Rewarding Learning

Centre Number

Candidate Number

ADVANCED
General Certificate of Education
2018

Chemistry

Assessment Unit A2 1

assessing
Periodic Trends and Further Organic, Physical and Inorganic Chemistry

[AC212]

AC212

TUESDAY 5 JUNE, AFTERNOON

TIME

2 hours.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all sixteen** questions.
Answer **all ten** questions in **Section A**. Record your answers by marking the appropriate letter on the answer sheet provided. Use only the spaces numbered 1 to 10. Keep in sequence when answering.
Answer **all six** questions in **Section B**.
You must answer the questions in the spaces provided.
Complete in black ink only. **Do not write with a gel pen.**

INFORMATION FOR CANDIDATES

The total mark for this paper is 120.
Quality of written communication will be assessed in Question **16(b)**.
In Section A all questions carry equal marks, i.e. **two** marks for each question.
In Section B the figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
A Periodic Table of Elements, containing some data, is included in 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 in each case and mark its code letter by connecting the dots as illustrated on the answer sheet.

1 Which one of the following is the general formula for a simple carboxylic acid?

A C_nH_nCOOH

B $C_nH_{2n}COOH$

C $C_nH_{2n+1}COOH$

D $C_nH_{2n-1}COOH$

2 The reaction, $RBr + OH^- \longrightarrow ROH + Br^-$, has the following associated rate equation:

$$\text{Rate} = k[RBr]$$

Which one of the following reaction mechanisms would produce this rate equation?

A $RBr + OH^- \xrightarrow{\text{slow}} RBrOH^-$
$RBrOH^- \xrightarrow{\text{fast}} ROH + Br^-$

B $RBr \xrightarrow{\text{fast}} R^+ + Br^-$
$R^+ + OH^- \xrightarrow{\text{slow}} ROH$

C $RBr \xrightarrow{\text{slow}} R^+ + Br^-$
$R^+ + OH^- \xrightarrow{\text{fast}} ROH$

D $RBr + OH^- \xrightarrow{\text{fast}} RBrOH^-$
$RBrOH^- \xrightarrow{\text{slow}} ROH + Br^-$

3 Calcium fluoride has a lattice enthalpy of 2602 kJ mol^{-1} and an enthalpy of solution of –60 kJ mol^{-1}. If the enthalpy of hydration for Ca^{2+} ions is –1650 kJ mol^{-1} which one of the following is the enthalpy of hydration for F^- ions?

A –253 kJ mol^{-1}

B –506 kJ mol^{-1}

C –1012 kJ mol^{-1}

D –2156 kJ mol^{-1}

4 Which one of the following is the pH of a 100 cm^3 solution containing 0.10 g of the strong acid, benzenesulfonic acid, $C_6H_5SO_3H$?

A 0.20

B 1.20

C 2.20

D 3.20

5 Carbon monoxide reacts with hydrogen to form methanol.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

Which one of the following represents the units of K_p for the reaction?

A kPa^2

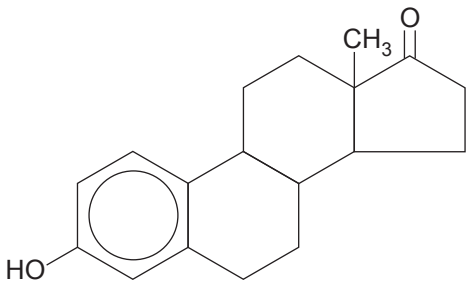
B k^2Pa^2

C kPa^{-2}

D $k^{-2}Pa^{-2}$

[Turn over

6 How many chiral centres are there in oestrone?



oestrone

A 2

B 3

C 4

D 5

7 Which one of the following is the saponification value of the triester formed by the reaction between glycerol and cerotic acid $CH_3(CH_2)_{24}COOH$?

A 32.6

B 97.8

C 45.7

D 137.0

8 A 1.6 g sample of an oil was treated with Wij's solution and excess potassium iodide solution. The liberated iodine reacted with 8.4 cm^3 of 0.1 mol dm^{-3} sodium thiosulfate solution. The blank titration required 41.2 cm^3 of sodium thiosulfate solution. Which one of the following is the iodine value of the oil?

A 16.1

B 26.0

C 39.3

D 48.9

9 Which one of the following oxides will produce a solution with the lowest pH value when equimolar amounts of the oxides are added to 100 cm^3 of water?

