



Cambridge International AS & A Level

CANDIDATE
NAME

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CENTRE
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CHEMISTRY

9701/22

Paper 2 AS Level Structured Questions

February/March 2023

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. Any blank pages are indicated.

- 1 The Pauling electronegativity values of elements can be used to predict the chemical properties of compounds.

Use the information in Table 1.1 to answer the following questions.

Table 1.1

element	H	Li	C	O	S
Pauling electronegativity value	2.1	1.0	2.5	3.5	2.6
first ionisation energy/ kJ mol^{-1}	1310	519	1090	1310	1000
second ionisation energy/ kJ mol^{-1}	—	7300	2350	3390	2260

- (a) (i) Define electronegativity.

.....
 [1]

- (ii) O and S are in Group 16.

Explain the difference in the Pauling electronegativity values of O and S.

.....

 [2]

- (b) (i) LiH is an ionic compound.

Draw a dot-and-cross diagram of LiH.

Include **all** electrons.

[2]

- (ii) Suggest the shape of a molecule of H_2S .

..... [1]

- (c) (i) Write an equation that represents the first ionisation energy of H.
..... [1]
- (ii) Explain why there is no information given in Table 1.1 for the second ionisation energy of H.
..... [1]
- (iii) Give the full electronic configuration of $S^{2+}(g)$.
..... [1]
- (d) CO_2 and SO_2 are acidic gases.
- (i) Write an equation for the reaction of SO_2 with H_2O .
..... [1]
- (ii) Write an equation for the reaction of SO_2 with $NaOH$.
..... [1]
- (iii) Construct an equation for the reaction of CO_2 with $Mg(OH)_2$.
..... [1]

- (e) (i) Complete Table 1.2 by placing a tick (✓) to show which of the compounds have molecules with an overall dipole moment.

Table 1.2

compound	O=C=O	O=S=O	S=C=S	S=C=O
overall dipole moment				

[2]

- (ii) At 150 °C and 103 kPa, all of the compounds listed in Table 1.2 are gases.

Under these conditions, 0.284 g of one of the compounds occupies a volume of 127 cm³.

Use this information to calculate the M_r of the compound. Hence, identify the compound from those given in Table 1.2.

Show your working.

$M_r = \dots\dots\dots$ identity of compound = $\dots\dots\dots$ [3]

[Total: 17]

2 The Group 2 elements Mg to Ba are all silvery-white reactive metals.

- (a) (i) Draw a labelled diagram to show the bonding and structure of the Group 2 metals at room temperature.

[2]

- (ii) Explain why Mg has a higher electrical conductivity than Na.

.....
..... [1]

- (b) Write an equation for the reaction of magnesium with cold water.

..... [1]

- (c) Identify a single reagent that can be used to distinguish separate samples of dilute $\text{Mg}(\text{NO}_3)_2(\text{aq})$ and dilute $\text{Ba}(\text{NO}_3)_2(\text{aq})$.

Explain your answer.

reagent

explanation

..... [2]

- (d) (i) Describe what is observed when $\text{SrI}_2(\text{aq})$ reacts with concentrated sulfuric acid.

.....
..... [2]

- (ii) Compound **X**, an anhydrous Group 2 bromide, is dissolved in water and titrated against aqueous silver nitrate.

A solution containing 0.250 g of **X** requires 33.65 cm^3 of $0.0500 \text{ mol dm}^{-3} \text{ AgNO}_3(\text{aq})$ for complete reaction.

Identify **X**.

Show your working.

X = [3]

[Total: 11]

- 3 Alkenes undergo an addition reaction with a 1:1 mixture of CO and H₂ to form aldehydes.

Fig. 3.1 shows the reaction of propene with a 1:1 mixture of CO and H₂.

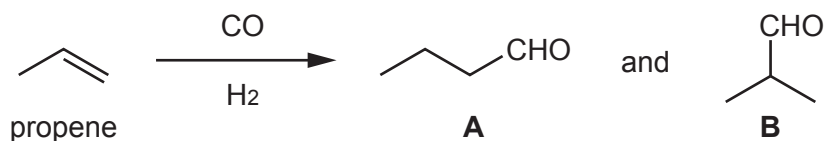


Fig. 3.1

- (a) (i) Define addition reaction.

.....
 [1]

- (ii) Aldehydes **A** and **B** are structural isomers.

State the type of structural isomerism shown by **A** and **B**.

..... [1]

- (iii) Name **A**.

..... [1]

- (iv) The complete reaction of propene with a 1:1 mixture of CO and H₂ produces **A** and **B** only. The product mixture contains 96% **A** and 4% **B**.

Calculate the mass of **A** produced in this reaction when 5.00×10^3 kg of propene is used.

mass of **A** = kg [1]

(b) **A** and **B** show reactions typical of aliphatic aldehydes.

- (i) **A** undergoes a nucleophilic addition reaction with a mixture of HCN and KCN, forming compound **C**.

Complete the diagram to show the mechanism for this reaction.

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

Draw the structure of the organic intermediate.



[4]

- (ii) Table 3.1 shows information about three experiments involving **B**.

