



## SECTION A

Answer ALL the questions in this section.

You should aim to spend no more than 20 minutes on this section.

For each question, select one answer from A to D and put a cross in the box ☐. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☐.

- 1 The numbers of subatomic particles present in four species W, X, Y and Z are given in the table.

Species	Number of protons	Number of neutrons	Number of electrons
W	19	20	18
X	19	20	19
Y	20	20	18
Z	20	22	20

Which of these species are isotopic?

- ☐ A W and X  
☐ B W and Y  
☐ C X and Z  
☐ D Y and Z

(Total for Question 1 = 1 mark)

- 2 Iodine exists as one isotope with mass number 127.

Chlorine exists as two isotopes with mass numbers 35 and 37.

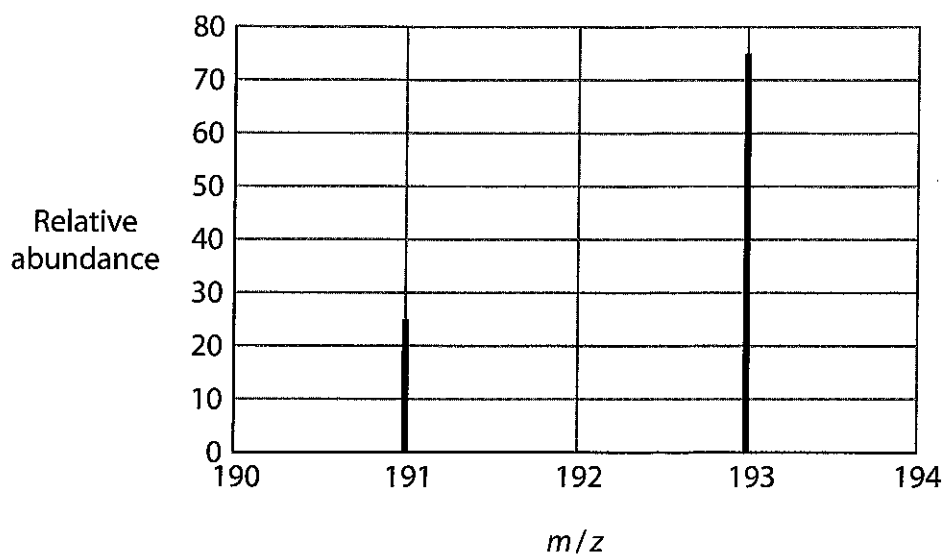
How many molecular ion ( $\text{ICl}_3^+$ ) peaks are there in the mass spectrum of  $\text{ICl}_3$ ?

- ☐ A 2  
☐ B 3  
☐ C 4  
☐ D 5

(Total for Question 2 = 1 mark)



3 The mass spectrum of a sample of an element has only two peaks.



What is the approximate relative atomic mass of the element in this sample?

- ☐ A 191.5
- ☐ B 192.0
- ☐ C 192.5
- ☐ D 193.0

(Total for Question 3 = 1 mark)

