



# Cambridge International AS & A Level

CANDIDATE  
NAME

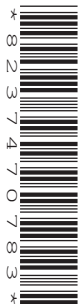
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## CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

May/June 2024

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

### 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 40.
- 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.
- Notes for use in qualitative analysis are provided in the question paper.

<b>Session</b>
<b>Laboratory</b>

For Examiner's Use	
1	
2	
3	
<b>Total</b>	

This document has **12** pages.

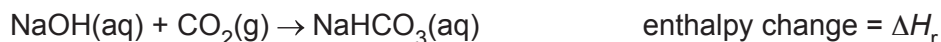
## Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

**1** In this experiment you will determine the enthalpy change,  $\Delta H_r$ , for the reaction shown.



You will react each of sodium hydroxide and sodium hydrogencarbonate with excess dilute sulfuric acid. You will determine the enthalpy change for each reaction, then use Hess's law to calculate  $\Delta H_r$ .

### (a) Reaction of sodium hydroxide with sulfuric acid



**FA 1** is  $2.00 \text{ mol dm}^{-3}$  sodium hydroxide, NaOH.

**FA 2** is  $2.00 \text{ mol dm}^{-3}$  sulfuric acid,  $\text{H}_2\text{SO}_4$ .

#### Method

- Support a cup in the  $250 \text{ cm}^3$  beaker.
- Use the  $50 \text{ cm}^3$  measuring cylinder to transfer  $30.0 \text{ cm}^3$  of **FA 1** into the cup.
- Place the thermometer in **FA 1** and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature of **FA 1**.
- Use the  $25 \text{ cm}^3$  measuring cylinder to add  $20.0 \text{ cm}^3$  of **FA 2** to the **FA 1** in the cup.
- Stir the mixture.
- Measure and record the maximum temperature reached.
- Calculate and record the change in temperature.

#### Results

I	
II	

[2]

### (b) Calculations

(i) Calculate the energy change, in J, in your experiment.

energy change = ..... J [1]

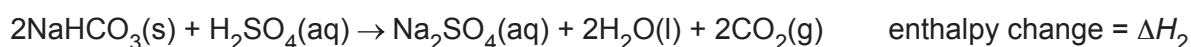
- (ii) Calculate the amount, in mol, of sulfuric acid that reacted with **FA 1** in your experiment.

amount of  $\text{H}_2\text{SO}_4$  = ..... mol [1]

- (iii) Calculate the enthalpy change of reaction,  $\Delta H_1$ , in  $\text{kJ mol}^{-1}$  of sulfuric acid, for the neutralisation of  $\text{NaOH}(\text{aq})$  with  $\text{H}_2\text{SO}_4(\text{aq})$ .  
Show your working.

$\Delta H_1 = \dots\dots\dots \text{kJ mol}^{-1}$  of  $\text{H}_2\text{SO}_4$  [1]  
*sign value*

**(c) Reaction of sodium hydrogencarbonate with sulfuric acid**



**FA 2** is  $2.00 \text{ mol dm}^{-3}$  sulfuric acid,  $\text{H}_2\text{SO}_4$ .

**FA 3** is sodium hydrogencarbonate,  $\text{NaHCO}_3$ .

**Method**

- Support the other cup in the  $250 \text{ cm}^3$  beaker.
- Use the  $25 \text{ cm}^3$  measuring cylinder to transfer  $25.0 \text{ cm}^3$  of **FA 2** into the cup.
- Place the thermometer in **FA 2** and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature of **FA 2**.
- Weigh the container with **FA 3**. Record the mass.
- Adding **small** quantities at a time, tip all the **FA 3** from the container into the **FA 2** in the cup.
- Stir the mixture.
- Measure and record the minimum temperature reached.
- Calculate and record the change in temperature.
- Weigh the container with any residual **FA 3**. Record the mass.
- Calculate and record the mass of **FA 3** added.

**Results**

I	
II	
III	

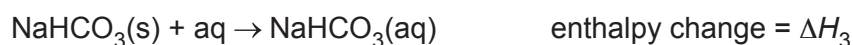
[3]

**(d) Calculations**

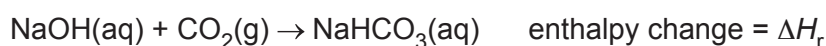
Use your data to calculate the enthalpy change,  $\Delta H_2$ , in  $\text{kJ mol}^{-1}$  of sulfuric acid, for the reaction of  $\text{NaHCO}_3(\text{s})$  with  $\text{H}_2\text{SO}_4(\text{aq})$ .  
Show your working.

$$\Delta H_2 = \underset{\text{sign}}{\dots\dots\dots} \underset{\text{value}}{\dots\dots\dots} \text{kJ mol}^{-1} \text{ of } \text{H}_2\text{SO}_4 \quad [3]$$

**(e)** The enthalpy change when one mole of sodium hydrogencarbonate dissolves in water is  $\Delta H_3$ .



Using the symbols  $\Delta H_1$ ,  $\Delta H_2$  and  $\Delta H_3$  in your answer, use Hess's law to deduce an expression for  $\Delta H_r$ .



