Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2023

Centre Number

Candidate Number

Chemistry

Assessment Unit AS 2

assessing
Further Physical and Inorganic Chemistry and an Introduction to Organic Chemistry

SCH24

[SCH24]

TUESDAY 23 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.
Answer **all fifteen** questions in **Sections A and 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 in black ink only. **Do not write with a gel pen or a pencil.**

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.
Quality of written communication will be assessed in Question **15(f)**.
The figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.
A Periodic Table of Elements, containing some data, is included with this question paper.

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 and write the appropriate letter in the space provided.

1 Which Group II compound would be most suitable for use in indigestion remedies?

A Calcium chloride

B Calcium oxide

C Magnesium oxide

D Magnesium sulfate

Answer _____ [1]

2 Unsaturated vegetable oils are hardened to make margarine by reacting them with hydrogen in the presence of a nickel catalyst. Which terms could be used to describe this type of reaction?

A Addition and oxidation

B Addition and reduction

C Substitution and oxidation

D Substitution and reduction

Answer _____ [1]

3 Which one of the following species can act as a nucleophile?

A H_2

B H^+

C Na

D OH^-

Answer _____ [1]

4 When iodoethane is heated in a sealed tube with an excess of ammonia in ethanol as a solvent, which compound is **not** formed?

A $CH_3CH_2NH_2$

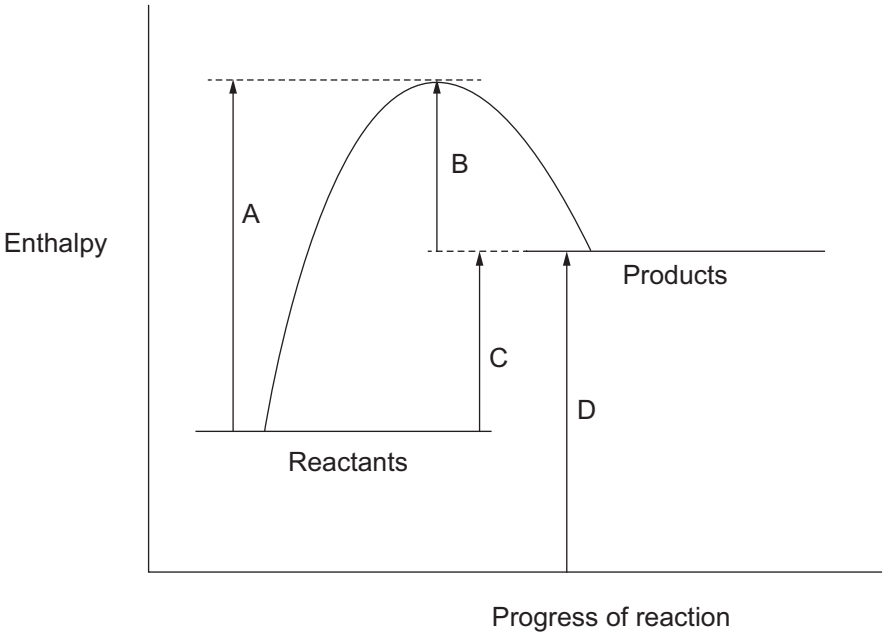
B $CH_3CH_2CH_2NH_2$

C $(CH_3CH_2)_2NH$

D NH_4I

Answer _____ [1]

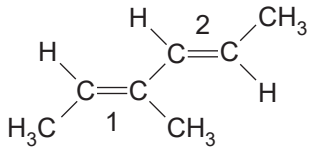
5 An enthalpy level diagram for a reversible reaction is shown below. Which letter represents the activation energy for the reverse reaction?



