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Cambridge Assessment
International Education

Cambridge International AS & A Level

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CHEMISTRY

9701/22

Paper 2 AS Level Structured Questions

May/June 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. Any blank pages are indicated.



1 (a) Complete Table 1.1 using relevant information from the Periodic Table.

Table 1.1

	nucleon number	proton number	number of electrons
Mg^{2+}	24		
Al^{3+}	27		

[2]

(b) State and explain the difference in the ionic radius of Al^{3+} compared to Mg^{2+} .

.....

[3]

(c) Draw a labelled diagram to show the structure and bonding in sodium.



[1]

(d) Fig. 1.1 shows the variation in melting point of some Period 3 elements in their standard states at room temperature and pressure.

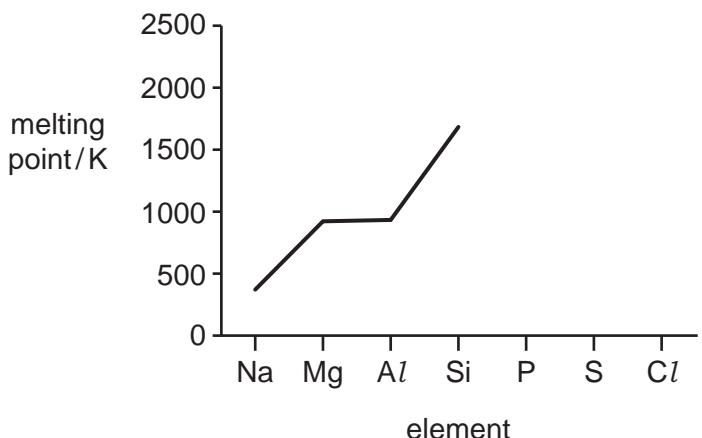


Fig. 1.1





(i) Explain why Si has a high melting point.

.....
.....
.....

[1]

(ii) Complete Fig. 1.1 to show the variation in the melting points of the elements P, S and Cl.
[2]

(e) Two Period 3 elements react with an excess of oxygen at room pressure.

(i) Complete Table 1.2.

Table 1.2

1	2	3
Period 3 element	state of oxide at room temperature and pressure	approximate pH of solution made when oxide is added to water
Na		
S		

[2]

(ii) The solutions made in column 3 of Table 1.2 are mixed together.
Name the type of reaction that occurs.

.....

[1]

(iii) Write an equation to describe the reaction between P_4O_{10} and an excess of water.

.....

[1]

(f) Aluminium hydroxide is amphoteric.

(i) Explain what is meant by amphoteric.

.....
.....

[1]

(ii) Write an equation to describe the reaction that occurs when aluminium hydroxide, $Al(OH)_3$, reacts with $NaOH(aq)$.

.....

[1]

[Total: 15]





2 Separate samples of Na_2CO_3 and NaHCO_3 react with HCl(aq) to produce the same products, as shown in Table 2.1.

Table 2.1

reaction	equation	$\Delta H/\text{kJ mol}^{-1}$
1	$\text{Na}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$	ΔH_1
2	$\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$	$\Delta H_2 = +27.2$

(a) Complete the reaction pathway diagram in Fig. 2.1 for reaction 2.

Label the diagram to show the enthalpy change, ΔH_2 , and the activation energy, E_A .

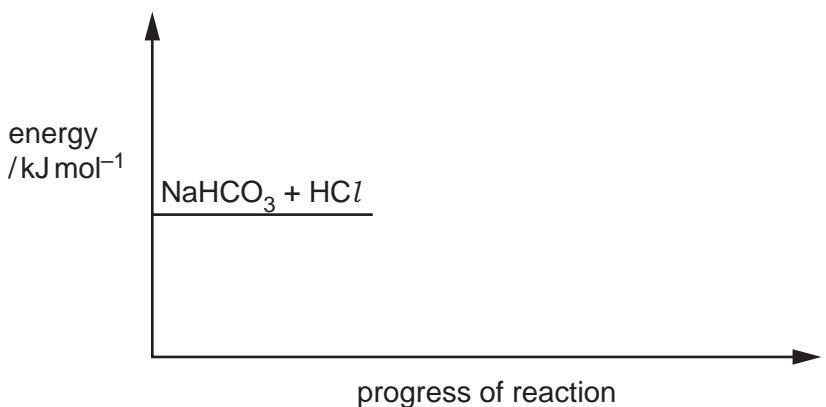


Fig. 2.1

[2]

(b) The value for ΔH_1 is determined by experiment using the following method.