Complete Table 3.1.

Table 3.1

experiment	reagents	observation with B
1		solution turns from orange to green
2		a silver mirror forms on the sides of the reaction vessel
3	Br ₂ (aq)	

[3]

- (iii) **B**, C₄H₈O, is oxidised by acidified potassium manganate(VII).

Complete the equation for this reaction. Use [O] to represent one atom of oxygen from the oxidising agent.



- (iv) **C** is a chiral molecule.

Circle any chiral centres in the structure of **C** shown in Fig. 3.2.

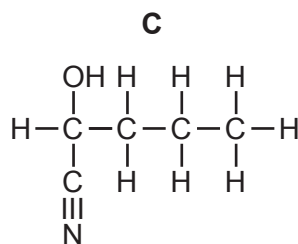


Fig. 3.2

[1]

- (c) When propene reacts with CO and an excess of H₂, an alkane and a mixture of alcohols are formed instead. The alcohols are isomers of each other.

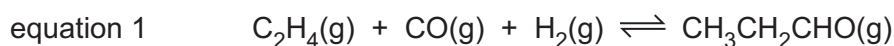
Suggest the molecular formulae of the alkane and the alcohols that are formed under these conditions.

molecular formula of alkane

molecular formula of alcohols

[2]

- (d) The reaction of ethene, C₂H₄, with a 1:1 mixture of CO and H₂ is shown in equation 1.



At atmospheric pressure a cobalt-based catalyst is used in this reaction.

- (i) State and explain the effect of using a catalyst on this reaction.

.....

[2]

- (ii) Explain why the yield of $\text{CH}_3\text{CH}_2\text{CHO}(\text{g})$ increases when the overall pressure of the reaction mixture is increased.

.....
 [1]

- (iii) Use the information in Table 3.2 to calculate the enthalpy change, ΔH_r , of the reaction in equation 1.

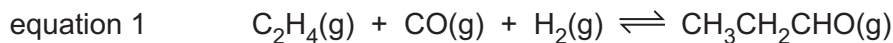


Table 3.2

compound	enthalpy change of formation, $\Delta H_f / \text{kJ mol}^{-1}$
$\text{C}_2\text{H}_4(\text{g})$	+52
$\text{CO}(\text{g})$	-111
$\text{CH}_3\text{CH}_2\text{CHO}(\text{g})$	-187

$\Delta H_r = \dots\dots\dots \text{kJ mol}^{-1}$ [2]

- (iv) The reaction mixture is cooled to collect $\text{CH}_3\text{CH}_2\text{CHO}$ as a liquid.

Identify all types of van der Waals' forces that are present between molecules of $\text{CH}_3\text{CH}_2\text{CHO}$.

.....
 [1]

[Total: 21]

