Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/51**

Paper 5 Planning, Analysis and Evaluation **October/November 2024**

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.

1 A student uses the following method to determine the percentage by mass of the painkiller aspirin, $C_9H_8O_4(s)$, in some tablets.

step 1 Grind five tablets into a powder.

step 2 Use a weighing boat to accurately weigh by difference approximately 0.4 g of powdered tablets into a pear-shaped flask containing anti-bumping granules.

step 3 Add 25 cm^3 of aqueous 1 mol dm^{-3} sodium hydroxide, NaOH(aq), to the pear-shaped flask, forming mixture **A**.

step 4 Reflux mixture **A** for 20 minutes.

step 5 Allow mixture **A** to cool and then filter into a small beaker. Label the filtrate solution **B**.

step 6 Add 30 cm^3 of alkaline aqueous iodine to solution **B** and leave to stand for 1 hour. A precipitate, **C**, $(C_6H_2I_2O)_2(s)$, will form.

step 7 Filter the resulting mixture under reduced pressure. Wash the residue, **C**, with a small volume of cold distilled water.

step 8 Allow solid **C** to dry.

step 9 Weigh solid **C** and record its mass.

Alkaline aqueous iodine is irritating to the skin and eyes.

(a) Identify an appropriate precaution, other than eye protection and a lab coat, that the student should take when using alkaline aqueous iodine.

.....

..... [1]

(b) Describe how the student should carry out **step 2**. Include a results table, with appropriate headings, for the student to fill in.

.....

.....

.....

[2]

(c) Complete Fig. 1.1 to show how **step 4** is carried out in the laboratory.

Label your diagram fully.

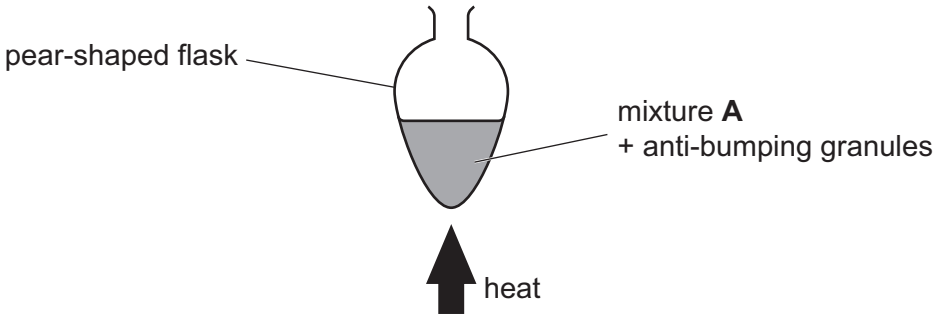

Fig. 1.1

[2]

(d) **(i)** The student uses a measuring cylinder to measure the volume of alkaline aqueous iodine in **step 6**. Suggest why this is a suitable piece of apparatus to use.

.....

..... [1]

(ii) Suggest why the student leaves the mixture to stand for 1 hour in **step 6**.

.....

..... [1]

(iii) Explain why the residue is washed in **step 7**.

.....

..... [1]

(iv) Explain why hot distilled water is **not** used in **step 7**.

.....

..... [1]

(e) The equation for the reaction between aspirin, $C_9H_8O_4(s)$, and NaOH(aq), which takes place in **step 4**, is shown.

$$C_9H_8O_4(s) + 2NaOH(aq) \rightarrow C_7H_5O_3^-Na^+(aq) + C_2H_3O_2^-Na^+(aq) + H_2O(l)$$

The equation for the reaction in which solid **C**, $(C_6H_2I_2O)_2(s)$, is formed in **step 6** is shown.

$$2C_7H_5O_3^-Na^+(aq) + 6I_2(aq) + 8OH^-(aq) \rightarrow (C_6H_2I_2O)_2(s) + 8I^-(aq) + 2NaHCO_3(aq) + 6H_2O(l)$$

The student's results are shown in Table 1.1.

