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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

7777713940 9

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **October/November 2024**

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 [ ].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

This document has **16** pages.

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[Turn over

1 Vanadium, niobium and tantalum are metals in the same group of the Periodic Table.

(a) The shorthand electronic configuration of vanadium in the ground state is $[Ar]3d^34s^2$.

(i) State what is meant by the term ground state.

..... [1]

(ii) Show the electronic configuration of vanadium using electrons in boxes notation.

[Ar] ☐ ☐ ☐ ☐ ☐ ☐

[1]

(iii) Deduce the total number of electrons in the p sub-shells of a vanadium atom.

..... [1]

(b) Pelopium was the suggested name for a new element discovered in a mineral.

Pelopium was later found to be a mixture of niobium, Nb, and tantalum, Ta.

Only one naturally occurring isotope exists for each of Nb and Ta.

(i) Complete Table 1.1.

Table 1.1

isotope	relative isotopic mass	number of protons	number of neutrons
$^{93}_{41}Nb$	92.91		
$^{181}_{73}Ta$	180.95		

[2]

(ii) Define relative isotopic mass.

.....

.....

..... [2]

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(iii) A sample of pelopium contains 90.9% by mass $^{93}_{41}Nb$ and 9.1% by mass $^{181}_{73}Ta$.

Calculate the theoretical relative atomic mass of pelopium based on these data and Table 1.1.

Give your answer to two decimal places.

Show your working.

theoretical relative atomic mass of pelopium = ...
[2]

[Total: 9]

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2 Oxygen is a Group 16 element.

(a) (i) Write equations for the following reactions.

- sodium and oxygen

.....

- sulfur and oxygen

.....

[2]

(ii) Draw a dot-and-cross diagram to show the species present in Al_2O_3.

Draw outer electrons only.

[1]

(iii) The maximum oxidation state of the Period 3 elements in their oxides varies across the period.

State and explain the variation.

.....

.....

.....

[2]

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(b) H_2O reacts with both inorganic and organic compounds.

(i) Complete Table 2.1 to give details of the reactions of some Period 3 oxides with H_2O.

Table 2.1

Period 3 oxide	product of reaction with H_2O	pH of solution formed
	$Mg(OH)_2$	
P_4O_{10}		

[2]

(ii) Write an equation for the reaction of CH_3CN with H_2O in acidic conditions.

CH_3CN + ...H_2O + ...H^+ .....

[1]

(iii) Draw the structures of the two alcohols formed in the reaction shown in equation 1.

equation 1 $C_3H_6(g) + H_2O(g) \xrightarrow{H_3PO_4} C_3H_8O(g)$

[2]

(iv) Explain why alcohols are less acidic than water.

.....

.....

..... [2]

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(c) Fig. 2.1 shows the boiling points of H_2O and other Group 16 hydrides.

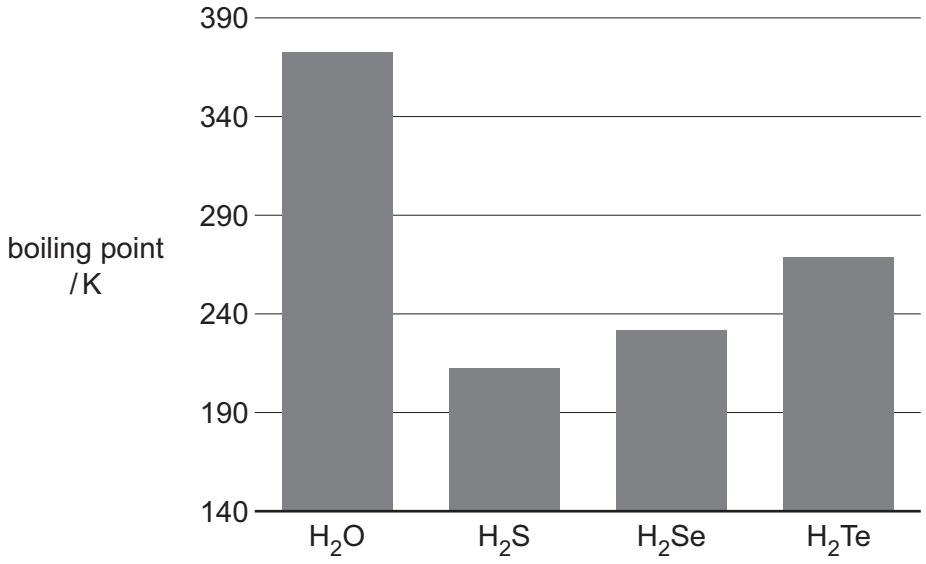

Fig. 2.1

(i) Explain the trend in the boiling points of the Group 16 hydrides H_2S to H_2Te.

