

Collins

Cambridge IGCSE™

Combined Science

STUDENT'S BOOK

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In this section you will extend the work you did in Section 2, Atoms, elements and compounds, and focus in detail on the structure of the Periodic Table and the characteristic properties of particular groups of elements. If you look at the Periodic Table in the back of this book (page 688), you will see that it includes 118 elements. The good news is that you will not have to study the properties of all these elements! Because of the way elements have been arranged in the Periodic Table, learning about one element often provides a very good idea about how other elements may behave. You will study in some detail a group of metals and a group of non-metals, followed by elements known as ‘transition elements’ and a group known as the noble gases.

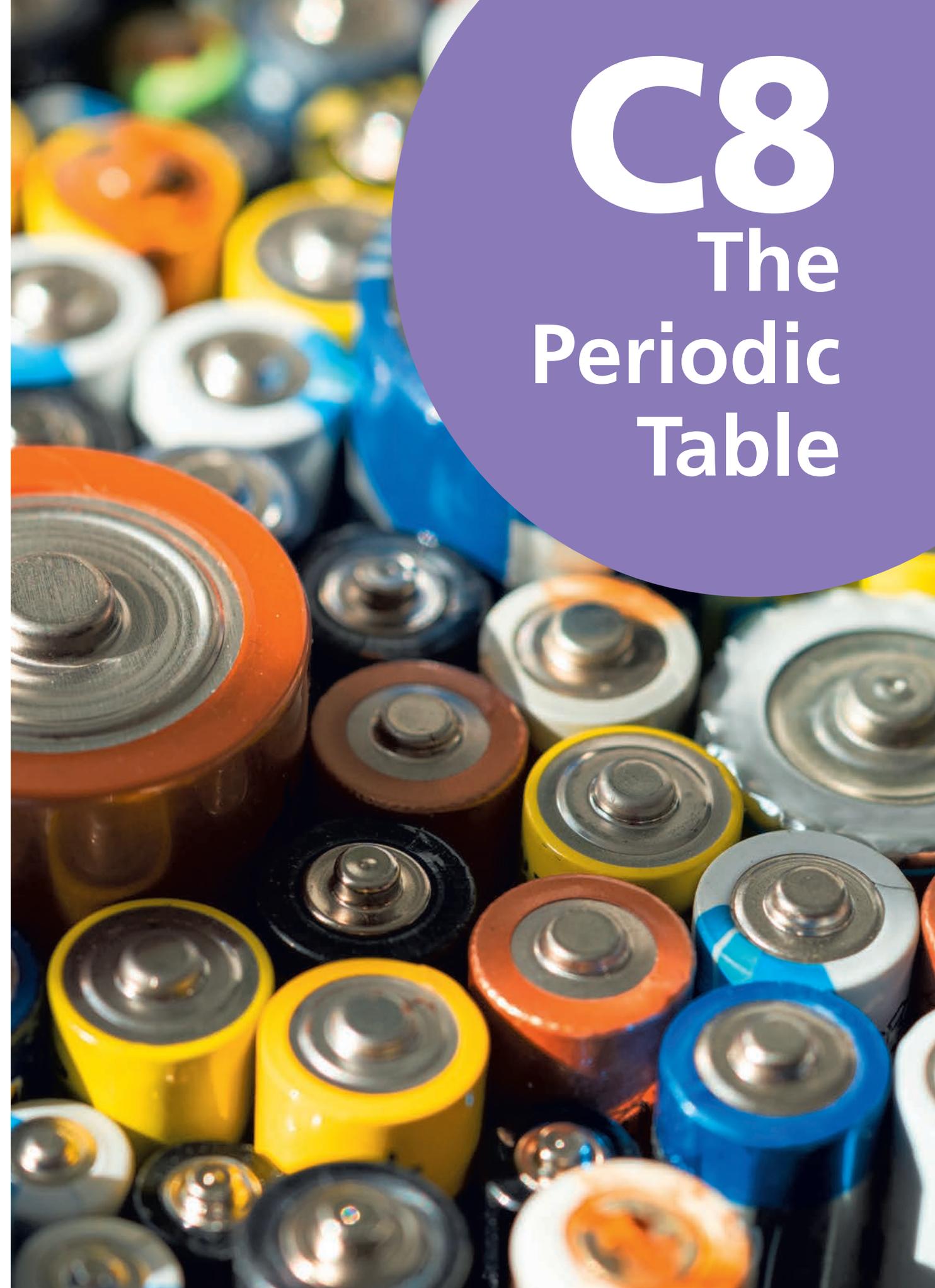
STARTING POINTS

1. What is an element – how would you define the term?
2. What does the proton number of an atom tell you about its structure?
3. In terms of electronic configuration what is the main difference between a metal and a non-metal?
4. Helium is a common noble gas. Do you know a use of helium?

SYLLABUS SECTIONS COVERED

- C8.1** Arrangement of elements
- C8.2** Group I properties
- C8.3** Group VII properties
- C8.4** Transition elements
- C8.5** Noble gases

▷ Many batteries contain lithium, which is a Group I metal.



