Cambridge Assessment International Education

# Cambridge International AS & A Level

**CHEMISTRY** **9701/13**

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.

This document has **20** pages. Any blank pages are indicated.


© UCLES 2022

**1** Which atom has exactly three unpaired electrons in the ground state?

**A** an isolated gaseous aluminium atom

**B** an isolated gaseous carbon atom

**C** an isolated gaseous chromium atom

**D** an isolated gaseous phosphorus atom

**2** Which element has the **second** smallest atomic radius in its group and the **second** highest electrical conductivity in its period?

**A** boron

**B** calcium

**C** magnesium

**D** sodium

**3** Analysis of the hormone thyroxine gives the results shown.

Heating 0.500 g of thyroxine with aqueous silver nitrate produces 0.604 g of silver iodide. All of the iodine in the thyroxine sample is converted to silver iodide.

Complete combustion of 0.500 g of thyroxine produces 232 $cm^3$ of carbon dioxide and 7.72 $cm^3$ of nitrogen, measured under room conditions.

Which molecular formula of thyroxine agrees with these values?

**A** $C_{15}H_{11}NO_4I_4$ $M_r = 776.6$

**B** $C_{15}H_7NO_4I_8$ $M_r = 1280.2$

**C** $C_{30}H_{25}NO_6I_4$ $M_r = 1002.6$

**D** $C_{30}H_{21}NO_6I_8$ $M_r = 1506.2$

**4** How many moles of oxygen, $O_2$, are needed to burn 1 mol of ethane if the products of the reaction are water and carbon only?

**A** 1.5 **B** 3 **C** 3.5 **D** 5

**5** Which compound has the smallest difference in electronegativity between its two elements?

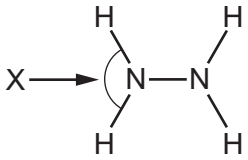
**A** KF **B** KBr **C** LiF **D** LiBr

© UCLES 2022

**6** VSEPR theory should be used to answer this question.

Hydrazine has the following structure.

hydrazine




What is the predicted bond angle X?

**A** 90° **B** 107° **C** 109.5° **D** 120°

**7** This question is about buckminsterfullerene, graphite, iodine and diamond.

How many of these substances have a simple molecular structure?

**A** 0 **B** 1 **C** 2 **D** 3

**8** A student reacts 1 mol of magnesium powder in a sealed 0.030 $m^3$ container of oxygen at a pressure of $2.0 \times 10^5$ Pa and a temperature of 600 K. The magnesium reacts completely to form MgO.

Which percentage of the oxygen will be used up?

**A** 5.0% **B** 10% **C** 42% **D** 83%

**9** Which equation represents an enthalpy change that is the average bond energy of the C–H bond in methane?

**A** $\frac{1}{4}C(g) + H(g) \rightarrow \frac{1}{4}CH_4(g)$

**B** $\frac{1}{4}CH_4(g) \rightarrow \frac{1}{4}C(g) + H(g)$

**C** $CH_4(g) \rightarrow C(g) + 4H(g)$

**D** $CH_4(g) \rightarrow CH_3(g) + H(g)$

© UCLES 2022

**10** Magnesium carbonate decomposes when heated in a Bunsen burner flame.

Values for the standard enthalpies of formation, $\Delta H_f^\ominus$, of the species involved are shown.

$\Delta H_f^\ominus$ $MgCO_3$ = –1095.8 kJ mol$^{-1}$

$\Delta H_f^\ominus$ MgO = –601.7 kJ mol$^{-1}$

$\Delta H_f^\ominus$ $CO_2$ = –393.5 kJ mol$^{-1}$

What is the standard enthalpy change for the decomposition of magnesium carbonate?

**A** +100.6 kJ mol$^{-1}$

**B** +887.6 kJ mol$^{-1}$

**C** +1095.8 kJ mol$^{-1}$

**D** +2091 kJ mol$^{-1}$

**11** $NH_4NO_3$ decomposes into $N_2O$ and $H_2O$ on heating.

Which statements are correct?

1 The ammonium ion is behaving as a reducing agent.

2 The nitrate(V) ion is behaving as an oxidising agent.

3 It is a redox reaction.

4 It is a disproportionation reaction.

**A** 1, 2, 3 and 4

**B** 1, 2 and 3 only

**C** 3 and 4 only

**D** 3 only

**12** A student adds 3 mol of acidified $K_2Cr_2O_7$ to an excess of $I^-$ ions.

The chromium is all reduced to $Cr^{3+}$ and $I^-$ ions are oxidised to $I_2$.

The $I_2$ released is reduced back to $I^-$ ions by X mol of $S_2O_3^{2-}$ ions.