.....

.....

.....

..... [2]

(ii) Explain why the boiling point of H_2O is much higher than that of H_2S.

.....

.....

..... [1]

[Total: 15]

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3 Nitrogen and phosphorus are elements in Group 15 of the Periodic Table.

(a) Nitrogen is found in inorganic compounds such as nitrogen oxides (NO_x), nitrates and nitric acid.

(i) Identify **one** natural and **one** man-made occurrence of nitrogen oxides in the atmosphere.

natural .....

man-made .....
[2]

(ii) Write an equation to describe the role of NO_2 in the direct formation of acid rain.

..... [1]

(iii) Peroxyacetyl nitrate, PAN, is a component of photochemical smog.

Describe how PAN forms from NO_2.

.....

..... [1]

(iv) Nitric acid reacts with basic oxides to form nitrates.

Write an equation for the reaction of nitric acid with calcium oxide.

..... [1]

(v) Describe what is seen when solid calcium nitrate is heated strongly.

..... [1]

(b) A common test for nitrates is the reaction with NaOH and A*l*. Equation 1 shows the reaction.

equation 1 $\quad 3NO_3^- + 8Al + 5OH^- + 18H_2O \rightarrow 3NH_3 + 8[Al(OH)_4]^-$

(i) Deduce the oxidation state of nitrogen in NO_3^-.

..... [1]

(ii) Identify the species that is oxidised in equation 1.

..... [1]

(iii) NH_3 is a basic gas.

Describe how NH_3 is able to act as a base.

.....

..... [1]

(iv) Suggest the shape of the $[Al(OH)_4]^-$ ion.

..... [1]

(c) Fig. 3.1 shows a sketch of some of the ionisation energies of phosphorus, P.

