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CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

May/June 2017

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.

| | |
|-------------------|--|
| Session | |
| | |
| Laboratory | |
| | |

| | |
|---------------------------|--|
| For Examiner's Use | |
| 1 | |
| 2 | |
| Total | |

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

- 1 Strong acids, such as hydrochloric acid, HCl , are completely ionised in aqueous solution. Weak acids, such as ethanoic acid, CH_3COOH , are partially ionised in aqueous solution.

You will investigate the enthalpy change for the reaction of an excess of each of these acids with magnesium and hence determine the energy needed to cause the weak acid to ionise completely.

(a) Reaction 1 Enthalpy change of a weak acid

FB 1 is ethanoic acid, CH_3COOH .

FB 2 is magnesium, Mg .

Method 1

- Weigh the strip of magnesium and record the balance reading in the space below.
- Support the plastic cup in the 250 cm^3 beaker.
- Coil the magnesium ribbon loosely so that it fits into the bottom of the plastic cup and then remove the ribbon.
- Use the measuring cylinder to transfer 25 cm^3 of the acid, **FB 1**, into the plastic cup.
- Place the thermometer in the acid and read the initial temperature. This is the temperature at time zero ($t = 0$).
- Start timing and do not stop the clock until the whole experiment has been completed.
- Read the temperature of the acid every half minute for two minutes.
- At time $t = 2\frac{1}{2}$ minutes drop the magnesium, **FB 2**, into the acid and stir the mixture.
- Measure and record, in the table below, the temperature of the mixture at $t = 3$ minutes and then every half minute until $t = 10$ minutes. Stir the mixture continuously between thermometer readings.
- Rinse the plastic cup for use in **Method 2**. Shake to remove excess water.

