

CANDIDATE  
NAME

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CENTRE  
NUMBER

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CANDIDATE  
NUMBER

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**CHEMISTRY**

**9701/36**

Paper 3 Advanced Practical Skills 2

**October/November 2016**

**2 hours**

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name on all the work you hand in.  
Give details of the practical session and laboratory where appropriate, in the boxes provided.  
Write in dark blue or black pen.  
You may use an HB pencil for any diagrams or graphs.  
Do not use staples, paper clips, glue or correction fluid.  
**DO NOT WRITE IN ANY BARCODES.**

Answer **all** questions.  
Electronic calculators may be used.  
You may lose marks if you do not show your working or if you do not use appropriate units.  
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 10 and 11.  
A copy of the Periodic Table is printed on page 12.

At the end of the examination, fasten all your work securely together.  
The number of marks is given in brackets [ ] at the end of each question or part question.

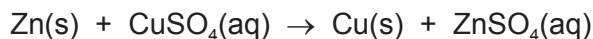
<b>Session</b>	
<b>Laboratory</b>	

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

This document consists of **12** printed pages.

- 1 Zinc metal is extracted from ores that, in addition to compounds of zinc, can also contain copper and silver. This means zinc metal is often impure.

You will investigate the percentage purity of a sample of zinc by reacting it with excess aqueous copper(II) sulfate and comparing the enthalpy change of the displacement reaction with the accepted value.



**FB 1** is 1.00 mol dm<sup>-3</sup> copper(II) sulfate, CuSO<sub>4</sub>.

**FB 2** is powdered impure zinc, Zn.

### (a) Method

**Read the whole method before starting any practical work.**

- Weigh the container with **FB 2** and record the mass in the space below.
- Support the plastic cup in the 250 cm<sup>3</sup> beaker.
- Use the measuring cylinder to transfer 25 cm<sup>3</sup> of **FB 1** into the plastic cup.
- Place the thermometer in the solution and record the initial temperature in a suitable table of results. Tilt the cup if necessary so that the bulb of the thermometer is fully covered. This is the temperature at time zero ( $t = 0$ ).
- Start timing and do not stop the clock until the whole experiment has been completed at  $t = 8$  minutes.
- Measure and record the temperature of the **FB 1** in the cup every half minute up to and including  $t = 2$  minutes.
- At  $t = 2\frac{1}{2}$  minutes add all the **FB 2** into the cup and stir the contents until  $t$  is nearly 3 minutes.
- Measure and record the temperature of the mixture in the cup every half minute from  $t = 3$  minutes until  $t = 8$  minutes. Stir occasionally throughout this time.
- Weigh the container and any residual **FB 2**. Record this mass and calculate the mass of **FB 2** added.