4 Which equation represents the **second** ionisation energy of magnesium?

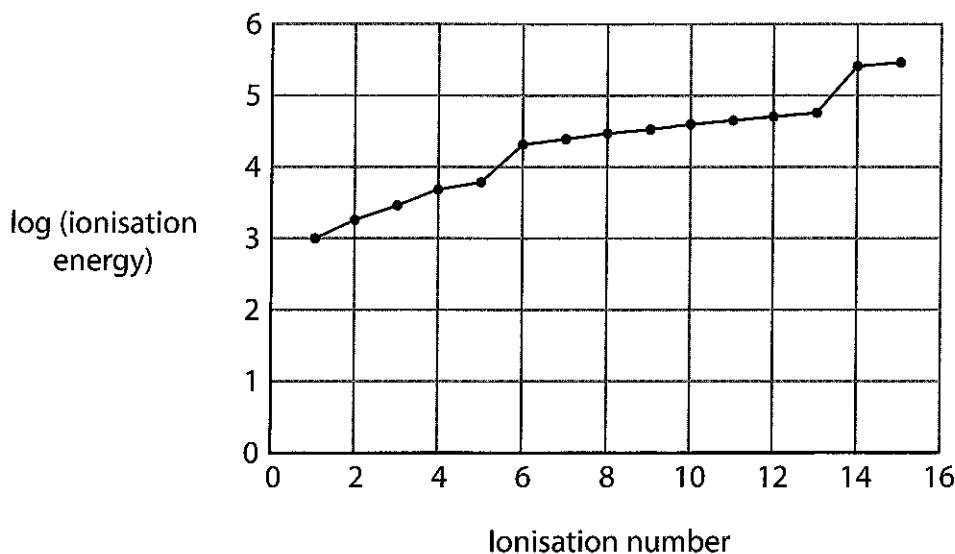
- ☐ A  $\text{Mg(g)} \rightarrow \text{Mg}^{2+}(\text{g}) + 2\text{e}^-$
- ☐ B  $\text{Mg}^+(\text{g}) \rightarrow \text{Mg}^{2+}(\text{g}) + \text{e}^-$
- ☐ C  $\text{Mg(s)} \rightarrow \text{Mg}^{2+}(\text{s}) + 2\text{e}^-$
- ☐ D  $\text{Mg}^+(\text{s}) \rightarrow \text{Mg}^{2+}(\text{s}) + \text{e}^-$

(Total for Question 4 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.



- 5 The graph shows log (ionisation energy) against ionisation number for the successive ionisations of an element.



In this element, how many quantum shells contain electrons, and how many electrons are in the outer quantum shell?

	Number of quantum shells containing electrons	Number of electrons in the outer quantum shell
<input type="checkbox"/> A	3	2
<input type="checkbox"/> B	3	5
<input type="checkbox"/> C	5	2
<input type="checkbox"/> D	5	5

(Total for Question 5 = 1 mark)

- 6 Which ion has the electronic configuration  $1s^2 2s^2 2p^6 3s^2 3p^6$  in its ground state?

- ☐ A  $Al^{3+}$   
☐ B  $Cl^-$   
☐ C  $N^{3-}$   
☐ D  $Na^+$

(Total for Question 6 = 1 mark)



7 What is the relative formula mass of hydrated sodium carbonate,  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ ?

[ $A_r$  values: H = 1.0 C = 12.0 O = 16.0 Na = 23.0]

- ☐ A 106
- ☐ B 142
- ☐ C 263
- ☐ D 286

(Total for Question 7 = 1 mark)

8 Which of these isoelectronic ions has the **largest** radius?

- ☐ A  $\text{Na}^+$
- ☐ B  $\text{Mg}^{2+}$
- ☐ C  $\text{O}^{2-}$
- ☐ D  $\text{F}^-$

(Total for Question 8 = 1 mark)

9 Which ion is the most polarisable?

- ☐ A  $\text{Mg}^{2+}$
- ☐ B  $\text{Ca}^{2+}$
- ☐ C  $\text{Cl}^-$
- ☐ D  $\text{I}^-$

(Total for Question 9 = 1 mark)

10 Which substance has a giant lattice of atoms?

- ☐ A diamond
- ☐ B ice
- ☐ C poly(ethene)
- ☐ D sodium chloride

(Total for Question 10 = 1 mark)



11 Which compound has bonds that are the most polar?

- ☐ A  $\text{H}_2\text{O}$
- ☐ B  $\text{H}_2\text{S}$
- ☐ C  $\text{NH}_3$
- ☐ D  $\text{PH}_3$

(Total for Question 11 = 1 mark)

12 Which molecule is planar?

- ☐ A  $\text{CF}_4$
- ☐ B  $\text{C}_2\text{F}_4$
- ☐ C  $\text{PF}_5$
- ☐ D  $\text{SF}_6$

(Total for Question 12 = 1 mark)

13 When  $\text{C}_{20}\text{H}_{42}$  is cracked, each molecule produces one molecule of ethene, one molecule of butane and two molecules of hydrocarbon E.

