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**General Certificate of Education**  
**2018**

Centre Number

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Candidate Number

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# 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.

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## 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,  $RBr + OH^- \rightarrow ROH + Br^-$ , 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  $2602 \text{ kJ mol}^{-1}$  and an enthalpy of solution of  $-60 \text{ kJ mol}^{-1}$ . If the enthalpy of hydration for  $\text{Ca}^{2+}$  ions is  $-1650 \text{ kJ mol}^{-1}$  which one of the following is the enthalpy of hydration for  $\text{F}^{-}$  ions?

- A  $-253 \text{ kJ mol}^{-1}$
- B  $-506 \text{ kJ mol}^{-1}$
- C  $-1012 \text{ kJ mol}^{-1}$
- D  $-2156 \text{ kJ mol}^{-1}$

4 Which one of the following is the pH of a  $100 \text{ cm}^3$  solution containing  $0.10 \text{ g}$  of the strong acid, benzenesulfonic acid,  $\text{C}_6\text{H}_5\text{SO}_3\text{H}$ ?

- A 0.20
- B 1.20
- C 2.20
- D 3.20

5 Carbon monoxide reacts with hydrogen to form methanol.



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

- A  $\text{kPa}^2$
- B  $\text{k}^2\text{Pa}^2$
- C  $\text{kPa}^{-2}$
- D  $\text{k}^{-2}\text{Pa}^{-2}$

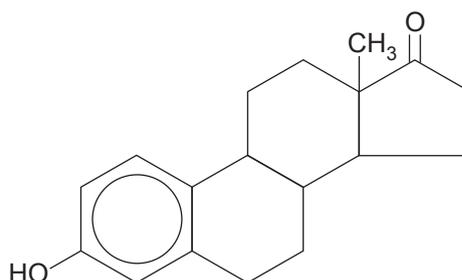
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6 How many chiral centres are there in oestrone?



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  $\text{CH}_3(\text{CH}_2)_{24}\text{COOH}$ ?
- A 32.6
- B 97.8
- C 45.7
- D 137.0



- 8 A 1.6 g sample of an oil was treated with Wijk's solution and excess potassium iodide solution. The liberated iodine reacted with  $8.4 \text{ cm}^3$  of  $0.1 \text{ mol dm}^{-3}$  sodium thiosulfate solution. The blank titration required  $41.2 \text{ cm}^3$  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  $100 \text{ cm}^3$  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  $\text{CH}_3\text{CH}_2\text{COOH}$   
B  $\text{CH}_3\text{CH}_2\text{COONa}$   
C  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$   
D  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COONa}$

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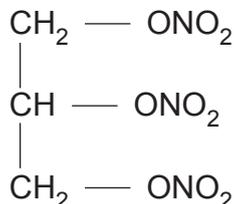


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## Section B

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,  $\text{NO}_2^+$ . 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  $20^\circ\text{C}$  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 <sup>-3</sup>	[H <sub>2</sub> ] / mol dm <sup>-3</sup>	initial rate / mol dm <sup>-3</sup> s <sup>-1</sup>
1	0.10	0.20	2.46 × 10 <sup>-3</sup>
2	0.30	0.40	4.43 × 10 <sup>-2</sup>
3	0.60	0.40	1.77 × 10 <sup>-1</sup>

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

\_\_\_\_\_ [1]

(ii) Calculate the order of the reaction with respect to H<sub>2</sub>.

\_\_\_\_\_ [1]



