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General Certificate of Secondary Education  
2024

Centre Number

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Candidate Number

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# GCSE Chemistry

Unit 2

Higher Tier



[GCM22]

\*GCM22\*

FRIDAY 14 JUNE, 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.

**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.**

Answer **all six** questions.

## INFORMATION FOR CANDIDATES

The total mark for this paper is 100.

Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

Quality of written communication will be assessed in Question **2(c)**.

A Data Leaflet, which includes a Periodic Table of the Elements, is included in this question paper.

13964



\*24GCM2201\*

1 The reactions of metals with oxygen in air, with water and with steam differ based on the reactivity of the metal.

(a) Information on the reactions of three metals when heated in air is given below.

Metal 1: Grey solid burns with orange sparks forming a black solid

Metal 2: Red-brown solid glows red when heated and changes to a black solid

Metal 3: Grey solid burns with a brick red flame forming a white solid

(i) Identify the metals.

Metal 1: \_\_\_\_\_

Metal 2: \_\_\_\_\_

Metal 3: \_\_\_\_\_ [3]

(ii) Based on your answer to (a)(i), write a balanced symbol equation for the reaction of Metal 3 when heated in air.

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

(b) Aluminium metal reacts with steam when heated. The word equation for this reaction is given below.

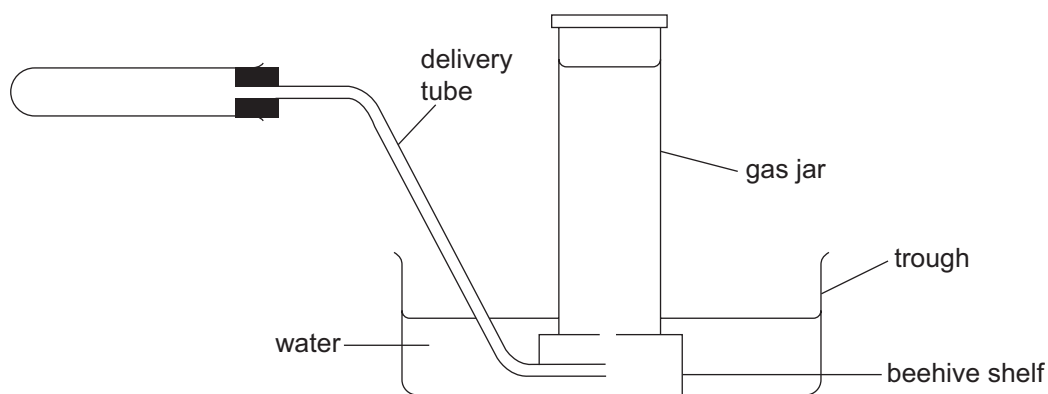
aluminium + steam → aluminium oxide + hydrogen

(i) Write a balanced symbol equation for this reaction. Include state symbols.

\_\_\_\_\_ [4]



- (ii) The apparatus below was used to react aluminium with steam. A small amount of hydrogen was produced.



Show the position of the following on the diagram using the letter indicated in the table below.

Letter label	Apparatus/chemicals
<b>A</b>	damp mineral wool
<b>B</b>	aluminium
<b>C</b>	hydrogen

[3]

- (iii) Explain, in terms of oxygen content, why the reaction of aluminium with steam is described as a redox reaction.

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[5]

[Turn over



- (c) Based on your knowledge of the reactivity of metals, predict which of the following reactions would occur. Place a tick (✓) in the right-hand box for any reactions which would occur.

aluminium + zinc sulfate solution

copper + steam

zinc + sodium chloride solution

magnesium + steam

[1]

- (d) The following two half equations represent the processes which occur during a chemical reaction between magnesium and copper(II) ions in solution.

Half equation 1:  $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^{-}$

Half equation 2:  $\text{Cu}^{2+} + 2\text{e}^{-} \rightarrow \text{Cu}$

- (i) Which half equation represents an oxidation reaction? Explain your answer.

\_\_\_\_\_

\_\_\_\_\_

[1]

- (ii) State the colour change of the solution during this reaction.

