

CANDIDATE  
NAME

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CENTRE  
NUMBER

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CANDIDATE  
NUMBER

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**CHEMISTRY**

**9701/33**

Paper 3 Advanced Practical Skills 1

**October/November 2018**

**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 14 and 15.  
A copy of the Periodic Table is printed on page 16.

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>	

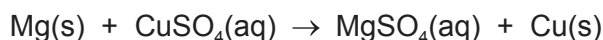
This document consists of **14** printed pages and **2** blank pages.

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

- 1 You will determine the enthalpy change,  $\Delta H$ , for the reaction between magnesium and aqueous copper(II) sulfate. To do this you will measure the change in temperature when magnesium powder reacts with aqueous copper(II) sulfate. The magnesium is in excess.



**FA 1** is a solution containing  $151.9 \text{ g dm}^{-3}$  copper(II) sulfate,  $\text{CuSO}_4$ .

**FA 2** is magnesium powder,  $\text{Mg}$ .

### (a) Method

- Weigh the container with **FA 2** and record the mass in the space below.
- Support the plastic cup in the  $250 \text{ cm}^3$  beaker.
- Use the measuring cylinder to transfer  $25 \text{ cm}^3$  of **FA 1** into the plastic cup.
- Place the thermometer in the solution and tilt the cup if necessary so that the bulb of the thermometer is fully covered. Record the temperature at time zero in the table of results.
- Start timing and do not stop the clock until the whole experiment has been completed.
- Record the temperature of the solution every half minute for 2 minutes.
- At  $2\frac{1}{2}$  minutes carefully transfer **all** of **FA 2** into the solution in the cup and stir the mixture.
- Record the temperature of the mixture at 3 minutes and complete the table by recording the temperature every half minute. Stir the mixture continuously between thermometer readings.
- Weigh the container with any residual **FA 2** and record the mass below.
- Calculate and record the mass of **FA 2** used.