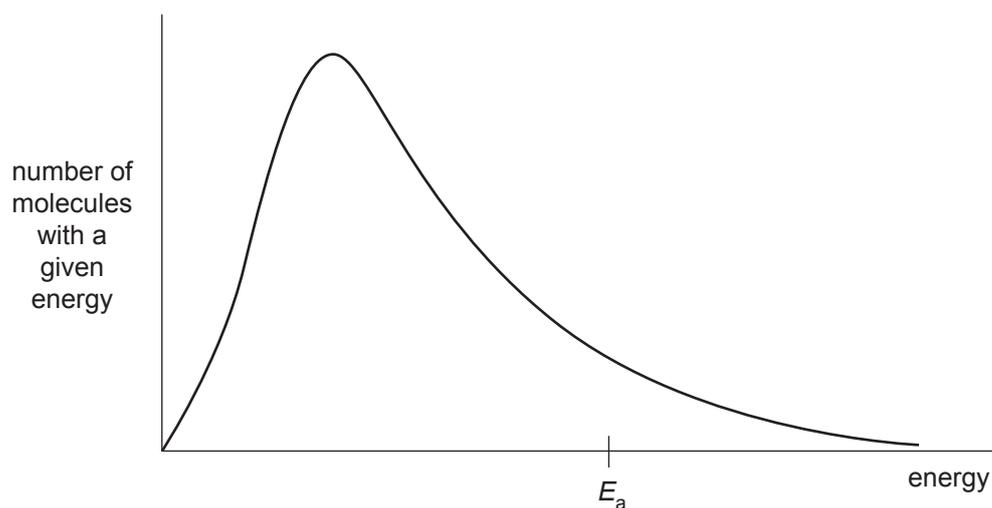
(iii) Write the rate equation for this reaction.

\_\_\_\_\_ [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]

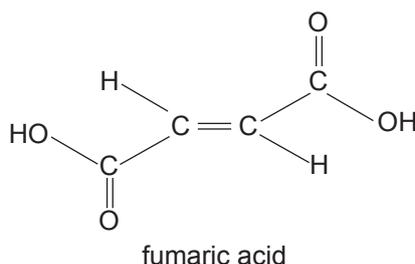
(ii) Explain why the graph never touches the x-axis at higher energies.

\_\_\_\_\_ [1]

[Turn over



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



(a) Suggest a systematic name for fumaric acid.

\_\_\_\_\_ [2]

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

(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  $0.05 \text{ mol dm}^{-3}$  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]

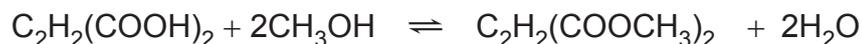
- (iii) Buffers can also be made with monoprotic acids such as ethanoic acid. Calculate the pH of the buffer formed when  $900 \text{ cm}^3$  of  $0.1 \text{ mol dm}^{-3}$  ethanoic acid is reacted with  $1.6 \text{ g}$  of sodium hydroxide. The acid dissociation value for ethanoic acid is  $1.8 \times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

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ [3]

[Turn over



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



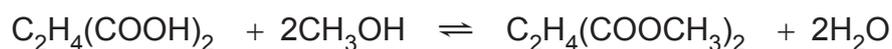
- (i) Explain the effect upon the yield of dimethyl fumarate by adding more methanol.

\_\_\_\_\_ [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:



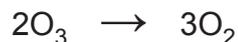
Write the equation for the equilibrium constant.

[2]





- 13 Ozone, O<sub>3</sub>, which is present in the upper atmosphere, can decompose to form oxygen gas in a reaction which is catalysed by chlorine radicals.



molecule	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$
O <sub>2</sub>	0.0	205
O <sub>3</sub>	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]





(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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**[Turn over**



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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.

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[2]

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

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[3]



(b) Aluminium chloride has found many uses both as a catalyst, and in its hydrated form  $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$ , 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.

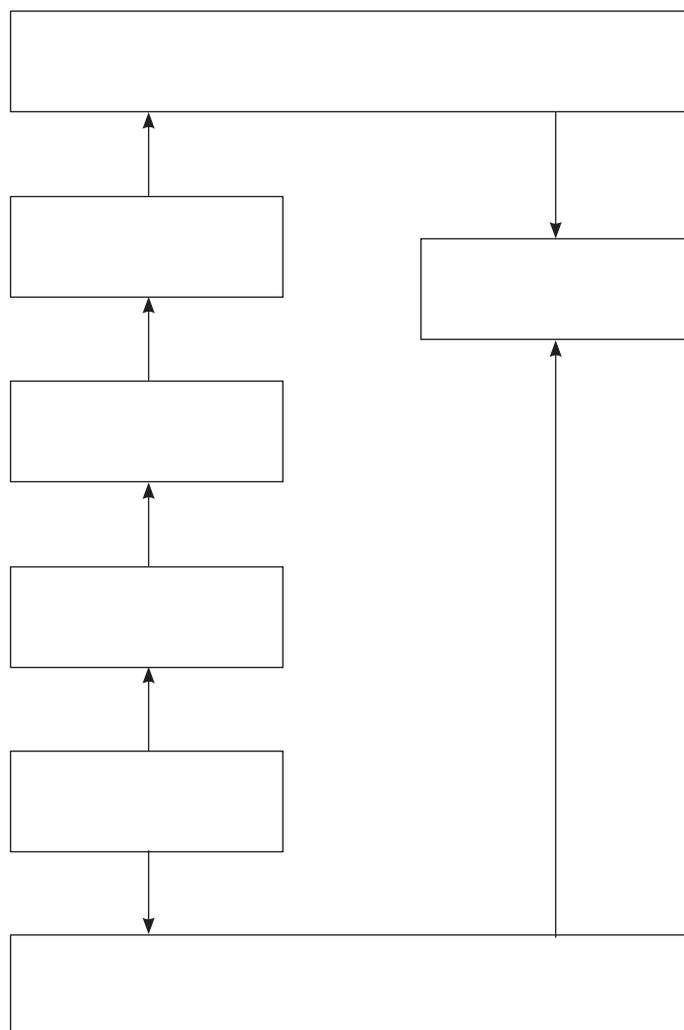
(a) (i) Write the equation for the decomposition of ammonia.