What is the molecular formula of E?

- ☐ A  $\text{C}_7\text{H}_{13}$
- ☐ B  $\text{C}_7\text{H}_{14}$
- ☐ C  $\text{C}_{14}\text{H}_{26}$
- ☐ D  $\text{C}_{14}\text{H}_{28}$

(Total for Question 13 = 1 mark)

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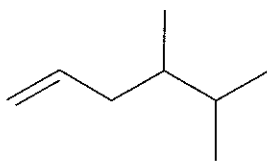


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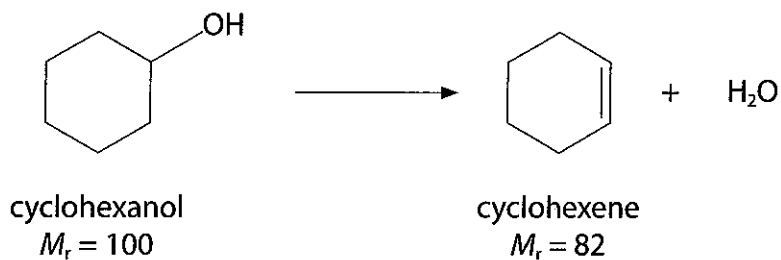
14 What is the systematic name of this compound?



- ☐ A 1,1,2-trimethylpent-4-ene
- ☐ B 2,3-dimethylhex-5-ene
- ☐ C 4,5-dimethylhex-1-ene
- ☐ D 4,5,5-trimethylpent-1-ene

(Total for Question 14 = 1 mark)

15 Cyclohexene may be prepared by the dehydration of cyclohexanol.



What mass of cyclohexene can be made from 12.5 g of cyclohexanol if the yield is 51.2%?

- ☐ A 5.25 g
- ☐ B 6.40 g
- ☐ C 7.80 g
- ☐ D 10.25 g

(Total for Question 15 = 1 mark)

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16 Which of these gases occupies  $6.0 \text{ dm}^3$  at room temperature and pressure (r.t.p.)?

[molar volume of gas at r.t.p. =  $24.0 \text{ dm}^3 \text{ mol}^{-1}$ ]

$A_r$  values: He = 4.0 C = 12.0 N = 14.0 O = 16.0]

- ☐ A 2.0 g of helium
- ☐ B 4.0 g of oxygen
- ☐ C 11.0 g of carbon dioxide
- ☐ D 14.0 g of nitrogen

(Total for Question 16 = 1 mark)

17 An oxide of lead contains 90.7 % by mass of lead.

What is the formula of this oxide?

[ $A_r$  values: O = 16.0 Pb = 207.2]

- ☐ A PbO
- ☐ B PbO<sub>2</sub>
- ☐ C Pb<sub>2</sub>O<sub>3</sub>
- ☐ D Pb<sub>3</sub>O<sub>4</sub>

(Total for Question 17 = 1 mark)

18 Propane burns completely in oxygen as shown.



$100 \text{ cm}^3$  of propane was mixed with  $600 \text{ cm}^3$  of oxygen and the mixture was ignited.

What is the **total** volume, in  $\text{cm}^3$ , of the gas mixture at the end of the reaction?  
All gas volumes were measured at room temperature and pressure.

- ☐ A 300
- ☐ B 400
- ☐ C 700
- ☐ D 800

(Total for Question 18 = 1 mark)



19 Which aqueous solution contains the greatest number of **ions**?

- ☐ A 200 cm<sup>3</sup> of 1.5 mol dm<sup>-3</sup> MgCl<sub>2</sub>
- ☐ B 400 cm<sup>3</sup> of 0.8 mol dm<sup>-3</sup> MgSO<sub>4</sub>
- ☐ C 500 cm<sup>3</sup> of 1.0 mol dm<sup>-3</sup> NaCl
- ☐ D 1000 cm<sup>3</sup> of 0.25 mol dm<sup>-3</sup> Na<sub>2</sub>SO<sub>4</sub>

(Total for Question 19 = 1 mark)

20 A sample of seawater with a mass of 1 kg contains  $6 \times 10^{-9}$  g of gold.

How many atoms of gold, to one significant figure, are there in 1 g of this seawater?