1 mol of $I_2$ is reduced by 2 mol of $S_2O_3^{2-}$ ions.

What is the value of X?

**A** 3 **B** 6 **C** 9 **D** 18

© UCLES 2022

**13** Which statement about acids and bases is **always** correct?

**A** An acid with two H atoms per molecule will be stronger than an acid with one H atom per molecule.

**B** A concentrated solution of a strong acid will have a lower pH than a dilute solution of a weak acid.

**C** A concentrated solution of a strong base will have a lower pH than a dilute solution of a weak base.

**D** A strong acid is more dissociated in solution than a strong base.

**14** The reaction between sulfur dioxide and oxygen is reversible.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad K_c = 280\,mol^{-1}\,dm^3 \text{ at } 1000\,K$$

In an equilibrium mixture at 1000 K the sulfur trioxide concentration is 6.00 mol $dm^{-3}$.

The sulfur dioxide concentration is twice the oxygen concentration.

What is the sulfur dioxide concentration?

**A** 0.175 mol $dm^{-3}$

**B** 0.252 mol $dm^{-3}$

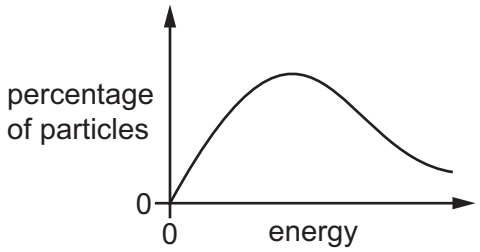
**C** 0.318 mol $dm^{-3}$

**D** 0.636 mol $dm^{-3}$

© UCLES 2022

**15** The Boltzmann distribution of the particles in a mixture of gas X and gas Y is shown in diagram 1.

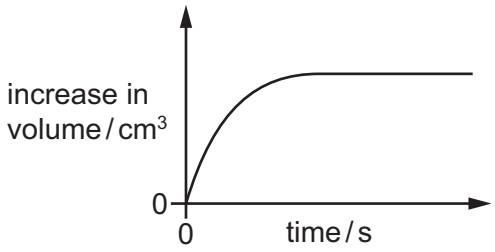
diagram 1




X and Y react and the reaction causes an increase in gas molecules present. The reaction goes to completion.

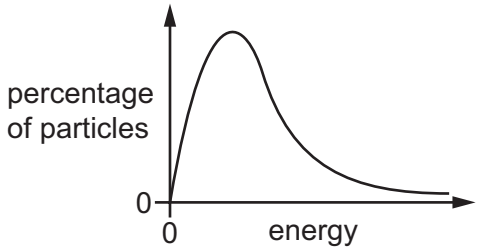
In experiment 1, the increase in volume is measured every 10 seconds. During the reaction, the temperature and pressure remain constant. The increase in volume is shown in the volume–time graph in diagram 2.

diagram 2

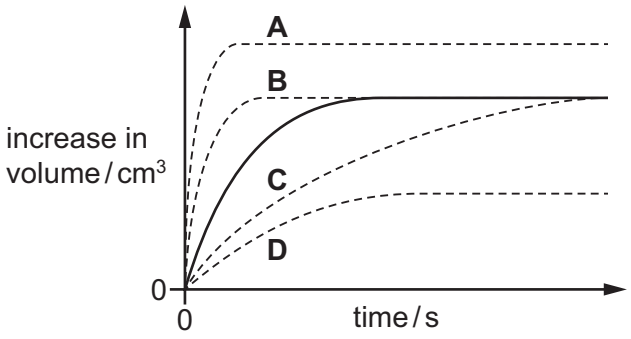



In experiment 2, the experiment is repeated using identical amounts of X and Y. A different temperature is used compared to experiment 1. The same pressure is used. The Boltzmann distribution of the second mixture of X and Y is shown in diagram 3. During the reaction the temperature and pressure remain constant.

diagram 3




Which curve on the volume–time graph would show the increase in volume against time for experiment 2? (The original line for experiment 1 is redrawn as a solid line.)




© UCLES 2022

**16** When the temperature of a particular reaction is increased by 10 °C (e.g. from 20 °C to 30 °C) the rate of the reaction approximately doubles.

What is the **most** significant reason for this increase?

