Cambridge Assessment International Education

# Cambridge International AS & A Level

**CHEMISTRY** **9701/11**

Paper 1 Multiple Choice **May/June 2022**

**1 hour 15 minutes**

You must answer on the multiple choice answer sheet.

You will need: Multiple choice answer sheet
Soft clean eraser
Soft pencil (type B or HB is recommended)

**INSTRUCTIONS**

- There are **forty** questions on this paper. Answer **all** questions.
- For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the multiple choice answer sheet.
- Follow the instructions on the multiple choice answer sheet.
- Write in soft pencil.
- Write your name, centre number and candidate number on the multiple choice answer sheet in the spaces provided unless this has been done for you.
- Do **not** use correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.

**INFORMATION**

- The total mark for this paper is 40.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.



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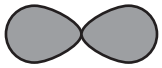
**[Turn over**

**1** Which atom has its outermost electron in an orbital of the shape shown, with principal quantum number 3?



**A** sodium

**B** chlorine

**C** calcium

**D** bromine

**2** Which atom has the same number of electrons as the hydroxide ion, $OH^-$?

**A** F **B** Ne **C** Na **D** Mg

**3** In separate experiments, 5.0 g samples of each of four s-block metals are added to an excess of water. The gas evolved is collected and its volume measured under the same conditions of temperature and pressure for each sample.

Which metal produces the largest volume of gas?

**A** calcium

**B** potassium

**C** rubidium

**D** strontium

**4** A student reacts 1 mol of copper with concentrated nitric acid to produce 1 mol of copper(II) nitrate, 2 mol of water and substance X. No other product is formed.

Substance X does not contain copper or hydrogen.

What could be substance X?

**A** $N_2$ **B** $N_2O$ **C** NO **D** $NO_2$

**5** In which structure are three atoms bonded together in a straight line?

**A** poly(ethene), $-(CH_2CH_2)_n-$

**B** propane, $C_3H_8$

**C** silicon tetrachloride, $SiCl_4$

**D** sulfur hexafluoride, $SF_6$

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**6** Which statement about aluminium chloride is correct?

**A** Aluminium chloride has a much higher melting point than magnesium chloride due to the small size of the aluminium ion.

**B** Anhydrous aluminium chloride reacts vigorously with water to form a solution with a pH greater than 7.

**C** Each $Al_2Cl_6$ molecule found in aluminium chloride vapour contains two coordinate bonds.

**D** The bonding between aluminium and chlorine is strongly ionic due to the large difference in electronegativity.

**7** 'Black powder' is a mixture of potassium nitrate, carbon and sulfur. The mixture reacts as shown.

$$4KNO_3(s) + 7C(s) + S(s) \rightarrow 3CO_2(g) + 3CO(g) + 2N_2(g) + K_2S(s) + K_2CO_3(s)$$

A sealed tube containing black powder has a volume of 10.0 $cm^3$. When all of the black powder reacts, the reaction causes a pressure of $2 \times 10^6$ Pa and a temperature of 2500 K.

The volume of the $K_2CO_3$ and $K_2S$ produced can be ignored.

How many moles of $KNO_3$ are contained in the sealed tube?

**A** $4.81 \times 10^{-4}$ **B** $9.63 \times 10^{-4}$ **C** $1.93 \times 10^{-3}$ **D** $9.63 \times 10^{-1}$

**8** For which pair is the boiling point of the first compound **higher** than the boiling point of the second compound?

**A** $CH_3CH_2OH$ and $CH_3CH_2SH$

**B** $CH_3CO_2CH_3$ and $CH_3CH_2CO_2H$

**C** $CH_3OCH_3$ and $CH_3CH_2OH$

**D** $CH_3CH_2CHO$ and $CH_3CH_2CO_2H$

**9** The equation for an enthalpy change is shown. The enthalpy change is Q.

$$2C(s) + 3H_2(g) + 3.5O_2(g) \xrightarrow{Q} 2CO_2(g) + 3H_2O(l)$$

What is the correct expression to calculate Q?