Table 1.1

mass of powdered tablets added to the pear-shaped flask in **step 2**	0.409 g
mass of dry $(C_6H_2I_2O)_2(s)$ recorded in **step 9**	0.764 g

(i) Calculate the amount, in mol, of $(C_6H_2I_2O)_2(s)$ collected in **step 9**.

[M_r: $(C_6H_2I_2O)_2$, 687.6]

amount of $(C_6H_2I_2O)_2$ ..... mol [1]

(ii) Use your answer to **(i)** to calculate the mass, in g, of $C_9H_8O_4(s)$ in the powdered tablets added to the flask in **step 2**.

mass of $C_9H_8O_4(s)$ ..... g [1]

(iii) Use your answer to **(ii)** to calculate the percentage by mass of aspirin, $C_9H_8O_4(s)$, in the tablets.

If you were unable to obtain an answer to **(ii)** you may use 0.374 g for the mass of $C_9H_8O_4(s)$. This is **not** the correct value.

percentage by mass $C_9H_8O_4(s)$ in the tablets ..... [1]

(f) Another student follows the same method but does not allow solid **C** to dry completely in **step 8**.

State and explain the effect that this has on the calculated percentage by mass of aspirin, $C_9H_8O_4(s)$, in the tablets.

.....

.....

..... [1]

[Total: 13]

2 Crystal violet, $C_{25}H_{30}N_3Cl$(s), is a purple dye.

Some light is absorbed when it passes through $C_{25}H_{30}N_3Cl$(aq).

Absorbance is the proportion of light absorbed at a particular wavelength. This is measured using a colorimeter.

A graph of absorbance against wavelength for $C_{25}H_{30}N_3Cl$(aq) is shown in Fig. 2.1.

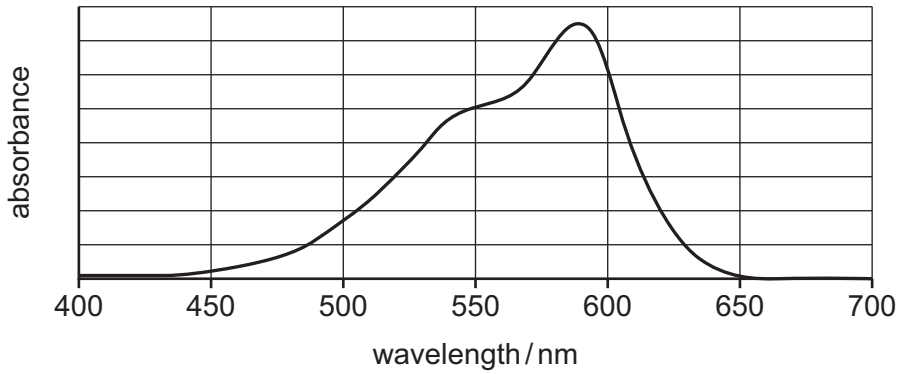

Fig. 2.1

A student investigates how to determine the concentration of aqueous crystal violet, $C_{25}H_{30}N_3Cl$(aq), using colorimetry.

(a) Suggest the best wavelength of light to use in the colorimeter when measuring the concentration of $C_{25}H_{30}N_3Cl$(aq).

wavelength = ... nm [1]

(b) Solution **D** is 500.0 cm^3 of 2.50×10^{-2} mol dm^{-3} $C_{25}H_{30}N_3Cl$(aq).

(i) Calculate the mass of $C_{25}H_{30}N_3Cl$(s) needed to prepare solution **D**.

Give your answer to **three significant figures**.

[M_r: $C_{25}H_{30}N_3Cl$(s), 407.5]

mass of $C_{25}H_{30}N_3Cl$(s) = ... g [1]

(ii) The student is given a small beaker containing the mass of $C_{25}H_{30}N_3Cl$(s) calculated in **(i)**.

