



# Cambridge International AS & A Level

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## CHEMISTRY

9701/03

Paper 3 Advanced Practical Skills

For examination from 2022

SPECIMEN PAPER

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.

### Session

|  |
|--|
|  |
|  |
|  |

### Laboratory

### For Examiner's Use

|       |  |
|-------|--|
| 1     |  |
| 2     |  |
| 3     |  |
| Total |  |

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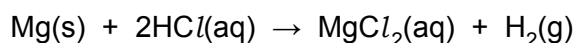
## Quantitative analysis

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 answer to **each** step of your calculations.

- 1 You will determine the enthalpy change,  $\Delta H$ , of the reaction between magnesium and hydrochloric acid. To do this you will measure the change in temperature when a piece of magnesium ribbon reacts with an excess of hydrochloric acid.



**FA 1** is hydrochloric acid,  $\text{HCl}$ .

**FA 2** is magnesium ribbon,  $\text{Mg}$ . You should assume its mass is 0.19 g.

### (a) Method

- Support the cup in the 250 cm<sup>3</sup> beaker.
- Coil **FA 2** so that it will fit into the bottom of the cup then remove it.
- Use the measuring cylinder to transfer 25.0 cm<sup>3</sup> of **FA 1** into the cup.
- Place the thermometer in the acid and, if necessary, tilt the cup so that the bulb of the thermometer is fully covered. Measure and record the temperature at time = 0 in the table of results.
- Start timing and do not stop the clock until the whole experiment has been completed at time = 8 minutes.
- Record the temperature of **FA 1** in the cup every half minute for 1½ minutes.
- At time = 2 minutes carefully drop the coil of **FA 2** into the acid and stir the mixture.
- Record the temperature every half minute. Stir the mixture between thermometer readings.

