Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

0123456789

CHEMISTRY **9701/02**

Paper 2 AS Level Structured Questions **For examination from 2022**

SPECIMEN PAPER **1 hour 15 minutes**

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **18** pages. Blank pages are indicated.

1 The properties of elements and their compounds show similarities, differences and trends depending on the positions of the elements in the Periodic Table.

(a) The positions of some elements are shown.

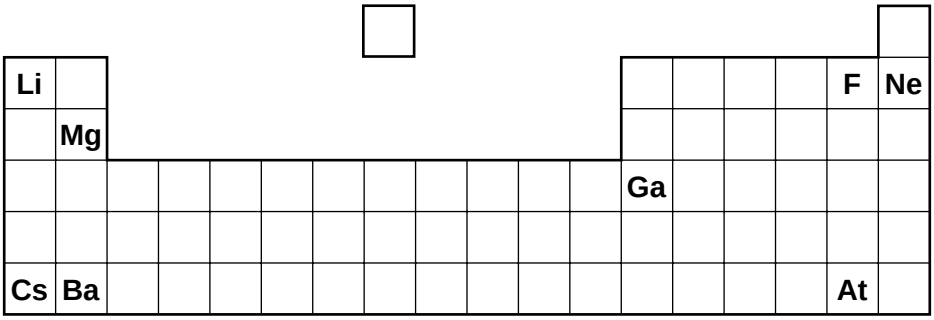


Fig. 1.1

(i) Using Fig. 1.1 identify the element that forms a soluble hydroxide and an insoluble sulfate.

..... [1]

(ii) Using Fig. 1.1 identify the most volatile element in a group that contains elements in all three states of matter at room temperature and pressure.

..... [1]

(iii) Using Fig. 1.1 identify the element that forms the largest cation.

..... [1]

(b) Fig. 1.2 shows the relative first ionisation energies of six successive elements in the Periodic Table.

The letters are **not** the symbols of the elements.

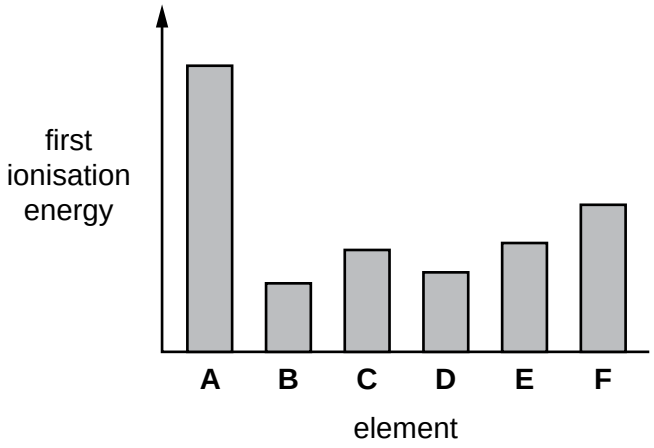


Fig. 1.2

(i) Define first ionisation energy.

.....

.....

.....

..... [2]

(ii) Suggest why the first ionisation energy of **B** is much less than that of **A** in Fig 1.2.

.....

.....

.....

.....

..... [3]

(c) (i) On Fig. 1.3, sketch a graph to show the trend in the atomic radius of successive elements in Period 3.

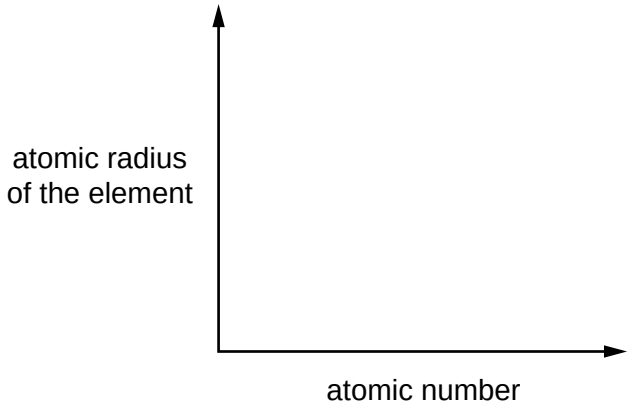


Fig. 1.3

[1]

(ii) Explain your answer to **(c)(i)**.