**Keep FA 1 for use in Question 2.**

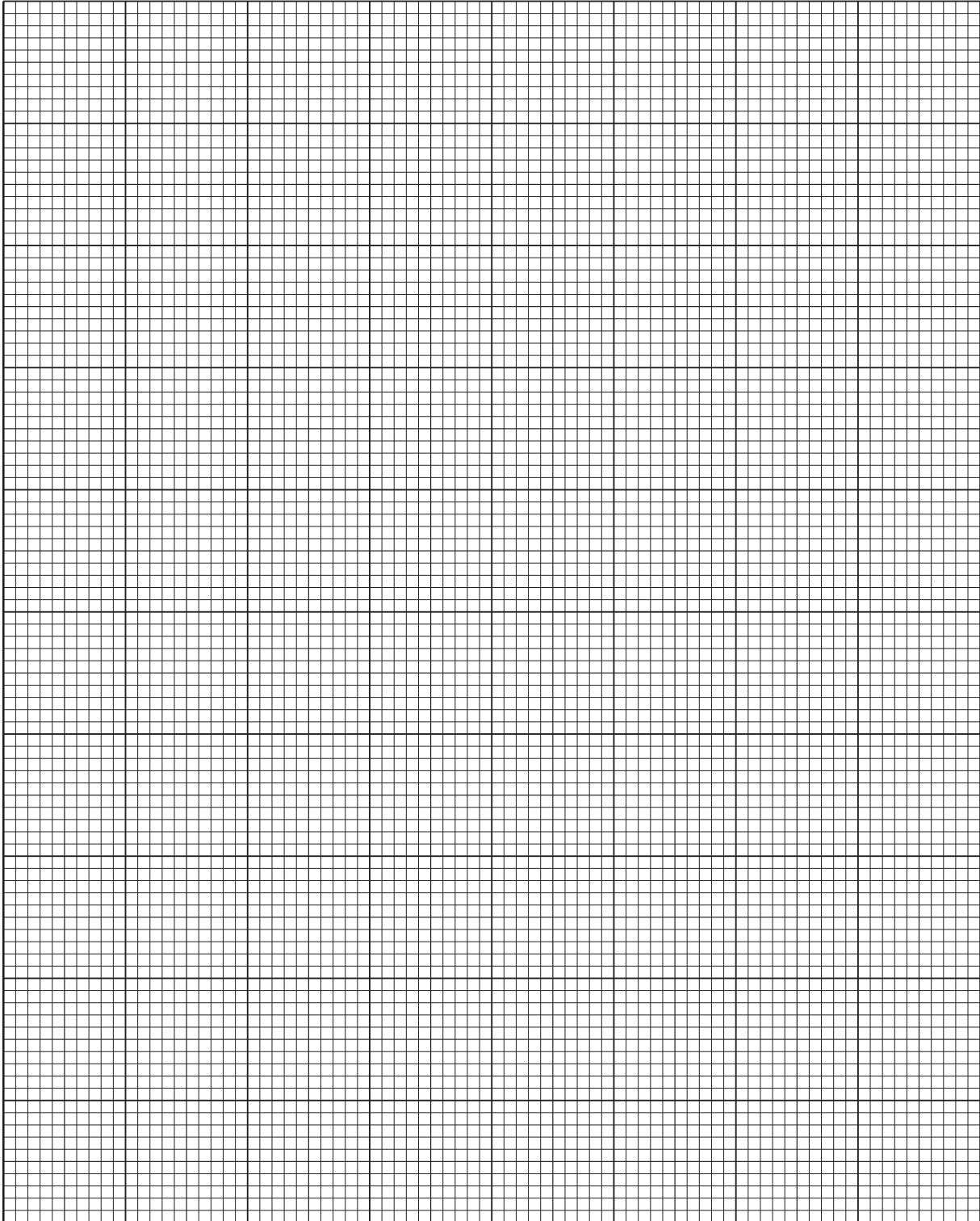
### Results

time / minutes	0	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4
temperature / °C									

time / minutes	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8
temperature / °C								

[4]

- (b) (i) 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 at least  $10^{\circ}\text{C}$  above your highest recorded temperature. You will use the graph to determine the theoretical maximum temperature rise at  $2\frac{1}{2}$  minutes. Draw two lines of best fit through the points on your graph, the first for the temperature before adding **FA 2** and the second for the cooling of the mixture. Label any points you consider anomalous.



I	
II	
III	

[3]

- (ii) Extrapolate the two lines to  $2\frac{1}{2}$  minutes, draw a vertical line between the two lines of best fit and so determine the theoretical rise in temperature,  $\Delta T$ , at this time.

$$\Delta T = \dots\dots\dots \text{ }^\circ\text{C}$$

[2]

**(c) Calculations**

- (i) Use the information given to calculate the concentration of copper(II) sulfate in **FA 1** in  $\text{mol dm}^{-3}$ .

$$\text{concentration of FA 1} = \dots\dots\dots \text{ mol dm}^{-3} \quad [1]$$

- (ii) Hence calculate the number of moles of copper(II) sulfate you used in **(a)**.

$$\text{moles of CuSO}_4 = \dots\dots\dots \text{ mol} \quad [1]$$

- (iii) Use your answer to **(b)(ii)** to calculate the heat energy evolved when **FA 2** is added to **FA 1**. (Assume 4.2 J of heat energy changes the temperature of  $1.0 \text{ cm}^3$  of the mixture by  $1.0 \text{ }^\circ\text{C}$ .)

$$\text{heat energy evolved} = \dots\dots\dots \text{ J} \quad [1]$$

- (iv) Calculate the enthalpy change, in  $\text{kJ mol}^{-1}$ , when 1 mole of  $\text{CuSO}_4$  reacts with magnesium.

$$\text{enthalpy change} = \dots\dots \dots \text{ kJ mol}^{-1} \quad [1]$$

(sign)                      (value)

(v) Show by calculation that the magnesium was in excess.

[1]

(d) (i) A student suggested that the calculated enthalpy change would be more accurate if magnesium turnings were used instead of magnesium powder.

State whether you agree with the student and give a reason for your answer.

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

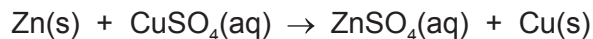
(ii) The enthalpy change determined in (c)(iv) is only an approximation of the actual value.

Suggest and explain **one** improvement to the **method** in (a) you would make to increase the accuracy of the experiment.

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

[Total: 16]

- 2 In this experiment you will determine the enthalpy change,  $\Delta H$ , for the reaction between aqueous copper(II) sulfate and zinc. The zinc is in excess. The method used in this question is slightly different from that used in **Question 1**.



**FA 3** is zinc powder, Zn.

**(a) Method**

- Weigh a clean, dry plastic cup and record the mass.
- Add between 1.8g and 2.0g of zinc powder, **FA 3**, and record the mass.
- Place the plastic cup in the 250 cm<sup>3</sup> beaker.
- Pour 25 cm<sup>3</sup> of **FA 1** into the 25 cm<sup>3</sup> measuring cylinder.
- Place the thermometer in the solution in the measuring cylinder and record the initial temperature.
- Pour the 25 cm<sup>3</sup> of **FA 1** into the plastic cup.
- Stir the contents of the cup and record the highest temperature of the mixture. Tilt the cup if necessary to ensure the thermometer bulb is fully covered.
- Calculate and record the mass of **FA 3** used and the change in temperature.