- 50.0 cm^3 of 2.00 mol dm^{-3} HCl(aq) is added to a polystyrene cup.
- The initial temperature of the acid is recorded as 19.6°C .
- 0.0400 mol of Na_2CO_3 is added and the mixture is stirred.
- All the solid Na_2CO_3 disappears and a colourless solution is produced.

The maximum temperature recorded during the reaction is 26.2°C .

(i) Describe **one** other observation that shows the reaction is complete.

..... [1]





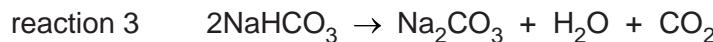
(ii) Calculate the value of ΔH_1 in kJ mol^{-1} .

Assume the specific heat capacity of the reaction mixture is the same as for water and no heat is lost to the surroundings.

Show your working.

$$\Delta H_1 = \dots \text{ kJ mol}^{-1} \quad [3]$$

(iii) Thermal decomposition occurs when NaHCO_3 is heated.



Calculate the enthalpy change for reaction 3, ΔH_r , using the data in Table 2.1 and the value of ΔH_1 calculated in (b)(ii).

(If you were unable to calculate a value for ΔH_1 in (b)(ii), assume the enthalpy change is $-38.4 \text{ kJ mol}^{-1}$. This is **not** the correct value.)

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

(c) **Z** is a salt that contains a Period 4 element from Group 2. When **Z** is heated brown gas forms.

Identify the formula of **Z** and use it to write an equation for the reaction.

..... [2]

[Total: 10]





3 (a) Describe what is meant by dynamic equilibrium.

[2]

(b) Reaction 4 describes the reversible reaction between yellow $\text{Fe}^{3+}(\text{aq})$ and colourless $\text{SCN}^-(\text{aq})$ to produce red $\text{FeSCN}^{2+}(\text{aq})$.



An equilibrium mixture contains $\text{Fe}^{3+}(\text{aq})$, $\text{SCN}^-(\text{aq})$ and $\text{FeSCN}^{2+}(\text{aq})$. A few colourless crystals of soluble $\text{KSCN}(\text{s})$ are added. The mixture is then left until it reaches equilibrium again. The temperature of both equilibrium mixtures is the same.

(i) Deduce the changes that occur, if any, in the equilibrium mixture after $\text{KSCN}(\text{s})$ is added compared to the original equilibrium mixture.

- change in appearance

- change in relative concentration of $\text{Fe}^{3+}(\text{aq})$

- change in value of the equilibrium constant, K_c

[3]





(ii) The expression for the equilibrium constant, K_c , for reaction 4 is shown.

$$K_c = \frac{[\text{FeSCN}^{2+}(\text{aq})]}{[\text{Fe}^{3+}(\text{aq})] \times [\text{SCN}^-(\text{aq})]}$$

5.00×10^{-5} mol of $\text{Fe}^{3+}(\text{aq})$ and 5.00×10^{-5} mol of $\text{SCN}^-(\text{aq})$ are added together and allowed to reach equilibrium. The total volume of the mixture is 25.0 cm^3 .

At equilibrium the concentration of $\text{FeSCN}^{2+}(\text{aq})$ is 4.23×10^{-4} mol dm^{-3} .

Calculate the equilibrium constant, K_c , for reaction 4.

Include the units in your answer.

$$K_c = \dots$$

units

[4]





(c) Determine the full electronic configuration of Fe^{3+} .

..... [1]

(d) $\text{SCN}^-(\text{aq})$ is colourless.

Complete the dot-and-cross diagram in Fig. 3.1 to show the arrangement of outer electrons in an SCN^- ion.

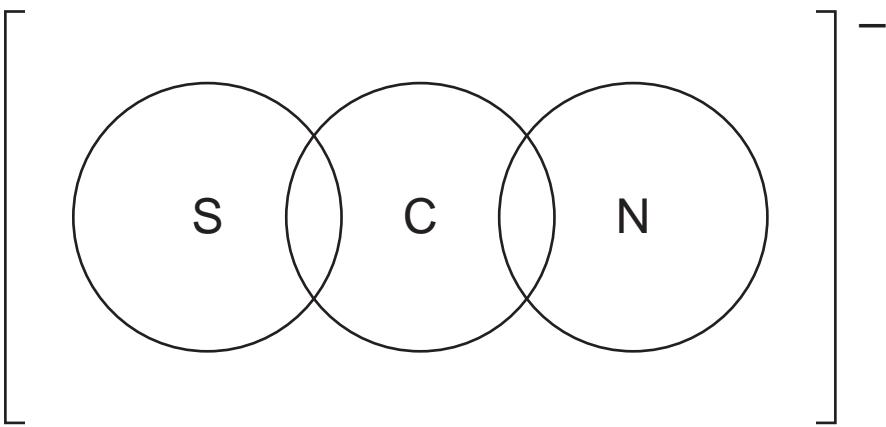


Fig. 3.1

[2]

