Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2025

Centre Number

Candidate Number

Chemistry

Assessment Unit AS 2

assessing

Further Physical and Inorganic Chemistry and an Introduction to Organic Chemistry

SCH24

[SCH24]

TUESDAY 20 MAY, MORNING

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
In Section A, answer each question by circling the appropriate letter below the question.
In Section B, you must answer the questions in the spaces provided.
Do not write outside the boxed area on each page or on blank pages.
Complete questions in black ink and use a dark HB pencil for drawings and graphs.
Do not write with a gel pen.
Answer all **sixteen** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
You may use a scientific calculator.
Quality of written communication will be assessed in Question **14(a)(i)**.
A Data Leaflet, which includes a Periodic Table of the Elements, is included in this question paper.

14552

Section A

For each of the following questions, only **one** of the lettered responses (A – D) is correct.

Select the correct response for each question by circling the appropriate letter below the question.

1 Which one of the following gives the standard conditions for enthalpy changes?

	Temperature /K	Pressure /kPa
A	273	1
B	273	100
C	298	1
D	298	100

Answer: A B C D [1]

2 6.4 g of a metal M reacted completely with 1.6 g of oxygen to form an oxide with formula MO. Metal M also forms an oxide in which metal M and oxygen are present in a mass ratio of 8:1. Which one of the following is the empirical formula of this oxide?

A MO_2

B M_2O

C M_2O_3

D M_2O_5

Answer: A B C D [1]

3 Which one of the following contains 83.7% carbon by mass?

A butane

B hexane

C pentane

D propane

Answer: A B C D [1]

4 Which one of the following statements is **incorrect** for compounds in a homologous series?

A They have similar chemical properties and the same general formula

B They have the same general formula and each successive compound differs by a CH_2 unit

C They have the same general formula and show an increase in boiling point with increasing relative molecular mass

D They have the same physical properties and the same general formula

Answer: A B C D [1]

5 Which one of the following is a tertiary alcohol?

A 2,2-dimethylpropan-1-ol

B 2-methylbutan-2-ol

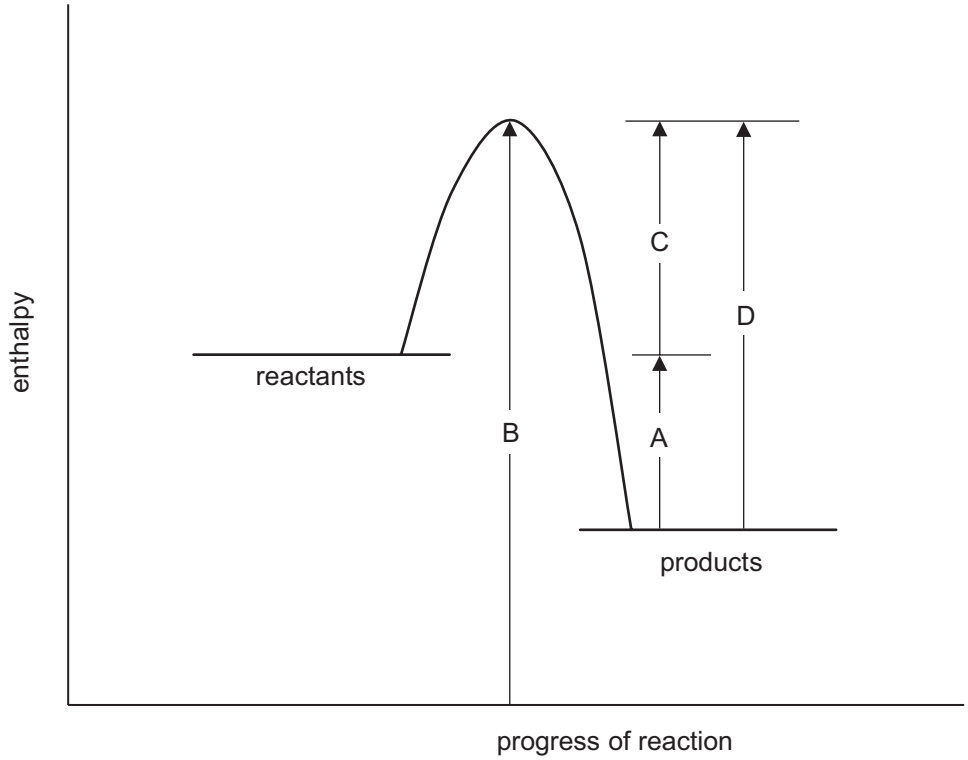
C 3-methylbutan-2-ol

D pentan-3-ol

Answer: A B C D [1]