\_\_\_\_\_ [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 <sup>-1</sup>
first ionisation energy of magnesium	736 kJ mol <sup>-1</sup>
second ionisation energy of magnesium	1450 kJ mol <sup>-1</sup>
enthalpy of atomisation of chlorine	121 kJ mol <sup>-1</sup>
first electron affinity of chlorine	-364 kJ mol <sup>-1</sup>
enthalpy of formation of magnesium chloride	-642 kJ mol <sup>-1</sup>
lattice enthalpy of magnesium chloride	x kJ mol <sup>-1</sup>





[4]

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

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[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  $\text{Mg}(\text{NH}_3)_6\text{Cl}_2$ . Calculate the mass of hydrogen that could be obtained from 100 tonnes of the compound (1 tonne = 1000 kg).

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ [3]





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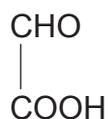
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**[Turn over**



\*28AC21223\*

- 16 Glyoxylic acid,  $\text{CHOCOOH}$ , is a colourless solid with a melting point of  $80^\circ\text{C}$  and a boiling point of  $111^\circ\text{C}$ . It is a bifunctional molecule.



glyoxylic acid

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

\_\_\_\_\_ [2]

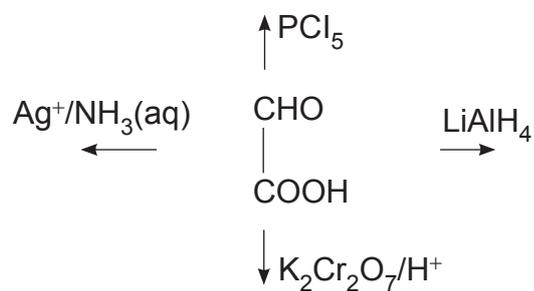
- (b) Glyoxylic acid reacts with 2,4-dinitrophenylhydrazine. Outline, giving experimental details, how the 2,4-dinitrophenylhydrazone derivative can be obtained and the glyoxylic acid identified.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ [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.

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[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	
<b>Total Marks</b>	