Describe how the student should prepare 500.0 cm^3 of solution **D**.

Include the name and capacity of the key apparatus which should be used and describe how the student should ensure the volume is exactly 500.0 cm^3.

.....

.....

.....

.....

.....

.....

..... [3]

(c) A small sample of solution **D** was diluted to form solution **E**, 2.50×10^{-4} mol dm^{-3} $C_{25}H_{30}N_3C\ell$(aq).

The student prepares solutions 2 to 6 as shown in Table 2.1.

The total volume needed for each of solutions 2 to 6 is 20.00 cm^3.

Each solution is placed into a colorimeter and the absorbance is measured.

(i) Complete Table 2.1 to show the volumes of solution **E** and distilled water needed to prepare each of the solutions from 2 to 6. Give all volumes to **two** decimal places.

Table 2.1

solution	volume of 2.50×10^{-4} mol dm^{-3} $C_{25}H_{30}N_3C\ell$(aq) (solution **E**) / cm^3	volume of distilled water / cm^3	[$C_{25}H_{30}N_3C\ell$(aq)] / mol dm^{-3}	absorbance
1	0.00	20.00	0.00	0.000
2			0.50×10^{-4}	0.191
3			1.00×10^{-4}	0.270
4			1.50×10^{-4}	0.545
5			2.00×10^{-4}	0.711
6			2.50×10^{-4}	0.860

[1]

(ii) Identify the dependent variable.

..... [1]

(d) (i) Plot a graph of absorbance against $[C_{25}H_{30}N_3Cl(aq)]$ on the grid in Fig. 2.2.

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

Draw a straight line of best fit.

