Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/52**

Paper 5 Planning, Analysis and Evaluation **October/November 2025**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

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 30.
- 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.

This document has **16** pages. Any blank pages are indicated.

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1 Aqueous silver ions, $Ag^+(aq)$, react slowly with aqueous iron(II) ions, $Fe^{2+}(aq)$. An equilibrium is established.

$$Ag^+(aq) + Fe^{2+}(aq) \rightleftharpoons Ag(s) + Fe^{3+}(aq)$$

The concentration of $Ag^+(aq)$ at equilibrium can be determined by titration with a standard solution of aqueous potassium thiocyanate, KSCN(aq).

During the titration, the remaining $Ag^+(aq)$ ions react with $SCN^-(aq)$ ions to form a precipitate of AgSCN(s).

$$Ag^+(aq) + SCN^-(aq) \rightarrow AgSCN(s)$$

When all $Ag^+(aq)$ ions have been removed from solution, excess $SCN^-(aq)$ ions react with $Fe^{3+}(aq)$ to form a complex ion, $FeSCN^{2+}(aq)$, which has a red colour.

$$Fe^{3+}(aq) + SCN^-(aq) \rightarrow FeSCN^{2+}(aq)$$

The appearance of the red colour indicates the end-point.

A student carries out an experiment to determine the equilibrium constant, K_c.

$$K_c = \frac{[Fe^{3+}(aq)]_{eqm}}{[Fe^{2+}(aq)]_{eqm}\,[Ag^+(aq)]_{eqm}}$$

The student makes 250.0 cm^3 of 0.0200 mol dm^{-3} KSCN(aq) to use in the titration.

(a) Calculate the mass of solid potassium thiocyanate, KSCN(s), needed to make 250.0 cm^3 of 0.0200 mol dm^{-3} KSCN(aq).

mass of KSCN(s) = ... g [1]

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(b) Describe how the student should make 250.0 cm^3 of 0.0200 mol dm^{-3} KSCN(aq) starting from the mass of KSCN(s) calculated in **(a)** in a 50 cm^3 beaker.

Give the name and size of any key apparatus used.

Write your answer using a series of numbered steps.

.....

.....

.....

.....

.....

.....

..... [3]

(c) The student uses the following method to determine K_c.

step 1 Add 25.0 cm^3 of 0.100 mol dm^{-3} aqueous silver nitrate, $AgNO_3$(aq), into a dry conical flask. Label this flask **A**.

step 2 Add 25.0 cm^3 of 0.100 mol dm^{-3} aqueous iron(II) sulfate, $FeSO_4$(aq), into flask **A**.

step 3 Seal flask **A**, using a bung.

step 4 Allow flask **A** to stand for twelve hours.

step 5 Transfer 10.0 cm^3 of the mixture from flask **A** into another conical flask, flask **B**, without disturbing the precipitate in flask **A**.

step 6 Titrate the sample in flask **B** with 0.0200 mol dm^{-3} aqueous potassium thiocyanate, KSCN(aq).

step 7 Repeat steps 5 and 6 until concordant values are obtained.

(i) Suggest why flask **A** is sealed with a bung in step 3.

.....

..... [1]

(ii) Suggest why flask **A** is left to stand for twelve hours in step 4.

.....

..... [1]

(iii) Identify the precipitate in flask **A** in step 5.

..... [1]

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(d) The student's results are shown in Table 1.1

Table 1.1

	rough titration	titration 1	titration 2	titration 3
final burette reading / cm^3	22.50	21.75	31.65	32.20
initial burette reading / cm^3	0.00	0.00	9.75	10.20
titre / cm^3	22.50	21.75	21.90	22.00

(i) State if concordant titres have been achieved.

Explain your answer.

.....

..... [1]

(ii) Calculate the percentage error in the titre volume in titration 2.

Show your working.

percentage error = ... [1]

(iii) The student repeats the experiment using KSCN(aq) at a **higher** concentration. The student obtains **smaller** titres.

Suggest **one** reason why a larger titre is better than a smaller titre.

..... [1]

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(e) Another student calculates a mean titre of 21.85 cm^3. Use this value to complete the following calculation.

(i) Calculate $[Ag^+(aq)]$ in the equilibrium mixture in flask **A**.

$[Ag^+(aq)]_{eqm}$ = ... $mol\,dm^{-3}$ [1]

(ii) Calculate $[Fe^{3+}(aq)]$ in the equilibrium mixture in flask **A**.

$[Fe^{3+}(aq)]_{eqm}$ = ... $mol\,dm^{-3}$ [1]

(iii) The formula for the equilibrium constant, K_c, is shown.

$$K_c = \frac{[Fe^{3+}(aq)]_{eqm}}{[Fe^{2+}(aq)]_{eqm}\,[Ag^+(aq)]_{eqm}}$$

Determine the value of K_c.