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

**(f)** A student suggested that the experiment in **(c)** would be more accurate if  $25.0 \text{ cm}^3$  of  $3.00 \text{ mol dm}^{-3}$  sulfuric acid was used instead of  $25.0 \text{ cm}^3$  of  $2.00 \text{ mol dm}^{-3}$  sulfuric acid.

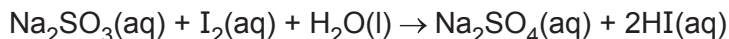
State whether the student's suggestion is correct.

Explain your answer.

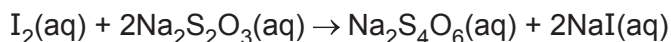
.....  
 .....  
 ..... [1]

[Total: 13]

2 Sodium sulfite is oxidised when it reacts with excess iodine.



The remaining iodine is then titrated using aqueous sodium thiosulfate.



You will determine the integer value of  $x$  in the formula of hydrated sodium sulfite,  $\text{Na}_2\text{SO}_3 \cdot x\text{H}_2\text{O}$ , by titration.

**FA 4** is aqueous sodium thiosulfate containing 14.24 g of  $\text{Na}_2\text{S}_2\text{O}_3$  in  $1.00 \text{ dm}^3$ .

**FA 5** is aqueous iodine, prepared as shown.

- 5.00 g of hydrated sodium sulfite is added to  $600 \text{ cm}^3$  of  $0.100 \text{ mol dm}^{-3}$  aqueous iodine.
- The mixture is allowed to stand to ensure that all the sodium sulfite has been oxidised.
- The mixture containing the remaining iodine is made up to  $1.00 \text{ dm}^3$  with distilled water.

**FA 6** is starch indicator.

**(a) Method**

- Fill the burette with **FA 4**.
- Pipette  $25.0 \text{ cm}^3$  of **FA 5** into a conical flask.
- Add **FA 4** from the burette into the conical flask until the colour of the solution changes to yellow.
- Add 10 drops of **FA 6** to the conical flask. Continue titrating until the blue-black colour just disappears.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .....  $\text{cm}^3$ .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record, in a suitable form in the space below, all your burette readings and the volume of **FA 4** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm<sup>3</sup> of **FA 5** required ..... cm<sup>3</sup> of **FA 4**. [1]

(c) **Calculations**

- (i) Give your answers to (c)(ii), (c)(iii), (c)(iv) and (c)(v) to an appropriate number of significant figures. [1]

- (ii) Calculate the amount, in mol, of sodium thiosulfate present in the volume of **FA 4** in (b).

amount of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> = ..... mol [1]

- (iii) Calculate the amount, in mol, of iodine in 1.00 dm<sup>3</sup> of **FA 5**.

amount of I<sub>2</sub> in 1.00 dm<sup>3</sup> = ..... mol [1]

- (iv) Use the information given and your answer to (c)(iii) to calculate the amount, in mol, of iodine that reacted with sodium sulfite when solution **FA 5** was prepared.

amount of I<sub>2</sub> reacted with sodium sulfite = ..... mol [1]

- (v) Use your answer to (c)(iv) to calculate the relative formula mass,  $M_r$ , of hydrated sodium sulfite.

$M_r$  of Na<sub>2</sub>SO<sub>3</sub>·xH<sub>2</sub>O = ..... [1]

- (vi) Calculate the value of x.

Show your working.

x = ..... [1]

[Total: 14]

## Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed, you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used. If a solid is heated, a hard-glass test-tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

**3 (a) FA 7, FA 8 and FA 9** are dilute ethanoic acid, dilute hydrochloric acid and aqueous silver nitrate but **not** necessarily in that order. The solutions of acids have equal concentrations.

- (i) You are supplied with strips of magnesium ribbon.  
You must **not** use any other reagents in this part of the question.

Carry out tests to identify each of the three solutions, **FA 7**, **FA 8** and **FA 9**.  
Obtain as much evidence as you can for your identifications.  
Use a 1 cm depth of solution in a test-tube for each test you carry out.

Record all your observations.