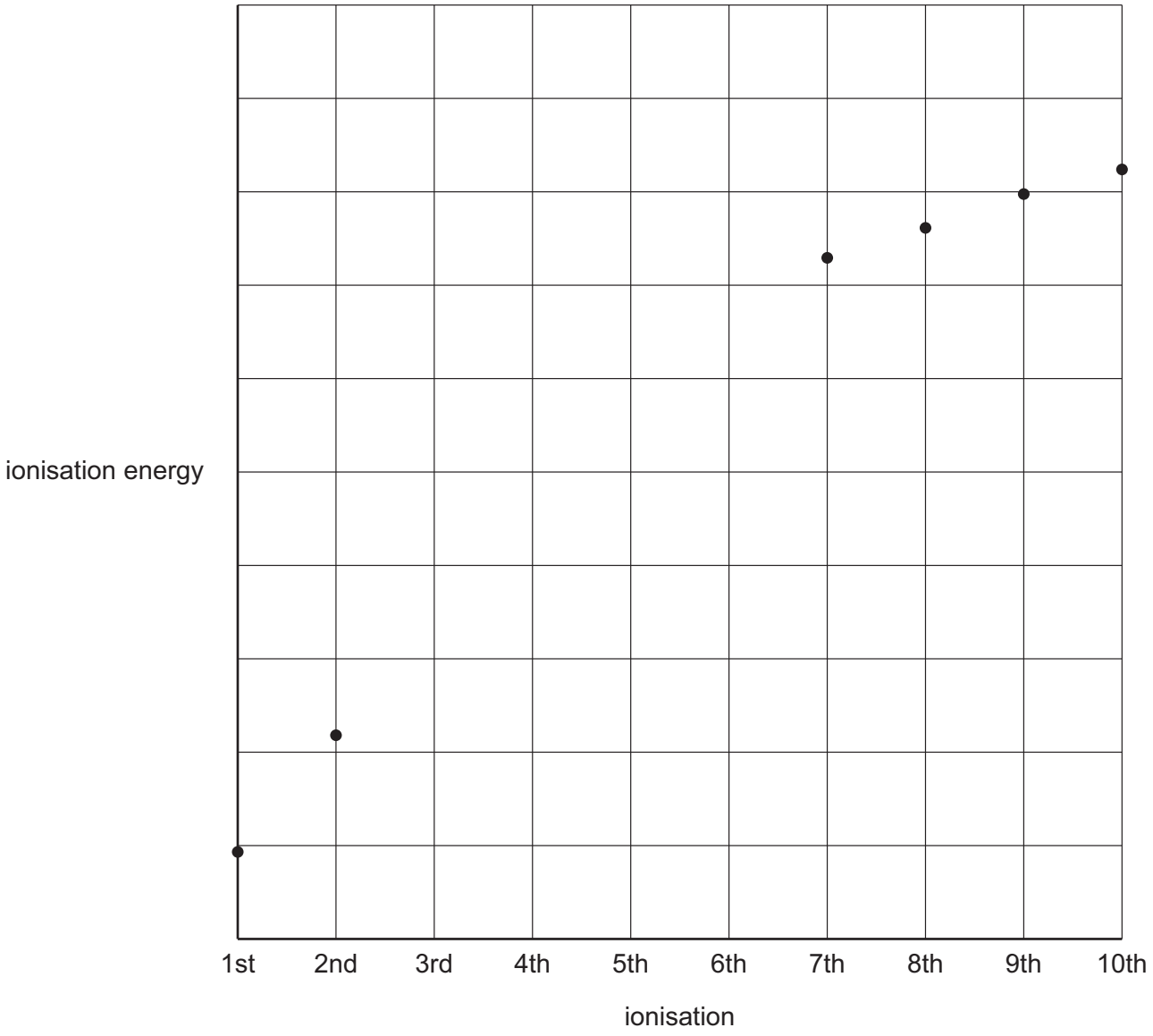

Fig. 3.1

(i) Construct an equation to represent the third ionisation energy of P.

..... [1]

(ii) Complete the graph in Fig. 3.1 to show the third to sixth ionisation energies of P.

[2]

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(d) Complete Table 3.1 to show the properties of nitrogen and phosphorus in their standard states.

Table 3.1

	nitrogen	phosphorus
state and appearance of standard state	colourless gas	white solid
electrical conductivity		poor
type of bonding		
type of structure	simple	

[2]

(e) A form of solid nitrogen has a lattice structure similar to solid iodine.

Identify the type of lattice structure of solid nitrogen.

..... [1]

(f) At very high temperatures, phosphorus can form P_2 molecules.

P_2 contains a triple bond, P≡P.

(i) Describe the formation of the P≡P bond in terms of orbital overlap.

.....

.....

.....

..... [2]

(ii) The bond energy of P≡P is 485 kJ mol^{-1}. The bond energy of N≡N is 944 kJ mol^{-1}. Compare the reactivity of P_2 and N_2. Explain your answer.

.....

.....

..... [1]

[Total: 19]

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4 Bromoalkanes are used widely in industry, although there is increasing concern about their environmental impact.

Fig. 4.1 shows a reaction scheme involving 1,2-dibromoethane.