### Results

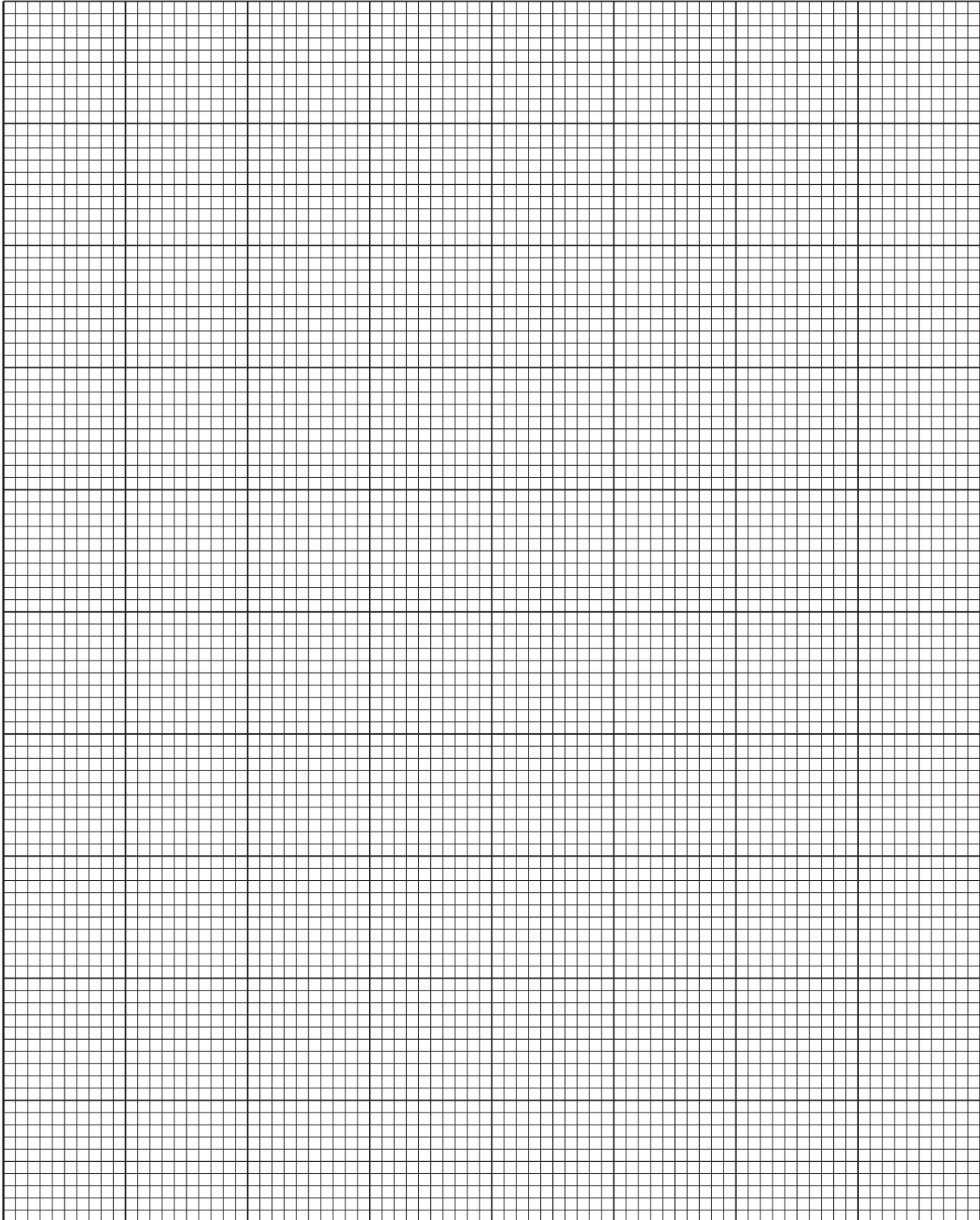
#### Mass

#### Temperature

I	
II	
III	
IV	

[4]

- (b) Plot a graph of temperature on the  $y$ -axis against time on the  $x$ -axis on the grid below. The scale for temperature should extend  $3^{\circ}\text{C}$  above your highest recorded temperature. You will use the graph to determine the theoretical maximum temperature rise at  $t = 2\frac{1}{2}$  minutes.



I	
II	
III	
IV	

Draw two lines of best fit through the points on your graph, the first for the temperature before adding **FB 2** and the second for the temperature of the mixture after addition of **FB 2**. Extrapolate the lines to  $t = 2\frac{1}{2}$  minutes and determine the theoretical maximum temperature rise,  $\Delta T$ .

theoretical maximum temperature rise at  $t = 2\frac{1}{2}$  minutes,  $\Delta T = \dots\dots\dots^{\circ}\text{C}$  [4]

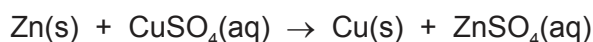
**(c) Calculations**

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

- (i) Use your answer to (b) to calculate the heat energy, in J, given out when **FB 2** was added to the **FB 1** in the cup.  
(Assume that 4.2 J of heat energy raises the temperature of 1.0 cm<sup>3</sup> of the mixture by 1.0 °C.)

heat energy given out = ..... J

- (ii) Use your answer to (i) and the Periodic Table on page 12 to calculate the enthalpy change, in kJ mol<sup>-1</sup>, for the displacement reaction.



You should assume that **FB 2** was pure zinc for this calculation.

enthalpy change,  $\Delta H =$  ..... kJ mol<sup>-1</sup>  
(sign) (value)

[3]

- (d) The accepted value for the enthalpy change of this reaction is  $-217 \text{ kJ mol}^{-1}$ .

Assuming no heat loss and that the other metals present in **FB 2** do not react with aqueous copper(II) sulfate, calculate the percentage of zinc present in **FB 2**.

percentage of Zn = ..... % [1]

- (e) A student carried out the same experiment but used pieces of zinc instead of zinc powder. All quantities and the initial temperature of the aqueous copper(II) sulfate remained the same.

State and explain what effects this change would have on the graph plotted.

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

[Total: 14]

- 2 Solid hydrated copper(II) sulfate has the formula  $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$  where  $x$  is the number of moles of water of crystallisation present in 1 mole of compound.