**A** a different mechanism for the reaction

**B** an increased collision frequency of the reactant molecules

**C** more collisions have energy greater than the activation energy

**D** a reduced activation energy for the reaction

**17** Which ion has the smallest radius?

**A** $Al^{3+}$ **B** $Ba^{2+}$ **C** $Mg^{2+}$ **D** $Na^{+}$

**18** Which row is correct?

| | element with the greater fifth ionisation energy | element with an amphoteric oxide |
|---|---|---|
| **A** | aluminium | aluminium only |
| **B** | aluminium | both aluminium and phosphorus |
| **C** | phosphorus | aluminium only |
| **D** | phosphorus | both aluminium and phosphorus |

**19** Each of the chlorides listed is added to water.

1 aluminium chloride

2 magnesium chloride

3 silicon tetrachloride

4 phosphorus pentachloride

Which chlorides form an aqueous solution that reacts with sodium carbonate to produce carbon dioxide?

**A** 1 and 2 only

**B** 3 and 4 only

**C** 1, 3 and 4 only

**D** 1, 2, 3 and 4

© UCLES 2022

**20** NaOH(aq) is added to separate samples of magnesium chloride and barium chloride solutions.

$H_2SO_4$(aq) is then added slowly to each reaction mixture until in excess.

What is observed at the **end** of the reaction sequence?

| | $MgCl_2$(aq) | $BaCl_2$(aq) |
|---|---|---|
| **A** | colourless solution only | colourless solution only |
| **B** | colourless solution only | white precipitate |
| **C** | white precipitate | colourless solution only |
| **D** | white precipitate | white precipitate |

**21** A 4.00 g sample of an anhydrous Group 2 metal nitrate, Z, is heated strongly until there is no further change of mass. A solid residue of mass 1.37 g is formed.

Which metal is present in Z?

**A** barium

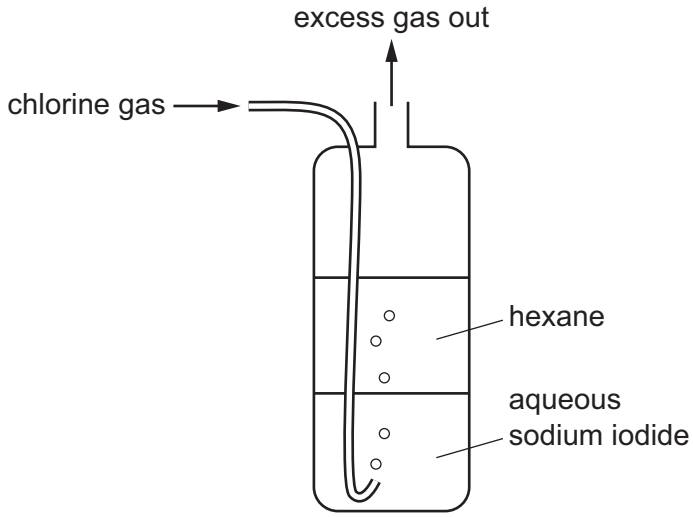
**B** calcium

**C** magnesium

**D** strontium

© UCLES 2022

**22** Chlorine is bubbled through a cylinder containing aqueous sodium iodide and an immiscible layer of hexane.




As the bubbles pass through the cylinder, what is observed in the lower and upper layers?

| | lower aqueous layer | upper hexane layer |
|---|---|---|
| **A** | colourless solution becomes brown | colourless liquid becomes coloured |
| **B** | colourless solution becomes brown | colourless liquid is unchanged |
| **C** | brown solution becomes colourless | colourless liquid becomes coloured |
| **D** | brown solution becomes colourless | colourless liquid is unchanged |

**23** Chlorine and bromine have different volatilities.

Which row identifies the more volatile of the two elements, and gives the correct explanation?

| | identity of the more volatile element | explanation for the difference in volatility |
|---|---|---|
| **A** | bromine | intermolecular forces are greater in bromine than they are in chlorine |
| **B** | bromine | intermolecular forces are greater in chlorine than they are in bromine |
| **C** | chlorine | intermolecular forces are greater in bromine than they are in chlorine |
| **D** | chlorine | intermolecular forces are greater in chlorine than they are in bromine |

© UCLES 2022

**24** Ammonium chloride dissolves readily in water.

Which statement about the colourless solution formed is correct?

**A** Ions in the solution can form hydrogen bonds with water molecules.

**B** The solution is slightly basic.

**C** The solution would smell of chlorine.

**D** When sodium hydroxide is added, a gas is formed which turns damp blue litmus paper red.

**25** At 550 °C nitrogen dioxide reacts with unburnt hydrocarbon fragments, such as $CH_3$, in the catalytic converter of a motor vehicle.