**A** $2 \times \Delta H_c^{\ominus}[CO_2(g)] - 3 \times \Delta H_f^{\ominus}[H_2(g)]$

**B** $3 \times \Delta H_f^{\ominus}[H_2O(g)] + 2 \times \Delta H_c^{\ominus}[CO_2(g)]$

**C** $2 \times \Delta H_f^{\ominus}[CO_2(g)] - 3 \times \Delta H_f^{\ominus}[H_2(g)]$

**D** $3 \times \Delta H_f^{\ominus}[H_2O(l)] + 2 \times \Delta H_f^{\ominus}[CO_2(g)]$

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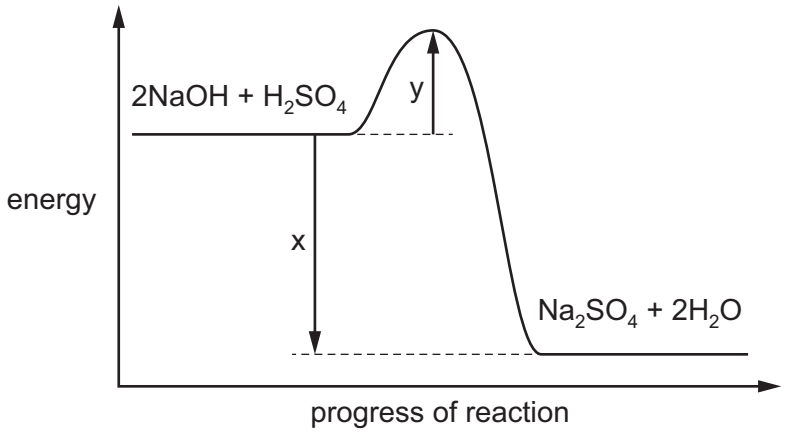
**10** A reaction pathway diagram for the reaction of aqueous sodium hydroxide and dilute sulfuric acid is shown.




What is the value of the enthalpy change of neutralisation, $\Delta H_{neut}$?

**A** x **B** x – y **C** $\frac{x}{2}$ **D** $\frac{(x-y)}{2}$

**11** A student reacts 4 mol of ammonia with oxygen to produce an oxide of nitrogen and water only. Each nitrogen atom increases its oxidation state by 5 in the reaction.

How many moles of oxygen gas react with 4 mol of ammonia in this reaction?

**A** 4 mol **B** 5 mol **C** 7 mol **D** 10 mol

**12** In the treatment of domestic water supplies, chlorine is added to water to kill bacteria. Some $ClO^-$ ions are formed.

What is the change in oxidation number of chlorine when forming the $ClO^-$ ion from aqueous chlorine?

**A** –1 **B** 0 **C** +1 **D** +2

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**13** Ethanoic acid is mixed with ethanol.

The ethanol is contaminated with a small amount of methanol.

The following equilibria are established.

$$CH_3CO_2H(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3CO_2CH_2CH_3(l) + H_2O(l) \qquad K_c = K_1$$

$$CH_3CO_2H(l) + CH_3OH(l) \rightleftharpoons CH_3CO_2CH_3(l) + H_2O(l) \qquad K_c = K_2$$

Which statement about the equilibrium mixture is correct?

**A** Only ethyl ethanoate will be formed because there is much more ethanol present than methanol.

**B** In this mixture $\frac{[CH_3CO_2CH_2CH_3]}{[CH_3CO_2CH_3]} = \frac{K_1}{K_2}$.

**C** Adding water to the mixture will alter the mole ratio of the two esters.

**D** Adding methyl ethanoate to the mixture will increase the number of moles of ethyl ethanoate.

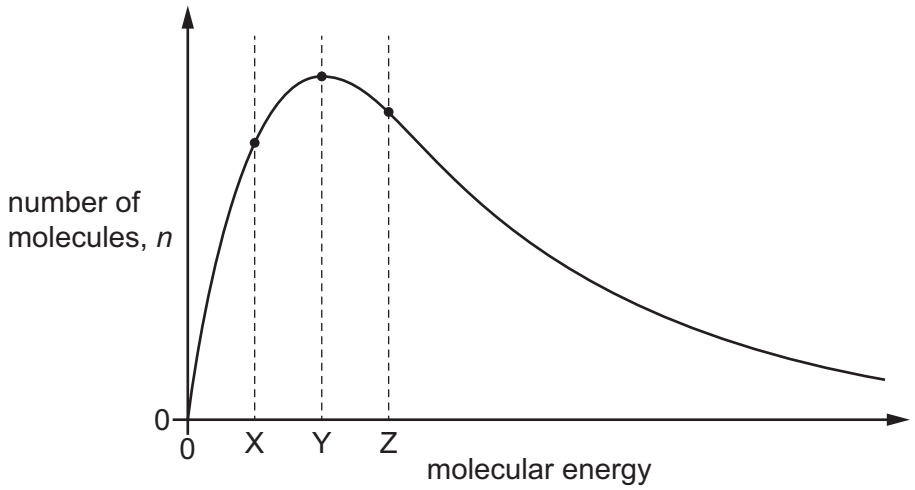
**14** $SO_3$ is manufactured from $SO_2$ and $O_2$ in the Contact process.

