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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

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CHEMISTRY **9701/21**

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 **20** pages. Any blank pages are indicated.

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[Turn over

1 Cobalt, rhodium and iridium are metals in the same group of the Periodic Table.

(a) The shorthand electronic configuration of cobalt is $[Ar]3d^74s^2$.

(i) Identify what is meant by [Ar] by giving its full electronic configuration.

..... [1]

(ii) The lowest-energy electrons in cobalt are in the 1s orbital.

Draw the shape of a 1s orbital.

[1]

(iii) Deduce the number of unpaired electrons in a cobalt atom.

..... [1]

(b) Table 1.1 gives some details of the stable naturally occurring isotopes of rhodium and iridium.

Table 1.1

isotope	number of protons	number of neutrons	total number of electron shells
$^{103}_{45}Rh$		58	
$^{191}_{77}Ir$			6
$^{193}_{77}Ir$			6

Complete Table 1.1.

[3]

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(c) Table 1.2 shows the relative abundances of isotopes in a sample of an alloy containing rhodium and iridium only.

Table 1.2

isotope	relative isotopic mass	relative abundance in alloy
$^{103}_{45}Rh$	102.91	50.00
$^{191}_{77}Ir$	190.96	15.18
$^{193}_{77}Ir$	192.96	34.82

(i) Define relative isotopic mass.

.....

.....

..... [2]

(ii) Use Table 1.2 to calculate the relative atomic mass, A_r, of iridium in the alloy.

Give your answer to **two** decimal places.

relative atomic mass of iridium = ... [2]

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(d) Hydrated rhodium(III) chloride, $RhCl_3 \cdot xH_2O$, catalyses the conversion of ethene to but-2-ene.

Both stereoisomers of but-2-ene are formed in the reaction.

(i) Hydrated rhodium(III) chloride contains 20.5% by mass of water of crystallisation.

Deduce the integer value of x in $RhCl_3 \cdot xH_2O$.

Show your working.

x = ...
[2]

(ii) Define stereoisomers.

.....

..... [1]

(iii) Explain how the conversion of ethene to but-2-ene can be described as an addition reaction.

.....

..... [1]

(iv) Draw the two stereoisomers of but-2-ene.

[2]

[Total: 16]

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2 Chlorine is one of the elements in Group 17 of the Periodic Table.

(a) **(i)** Describe the colours of the Group 17 elements, chlorine to iodine, at room temperature.

.....

..... [1]

(ii) Describe the relative reactivity of the elements chlorine to iodine as oxidising agents.

..... [1]

(iii) State what is observed when chlorine reacts with hydrogen.

..... [1]

(iv) Explain why the thermal stability of the hydrogen halides decreases down the group.

.....

..... [1]

(b) The halogenoalkane CH_3CH_2Cl forms when chlorine reacts with C_2H_6 via a free-radical substitution mechanism.

(i) Define free radical.

.....

..... [1]

(ii) State the essential condition for chlorine to react with C_2H_6 at room temperature.

..... [1]

(iii) Write **two** equations to show the propagation steps in this reaction.

1 .....

2 .....

[2]

(c) $CHCl_3$ is another halogenoalkane. $CHCl_3$ forms when propanone reacts with NaClO.

NaClO is made from chlorine in a disproportionation reaction.

(i) Identify a reagent and conditions that can be used to convert chlorine to NaClO.

..... [1]

(ii) Define disproportionation.

.....

..... [1]

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(iii) Write numbers in the boxes to balance the equation showing the reaction of propanone with NaC*l*O.

CH_3COCH_3 + ☐ NaC*l*O → ☐ CHCl_3 + ☐ CH_3COONa + ☐ NaOH

[1]

(iv) Aqueous $AgNO_3$ dissolved in ethanol reacts with an aqueous solution of CHCl_3.

State what is observed in this reaction. Explain your answer.

.....

.....

..... [2]

[Total: 13]

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3 The Group 14 elements show a change from non-metallic to metallic character down the group.

(a) Table 3.1 shows some properties of two Group 14 elements, C and Sn, in their standard states. The table is incomplete.

Table 3.1

	C (graphite)	Sn
state and appearance in standard state	grey shiny solid	silvery solid
electrical conductivity		good
type of bonding		metallic
type of structure	giant	

(i) Complete Table 3.1. [3]

(ii) Identify the lattice structure shown by graphite.

..... [1]

(iii) Explain why Sn has good electrical conductivity.

.....

..... [1]

(b) Carbon is found in inorganic compounds such as carbonates.

(i) Write an equation for the reaction of magnesium carbonate with dilute HC*l*(aq).

..... [1]

(ii) Describe the thermal stability of the carbonates down Group 2.