Results

Mass of magnesium

Temperature

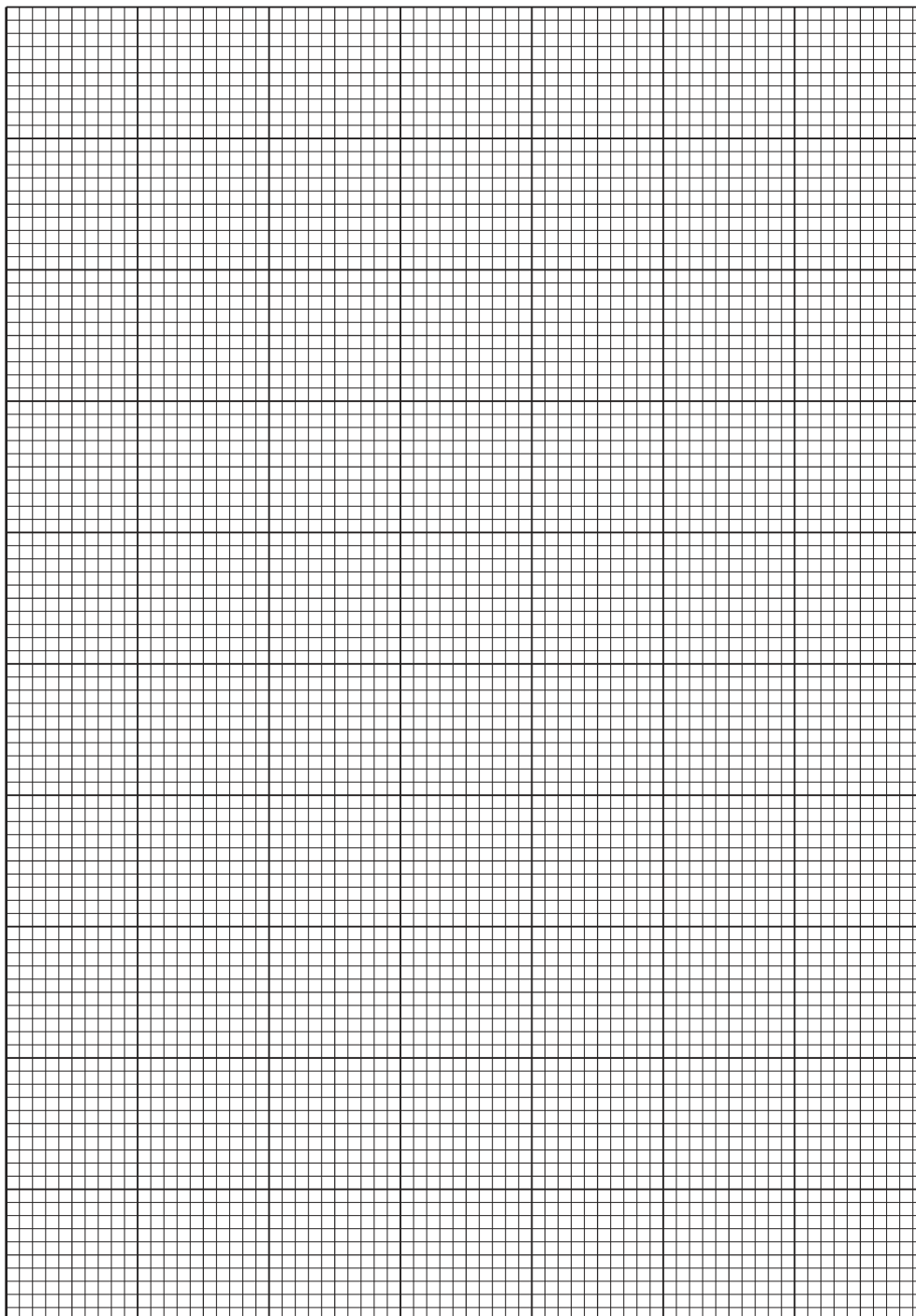
| | | | | | | | | | | | |
|---------------------------------|---|---------------|---|----------------|---|----------------|---|----------------|---|----------------|---|
| time/minutes | 0 | $\frac{1}{2}$ | 1 | $1\frac{1}{2}$ | 2 | $2\frac{1}{2}$ | 3 | $3\frac{1}{2}$ | 4 | $4\frac{1}{2}$ | 5 |
| temperature/ $^{\circ}\text{C}$ | | | | | | | | | | | |

| | | | | | | | | | | |
|---------------------------------|----------------|---|----------------|---|----------------|---|----------------|---|----------------|----|
| time/minutes | $5\frac{1}{2}$ | 6 | $6\frac{1}{2}$ | 7 | $7\frac{1}{2}$ | 8 | $8\frac{1}{2}$ | 9 | $9\frac{1}{2}$ | 10 |
| temperature/ $^{\circ}\text{C}$ | | | | | | | | | | |

[4]

| | |
|-----|--|
| I | |
| II | |
| III | |
| IV | |

- (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 10°C above your highest recorded temperature. You will use this graph to determine the theoretical maximum temperature rise at $2\frac{1}{2}$ minutes.



| | |
|-----|--|
| I | |
| II | |
| III | |
| IV | |
| V | |

Draw two lines of best fit through the points on your graph. The first line should be for the temperature before adding **FB 2** and the second for the cooling of the mixture once the reaction is complete.

Extrapolate the two lines to $2\frac{1}{2}$ minutes, draw a vertical line between the two and determine the theoretical rise in temperature at this time.

theoretical rise in temperature at $2\frac{1}{2}$ minutes = $^{\circ}\text{C}$ [5]

(d) Reaction 2 Enthalpy change of a strong acid.

FB 3 is hydrochloric acid, HCl .

The tube labelled **FB 4** contains two strips of magnesium, Mg . One strip is longer than the other strip.

Method 2

Read the whole method before starting any practical work and prepare a table for your results in the space below.

