



Cambridge International AS & A Level

CANDIDATE
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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.

Li																		F	Ne
	Mg																		
													Ga						
Cs	Ba																		At

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.

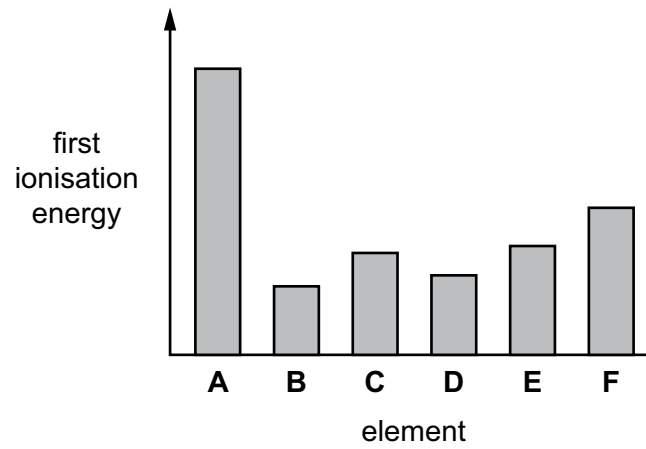


Fig. 1.2

- (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.

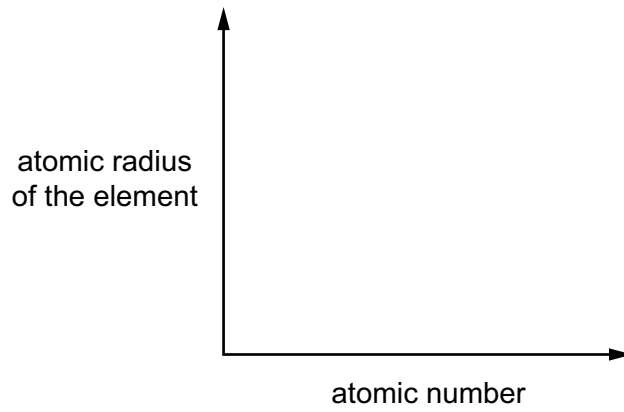


Fig. 1.3

[1]

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

.....

.....

.....

.....

..... [3]

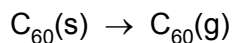
[Total: 12]

2 Carbon and silicon are elements in Group 14.

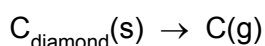
(a) (i) Describe in simple terms the structure of solid C_{60} .

.....
 [2]

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



Diamond also sublimes but only above 3800 K.



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.

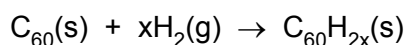
.....
 [1]

(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 $20\text{ }^\circ\text{C}$ and a pressure of $1.00 \times 10^5\text{ Pa}$.

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



After the reaction, the container is allowed to cool to $20\text{ }^\circ\text{C}$. The pressure decreases to $2.21 \times 10^4\text{ Pa}$. 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 $C_{60} = \dots\dots\dots\text{ mol [1]}$

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

amount of hydrogen gas = $\dots\dots\dots\text{ mol [3]}$

- (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, HOOC-COOH. 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]

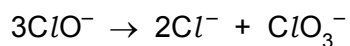
(c) Calcium chlorate(I), $\text{Ca}(\text{ClO})_2$, is used as an alternative to sodium chlorate(I), NaClO , in some household products.

(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.



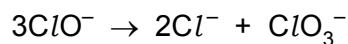
This reaction can be described as a disproportionation reaction.

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.



oxidation number of chlorine

[1]

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

2-hydroxypropanoic acid

Y



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.