..... [1]

(iii) Ammonium carbonate undergoes an acid–base reaction with NaOH(aq).

Explain this statement.

.....

.....

..... [2]

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(c) Fig. 3.1 shows a sketch of some of the ionisation energies of silicon, Si.

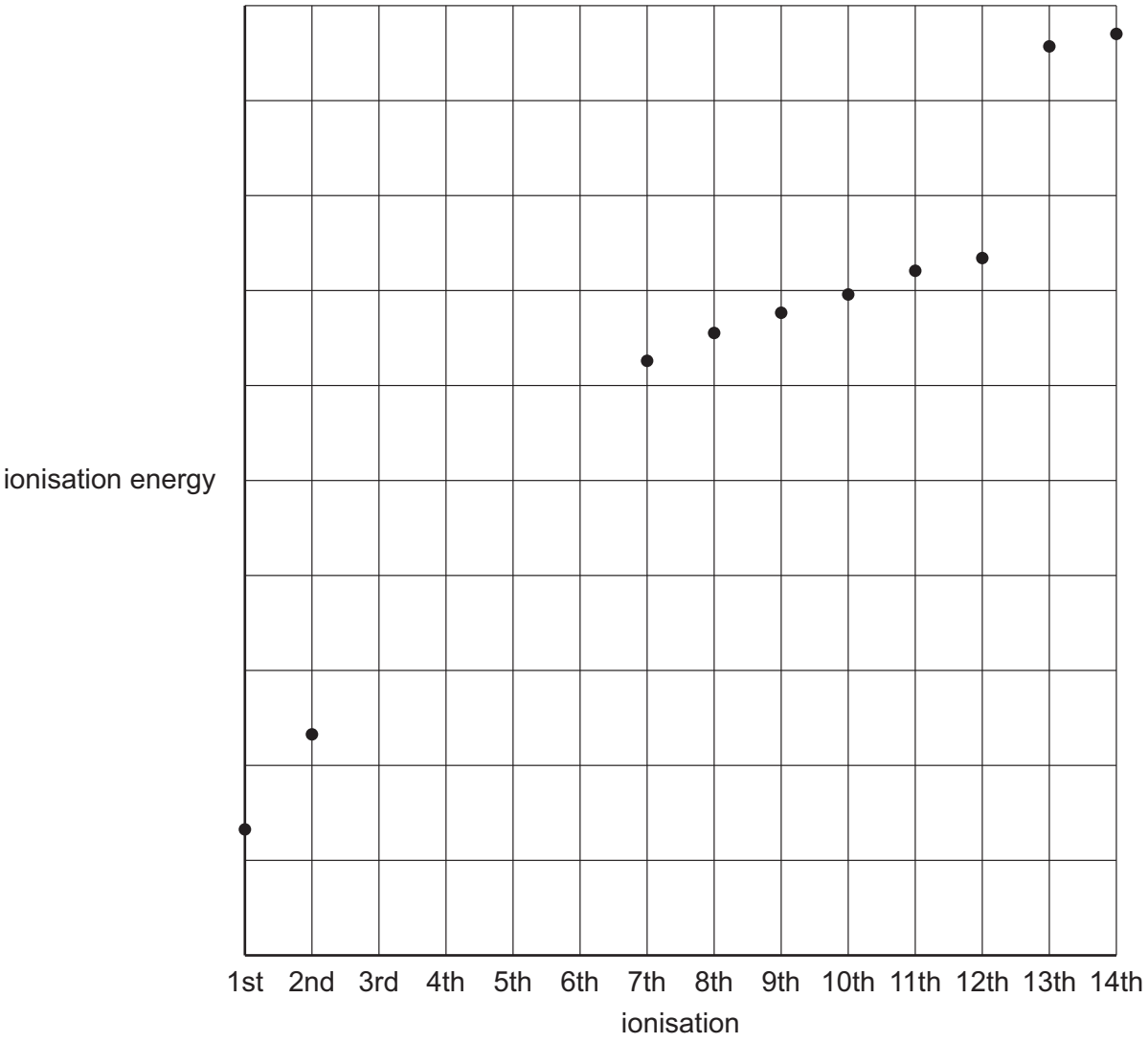

Fig. 3.1

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

[2]

(ii) Construct an equation to represent the second ionisation energy of Si.

..... [1]

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(d) Fig. 3.2 shows the boiling points of the simplest hydrides of the Group 14 elements, C to Pb.