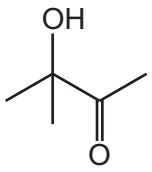
$$4CH_3 + 7NO_2 \rightarrow 3\tfrac{1}{2}N_2 + 4CO_2 + 6H_2O$$

Which row gives the energy change for this reaction and a possible reason for it?

| | energy change of reaction | reason why the reaction is endothermic or exothermic |
|---|---|---|
| **A** | endothermic | chemical energy is converted to heat energy |
| **B** | endothermic | the N≡N bond energy is very high |
| **C** | exothermic | $CO_2$ and $H_2O$ have negative $\Delta H_f^{\ominus}$ values |
| **D** | exothermic | double bonds are broken in $NO_2$ |

**26** Compound X contains an alcohol group and a carbonyl group.

compound X



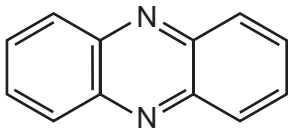

Which row is correct?

| | type of alcohol group | type of carbonyl group |
|---|---|---|
| **A** | primary | aldehyde |
| **B** | primary | ketone |
| **C** | tertiary | aldehyde |
| **D** | tertiary | ketone |

© UCLES 2022

**27** The diagram shows the skeletal formula of phenazine.

phenazine

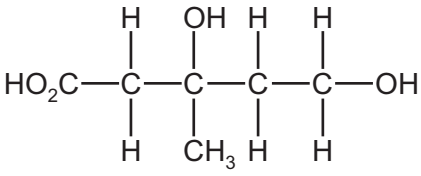



What is the empirical formula of phenazine?

**A** $C_6H_4N$ **B** $C_6H_6N$ **C** $C_{12}H_8N_2$ **D** $C_{12}H_{12}N_2$

**28** The diagram shows the structural formula of mevalonic acid.

mevalonic acid




Which reagent and conditions will react with mevalonic acid to produce an organic compound **without** a chiral carbon atom?

**A** heat under reflux with $CH_3OH$ / $H^+$

**B** heat under reflux with $Cr_2O_7^{2-}$ / $H^+$

**C** Na at room temperature

**D** $PCl_5$ at room temperature

**29** Structural isomerism and stereoisomerism should be considered when answering this question.

Y is a gaseous hydrocarbon which decolourises aqueous bromine.

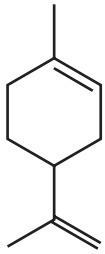
10.0 g of Y occupies a volume of 3.43 $dm^3$ under room conditions.

How many isomeric structures are possible for Y?

**A** 4 **B** 5 **C** 6 **D** 7

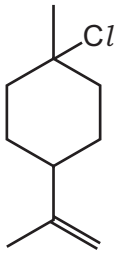
**30** Limonene is found in lemon and orange oils.

limonene

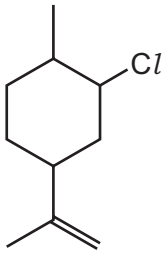


What is the major product when limonene reacts with an excess of dry hydrogen chloride?

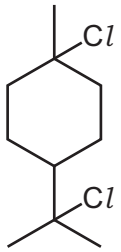
**A**



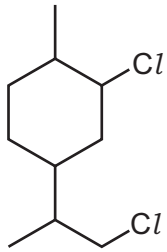

**B**




**C**




**D**




**31** Which statement concerning the hydrolysis of 1-bromopropane with water is correct?

**A** The hydrolysis reaction between water and 1-iodopropane is faster because the C–Br bond is less polar than the C–I bond.

**B** The hydrolysis reaction with water is very slow because water is a weak electrophile.

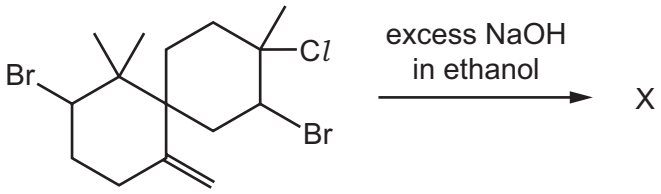
**C** The mechanism of the reaction involves the formation of a stable carbocation.

**D** The reaction is slower with 1-chloropropane because the C–Cl bond is stronger than the C–Br bond.

© UCLES 2022

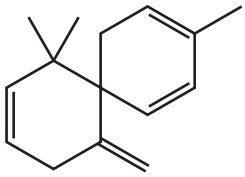
**32** Compound J, $C_{15}H_{23}Br_2Cl$, is reacted with an excess of a hot concentrated solution of sodium hydroxide in ethanol. One of the products is X.

compound J

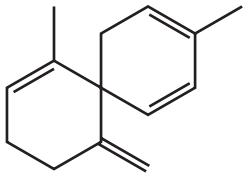



What could be the skeletal formula of X?