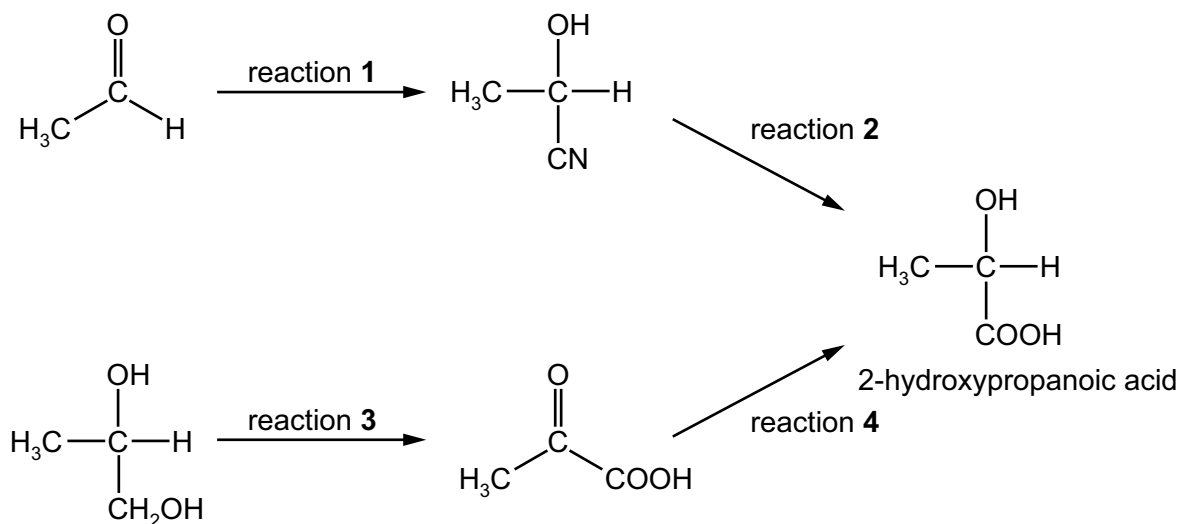


Fig. 3.2

(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.

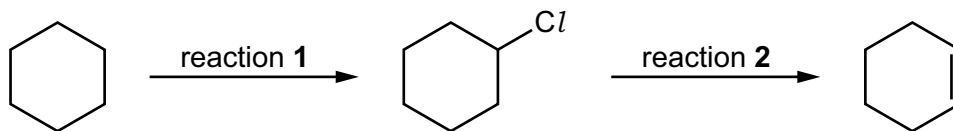


Fig. 4.1

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

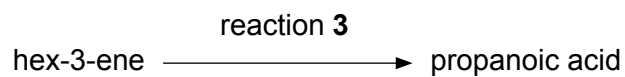
name of step	equation
.....	$Cl_2 \longrightarrow 2Cl\cdot$
propagation	
.....	
termination	

[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.

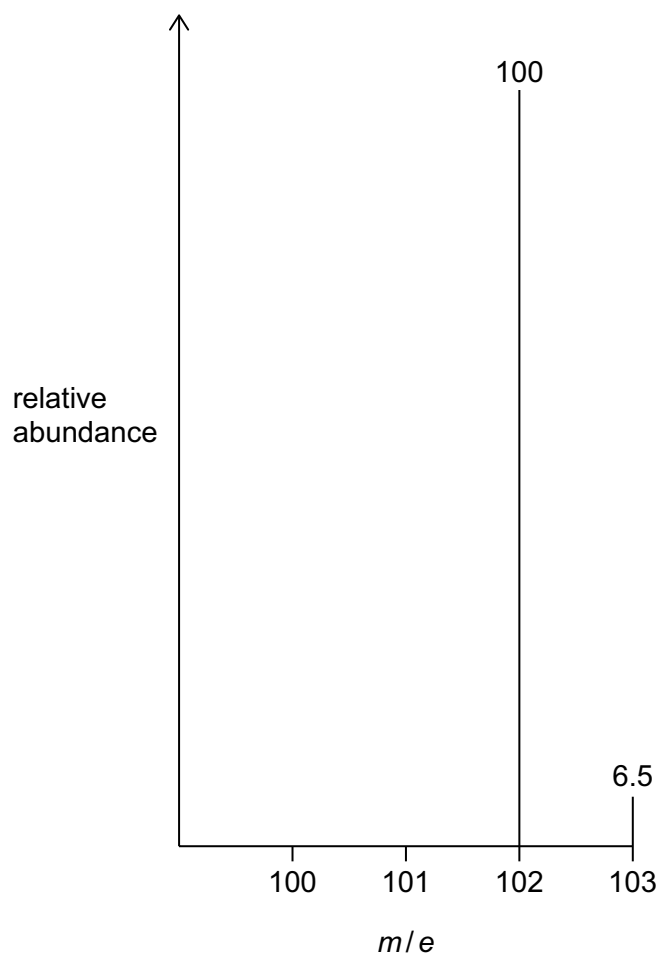


Fig. 5.1

- (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**.