Answer _____ [1]

[Turn over

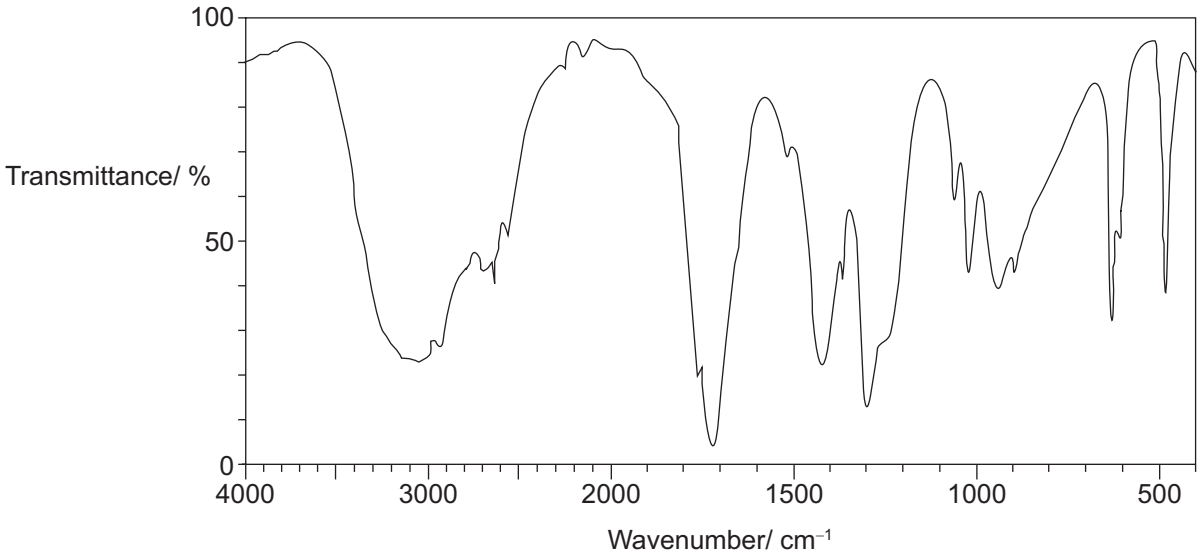
6 The alkene 3-methylhexa-2,4-diene has two C═C double bonds. The arrangement around each double bond can be E or Z. Which one of the following shows the correct orientations of double bond 1 and double bond 2 in the isomer shown below?



	Double bond 1	Double bond 2
A	E	E
B	E	Z
C	Z	E
D	Z	Z

Answer _____ [1]

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



Which one of the following compounds could produce this infrared spectrum?

A Propan-1-ol

B Propanal

C Propanone

D Propanoic acid

Answer _____ [1]

[Turn over

8 Brown nitrogen dioxide, NO_2, exists in equilibrium with colourless dinitrogen tetroxide, N_2O_4.

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

The pressure on the equilibrium is decreased. What effect will this have on the appearance of the mixture of the gases?

A The appearance of the mixture of gases is unchanged

B The mixture of gases becomes colourless

C The mixture of gases becomes darker brown

D The mixture of gases becomes lighter brown

Answer _____ [1]

9 The molecular formula of penicillin is $C_{16}H_{18}N_2O_4S$. A sample of penicillin contains 0.25 moles of carbon. The mass of sulfur in the sample is:

A 0.016 g

B 0.50 g

C 4.0 g

D 8.0 g

Answer _____ [1]

10 Calculate the standard enthalpy of formation of propane using the data below.

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ $\quad \Delta H^{\ominus} = -2220\,kJ\,mol^{-1}$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\quad \Delta H^{\ominus} = -286\,kJ\,mol^{-1}$

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H^{\ominus} = -394\,kJ\,mol^{-1}$

A $-1540\,kJ\,mol^{-1}$

B $-106\,kJ\,mol^{-1}$

C $+106\,kJ\,mol^{-1}$

D $+1540\,kJ\,mol^{-1}$

Answer _____ [1]

[Turn over

Section B

Answer all **five** questions in the spaces provided.

11 The Solvay process is used to produce sodium carbonate. The process consists of several steps involving the use of ammonia, sodium chloride and calcium carbonate.