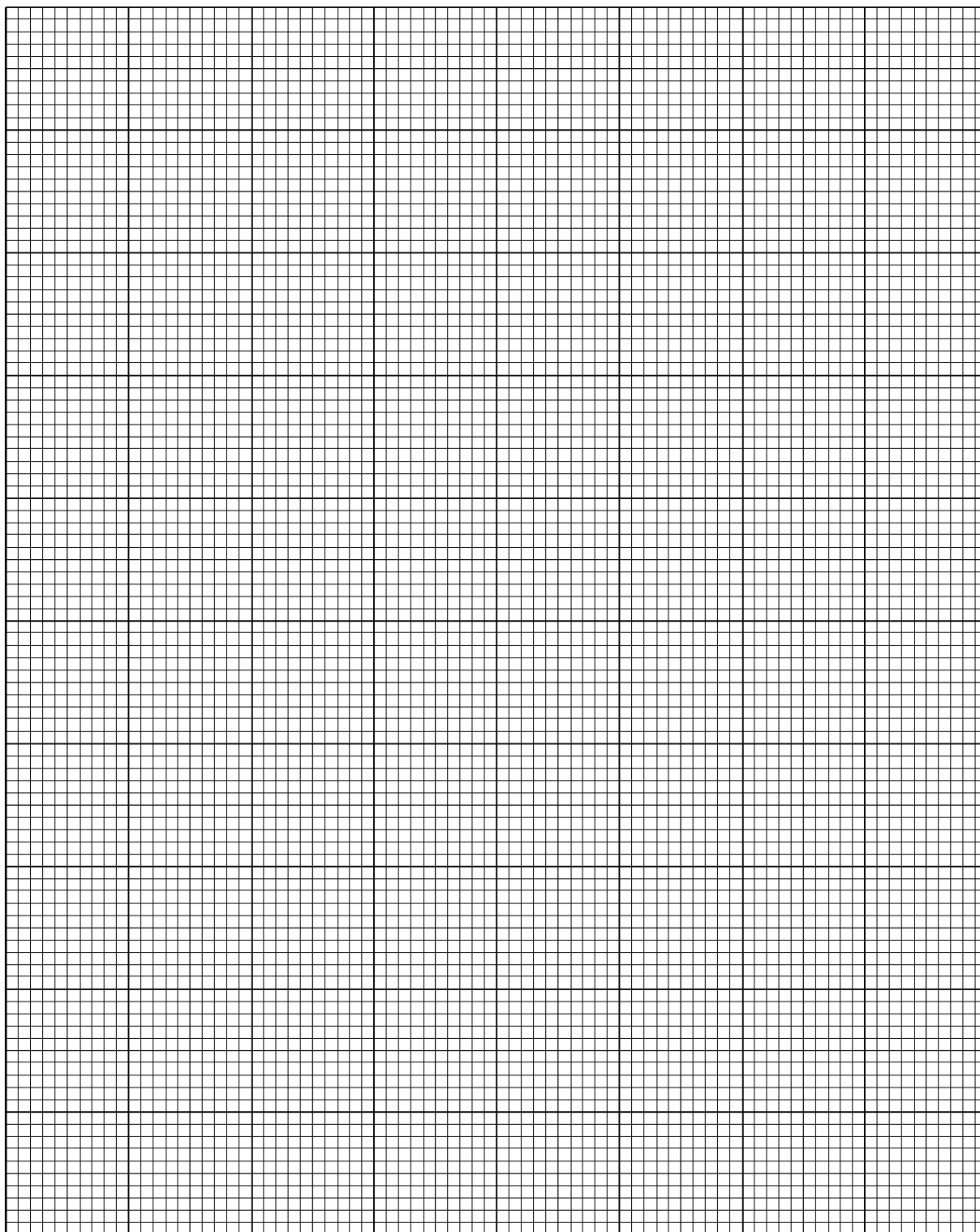
### Results

|                  |   |               |   |                |   |                |   |                |   |
|------------------|---|---------------|---|----------------|---|----------------|---|----------------|---|
| 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) Plot a graph of temperature (on the y-axis) against time (on the x-axis) on the grid. The scale for the y-axis should extend 10 °C above the maximum temperature you recorded. Circle any points you consider to be anomalous. You will use the graph to determine the theoretical maximum temperature rise at time = 2 minutes.



Draw two lines of best fit, the first for the temperature before adding **FA 2** and the second for the cooling of the mixture. Extrapolate both lines to 2 minutes and determine the theoretical rise in temperature at this time.

theoretical rise in temperature at 2 minutes = ..... °C [4]

**(c) Calculations**

- (i) Use your answer to **(b)** to calculate the energy change when **FA 2** is added to **FA 1**.  
(Assume 4.2 J of energy changes the temperature of 1.0 cm<sup>3</sup> of the mixture by 1.0 °C.)

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

- (ii) Use your answer to **(c)(i)** to calculate the enthalpy change,  $\Delta H$ , in kJ mol<sup>-1</sup>, when 1 mol of magnesium, **FA 2**, reacts with hydrochloric acid, **FA 1**.

$\Delta H = \dots\dots\dots$  kJ mol<sup>-1</sup>  
(sign) (value) [2]

- (d) A student repeats the procedure, but instead of hydrochloric acid, uses sulfuric acid, H<sub>2</sub>SO<sub>4</sub>, of the same concentration. The student predicts that the enthalpy change will be twice the value of the enthalpy change with hydrochloric acid.

Explain whether the student's prediction is correct.

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

- (e) The enthalpy change determined in **(c)(ii)** is **not** accurate.

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

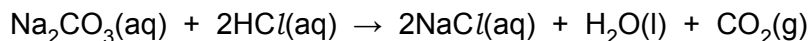
improvement .....

explanation .....

..... [1]

[Total: 13]

- 2 You will determine the concentration of the hydrochloric acid, **FA 1**, used in **Question 1** by titration of a diluted solution of **FA 1** with aqueous sodium carbonate of known concentration.



**FA 3** is a diluted solution of **FA 1**,  $\text{HCl}$ . **FA 3** was prepared by diluting  $10.0 \text{ cm}^3$  of **FA 1** to  $250 \text{ cm}^3$  with distilled water.