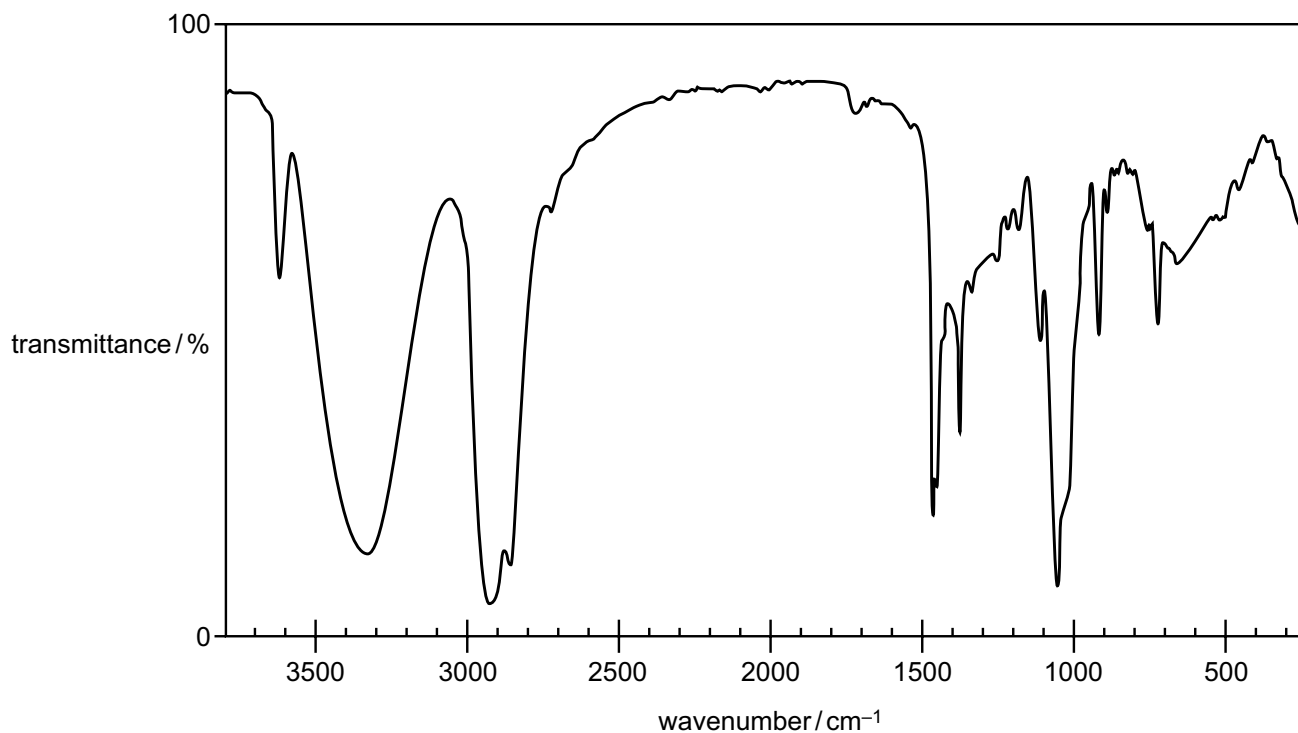


Fig. 5.2

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]