You will determine the equation for the reaction that occurs when hydrated copper(II) sulfate is heated to remove the water of crystallisation producing anhydrous copper(II) sulfate.

**FB 3** is hydrated copper(II) sulfate  $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ .

**(a) Method**

Record all masses in the space below.

- Weigh the crucible and add 2.2–2.4 g of **FB 3**.
- Weigh the crucible plus **FB 3**.
- Place the crucible on the pipe-clay triangle and heat it gently for approximately 4 minutes.
- Leave the crucible to cool and reweigh the crucible plus residue.

**Keep the crucible and residue for test (c).**

I	
II	
III	
IV	

[4]

**(b) Calculations**

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

- (i) Calculate the mass of anhydrous copper(II) sulfate,  $\text{CuSO}_4$ , produced after heating.

mass of  $\text{CuSO}_4$  = ..... g

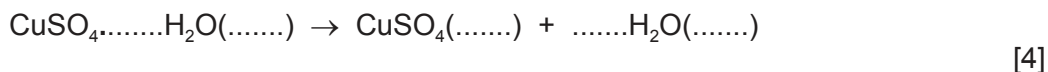
- (ii) Calculate the mass of water lost by heating.

mass of water = ..... g

- (iii) Use your answers to (i) and (ii) and the Periodic Table on page 12 to deduce the value of **x** in the formula  $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ .

**x** is .....

- (iv) Use your answer to (iii) to complete the equation for the reaction that occurs when hydrated copper(II) sulfate is heated. You should include state symbols.



- (c) Place the cooled crucible, with the residue, **on a heatproof mat** and carefully add a few drops of water.

- (i) Note your observations.

.....  
 .....

- (ii) Explain your observations in (i) in terms of the reaction occurring.

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

[3]

- (d) Two students carried out the experiment in (a) and obtained values for **x** that did not agree with the accepted value. One student calculated a value that was less than the accepted value and the other student calculated a value that was more than the accepted value.

In each case, suggest a reason for the error and an improvement that could be made to minimise it. You can assume that the calculations were correctly carried out.

**Value less than accepted value**

error .....

improvement .....

**Value more than accepted value**

error .....

improvement .....

[2]

[Total: 13]

### 3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations.**

You should indicate clearly at what stage in a test a change occurs.

**No additional tests for ions present should be attempted.**

**If any solution is warmed, a boiling tube MUST be used.**

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

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

- (a) **FB 4** and **FB 5** are aqueous solutions of equal concentrations, in  $\text{mol dm}^{-3}$ . Each contains one anion and one cation. The cation is the same in both **FB 4** and **FB 5**.

Half fill the  $250\text{ cm}^3$  beaker with water. Heat the water to about  $80^\circ\text{C}$  and then turn off the Bunsen burner. This is the hot water bath needed in the tests below.

To about a 2 cm depth of aqueous silver nitrate in a test-tube, add a few drops of aqueous sodium hydroxide to give a grey/brown precipitate. Then add aqueous ammonia dropwise until the precipitate **just** disappears. This solution is Tollens' reagent and is needed in a test below.

- (i) Carry out the tests on separate samples of **FB 4** and **FB 5** and complete the table.

test	observations	
	FB 4	FB 5
To a 1 cm depth of solution in a test-tube in a test-tube rack, add a spatula measure of sodium carbonate.		
To a 1 cm depth of solution in a test-tube, add a few drops of acidified potassium manganate(VII). Place the test-tube in the hot water bath.		
To a 1 cm depth of Tollens' reagent in a test-tube, add a few drops of solution. Place the test-tube in the hot water bath and leave for several minutes.		

(ii) From your observations in (i), identify the cation present in **both FB 4 and FB 5**.

cation .....

(iii) From your observations in (i), what can be deduced about the anion present in **FB 4**?

.....

(iv) Place a 1 cm depth of **FB 4** and **FB 5** separately in two test-tubes.

Measure and record the temperature of the two solutions.

**FB 4** ..... °C      **FB 5** ..... °C

To each solution, add an approximately 2 cm length of magnesium ribbon. Measure and record the maximum temperature reached in each test-tube.

**FB 4 + Mg** ..... °C      **FB 5 + Mg** ..... °C

(v) Explain why there is a difference in the temperature rise for the reactions of magnesium with solutions **FB 4** and **FB 5**.

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

[8]



(b) **FB 6** is a solid that contains two cations from those listed on page 10.

