Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/13**

Paper 1 Multiple Choice **May/June 2024**

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.

[Turn over

1 X is an impure sample of a Group 2 metal carbonate, MCO_3. X contains 57% by mass of MCO_3. The impurities in X do **not** react with hydrochloric acid.

7.4 g of X is reacted with an excess of dilute hydrochloric acid.

0.050 mol of the Group 2 metal chloride is produced.

What is the identity of the Group 2 metal?

A Mg **B** Ca **C** Sr **D** Ba

2 Which of these samples of gas contains the same number of atoms as 1 g of hydrogen gas?

A 22 g of carbon dioxide (M_r: CO_2, 44)

B 8 g of methane (M_r: CH_4, 16)

C 20 g of neon (M_r: Ne, 20)

D 8 g of ozone (M_r: O_3, 48)

3 What is the total number of protons, neutrons and electrons present in an ammonium ion with a relative formula mass of 21?

	number of protons	number of neutrons	number of electrons
A	11	10	10
B	10	11	11
C	10	11	10
D	11	10	11

4 This question is about the first ionisation energies of magnesium and neon.

Which row is correct?

	first ionisation energy	type of electron removed	
		from Mg	from Ne
A	Mg > Ne	p	s
B	Mg > Ne	s	p
C	Ne > Mg	p	s
D	Ne > Mg	s	p

5 Arsenic forms a compound with fluorine. In this compound, the arsenic atom has no lone pair of electrons and there are no dative bonds.

Selenium also forms a compound with fluorine. In this compound, the selenium atom has no lone pair of electrons and there are no dative bonds.

In which compounds are there two different bond angles?

(In this question, 180° bond angles should be ignored.)

A both arsenic fluoride and selenium fluoride

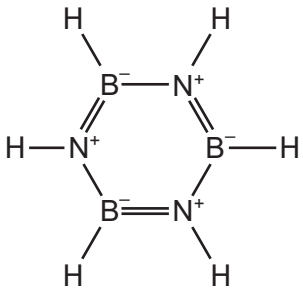
B arsenic fluoride only

C selenium fluoride only

D neither arsenic fluoride nor selenium fluoride

6 A structure for borazole, $N_3B_3H_6$, is shown.

borazole



Which shape is borazole and how many π electrons are there in the structure?

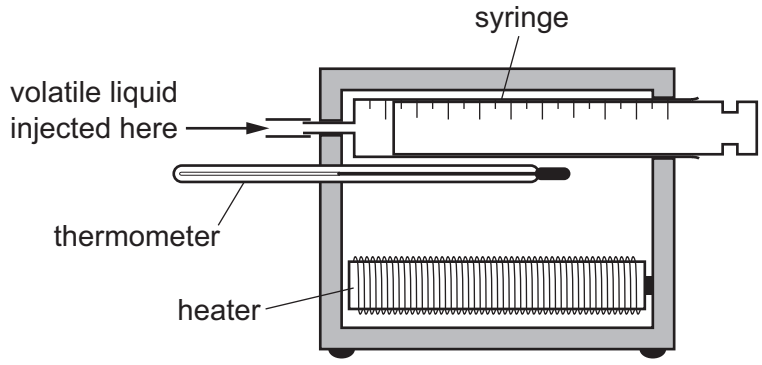
	shape	number of π electrons
A	non-planar	3
B	non-planar	6
C	planar	3
D	planar	6

[Turn over

7 The diagram shows the apparatus used to find the relative molecular mass of a volatile liquid.

When 0.10 g of a volatile liquid is injected into the syringe, all of the volatile liquid evaporates and the volume increases by 85 cm^3.

The heater maintains a temperature of 400 K and the experiment is carried out at a pressure of 101 300 Pa.



If the vapour of the volatile liquid behaves as an ideal gas, which expression can be used to calculate the relative molecular mass of the liquid?