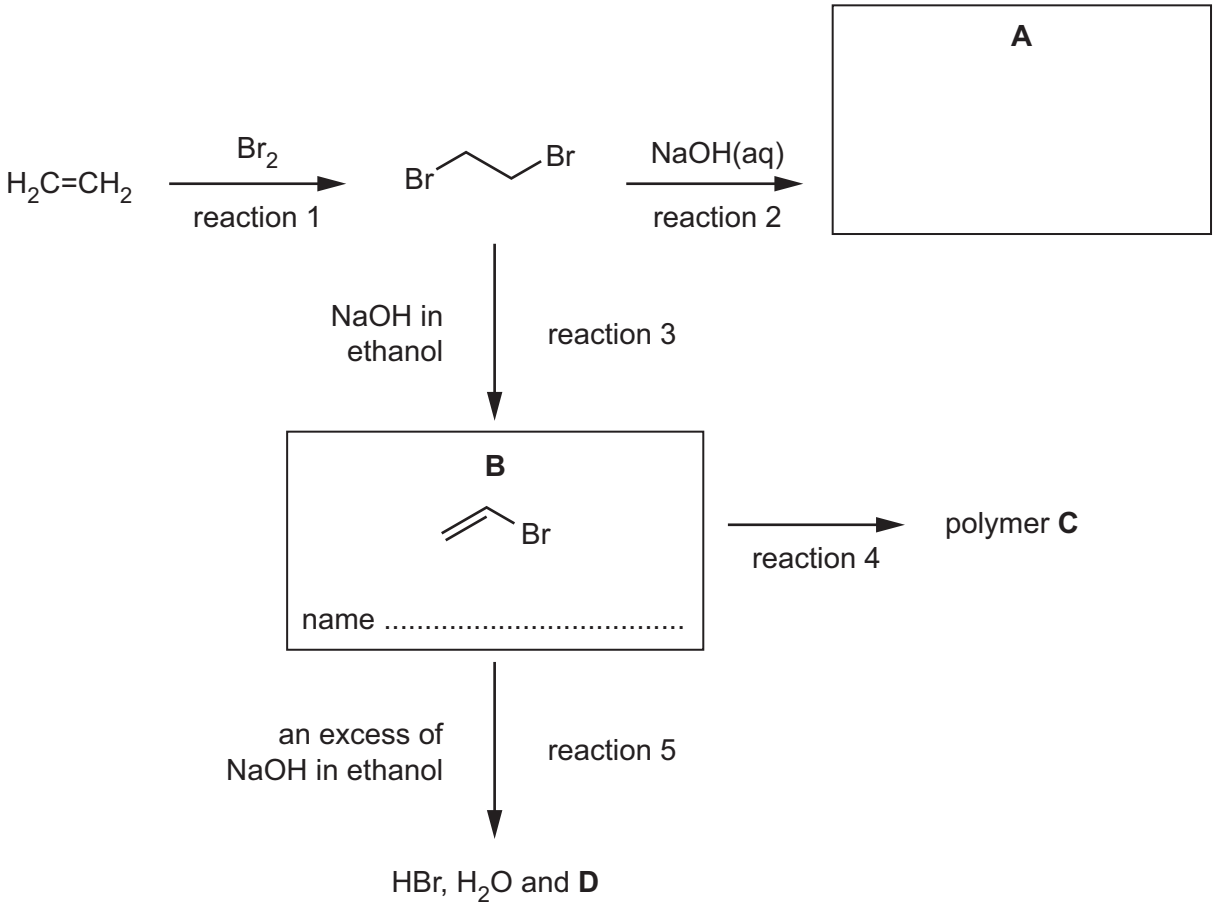

Fig. 4.1

(a) Complete Fig. 4.2 to show the mechanism for the formation of 1,2-dibromoethane in reaction 1.

Include charges, dipoles, lone pairs of electrons and curly arrows as appropriate.



Fig. 4.2

[3]

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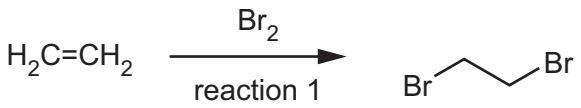
(b) The enthalpy change of reaction 1, $\Delta H_r = -90.0\,kJ\,mol^{-1}$.



The enthalpy change of formation of ethene, $\Delta H_f = +52.2\,kJ\,mol^{-1}$.

Calculate the enthalpy change of formation of 1,2-dibromoethane.

ΔH_f of 1,2-dibromoethane = ... $kJ\,mol^{-1}$ [1]

(c) (i) Complete Fig. 4.1 to:

- draw the structure of compound **A**
- name compound **B**.

[2]

(ii) Draw the structure of one repeat unit of polymer **C** in the box.

one repeat unit of polymer **C**

[1]

(iii) In reaction 5, compound **B** reacts with an excess of NaOH dissolved in ethanol. The products are HBr, H_2O and an unsaturated hydrocarbon **D**.

Suggest the identity of **D**.

..... [1]

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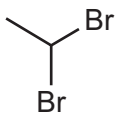
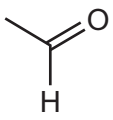
(d) Compound **E** is the only isomer of 1,2-dibromoethane.

Alkaline hydrolysis of **E** gives compound **F**.

E



F



(i) Identify the type of isomerism shown by **E** and 1,2-dibromoethane.