Give the units of K_c.

K_c = ...

units .....

[2]

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(f) Several other students perform the same experiment at different temperatures. The K_c values that they obtain are used to produce the graph in Fig. 1.1.

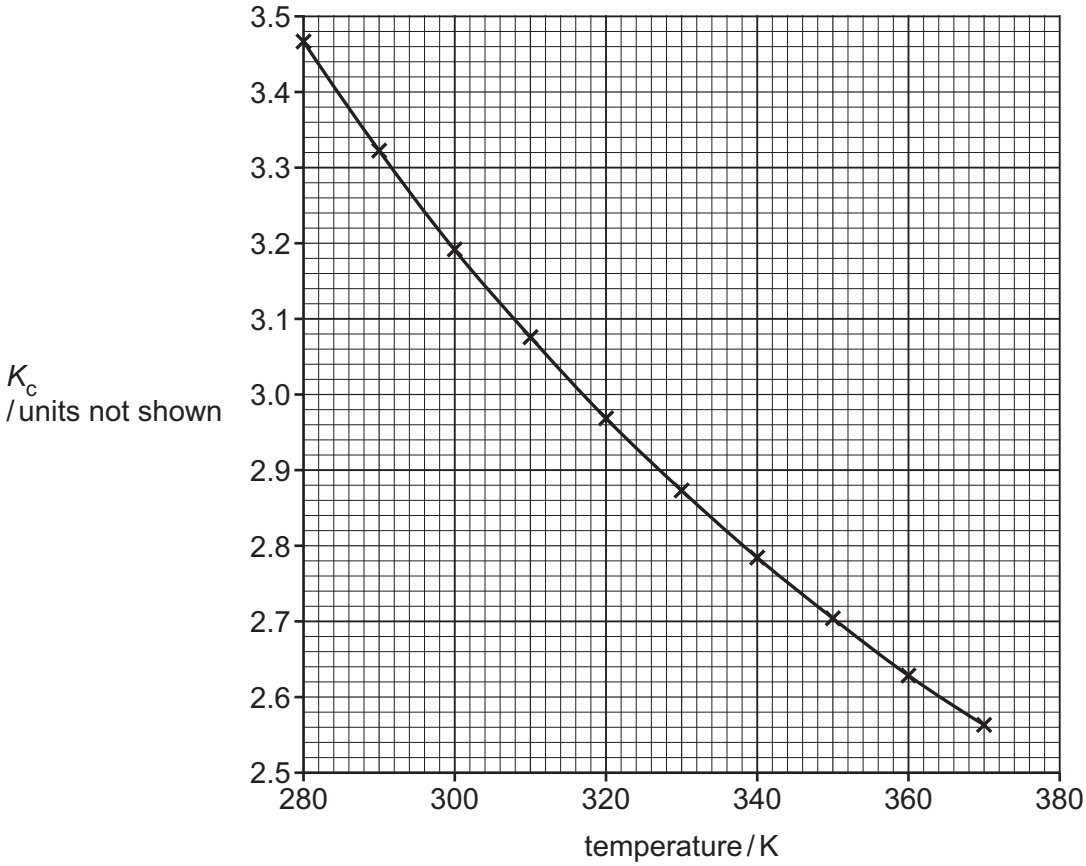

Fig. 1.1

(i) One student suggests that K_c is directly proportional to temperature.

State and explain if the results displayed in Fig. 1.1 support this suggestion.

.....

..... [1]

(ii) Another student suggests that the data represented in the graph in Fig. 1.1 is reliable.

Explain how the graph supports this suggestion.

.....

.....

..... [1]

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(iii) Use the data displayed in Fig. 1.1 to state if the forward reaction is exothermic or endothermic.

$$Ag^{+}(aq) + Fe^{2+}(aq) \rightleftharpoons Ag(s) + Fe^{3+}(aq)$$

Explain your answer.

forward reaction .....

explanation .....

.....

.....
[1]

[Total: 17]

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2 A student carries out an experiment to determine the concentration of aqueous sulfate ions, $SO_4^{2-}(aq)$, in a sample of lake water.

(a) The student uses the following method.

step 1 Transfer 25.00 cm^3 of the lake water sample to a beaker and record its conductivity as shown in Fig. 2.1.

step 2 Add 5.00 cm^3 of 0.100 mol dm^{-3} aqueous barium hydroxide, $Ba(OH)_2(aq)$, to the beaker.

step 3 Stir the mixture and record the conductivity of the contents of the beaker as shown in Fig. 2.1.

step 4 Repeat steps 2 and 3 until a total of 40.00 cm^3 of 0.100 mol dm^{-3} $Ba(OH)_2(aq)$ has been added to the beaker.