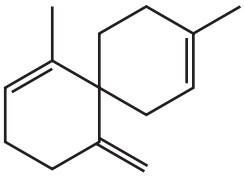
**A**



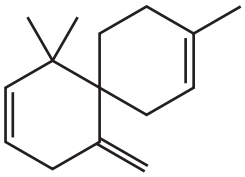
**B**



**C**



**D**



**33** Structural isomerism only should be considered when answering this question.

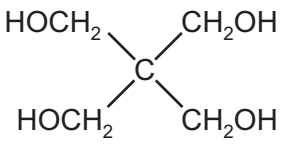
Several compounds with molecular formula $C_4H_8O_2$ have **one** carbonyl group and **one** OH group.

How many of these compounds produce yellow crystals with alkaline $I_2$(aq) at room temperature?

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

**34** Pentaerythritol is used as an intermediate in the manufacture of paint.

pentaerythritol




Which statement is correct?

**A** Pentaerythritol can be dehydrated by concentrated sulfuric acid to form an alkene.

**B** The empirical formula and molecular formula of pentaerythritol are different.

**C** Pentaerythritol does not react with acidified potassium manganate(VII).

**D** One mole of pentaerythritol gives two moles of hydrogen gas on reaction with an excess of sodium.

**35** Which reaction has a nucleophilic addition mechanism and gives a good yield of product under the stated conditions?

**A** 1-bromopropane reacting with hot ethanolic sodium hydroxide

**B** 2-iodopropane reacting with hot aqueous sodium hydroxide

**C** propanal reacting with hydrogen cyanide under alkaline conditions

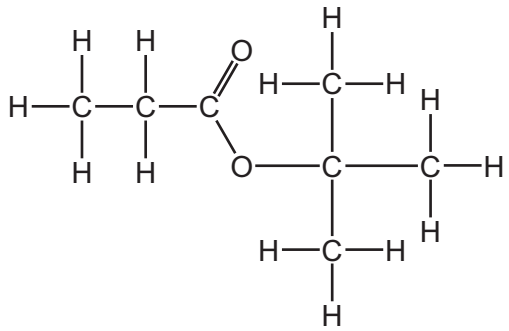
**D** propanal reacting with hydrogen cyanide under acidic conditions

**36** A carbonyl compound has the structural formula $CH_3COCHO$.

Which row is correct for the observations made when this compound is treated with the given reagents?

| | 2,4-DNPH reagent | Fehling's reagent |
|---|---|---|
| **A** | silver mirror | red precipitate |
| **B** | silver mirror | orange precipitate |
| **C** | orange precipitate | silver mirror |
| **D** | orange precipitate | red precipitate |

**37** An ester is shown.



Which two compounds react to form this ester?

**A** 2-methylpropan-1-ol and propanoic acid

**B** 2-methylpropan-2-ol and propanoic acid

**C** propan-1-ol and 2-methylpropanoic acid

**D** 2-methylpropan-2-ol and ethanoic acid

**38** Which compound can be used to make propanoic acid by treatment with a single reagent?

**A** $CH_2=CHCH_2CH_3$

**B** $CH_3CH_2CH_2CN$

**C** $CH_3CH(OH)CN$

**D** $CH_3CH(OH)CH_3$

**39** A sample of sulfur consists mostly of $^{32}S$. It also contains 4.2% $^{34}S$ and 2.8% $^{36}S$. No other isotopes of sulfur are present.

What is the relative atomic mass, $A_r$, of **this** sample of sulfur?

**A** 32.1 **B** 32.2 **C** 34.0 **D** 34.3

**40** One molecule of an addition polymer containing 2000 repeat units has an $M_r$ of 112 000.

The polymer molecule contains chiral centres.

What is a possible monomer for this polymer?

**A** $CH_2=CHCH_3$

**B** $CH_2=C(CH_3)_2$

**C** $CH_2=CHCH_2CH_3$

**D** $CH_2=CHCH_2CH_2CH_3$

© UCLES 2022

**BLANK PAGE**

**BLANK PAGE**

**BLANK PAGE**

## 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 | $c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$) |

Permission to reproduce items where third-party owned material protected by copyright is included has been sought and cleared where possible. Every reasonable effort has been made by the publisher (UCLES) to trace copyright holders, but if any items requiring clearance have unwittingly been included, the publisher will be pleased to make amends at the earliest possible opportunity.

To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced online in the Cambridge Assessment International Education Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download at www.cambridgeinternational.org after the live examination series.

Cambridge Assessment International Education is part of Cambridge Assessment. Cambridge Assessment is the brand name of the University of Cambridge Local Examinations Syndicate (UCLES), which is a department of the University of Cambridge.

© UCLES 2022

© UCLES 2022





## 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 – |