(a) The overall equation for the formation of sodium carbonate may be written as the reaction between calcium carbonate and sodium chloride. Write the overall equation for this process.

_____ [2]

(b) The equation for one of the steps in the process is shown below.

$$2NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + 2NH_3 + 2H_2O$$

(i) Calculate the percentage atom economy for the formation of ammonia in the above reaction. Give your answer to 1 decimal place.

Answer _____ % [2]

(ii) During this stage of the process, 3.25 tonnes of ammonium chloride are reacted with an excess of calcium hydroxide and 0.92 tonnes of ammonia were obtained. Calculate the percentage yield of ammonia. Give your answer to 1 decimal place.

Answer _____ % [3]

12 The thermal decomposition of potassium hydrogencarbonate establishes a dynamic equilibrium in a closed vessel at 200 °C. The enthalpy change for the decomposition reaction is difficult to determine directly.

$$2KHCO_3(s) \rightleftharpoons K_2CO_3(s) + CO_2(g) + H_2O(g)$$

(a) (i) The equilibrium is heterogeneous. Define the term **heterogeneous**.

_____

_____ [1]

(ii) Suggest why the water is present as a gas in the equilibrium mixture.

_____ [1]

(b) The enthalpy change for this thermal decomposition reaction can be calculated from the enthalpy changes of neutralisation of both potassium carbonate and potassium hydrogencarbonate.

$$K_2CO_3 + 2HCl \rightarrow 2KCl + H_2O + CO_2$$

$$KHCO_3 + HCl \rightarrow KCl + H_2O + CO_2$$

Both of these enthalpy changes may be determined using the following procedure:

- Using a measuring cylinder, place 25 cm^3 of 2.0 mol dm^{-3} hydrochloric acid into a polystyrene cup.
- Measure the temperature of the acid with a thermometer.
- Add a known mass of either potassium carbonate or potassium hydrogencarbonate to the acid in the polystyrene cup, stir, and measure the highest or lowest temperature reached.

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

_____

_____

_____

_____ [2]

[Turn over

(ii) When the procedure was carried out using 2.5 g of potassium carbonate, a temperature rise of 5.5 °C was recorded. Calculate the enthalpy change for the reaction per mole of potassium carbonate. Give your answer in kJ mol^{-1} to 1 decimal place.

($c = 4.2\,J\,g^{-1}\,°C^{-1}$, density of solution = 1 g cm^{-3})

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

(iii) When the procedure was repeated using potassium hydrogencarbonate, the enthalpy change for the reaction was determined to be +29.1 kJ mol^{-1} (per mole of potassium hydrogencarbonate). Use this value and the value calculated in **(b)(ii)** to calculate the enthalpy change for the thermal decomposition of potassium hydrogencarbonate.

$$2KHCO_3(s) \rightleftharpoons K_2CO_3(s) + CO_2(g) + H_2O(g)$$

Answer _____ [2]

13 Isooctane (2,2,4-trimethylpentane) is an important component of petrol used in cars. It is a liquid at room temperature. Isooctane is one of eighteen structural isomers of C_8H_{18}.

(a) (i) Draw the skeletal formula of isooctane.

[1]

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

_____

_____

_____ [2]

(iii) Draw the structural formula and state the IUPAC name of the structural isomer of C_8H_{18} which is the most branched.

IUPAC name: _____ [2]

[Turn over

(b) **(i)** Write an equation for the complete combustion of isooctane, C_8H_{18}.

_____ [2]

(ii) Suggest why a sooty flame is observed when a sample of isooctane burns.

_____ [1]

(iii) When 1.00 g of liquid isooctane reacts completely in excess oxygen, the enthalpy change is –47.9 kJ. Calculate the heat energy released when 5.00 dm^3 of liquid isooctane burns completely in oxygen (density of isooctane = 0.692 g cm^{-3}). Give your answer to 3 significant figures.