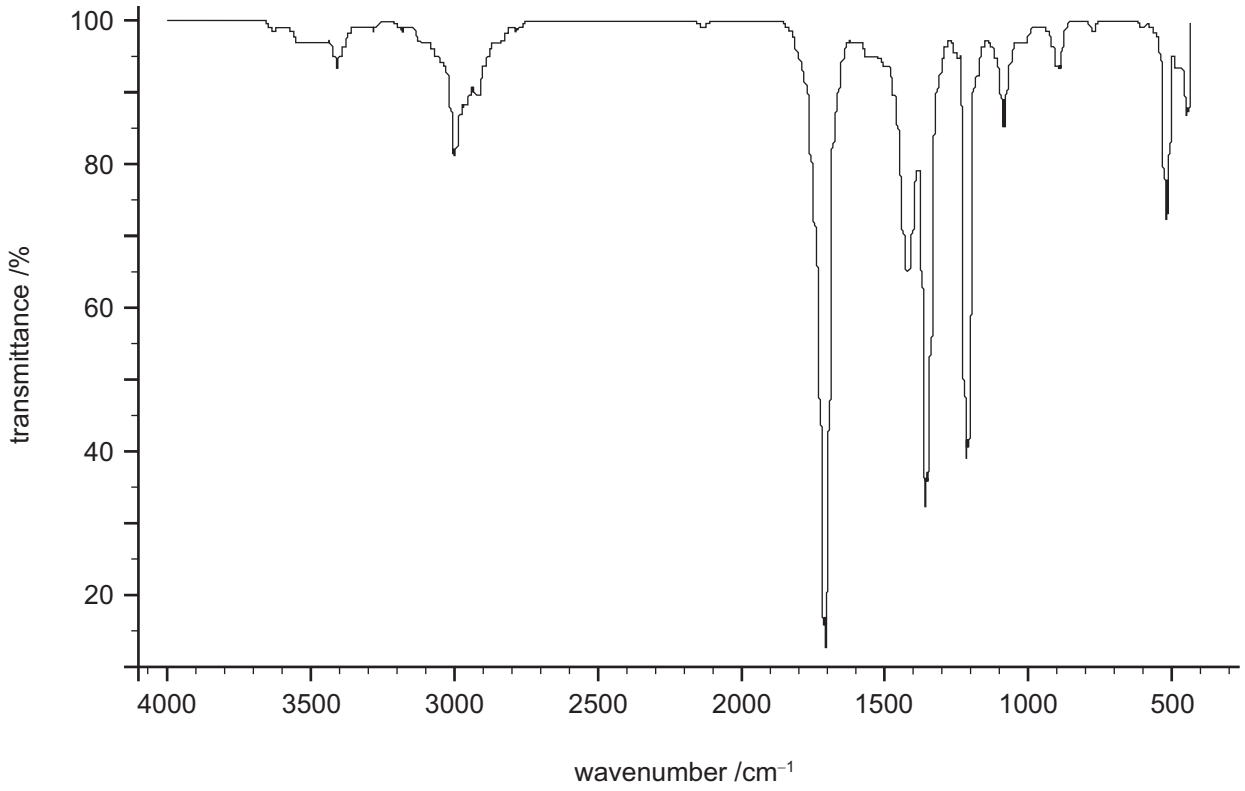
[Turn over

6 Which letter represents the activation energy of the reverse reaction in the enthalpy level diagram below?



Answer: A B C D [1]

7 The infrared spectrum of an organic compound is shown below.



Which one of the following is the homologous series to which this organic compound belongs?

A alcohol

B aldehyde

C alkane

D carboxylic acid

Answer: A B C D [1]

[Turn over

8 Which one of the following alcohols will produce a ketone when heated with acidified potassium dichromate(VI) solution?