- Weigh the longer strip of magnesium and record the balance reading.
 - Support the plastic cup in the 250 cm^3 beaker.
 - Coil the magnesium ribbon loosely so that it fits into the bottom of the plastic cup and then remove the ribbon.
 - Use the measuring cylinder to transfer 25 cm^3 of the acid, **FB 3**, into the plastic cup.
 - Place the thermometer in the acid and measure and record the initial temperature of the acid.
 - Add the piece of magnesium into the acid in the cup.
 - Stir constantly until the maximum temperature is reached.
 - Measure and record the maximum temperature.
 - Rinse the plastic cup for use in the next experiment.
 - Calculate and record the temperature rise.
-
- Repeat this experiment using the shorter strip of magnesium and record all results.

[3]

(g) Ethanoic acid is a weak acid. It is partially ionised in aqueous solution.



You are to determine the energy needed to cause the molecules of ethanoic acid to ionise completely.



Hydrochloric acid is a strong acid; it is fully ionised in aqueous solution.

The values for the enthalpy changes you obtained in (c)(ii) and (e) could be used to calculate the energy change for the ionisation **but** more accurate experiments give the results in Table 1.

Table 1

| reaction | equation | $\Delta H/\text{kJ mol}^{-1}$ |
|----------|---|-------------------------------|
| 1 | $\text{Mg}(\text{s}) + 2\text{CH}_3\text{COOH}(\text{aq}) \rightarrow \text{Mg}(\text{CH}_3\text{COO})_2(\text{aq}) + \text{H}_2(\text{g})$ | -460.3 |
| 2 | $\text{Mg}(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g})$ | -464.1 |

(i) Write the **ionic** equation, including state symbols, for the reaction of magnesium with aqueous hydrochloric acid.

.....

(ii) Use the data in **Table 1** to calculate the enthalpy change for the ionisation of ethanoic acid.



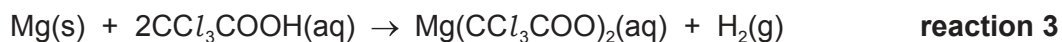
Show clearly how you obtained your answer.

$$\Delta H = \dots\dots \dots\dots \text{kJ mol}^{-1}$$

(sign) (value)

[4]

(h) The experiment in (a) was repeated using trichloroethanoic acid instead of ethanoic acid.



Trichloroethanoic acid, CCl_3COOH , is a weak acid that is however stronger than ethanoic acid.

The enthalpy change for reaction 3 is between the two values given in Table 1.

Table 1

| reaction | equation | $\Delta H/\text{kJ mol}^{-1}$ |
|----------|---|-------------------------------|
| 1 | $\text{Mg(s)} + 2\text{CH}_3\text{COOH(aq)} \rightarrow \text{Mg}(\text{CH}_3\text{COO})_2\text{(aq)} + \text{H}_2\text{(g)}$ | -460.3 |
| 2 | $\text{Mg(s)} + 2\text{HCl(aq)} \rightarrow \text{MgCl}_2\text{(aq)} + \text{H}_2\text{(g)}$ | -464.1 |

(i) Explain why the enthalpy change for reaction 3 is more exothermic than the enthalpy change for reaction 1.

.....

(ii) Explain why the enthalpy change for reaction 3 is less exothermic than the enthalpy change for reaction 2.

.....

[2]

[Total: 25]

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

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.

(a) (i) **FB 5, FB 6** and **FB 7** each contain one anion and one cation.

Carry out the following tests and record your observations.

| <i>test</i> | <i>observations</i> | | |
|---|---------------------|-------------|-------------|
| | FB 5 | FB 6 | FB 7 |
| To a 1 cm depth of solution in a test-tube, add a few drops of aqueous silver nitrate, then | | | |
| add aqueous ammonia. | | | |
| To a 1 cm depth of solution in a test-tube, add a few drops of aqueous barium nitrate, or barium chloride, then | | | |
| add dilute nitric acid. | | | |
| To a 1 cm depth of solution in a test-tube, add a spatula measure of solid sodium carbonate. | | | |

(ii) What cation is present in **FB 5**, **FB 6** and **FB 7**?