.....

.....

.....

.....

..... [3]

[Total: 12]

2 Carbon and silicon are elements in Group 14.

(a) **(i)** Describe in simple terms the structure of solid C_{60}.

.....

..... [2]

(ii) C_{60} sublimes (turns directly from solid to gas) at approximately 800 K.

$$C_{60}(s) \rightarrow C_{60}(g)$$

Diamond also sublimes but only above 3800 K.

$$C_{diamond}(s) \rightarrow C(g)$$

Explain why C_{60} and diamond sublime at such different temperatures.

.....

.....

.....

.....

.....

.....

.....

..... [4]

(b) C_{60} forms hydrocarbons with similar chemical properties to those of alkenes. One such hydrocarbon is $C_{60}H_{18}$.

(i) Define hydrocarbon.

.....

..... [1]

(ii) $C_{60}H_{18}$ is an alkene.
State a test to indicate the presence of double bonds between carbon atoms in alkene molecules.

.....

..... [1]

(iii) State the observations seen when the test in **(b)(ii)** is carried out on an alkene.

.....

..... [1]

(c) 0.144 g of C_{60} is placed in a 100 cm^3 container of hydrogen gas at a temperature of 20 °C and a pressure of 1.00×10^5 Pa.

The container is heated to make the C_{60} and hydrogen gas react. The reaction occurs as shown in the equation.

$$C_{60}(s) + xH_2(g) \rightarrow C_{60}H_{2x}(s)$$

After the reaction, the container is allowed to cool to 20 °C. The pressure decreases to 2.21×10^4 Pa. All of the C_{60} has reacted.

(i) Name the type of reaction that occurs.

..... [1]

(ii) Calculate the amount, in moles, of C_{60} that reacts.

amount of C_{60} = ... mol [1]

(iii) Calculate the amount, in moles, of hydrogen gas that reacted with the C_{60}.
Show your working.

amount of hydrogen gas = ... mol [3]

(iv) Use your answers from **(c)(ii)** and **(c)(iii)** to deduce the molecular formula of the hydrocarbon, $C_{60}H_{2x}$.

(If you were unable to calculate the amount of hydrogen gas, assume that 0.00240 mol of hydrogen gas reacts. This is **not** the correct value.)
Show your working.

molecular formula = ... [2]

(d) Silicon shows the same type of bonding and structure as diamond.

Silicon reacts with magnesium to form Mg_2Si.

Solid Mg_2Si reacts with dilute hydrochloric acid to form gaseous SiH_4 and a solution of magnesium chloride.

(i) Construct an equation for this reaction. Include state symbols.

..... [2]

(ii) Predict the shape of the SiH_4 molecule.

..... [1]

[Total: 19]

3 Calcium and its compounds have a large variety of applications.

(a) Calcium metal reacts readily with most acids.

When calcium metal is placed in dilute sulfuric acid, it reacts vigorously at first.

After a short time, a layer of calcium sulfate forms on the calcium metal and the reaction stops. Some of the calcium metal and dilute sulfuric acid remain unreacted.

Suggest an explanation for these observations.

.....

..... [1]

(b) Calcium ethanedioate is formed when calcium reacts with ethanedioic acid, HOOCCOOH. Calcium ethanedioate contains one cation and one anion.

(i) State the full electronic configuration of the cation in calcium ethanedioate.

..... [1]

(ii) Deduce the charge on the cation.

..... [1]

(iii) Draw the fully displayed formula of ethanedioic acid.

[1]

(c) Calcium chlorate(I), $Ca(ClO)_2$, is used as an alternative to sodium chlorate(I), NaClO, in some household products.

(i) The chlorate(I) ion is formed when cold aqueous sodium hydroxide reacts with chlorine.

Write an ionic equation for this reaction. State symbols are **not** required.

..... [1]

(ii) The chlorate(I) ion is unstable and decomposes when heated as shown.

$$3ClO^- \rightarrow 2Cl^- + ClO_3^-$$

This reaction can be described as a disproportionation reaction.

Describe what is meant by disproportionation reaction.

.....