A butan-1-ol

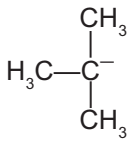
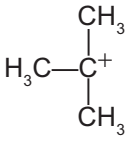
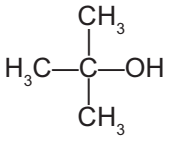
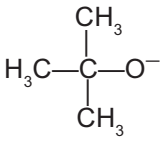
B butan-2-ol

C 2-methylpropan-1-ol

D 2-methylpropan-2-ol

Answer: A B C D [1]

9 When 2-bromo-2-methylpropane reacts with aqueous potassium hydroxide, an intermediate structure is formed. Which one of the following is the correct structure of the intermediate?

A	B	C	D
			

Answer: A B C D [1]

10 Which one of the following equations represents the standard enthalpy of formation of sodium bromide?

A $2Na(s) + Br_2(g) \rightarrow 2NaBr(s)$

B $2Na(s) + Br_2(l) \rightarrow 2NaBr(s)$

C $Na(s) + \frac{1}{2}Br_2(g) \rightarrow NaBr(s)$

D $Na(s) + \frac{1}{2}Br_2(l) \rightarrow NaBr(s)$

Answer: A B C D [1]

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(Questions continue overleaf)

Section B

Answer **all six** questions in this section.

11 (a) Three steps in the mechanism for the bromination of ethane are shown below.

Step 1 $Br_2 \rightarrow 2Br\bullet$

Step 2 $Br\bullet + CH_3CH_3 \rightarrow CH_3CH_2\bullet + HBr$

Step 3 $CH_3CH_2\bullet + Br_2 \rightarrow CH_3CH_2Br + Br\bullet$

(i) What is the name of this mechanism?

_____ [1]

(ii) In Step 1, the bond between the two bromine atoms is broken. What condition is required to break this bond?

_____ [1]

(iii) What term is used to describe Steps 2 and 3?

_____ [1]

(iv) Write an equation for a termination step in the mechanism for the bromination of ethane.

_____ [1]

(b) Butane is a fuel used in disposable lighters. Butane can undergo incomplete combustion.

(i) State the condition required for incomplete combustion to occur.

_____ [1]

(ii) Write an equation for the incomplete combustion of butane to produce carbon dioxide and carbon monoxide in a 1:3 ratio.

_____ [1]

(c) Organic fuels can be contaminated with sulfur-containing compounds such as CH_2SH.

(i) Write an equation for the **complete** combustion of CH_2SH forming sulfur dioxide as one of the products.

_____ [2]

(ii) State two ways in which the products of the combustion in **(c)(i)** may cause damage to the environment.

1. _____

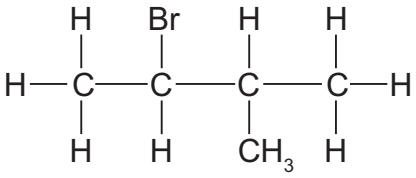
_____

2. _____

_____ [2]

[Turn over

12 There are eight structural isomers of $C_5H_{11}Br$ including 2-bromo-3-methylbutane which is used as a solvent.



2-bromo-3-methylbutane

(a) (i) Draw the skeletal formula of 2-bromo-3-methylbutane.

[1]

(ii) Define the term **structural isomers**.

_____

_____

_____ [1]

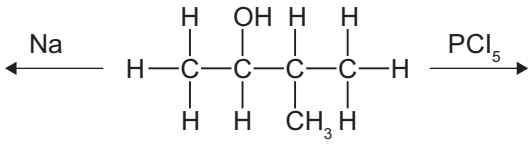
(b) 2-bromo-3-methylbutane can undergo a reaction to produce the alcohol 3-methylbutan-2-ol.

(i) Name the mechanism for this reaction.

_____ [1]

(ii) 3-methylbutan-2-ol reacts with sodium and with phosphorus pentachloride.

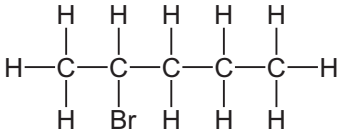
Complete the flow scheme below by giving the structural formulae of the organic products of these reactions.



[2]

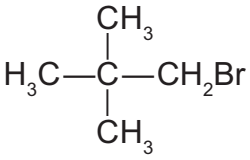
[Turn over

(c) Complete the following table for three other structural isomers of $C_5H_{11}Br$, labelled **A**, **B** and **C**.