..... [1]

(ii) Name the homologous series that **F** belongs to.

..... [1]

(iii) Complete Table 4.1 to state what is observed when **F** reacts with the reagents listed.

Table 4.1

reagent	observation with **F**
2,4-dinitrophenylhydrazine (2,4-DNPH reagent)	
Tollens' reagent	
alkaline I_2(aq)	

[3]

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Question 4 continues on page 14.

(e) Compound **F** reacts with reagent **G** to form compound **H**.



The infrared spectrum of **H** is shown in Fig. 4.3.

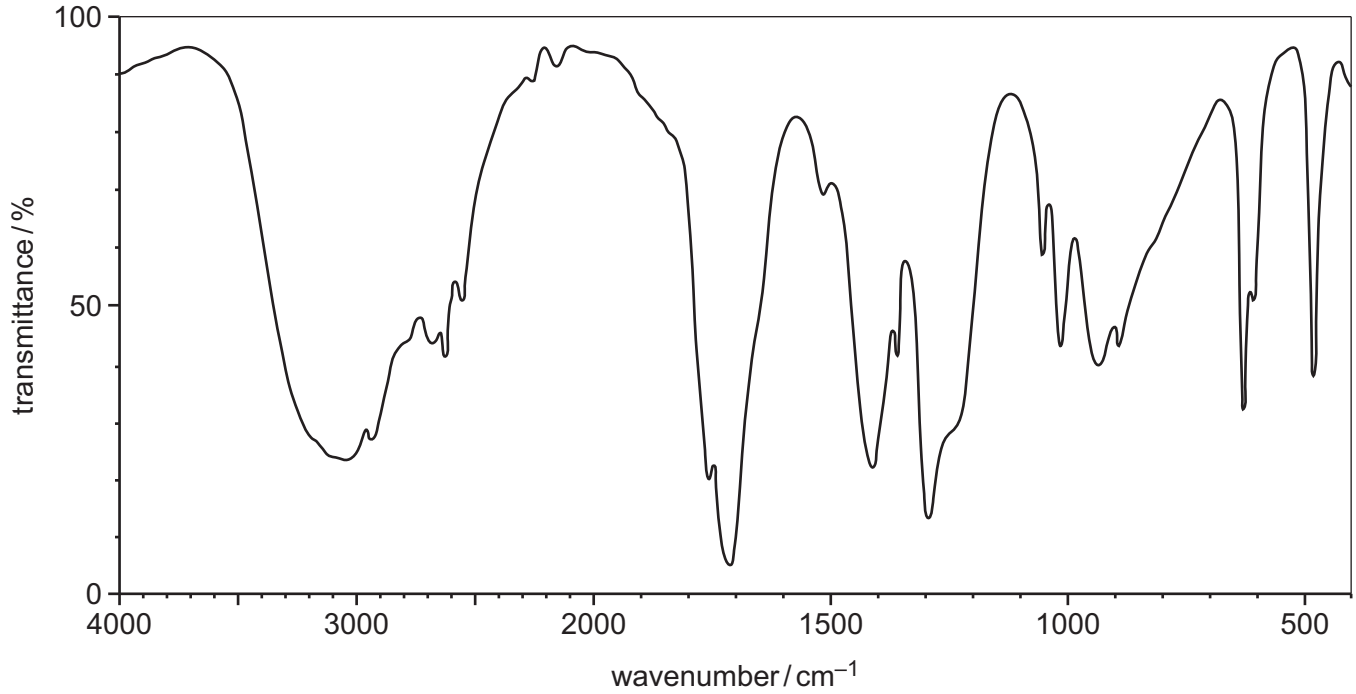

Fig. 4.3

Table 4.2

bond	functional groups containing the bond	characteristic infrared 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	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3600

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H also shows a molecular ion peak at *m*/*e* = 60 in its mass spectrum.

(i) Use the information in **(e)**, Fig. 4.3 and Table 4.2 to deduce the structure of **H**. Explain your answer fully.

H

.....

.....

.....

[3]

(ii) Suggest the role of reagent **G**.

.....

[1]

[Total: 17]

Important values, constants and standards

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

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The Periodic Table of Elements

Group																	
1	2											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	3	4	5	6	7	8	9	10	11	12	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 –

Key

atomic number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	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 –

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