A Chlorine heptoxide

B Silicon dioxide

C Sodium oxide

D Sulfur dioxide

10 Which one of the following is a product of the reaction between propanenitrile and sodium hydroxide?

A CH_3CH_2COOH

B CH_3CH_2COONa

C $CH_3CH_2CH_2COOH$

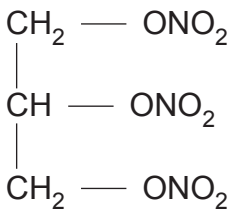
D $CH_3CH_2CH_2COONa$

[Turn over

Section B

Answer **all six** questions in the spaces provided

11 In 1847 Ascanio Sobrero first synthesised nitroglycerine by reacting glycerol with concentrated nitric and sulfuric acids.



nitroglycerine

(a) (i) Draw the structural formula of glycerol showing all the bonds present.

[2]

(ii) Write the equation for the formation of nitroglycerine by reacting glycerol with nitric acid.

[2]

(iii) Nitroglycerine can be described as a nitro ester. Draw the structure of the ester link in nitroglycerine.

[1]

(iv) The production of nitroglycerine occurs via the formation of a nitronium ion, NO_2^+. The nitronium ion consists of nitrogen covalently bonded to oxygen atoms via double bonds. Suggest a dot and cross diagram, using outer electrons only, for the nitronium ion.

[1]

(b) When heated, liquid nitroglycerine decomposes explosively to produce steam, carbon dioxide, nitrogen and oxygen.

(i) Write an equation, including state symbols, for this decomposition.

_____ [2]

(ii) Calculate the total volume of gas produced at 20 °C and 1 atmosphere pressure if 50 g of nitroglycerine decomposes.

_____

_____

_____

_____ [2]

[Turn over

(c) Nitroglycerine has been used to treat angina as it is converted in the body to nitrogen monoxide which relaxes the blood vessels. Nitrogen monoxide is also a pollutant and can be easily oxidised to nitrogen dioxide in the air.

(i) Write an equation for the oxidation of nitrogen monoxide to form nitrogen dioxide.

_____ [1]

(ii) Nitrogen oxides are removed from car exhaust fumes by a catalytic converter. Suggest how nitrogen oxides are formed in car engines.

_____

_____ [2]

(d) Nitrogen monoxide can also be reacted with hydrogen to form nitrogen and water. A kinetic study of this reaction, at constant temperature, produced the following data.

experiment	**[NO] / mol dm^{-3}**	**[H_2] / mol dm^{-3}**	**initial rate / mol dm^{-3} s^{-1}**
1	0.10	0.20	2.46×10^{-3}
2	0.30	0.40	4.43×10^{-2}
3	0.60	0.40	1.77×10^{-1}

(i) Calculate the order of the reaction with respect to NO.

_____ [1]

(ii) Calculate the order of the reaction with respect to H_2.

_____ [1]

(iii) Write the rate equation for this reaction.

_____ [1]

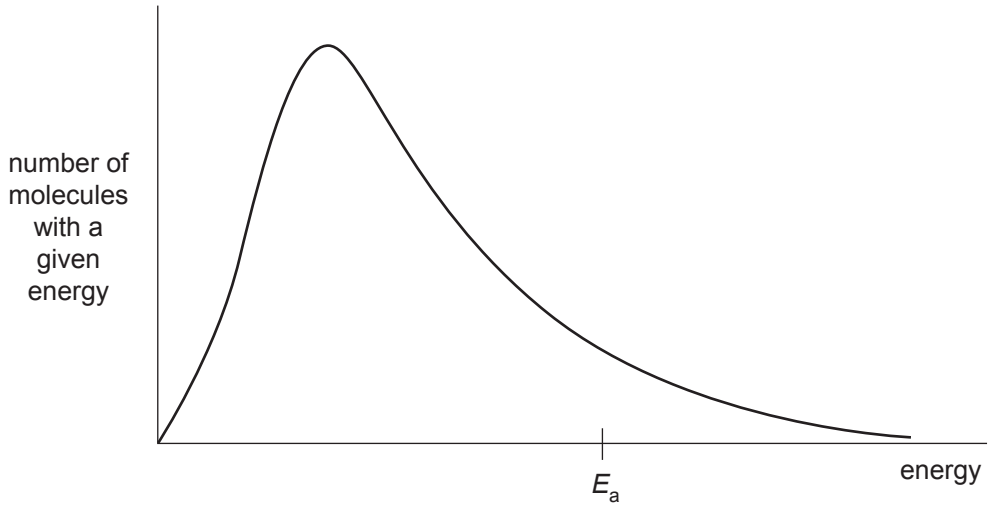
(iv) Calculate the rate constant for this reaction and write its units.