Answer _____ kJ [3]

(c) The combustion of organic compounds has contributed to the increase in the percentage composition of carbon dioxide in the atmosphere.

(i) State the percentage increase in atmospheric carbon dioxide caused by the combustion of organic compounds.

_____ [1]

(ii) State a consequence of an increase in atmospheric carbon dioxide.

_____ [1]

(d) Pollutants such as carbon monoxide and oxides of nitrogen are also produced when alkane fuels are burned. Catalytic converters are used to reduce the environmental impact of burning alkane fuels. They consist of a thin layer of a metal catalyst on a ceramic honeycomb structure.

(i) Suggest why a catalytic converter has a honeycomb structure.

_____ [1]

(ii) Suggest why a **thin layer** of the metal catalyst is used in a catalytic converter.

_____ [1]

(iii) Write an equation for the overall reaction between nitrogen(II) oxide and carbon monoxide in a catalytic converter.

_____ [2]

(iv) Define the term **catalyst**.

_____

_____ [1]

(v) State the name given to the graphical distribution of molecular energies in gaseous reactions.

_____ [1]

[Turn over

(vi) Explain, with reference to the graphical distribution named in **(d)(v)**, how a catalyst changes the rate of reaction between nitrogen(II) oxide and carbon monoxide.

[3]

14 The Group II elements are known as the alkaline earth metals and they display trends in their physical and chemical properties.

(a) State and explain the trend in atomic radius down Group II.

_____

_____

_____

_____ [2]

(b) The Group II elements react with oxygen to form the corresponding metal oxides.

(i) Write an equation for the reaction of magnesium with oxygen.

_____ [1]

(ii) The magnesium oxide produced in **(b)(i)** was added to a flask containing water and phenolphthalein. Suggest and explain, using an ionic equation, why the solution will change colour.

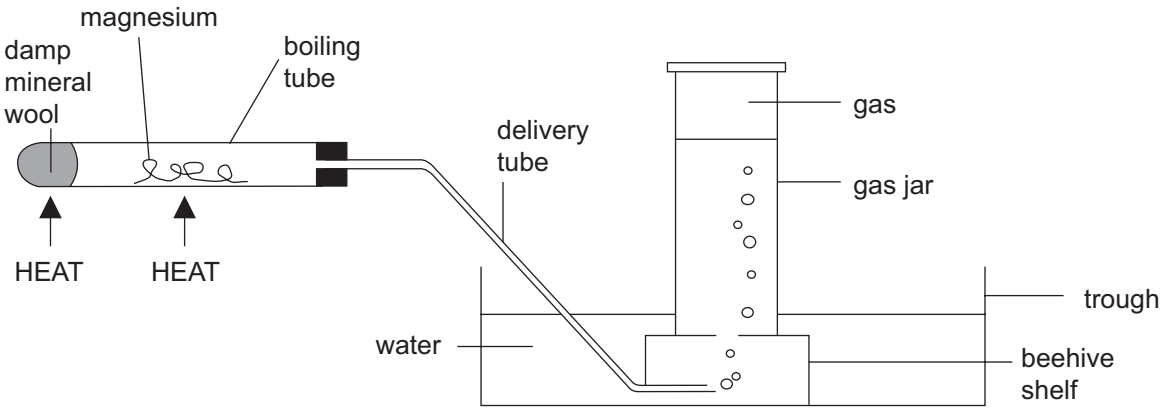
_____

_____

_____ [2]

[Turn over

(c) Magnesium oxide may also be produced by reacting magnesium with steam. The diagram below shows the apparatus used in the reaction.



(i) State why the damp mineral wool is heated.

_____ [1]

(ii) State two observations which would be made in the boiling tube during the reaction.

_____

_____

_____ [2]

(iii) Write an equation for the reaction which takes place in the boiling tube.

_____ [1]

(iv) Suggest why the gas produced is collected over water.