**FA 4** is a solution containing  $1.25 \text{ g Na}_2\text{CO}_3$  in each  $250 \text{ cm}^3$ .  
The indicator is bromophenol blue.

**(a) Method**

- Fill a burette with **FA 3**.
- Use the pipette to transfer  $25.0 \text{ cm}^3$  of **FA 4** into a conical flask.
- Add approximately 10 drops of bromophenol blue.
- Carry out 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 certain any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 3** added in each accurate titration.

[7]

- (b)** Calculate the mean titre of **FA 3**. Show clearly how you obtained this value.

Mean titre of **FA 3** = .....  $\text{cm}^3$ . [1]

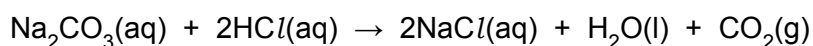
**(c) Calculations**

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

- (ii) Calculate the number of moles of sodium carbonate present in 25.0 cm<sup>3</sup> of **FA 4**.

moles of Na<sub>2</sub>CO<sub>3</sub> in 25.0 cm<sup>3</sup> of **FA 4** = ..... mol [1]

- (iii) Calculate the concentration, in mol dm<sup>-3</sup>, of hydrochloric acid in **FA 3**.



concentration of HCl in **FA 3** = ..... mol dm<sup>-3</sup> [1]

- (iv) Calculate the concentration of hydrochloric acid in **FA 1**.

concentration of HCl in **FA 1** = ..... mol dm<sup>-3</sup> [1]

- (v) Show, by calculation, that the amount of hydrochloric acid used in **Question 1(a)** was in excess of the amount of magnesium used.

[1]

[Total: 13]

## 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.

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

No additional tests should be attempted.

**3 (a) FA 5** is a salt containing three ions all of which are listed in the Qualitative analysis notes.

Place a small spatula measure of **FA 5** in a hard-glass test-tube and heat for no longer than one minute. Record **all** your observations.

.....

.....

.....

.....

..... [3]

- (b) **FA 6** is an aqueous solution of **FA 5**.  
**FA 7** is an aqueous solution of a salt containing two ions.

Carry out the tests and record your observations in Table 3.1.

**Table 3.1**

| <i>test</i>   | <i>observations</i> |             |
|---|---------------------|-------------|
|   | <b>FA 6</b>         | <b>FA 7</b> |
| <b>Test 1</b><br>To a 0.5 cm depth of solution in a boiling tube add aqueous sodium hydroxide, then                                     |                     |             |
| warm gently.  |                     |             |
| Allow to cool, add a piece of aluminium foil and warm again.  |                     |             |
| <b>Test 2</b><br>To a 1 cm depth of solution in a test-tube add 2 or 3 drops of aqueous acidified potassium manganate(VII).             |                     |             |
| <b>Test 3</b><br>To a 1 cm depth of solution in a test-tube add a 2 cm depth of aqueous hydrogen peroxide, then                         |                     |             |
| leave to stand for about a $\frac{1}{2}$ minute.  |                     |             |
| <b>Test 4</b><br>To a 1 cm depth of solution in a test-tube add 2 or 3 drops of aqueous barium chloride or aqueous barium nitrate, then |                     |             |
| add a 1 cm depth of dilute nitric acid.<br>Wash the test-tubes after use.   |                     |             |



- (c) Identify as many ions present in **FA 6** and **FA 7** as possible from your observations in (a) and (b).

Write the formulae of the ions in Table 3.2. If an ion cannot be positively identified from the tests, write 'unknown' in the space.

**Table 3.2**

|             | cations | anions |
|-------------|---------|--------|
| <b>FA 6</b> |         |        |
| <b>FA 7</b> |         |        |

[3]

- (d) Write an ionic equation for a precipitation reaction occurring in (b). Include state symbols.