_____

_____

_____ [2]

(e) The Maxwell–Boltzmann distribution for a mixture of nitrogen monoxide and hydrogen is shown below:



(i) Explain why the graph starts at the origin.

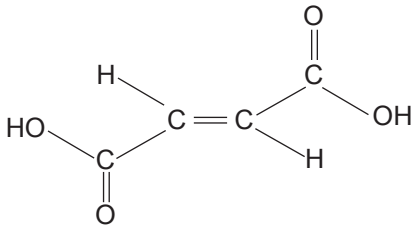
_____ [1]

(ii) Explain why the graph never touches the x-axis at higher energies.

_____ [1]

[Turn over

12 Fumaric acid and its esters are used in the treatment of the skin condition, psoriasis:



fumaric acid

(a) Suggest a systematic name for fumaric acid.

_____ [2]

(b) The first dissociation constant for fumaric acid is 8.85×10^{-4} mol dm^{-3}, the second dissociation constant is 3.21×10^{-5} mol dm^{-3}.

(i) Write an equation for the first dissociation of fumaric acid.

_____ [1]

(ii) Write an equation for the second dissociation of fumaric acid.

_____ [1]

(iii) Calculate the pH of a 0.05 mol dm^{-3} solution of fumaric acid using the first dissociation constant.

_____

_____

_____ [3]

(iv) Suggest why the second dissociation constant does not need to be considered when calculating the pH.

[1]

(c) Sodium fumarate is a food additive used as an acidity regulator.

(i) A buffer solution can be made by reacting fumaric acid with sodium hydroxide. Write an equation for the reaction of fumaric acid with excess sodium hydroxide.

[2]

(ii) Suggest how a solution of sodium fumarate could maintain the pH of an aqueous solution when acid is added.

[2]

(iii) Buffers can also be made with monoprotic acids such as ethanoic acid. Calculate the pH of the buffer formed when 900 cm^3 of 0.1 mol dm^{-3} ethanoic acid is reacted with 1.6 g of sodium hydroxide. The acid dissociation value for ethanoic acid is 1.8×10^{-5} mol dm^{-3}.

[3]

[Turn over

(d) Fumaric acid reacts with methanol to form dimethyl fumarate according to the following reaction.

$$C_2H_2(COOH)_2 + 2CH_3OH \rightleftharpoons C_2H_2(COOCH_3)_2 + 2H_2O$$

(i) Explain the effect upon the yield of dimethyl fumarate by adding more methanol.

[2]

(ii) Explain the effect upon the yield and the rate of this reaction if concentrated sulfuric acid was added.

[4]

(iii) Succinic acid also reacts with methanol according to the reaction shown:

$$C_2H_4(COOH)_2 + 2CH_3OH \rightleftharpoons C_2H_4(COOCH_3)_2 + 2H_2O$$

Write the equation for the equilibrium constant.

[2]

(iv) Calculate the equilibrium constant for this reaction if a mixture, which initially contains 0.5 mol of succinic acid and 0.7 mol of methanol, was found to contain 0.18 mol of methanol after equilibrium is reached.

[4]

(v) Explain why the volume of the container is not necessary for the calculation of the equilibrium constant.

[1]

[Turn over

13 Ozone, O_3, which is present in the upper atmosphere, can decompose to form oxygen gas in a reaction which is catalysed by chlorine radicals.

$$2O_3 \longrightarrow 3O_2$$

molecule	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
O_2	0.0	205
O_3	143	239

(a) Explain the difference between the enthalpy of formation values of oxygen and of ozone.

_____

_____ [1]

(b) Calculate the entropy change of the reaction to form oxygen from ozone.

_____ [1]

(c) Explain why the reaction to form oxygen from ozone is feasible at all temperatures.