The reaction is exothermic.

Which row shows the effect on the equilibrium yield obtained in the Contact process of increasing the temperature and of adding a vanadium(V) oxide catalyst?

| | increasing the temperature | adding vanadium(V) oxide as catalyst |
|---|---|---|
| **A** | equilibrium yield decreases | equilibrium yield increases |
| **B** | equilibrium yield decreases | equilibrium yield unchanged |
| **C** | equilibrium yield increases | equilibrium yield unchanged |
| **D** | equilibrium yield increases | equilibrium yield increases |

**15** The Boltzmann distribution for a gas at a constant temperature of 50 °C is shown.




If the temperature of the gas is **reduced** by 10 °C, the graph changes shape.

What happens to the values of *n* for the molecular energies X, Y and Z?

| | X | Y | Z |
|---|---|---|---|
| **A** | higher | lower | higher |
| **B** | higher | lower | lower |
| **C** | lower | higher | lower |
| **D** | lower | lower | lower |

**16** A 3.0 g sample of $Na_2CO_3$ powder is stirred into 50 $cm^3$ of 1.0 mol $dm^{-3}$ HC*l*. The volume of $CO_2$ produced is 600 $cm^3$.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

[$M_r$: $Na_2CO_3$, 106.0]

Which volume of $CO_2$ is produced if 1.0 g of $Na_2CO_3$ powder is stirred into 50 $cm^3$ of 1.0 mol $dm^{-3}$ HC*l* under the same conditions?

**A** 600 $cm^3$ **B** 452 $cm^3$ **C** 226 $cm^3$ **D** 200 $cm^3$

**17** Solid sodium iodide reacts with concentrated sulfuric acid to form more than one product that contains sulfur.

What is the lowest oxidation number of sulfur in these products?

**A** –2 **B** 0 **C** +4 **D** +6

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**18** Which statement for the element in Period 3 and Group 13 of the Periodic Table is correct?

**A** It has the highest melting point of the elements in its period.

**B** It has exactly one electron in its shell with principal quantum number 3.

**C** It forms an oxide that reacts with aqueous sodium hydroxide.

**D** It forms a chloride that dissolves in water to give a neutral solution.

**19** A student reacts 0.100 mol of each of sodium, magnesium and phosphorus atoms separately with an excess of oxygen.

Which rows are correct?

| | oxide | mass of oxide formed / g |
|---|---|---|
| 1 | sodium | 3.10 |
| 2 | magnesium | 4.03 |
| 3 | phosphorus | 7.10 |

**A** 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

**20** A mixture contains magnesium carbonate and barium carbonate only. A sample of the mixture is dissolved in nitric acid to produce a solution.

How could this solution be processed into a magnesium compound and a separate barium compound?

**A** Add HC$l$(aq), filter off the solid barium chloride.

**B** Add HC$l$(aq), filter off the solid magnesium chloride.

**C** Add $H_2SO_4$(aq), filter off the solid barium sulfate.

**D** Add $H_2SO_4$(aq), filter off the solid magnesium sulfate.

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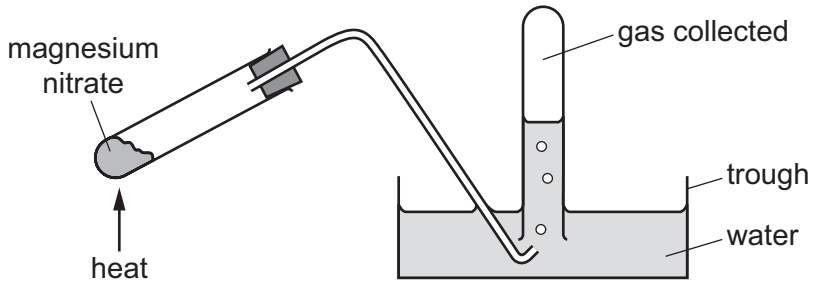
**21** A sample of magnesium nitrate is heated in the apparatus shown.




The pH of the solution in the trough is measured.

The gas collected is tested with a glowing splint.