Isomer	Name	Structural formula	Classification	Boiling point /°C
A	1-bromo-3-methylbutane			121
B				117
C			Tertiary	107

[3]

(d) Another isomer of $C_5H_{11}Br$, labelled isomer **D**, has the structural formula given below. It has a boiling point of 105°C.



isomer **D**

(i) State the IUPAC name of isomer **D**.

_____ [1]

(ii) Explain why isomer **B** from the table in **(c)** has a higher boiling point than isomer **D**.

_____

_____

_____

_____

_____ [2]

[Turn over

13 **(a)** 3-methylhex-2-ene, $CH_3CHC(CH_3)CH_2CH_2CH_3$, exhibits E-Z isomerism.

(i) State two reasons why 3-methylhex-2-ene can exhibit E-Z isomerism.

1. _____

_____

2. _____

_____ [2]

(ii) Draw the structure of the Z isomer of 3-methylhex-2-ene.

[1]

(b) 3-methylhex-2-ene is unsaturated.

(i) Define the term **unsaturated**.

_____

_____ [1]

(ii) Name the reagent used to test for unsaturation and state the result for a positive test.

Reagent _____

Result for positive test _____

_____ [2]

(c) 3-methylhex-1-ene is a structural isomer of 3-methylhex-2-ene.
3-methylhex-1-ene reacts with hydrogen bromide in an electrophilic addition reaction.

A mixture of 1-bromo-3-methylhexane and 2-bromo-3-methylhexane are formed.

(i) Define the term **electrophile**.

_____

_____ [1]

(ii) Draw the mechanism for the reaction of 3-methylhex-1-ene with hydrogen bromide to form 1-bromo-3-methylhexane.

[3]

(iii) State whether 1-bromo-3-methylhexane is the major or minor product and explain your answer.

_____

_____

_____

_____ [2]

[Turn over

14 (a) The enthalpy change for a neutralisation reaction may be determined experimentally by mixing 50 cm^3 of 1.00 mol dm^{-3} potassium hydroxide solution with 25 cm^3 of 1.00 mol dm^{-3} sulfuric acid. The equation for the reaction is:

$$2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$$

(i) Describe, giving practical details, how the enthalpy change for this neutralisation reaction between potassium hydroxide solution and sulfuric acid may be determined experimentally.

In this question you will be assessed on the quality of your written communication skills, including the use of specialist scientific terms.

[6]

(ii) Define the term **standard enthalpy of neutralisation**.

_____

_____

_____ [2]

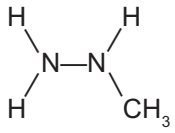
(iii) When this experiment was carried out, the temperature increase was 9.0°C. Calculate the standard enthalpy of neutralisation in kJ mol^{-1}. Give your answer to 1 decimal place.

The reaction mixture is assumed to have a specific heat capacity of 4.2 J g^{-1} $°C^{-1}$ and a density of 1.0 g cm^{-3}.

Answer _____ kJ mol^{-1} [3]

[Turn over

(b) Methylhydrazine (CH_6N_2), is a liquid rocket fuel.



methylhydrazine

The complete combustion of methylhydrazine is shown in the equation below.

$$CH_6N_2(l) + 2\tfrac{1}{2}O_2(g) \rightarrow N_2(g) + CO_2(g) + 3H_2O(l)$$

The standard enthalpy of combustion of methylhydrazine is $-1198\,kJ\ mol^{-1}$.

The table below gives some average bond enthalpy values.

Bond	Average bond enthalpy /kJ mol^{-1}
C—H	412
C—N	305
N—H	386
N—N	to be calculated
C═O	803
O—H	463
N≡N	916
O═O	496

Use the average bond enthalpy values in the table opposite to calculate the average bond enthalpy of the N—N bond.

Answer _____ kJ mol^{-1} [3]

[Turn over

(c) Hydrazine, N_2H_4, is another fuel used in rockets. It undergoes complete combustion to form nitrogen dioxide and water as shown in the equation below.

$$N_2H_4(l) + 3O_2(g) \rightarrow 2NO_2(g) + 2H_2O(l) \qquad \Delta_cH^{\ominus} = -557\,kJ\,mol^{-1}$$

(i) State **Hess's Law**.

_____

_____

_____ [2]

(ii) Using the standard enthalpy of combustion of hydrazine and the enthalpy of formation data given in the table below, calculate the standard enthalpy of formation of nitrogen dioxide.

