Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/13**

Paper 1 Multiple Choice **October/November 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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1 Which sample contains the same number of the named species as the number of molecules in 35.5 g of chlorine?

A atoms in 16 g of sulfur

B atoms in 23 g of sodium

C ions in 74.5 g of potassium chloride

D molecules in 88 g of carbon dioxide

2 Mixture R consists of one mole of C_3H_6 and one mole of C_4H_6.

What is the minimum number of moles of oxygen molecules needed for complete combustion of mixture R?

A 6.5 **B** 7 **C** 10 **D** 20

3 Which statement about the electrons in a ground state carbon atom is correct?

A Electrons are present in four different energy levels.

B There are more electrons in p orbitals than there are in s orbitals.

C The occupied orbital of highest energy is spherical.

D The occupied orbital of lowest energy is spherical.

4 For the element sulfur, which pair of ionisation energies has the largest difference between them?

A third and fourth ionisation energies

B fourth and fifth ionisation energies

C fifth and sixth ionisation energies

D sixth and seventh ionisation energies

5 How many σ bonds are present in one $H–C{\equiv}C–C(CH_3)=CH(CH_3)$ molecule?

A 5 **B** 11 **C** 13 **D** 16

6 Which molecule has an equal number of bonding electrons and lone-pair electrons?

A BH_3 **B** CO_2 **C** F_2O **D** SO_2

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7 The table shows properties of four solids held together by different types of bonding.

Which row correctly describes the properties of a solid with a giant covalent structure?

	melting point	solubility in polar solvents
A	high	insoluble
B	high	soluble
C	low	insoluble
D	low	soluble

8 The carbonate of an s-block element is reacted with an excess of hydrochloric acid.

0.833 g of the carbonate releases 200 cm^3 of gas, measured under room conditions.

What is the identity of the metal carbonate?

A Na_2CO_3 **B** K_2CO_3 **C** $MgCO_3$ **D** $CaCO_3$

9 The enthalpy changes of formation, $\Delta H_f^{\ominus}$, of both PCl_3 and PCl_5 are exothermic.

PCl_3 reacts with chlorine.

$$PCl_3(l) + Cl_2(g) \rightarrow PCl_5(s) \qquad \Delta H_{reaction}^{\ominus} = -124\ kJ\ mol^{-1}$$

Which pair of statements is correct?

	statement 1	statement 2
A	$\Delta H_{reaction}^{\ominus}$ is less negative than $\Delta H_f^{\ominus}$ (PCl_5).	The Cl_2 bond energy is needed in calculating $\Delta H_{reaction}^{\ominus}$ from enthalpies of formation.
B	$\Delta H_{reaction}^{\ominus}$ is more negative than $\Delta H_f^{\ominus}$ (PCl_5).	The Cl_2 bond energy is needed in calculating $\Delta H_{reaction}^{\ominus}$ from enthalpies of formation.
C	$\Delta H_{reaction}^{\ominus}$ is less negative than $\Delta H_f^{\ominus}$ (PCl_5).	The Cl_2 bond energy is not needed in calculating $\Delta H_{reaction}^{\ominus}$ from enthalpies of formation.
D	$\Delta H_{reaction}^{\ominus}$ is more negative than $\Delta H_f^{\ominus}$ (PCl_5).	The Cl_2 bond energy is not needed in calculating $\Delta H_{reaction}^{\ominus}$ from enthalpies of formation.

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10 A student mixes 25.0 cm^3 of 0.350 mol dm^{-3} sodium hydroxide solution with 25.0 cm^3 of 0.350 mol dm^{-3} hydrochloric acid. The temperature increases by 2.5 °C. No heat is lost to the surroundings.

The final mixture has a specific heat capacity of 4.2 J cm^{-3} K^{-1}.

What is the molar enthalpy change for the reaction?

A –150 kJ mol^{-1}

B –60 kJ mol^{-1}

C –30 kJ mol^{-1}

D –0.15 kJ mol^{-1}

11 Ammonium ions are converted into nitrate ions by bacteria.

What is the change in the oxidation number of nitrogen?