4 Fig. 4.1 shows some reactions of compound **D**, 2-bromobutane.

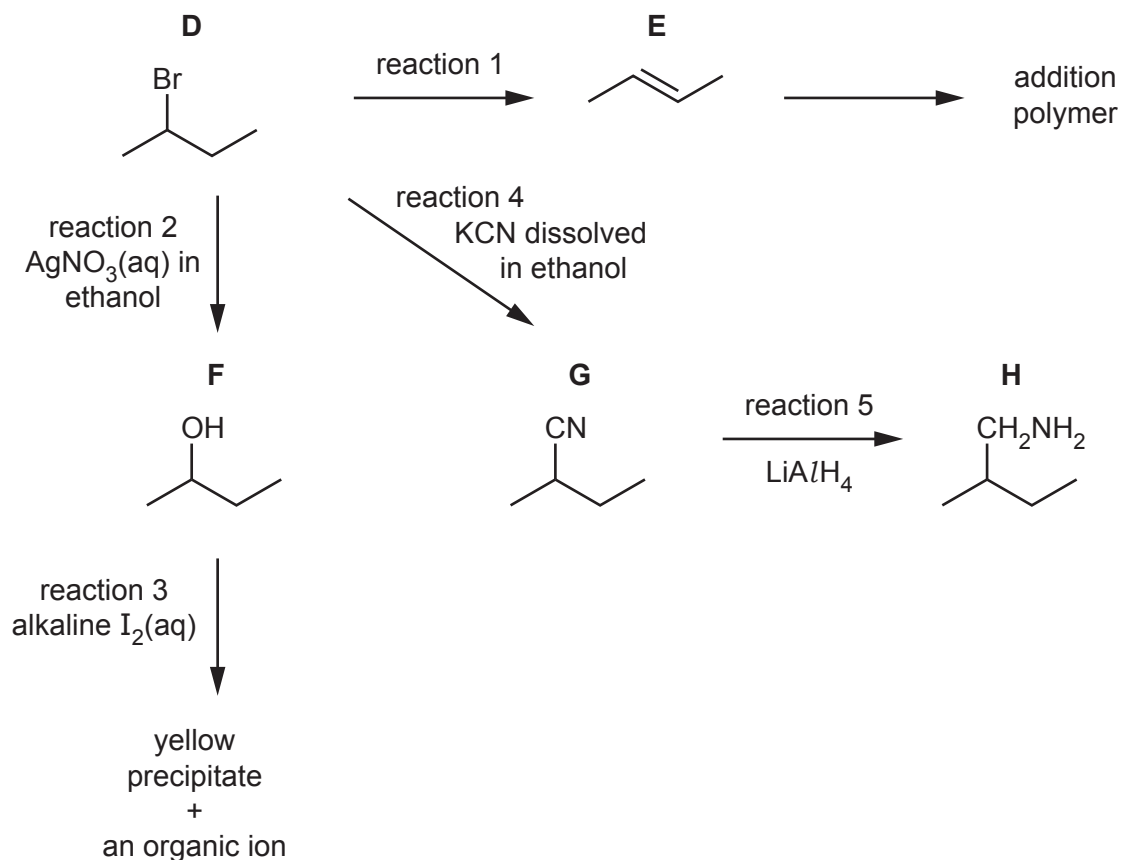


Fig. 4.1

(a) (i) State the reagent and conditions used to form **E** in reaction 1.

..... [1]

(ii) Draw the structure of **one** repeat unit of the addition polymer that forms from **E**.

[1]

(iii) **E** also forms when **F** is heated strongly in the presence of an Al₂O₃ catalyst.

Write an equation for this reaction.

..... [1]

(b) (i) Predict what is observed in reaction 2.

..... [1]

(ii) Identify the yellow precipitate and the organic ion formed in reaction 3.

yellow precipitate

organic ion

[2]

(c) (i) State the type of reaction that occurs in reaction 4.

..... [1]

(ii) Reaction 5 is similar to the reaction of LiAlH_4 with carboxylic acids to form alcohols.

Suggest the role of LiAlH_4 in reaction 5.

..... [1]

(d) (i) Fig. 4.2 shows the infrared spectrum of one of the compounds **D**, **E**, **F**, **G** or **H**.

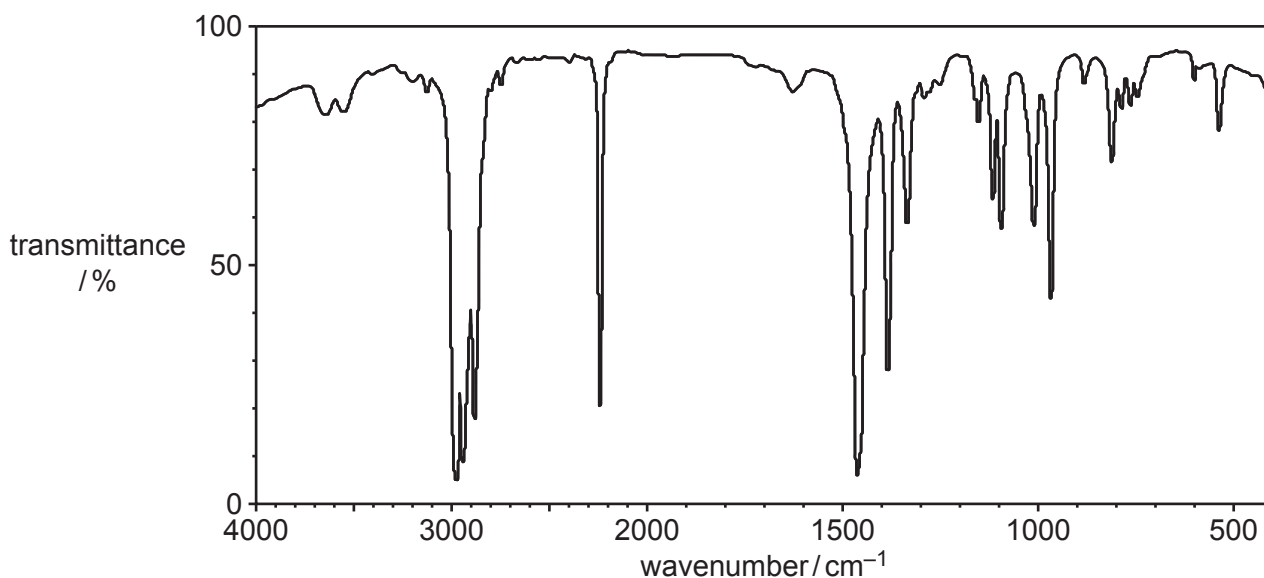


Fig. 4.2

Use information from Table 4.1 (on page 14) to identify which of the compounds **D**, **E**, **F**, **G** or **H** produces the infrared spectrum in Fig. 4.2.

Explain your answer.

.....

.....

..... [2]

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

(ii) In the mass spectrum of **D**, the relative abundance of the molecular ion peak is 3.4.

Predict the relative abundance of the M+2 peak for **D**.

Explain your answer.

.....

 [1]

[Total: 11]

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											13	14	15	16	17	18
		<div style="display: flex; justify-content: space-between;"> <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;"> <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;"> <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;"> <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;"> <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;"> <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;"> <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;"> <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;"> <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;"> <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;"> <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;"> <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;"> <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

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 —

actinoids