**FA 7** is ..... **FA 8** is ..... **FA 9** is ..... [5]

- (ii) Give the ionic equation for the reaction of magnesium with **FA 8**. Include state symbols.  
..... [1]

(b) **FA 10** and **FA 11** are both aqueous solutions of salts, each of which contains one cation and one anion listed in the Qualitative analysis notes.

(i) Carry out the following tests and record your observations in Table 3.1.

For Tests 1 and 2, use a 1 cm depth of **FA 10** or **FA 11** in a test-tube.

For Test 3, use a 1 cm depth of **FA 10** or **FA 11** in a boiling tube.

**Table 3.1**

<i>test</i>	<i>observations</i>	
	<b>FA 10</b>	<b>FA 11</b>
<b>Test 1</b> Add aqueous ammonia.		
<b>Test 2</b> Add a few drops of aqueous barium chloride or aqueous barium nitrate, then		
add dilute hydrochloric acid.		
<b>Test 3</b> Add aqueous sodium hydroxide, then		
warm the mixture carefully, then		
add one piece of aluminium foil.		

[5]



- (ii) Use your observations in (b)(i) to complete Table 3.2 by identifying the formulae of the ions present in **FA 10** and **FA 11**.  
If you cannot identify an ion write 'unknown'.

**Table 3.2**

	cation	anion
<b>FA 10</b>		
<b>FA 11</b>		

[2]

[Total: 13]

## Qualitative analysis notes

## 1 Reactions of cations

cation	reaction with	
	NaOH(aq)	NH <sub>3</sub> (aq)
aluminium, Al <sup>3+</sup> (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH <sub>4</sub> <sup>+</sup> (aq)	no ppt. ammonia produced on warming	–
barium, Ba <sup>2+</sup> (aq)	faint white ppt. is observed unless [Ba <sup>2+</sup> (aq)] is very low	no ppt.
calcium, Ca <sup>2+</sup> (aq)	white ppt. unless [Ca <sup>2+</sup> (aq)] is very low	no ppt.
chromium(III), Cr <sup>3+</sup> (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu <sup>2+</sup> (aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution
iron(II), Fe <sup>2+</sup> (aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe <sup>3+</sup> (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg <sup>2+</sup> (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn <sup>2+</sup> (aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn <sup>2+</sup> (aq)	white ppt. soluble in excess	white ppt. soluble in excess

## 2 Reactions of anions

anion	reaction
carbonate, CO <sub>3</sub> <sup>2-</sup>	CO <sub>2</sub> liberated by dilute acids
chloride, Cl <sup>-</sup> (aq)	gives white ppt. with Ag <sup>+</sup> (aq) (soluble in NH <sub>3</sub> (aq))
bromide, Br <sup>-</sup> (aq)	gives cream / off-white ppt. with Ag <sup>+</sup> (aq) (partially soluble in NH <sub>3</sub> (aq))
iodide, I <sup>-</sup> (aq)	gives pale yellow ppt. with Ag <sup>+</sup> (aq) (insoluble in NH <sub>3</sub> (aq))
nitrate, NO <sub>3</sub> <sup>-</sup> (aq)	NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and Al foil
nitrite, NO <sub>2</sub> <sup>-</sup> (aq)	NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and Al foil; decolourises acidified aqueous KMnO <sub>4</sub>
sulfate, SO <sub>4</sub> <sup>2-</sup> (aq)	gives white ppt. with Ba <sup>2+</sup> (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca <sup>2+</sup> (aq)]
sulfite, SO <sub>3</sub> <sup>2-</sup> (aq)	gives white ppt. with Ba <sup>2+</sup> (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO <sub>4</sub>
thiosulfate, S <sub>2</sub> O <sub>3</sub> <sup>2-</sup> (aq)	gives off-white / pale yellow ppt. slowly with H <sup>+</sup>

### 3 Tests for gases

gas	test and test result
ammonia, NH <sub>3</sub>	turns damp red litmus paper blue
carbon dioxide, CO <sub>2</sub>	gives a white ppt. with limewater
hydrogen, H <sub>2</sub>	'pops' with a lighted splint
oxygen, O <sub>2</sub>	relights a glowing splint

### 4 Tests for elements

element	test and test result
iodine, I <sub>2</sub>	gives blue-black colour on addition of starch solution

### 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 J g <sup>-1</sup> K <sup>-1</sup> )

## 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-around; 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-around; 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 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-around; 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 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-around; 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 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 83.8</div> <div style="border: 1px solid black; padding: 5px;">36 Kr krypton 83.8</div> </div>															
		<div style="display: flex; justify-content: space-around; 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 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-around; 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 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-around; 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 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 oganesson —</div> </div>															

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
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