..... [1]

(iii) Deduce the oxidation number of chlorine in each species for the equation in **(c)(ii)**.

Complete the boxes.

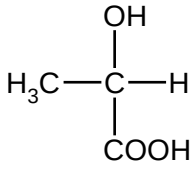
$3ClO^- \rightarrow 2Cl^- + ClO_3^-$

oxidation number of chlorine | +1 | | |

[1]

(d) Calcium carbonate reacts with 2-hydroxypropanoic acid to form product **Y**.

2-hydroxypropanoic acid



Y

$Ca(CH_3CH(OH)COO)_2$

Fig. 3.1

(i) Identify the **two** other products of the reaction of 2-hydroxypropanoic acid with calcium carbonate.

..... [1]

Two possible methods of making 2-hydroxypropanoic acid are shown in Fig. 3.2.

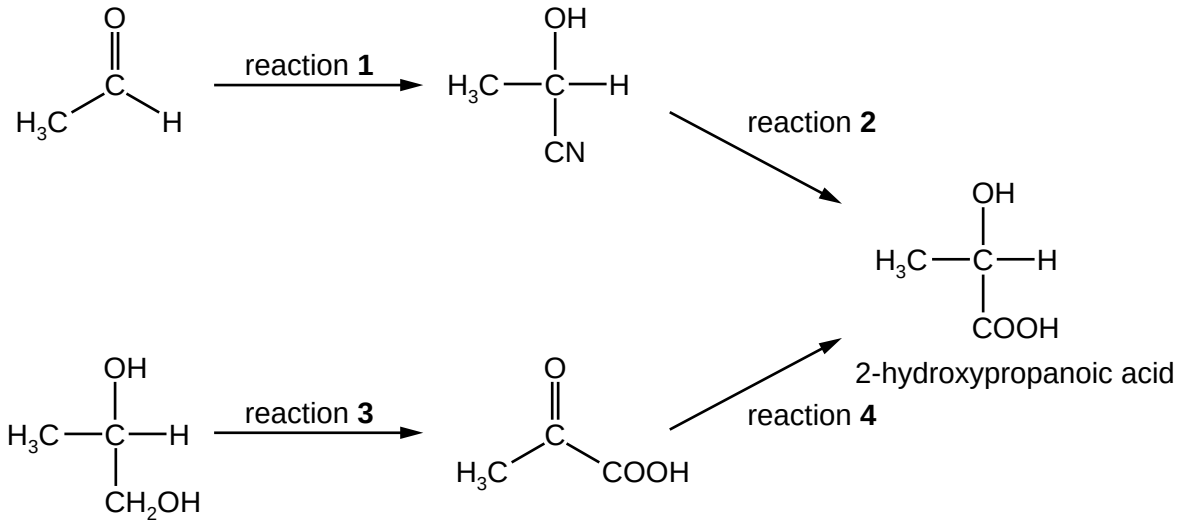


Fig. 3.2

(ii) State suitable reagents and conditions for reactions **1** and **3**.

reaction **1** .....

reaction **3** .....
[4]

(iii) Deduce the type of reaction that occurs in reaction **2**.

..... [1]

(iv) The reagent for reaction **4** is $NaBH_4$.

Identify the role of $NaBH_4$ in this reaction.

..... [1]

(v) 2-hydroxypropanoic acid has a chiral centre.

State what is meant by chiral centre.

.....

.....

..... [1]

[Total: 15]