What are the results?

| | pH of solution in trough | splint test |
|---|---|---|
| **A** | 8 | relights |
| **B** | 2 | relights |
| **C** | 8 | extinguished |
| **D** | 2 | extinguished |

**22** The results of tests performed on a white crystalline solid, X, are given in the table.

| reagent and conditions | observation |
|---|---|
| X is gently heated | X sublimes |
| X is shaken with $H_2O$ | a colourless solution, Y, forms |
| Y is warmed with NaOH(aq) | a gas is given off |
| $AgNO_3$(aq) is added to Y | a white precipitate, Z, forms |
| Z is shaken with $NH_3$(aq) | a colourless solution forms |

What is the identity of X?

**A** aluminium bromide

**B** aluminium chloride

**C** ammonium bromide

**D** ammonium chloride

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**23** Silicon is heated in an excess of chlorine, producing compound J.

An excess of water is added to the sample of J produced.

Which row is correct?

| | structure of J | Is HC$l$ produced when water is added to J? |
|---|---|---|
| **A** | giant molecular | no |
| **B** | giant molecular | yes |
| **C** | simple molecular | no |
| **D** | simple molecular | yes |

**24** In a catalytic converter, 5.6 g of carbon monoxide react with an excess of nitrogen monoxide.

What is produced in this reaction?

**A** 2.4 g of C and 6.0 g of $NO_2$

**B** 2.4 g of C and 9.2 g of $NO_2$

**C** 8.8 g of $CO_2$ and 1.4 g of $N_2$

**D** 8.8 g of $CO_2$ and 2.8 g of $N_2$

**25** Which reaction mixture produces an acidic gas?

**A** aqueous ammonium nitrate and solid calcium oxide

**B** calcium and aqueous hydrochloric acid

**C** potassium chloride and concentrated sulfuric acid

**D** sodium oxide and water

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**26** Ethanol can be used to make propanenitrile in two steps.

$$CH_3CH_2OH \xrightarrow{X} CH_3CH_2Br \xrightarrow{Y} CH_3CH_2CN$$

What types of reaction are X and Y?

| | X | Y |
|---|---|---|
| **A** | free-radical substitution | electrophilic substitution |
| **B** | free-radical substitution | nucleophilic substitution |
| **C** | nucleophilic substitution | nucleophilic substitution |
| **D** | nucleophilic substitution | electrophilic substitution |

**27** Which compound will react with $LiAlH_4$ to form two optical isomers?

**A** $CH_3CH_2COCH_3$

**B** $CH_3CH_2CH_2CHO$

**C** $CH_3CH_2COCH_2CH_3$

**D** $CH_3CH(CH_3)CH_2CO_2H$

**28** How many esters have the molecular formula $C_4H_8O_2$?

**A** 2 **B** 3 **C** 4 **D** 5

**29** Carbon monoxide, CO, nitrogen dioxide, $NO_2$, and sulfur dioxide, $SO_2$, are all atmospheric pollutants.

Which reaction occurs in the atmosphere?

**A** CO is spontaneously oxidised to $CO_2$.

**B** $NO_2$ is reduced to NO by $SO_2$.

**C** $NO_2$ is reduced to NO by CO.

**D** $SO_2$ is oxidised to $SO_3$ by $CO_2$.

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**30** Oct-1-ene, $CH_3(CH_2)_5CH=CH_2$, can be thermally cracked.

Which of the compounds W, X, Y and Z can be obtained by thermally cracking oct-1-ene?

| W | X | Y | Z |
|---|---|---|---|
| $CH_2=CH_2$ | $CH_3CH=CH_2$ | $CH_3CH_2CH_3$ | $CH_2=CHCH=CH_2$ |

**A** W, X, Y and Z

**B** W, X and Y only

**C** W, X and Z only

**D** W and X only

**31** Structural isomerism and stereoisomerism should be taken into account when answering this question.

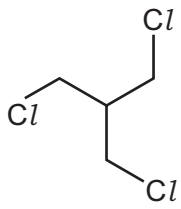
How many isomeric alkenes with formula $C_5H_8$ are present in the mixture produced when 1,4-dibromopentane is reacted with NaOH in ethanol?

**A** 1 **B** 2 **C** 3 **D** 4

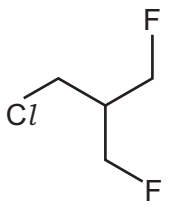
**32** The presence of a halogen in an organic compound may be detected by warming the organic compound with aqueous silver nitrate.

Which compound would be the quickest to produce a precipitate?