_____

_____ [2]

(d) Chlorine radicals are part of the mechanism for the formation of chloromethane from methane.

$$CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl$$

(i) Calculate the enthalpy change for this reaction using the following data:

reaction	$\Delta H^{\ominus}$ / kJ mol^{-1}
$H_2 + Cl_2 \longrightarrow 2HCl$	−184.6
$2C + 3H_2 + Cl_2 \longrightarrow 2CH_3Cl$	−167.4
$C + 2H_2 \longrightarrow CH_4$	−74.7

[2]

[Turn over

(ii) Chloromethane can be hydrolysed by reaction with hydroxide ions. Draw a flow scheme showing the mechanism of this reaction.

[3]

(iii) Write the rate equation that would be associated with the mechanism drawn, stating the overall order of the reaction.

_____ [2]

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(Questions continue overleaf)

[Turn over

14 The table below gives the melting points of the Period 3 oxides:

compound	melting point /K
sodium oxide	1405
magnesium oxide	3125
aluminium oxide	2345
silicon dioxide	1986
phosphorus(V) oxide	340
sulfur dioxide	201
sulfur trioxide	290
chlorine(VII) oxide	182

(a) (i) Explain why the melting point of magnesium oxide is higher than that of sodium oxide.

[2]

(ii) Explain the differences in the melting points of silicon dioxide, phosphorus(V) oxide and sulfur trioxide.

[3]

(b) Aluminium chloride has found many uses both as a catalyst, and in its hydrated form $AlCl_3.6H_2O$, as an antiperspirant.

(i) When the hydrated form of aluminium chloride is gently heated it decomposes to form aluminium hydroxide, hydrogen chloride and water vapour. Write an equation for this reaction.

_____ [2]

(ii) In the liquid and vapour phase anhydrous aluminium chloride dimerises. Draw a structure of the dimer showing all the bonds present.

[2]

(iii) Aluminium chloride produces an acidic solution as it undergoes hydrolysis. Define the term **hydrolysis**.

_____ [1]

(iv) Write an equation showing the hydrolysis of dimeric aluminium chloride.

_____ [2]

[Turn over

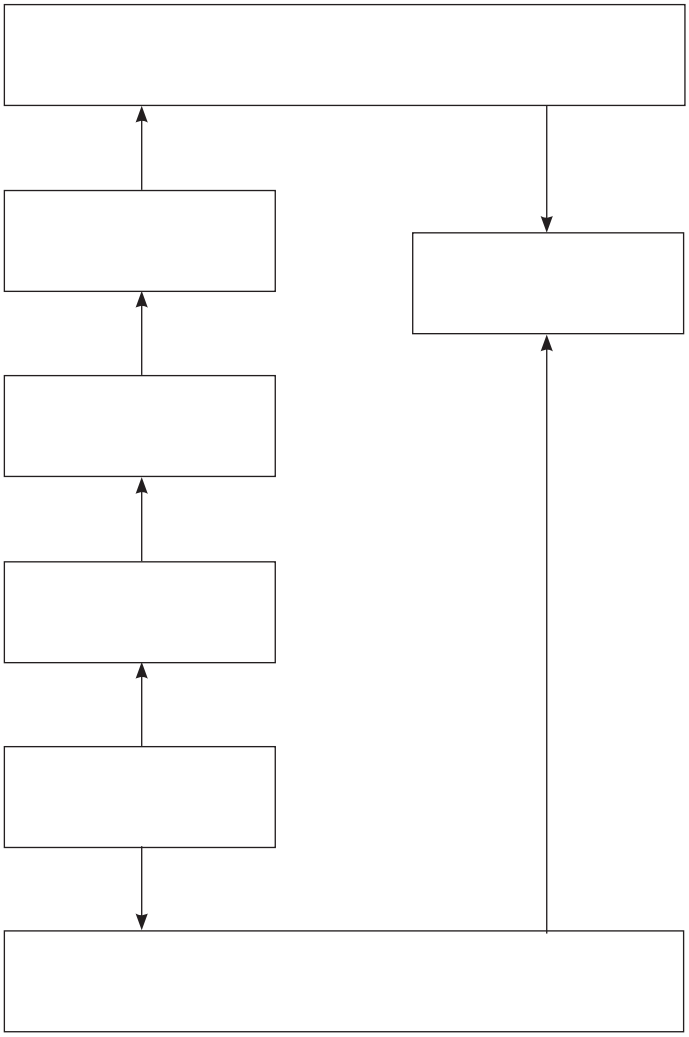
15 The ionic solid, magnesium chloride, has been identified as a possible substance for storing hydrogen. Ammonia is absorbed by magnesium chloride. This ammonia, once released, is decomposed to form hydrogen.