From \_\_\_\_\_ to \_\_\_\_\_

[2]





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**(Questions continue overleaf)**

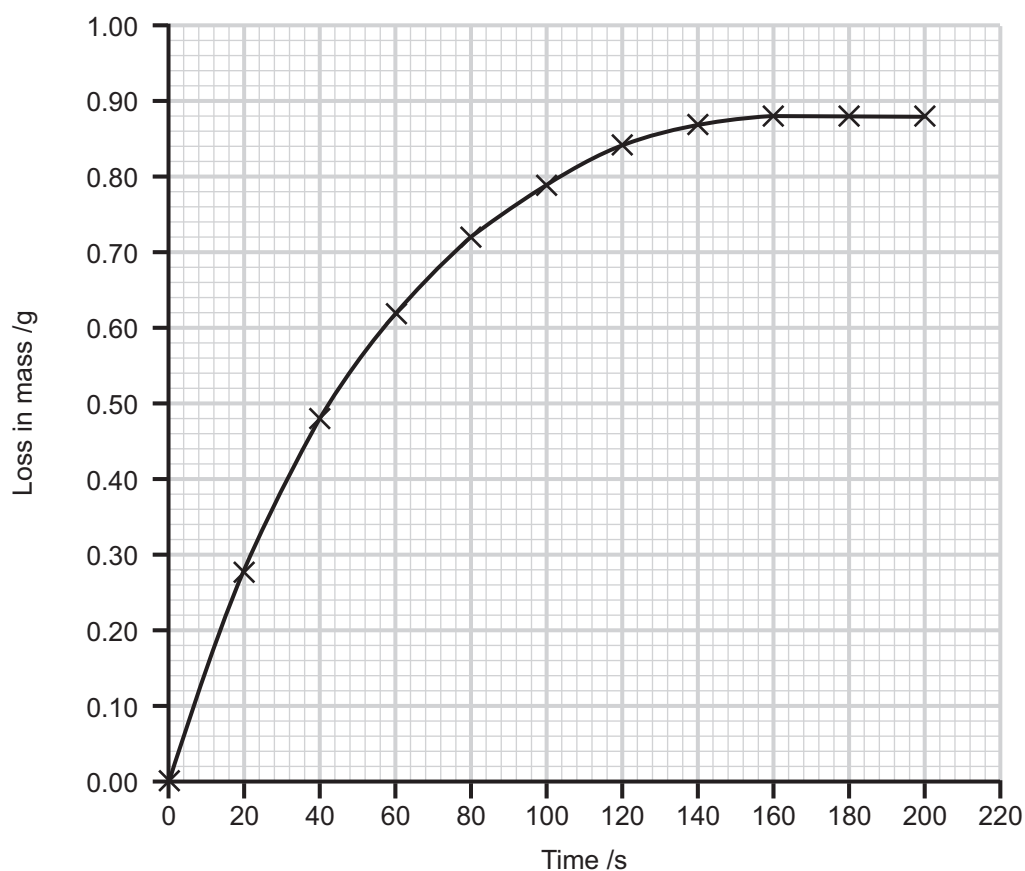
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**[Turn over**



**\*24GCM2205\***

- 2 In an experiment, 2.0 g of marble chips (calcium carbonate) and 25 cm<sup>3</sup> of 2.0 mol/dm<sup>3</sup> hydrochloric acid (an excess) were reacted in a conical flask at room temperature. The mass of the reaction mixture was recorded and, from the data obtained, a graph of loss in mass against time was drawn. The graph is shown below.



- (a) What was the total loss in mass?

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

- (b) At what time did the reaction finish?

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





(e) A student analysed the original graph and made the following conclusion:

**The rate of the reaction decreases as the reaction proceeds.**

(i) Explain how the graph supports the conclusion above.

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[1]

(ii) Explain, in terms of particles, why the rate of reaction decreases as the reaction proceeds.

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[3]



3 Organic compounds are classified into different homologous series. All the compounds in a homologous series have the same general formula. Some homologous series are hydrocarbons.

(a) (i) State one feature which is **similar** for all compounds of a homologous series.

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[1]

(ii) State one way in which successive members of a homologous series differ from each other.

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[1]

(iii) What is meant by the term hydrocarbon?

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[1]

[Turn over



(b) The table below shows some details of four organic compounds, **A**, **B**, **C** and **D**.

	Homologous series	Number of carbon atoms	Name	Structural formula	Molecular formula
<b>A</b>	Alkene			$\begin{array}{cccc} & \text{H} & \text{H} & \text{H} & \text{H} \\ &   &   &   &   \\ \text{H} & - \text{C} & - \text{C} = & \text{C} & - \text{C} - \text{H} \\ &   & & &   \\ & \text{H} & & & \text{H} \end{array}$	
<b>B</b>		3	propan-2-ol		
<b>C</b>			butane	$\begin{array}{cccc} & \text{H} & \text{H} & \text{H} & \text{H} \\ &   &   &   &   \\ \text{H} & - \text{C} & - \text{C} & - \text{C} & - \text{C} - \text{H} \\ &   &   &   &   \\ & \text{H} & \text{H} & \text{H} & \text{H} \end{array}$	
<b>D</b>	Carboxylic acid	1			

(i) Complete the table. [8]

(ii) Which of the organic compounds in the table (**A**, **B**, **C**, **D**) would react with acidified potassium dichromate solution? State the colour change observed.