[Total: 12]



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4 $\text{CH}_3(\text{CH}_2)_5\text{CHBrCH}_3$ exists as a pair of stereoisomers.

(a) Draw the three-dimensional structures of the **two** stereoisomers of $\text{CH}_3(\text{CH}_2)_5\text{CHBrCH}_3$. R can be used to represent $\text{CH}_3(\text{CH}_2)_5$.

|
|
|
|
|
|
|
|

[2]

(b) A sample of $\text{CH}_3(\text{CH}_2)_5\text{CHBrCH}_3$ reacts with NaOH to make $\text{CH}_3(\text{CH}_2)_5\text{CH}(\text{OH})\text{CH}_3$ in an $\text{S}_{\text{N}}1$ mechanism.

Complete Fig. 4.1 to show the mechanism for the reaction of $\text{CH}_3(\text{CH}_2)_5\text{CHBrCH}_3$ and NaOH.

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



Fig. 4.1

[3]

(c) Separate samples of $\text{CH}_3(\text{CH}_2)_5\text{CHBrCH}_3$, $\text{CH}_3(\text{CH}_2)_5\text{CH}(\text{OH})\text{CH}_3$ and $\text{CH}_3(\text{CH}_2)_5\text{CHCH}_2$ are tested with different reagents.

Complete Table 4.1. If no reaction occurs, write \times in the relevant box.

Table 4.1

reagent added	observation with $\text{CH}_3(\text{CH}_2)_5\text{CHBrCH}_3$	observation with $\text{CH}_3(\text{CH}_2)_5\text{CH}(\text{OH})\text{CH}_3$	observation with $\text{CH}_3(\text{CH}_2)_5\text{CHCH}_2$
$\text{Br}_2(\text{l})$ in the dark		\times	
$\text{PCl}_5(\text{s})$	\times		
$\text{AgNO}_3(\text{aq})$			\times

[3]





(d) $\text{CH}_3(\text{CH}_2)_5\text{CHBrCH}_3$ is heated with **D** to produce three different molecules, **E**, **F** and **G**.

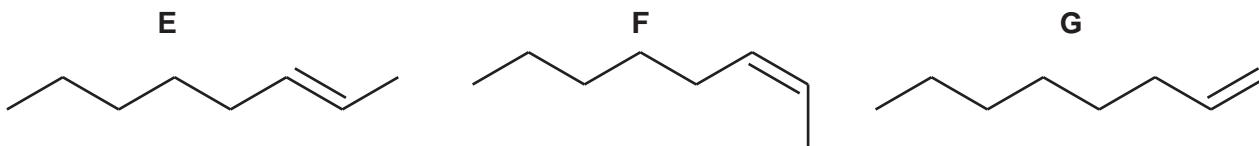


Fig. 4.2

(i) Name the type of reaction.

..... [1]

(ii) Identify **D** and the conditions used.

..... [1]

(e) (i) Both σ and π bonds are present in a molecule of **E** as a result of different types of hybridisation in the carbon atoms.

Complete Table 4.2 to show the number of carbon atoms with each type of hybridisation in a molecule of **E**.

Table 4.2

	number of carbon atoms		
	sp hybridised	sp ² hybridised	sp ³ hybridised
E 			

[2]

(ii) Describe the essential feature of an unbranched hydrocarbon that causes its molecules to show stereoisomerism. Explain how this feature leads to stereoisomerism.

.....
.....
..... [3]

[Total: 15]





5 Compound **W** has molecular formula $C_4H_{10}O$. It contains only **one** functional group.

(a) Table 5.1 shows the two peaks with the greatest m/e values in the mass spectrum of **W**.

Table 5.1

m/e	relative abundance
74	50
75	x

(i) Calculate the relative abundance, x, of the peak at $m/e = 75$ using the information from Table 5.1.

$$x = \dots \quad [1]$$

(ii) The mass spectrum of **W** also shows peaks at $m/e = 29$ and $m/e = 59$.