A $M_r = (85 \times 101\,300) \div (0.10 \times 8.31 \times 400)$

B $M_r = (85 \times 101.3) \div (0.10 \times 8.31 \times 400)$

C $M_r = (0.10 \times 8.31 \times 400) \div (85 \times 10^{-6} \times 101\,300)$

D $M_r = (0.10 \times 8.31 \times 400) \div (85 \times 10^{-6} \times 101.3)$

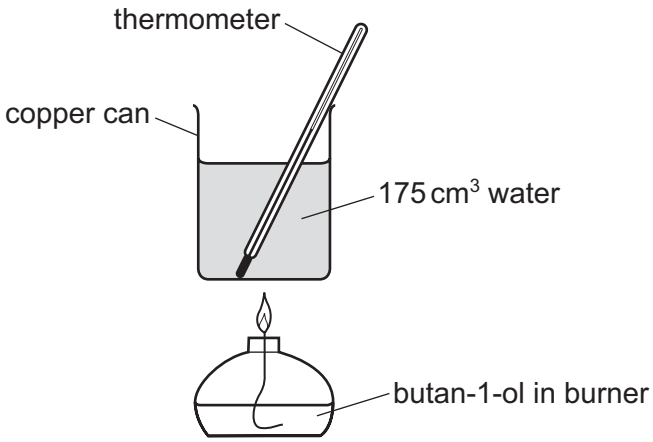
8 The table shows physical properties of four substances, W, X, Y and Z.

	melting point / °C	boiling point / °C	electrical conductivity of solid	electrical conductivity of liquid	electrical conductivity in water
W	993	1695	poor	good	good
X	–119	39	poor	poor	insoluble
Y	1535	2750	good	good	insoluble
Z	1610	2230	poor	poor	insoluble

What are the identities of W, X, Y and Z?

	W	X	Y	Z
A	MgO	C_2H_5Br	Fe	Al_2O_3
B	MgO	HCl	K	Al_2O_3
C	NaF	C_2H_5Br	Fe	SiO_2
D	NaF	HCl	K	SiO_2

9 The apparatus used to determine a value for the enthalpy of combustion of butan-1-ol is shown. The mass of 1.00 cm^3 of water is 1.00 g.



initial mass of burner + butan-1-ol	58.34 g
initial temperature of water	17.6 °C
final mass of burner + butan-1-ol	57.85 g
final temperature of water	41.1 °C

butan-1-ol M_r = 74

Which value, to three significant figures, for the enthalpy of combustion of butan-1-ol can be calculated from these data?

A $-114\ J\ mol^{-1}$

B $-17.2\ kJ\ mol^{-1}$

C $-2600\ kJ\ mol^{-1}$

D $-4540\ kJ\ mol^{-1}$

[Turn over

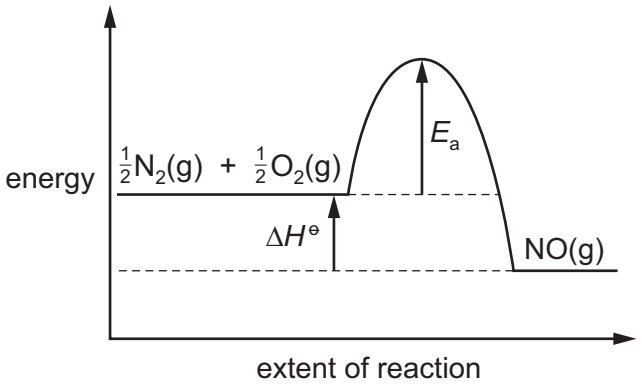
10 In the high temperatures of car engines, nitrogen reacts with oxygen to produce nitrogen monoxide.

$$\tfrac{1}{2}N_2(g) + \tfrac{1}{2}O_2(g) \rightarrow NO(g) \qquad \Delta H^{\ominus} = +90\,kJ\,mol^{-1}$$

This reaction has activation energy E_a.

Which reaction pathway diagram correctly represents this reaction?

A



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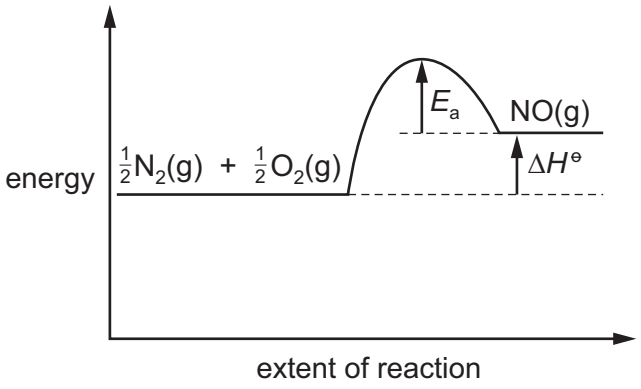