4 A reaction scheme involving cyclohexane is shown in Fig. 4.1.

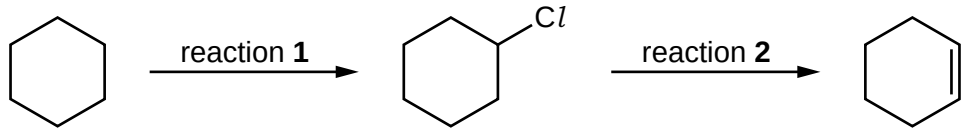


Fig. 4.1

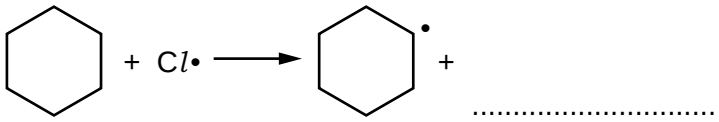
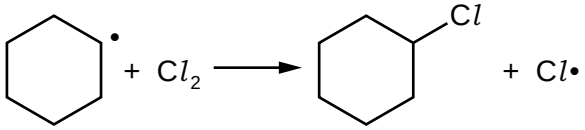
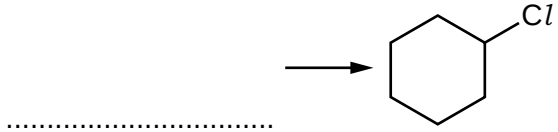
Reaction **1** involves a free radical substitution mechanism.

(a) State the essential condition required for reaction **1** to occur.

..... [1]

(b) Complete Table 4.1 to give details of the mechanism in reaction **1**. Include curly arrows to show the movement of electrons occurring in the termination step.

Table 4.1

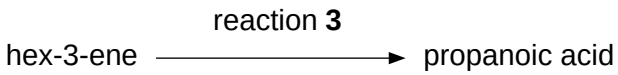
name of step	equation
.....	$Cl_2 \longrightarrow 2Cl\bullet$
propagation	 + ...
.....	
termination	 .....

[5]

(c) Deduce the type of reaction that occurs in reaction **2**.

..... [1]

(d) Hex-3-ene is an isomer of cyclohexane. Hex-3-ene can be converted into propanoic acid.



Deduce the reagents and conditions for reaction **3**.

.....

..... [2]

[Total: 9]

5 Compound **X** contains atoms of carbon, hydrogen and oxygen only.

The mass spectrum of **X** is recorded. Information about the two peaks with *m* / *e* greater than 100 is shown in Fig. 5.1.

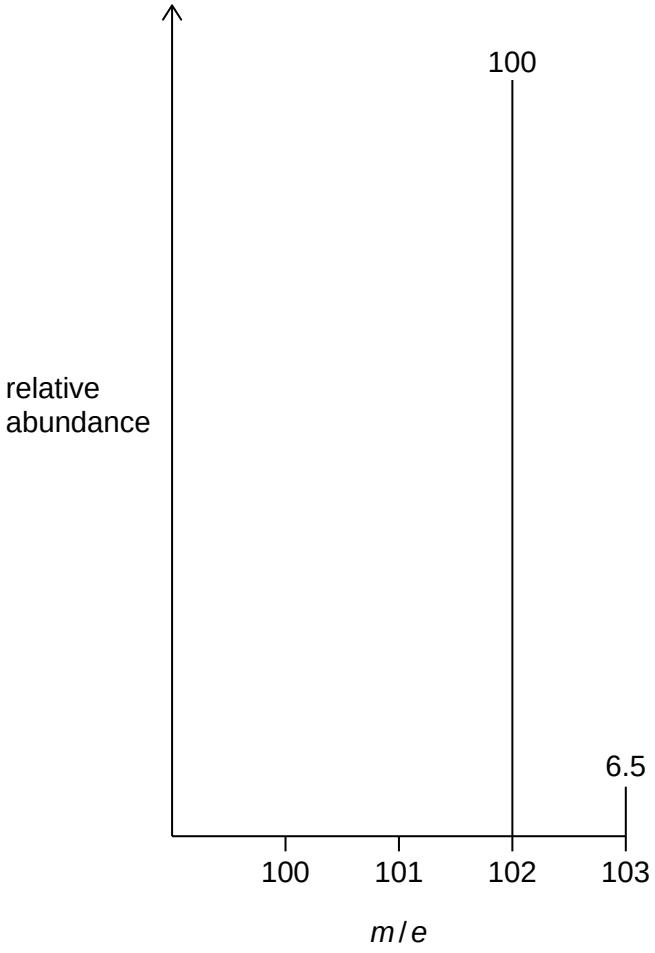


Fig. 5.1

(a) A molecule of **X** contains 6 carbon atoms.

Demonstrate that this is correct using information from Fig 5.1. Show your working.

[2]

(b) Suggest the molecular formula of **X** using information from Fig. 5.1.

..... [1]

(c) Suggest the molecular formula of the fragment of **X** at *m* / *e* = 31.