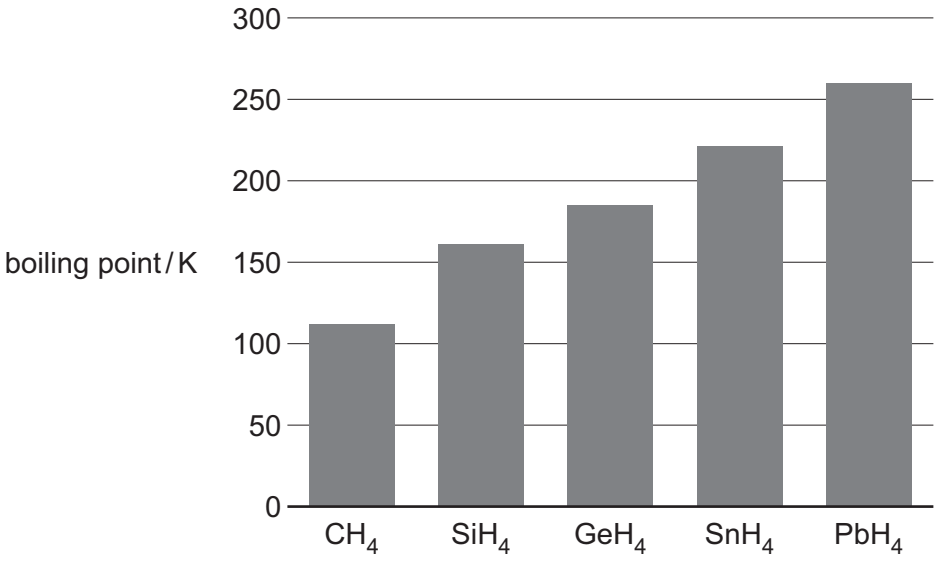

Fig. 3.2

(i) Explain the trend in the boiling points of the Group 14 hydrides shown in Fig. 3.2.

.....

.....

.....

..... [2]

(ii) Deduce the shape of a molecule of SiH_4.

..... [1]

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(e) Silicon readily reacts with elements of high electronegativity.

(i) Write an equation for the formation of $SiCl_4$ from its constituent elements.

..... [1]

(ii) Describe what is observed when a small sample of $SiCl_4$ is added to water.

.....

..... [1]

(iii) SiO_2 is a white solid that melts above 1700 °C.

$SiCl_4$ is a colourless liquid at room temperature.

Explain the difference in the melting points of these two compounds with reference to their structure and bonding.

.....

.....

.....

.....

..... [2]

(f) Tin forms an amphoteric oxide, SnO_2.

Suggest the formula of the tin compound that forms when SnO_2 reacts with H_2SO_4 in an acid–base reaction.

..... [1]

[Total: 20]

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4 Propanone, CH_3COCH_3, is an important organic reagent. Fig. 4.1 shows some reactions of propanone and its derivatives.

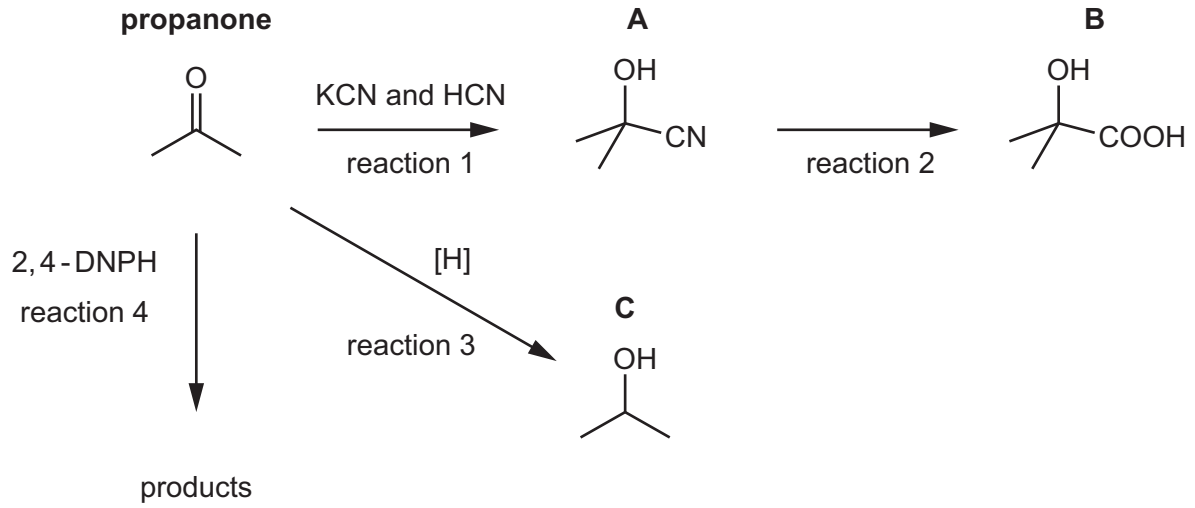

Fig. 4.1

(a) Reaction 1 is a nucleophilic addition reaction.

