25^{o}C and normal atmosphere pressure
(A)	2	1
(B)	2	4
(C)	3	4
(D)	3	1

8 Which of the following is the best description of the structure and bonding in solid iodine at room temperature?

(A) a network of iodine molecules with covalent bonding between the atoms, and weak intermolecular forces
(B) a network of iodide ions held together by a 'sea' of delocalised electrons
(C) a network of iodine atoms held together by covalent bonds in three dimensions
(D) a network of iodide ions held together by ionic bonds in a 3-dimensional lattice

9 The diagram below shows a block of neighbouring elements on the periodic table.

K	**Ca**	**Sc**
Rb	**Sr**	**Y**
Cs	**Ba**	**La**

Which of the following elements would have an atomic radius greater than Sr?

(A) La, Y
(B) Cs, Rb
(C) Ba, Y
(D) Ca, Sc

10 The table shows the current cost of four metals which are mined and extracted in Australia.

METAL	PRICE
aluminium	$2300 per tonne
gold	$570 per 30 g
lead	$750 per tonne
iron	$1300 per tonne

Which of the following statements correctly identifies the cost factors of producing the metal?

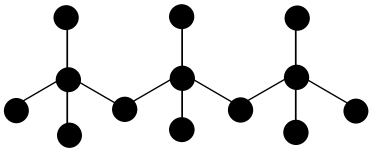
(A) Aluminium ore is abundant but requires much energy to extract.
(B) Gold ore is abundant but difficult to find and extract.
(C) Lead ore is rare but cheap to extract.
(D) Iron ore is scarce and expensive to extract.

11 Which of the choices give a correct matching of the mixture and the sphere of the Earth where the mixture can be found?

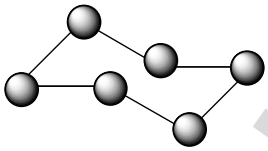
sphere	A	B	C	D
hydrosphere	seawater and fish	beach sand and gravel	seawater and fish	seawater and fish
biosphere	bacterial spores in air	seawater and fish	bacterial spores in air	seawater and fish
lithosphere	beach sand and gravel	beach sand and gravel	dusty air	dusty air
atmosphere	dusty air	bacterial spores in air	beach sand and gravel	bacterial spores in air

(A) A
(B) B
(C) C
(D) D

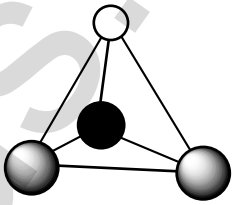
12 Study the following symbolic structures…



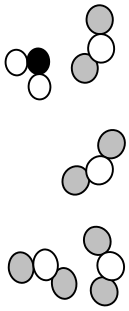
(i)



(ii)



(iii)



(iv)

Which of the following best describes the substances in i, ii, iii and iv?

Substance	A	B	C	D
i	compound	element	element	element
ii	compound	element	element	element
iii	compound	compound	element	compound
iv	compound	compound	compound	mixture

(A) A
(B) B
(C) C
(D) D

Part B – 35 marks
Attempt Questions 13 – 23
Allow about 45 minutes for this part

Question 13 (6 marks)

Write balanced formulae equations for the following reactions. **OUTCOME – P 13**
(1 mark each; lack of subscripts – minus 1 mark max.)

(a) calcium + water

$$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2\,(aq)} + H_{2\,(g)}$$

(b) magnesium + dilute hydrochloric acid

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2\,(aq)} + H_{2\,(g)}$$

(c) sodium + oxygen

$$4Na_{(s)}\ O_{2\,(g)} \rightarrow 2Na_2O_{(s)}$$

Write a pair of half-equations for the following reactions. **OUTCOME – P 13**
(1 mark per pair; maximum of 1 mark lost for reduction half–equation)

(d) aluminium + dilute nitric acid

$$Al_{(s)} \rightarrow Al^{3+} + 3e^-$$

$$2H^+ + 2e^- \rightarrow H_{2\,(g)}$$

(e) potassium + dilute sulfuric acid

$$K_{(s)} \rightarrow K^+ + e^-$$

$$2H^+ + 2e^- \rightarrow H_{2\,(g)}$$

(f) barium + dilute hydrochloric acid

$$Ba_{(s)} \rightarrow Ba^{2+}$$

$$2H^+ + 2e^- \rightarrow H_{2\,(g)}$$

Question 14 (7 marks)

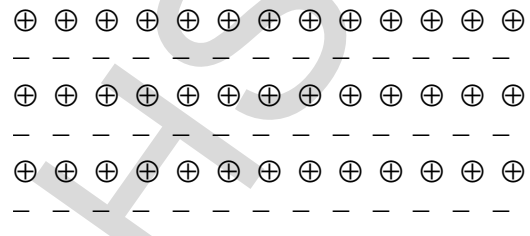
(a) Using the information in the table, classify the substances (A, B, C, D) as either metallic, ionic, covalent network or covalent molecular structures. **OUTCOME – P 14 (2 marks)**