A –6 **B** +6 **C** +8 **D** +9

12 Sodium dichromate(VI), $Na_2Cr_2O_7$, reacts with hydrogen peroxide, H_2O_2, producing Cr^{3+} ions, water and oxygen.

What is the correctly balanced ionic equation for this reaction?

A $Cr_2O_7^{2-} + 2H^+ + H_2O_2 \rightarrow 2Cr^{3+} + 2H_2O + 4O_2$

B $Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$

C $Cr_2O_7^{2-} + 8H^+ + 6H_2O_2 \rightarrow 2Cr^{3+} + 10H_2O + 6O_2$

D $Cr_2O_7^{2-} + 14H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$

13 In which equilibrium reaction is the position of equilibrium moved to the right-hand side by increasing the temperature and also by decreasing the pressure?

A $H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$ $\Delta H = 40$ kJ mol^{-1}

B $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ $\Delta H = 58$ kJ mol^{-1}

C $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -197$ kJ mol^{-1}

D $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$ $\Delta H = -10$ kJ mol^{-1}

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14 Ethanol is produced industrially by reacting ethene and steam.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

K_p has a value of 1.8×10^{-5} and the partial pressures of the reactants at equilibrium are shown.

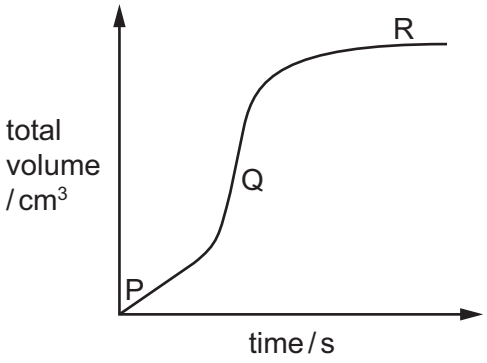
reactant	partial pressure / kPa
ethene	4.8×10^3
steam	2.8×10^3

Which row is correct?

	partial pressure of ethanol at equilibrium / kPa	units of K_p
A	2.42×10^2	kPa^{-1}
B	2.42×10^2	kPa
C	7.47×10^{11}	kPa^{-1}
D	7.47×10^{11}	kPa

15 A large excess of magnesium ribbon is added to dilute hydrochloric acid and the volume of hydrogen gas produced is measured as the reaction proceeds. The reaction is exothermic.

The results are shown.



Which row explains the changes in the rate of reaction between points P and Q and between points Q and R?

	between points P and Q	between points Q and R
A	the reaction temperature is increasing	the acid concentration is falling
B	the reaction temperature is increasing	the magnesium has been used up
C	magnesium's surface area is decreasing	the acid concentration is falling
D	magnesium's surface area is decreasing	the magnesium has been used up

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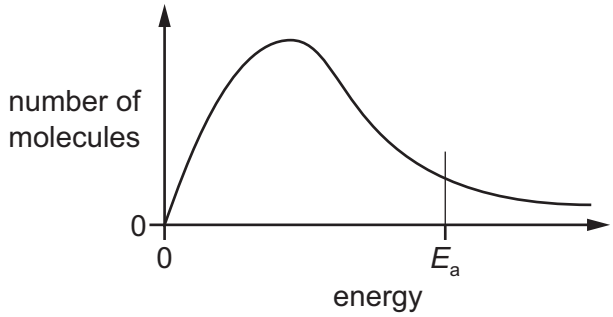
16 Measurements are made to determine the activation energy, E_a, of a reaction.

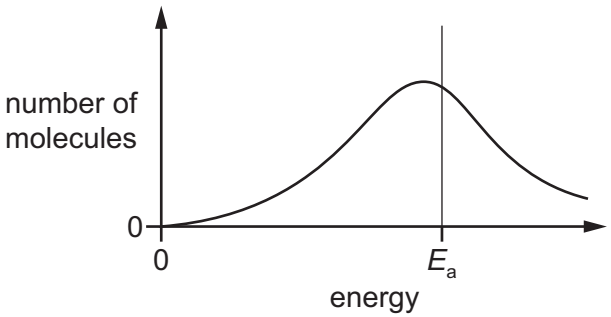
The diagram shows E_a on the Boltzmann distribution at temperature T_1.