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





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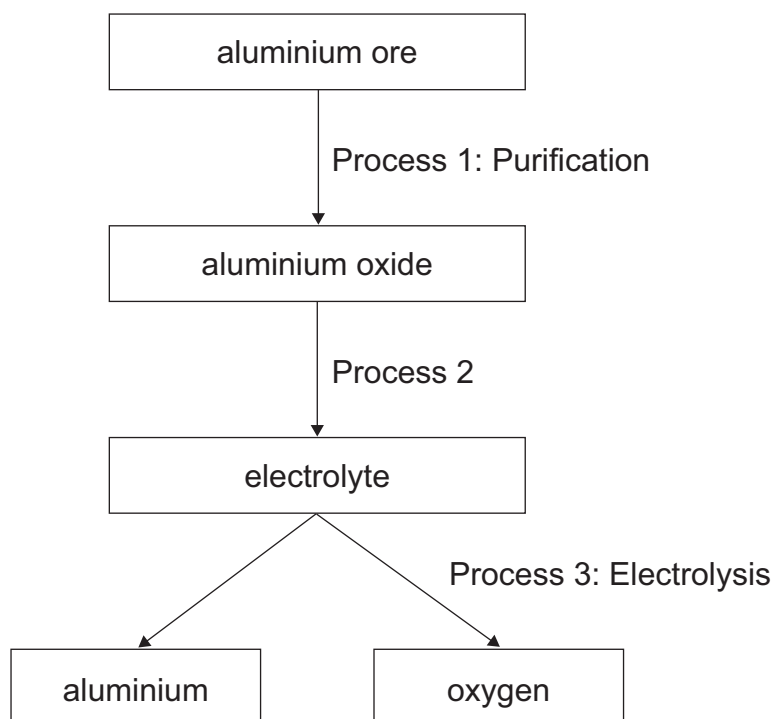


\*24GCM2212\*



4 Many useful materials, such as aluminium, iron and plastics, are produced from the Earth's natural resources.

(a) The flow scheme below shows the main processes involved in the production of aluminium from its ore.



(i) Name the ore from which aluminium is extracted.

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

(ii) What name is used for the purified aluminium oxide formed in Process 1?

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

(iii) How is the electrolyte made in Process 2?

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

[Turn over



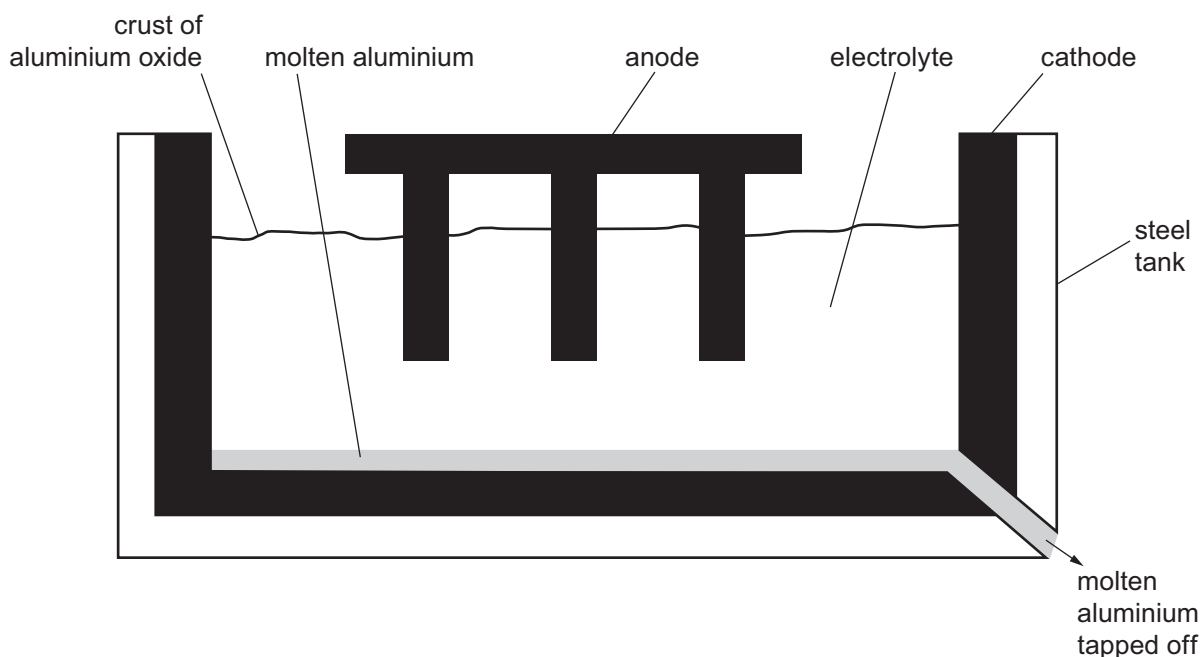
(iv) What is meant by the term electrolyte?