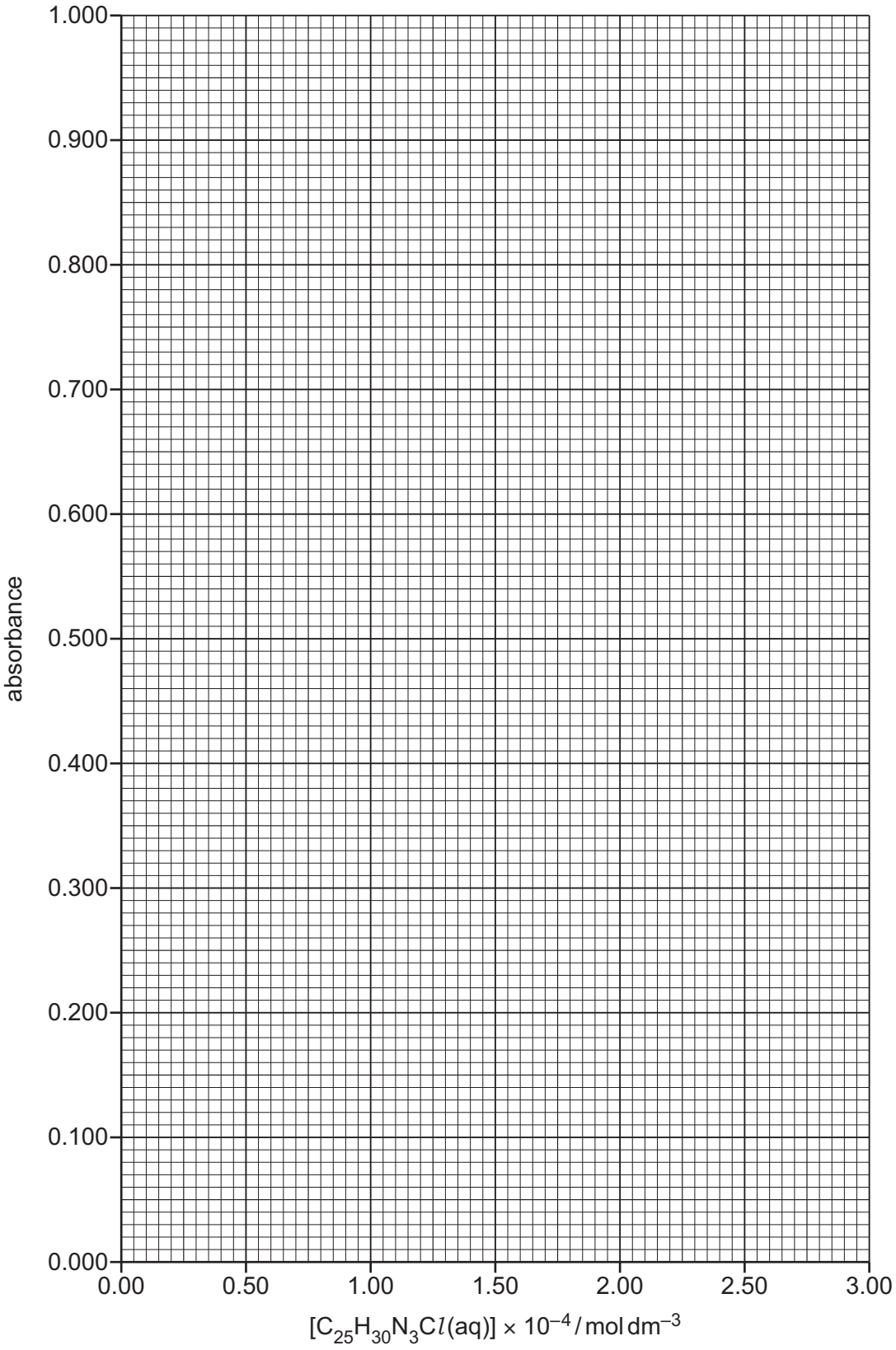

Fig. 2.2

[2]

(ii) Circle the point on the graph you consider to be most anomalous.

Suggest **one** reason why this anomaly may have occurred during this experimental procedure.

Assume no error was made in the measurement of absorbance.

.....

..... [2]

(iii) State the relationship between [$C_{25}H_{30}N_3C\ell$(aq)] and absorbance.

..... [1]

(iv) Suggest how the student could improve the reliability of the data obtained in the experiment in **(c)**.

.....

..... [1]

Question 2 continues on the next page.

(e) The student carries out a further experiment to examine the kinetics of the reaction between crystal violet, $C_{25}H_{30}N_3Cl(aq)$, and aqueous sodium hydroxide, NaOH(aq).

$$C_{25}H_{30}N_3Cl(aq) + OH^-(aq) \rightarrow C_{25}H_{30}N_3OH(aq) + Cl^-(aq)$$

The disappearance of the purple colour as the reaction proceeds can be monitored by measuring how the absorbance of light by the mixture changes using a colorimeter.

The student mixes 5 cm^3 of solution 6 with 5 cm^3 of NaOH(aq), a large excess, and immediately starts the stopwatch.

The resulting mixture is then placed in a colorimeter. The absorbance of this mixture is measured every 100 seconds after starting the stop-watch.

Fig. 2.3 shows a graph of the student's results.