Suggest the molecular formulae of these fragments.

$m/e = 29$

$m/e = 59$

[2]

(b) A sample of **W**, $C_4H_{10}O$, is heated under reflux with an excess of acidified $K_2Cr_2O_7$ until there is no further reaction. Only **one** organic product, **X**, is present in the mixture at the end of the reaction.

Fig. 5.1 shows the infrared spectrum of **W**.

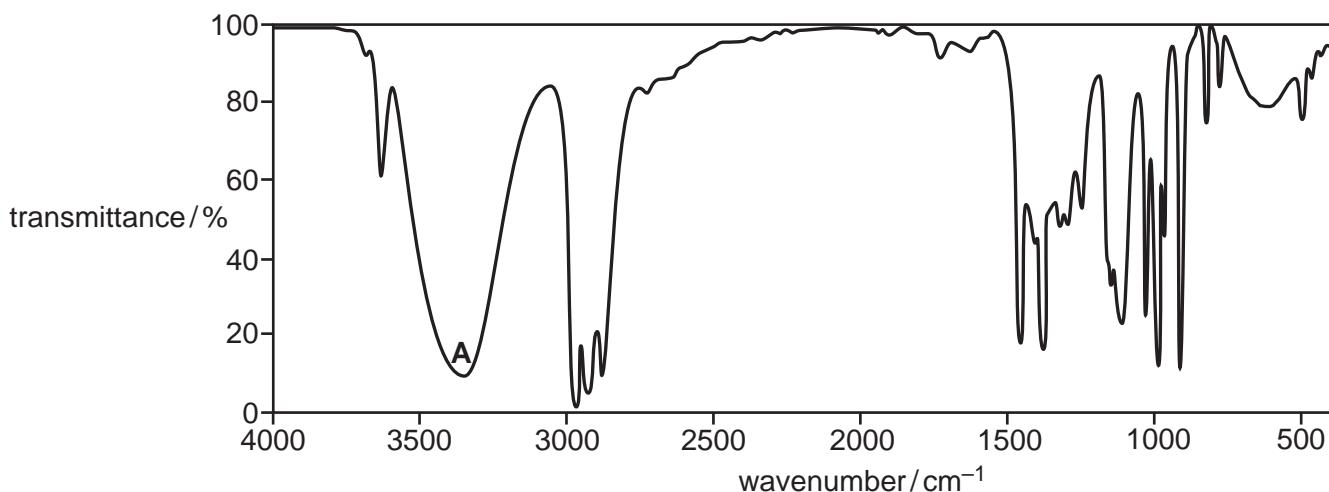


Fig. 5.1





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Fig. 5.2 shows the infrared spectrum of X.

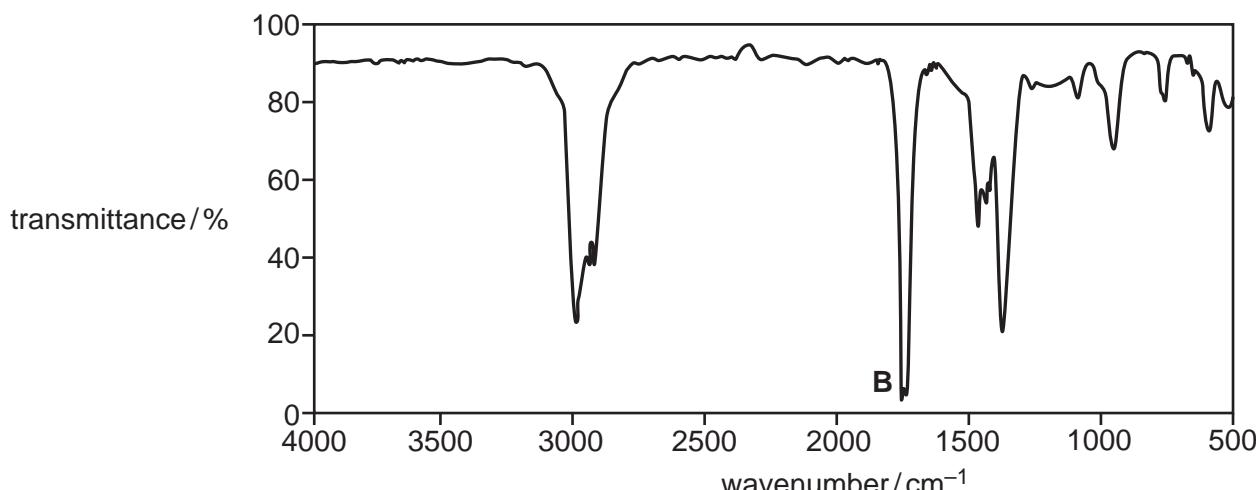


Fig. 5.2

Table 5.2

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 3200–3650

(i) Absorption **A** is shown in Fig. 5.1.
Absorption **B** is shown in Fig. 5.2.