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[1]

(b) The diagram below shows the industrial apparatus used to extract aluminium from the electrolyte. Aluminium is produced at the cathode and oxygen gas is produced at the anode. The anode and cathode are made of graphite.



(i) State one function of the crust of aluminium oxide.

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[1]

(ii) What is the operating temperature of this process?

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[1]



(iii) State two reasons why the electrodes are made of graphite.

1. \_\_\_\_\_

\_\_\_\_\_

2. \_\_\_\_\_

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

(iv) Describe one problem which occurs due to the use of graphite for the electrodes.

\_\_\_\_\_

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

(v) Write half equations for the production of aluminium at the cathode and the production of oxygen at the anode.

Cathode: \_\_\_\_\_

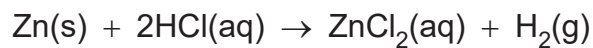
Anode: \_\_\_\_\_ [6]

[Turn over



- 5 (a) In an experiment, a sample of 0.325 g of **impure** zinc metal was reacted with 25.0 cm<sup>3</sup> of 2.0 mol/dm<sup>3</sup> hydrochloric acid in a conical flask. The volume of hydrogen gas produced was measured using a gas syringe.

The equation for the reaction is:



The total volume of hydrogen gas collected was 90 cm<sup>3</sup>.

- (i) Draw a labelled diagram of the assembled apparatus used to carry out the experiment.

[4]

- (ii) Calculate the mass of zinc in the impure sample.

mass of zinc = \_\_\_\_\_ g [3]



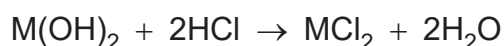
(iii) Calculate the percentage of zinc in the impure sample.

percentage = \_\_\_\_\_ % [1]



- (b) A sample of 3.72 g of an unknown metal hydroxide,  $M(OH)_2$ , was dissolved in  $250\text{ cm}^3$  of deionised water in a volumetric flask.  $25.0\text{ cm}^3$  samples of this solution were titrated against  $0.25\text{ mol/dm}^3$  hydrochloric acid using phenolphthalein indicator. The average titre was determined to be  $17.4\text{ cm}^3$ .

The equation for the reaction may be represented as:



- (i) State the colour change at the end point of this titration.

From \_\_\_\_\_ to \_\_\_\_\_ [2]

- (ii) Calculate the number of moles of hydrochloric acid used.

moles of hydrochloric acid = \_\_\_\_\_ [1]

- (iii) Calculate the number of moles of  $M(OH)_2$  present in  $25.0\text{ cm}^3$ .

moles of  $M(OH)_2$  = \_\_\_\_\_ [1]



(iv) Calculate the number of moles of  $M(OH)_2$  present in  $250\text{ cm}^3$ .

moles of  $M(OH)_2 =$  \_\_\_\_\_ [1]

(v) Using the initial mass of the unknown metal hydroxide and your answer to (b)(iv), calculate the relative formula mass ( $M_r$ ) of  $M(OH)_2$ .

relative formula mass ( $M_r$ ) = \_\_\_\_\_ [1]

(vi) Using your answer to (b)(v), calculate the relative atomic mass ( $A_r$ ) of M and determine its identity.

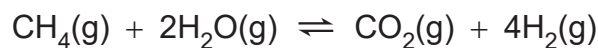
relative atomic mass ( $A_r$ ) = \_\_\_\_\_

identity of M = \_\_\_\_\_ [2]

[Turn over



- 6 (a) The reaction between methane and water vapour is a reversible reaction producing hydrogen. Carbon dioxide is a waste product.



The energy change of the reaction is +150 kJ.

- (i) State and explain how the yield of hydrogen would change as temperature increases.

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[3]

- (ii) Explain why the yield of hydrogen decreases as pressure increases.