(i) Complete Fig. 4.2 to show the mechanism for the formation of **A** from propanone.

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



Fig. 4.2

[3]

(ii) Explain why **A** does **not** show optical isomerism.

.....

..... [1]

(b) Suggest the reagents and conditions for reaction 2.

..... [1]

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(c) Reaction 3 is a reduction reaction.

(i) Construct an equation to represent reaction 3.

Use [H] to represent one atom of hydrogen from the reducing agent.

..... [1]

(ii) Name **C**.

..... [1]

(d) State what is observed in reaction 4.

..... [1]

(e) Explain why Fehling's reagent does **not** react with propanone.

.....

..... [1]

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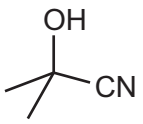
(f) Compounds **A**, **B** and **C** can be distinguished using infrared spectroscopy.

A



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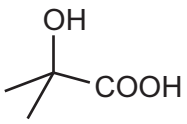

C

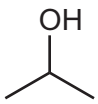

Fig. 4.3 shows the infrared spectrum of one of the compounds.

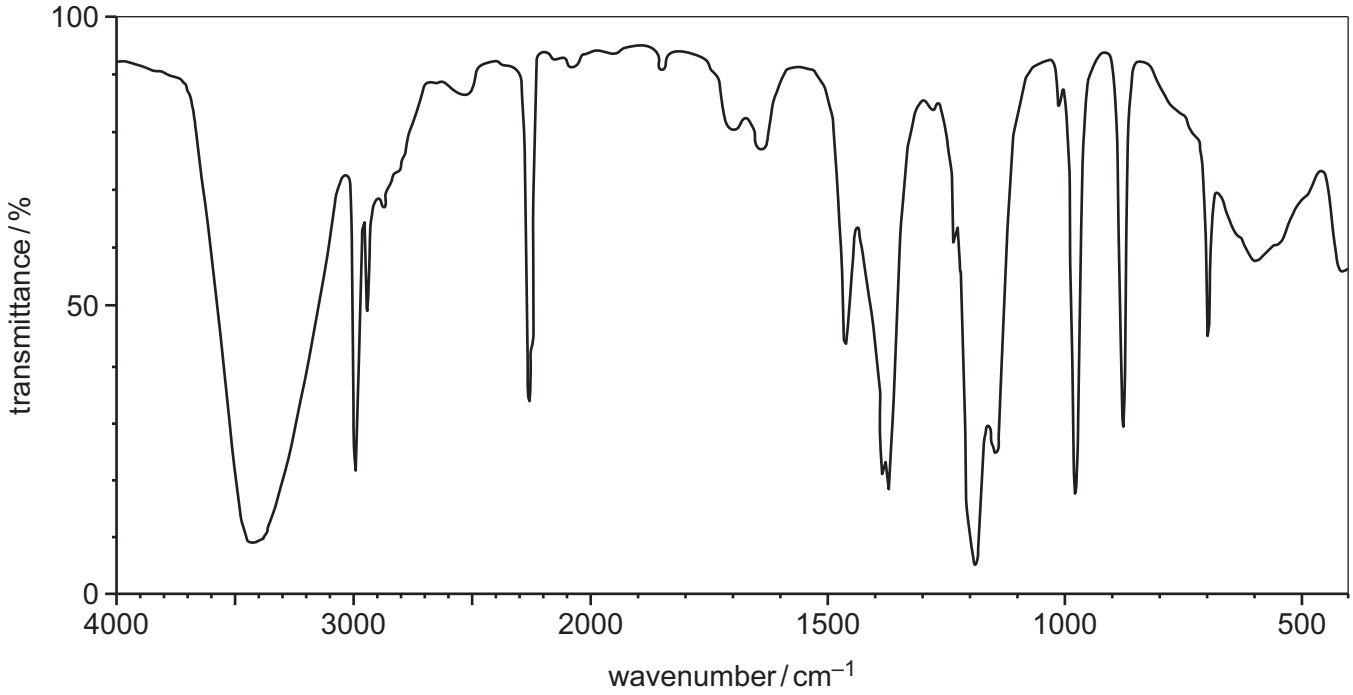

Fig. 4.3

Table 4.1

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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(i) Explain why the absorptions at 2850–2950 cm^{-1} are **not** useful to help determine which of the compounds **A**, **B** or **C** produces the infrared spectrum in Fig. 4.3.

Use Table 4.1 to answer this question.

.....

..... [1]

(ii) Identify which of compounds **A**, **B** or **C** produces the infrared spectrum in Fig. 4.3. Explain your answer.

compound .....

explanation .....

.....

.....

[1]

[Total: 11]

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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	$c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$)

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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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