**Keep the remainder of FA 3 for use in Question 3.**

**Results**

[3]

**(b) Calculations**

- (i) Use your answer to **1(c)(ii)** and the volume of **FA 1** used in **2(a)** to calculate the enthalpy change, in  $\text{kJ mol}^{-1}$ , when 1 mole of  $\text{CuSO}_4$  reacts with zinc.  
(Assume 4.2 J of heat energy changes the temperature of  $1.0 \text{ cm}^3$  of the mixture by  $1.0 \text{ }^\circ\text{C}$ .)

enthalpy change = .....  $\text{kJ mol}^{-1}$  [2]  
(sign) (value)

- (ii) The maximum error in a single thermometer reading is  $\pm 0.5 \text{ }^\circ\text{C}$ .

Calculate the maximum percentage error in the temperature change for the experiment in **(a)**.

maximum percentage error = ..... % [1]

- (c) A student decided to repeat this experiment using the same concentration of copper(II) sulfate solution and the same batch of zinc powder. However,  $50 \text{ cm}^3$  of **FA 1** and double the mass of **FA 3** were used.

What effect would doubling the quantities of **FA 1** and **FA 3** have on the temperature rise?  
The possible results are listed below.

The temperature rise would be approximately half that for the first experiment.

The temperature rise would be approximately the same as that for the first experiment.

The temperature rise would be approximately double that for the first experiment.

Tick the box you think correct and explain your answer.

.....

.....

.....

[1]

- (d) Use the information given in **Question 1** and **Question 2** and your answers to **1(c)(iv)** and **2(b)(i)** to construct a Hess' cycle diagram for the reaction between magnesium and zinc sulfate to form magnesium sulfate and zinc.

Calculate the enthalpy change for this reaction.

(If you were unable to complete the calculations then assume the enthalpy change for **1(c)(iv)** is  $-320 \text{ kJ mol}^{-1}$  and the enthalpy change for **2(b)(i)** is  $-201 \text{ kJ mol}^{-1}$ . These are not the correct values.)

enthalpy change = ..... kJ mol<sup>-1</sup> [2]  
(sign) (value)

[Total: 9]



### Qualitative Analysis

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

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

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

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

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

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

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

**3 (a) FA 4** is a solution of a transition metal compound dissolved in acid.

Carry out the following tests on **FA 4** and record your observations.

<i>test</i>	<i>observations</i>
To a 1 cm depth of <b>FA 4</b> in a test-tube, add a 1 cm depth of potassium iodide, then	
add aqueous sodium thiosulfate.	
To a 3 cm depth of <b>FA 4</b> in a boiling tube, add a spatula measure of zinc powder, <b>FA 3</b> . If no reaction occurs, <b>carefully</b> warm the mixture. Leave the mixture for 5–15 minutes, observing the mixture occasionally.	
<p><b>Keep the mixture of FA 4 and FA 3 for use in (c).</b>            The solution formed from the mixture is <b>FA 6</b>.            Complete part (b) while <b>FA 4</b> and <b>FA 3</b> continue reacting.</p>	

[5]

- (b) (i) **FA 5** is the acid used to make **FA 4**. The anion in **FA 5** is listed in the Qualitative Analysis Notes.

List the reagents you would use to identify this anion and state which acid the reagents are testing for.

[2]

- (ii) Carry out **one** of your tests in (i) and record your observations.

Give the formula of the anion present in **FA 5**. Write 'unknown' if your test could not positively identify this anion.

..... [2]

- (c) Carry out the following tests on **FA 6** (the solution formed in (a)).

<i>test</i>	<i>observations</i>
To a 1 cm depth of <b>FA 6</b> in a test-tube, add acidified potassium manganate(VII) a few drops at a time until in excess. At this stage the solution will be pink.	
To a 1 cm depth of <b>FA 6</b> in a test-tube, add a 1 cm depth of <b>FA 4</b> .	

[3]

- (d) (i) State the type of reaction occurring in (c) when acidified potassium manganate(VII) was added to **FA 6**.

Give a reason for your answer.

.....

..... [2]

- (ii) The ion present in **FA 4** when in acidic solution is usually written as  $\text{MO}_2^+$  where **M** represents the transition metal.

Calculate the oxidation state of **M** in  $\text{MO}_2^+$ .

oxidation state of **M** = ..... [1]

[Total: 15]





## Qualitative Analysis Notes

## 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)	faint white ppt. is nearly always observed unless 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 <i>Al</i> foil
nitrite, $\text{NO}_2^-(\text{aq})$	$\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and <i>Al</i> foil
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	13										14	15	16	17	18	
		<div style="display: flex; justify-content: space-between;"> <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;"> <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;"> <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;"> <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;"> <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;"> <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;"> <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;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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;"> <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;"> <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>															
		<div style="display: flex; justify-content: space-between;"> <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;"> <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>															

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	euroium	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	meitnerium	—	102	No	nobelium	—	103	Lr	lawrencium	—