You are to plan a series of experiments that will enable you to identify the cations present. You should then carry out your plan, record all the observations you made in a suitable table and identify the cations present.

cations present are ..... and .....

[5]

[Total: 13]

## Qualitative Analysis Notes

Key: [ppt. = precipitate]

## 1 Reactions of aqueous cations

ion	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 heating	–
barium, Ba <sup>2+</sup> (aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca <sup>2+</sup> (aq)	white ppt. with high [Ca <sup>2+</sup> (aq)]	no ppt.
chromium(III), Cr <sup>3+</sup> (aq)	grey-green ppt. soluble in excess	grey-green ppt. insoluble in excess
copper(II), Cu <sup>2+</sup> (aq)	pale blue ppt. insoluble in excess	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

<i>ion</i>	<i>reaction</i>
carbonate, $\text{CO}_3^{2-}$	$\text{CO}_2$ liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$ )
bromide, $\text{Br}^-(\text{aq})$	gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$ )
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$ )
nitrate, $\text{NO}_3^-(\text{aq})$	$\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil
nitrite, $\text{NO}_2^-(\text{aq})$	$\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil; $\text{NO}$ liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown $\text{NO}_2$ in air)
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

## 3 Tests for gases

<i>gas</i>	<i>test and test result</i>
ammonia, $\text{NH}_3$	turns damp red litmus paper blue
carbon dioxide, $\text{CO}_2$	gives a white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$ )
chlorine, $\text{Cl}_2$	bleaches damp litmus paper
hydrogen, $\text{H}_2$	"pops" with a lighted splint
oxygen, $\text{O}_2$	relights a glowing splint