C8

The
Periodic
Table



△ Fig. C8.1 This ordering of elements was first published in 1871 by the Russian chemist Dmitri Mendeleev.

Arrangement of elements

INTRODUCTION

With over 100 different elements in existence, it is very important to have some way of ordering them. The Periodic Table puts elements with similar properties into columns, with a gradual change in properties moving from left to right along the rows. This topic looks at some of the basic features of the Periodic Table. Later topics will look in more detail at particular groups and arrangements of the elements.

KNOWLEDGE CHECK

- ✓ All matter is made up of elements.
- ✓ The proton number of an element gives the number of protons (and the number of electrons) in an atom of the element.
- ✓ Electrons are arranged in shells around the nucleus of the atom.

LEARNING OBJECTIVES

- ✓ Describe the Periodic Table as an arrangement of elements in periods and groups and in order of increasing proton number / atomic number.
- ✓ Describe the change from metallic to non-metallic character across a period.
- ✓ **SUPPLEMENT** Identify trends in groups, given information about the elements.

ARRANGEMENT OF ELEMENTS IN THE PERIODIC TABLE

An **element** is a substance that cannot be broken down into other substances by chemical means. As new elements were discovered in the 19th century, chemists tried to organise them into patterns based on the similarities in their properties. John Newlands classified elements according to their properties and Dmitri Mendeleev produced the classification system which is considered to be the basis of the modern Periodic Table. When the structure of the atom was better known, elements were arranged in order of increasing proton number, and then the patterns started to make more sense. (Proton/ atomic number is the number of protons in an atom.)

How are elements classified in the modern Periodic Table?

More than 110 elements have now been identified, and each has its own properties and reactions. In the **Periodic Table**, elements with similar properties and reactions are shown close together.

The modern **Periodic Table** arranges the elements in order of increasing proton number. They are then arranged in periods and groups so that elements with similar properties and reactions are shown close together. The complete Periodic Table on page 688 lists all the known elements. The simplified Periodic Table in Fig C8.2 shows the first 86 elements and the main groups and their names. The number below each element is the atomic number (**proton number**).

Groups	I	II	transition metals										III	IV	V	VI	VII	VIII		
Periods																				
1																	1 H hydrogen			2 He helium
2	3 Li lithium	4 Be beryllium											5 B boron	6 C carbon	7 N nitrogen	8 O oxygen	9 F fluorine	10 Ne neon		
3	11 Na sodium	12 Mg magnesium											13 Al aluminium	14 Si silicon	15 P phosphorus	16 S sulfur	17 Cl chlorine	18 Ar argon		
4	19 K potassium	20 Ca calcium	21 Sc scandium	22 Ti titanium	23 V vanadium	24 Cr chromium	25 Mn manganese	26 Fe iron	27 Co cobalt	28 Ni nickel	29 Cu copper	30 Zn zinc	31 Ga gallium	32 Ge germanium	33 As arsenic	34 Se selenium	35 Br bromine	36 Kr krypton		
5	37 Rb rubidium	38 Sr strontium	39 Y yttrium	40 Zr zirconium	41 Nb niobium	42 Mo molybdenum	43 Tc technetium	44 Ru ruthenium	45 Rh rhodium	46 Pd palladium	47 Ag silver	48 Cd cadmium	49 In indium	50 Sn tin	51 Sb antimony	52 Te tellurium	53 I iodine	54 Xe xenon		
6	55 Cs caesium	56 Ba barium	57-71 La lanthanides	72 Hf hafnium	73 Ta tantalum	74 W tungsten	75 Re rhenium	76 Os osmium	77 Ir iridium	78 Pt platinum	79 Au gold	80 Hg mercury	81 Tl thallium	82 Pb lead	83 Bi bismuth	84 Po polonium	85 At astatine	86 Rn radon		

metal	non metal	transition metal	metalloid
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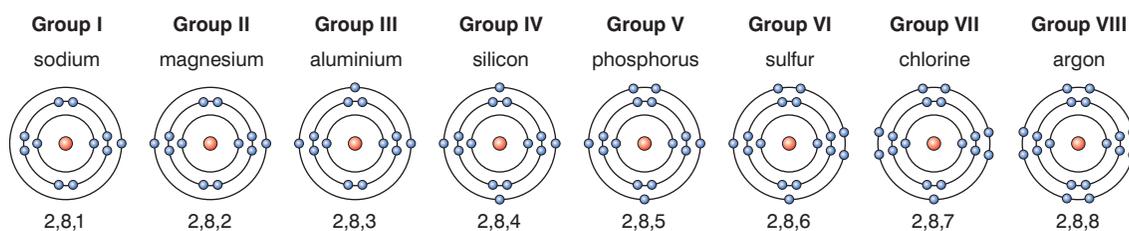
Δ Fig. C8.2 The Periodic Table.

Periods

Horizontal rows of elements are arranged in increasing proton number from left to right. Rows correspond to **periods**, which are numbered from 1 to 7.