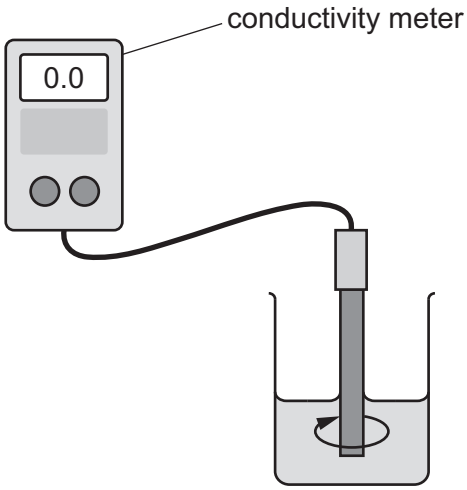

Fig. 2.1

(i) Suggest a suitable piece of apparatus to transfer 25.00 cm^3 of the lake water sample to the beaker in step 1.

..... [1]

(ii) 0.100 mol dm^{-3} $Ba(OH)_2(aq)$ is an irritant to skin and eyes. Other than wearing safety goggles, state **one** safety precaution that the student should take when conducting this experiment.

..... [1]

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(b) The student's results are given in Table 2.1.

A correction can be applied to the conductivity values to take into account dilution of the solution as its volume increases using the following equation.

$$\text{corrected conductivity} = \text{measured conductivity} \times \frac{\text{(total volume in beaker)}}{25.00}$$

Table 2.1

reading number	volume of 0.100 mol dm^{-3} $Ba(OH)_2(aq)$ added to beaker / cm^3	total volume in beaker / cm^3	measured conductivity / μS cm^{-1}	corrected conductivity / μS cm^{-1}
1	0.00	25.00	37 000	37 000
2	5.00		23 000	27 600
3	10.00		12 000	16 800
4	15.00		2 300	3 680
5	20.00		5 000	
6	25.00		12 000	
7	30.00		18 000	
8	35.00		21 000	
9	40.00		24 500	

(i) Complete Table 2.1. [2]

(ii) Identify the independent variable in this experiment.

..... [1]

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(c) Plot a graph on the grid in Fig. 2.2 to show the relationship between corrected conductivity and volume of 0.100 mol dm^{-3} $Ba(OH)_2$ added to beaker.

Use a cross (×) to plot each data point.

Draw a line of best fit using readings 1 to 4 and another line of best fit using readings 5 to 9. Extend the lines so that they intersect.