[A<sub>r</sub> value: Au = 197      Avogadro constant =  $6 \times 10^{23}$  mol<sup>-1</sup>]

- ☐ A  $2 \times 10^{10}$
- ☐ B  $4 \times 10^{12}$
- ☐ C  $2 \times 10^{13}$
- ☐ D  $4 \times 10^{15}$

(Total for Question 20 = 1 mark)

**TOTAL FOR SECTION A = 20 MARKS**



## SECTION B

Answer ALL the questions.

Write your answers in the spaces provided.

21 Heptane,  $C_7H_{16}$ , is an alkane found in crude oil.

(a) Heptane can undergo incomplete combustion.

(i) Give a reason why incomplete combustion sometimes occurs.

(1)

(ii) Write the equation for the incomplete combustion of heptane, forming carbon monoxide and water as the **only** products.  
State symbols are not required.

(1)

(b) Heptane is reformed into branched-chain and cyclic hydrocarbons that are used in petrol.

(i) Draw the **skeletal** formulae of a branched-chain alkane and a cycloalkane, each containing **seven** carbon atoms.

(2)

Branched-chain alkane

Cycloalkane

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- (ii) Write the equation for the reforming of heptane into a cycloalkane.  
Use molecular formulae.

(1)

- (iii) Give a reason for adding cycloalkanes to petrol.

(1)

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(c) Heptane,  $C_7H_{16}$ , reacts with chlorine in the presence of ultraviolet radiation.

(i) State the type and mechanism of this reaction.

(2)

(ii) Give the mechanism for the reaction to produce  $C_7H_{15}Cl$ ,  $C_{14}H_{30}$  and  $HCl$  as the **only** products.

Include the name of each of the steps in your mechanism.

Curly half-arrows are **not** required.

(7)

(Total for Question 21 = 15 marks)