Moving across a period, each successive atom of the elements gains one proton and one electron (in the same outer shell).

In Fig. C8.3 you can see how the number of electrons in the outer shell increases across a period, for the elements in Period 3.



Δ Fig. C8.3 Moving across a period shows the electronic configuration of each element.

Moving across a period like Period 3 (sodium to argon), the following trends take place:

- Metals on the left going to non-metals on the right.
- Group I elements are the most reactive metal group, and as you go to the right the reactivity of the groups decreases. Group IV elements are the least reactive.
- Continuing right from Group IV, the reactivity increases until Group VII, the most reactive of the non-metal groups.

Groups

Vertical columns contain elements with the proton number increasing down the column – they are called **groups**. They are numbered from I to VIII (Group VIII is sometimes referred to as Group 0).

Groups are referred to as ‘families’ of elements because they have similar characteristics, just like families – the alkali metals (Group I), the alkaline earth metals (Group II) and the halogens (Group VII).

Elements in the same group do not have identical physical and chemical properties. For example, within a group there will be a trend (a gradual change between elements as you move down the group) in physical properties, such as melting point and density, and a trend in chemical reactivity. These group characteristics will be covered in more detail in the topics on Group 1 and Group VII elements.

REMEMBER

It is important to understand the relationship between group number, number of outer electrons, and metallic and non-metallic character across periods.

QUESTIONS

1. Find the element calcium in the Periodic Table. Answer these questions about calcium:
 - a) What is its proton number?
 - b) Describe what information the proton number gives about the structure of a calcium atom.
 - c) Which group of the Periodic Table is calcium in?
 - d) Which period of the Periodic Table is calcium in?
 - e) Is calcium a metal or a non-metal?
2. What is the family name for the Group VII elements?
3. Are the Group VII elements metals or non-metals?
4. **SUPPLEMENT** The table provides information about the melting points and reactivity with cold water of three elements in Group 2.

element	melting point /°C	reactivity with cold water
calcium	842	reacts to form bubbles of gas
strontium	777	reacts rapidly to form bubbles of gas
barium	727	reacts very vigorously producing bubbles of gas

- a) What trend is there in the melting points of the three Group 2 elements?
- b) What trend is there in the reactivity with cold water of the three Group 2 elements?

Reactivities of elements

Going from the top to the bottom of a group in the Periodic Table, metals become more reactive, but non-metals become less reactive.

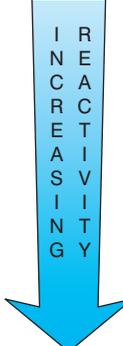
Group VIII elements, known as the noble gases, are very unreactive. They already have full outer electron shells and so rarely react with other elements to form compounds.

9 F fluorine
17 Cl chlorine
35 Br bromine
53 I iodine
85 At astatine



Δ Fig. C8.4 The Group VII elements (non-metals) become more reactive further up the group.

3 Li lithium
11 Na sodium
19 K potassium
37 Rb rubidium
55 Cs caesium



Δ Fig. C8.5 Group I elements (metals) become more reactive further down the group.

SCIENCE IN CONTEXT

THE FIRST PERIODIC TABLE

In 1871 the Russian chemist Dmitri Mendeleev published his work on the Periodic Table. It included the 66 elements that were known at the time. Interestingly, Mendeleev left gaps in his arrangement when the next element in his order did not seem to fit. He predicted that there should be elements in the gaps but that they had yet to be discovered. One such element is gallium (discovered in 1875), which Mendeleev predicted would be between aluminium and indium.

In 2022 there were 118 known elements, but only 98 of these occurred naturally – the remaining 24 have been made artificially. Some elements are radioactive – for example the element americium (Am, proton number 95), which is used in smoke detectors.

Challenge Question: The element americium can be represented as ${}_{95}^{243}\text{Am}$. Calculate how many protons, neutrons and electrons this atom has.

End of topic checklist

Key terms

element, group, period, Periodic Table, proton number (atomic number)

During your study of this topic you should have learned:

- How to describe the Periodic Table as a method of classifying elements into groups and periods.
- How to describe the change from metallic to non-metallic character across a period.
- SUPPLEMENT** How to identify trends in groups from information about the elements.

End of topic questions

1. Look at the diagram representing the simplified Periodic Table. The letters stand for elements.

	a																
													b				
					c											d	
e															f		

- a) State which element is in Group IV:
- A e
 - B c
 - C b
 - D d
- b) State which element is in the second period.
- c) State which element is a noble gas.
- d) State which element is a transition metal.
- e) State which elements are non-metals.
- f) State which element is most likely to be a gas.
2. Determine the electron configuration in the following atoms:
- a) sodium (proton number = 11)
 - b) silicon (proton number = 14)
 - c) fluorine (proton number = 9).
3. Describe how the metallic and non-metallic nature of the elements changes across Period 3 of the Periodic Table.
4. **SUPPLEMENT** In the Periodic Table, state what is the trend in reactivity:
- a) down a group of metals.
 - b) down a group of non-metals.