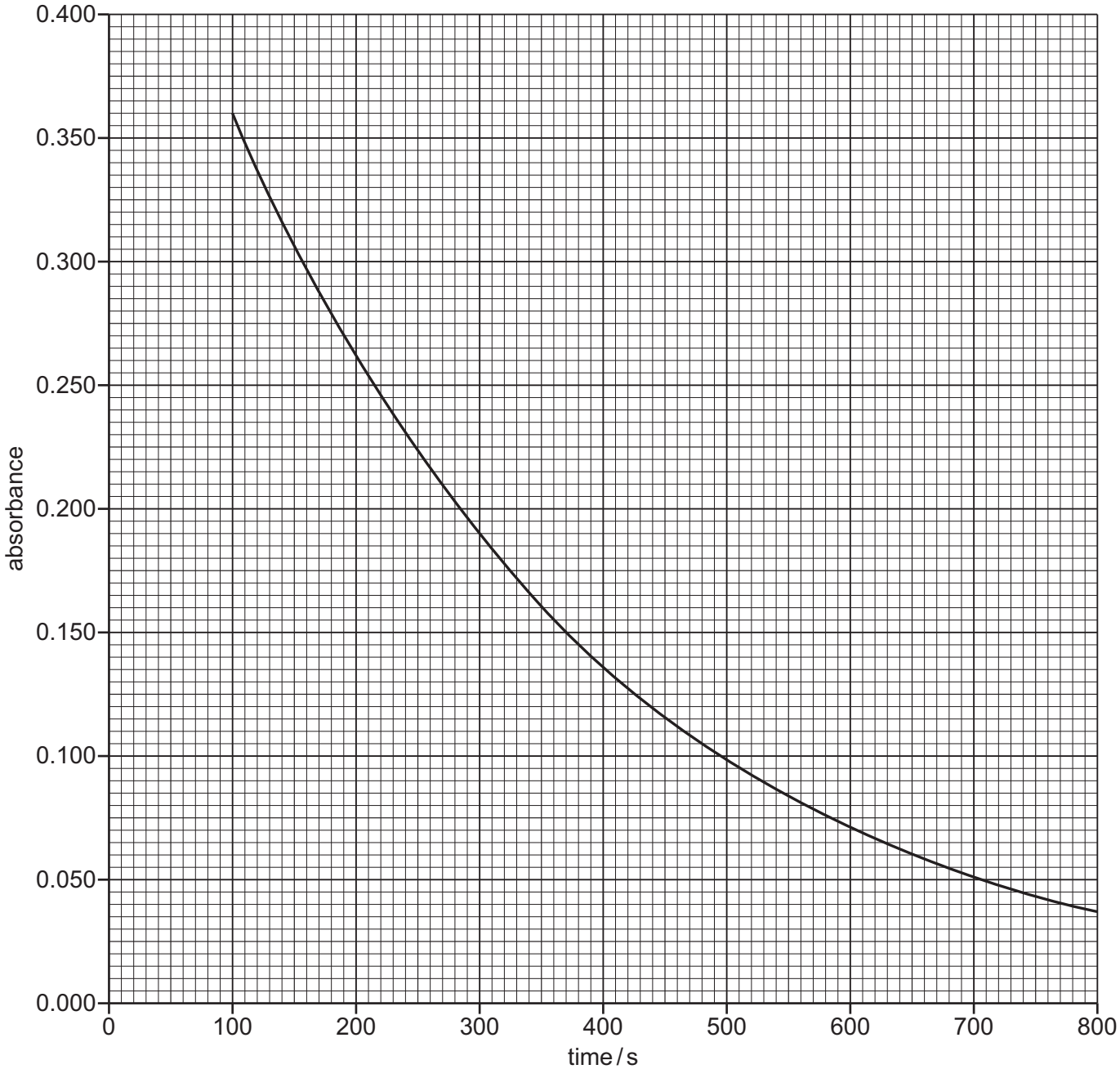

Fig. 2.3

(i) Suggest why it is **not** possible for the student to measure the absorbance of the mixture at t = 0 s.

.....

..... [1]

(ii) Use the graph in Fig. 2.3 to find the half-life, $t_{\frac{1}{2}}$, starting at 100 s.

State the coordinates of both points on the line of best fit used in your calculation.

coordinates 1 ..... coordinates 2 .....

half-life ..... s
[2]

(iii) Another student repeats the experiment at a different temperature and measures two half-life values. The values obtained are 420 s and 425 s.

Use these values to deduce the order of the reaction with respect to $C_{25}H_{30}N_3C\ell(aq)$. Explain your answer.

order = ...

explanation .....

..... [1]

[Total: 17]

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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) $V_m = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ 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											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	3	4	5	6	7	8	9	10	11	12	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 –

Key

atomic number
atomic symbol
name
relative atomic mass

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 –