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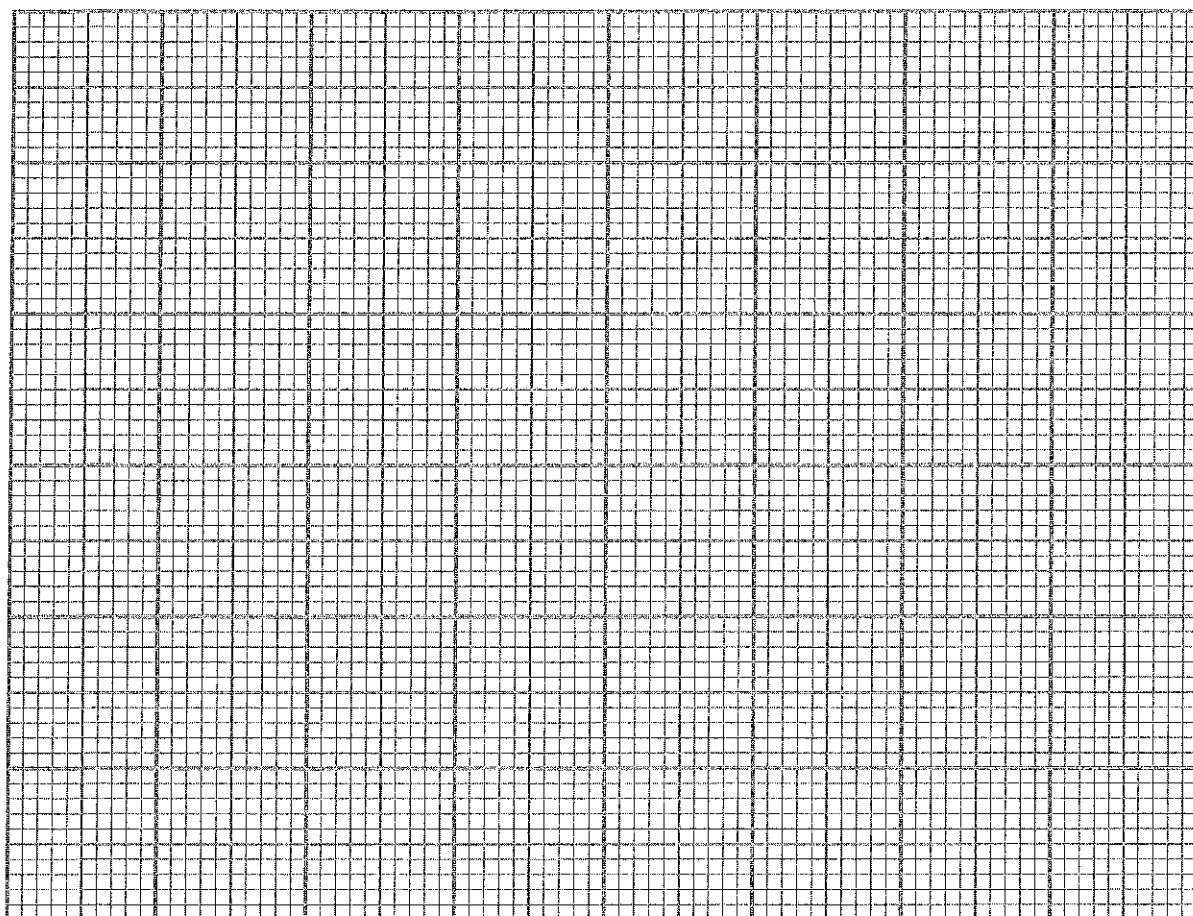
**22** This question is about the elements in Period 3 of the Periodic Table, and some of their compounds.

(a) The atomic radii of six of the elements are given.

Symbol	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic number	11	12	13	14	15	16	17	18
Atomic radius / nm	0.191	0.160	0.130			0.102	0.099	0.095

(i) Plot a graph of atomic radius against atomic number.

(2)



(ii) Use the graph to estimate the atomic radius of silicon, Si.

(1)



(iii) Suggest an explanation for the decrease in atomic radius as atomic number increases across a period.

(3)

(b) The melting temperatures of sodium, sodium chloride and chlorine are given in the table.

Complete the table to show the type of structure, the type of bond or force broken on melting and the particles involved.

(6)

Substance	Sodium	Sodium chloride	Chlorine
Melting temperature / °C	98	801	-101
Type of structure	giant		simple molecular
Type of bond or force broken on melting			
Particles involved			chlorine molecules



(c) Solid phosphorus(V) chloride contains  $\text{PCl}_4^+$  ions.

(i) Draw a dot-and-cross diagram of a  $\text{PCl}_4^+$  ion.

Show only outer shell electrons.

(1)

(ii) Predict the shape of a  $\text{PCl}_4^+$  ion.

Justify your answer.

(3)

Shape .....

Justification

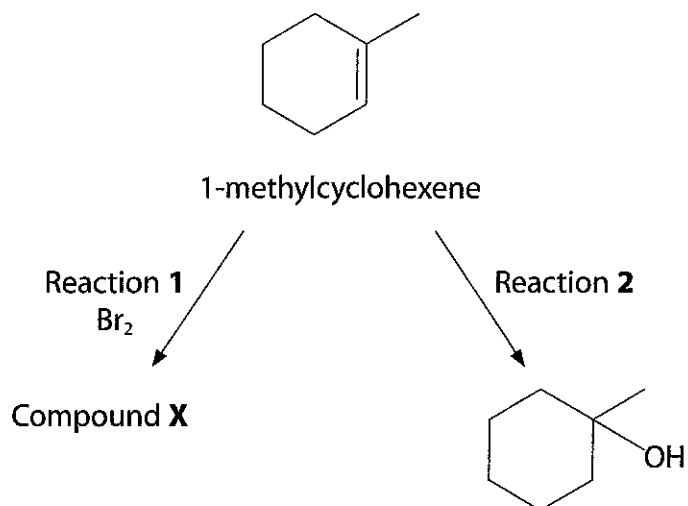
(Total for Question 22 = 16 marks)