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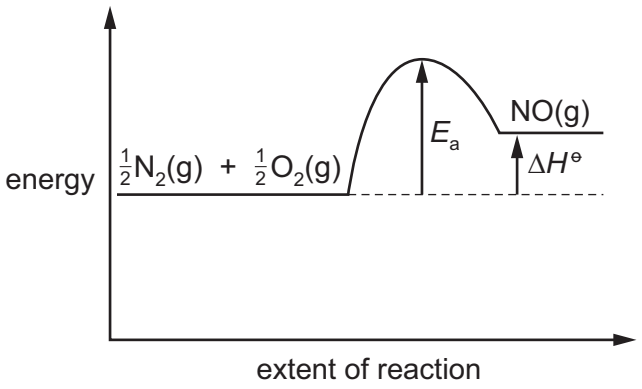

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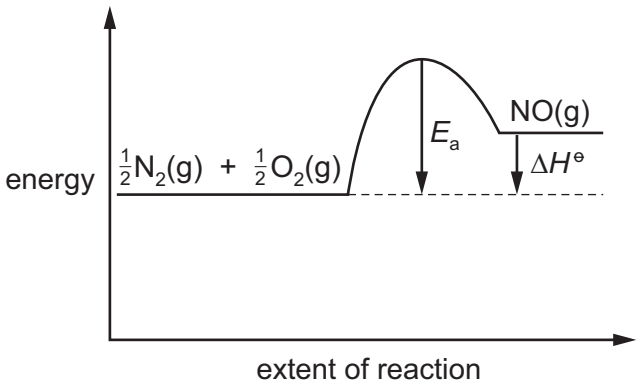


11 In which reaction does the oxidation number of chlorine change by the largest amount?

A $2KClO_3 \rightarrow 2KCl + 3O_2$

B $2ClO^- \rightarrow Cl^- + ClO_2^-$

C $Cl_2 + H_2O \rightarrow HCl + HClO$

D $2NaClO_2 + Cl_2 \rightarrow 2NaCl + 2ClO_2$

12 Hydrogen is produced industrially from methane as shown in the equation.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H^{\ominus} = +205\,kJ\,mol^{-1}$$

Which conditions give the highest yield of hydrogen at equilibrium?

	pressure	temperature
A	low	high
B	high	low
C	high	high
D	low	low

13 W moles of HNO_2 undergoes a disproportionation reaction to produce U moles of HNO_3 and V moles of NO.

- No other nitrogen containing product is produced.
- Nitrogen is the only element oxidised or reduced.

What are the values of W, U and V?

	W	U	V
A	2	1	1
B	3	1	2
C	5	3	2
D	5	1	4

14 Gas X dissociates on heating to set up the following equilibrium.

$$X(g) \rightleftharpoons Y(g) + Z(g)$$

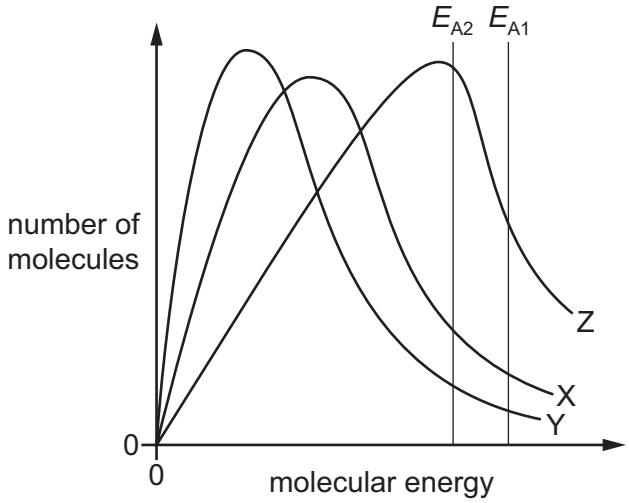
A quantity of gas X is heated at constant pressure, p, at a certain temperature. The equilibrium partial pressure of gas X is found to be $\frac{1}{7}p$.

What is the equilibrium constant, K_p, at this temperature?

A $\frac{6}{7}p$ **B** $\frac{9}{7}p$ **C** $\frac{36}{7}p$ **D** $9p$

[Turn over

15 In the diagram, X is the Boltzmann distribution for the energies of the particles in a reaction and E_{A1} is the activation energy for that reaction.



Which statement is correct?

A E_{A2} is the activation energy at a higher temperature.

B E_{A2} is the activation energy at a lower temperature.

C Y is the Boltzmann distribution at a lower temperature.

D Z is the Boltzmann distribution at a higher temperature.