(a) (i) Write the equation for the decomposition of ammonia.

_____ [1]

(ii) Use the following information to complete the Born–Haber cycle for magnesium chloride. Write the enthalpy values given on to the diagram.

atomisation energy of magnesium	149 kJ mol^{-1}
first ionisation energy of magnesium	736 kJ mol^{-1}
second ionisation energy of magnesium	1450 kJ mol^{-1}
enthalpy of atomisation of chlorine	121 kJ mol^{-1}
first electron affinity of chlorine	–364 kJ mol^{-1}
enthalpy of formation of magnesium chloride	–642 kJ mol^{-1}
lattice enthalpy of magnesium chloride	x kJ mol^{-1}



[4]

(iii) Calculate the lattice enthalpy, x, of magnesium chloride.

_____

_____ [1]

[Turn over

(b) When fossil fuels are burnt they release carbon dioxide, a greenhouse gas, into the atmosphere.

(i) State **two** factors that determine the impact of a gas upon the greenhouse effect.

[2]

(ii) State **two** strategies which are used to reduce and manage the atmospheric concentration of carbon dioxide.

[2]

(c) The storage of hydrogen is becoming increasingly important as hydrogen is investigated as an alternative fuel. The formula of the compound produced when magnesium chloride absorbs ammonia is $Mg(NH_3)_6Cl_2$. Calculate the mass of hydrogen that could be obtained from 100 tonnes of the compound (1 tonne = 1000 kg).

[3]

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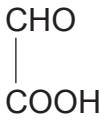
16 Glyoxylic acid, CHOCOOH, is a colourless solid with a melting point of 80 °C and a boiling point of 111 °C. It is a bifunctional molecule.



glyoxylic acid

(a) Suggest the meaning of the term **bifunctional** with reference to glyoxylic acid.

_____

_____ [2]

(b) Glyoxylic acid reacts with 2,4-dinitrophenylhydrazine. Outline, giving experimental details, how the 2,4-dinitrophenylhydrazone derivative can be obtained and the glyoxylic acid identified.

_____

_____

_____

_____

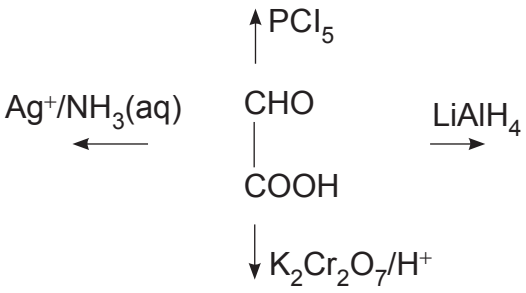
_____

_____

_____ [4]

Quality of written communication [2]

(c) Complete the following flow scheme, drawing the organic product from each reaction.



[5]

(d) Glyoxylic acid reacts with ethanol to form ethyl glyoxylate. Suggest and explain how the boiling point of glyoxylic acid would differ from that of ethyl glyoxylate.

_____

_____

_____ [3]

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For Examiner's use only	
Question Number	**Marks**
Section A	
1–10	
Section B	
11	
12	
13	
14	
15	
16	
Total Marks	

Examiner Number

Rewarding Learning

Periodic Table of the Elements

For the use of candidates taking
Advanced Subsidiary and Advanced Level
Chemistry 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 (advanced)

THE PERIODIC TABLE OF ELEMENTS

I	II										III	IV	V	VI	VII	0

Group

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

99 **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

One mole of any gas at 20 °C and a pressure of 1 atmosphere (10^5 Pa) occupies a volume of 24 dm^3.

Planck Constant = 6.63×10^{-34} Js

Gas Constant = 8.31 J mol^{-1} K^{-1}

Avogadro Constant = 6.02×10^{23} mol^{-1}

140 **Ce** Cerium 58	141 **Pr** Praseodymium 59	144 **Nd** Neodymium 60	147 **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
b x

a = relative atomic mass (approx.)

x = atomic symbol

b = atomic number