	SUBSTANCE			
PROPERTY	**A**	**B**	**C**	**D**
melting point (°C)	3350	– 114	961	801
soluble in water	no	yes	no	yes
solid conducts electricity	no	no	yes	no
molten (liquid) state conducts electricity	no	no	yes	yes
hardness	very hard	solid is soft	hard	hard
other properties	crystalline solid	aqueous solution conducts	shiny solid	–

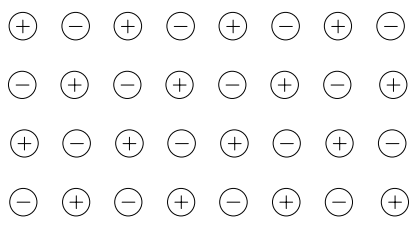
Substance A **covalent network**
Substance B **covalent molecular**
Substance C **metallic lattice**
Substance D **ionic lattice**

(b) Distinguish between structures C and D by drawing a diagram showing the arrangement and type of particles in each structure. **OUTCOME – P 13 (2 marks)**

Structure C (1 mark)
(Showing ⊕ nuclei & delocalised e^-)



Structure D (1 mark)
(Showing ± ions)



Question 14 continues on page 9

Question 14 (continued)

(c) Explain the difference in electrical conductivity between substances C and D. **(2 marks)**
OUTCOME – P 14

Substance C conducts electricity in solid and molten states due to free (delocalised) electrons which can move freely through the lattice.

Substance D does not conduct electricity in the solid state because ions are fixed. However, when molten, the ions are mobile, free to move and conduct electricity.

(d) State the type of particles found in substance A and the type of bonding between these particles.
OUTCOME – P 14 (1 mark)

Atoms; covalent bonding. (N.B. Must state both)

Question 15 OUTCOME – P 6 (3 marks)

Name the compounds listed below. **(3 @ ½ mark)**

(a) $NaHCO_3$ **sodium hydrogen carbonate or sodium bicarbonate**

(b) SF_6 **sulfur hexafluoride**

(c) $Ba(OH)_2$ **barium hydroxide**

Give the formulae for the compounds listed below. **(3 @ ½ mark)**

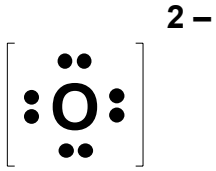
(d) ammonium nitrate **NH_4NO_3**

(e) dinitrogen pentoxide **N_2O_5**

(f) aluminium sulfate **$Al_2(SO_4)_3$**

Question 16 <u>OUTCOME</u> – P 6 (3 marks)

(a) Draw the Lewis electron dot structure for the oxide ion. **(1 mark)**



(b) Give the electronic configuration for the oxide ion. **(1 mark)**

2 – 8 or 2,8

(c) Write the name of another species with the same electronic configuration as the oxide ion. **(1 mark)**

neon, fluoride ion, sodium ion, etc.

Question 17 <u>OUTCOME</u> – P 8 (2 marks)

(a) Write a balanced formulae equation for the thermal decomposition of copper(II) carbonate. **(1 mark)**

$CuCO_{3\,(s)} \xrightarrow{\Delta} CuO_{(s)} + CO_{2\,(g)}$

(b) Describe a chemical test that can be used to prove that copper(II) carbonate can be decomposed by heat. **(1 mark)**

CO_2 is a product of the decomposition of $CuCO_3$ and this can react with limewater forming a white precipitate.
– OR –
CuO is a product which reacts with dilute H_2SO_4 forming a blue solution ($CuSO_4$).

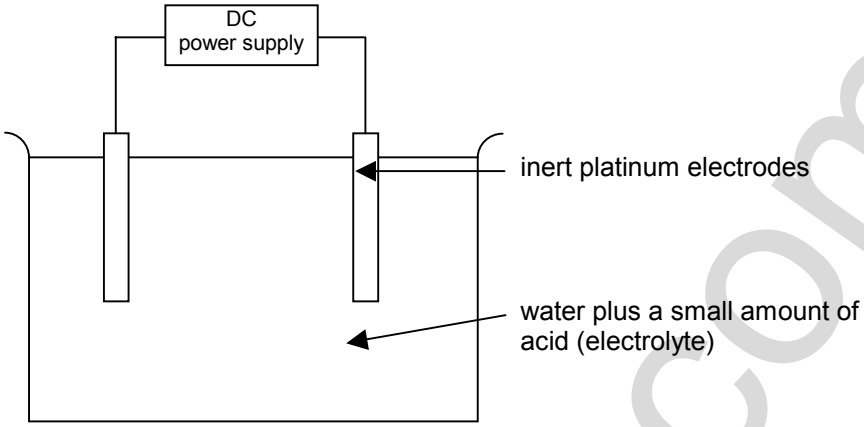
Question 18 <u>OUTCOME</u> – P 7 (1 mark)

Identify an example that demonstrates that light can be absorbed during the decomposition of a compound.