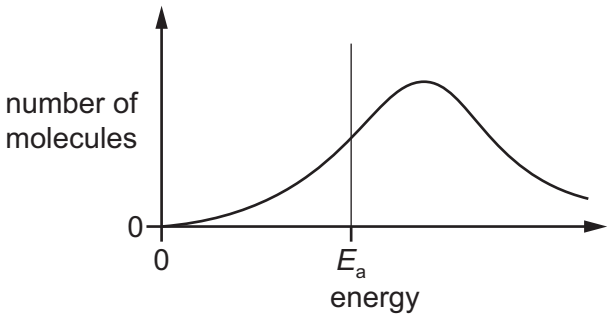
Measurements are then made at a higher temperature, T_2.

Which diagram correctly shows the Boltzmann distribution and E_a at T_2?

A



B



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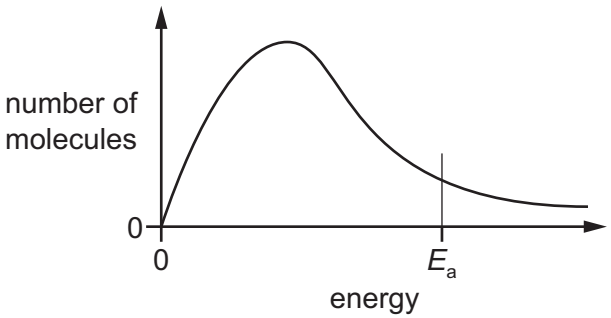
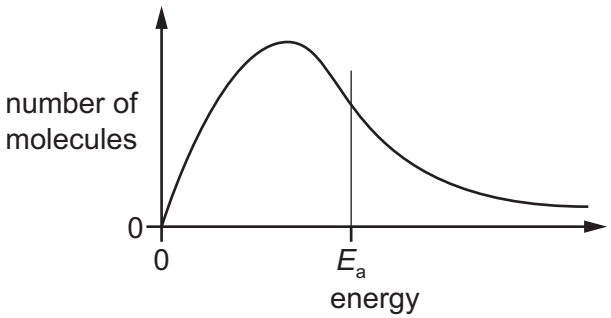


D



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17 The electrical conductivities of two compounds, Y and Z, are shown.

	for Y	for Z
conductivity of the compound in the liquid state	good	does not conduct
conductivity of the mixture obtained by adding the compound to water	good	good

What are compounds Y and Z?

	Y	Z
A	Al_2O_3	$SiCl_4$
B	$NaCl$	Al_2O_3
C	$NaCl$	$SiCl_4$
D	$SiCl_4$	Al_2O_3

18 Which row describes the relative sizes of the ionic radii of Na^+, Mg^{2+} and S^{2-}?

	smallest ⟶		largest
A	Na^+	Mg^{2+}	S^{2-}
B	Mg^{2+}	Na^+	S^{2-}
C	S^{2-}	Na^+	Mg^{2+}
D	S^{2-}	Mg^{2+}	Na^+

19 The oxides BaO, CaO, MgO and SrO all produce alkaline solutions when added to water.

Which oxide produces the saturated solution with the highest pH?

A BaO **B** CaO **C** MgO **D** SrO

20 Which row is correct?

	the temperature needed to decompose Group 2 metal nitrates	the solubility of Group 2 sulfates
A	decreases down the group	decreases down the group
B	decreases down the group	increases down the group
C	increases down the group	increases down the group
D	increases down the group	decreases down the group

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21 Which statement about Group 17 elements and compounds is correct?

A Sodium chloride produces chlorine when reacted with concentrated sulfuric acid.

B Sodium chloride produces chlorine when reacted with bromine.