_____ [1]

(v) The reaction was carried out using 0.08 g of magnesium. Calculate the volume of gas at 20 °C and 1 atm pressure that should be produced and suggest why this volume of gas was not obtained in the gas jar.

Answer _____ cm^3

_____

_____

_____

_____ [3]

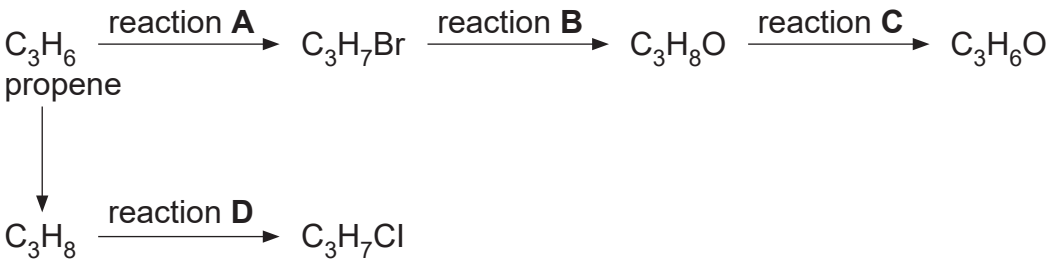
(d) Group II oxides can react with dilute acids.

Write an equation for the reaction between magnesium oxide and dilute nitric acid.

_____ [1]

[Turn over

15 Propene (C_3H_6) is a raw material obtained from crude oil which can be used to produce many important chemicals. A reaction scheme is shown below.



(a) State the name of the mechanism for reaction **A** and reaction **B**.

A _____

B _____ [4]

(b) **(i)** Write an equation for reaction **A**.

_____ [1]

(ii) Two isomers of C_3H_7Br are produced in reaction **A**. State the IUPAC name of the isomer which is the major product.

_____

_____ [1]

(iii) Draw a mechanism to show the formation of the major product in reaction **A**.

[3]

(c) (i) Write the formula of the reagent required in reaction **B**.

_____ [1]

(ii) Describe the conditions required for reaction **B**.

_____

_____

_____ [2]

(iii) The reagent required in reaction **B** can also be used, under different conditions, to convert C_3H_7Br back to C_3H_6. State the type of reaction which occurs when C_3H_7Br is converted to C_3H_6.

_____ [1]

(d) (i) Draw the structural formulae of the two isomers of C_3H_6O which are produced in reaction **C**.

[2]

(ii) Name the reagent used to carry out reaction **C**.

_____ [1]

[Turn over

(e) C_3H_8 reacts with Cl_2 to form C_3H_7Cl in reaction **D**. One by-product in this reaction is C_6H_{14}.

(i) Name the mechanism for this reaction.

_____ [1]

(ii) Write an equation for the initiation step in this mechanism.

_____ [1]

(iii) Write equations for the two propagation steps in this mechanism.

_____

_____ [2]

(iv) Write an equation for a termination step which produces C_3H_7Cl.

_____ [1]

(v) Write an equation to show how C_6H_{14} may be produced in this reaction.

_____ [1]

(f) Pentane, C_5H_{12}, is also obtained from crude oil. It has the same relative formula mass as butanal, C_4H_8O, and a similar relative formula mass to butan-1-ol, C_4H_9OH. However, the three compounds have very different boiling points.

Identify which compound (pentane, butanal or butan-1-ol) has the highest boiling point and which has the lowest boiling point.
Explain the variation in boiling points of the three compounds with reference to intermolecular forces.

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

[6]

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Sources

Q7.....© Science Ready

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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.

COUNCIL FOR THE **CURRICULUM, EXAMINATIONS** AND **ASSESSMENT**
29 Clarendon Road, Clarendon Dock, Belfast BT1 3BG
Tel: +44 (0)28 9026 1200 Fax: +44 (0)28 9026 1234
Email: info@ccea.org.uk Web: www.ccea.org.uk

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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

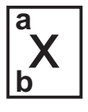
chemistry

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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