Silver salts ($AgNO_3$, AgCl, AgBr, AgI) can be decomposed using light energy.
e.g. $AgNO_3$ forms a black colour as a result of the Ag^+ forming $Ag_{(s)}$ and thus decomposing the $AgNO_3$.

Question 19 <u>OUTCOME</u> – P 7 (2 marks)

The diagram shows the set-up for a laboratory apparatus in which two inert (non-reactive) platinum electrodes are placed in a beaker of water that has a small amount of acid added to it.



Describe what would be observed at the electrodes when electricity flows into the the electrodes.
Give a reason why this happens.

Gas bubbles will be observed at <u>both</u> electrodes. (1 mark)
The gases are hydrogen and oxygen and these are a result of the electrolysis of water. (1 mark)

Question 20 (1 mark)

Why is the amount of energy needed to break the chemical bond in a hydrogen molecule greater than the energy needed to break the chemical bond in a hydrogen iodide molecule?

The H – H bond is stronger than the H – I bond.

Question 21 OUTCOMES – P 2, 10, 14 (4 marks)

An analytical chemist used fractional distillation to analyse a crude oil mixture from a newly discovered oil well. A 60 g sample of the crude oil was weighed accurately and then fractionally distilled.
Five fractions: A, B, C, D and E were isolated and weighed. The weights obtained in grams were:
2, 18, 9, 12, 16 for components A, B, C, D and E respectively.

(a) Construct a table of results for the data given. **(1 mark for whole table)**

Component	Weight (g)
A	2
B	18
C	9
D	12
E	16

(b) To be an economically productive source, component B must be at least 35% by mass of the crude oil. Assess the potential economic productivity of this sample of crude oil.
Justify your answer by including working. **(2 marks)**

According to the criterion set, the oil well will not be economically productive. (1 mark)

$$\text{Percentage of B} = \frac{\text{mass B}}{\text{mass sample}} \times 100\%$$

(1 mark)

$$\text{Percentage of B} = \frac{18\text{ g}}{60\text{ g}} \times 100\% = 30\% \text{ by mass}$$

(c) Describe **another** situation in which gravimetric analysis supplies useful data for scientists. **(1 mark)**

- **To determine the composition of soil in a particular location to see if it is suitable for growing certain crops.**
- **To determine the amounts of particular substances present in water or air to decide how polluted the samples are.**
- **To decide whether a particular commercial mixture being sold has the same percentage composition as a similar mixture marketed by a rival company.**
- **Other possible situations.**

Question 22 OUTCOME – P 4 (1 mark)

The recycling of aluminium cans is a great success in Australia with over 50% of cans being collected and recycled! Study the equations showing the extraction and recycling of aluminium…

$$Al_2O_3 + 3C \xrightarrow{+\ 50\ MJ/kg\ Al} 4Al + 3CO_2$$

$$Al_{(scrap\ can)} \xrightarrow{+\ 800\ kJ/kg\ Al} Al_{(recycled\ metal)}$$

Account for the huge difference in the energy requirement based on the nature of the processes involved.

The extraction of aluminium from Al_2O_3 involves a chemical reaction… the breaking of the strong bond with oxygen.
The recycling of aluminium involves melting which is a physical change requiring much less energy.
– OR –
The recycling of aluminium involves the breaking of the metallic bonding in the scrap Al.
This bond is weaker than the bond existent within Al_2O_3, ∴ less energy is required.

Question 23 OUTCOME – P 6 (5 marks)

(a) Identify the original data which Mendeleev used to formulate the Periodic Table.

(i) Physical data **(1 mark) Atomic weight, density, atomic volume (any one)**

(ii) Chemical data **(1 mark) Formulae of elemental oxides, chlorides, hydrides; valency; reaction with acid/alkali (any one)**

(b) Historically, Mendeleev made accurate predictions about element 32 (germanium) before it was discovered. According to the HSC Periodic Table, element 117 has not yet been synthesised; however, we also can make predictions about its properties in relation to its neighbouring elements based on periodic law principles.

(i) Compare the relative electronegativity of element 117 with that of ununoctium (element 118).

(1 mark) 117 > 118

(ii) Compare the valency of element 117 with that of astatine.

(1 mark) 117 = astatine

(iii) Compare the relative reactivity of element 117 with that of astatine.

(1 mark) 117 < astatine

DATA SHEET

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

Volume of 1 mole ideal gas: at 101.3 kPa (1.00 atm) and

at 273 K (0°C) ..... 22.41 L

at 298 K (25°C) ..... 24.47 L

Ionisation constant for water at 298 K (25°C), K_w ..... 1.0×10^{-14}

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

Some useful formulae

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

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* (4th 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.