CAMBRIDGE
Cambridge University Press & Assessment
978-1-009-22964-7 — Cambridge Chemistry VCE Units 1&2
Brett Drummond , Simon Maaser , Lauren Angley , Scott Fraser , Rebecca Greaves , Trent Lucas , Zhen Wang
Excerpt
More Information

UNIT 1 HOW CAN THE DIVERSITY OF MATERIALS BE EXPLAINED?

CHAPTER 1 ELEMENTS AND THE PERIODIC TABLE

Introduction

INTRODUCTION VIDEO
ELEMENTS AND THE PERIODIC TABLE

You will already know from previous years of science that atoms are the building blocks of everything in our universe. As you will revisit in this chapter, atoms are composed of smaller particles called protons, neutrons and electrons, and you will recall the placement of these within atoms. This knowledge will then be extended to discuss how different numbers of these smaller particles in atoms may result in the formation of either isotopes or ions.

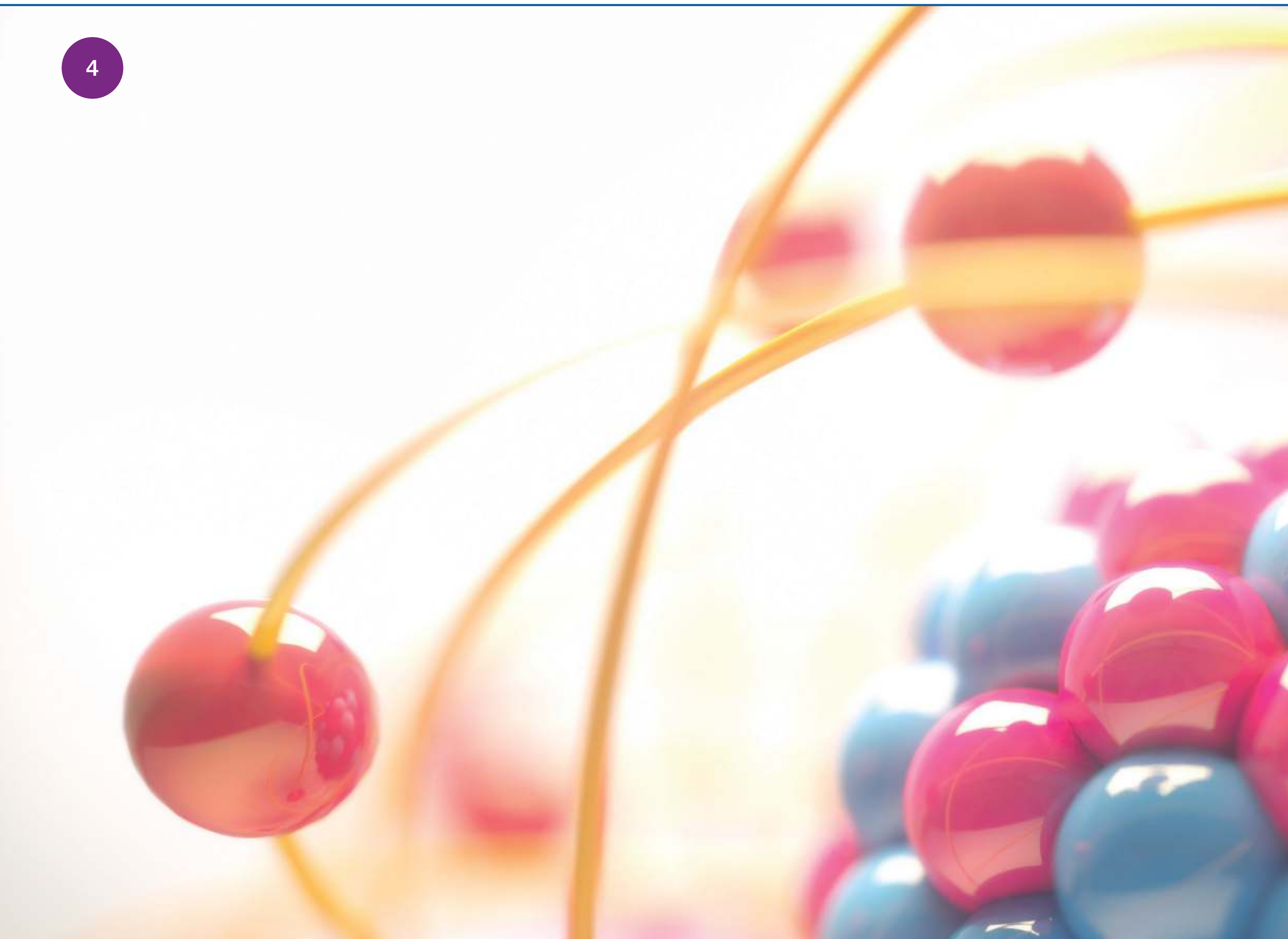
For elements, you will learn how to represent the numbers of these subatomic particles in atomic notation as well as their electron configurations in both shell and subshell notation. These electron configurations will then be used to look at how the periodic table is constructed and how scientists use this as a 'cheat sheet' for determining the properties of different elements and trends across different areas of the periodic table. The relationship between the properties of some critical elements and how they are recycled will also be investigated.