..... [1]

(d) Fig 5.2 shows the infra-red spectrum of **X**.

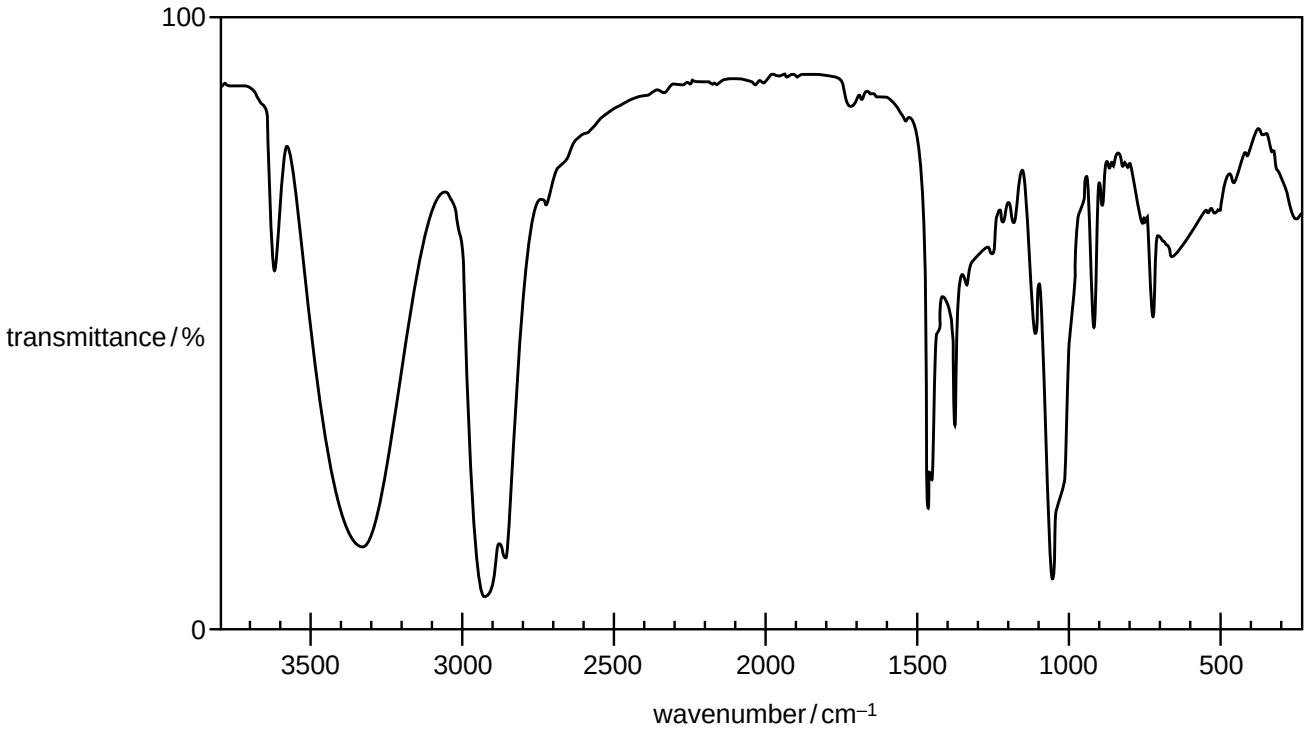


Fig. 5.2

Table 5.1

bond	functional group containing the bond	characteristic infra-red absorption range (in wavenumbers) / cm^{-1}
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–3100
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650

Identify the functional group present in **X** using your answer in **(b)** and information from Fig. 5.2 and Table 5.1. Give a reason for your answer.

.....

..... [1]

[Total: 5]

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Important values, constants and standards

molar gas constant	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\ \text{C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23}\ \text{mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\ \text{C}$
molar volume of gas	$V_m = 22.4\ \text{dm}^3\ \text{mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\ \text{dm}^3\ \text{mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\ \text{mol}^2\ \text{dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\ \text{kJ kg}^{-1}\ \text{K}^{-1}$ ($4.18\ \text{J g}^{-1}\ \text{K}^{-1}$)

The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

Group

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3											13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	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 lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.4	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	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 –