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

		Group															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">1 H hydrogen 1.0</div> <div style="border: 1px solid black; padding: 5px;">2 He helium 4.0</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">3 Li lithium 6.9</div> <div style="border: 1px solid black; padding: 5px;">4 Be beryllium 9.0</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">5 B boron 10.8</div> <div style="border: 1px solid black; padding: 5px;">6 C carbon 12.0</div> <div style="border: 1px solid black; padding: 5px;">7 N nitrogen 14.0</div> <div style="border: 1px solid black; padding: 5px;">8 O oxygen 16.0</div> <div style="border: 1px solid black; padding: 5px;">9 F fluorine 19.0</div> <div style="border: 1px solid black; padding: 5px;">10 Ne neon 20.2</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">11 Na sodium 23.0</div> <div style="border: 1px solid black; padding: 5px;">12 Mg magnesium 24.3</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">13 Al aluminium 27.0</div> <div style="border: 1px solid black; padding: 5px;">14 Si silicon 28.1</div> <div style="border: 1px solid black; padding: 5px;">15 P phosphorus 31.0</div> <div style="border: 1px solid black; padding: 5px;">16 S sulfur 32.1</div> <div style="border: 1px solid black; padding: 5px;">17 Cl chlorine 35.5</div> <div style="border: 1px solid black; padding: 5px;">18 Ar argon 39.9</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">19 K potassium 39.1</div> <div style="border: 1px solid black; padding: 5px;">20 Ca calcium 40.1</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">21 Sc scandium 45.0</div> <div style="border: 1px solid black; padding: 5px;">22 Ti titanium 47.9</div> <div style="border: 1px solid black; padding: 5px;">23 V vanadium 50.9</div> <div style="border: 1px solid black; padding: 5px;">24 Cr chromium 52.0</div> <div style="border: 1px solid black; padding: 5px;">25 Mn manganese 54.9</div> <div style="border: 1px solid black; padding: 5px;">26 Fe iron 55.8</div> <div style="border: 1px solid black; padding: 5px;">27 Co cobalt 58.9</div> <div style="border: 1px solid black; padding: 5px;">28 Ni nickel 58.7</div> <div style="border: 1px solid black; padding: 5px;">29 Cu copper 63.5</div> <div style="border: 1px solid black; padding: 5px;">30 Zn zinc 65.4</div> <div style="border: 1px solid black; padding: 5px;">31 Ga gallium 69.7</div> <div style="border: 1px solid black; padding: 5px;">32 Ge germanium 72.6</div> <div style="border: 1px solid black; padding: 5px;">33 As arsenic 74.9</div> <div style="border: 1px solid black; padding: 5px;">34 Se selenium 79.0</div> <div style="border: 1px solid black; padding: 5px;">35 Br bromine 79.9</div> <div style="border: 1px solid black; padding: 5px;">36 Kr krypton 83.8</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">37 Rb rubidium 85.5</div> <div style="border: 1px solid black; padding: 5px;">38 Sr strontium 87.6</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">39 Y yttrium 88.9</div> <div style="border: 1px solid black; padding: 5px;">40 Zr zirconium 91.2</div> <div style="border: 1px solid black; padding: 5px;">41 Nb niobium 92.9</div> <div style="border: 1px solid black; padding: 5px;">42 Mo molybdenum 95.9</div> <div style="border: 1px solid black; padding: 5px;">43 Tc technetium —</div> <div style="border: 1px solid black; padding: 5px;">44 Ru ruthenium 101.1</div> <div style="border: 1px solid black; padding: 5px;">45 Rh rhodium 102.9</div> <div style="border: 1px solid black; padding: 5px;">46 Pd palladium 106.4</div> <div style="border: 1px solid black; padding: 5px;">47 Ag silver 107.9</div> <div style="border: 1px solid black; padding: 5px;">48 Cd cadmium 112.4</div> <div style="border: 1px solid black; padding: 5px;">49 In indium 114.8</div> <div style="border: 1px solid black; padding: 5px;">50 Sn tin 118.7</div> <div style="border: 1px solid black; padding: 5px;">51 Sb antimony 121.8</div> <div style="border: 1px solid black; padding: 5px;">52 Te tellurium 127.6</div> <div style="border: 1px solid black; padding: 5px;">53 I iodine 126.9</div> <div style="border: 1px solid black; padding: 5px;">54 Xe xenon 131.3</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">55 Cs caesium 132.9</div> <div style="border: 1px solid black; padding: 5px;">56 Ba barium 137.3</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">57–71 lanthanoids</div> <div style="border: 1px solid black; padding: 5px;">72 Hf hafnium 178.5</div> <div style="border: 1px solid black; padding: 5px;">73 Ta tantalum 180.9</div> <div style="border: 1px solid black; padding: 5px;">74 W tungsten 183.8</div> <div style="border: 1px solid black; padding: 5px;">75 Re rhenium 186.2</div> <div style="border: 1px solid black; padding: 5px;">76 Os osmium 190.2</div> <div style="border: 1px solid black; padding: 5px;">77 Ir iridium 192.2</div> <div style="border: 1px solid black; padding: 5px;">78 Pt platinum 195.1</div> <div style="border: 1px solid black; padding: 5px;">79 Au gold 197.0</div> <div style="border: 1px solid black; padding: 5px;">80 Hg mercury 200.6</div> <div style="border: 1px solid black; padding: 5px;">81 Tl thallium 204.4</div> <div style="border: 1px solid black; padding: 5px;">82 Pb lead 207.2</div> <div style="border: 1px solid black; padding: 5px;">83 Bi bismuth 209.0</div> <div style="border: 1px solid black; padding: 5px;">84 Po polonium —</div> <div style="border: 1px solid black; padding: 5px;">85 At astatine —</div> <div style="border: 1px solid black; padding: 5px;">86 Rn radon —</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">87 Fr francium —</div> <div style="border: 1px solid black; padding: 5px;">88 Ra radium —</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">89–103 actinoids</div> <div style="border: 1px solid black; padding: 5px;">104 Rf rutherfordium —</div> <div style="border: 1px solid black; padding: 5px;">105 Db dubnium —</div> <div style="border: 1px solid black; padding: 5px;">106 Sg seaborgium —</div> <div style="border: 1px solid black; padding: 5px;">107 Bh bohrium —</div> <div style="border: 1px solid black; padding: 5px;">108 Hs hassium —</div> <div style="border: 1px solid black; padding: 5px;">109 Mt meitnerium —</div> <div style="border: 1px solid black; padding: 5px;">110 Ds darmstadtium —</div> <div style="border: 1px solid black; padding: 5px;">111 Rg roentgenium —</div> <div style="border: 1px solid black; padding: 5px;">112 Cn copernicium —</div> <div style="border: 1px solid black; padding: 5px;">113 Nh nihonium —</div> <div style="border: 1px solid black; padding: 5px;">114 Fl flerovium —</div> <div style="border: 1px solid black; padding: 5px;">115 Mc moscovium —</div> <div style="border: 1px solid black; padding: 5px;">116 Lv livermorium —</div> <div style="border: 1px solid black; padding: 5px;">117 Ts tennessine —</div> <div style="border: 1px solid black; padding: 5px;">118 Og oganeson —</div> </div>															

lanthanoids

actinoids

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
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 —

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