Complete Table 5.3 using the information given in Fig. 5.1, Fig. 5.2 and Table 5.2.

Table 5.3

absorption	bond	functional group containing the bond
A		
B		

[1]





(ii) Use the information in (a) and (b)(i) to draw the structure of X in the box in Fig. 5.3.

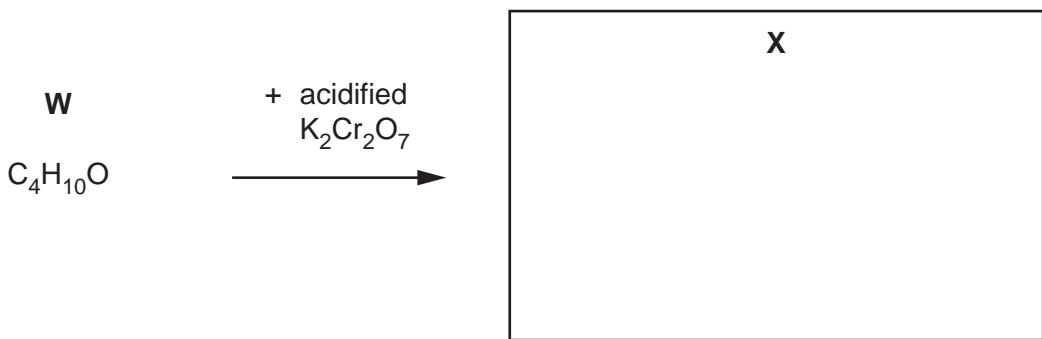


Fig. 5.3

[1]

(c) Y is a structural isomer of W.

Both **W** and **Y** produce colourless bubbles when sodium is added to them.

Y does **not** react when heated with acidified $K_2Cr_2O_7$.

Y does **not** react when warmed with alkaline $I_2(aq)$.

(i) Name the functional group present in Y.

..... [1]

(ii) Complete the equation to describe the reaction of **W** or **Y** with sodium.

.....C₄H₁₀O +Na → [1]

(iii) Draw the structure of Y.

[1]

[Total: 8]



**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 273K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)





The Periodic Table of Elements

1		2		Group																	
				1		H hydrogen 1.0															
				Key																	
3	Li	4	Be	atomic number name relative atomic mass	atomic symbol	atomic number name relative atomic mass	atomic symbol	5	B	6	C	7	N	8	O oxygen 16.0	9	F fluorine 19.0	10	Ne neon 20.2	11	He helium 4.0
11	Na	12	Mg	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
19	K	20	Ca	21	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	Ca
			calcium	45.0	scandium	titanium	vanadium	chromium	manganese	iron	cobalt	nickel	copper	zinc	gallium	germanium	arsenic	selenium	bromine	krypton	potassium
37	Rb	38	Y	39	40	41	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Te	Te	I	Xe	strontium
			rubidium	87.6	yttrium	88.9	zirconium	91.2	niobium	ruthenium	rhodium	palladium	silver	cadmium	indium	tin	antimony	iodine	iodine	xenon	potassium
55	Cs	56	Ba	57–71	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	barium	
			caesium	132.9	lanthanoids	hafnium	tantalum	rhenium	osmium	iridium	platinum	gold	mercury	thallium	lead	bismuth	polonium	astatine	radon	–	
87	Fr	88	Ra	89–103	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Ft	Mc	Lv	Ts	Og	francium	
			actinoids	–	rutherfordium	dubnium	seaborgium	bohrium	hassium	meitnerium	darmstadtium	roentgenium	copernicium	nihonium	flerovium	moscovium	livemorium	tennessine	oganeson	–	

57	La	58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Yb	70	Lu
	lanthanum		cerium		praseodymium		neodymium		promethium		samarium		europium		gadolinium		terbium		dysprosium		holmium		erbium		thulium		lutetium
89	Ac	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No
	actinium		thorium		protactinium		uranium		neptunium		plutonium		americium		curium		berkelium		californium		einsteinium		fermium		mendelevium		lawrencium

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