

CANDIDATE  
NAME

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CENTRE  
NUMBER

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CANDIDATE  
NUMBER

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**CHEMISTRY**

**9701/31**

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 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>Total</b>	

This document consists of **12** printed 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 In this experiment you will determine the percentage purity of a sample of impure anhydrous sodium carbonate. You will use two different methods to measure the enthalpy change of reaction when a sample of impure anhydrous sodium carbonate reacts with excess dilute hydrochloric acid.

**FA 1** is a sample of the impure anhydrous sodium carbonate.

**FA 2** is  $2.00 \text{ mol dm}^{-3}$  hydrochloric acid,  $\text{HCl}$ .

**FA 3** is a second sample of the impure anhydrous sodium carbonate used in **FA 1**.

### (a) Method 1

- Weigh the container with **FA 1**. Record this mass.

mass of container with **FA 1** = ..... g

- Support one of the plastic cups in the  $250 \text{ cm}^3$  beaker.
- Use the measuring cylinder to place  $25 \text{ cm}^3$  of **FA 2** into the cup.
- Measure the temperature of the **FA 2** in the cup. Tilt the cup if necessary so that the bulb of the thermometer is fully covered. Record this temperature at time  $t = 0$ .
- Start the stopclock and leave it running for the whole experiment.
- Measure and record the temperature of **FA 2** in the cup every half minute for 2 minutes.
- At  $t = 2\frac{1}{2}$  minutes tip all the **FA 1** into the cup. Stir the contents of the cup.
- Measure and record the temperature of the contents of the cup at  $t = 3$  minutes and then every half minute up to  $t = 9$  minutes.
- Weigh the container with any residual **FA 1**. Record this mass.

I	
II	
III	
IV	
V	

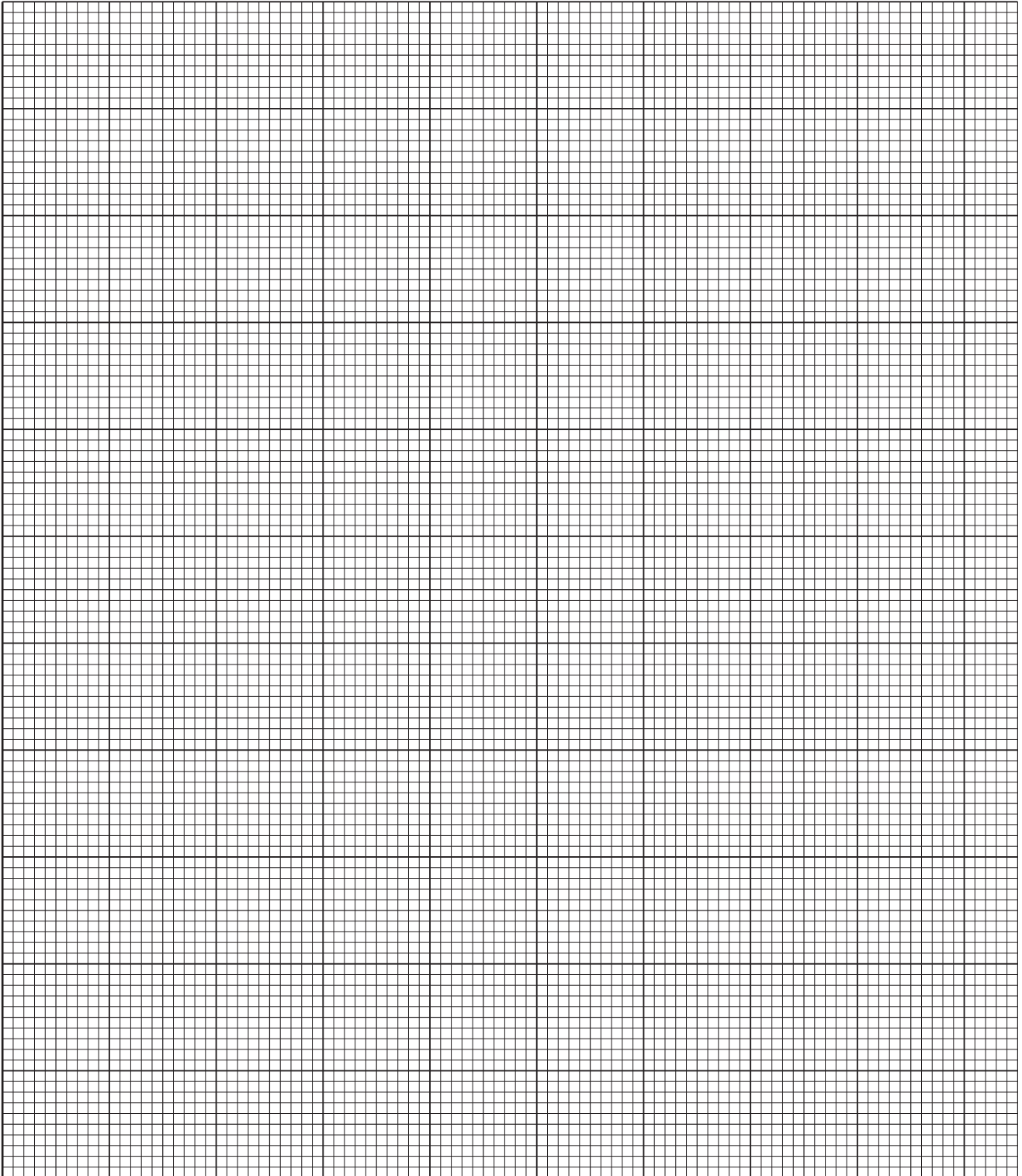
mass of container with residual **FA 1** = ..... g  
[5]