16 Magnesium, aluminium and silicon are elements in the Periodic Table. Each element forms an oxide.

Which row is correct?

	MgO	Al_2O_3	SiO_2
A	basic	amphoteric	amphoteric
B	giant ionic	simple molecular	giant ionic
C	high melting point	high melting point	low melting point
D	slight reaction with water	no reaction with water	no reaction with water

17 Which statement correctly describes what happens when silicon tetrachloride is added to water?

A The $SiCl_4$ dissolves to give a neutral solution only.

B The $SiCl_4$ reacts to give an acidic solution only.

C The $SiCl_4$ reacts to give a precipitate and an acidic solution.

D The $SiCl_4$ reacts to give a precipitate and a neutral solution.

18 X and Y are two elements from Period 3 of the Periodic Table.

Element X has a higher electrical conductivity than element Y. Element Y has a higher melting point than element X.

Which formula is a compound formed from element X and element Y?

A MgS **B** Mg_2Si **C** $NaCl$ **D** $SiCl_4$

19 A sample consisting of 1.0 mol of anhydrous calcium nitrate is completely decomposed by strong heating.

What is the total amount of gas produced in this reaction?

A 1.0 mol **B** 2.0 mol **C** 2.5 mol **D** 3.0 mol

20 Steam is passed over heated magnesium to give compound J and hydrogen.

What is **not** a property of compound J?

A It has an M_r of 40.3.

B It is basic.

C It is a white solid.

D It is very soluble in water.

21 Which statement is correct?

A Hydrogen bromide reduces concentrated sulfuric acid to form sulfur dioxide gas.

B Hydrogen bromide decomposes at a higher temperature than hydrogen chloride.

C When hydrogen bromide gas is shaken with aqueous silver nitrate a yellow precipitate is formed.

D When hydrogen bromide gas is bubbled through aqueous iodine the solution becomes colourless.

22 ICl is made when Cl_2 and I_2 react together.

$$Cl_2 + I_2 \rightleftharpoons 2ICl$$

ICl reacts with water.

$$5ICl + 3H_2O \rightarrow 5HCl + HIO_3 + 2I_2$$

Which row is correct?

	oxidation number of I in ICl	reaction occurring when ICl reacts with H_2O
A	+1	the iodine atoms are oxidised to form I_2
B	+1	the iodine atoms are oxidised to form HIO_3
C	–1	the chlorine atoms are reduced to form HCl
D	–1	the iodine atoms are oxidised to form HIO_3

23 NH_4Cl reacts with NaOH in an aqueous solution.

Which statement is correct?

A The reaction gives rise to two different polar product molecules.

B The bond angle in the nitrogen-containing species remains unchanged.

C The ammonium ion acts as a base.

D The oxidation state of nitrogen increases in the reaction.

24 What is produced when 60 g of nitrogen monoxide reacts with an excess of carbon monoxide in a catalytic converter?

A 12 g of carbon and 92 g of nitrogen dioxide

B 24 g of carbon and 92 g of nitrogen dioxide

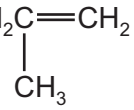
C 88 g of carbon dioxide and 28 g of nitrogen

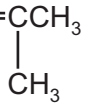
D 88 g of carbon dioxide and 56 g of nitrogen

25 Which alkene shows geometric isomerism?

A $CH_3CH_2CH_2CH{=}CH_2$

B $CH_3CH_2CH{=}CHCH_3$

C 

D 

26 What is the correct name of the major product of the reaction of HBr with 3-ethylhex-3-ene?

A 3-bromo-3-ethylhexane

B 3-bromo-4-ethylhexane

C 4-bromo-3-ethylhexane

D 4-bromo-4-ethylhexane

27 The alkane $CH_3CH_2CH(CH_3)_2$ undergoes free radical substitution with chlorine. No C–C bonds are broken in this reaction.

How many isomeric products, including positional and optical isomers, of molecular formula $C_5H_{11}Cl$ can be formed?

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

28 What is involved in the mechanism of the reaction between aqueous NaOH and 1-bromobutane?

A attack by a nucleophile on a carbon atom with a partial positive charge

B heterolytic bond fission and attack by a nucleophile on a carbocation

C homolytic bond fission and attack by an electrophile on a carbanion

D homolytic bond fission and attack by a nucleophile on a carbocation

[Turn over

29 But-2-ene reacts with cold dilute acidified $KMnO_4$ to give product X.

But-2-ene reacts with an excess of hot concentrated acidified $KMnO_4$ to give product Y.