Curriculum

Area of Study 1 Outcome 1
Elements and the periodic table

Study Design:	Learning intentions – at the end of this chapter I will be able to:
• The definitions of elements, isotopes and ions, including appropriate notation: atomic number; mass number; and number of protons, neutrons and electrons	**1A Introduction to the elements** **1A.1** Recall what an element, isotope and ion are and how they are different **1A.2** Be able to write correct atomic notation for different elements, isotopes and ions **1A.3** Recall the difference between the atomic number and mass number of an element **1A.4** Determine the atomic number and/or mass number by looking at the atomic notation of an element **1A.5** Recall what an electron, proton and neutron are and the differences between them **1A.6** Determine the number of protons, neutrons and/or electrons for an element, isotope or ion from atomic notation

Study Design:	Learning intentions – at the end of this chapter I will be able to:
• The periodic table as an organisational tool to identify patterns and trends in, and relationships between, the structures (including shell and subshell electronic configurations and atomic radii) and properties (including electronegativity, first ionisation energy, metallic and non-metallic character and reactivity) of elements	**1B Electron configurations** **1B.1** Recall Bohr's model for writing electron configurations **1B.2** Recall the difference between shells, subshells and orbitals **1B.3** Recall the types of subshells and number of orbitals in each **1B.4** Understand the limitations of Bohr's model for electron configurations **1B.5** Use the position of an element on the periodic table to determine its electron configuration **1B.6** Write the electron configuration for both atoms and ions
• The periodic table as an organisational tool to identify patterns and trends in, and relationships between, the structures (including shell and subshell electronic configurations and atomic radii) and properties (including electronegativity, first ionisation energy, metallic and non-metallic character and reactivity) of elements	**1C The periodic table** **1C.1** Recall the different areas and overall structure of the periodic table (blocks, groups and periods) **1C.2** Understand and be able to calculate the core charge of an atom or ion **1C.3** Explain how core charge and the number of electron shells relate to the attraction of the valence electrons to the nucleus **1C.4** Explain the difference in atomic radius when comparing elements down a group and across the same period **1C.5** Recall the definitions of electronegativity, first ionisation energy, reactivity, and metallic and non-metallic character **1C.6** Use the core charge and atomic radius of an element to explain trends in electronegativity, first ionisation energy, reactivity, and metallic and non-metallic character both down a group and across a period
• Critical elements (for example, helium, phosphorus, rare-earth elements and post-transition metals and metalloids) and the importance of recycling processes for element recovery	**1D Critical elements and recycling processes** **1D.1** Explain examples of critical elements, including helium, phosphorus, rare-earth elements, post-transition metals and metalloids, and why they are classified as such **1D.2** Recall examples of the mining, extraction and processing of critical elements **1D.3** Explain the different uses of critical elements **1D.4** Outline examples of current recycling processes for recovering critical elements **1D.5** Explain the importance of element recovery with reference to environmental, economic and/or social implications



Glossary

Atom
Atomic number
Atomic radius
Aufbau's principle
Bohr model
Boiling point
Chemical property
Circular economy
Compound
Core charge
Critical element
Cryogenics
Diatomic
Electron
Electronegativity
Electrostatic force of attraction
Element
Emission spectrum
Eutrophication
Excited state
First ionisation energy
Ground state
Hund's rule
Ion
Ionisation energy
Isotope
Mass number
Melting point
Metallic character
Monoatomic
Neutron
Orbital
Ore
Physical property
Proton
Relative atomic mass
Slag
Smelting
Subshell
Subatomic particle
Valence electron
Valence shell

Cambridge University Press & Assessment
978-1-009-22964-7 — Cambridge Chemistry VCE Units 1&2
Brett Drummond , Simon Maaser , Lauren Angley , Scott Fraser , Rebecca Greaves , Trent Lucas , Zhen Wang
Excerpt
More Information

Concept map

Elements, isotopes, ions, atomic number, mass number and number of protons, neutrons and electrons