(c) Two reactions of 1-methylcyclohexene are shown.



(i) Draw the **skeletal** formula of compound X formed in Reaction 1.

(1)

(ii) Give the reagent and condition needed for Reaction 2.

(2)

Reagent .....

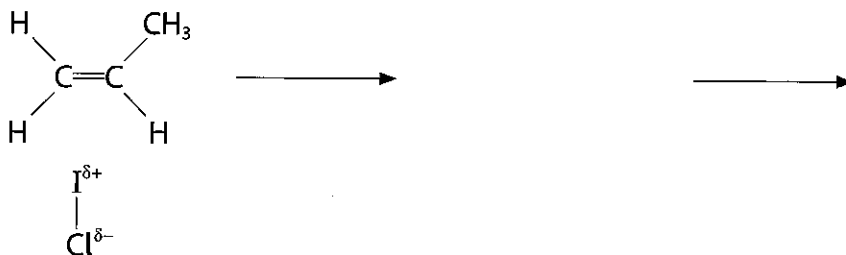
Condition .....



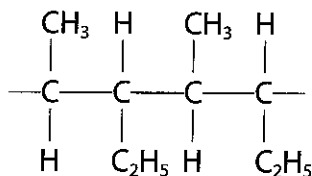
- (d) Iodine monochloride, ICl, reacts with alkenes in a similar way to hydrogen bromide.

Complete the mechanism for the reaction of iodine monochloride with propene to form the **major** product.  
Include curly arrows, the relevant lone pair and the structures of the intermediate and product.

(4)



- (e) A section of a polymer showing two repeat units is given.



Give the **name** of the monomer that forms this polymer.

(1)



- (f) 0.0100 mol of an alkene reacts completely with exactly 600 cm<sup>3</sup> of hydrogen gas, measured at 298 K and  $1.24 \times 10^5$  Pa pressure, to form an alkane.

Use the ideal gas equation to deduce the number of double bonds in **one** molecule of the alkene.

You **must** show your working.

$$[pV = nRT \quad R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}]$$

(4)

(Total for Question 23 = 16 marks)

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**24** This question is about iron and some of its compounds.

(a) Complete the table to show the numbers of subatomic particles in  $^{56}\text{Fe}^{2+}$ .

(1)

Number of protons	Number of neutrons	Number of electrons

(b) A sample of iron contains the following isotopes.

Isotope	Percentage abundance
$^{54}\text{Fe}$	5.84
$^{56}\text{Fe}$	91.68
$^{57}\text{Fe}$	2.17
$^{58}\text{Fe}$	0.31

Calculate the relative atomic mass of this sample of iron.  
Give your answer to **three** significant figures.

(2)

(c) Magnesium reacts with aqueous iron(II) sulfate in a displacement reaction.

Write the **ionic** equation for this reaction.  
Include state symbols.

(2)



(d) 25.00 g of a compound contains 6.98 g of iron and 6.03 g of sulfur.

The remaining mass is oxygen.

Calculate the **empirical** formula of this compound.

[ $A_r$  values: O = 16.0 S = 32.1 Fe = 55.8]

(3)

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- (e) When 6.95 g of  $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$  is heated, 2.00 g of iron(III) oxide, 0.80 g of sulfur dioxide and 1.00 g of sulfur trioxide are produced. The only other product is water.

Deduce the overall equation for the reaction using these data. State symbols are not required.

You **must** show your working.