- (b) (i) On the grid on page 3, plot a graph of temperature ( $y$ -axis) against time ( $x$ -axis). You should choose a scale that allows you to plot  $2^\circ\text{C}$  above the maximum temperature reached.

I	
II	
III	
IV	

On your graph, draw two straight lines of best fit. One line is for the temperature before adding **FA 1** and the other line for the cooling of the solution once reaction is complete.

Extrapolate these two lines to  $t = 2\frac{1}{2}$  minutes. [4]



(ii) From your graph, find the theoretical temperature rise at  $t = 2\frac{1}{2}$  minutes.

theoretical temperature rise = ..... °C [1]

(c) (i) Calculate the energy released in the reaction.

(Assume 4.2 J of heat energy changes the temperature of 1.0 cm<sup>3</sup> of solution by 1.0 °C.)

energy released = ..... J [1]

(ii) The equation for the reaction between anhydrous sodium carbonate and hydrochloric acid is shown.



The literature value for the enthalpy change of this reaction is  $-27.0 \text{ kJ mol}^{-1}$ .

Use this figure, and the value that you found in (i), to find the mass of anhydrous sodium carbonate you used in (a). You should assume that no energy was lost to the surroundings in your experiment.

mass  $\text{Na}_2\text{CO}_3$  = ..... g [2]

(iii) Calculate the percentage of anhydrous sodium carbonate present in **FA 1**.

percentage  $\text{Na}_2\text{CO}_3$  in **FA 1** = ..... % [1]

(d) In your calculation in (c), what assumption have you made about the impurity present in **FA 1**?

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

**(e) Method 2**

- Weigh a clean, dry plastic cup and record the mass.
- Add between 1.70g and 1.90g of **FA 3** to the plastic cup and record the mass.
- Support the plastic cup in the 250 cm<sup>3</sup> beaker.
- Pour 25 cm<sup>3</sup> of **FA 2** into the measuring cylinder.
- Measure and record the initial temperature of **FA 2** in the measuring cylinder.
- Pour the 25 cm<sup>3</sup> of **FA 2** into the plastic cup.
- Stir the contents of the cup and record the maximum temperature. Tilt the cup if necessary so that the bulb of the thermometer is fully covered.
- Calculate and record the mass of **FA 3** used and the change in temperature.

[2]

- (f)** Use the temperature rise in **(e)**, and the fact that the enthalpy change for the reaction between anhydrous sodium carbonate and hydrochloric acid is  $-27.0 \text{ kJ mol}^{-1}$ , to calculate the percentage of anhydrous sodium carbonate in **FA 3**.

percentage Na<sub>2</sub>CO<sub>3</sub> in **FA 3** = ..... % [2]

- (g) **FA 1** and **FA 3** are both samples of the same impure anhydrous sodium carbonate and so the percentage of anhydrous sodium carbonate found using **Method 1** and **Method 2** should be the same. In practice the percentages are sometimes different from each other.

In both methods, percentage errors occur due to measuring the mass of solid and the temperature rise.

Ignoring these errors, which method is more accurate?

Tick the correct box and explain your answer.

Method 1 more accurate

Method 2 more accurate

Method 1 and Method 2 equally accurate

.....

.....

.....

[1]

- (h) A student decided to confirm by experiment the literature value for the enthalpy change of the reaction between anhydrous sodium carbonate and hydrochloric acid. By mistake the student weighed a sample of hydrated sodium carbonate,  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ , instead of anhydrous sodium carbonate,  $\text{Na}_2\text{CO}_3$ .

State what effect this would have on the calculated value of the enthalpy change for the reaction. Explain your answer.

.....

.....

.....

..... [2]

- (i) A student used 3.00g of anhydrous sodium carbonate that was 80.0% pure by mass.

Calculate the minimum volume of  $2.00 \text{ mol dm}^{-3}$  hydrochloric acid that would be needed to react completely with this sample of impure anhydrous sodium carbonate.

volume of  $\text{HCl} = \dots\dots\dots \text{ cm}^3$  [3]

[Total: 25]

## 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.**

- 2 (a) (i) **FA 4** is a sodium compound that was the impurity in the **FA 1** and **FA 3** that you used in **Question 1**. The anion in **FA 4** is one of those listed in the Qualitative Analysis Notes.