..... [1]

[Total: 14]

## 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.<br>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<br>insoluble in excess             | green ppt. turning brown on contact with air<br>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<br>insoluble in excess | off-white ppt. rapidly turning brown on contact with air<br>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;<br>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);<br>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);<br>decolourises acidified aqueous KMnO <sub>4</sub>     |
| thiosulfate, S <sub>2</sub> O <sub>3</sub> <sup>2-</sup> (aq) | gives white ppt. slowly with H <sup>+</sup>  |

### 3 Tests for gases

| gas                           | test and test result              |
|-------------------------------|-----------------------------------|
| ammonia, $\text{NH}_3$        | turns damp red litmus paper blue  |
| carbon dioxide, $\text{CO}_2$ | gives a white ppt. with limewater |
| hydrogen, $\text{H}_2$        | 'pops' with a lighted splint      |
| oxygen, $\text{O}_2$          | relights a glowing splint         |

### 4 Tests for elements

| element              | test and test result                                   |
|----------------------|--|
| iodine, $\text{I}_2$ | 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)<br>$V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ 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 | $c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ ( $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ )   |

The Periodic Table of Elements

| Group                  |                         |  |                          |                       |                          |                         |                          |                        |                          |                        |                        |                       |                         |                         |                          |                       |                       |    |    |    |    |
|------------------------|-------------------------|--|--------------------------|-----------------------|--------------------------|-------------------------|--------------------------|------------------------|--------------------------|------------------------|------------------------|-----------------------|-------------------------|-------------------------|--------------------------|-----------------------|-----------------------|----|----|----|----|
| 1                      | 2                       | 1<br>H<br>hydrogen<br>1.0                                      |                          |                       |                          |                         |                          |                        |                          |                        |                        |                       |                         |                         |                          | 13                    | 14                    | 15 | 16 | 17 | 18 |
|                        |                         | Key  |                          |                       |                          |                         |                          |                        |                          |                        |                        |                       |                         |                         |                          |                       |                       |    |    |    |    |
|                        |                         | atomic number<br>atomic symbol<br>name<br>relative atomic mass |                          |                       |                          |                         |                          |                        |                          |                        |                        |                       |                         |                         |                          |                       |                       |    |    |    |    |
| 3                      | 4                       |  |                          |                       |                          |                         |                          |                        |                          |                        |                        |                       |                         |                         |                          |                       |                       |    |    |    |    |
| Li<br>lithium<br>6.9   | Be<br>beryllium<br>9.0  |  |                          |                       |                          |                         |                          |                        |                          |                        |                        |                       |                         |                         |                          |                       |                       |    |    |    |    |
| 11                     | 12                      |  |                          |                       |                          |                         |                          |                        |                          |                        |                        |                       |                         |                         |                          |                       |                       |    |    |    |    |
| Na<br>sodium<br>23.0   | Mg<br>magnesium<br>24.3 |  |                          |                       |                          |                         |                          |                        |                          |                        |                        |                       |                         |                         |                          |                       |                       |    |    |    |    |
|                        |                         | 3  | 4                        | 5                     | 6                        | 7                       | 8                        | 9                      | 10                       | 11                     | 12                     |                       |                         |                         |                          |                       |                       |    |    |    |    |
| 19                     | 20                      | 21   | 22                       | 23                    | 24                       | 25                      | 26                       | 27                     | 28                       | 29                     | 30                     | 31                    | 32                      | 33                      | 34                       | 35                    | 36                    |    |    |    |    |
| K<br>potassium<br>39.1 | Ca<br>calcium<br>40.1   | Sc<br>scandium<br>45.0   | Ti<br>titanium<br>47.9   | V<br>vanadium<br>50.9 | Cr<br>chromium<br>52.0   | Mn<br>manganese<br>54.9 | Fe<br>iron<br>55.8       | Co<br>cobalt<br>58.9   | Ni<br>nickel<br>58.7     | Cu<br>copper<br>63.5   | Zn<br>zinc<br>65.4     | Ga<br>gallium<br>69.7 | Ge<br>germanium<br>72.6 | As<br>arsenic<br>74.9   | Se<br>selenium<br>79.0   | Br<br>bromine<br>79.9 | Kr<br>krypton<br>83.8 |    |    |    |    |
| 37                     | 38                      | 39   | 40                       | 41                    | 42                       | 43                      | 44                       | 45                     | 46                       | 47                     | 48                     | 49                    | 50                      | 51                      | 52                       | 53                    | 54                    |    |    |    |    |
| Rb<br>rubidium<br>85.5 | Sr<br>strontium<br>87.6 | Y<br>yttrium<br>88.9   | Zr<br>zirconium<br>91.2  | Nb<br>niobium<br>92.9 | Mo<br>molybdenum<br>95.9 | Tc<br>technetium<br>—   | Ru<br>ruthenium<br>101.1 | Rh<br>rhodium<br>102.9 | Pd<br>palladium<br>106.4 | Ag<br>silver<br>107.9  | Cd<br>cadmium<br>112.4 | In<br>indium<br>114.8 | Sn<br>tin<br>118.7      | Sb<br>antimony<br>121.8 | Te<br>tellurium<br>127.6 | I<br>iodine<br>126.9  | Xe<br>xenon<br>131.3  |    |    |    |    |
| 55                     | 56                      | 57–71<br>lanthanoids   | 72                       | 73                    | 74                       | 75                      | 76                       | 77                     | 78                       | 79                     | 80                     | 81                    | 82                      | 83                      | 84                       | 85                    | 86                    |    |    |    |    |
| Cs<br>caesium<br>132.9 | Ba<br>barium<br>137.3   |  |                          |                       |                          |                         |                          |                        |                          |                        |                        |                       |                         |                         |                          |                       |                       |    |    |    |    |
| 87                     | 88                      | 89–103<br>actinoids  | 104                      | 105                   | 106                      | 107                     | 108                      | 109                    | 110                      | 111                    | 112                    | 113                   | 114                     | 115                     | 116                      | 117                   | 118                   |    |    |    |    |
| Fr<br>francium<br>—    | Ra<br>radium<br>—       |  |                          |                       |                          |                         |                          |                        |                          |                        |                        |                       |                         |                         |                          |                       |                       |    |    |    |    |
|                        |                         |  | Rf<br>rutherfordium<br>— | Db<br>dubnium<br>—    | Sg<br>seaborgium<br>—    | Bh<br>bohrium<br>—      | Hs<br>hassium<br>—       | Mt<br>meitnerium<br>—  | Ds<br>darmstadtium<br>—  | Rg<br>roentgenium<br>— | Cn<br>copernicium<br>— | Nh<br>nihonium<br>—   | Fl<br>flerovium<br>—    | Mc<br>moscovium<br>—    | Lv<br>livermorium<br>—   | Ts<br>tennessine<br>— | Og<br>oganesson<br>—  |    |    |    |    |