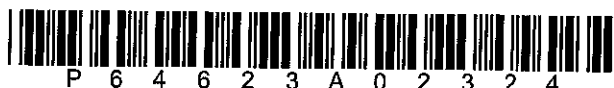
[ $A_r$  values: H = 1.0 O = 16.0 S = 32.1 Fe = 55.8]

(5)

(Total for Question 24 = 13 marks)

TOTAL FOR SECTION B = 60 MARKS

TOTAL FOR PAPER = 80 MARKS



# The Periodic Table of Elements

1	2	3	4	5	6	7	0 (8)
6.9 <b>Li</b> lithium 3	9.0 <b>Be</b> beryllium 4	10.8 <b>B</b> boron 5	12.0 <b>C</b> carbon 6	14.0 <b>N</b> nitrogen 7	16.0 <b>O</b> oxygen 8	19.0 <b>F</b> fluorine 9	20.2 <b>Ne</b> neon 10
23.0 <b>Na</b> sodium 11	24.3 <b>Mg</b> magnesium 12	27.0 <b>Al</b> aluminium 13	28.1 <b>Si</b> silicon 14	31.0 <b>P</b> phosphorus 15	32.1 <b>S</b> sulfur 16	35.5 <b>Cl</b> chlorine 17	39.9 <b>Ar</b> argon 18
39.1 <b>K</b> potassium 19	40.1 <b>Ca</b> calcium 20	69.7 <b>Ga</b> gallium 31	72.6 <b>Ge</b> germanium 32	74.9 <b>As</b> arsenic 33	79.0 <b>Se</b> selenium 34	79.9 <b>Br</b> bromine 35	83.8 <b>Kr</b> krypton 36
85.5 <b>Rb</b> rubidium 37	87.6 <b>Sr</b> strontium 38	114.8 <b>In</b> indium 49	118.7 <b>Sn</b> tin 50	121.8 <b>Sb</b> antimony 51	127.6 <b>Te</b> tellurium 52	126.9 <b>I</b> iodine 53	131.3 <b>Xe</b> xenon 54
132.9 <b>Cs</b> caesium 55	137.3 <b>Ba</b> barium 56	204.4 <b>Tl</b> thallium 81	207.2 <b>Pb</b> lead 82	209.0 <b>Bi</b> bismuth 83	[209] <b>Po</b> polonium 84	[210] <b>At</b> astatine 85	[222] <b>Rn</b> radon 86

1.0  
**H**  
hydrogen  
1

Key  
relative atomic mass  
atomic symbol  
name  
atomic (proton) number

Elements with atomic numbers 112-116 have been reported  
but not fully authenticated

140 <b>Ce</b> cerium 58	141 <b>Pr</b> praseodymium 59	144 <b>Nd</b> neodymium 60	147 <b>Pm</b> promethium 61	150 <b>Sm</b> samarium 62	152 <b>Eu</b> europium 63	157 <b>Gd</b> gadolinium 64	159 <b>Tb</b> terbium 65	163 <b>Dy</b> dysprosium 66	165 <b>Ho</b> holmium 67	167 <b>Er</b> erbium 68	169 <b>Tm</b> thulium 69	173 <b>Yb</b> ytterbium 70	175 <b>Lu</b> lutetium 71
232 <b>Th</b> thorium 90	[231] <b>Pa</b> protactinium 91	238 <b>U</b> uranium 92	[237] <b>Np</b> neptunium 93	[242] <b>Pu</b> plutonium 94	[243] <b>Am</b> americium 95	[247] <b>Cm</b> curium 96	[245] <b>Bk</b> berkelium 97	[251] <b>Cf</b> californium 98	[254] <b>Es</b> einsteinium 99	[253] <b>Fm</b> fermium 100	[256] <b>Md</b> mendelevium 101	[254] <b>No</b> nobelium 102	[257] <b>Lr</b> lawrencium 103

\* Lanthanide series

\* Actinide series