Carry out appropriate tests to allow you to positively identify the anion in **FA 4**.

For the test that gives a positive result, record the test and the results of it.  
State the name of the anion in **FA 4**.

anion in **FA 4** = .....

[2]

- (ii) Write the ionic equation for the reaction that you have used to identify the anion in **FA 4**.  
Include state symbols.

..... [1]

- (b) **FA 5** is a mixture that contains two cations and three anions from those listed in the Qualitative Analysis Notes.

A sample of **FA 5** was added to water and the water stirred. The mixture produced was filtered to give a solid residue, **FA 6**, and a filtrate, **FA 7**.

- (i) Carry out the following tests on **FA 6** and record your observations.

<i>test</i>	<i>observations</i>
To a small spatula measure of <b>FA 6</b> in a test-tube add dilute hydrochloric acid, then	
add aqueous ammonia.	
Place a small spatula measure of <b>FA 6</b> in a hard-glass test-tube and heat gently.	

[4]

- (ii) Carry out the following tests on **FA 7** and record your observations.

<i>test</i>	<i>observations</i>
To a 1 cm depth of <b>FA 7</b> in a test-tube add aqueous sodium hydroxide.	
To a 1 cm depth of <b>FA 7</b> in a test-tube add aqueous ammonia.	
To a 1 cm depth of <b>FA 7</b> in a test-tube add a few drops of aqueous silver nitrate.	
To a 1 cm depth of <b>FA 7</b> in a test-tube add a few drops of aqueous barium nitrate or aqueous barium chloride, then	
add dilute nitric acid.	
To a 0.5 cm depth of <b>FA 7</b> in a boiling tube add a 2 cm depth of aqueous sodium hydroxide and warm, then	
add a small piece of aluminium foil.	

[5]



(iii) From your observations, identify the two cations present in **FA 5**.

cations ..... and ..... [1]

(iv) From your observations, identify two anions present in **FA 5**.

..... [1]

(v) From your observations, identify two anions that could be present in **FA 5**.

..... [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 $\text{Al}$ foil
nitrite, $\text{NO}_2^-(\text{aq})$	$\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ 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; 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-between; 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-between; 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-between; 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 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; 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-between; 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-between; 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 oganeson —</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">57 La lanthanum 138.9</div> <div style="border: 1px solid black; padding: 5px;">58 Ce cerium 140.1</div> <div style="border: 1px solid black; padding: 5px;">59 Pr praseodymium 140.9</div> <div style="border: 1px solid black; padding: 5px;">60 Nd neodymium 144.4</div> <div style="border: 1px solid black; padding: 5px;">61 Pm promethium —</div> <div style="border: 1px solid black; padding: 5px;">62 Sm samarium 150.4</div> <div style="border: 1px solid black; padding: 5px;">63 Eu europium 152.0</div> <div style="border: 1px solid black; padding: 5px;">64 Gd gadolinium 157.3</div> <div style="border: 1px solid black; padding: 5px;">65 Tb terbium 158.9</div> <div style="border: 1px solid black; padding: 5px;">66 Dy dysprosium 162.5</div> <div style="border: 1px solid black; padding: 5px;">67 Ho holmium 164.9</div> <div style="border: 1px solid black; padding: 5px;">68 Er erbium 167.3</div> <div style="border: 1px solid black; padding: 5px;">69 Tm thulium 168.9</div> <div style="border: 1px solid black; padding: 5px;">70 Yb ytterbium 173.1</div> <div style="border: 1px solid black; padding: 5px;">71 Lu lutetium 175.0</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">89 Ac actinium —</div> <div style="border: 1px solid black; padding: 5px;">90 Th thorium 232.0</div> <div style="border: 1px solid black; padding: 5px;">91 Pa protactinium 231.0</div> <div style="border: 1px solid black; padding: 5px;">92 U uranium 238.0</div> <div style="border: 1px solid black; padding: 5px;">93 Np neptunium —</div> <div style="border: 1px solid black; padding: 5px;">94 Pu plutonium —</div> <div style="border: 1px solid black; padding: 5px;">95 Am americium —</div> <div style="border: 1px solid black; padding: 5px;">96 Cm curium —</div> <div style="border: 1px solid black; padding: 5px;">97 Bk berkelium —</div> <div style="border: 1px solid black; padding: 5px;">98 Cf californium —</div> <div style="border: 1px solid black; padding: 5px;">99 Es einsteinium —</div> <div style="border: 1px solid black; padding: 5px;">100 Fm fermium —</div> <div style="border: 1px solid black; padding: 5px;">101 Md mendelevium —</div> <div style="border: 1px solid black; padding: 5px;">102 No nobelium —</div> <div style="border: 1px solid black; padding: 5px;">103 Lr lawrencium —</div> </div>															

lanthanoids

actinoids