C Sodium bromide produces bromine when reacted with concentrated sulfuric acid.

D Sodium bromide produces bromine when reacted with iodine in aqueous potassium iodide.

22 Chlorine is bubbled through $100\,cm^3$ of hot $4.0\,mol\,dm^{-3}$ sodium hydroxide until the reaction is complete.

$$6NaOH(aq) + xCl_2(aq) \rightarrow yNaCl(aq) + zNaClO_3(aq) + 3H_2O(l)$$

Which row is correct?

	x	$[Na^+](aq)$ after reaction / $mol\,dm^{-3}$
A	3	4.0
B	3	less than 4.0
C	6	4.0
D	6	less than 4.0

23 Which statement about ammonia or the ammonium ion is correct?

A Ammonia gas is produced when an aqueous solution containing the ammonium ion is reacted with a strong acid.

B Silver iodide is soluble in a concentrated aqueous solution of ammonia.

C The ammonium ion has the same number of electrons as a methane molecule.

D The square planar ammonium ion contains a dative covalent bond.

24 Sulfur dioxide can be catalytically oxidised by an oxide of nitrogen in the atmosphere.

Which reaction shows how the catalyst is reformed?

A $N_2 + 2O_2 \rightleftharpoons 2NO_2$

B $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

C $N_2 + O_2 \rightarrow 2NO$

D $NO + \frac{1}{2}O_2 \rightarrow NO_2$

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25 Separate 1.0 g samples of Na_2O, MgO, Al_2O_3, SiO_2, NaCl, $MgCl_2$, Al_2Cl_6 and $SiCl_4$ are added to separate beakers containing water and stirred.

The number of beakers containing a white solid is Q.

An excess of NaOH(aq) is then added to each beaker and stirred.

The number of beakers now containing a white solid is R.

Which row is correct?

	Q	R
A	3	2
B	3	3
C	4	3
D	4	4

26 Which pair of alcohols are isomers of each other?

A butan-1-ol and 2,2-dimethylpropan-1-ol

B butan-2-ol and 2-methylpropan-2-ol

C pentan-1-ol and 2-methylpropan-2-ol

D propan-2-ol and 2-methylpropan-2-ol

27 How many chiral carbon atoms are there in one molecule of 2,2,4,5-tetramethylhexan-3-ol?

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

28 Which pair of reagents react together in a redox reaction?

A CH_3CHCH_2 + Br_2

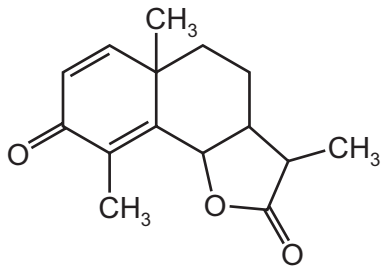
B $CH_3CH_2CH_2OH$ + concentrated H_3PO_4

C CH_3COCH_3 + HCN

D $HCO_2C_2H_5$ + dilute H_2SO_4

29 The structure of santonin is shown.

santonin



Santonin is first treated with warm dilute H_2SO_4. The product of this reaction is treated with cold dilute acidified $KMnO_4$. A final product, Q, is obtained.

How many atoms of hydrogen in each molecule of product Q will react with sodium metal?

A 2 **B** 4 **C** 5 **D** 6

30 Compound R can be formed from 1-bromopropane using a nucleophilic substitution reaction followed by an oxidation reaction.

What is the identity of R?

A propanoic acid

B propanone

C propylamine

D propyl ethanoate

31 Three colourless liquids with the following formulae are contained in separate unlabelled bottles.

$CH_3CH_2CO_2H$ $CH_3CH(OH)CO_2H$ CH_3COCO_2H

Which two tests, carried out on separate samples of each liquid, will successfully identify each liquid?

	test 1	test 2
A	$NaHCO_3$	2,4-DNPH reagent
B	$NaHCO_3$	Tollens' reagent
C	warm acidified dichromate	2,4-DNPH reagent
D	warm acidified dichromate	Tollens' reagent

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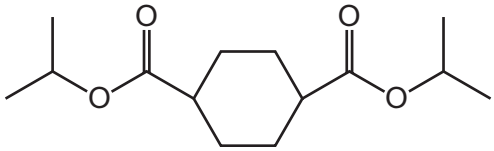
32 An alcohol, X, reacts with a dicarboxylic acid, Y, to form a double ester, Z.