.....

(iii) Suggest another test that you could carry out to confirm the presence of the cation you identified in (ii).

Carry out this test on one of **FB 5**, **FB 6** or **FB 7** and record your observation.

test

observation

(iv) Complete the table to identify, as far as possible, the anions present in **FB 5**, **FB 6** and **FB 7**. If you are not able to identify the anion from the tests you carried out in (i), write 'unknown'.

| | FB 5 | FB 6 | FB 7 |
|-------------|-------------|-------------|-------------|
| ion present | | | |

(v) For any **one** anion that you were unable to identify in (iv) you are to devise a test or tests that will enable you to identify it. You can assume that it is one of the anions listed in the Qualitative Analysis Notes.

Carry out the test(s), record the observation(s) you obtained and identify the unknown anion.

test(s)

.....

.....

observation(s)

.....

.....

Anion present in is

[10]

(b) **FB 8** is an aqueous solution of a mixture containing two anions and two cations.

Carry out the following tests and record your observations.

| <i>test</i> | <i>observations</i> |
|---|---------------------|
| To a 1 cm depth of FB 8 in a test-tube, add a 1 cm depth of dilute hydrochloric acid, then | |
| add a few drops of hydrogen peroxide, then | |
| add a few drops of starch. | |
| To a 1 cm depth of FB 8 in a test-tube, add aqueous sodium hydroxide. | |
| To a 1 cm depth of FB 8 in a test-tube, add a 3 cm depth of aqueous copper(II) sulfate, then | |
| add a 1 cm depth of dilute hydrochloric acid, then | |
| add aqueous sodium thiosulfate. | |

From these observations, identify two ions present in **FB 8**.

ions present in **FB 8** and [5]

[Total: 15]

Qualitative Analysis Notes

1 Reactions of aqueous cations

| ion | reaction with | |
|--|--|--|
| | NaOH(aq) | NH ₃ (aq) |
| aluminium, Al ³⁺ (aq) | white ppt. soluble in excess | white ppt. insoluble in excess |
| ammonium, NH ₄ ⁺ (aq) | no ppt. ammonia produced on heating | – |
| barium, Ba ²⁺ (aq) | faint white ppt. is nearly always observed unless reagents are pure | no ppt. |
| calcium, Ca ²⁺ (aq) | white ppt. with high [Ca ²⁺ (aq)] | no ppt. |
| chromium(III), Cr ³⁺ (aq) | grey-green ppt. soluble in excess | grey-green ppt. insoluble in excess |
| copper(II), Cu ²⁺ (aq) | pale blue ppt. insoluble in excess | blue ppt. soluble in excess giving dark blue solution |
| iron(II), Fe ²⁺ (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 ³⁺ (aq) | red-brown ppt. insoluble in excess | red-brown ppt. insoluble in excess |
| magnesium, Mg ²⁺ (aq) | white ppt. insoluble in excess | white ppt. insoluble in excess |
| manganese(II), Mn ²⁺ (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 ²⁺ (aq) | white ppt. soluble in excess | white ppt. soluble in excess |

2 Reactions of anions

| <i>ion</i> | <i>reaction</i> |
|---|---|
| carbonate, CO_3^{2-} | 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, $\text{NO}_3^-(\text{aq})$ | NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil |
| nitrite, $\text{NO}_2^-(\text{aq})$ | NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil; NO liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown 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, NH_3 | turns damp red litmus paper blue |
| carbon dioxide, CO_2 | gives a white ppt. with limewater (ppt. dissolves with excess CO_2) |
| chlorine, Cl_2 | bleaches damp litmus paper |
| hydrogen, H_2 | 'pops' with a lighted splint |
| oxygen, 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 oganeson —</div> </div> | | | | | | | | | | | | | | | |
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