## 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-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">1 H hydrogen 1.0</div> <div style="border: 1px solid black; padding: 2px;">2 He helium 4.0</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">3 Li lithium 6.9</div> <div style="border: 1px solid black; padding: 2px;">4 Be beryllium 9.0</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">5 B boron 10.8</div> <div style="border: 1px solid black; padding: 2px;">6 C carbon 12.0</div> <div style="border: 1px solid black; padding: 2px;">7 N nitrogen 14.0</div> <div style="border: 1px solid black; padding: 2px;">8 O oxygen 16.0</div> <div style="border: 1px solid black; padding: 2px;">9 F fluorine 19.0</div> <div style="border: 1px solid black; padding: 2px;">10 Ne neon 20.2</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">11 Na sodium 23.0</div> <div style="border: 1px solid black; padding: 2px;">12 Mg magnesium 24.3</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">13 Al aluminium 27.0</div> <div style="border: 1px solid black; padding: 2px;">14 Si silicon 28.1</div> <div style="border: 1px solid black; padding: 2px;">15 P phosphorus 31.0</div> <div style="border: 1px solid black; padding: 2px;">16 S sulfur 32.1</div> <div style="border: 1px solid black; padding: 2px;">17 Cl chlorine 35.5</div> <div style="border: 1px solid black; padding: 2px;">18 Ar argon 39.9</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">19 K potassium 39.1</div> <div style="border: 1px solid black; padding: 2px;">20 Ca calcium 40.1</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">21 Sc scandium 45.0</div> <div style="border: 1px solid black; padding: 2px;">22 Ti titanium 47.9</div> <div style="border: 1px solid black; padding: 2px;">23 V vanadium 50.9</div> <div style="border: 1px solid black; padding: 2px;">24 Cr chromium 52.0</div> <div style="border: 1px solid black; padding: 2px;">25 Mn manganese 54.9</div> <div style="border: 1px solid black; padding: 2px;">26 Fe iron 55.8</div> <div style="border: 1px solid black; padding: 2px;">27 Co cobalt 58.9</div> <div style="border: 1px solid black; padding: 2px;">28 Ni nickel 58.7</div> <div style="border: 1px solid black; padding: 2px;">29 Cu copper 63.5</div> <div style="border: 1px solid black; padding: 2px;">30 Zn zinc 65.4</div> <div style="border: 1px solid black; padding: 2px;">31 Ga gallium 69.7</div> <div style="border: 1px solid black; padding: 2px;">32 Ge germanium 72.6</div> <div style="border: 1px solid black; padding: 2px;">33 As arsenic 74.9</div> <div style="border: 1px solid black; padding: 2px;">34 Se selenium 79.0</div> <div style="border: 1px solid black; padding: 2px;">35 Br bromine 79.9</div> <div style="border: 1px solid black; padding: 2px;">36 Kr krypton 83.8</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">37 Rb rubidium 85.5</div> <div style="border: 1px solid black; padding: 2px;">38 Sr strontium 87.6</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">39 Y yttrium 88.9</div> <div style="border: 1px solid black; padding: 2px;">40 Zr zirconium 91.2</div> <div style="border: 1px solid black; padding: 2px;">41 Nb niobium 92.9</div> <div style="border: 1px solid black; padding: 2px;">42 Mo molybdenum 95.9</div> <div style="border: 1px solid black; padding: 2px;">43 Tc technetium —</div> <div style="border: 1px solid black; padding: 2px;">44 Ru ruthenium 101.1</div> <div style="border: 1px solid black; padding: 2px;">45 Rh rhodium 102.9</div> <div style="border: 1px solid black; padding: 2px;">46 Pd palladium 106.4</div> <div style="border: 1px solid black; padding: 2px;">47 Ag silver 107.9</div> <div style="border: 1px solid black; padding: 2px;">48 Cd cadmium 112.4</div> <div style="border: 1px solid black; padding: 2px;">49 In indium 114.8</div> <div style="border: 1px solid black; padding: 2px;">50 Sn tin 118.7</div> <div style="border: 1px solid black; padding: 2px;">51 Sb antimony 121.8</div> <div style="border: 1px solid black; padding: 2px;">52 Te tellurium 127.6</div> <div style="border: 1px solid black; padding: 2px;">53 I iodine 126.9</div> <div style="border: 1px solid black; padding: 2px;">54 Xe xenon 131.3</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">55 Cs caesium 132.9</div> <div style="border: 1px solid black; padding: 2px;">56 Ba barium 137.3</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">57–71 lanthanoids</div> <div style="border: 1px solid black; padding: 2px;">72 Hf hafnium 178.5</div> <div style="border: 1px solid black; padding: 2px;">73 Ta tantalum 180.9</div> <div style="border: 1px solid black; padding: 2px;">74 W tungsten 183.8</div> <div style="border: 1px solid black; padding: 2px;">75 Re rhenium 186.2</div> <div style="border: 1px solid black; padding: 2px;">76 Os osmium 190.2</div> <div style="border: 1px solid black; padding: 2px;">77 Ir iridium 192.2</div> <div style="border: 1px solid black; padding: 2px;">78 Pt platinum 195.1</div> <div style="border: 1px solid black; padding: 2px;">79 Au gold 197.0</div> <div style="border: 1px solid black; padding: 2px;">80 Hg mercury 200.6</div> <div style="border: 1px solid black; padding: 2px;">81 Tl thallium 204.4</div> <div style="border: 1px solid black; padding: 2px;">82 Pb lead 207.2</div> <div style="border: 1px solid black; padding: 2px;">83 Bi bismuth 209.0</div> <div style="border: 1px solid black; padding: 2px;">84 Po polonium —</div> <div style="border: 1px solid black; padding: 2px;">85 At astatine —</div> <div style="border: 1px solid black; padding: 2px;">86 Rn radon —</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">87 Fr francium —</div> <div style="border: 1px solid black; padding: 2px;">88 Ra radium —</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">89–103 actinoids</div> <div style="border: 1px solid black; padding: 2px;">104 Rf rutherfordium —</div> <div style="border: 1px solid black; padding: 2px;">105 Db dubnium —</div> <div style="border: 1px solid black; padding: 2px;">106 Sg seaborgium —</div> <div style="border: 1px solid black; padding: 2px;">107 Bh bohrium —</div> <div style="border: 1px solid black; padding: 2px;">108 Hs hassium —</div> <div style="border: 1px solid black; padding: 2px;">109 Mt meitnerium —</div> <div style="border: 1px solid black; padding: 2px;">110 Ds darmstadtium —</div> <div style="border: 1px solid black; padding: 2px;">111 Rg roentgenium —</div> <div style="border: 1px solid black; padding: 2px;">112 Cn copernicium —</div> <div style="border: 1px solid black; padding: 2px;">113 Nh nihonium —</div> <div style="border: 1px solid black; padding: 2px;">114 Fl flerovium —</div> <div style="border: 1px solid black; padding: 2px;">115 Mc moscovium —</div> <div style="border: 1px solid black; padding: 2px;">116 Lv livermorium —</div> <div style="border: 1px solid black; padding: 2px;">117 Ts tennessine —</div> <div style="border: 1px solid black; padding: 2px;">118 Og oganesson —</div> </div>															

lanthanoids

actinoids

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 —