	$\Delta_f H^{\ominus}$ /kJ mol^{-1}
$N_2H_4(l)$	+51
$O_2(g)$	0
$NO_2(g)$	to be calculated
$H_2O(l)$	–286

Answer _____ kJ mol^{-1} [3]

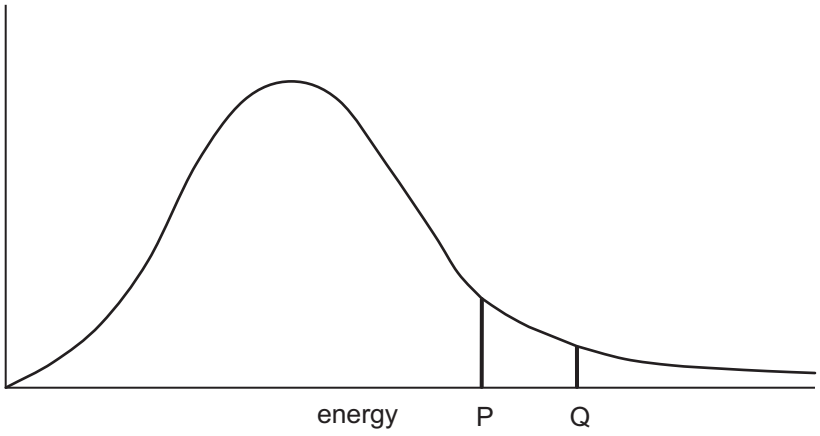
(iii) Explain why the standard enthalpy of formation of oxygen is zero.

_____

_____ [1]

[Turn over

15 (a) A Maxwell–Boltzmann distribution curve for a reaction mixture at 200 K is shown below. P and Q correspond to two activation energy values, one of which is for the catalysed reaction.



(i) What label should be placed on the y axis of the Maxwell–Boltzmann distribution curve?

_____ [1]

(ii) Explain why the distribution curve starts at the origin.

_____

_____ [1]

(iii) Define the term **activation energy**.

_____

_____ [1]

(iv) State and explain which activation energy value, P or Q, is the activation energy for the catalysed reaction.

_____

_____

_____ [1]

(v) On the axes opposite, sketch the curve you would expect to obtain at 300K. [1]

[Turn over

(b) In industry, ammonia may be oxidised to form nitrogen(II) oxide. The equation for this reaction is:

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -1268\,kJ\,mol^{-1}$$

The reaction is carried out at a temperature of 900°C and a pressure of 1 atm using a catalyst.

(i) State and explain what effect an increase in temperature will have on the rate of reaction and on the position of equilibrium for this reaction.

Rate of reaction:

Position of equilibrium:

[4]

(ii) State and explain what effect an increase in pressure will have on the yield of nitrogen(II) oxide.

[3]

(iii) Explain how a catalyst increases the rate of reaction.

_____

_____ [1]

(iv) State the effect, if any, of the presence of a catalyst on the position of equilibrium.

_____

_____ [1]

(v) Write an expression for the equilibrium constant, K_c, for this reaction. State the units.

Units _____ [2]

[Turn over

16 (a) Some tests were carried out on three Group II compounds (**Compounds 1**, **2** and **3**).

Test	Compound 1	Compound 2	Compound 3
Add to water	Insoluble	Insoluble	Soluble
Add to dilute hydrochloric acid	Carbon dioxide gas evolved	Solution remains colourless; heat is released	Solution remains colourless; heat is released
Add to dilute sulfuric acid	Carbon dioxide gas evolved	White precipitate forms slowly	White precipitate forms

(i) State and explain which compound (**1**, **2** or **3**) is a metal carbonate.

_____

_____

_____ [2]

(ii) Compound 3 is a strontium compound. Write an ionic equation, including state symbols, for the reaction which occurs when a solution of compound 3 is added to dilute sulfuric acid.

_____ [2]

(iii) Describe the test for carbon dioxide gas.

_____

_____ [1]

(b) Barium carbonate thermally decomposes at 1360°C and magnesium carbonate thermally decomposes at 540°C.

(i) Write an equation for the thermal decomposition of barium carbonate.

_____ [1]

(ii) Explain why the thermal decomposition temperature of magnesium carbonate is lower than that of barium carbonate.