|             |  |    |           |         |              |           |            |           |           |            |           |             |             |         |               |           |            |
|-------------|--|----|-----------|---------|--------------|-----------|------------|-----------|-----------|------------|-----------|-------------|-------------|---------|---------------|-----------|------------|
| lanthanoids |  | 57 | La        | Ce      | Pr           | Nd        | Pm         | Sm        | Eu        | Gd         | Tb        | Dy          | Ho          | Er      | Tm            | Yb        | Lu         |
|             |  |    | lanthanum | cerium  | praseodymium | neodymium | promethium | samarium  | europtium | gadolinium | terbium   | dysprosium  | holmium     | erbium  | thulium       | ytterbium | lutetium   |
|             |  |    | 138.9     | 140.1   | 140.9        | 144.4     | —          | 150.4     | 152.0     | 157.3      | 158.9     | 162.5       | 164.9       | 167.3   | 168.9         | 173.1     | 175.0      |
| actinoids   |  | 89 | Ac        | Th      | Pa           | U         | Np         | Pu        | Am        | Cm         | Bk        | Cf          | Es          | Fm      | Md            | No        | Lr         |
|             |  |    | actinium  | thorium | protactinium | uranium   | neptunium  | plutonium | americium | curium     | berkelium | californium | einsteinium | fermium | merendelevium | nobelium  | lawrencium |
|             |  |    | —         | 232.0   | 231.0        | 238.0     | —          | —         | —         | —          | —         | —           | —           | —       | —             | —         | —          |

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