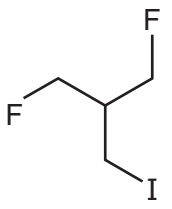
**A**



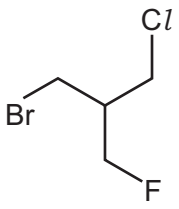

**B**




**C**




**D**




**33** 17.6 g of pentan-1-ol is completely combusted.

Which volume of gaseous products is formed when measured at s.t.p.?

**A** 22.4 $dm^3$ **B** 24.0 $dm^3$ **C** 49.3 $dm^3$ **D** 52.8 $dm^3$

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**34** Crotyl alcohol, $CH_3CH=CHCH_2OH$, is a colourless liquid which is used as a solvent.

Crotyl alcohol will react separately with $Br_2$, $K_2Cr_2O_7/H^+$, conc. $KMnO_4/H^+$ and $PCl_5$ under suitable conditions.

Which row is correct?

| | reactant | conditions | main product |
|---|---|---|---|
| **A** | $Br_2$ | room temperature | $CH_3CH=CHCH_2Br$ |
| **B** | $K_2Cr_2O_7/H^+$ | heat under reflux | $CH_3CH=CHCHO$ |
| **C** | conc. $KMnO_4/H^+$ | heat under reflux | $CH_3CH=CHCO_2H$ |
| **D** | $PCl_5$ | room temperature | $CH_3CH=CHCH_2Cl$ |

**35** The skeletal formulae of two organic compounds are shown.




Which reagents can be used to distinguish these two compounds?

1 alkaline $I_2$(aq)

2 acidified $K_2Cr_2O_7$

3 2,4-dinitrophenylhydrazine (2,4-DNPH reagent)

**A** 1, 2 and 3 **B** 1 and 3 only **C** 2 and 3 only **D** 2 only

**36** A carbonyl compound, X, reacts with HCN in the presence of NaCN to make a compound with $M_r$ 85. Compound X does **not** react with Fehling's reagent.

What is compound X?

**A** butanal

**B** butanone

**C** propanal

**D** propanone

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**37** Which compound produces butan-2-ol and ethanoic acid on hydrolysis?

**A** $CH_3CO_2CH(CH_3)_2$

**B** $CH_3CO_2CH(CH_3)CH_2CH_3$

**C** $CH_3CH(CH_3)CO_2CH_2CH_3$

**D** $CH_3CH_2CO_2CH(CH_3)CH_2CH_3$

**38** Two 1 g samples of Y are reacted separately and completely with sodium and with sodium carbonate. The volumes of the gases produced are collected and measured.

| | relative volumes of gases | |
|---|---|---|
| | with Na | with $Na_2CO_3$ |
| Y | 2 | 1 |

What could Y be?

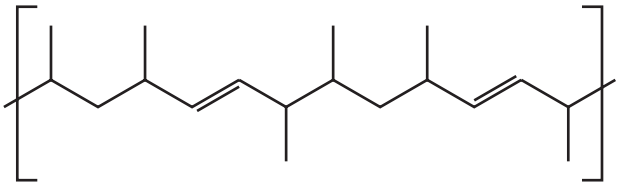
**A** $CH_3CH(OH)CH_2OH$

**B** $CH_3CH(OH)CO_2H$

**C** $CH_3COCH_2OH$

**D** $CH_3COCO_2H$

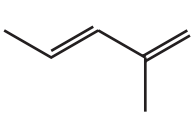
**39** The diagram shows a section of an addition polymer formed from two different monomers.



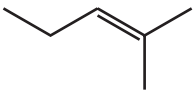
One of the monomers is propene.

What is the other monomer?

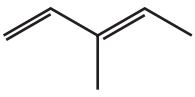
**A**



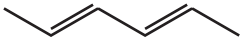
**B**



**C**



**D**



**40** A scientist chooses either infrared spectroscopy or mass spectrometry to find a particular piece of information.

In which row has the **best** choice been made?

| | target information | analytic method used |
|---|---|---|
| **A** | identities of functional groups in an organic compound | infrared spectroscopy |
| **B** | identities of functional groups in an organic compound | mass spectrometry |
| **C** | values of successive ionisation energies of Na | infrared spectroscopy |
| **D** | values of successive ionisation energies of Na | mass spectrometry |

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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 | $L = 6.02 \times 10^{23}\,\text{mol}^{-1}$ |
| 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 | $c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$) |

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## 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 144.4 | 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 – |