_____

_____

_____

_____ [2]

(c) Barium oxide is produced by the thermal decomposition of barium nitrate as shown in the following equation.

$$2Ba(NO_3)_2(s) \rightarrow 2BaO(s) + 4NO_2(g) + O_2(g)$$

Calculate the total volume of gas produced, at 293 K and 1 atm pressure, if a sample of 3.50 kg of barium nitrate is thermally decomposed. Give your answer to 3 significant figures and state the units.

Answer _____ [3]

THIS IS THE END OF THE QUESTION PAPER

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General Information

1 tonne = 10^6 g
1 metre = 10^9 nm
One mole of any gas at 293 K and a pressure of 1 atmosphere (10^5 Pa) occupies a volume of 24 dm^3
Avogadro Constant = 6.02×10^{23} mol^{-1}
Planck Constant = 6.63×10^{-34} J s
Specific Heat Capacity of water = 4.2 J g^{-1} K^{-1}
Speed of Light = 3×10^8 m s^{-1}

Characteristic absorptions in IR spectroscopy

Wavenumber/cm^{-1}	Bond	Compound
550–850	C–X (X = Cl, Br, I)	Haloalkanes
750–1100	C–C	Alkanes, alkyl groups
1000–1300	C–O	Alcohols, esters, carboxylic acids
1450–1650	C=C	Arenes
1600–1700	C=C	Alkenes
1650–1800	C=O	Carboxylic acids, esters, aldehydes, ketones, amides, acyl chlorides
2200–2300	C≡N	Nitriles
2500–3200	O–H	Carboxylic acids
2750–2850	C–H	Aldehydes
2850–3000	C–H	Alkanes, alkyl groups, alkenes, arenes
3200–3600	O–H	Alcohols
3300–3500	N–H	Amines, amides

Proton Chemical Shifts in Nuclear Magnetic Resonance Spectroscopy (relative to TMS)

Chemical Shift	Structure	
0.5–2.0	–C**H**	Saturated alkanes
0.5–5.5	–O**H**	Alcohols
1.0–3.0	–N**H**	Amines
2.0–3.0	–CO–C**H**	Ketones
	–N–C**H**	Amines
	C_6H_5–C**H**	Arene (aliphatic on ring)
2.0–4.0	X–C**H**	X = Cl or Br (3.0–4.0)
		X = I (2.0–3.0)
4.5–6.0	–C=C**H**	Alkenes
5.5–8.5	RCON**H**	Amides
6.0–8.0	–C_6**H**$_5$	Arenes (on ring)
9.0–10.0	–C**H**O	Aldehydes
10.0–12.0	–COO**H**	Carboxylic acids

These chemical shifts are concentration and temperature dependent and may be outside the ranges indicated above.

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Data Leaflet

Including the Periodic Table of the Elements

For the use of candidates taking
Advanced Subsidiary and
Advanced Level Examinations

Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations

gce a/as examinations

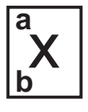
chemistry

THE PERIODIC TABLE OF ELEMENTS

I	II											III	IV	V	VI	VII	0
Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1																	4 He Helium 2
7 Li Lithium 3	9 Be Beryllium 4											11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
23 Na Sodium 11	24 Mg Magnesium 12											27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulfur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	64 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	98 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
133 Cs Caesium 55	137 Ba Barium 56	139 La* Lanthanum 57	178 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	210 Po Polonium 84	210 At Astatine 85	222 Rn Radon 86
223 Fr Francium 87	226 Ra Radium 88	227 Ac† Actinium 89	261 Rf Rutherfordium 104	262 Db Dubnium 105	266 Sg Seaborgium 106	264 Bh Bohrium 107	277 Hs Hassium 108	268 Mt Meitnerium 109	271 Ds Darmstadtium 110	272 Rg Roentgenium 111	285 Cn Copernicium 112						

140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	145 Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	162 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
232 Th Thorium 90	231 Pa Protactinium 91	238 U Uranium 92	237 Np Neptunium 93	242 Pu Plutonium 94	243 Am Americium 95	247 Cm Curium 96	245 Bk Berkelium 97	251 Cf Californium 98	254 Es Einsteinium 99	253 Fm Fermium 100	256 Md Mendelevium 101	254 No Nobelium 102	257 Lr Lawrencium 103

* 58 – 71 Lanthanum series
† 90 – 103 Actinium series



a = relative atomic mass (approx)
x = atomic symbol
b = atomic number

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