The diagram shows the structure of the ester.

Z



Which row about the reactants forming ester Z is correct?

	the class of alcohol X	the shape of the ring in Y
A	secondary	non-planar
B	secondary	planar
C	tertiary	non-planar
D	tertiary	planar

33 W reacts with alkaline I_2(aq) to form a yellow precipitate and $CH_3CH_2CO_2^-$ ions.

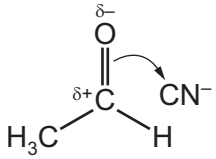
Which row identifies W and the yellow precipitate?

	identity of W	identity of yellow precipitate
A	butanone	CHI_3
B	butanone	CH_3I
C	propanone	CHI_3
D	propanone	CH_3I

34 Ethanal reacts with hydrogen cyanide in the presence of KCN to produce a hydroxynitrile.

What is the first step in the mechanism of this reaction?

A



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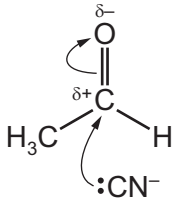
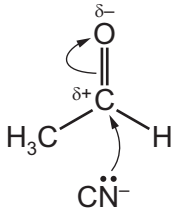


C



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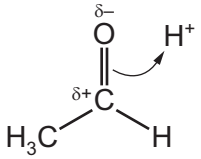
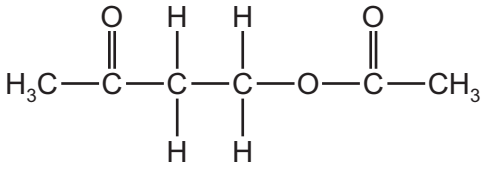


35 Structural isomerism and stereoisomerism should be considered when answering this question.

How many isomeric compounds with molecular formula $C_5H_6O_4$ contain two $–CO_2H$ groups and one C=C double bond?

A 5 **B** 6 **C** 7 **D** 8

36 Compound X reacts with ethanoic acid in the presence of an H^+ catalyst to produce the compound shown.



What is the molecular formula of compound X?

A C_2H_4O **B** $C_2H_6O_2$ **C** C_4H_8O **D** $C_4H_8O_2$

37 2-bromopropane reacts with hot ethanolic sodium hydroxide.

Which substance is the major product of this reaction?

A propan-1-ol

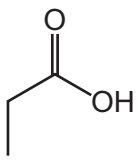
B propan-2-ol

C 2-hydroxypropene

D propene

38 Which compounds can be used to make Y in a single-step reaction?

Y



1 propanenitrile

2 ethanenitrile

3 propyl ethanoate

4 ethyl propanoate

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

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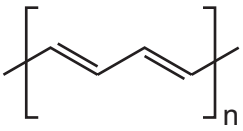
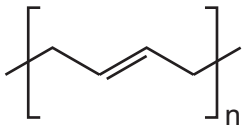
39 The monomer buta-1,3-diene can undergo addition polymerisation in various ways. Two of the polymers that can be made are called *cis*-poly(buta-1,3-diene) and *trans*-poly(buta-1,3-diene). In these names *cis* and *trans* have their usual meanings.

What is the structure of the repeat unit of *cis*-poly(buta-1,3-diene)?

A



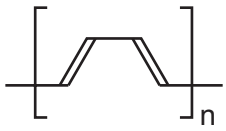
B



C



D



40 In the mass spectrum of a compound, Z, the relative abundances of the M and M+1 peaks are in the ratio 13 : 1.

What is compound Z?

A butyl butanoate

B hexan-3-one

C 2,2,3-trimethylhexane

D 3,3-dimethylpentan-1-ol

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

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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											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 –

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