Which statement about X and Y is correct?

A Only one of X and Y reacts with 2,4-dinitrophenylhydrazine.

B X and Y both react with sodium hydroxide.

C X and Y both react with sodium metal.

D Y reacts with $LiAlH_4$ to give X.

30 When heated with KOH dissolved in ethanol, halogenoalkanes can undergo an elimination reaction to form alkenes.

What are the possible elimination products when 2-bromobutane is heated with KOH dissolved in ethanol?

A $CH_3CH{=}CHCH_3$ only

B $CH_3CH_2CH{=}CH_2$ only

C $CH_3CH{=}CHCH_3$ and $CH_3CH_2CH{=}CH_2$

D $CH_3CH{=}CHCH_3$ and $CH_2{=}CHCH{=}CH_2$

31 Chloroethane can be used to make sodium propanoate.

chloroethane $\rightarrow$ intermediate Q $\rightarrow$ sodium propanoate

Intermediate Q is hydrolysed with boiling aqueous NaOH to give sodium propanoate.

Which reagent would produce intermediate Q from chloroethane?

A concentrated ammonia solution

B dilute sulfuric acid

C hydrogen cyanide in water

D potassium cyanide in ethanol

32 Four different alcohols are treated with alkaline I_2(aq).

Which row is correct?

	name of alcohol	formulae of products
A	butan-2-ol	CH_3COO^- and CH_3CI_3
B	propan-1-ol	CH_3COO^- and CHI_3
C	propan-2-ol	CH_3COO^- and CHI_3
D	butan-2-ol	$CH_3CH_2COO^-$ and CH_3I

33 The M_r of compound X is 88.

Compound X is heated under reflux with an excess of acidified potassium dichromate(VI) to produce compound Y.

Compound Y reacts with compound X under suitable conditions to produce compound Z. The M_r of compound Z is 172.

What is compound X?

A $CH_3CH_2CHOHCH_2CH_3$

B $(CH_3)_2COHCH_2CH_3$

C $(CH_3)_2CHCHOHCH_3$

D $(CH_3)_3CCH_2OH$

34 Butanedione, $CH_3COCOCH_3$, is a yellow liquid.

How does butanedione react with 2,4-dinitrophenylhydrazine reagent and Fehling's reagent?

	2,4-dinitrophenylhydrazine	Fehling's
A	positive	positive
B	positive	negative
C	negative	positive
D	negative	negative

35 Which substance reacts with ethanoic acid to give the organic product with the highest M_r?

A lithium aluminium hydride

B magnesium

C potassium carbonate

D propan-2-ol

36 A sample of propyl ethanoate is hydrolysed by heating under reflux with aqueous NaOH. The two organic products of the hydrolysis are separated, purified and weighed.

Out of the total mass of products obtained, what is the percentage by mass of each product?

A 32.4% and 67.6%

B 38.3% and 61.7%

C 42.3% and 57.7%

D 50.0% and 50.0%

[Turn over

37 Which statement about PVC is correct?

A Combustion products of PVC are very alkaline and harmful to breathe in.

B The empirical formula of PVC is the same as the empirical formula of the monomer.

C Molecules of PVC are unsaturated.

D The repeat unit of PVC is (CH_2CCl_2).

38 Compound Q reacts separately with HCN and $NaBH_4$ under suitable conditions.

Both reactions produce an organic product with a chiral centre.

What is compound Q?

A butanone

B ethanal

C propanal

D propanone

39 Compound X has the following properties.

- When 0.20 mol of X undergoes complete combustion, 14.4 dm^3 of carbon dioxide is produced, measured under room conditions.
- X reacts with 2,4-dinitrophenylhydrazine reagent to give an orange crystalline product.
- X does **not** give a yellow precipitate with alkaline I_2(aq).

What could be X?

A hexan-3-one

B propanal

C propan-1-ol

D propanone

40 A sample of but-2-enoic acid, $CH_3CH=CHCOOH$, is analysed using infrared spectroscopy.

The infrared spectrum shows a broad peak in the range 2500–3000 cm^{-1}.

bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers) / cm^{-1}
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3600

Which bond is responsible for this peak?

A C=C **B** C=O **C** C–O **D** O–H

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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		Key: atomic number / atomic symbol / name / relative atomic mass									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 –

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 –