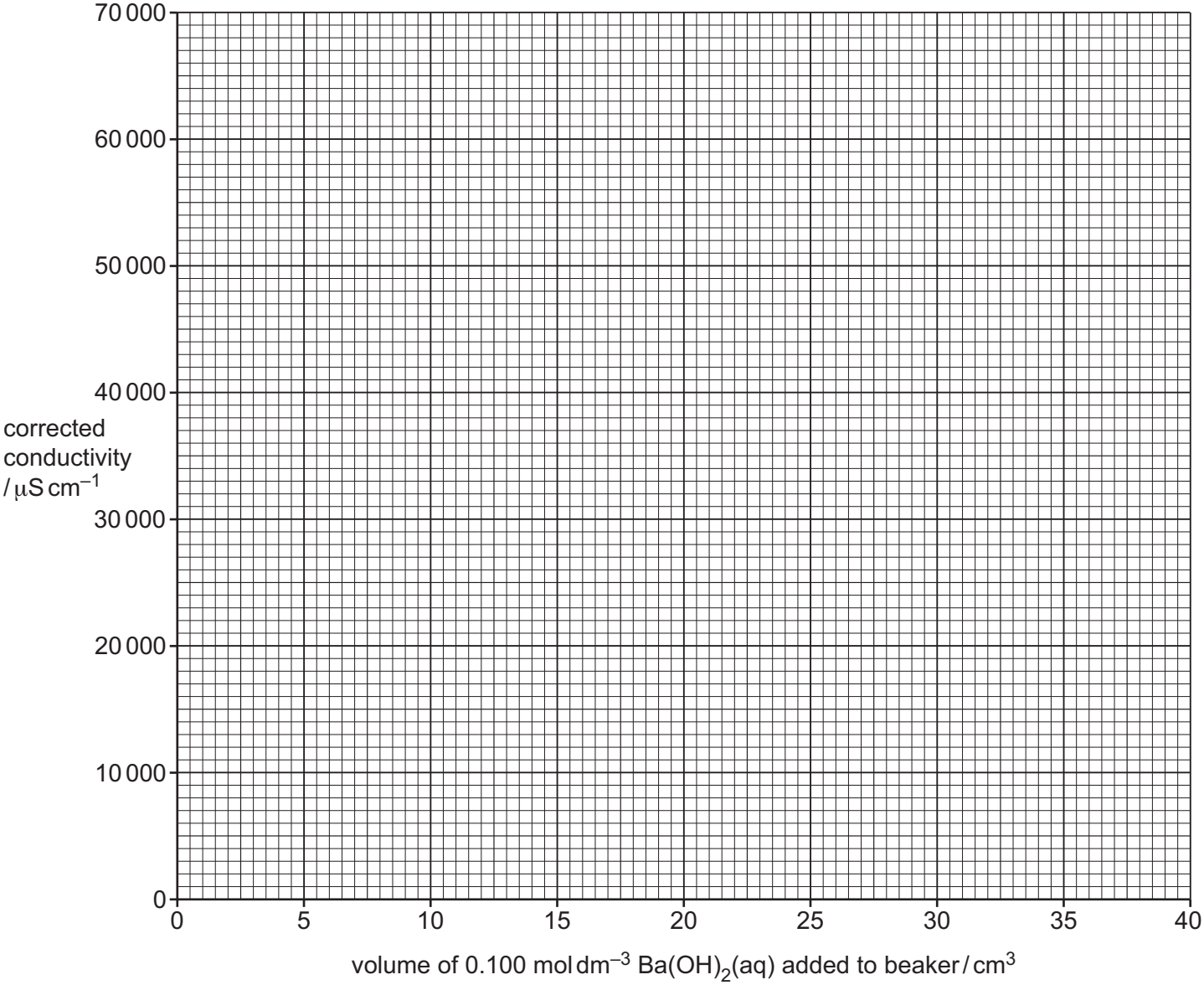

Fig. 2.2

[2]

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(d) The point on the graph where the two lines intersect indicates the volume of 0.100 mol dm^{-3} $Ba(OH)_2$(aq) required to react exactly with the SO_4^{2-}(aq) present in 25.00 cm^3 of lake water being tested.

(i) Use the graph in Fig. 2.2 to determine the volume of 0.100 mol dm^{-3} $Ba(OH)_2$(aq) required to react exactly with SO_4^{2-}(aq) in the lake water sample.

volume required = ... cm^3 [1]

(ii) The equation for the reaction taking place in the beaker is shown.

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

Use your answer in **(d)(i)** to calculate the concentration of SO_4^{2-}(aq) in the lake water sample.

concentration of SO_4^{2-}(aq) = ... mol dm^{-3} [1]

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(e) The concentration of $SO_4^{2-}(aq)$ in a sample of water can also be determined by measuring the mass of precipitate produced when excess $Ba(OH)_2(aq)$ is added to the sample.

The student suggests the following method.

step 1 Place 25.0 cm^3 of the water sample in a conical flask.

step 2 Add excess 0.100 mol dm^{-3} $Ba(OH)_2(aq)$ to the flask.

step 3 Filter the contents of the flask.

step 4 Dry the residue in a warm oven.

step 5 Measure the mass of residue.

(i) Draw a labelled diagram to describe the arrangement of apparatus that would be needed to complete step 3.

[1]

(ii) Suggest a step that the student should add between steps 3 and 4 to improve this method.

..... [1]

(iii) Describe what the student can do to ensure that the residue weighed in step 5 is completely dry.

.....

..... [1]

(iv) The mass of residue is used to calculate the concentration of $SO_4^{2-}(aq)$.

Suggest the effect, if any, on the concentration of $SO_4^{2-}(aq)$ that is calculated if the residue is **not** completely dried in step 4.

Explain your answer.

effect on concentration of $SO_4^{2-}(aq)$ calculated .....

explanation .....

.....

[1]

[Total: 13]

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Important values, constants and standards

molar gas constant	$R = 8.31\,J\,K^{-1}\,mol^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,C\,mol^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23}\,mol^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,C$
molar volume of gas	$V_m = 22.4\,dm^3\,mol^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,dm^3\,mol^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$)

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The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

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

lanthanoids	57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium –	62 **Sm** samarium 150.4	63 **Eu** europium 152.0	64 **Gd** gadolinium 157.3	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.1	71 **Lu** lutetium 175.0
actinoids	89 **Ac** actinium –	90 **Th** thorium 232.0	91 **Pa** protactinium 231.0	92 **U** uranium 238.0	93 **Np** neptunium –	94 **Pu** plutonium –	95 **Am** americium –	96 **Cm** curium –	97 **Bk** berkelium –	98 **Cf** californium –	99 **Es** einsteinium –	100 **Fm** fermium –	101 **Md** mendelevium –	102 **No** nobelium –	103 **Lr** lawrencium –

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