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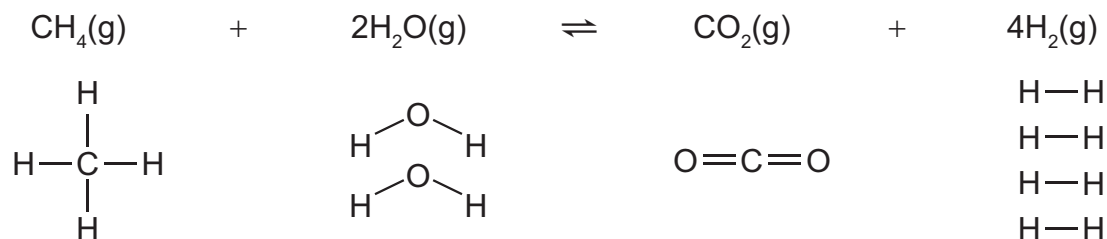
[2]

- (iii) Calculate the percentage atom economy of this reaction. Give your answer to 1 decimal place.  
Show your working out.

percentage atom economy = \_\_\_\_\_ % [3]



(b) The diagram below shows the molecules present in the reactants and products for the reaction in (a). The energy change of the reaction is +150 kJ.



The table below gives the bond energies of some of the covalent bonds present in the molecules in this reaction.

Bond	Bond energy /kJ
C—H	412
O—H	missing value
C=O	803
H—H	436

Using the values in the table and the energy change of the reaction, calculate the O—H bond energy.

O—H bond energy = \_\_\_\_\_ kJ [4]



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**THIS IS THE END OF THE QUESTION PAPER**

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<b>For Examiner's use only</b>	
<b>Question Number</b>	<b>Marks</b>
1	
2	
3	
4	
5	
6	

<b>Total Marks</b>	
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**Examiner Number**

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## SYMBOLS OF SELECTED IONS

### Positive ions

Name	Symbol
Ammonium	$\text{NH}_4^+$
Chromium(III)	$\text{Cr}^{3+}$
Copper(II)	$\text{Cu}^{2+}$
Iron(II)	$\text{Fe}^{2+}$
Iron(III)	$\text{Fe}^{3+}$
Lead(II)	$\text{Pb}^{2+}$
Silver	$\text{Ag}^+$
Zinc	$\text{Zn}^{2+}$

### Negative ions

Name	Symbol
Butanoate	$\text{C}_3\text{H}_7\text{COO}^-$
Carbonate	$\text{CO}_3^{2-}$
Dichromate	$\text{Cr}_2\text{O}_7^{2-}$
Ethanoate	$\text{CH}_3\text{COO}^-$
Hydrogencarbonate	$\text{HCO}_3^-$
Hydroxide	$\text{OH}^-$
Methanoate	$\text{HCOO}^-$
Nitrate	$\text{NO}_3^-$
Propanoate	$\text{C}_2\text{H}_5\text{COO}^-$
Sulfate	$\text{SO}_4^{2-}$
Sulfite	$\text{SO}_3^{2-}$



## Data Leaflet

### Including the Periodic Table of the Elements

For the use of candidates taking  
 Science: Chemistry,  
 Science: Double Award  
 or Science: Single Award

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

### SOLUBILITY IN COLD WATER OF COMMON SALTS, HYDROXIDES AND OXIDES

Soluble
All sodium, potassium and ammonium salts
All nitrates
Most chlorides, bromides and iodides EXCEPT silver and lead chlorides, bromides and iodides
Most sulfates EXCEPT lead and barium sulfates Calcium sulfate is slightly soluble
Insoluble
Most carbonates EXCEPT sodium, potassium and ammonium carbonates
Most hydroxides EXCEPT sodium, potassium and ammonium hydroxides
Most oxides EXCEPT sodium, potassium and calcium oxides which react with water

# gcse examinations chemistry

# THE PERIODIC TABLE OF ELEMENTS

## Group

												1 <b>H</b> Hydrogen 1						4 <b>He</b> Helium 2	
		1	2											3	4	5	6	7	0
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	98 <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> <sup>*</sup> 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> <sup>†</sup> Actinium 89	261 <b>Rf</b> Rutherfordium 104	262 <b>Db</b> Dubnium 105	266 <b>Sg</b> Seaborgium 106	264 <b>Bh</b> Bohrium 107	277 <b>Hs</b> Hassium 108	268 <b>Mt</b> Meitnerium 109	271 <b>Ds</b> Darmstadtium 110	272 <b>Rg</b> Roentgenium 111	285 <b>Cn</b> Copernicium 112								

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

$\begin{matrix} a \\ \boxed{X} \\ b \end{matrix}$  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	145 <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