Examiner Number

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237487



## **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)**

I	II	THE PERIODIC TABLE OF ELEMENTS Group										III	IV	V	VI	VII	0						
1 <b>H</b> Hydrogen 1	One mole of any gas at 20°C and a pressure of 1 atmosphere (10 <sup>5</sup> Pa) occupies a volume of 24 dm <sup>3</sup> . Planck Constant = 6.63 × 10 <sup>-34</sup> Js Gas Constant = 8.31 J mol <sup>-1</sup> K <sup>-1</sup> Avogadro Constant = 6.02 × 10 <sup>23</sup> mol <sup>-1</sup>																4 <b>He</b> Helium 2						
7 <b>Li</b> Lithium 3											9 <b>Be</b> Beryllium 4							11 <b>B</b> Boron 5	12 <b>C</b> Carbon 6	14 <b>N</b> Nitrogen 7	16 <b>O</b> Oxygen 8	19 <b>F</b> Fluorine 9	20 <b>Ne</b> Neon 10
23 <b>Na</b> Sodium 11											24 <b>Mg</b> Magnesium 12							27 <b>Al</b> Aluminium 13	28 <b>Si</b> Silicon 14	31 <b>P</b> Phosphorus 15	32 <b>S</b> Sulfur 16	35.5 <b>Cl</b> Chlorine 17	40 <b>Ar</b> Argon 18
39 <b>K</b> Potassium 19	40 <b>Ca</b> Calcium 20	45 <b>Sc</b> Scandium 21	48 <b>Ti</b> Titanium 22	51 <b>V</b> Vanadium 23	52 <b>Cr</b> Chromium 24	55 <b>Mn</b> Manganese 25	56 <b>Fe</b> Iron 26	59 <b>Co</b> Cobalt 27	59 <b>Ni</b> Nickel 28	64 <b>Cu</b> Copper 29	65 <b>Zn</b> Zinc 30	70 <b>Ga</b> Gallium 31	73 <b>Ge</b> Germanium 32	75 <b>As</b> Arsenic 33	79 <b>Se</b> Selenium 34	80 <b>Br</b> Bromine 35	84 <b>Kr</b> Krypton 36						
85 <b>Rb</b> Rubidium 37	88 <b>Sr</b> Strontium 38	89 <b>Y</b> Yttrium 39	91 <b>Zr</b> Zirconium 40	93 <b>Nb</b> Niobium 41	96 <b>Mo</b> Molybdenum 42	99 <b>Tc</b> Technetium 43	101 <b>Ru</b> Ruthenium 44	103 <b>Rh</b> Rhodium 45	106 <b>Pd</b> Palladium 46	108 <b>Ag</b> Silver 47	112 <b>Cd</b> Cadmium 48	115 <b>In</b> Indium 49	119 <b>Sn</b> Tin 50	122 <b>Sb</b> Antimony 51	128 <b>Te</b> Tellurium 52	127 <b>I</b> Iodine 53	131 <b>Xe</b> Xenon 54						
133 <b>Cs</b> Caesium 55	137 <b>Ba</b> Barium 56	139 <b>La</b> * Lanthanum 57	178 <b>Hf</b> Hafnium 72	181 <b>Ta</b> Tantalum 73	184 <b>W</b> Tungsten 74	186 <b>Re</b> Rhenium 75	190 <b>Os</b> Osmium 76	192 <b>Ir</b> Iridium 77	195 <b>Pt</b> Platinum 78	197 <b>Au</b> Gold 79	201 <b>Hg</b> Mercury 80	204 <b>Tl</b> Thallium 81	207 <b>Pb</b> Lead 82	209 <b>Bi</b> Bismuth 83	210 <b>Po</b> Polonium 84	210 <b>At</b> Astatine 85	222 <b>Rn</b> Radon 86						
223 <b>Fr</b> Francium 87	226 <b>Ra</b> Radium 88	227 <b>Ac</b> † Actinium 89																					

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

$\begin{matrix} a \\ b \end{matrix} x$  a = relative atomic mass (approx.)  
x = atomic symbol  
b = atomic number

140 <b>Ce</b> Cerium 58	141 <b>Pr</b> Praseodymium 59	144 <b>Nd</b> Neodymium 60	147 <b>Pm</b> Promethium 61	150 <b>Sm</b> Samarium 62	152 <b>Eu</b> Europium 63	157 <b>Gd</b> Gadolinium 64	159 <b>Tb</b> Terbium 65	162 <b>Dy</b> Dysprosium 66	165 <b>Ho</b> Holmium 67	167 <b>Er</b> Erbium 68	169 <b>Tm</b> Thulium 69	173 <b>Yb</b> Ytterbium 70	175 <b>Lu</b> Lutetium 71
232 <b>Th</b> Thorium 90	231 <b>Pa</b> Protactinium 91	238 <b>U</b> Uranium 92	237 <b>Np</b> Neptunium 93	242 <b>Pu</b> Plutonium 94	243 <b>Am</b> Americium 95	247 <b>Cm</b> Curium 96	245 <b>Bk</b> Berkelium 97	251 <b>Cf</b> Californium 98	254 <b>Es</b> Einsteinium 99	253 <b>Fm</b> Fermium 100	256 <b>Md</b> Mendelevium 101	254 <b>No</b> Nobelium 102	257 <b>Lr</b> Lawrencium 103