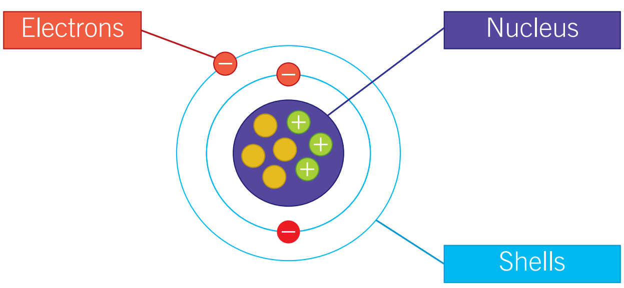
1A Introduction to the elements

Mass number → $^{24}_{12}Mg$ ← Chemical symbol

Atomic number →

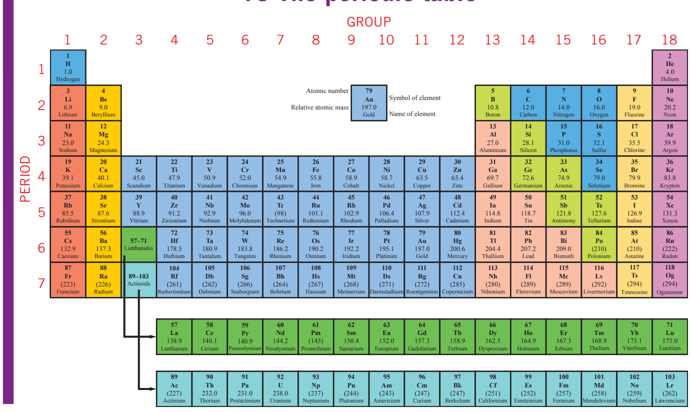
Shell and subshell electron configuration

1B Electron configurations



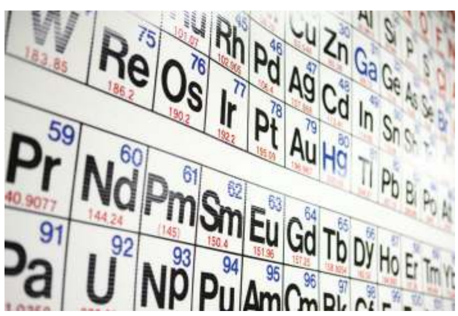
Using the periodic table as an organisational tool

1C The periodic table



Critical elements and the importance of recovery through recycling

1D Critical elements and recycling processes



See the Interactive Textbook for an interactive version of this concept map interlinked with all concept maps for the course.

978-1-009-22964-7 — Cambridge Chemistry VCE Units 1&2
Brett Drummond , Simon Maaser , Lauren Angley , Scott Fraser , Rebecca Greaves , Trent Lucas , Zhen Wang

1A Introduction to the elements

Study Design:

The definitions of elements, isotopes and ions, including appropriate notation: atomic number; mass number; and number of protons, neutrons and electrons

Glossary:

Atom
Atomic number
Chemical property
Compound
Diatomic
Electron
Element
Ion
Isotope
Mass number
Monatomic
Neutron
Physical property
Proton
Relative atomic mass
Subatomic particle

ENGAGE

The discovery of the atom

It was 1802 when John Dalton, an English chemist and physicist, presented his first ideas of the atomic theory of matter. In this theory, he proposed the following:

- All matter is made up of tiny spherical particles, which are indivisible.
- Atoms cannot be created or destroyed.
- Elements contain only one type of atom, whereas compounds contain different types of atoms in fixed ratios.

Dalton also developed symbols to represent elements and compounds known at the time.

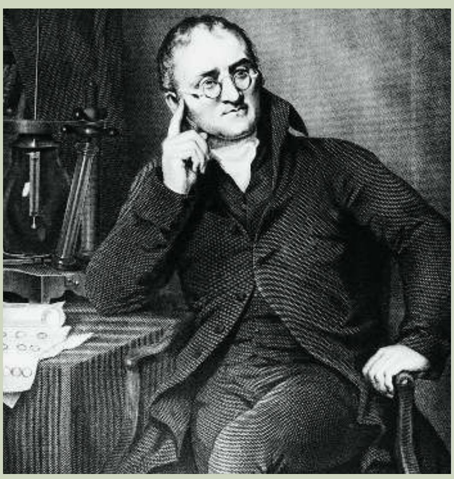


Figure 1A–1 John Dalton (1766–1844) concluded that matter is composed of atoms.

Figure 1A–2 Symbols of elements and compounds known to exist at the time

Since Dalton's work in the early nineteenth century, many other scientists have contributed their own ideas through discovery, which have continued to shape the structure of the atom and understanding of elements that we know today.

In 2016, four new elements were named and given a permanent place in the periodic table:

- nihonium (113)
- moscovium (115)
- tennessine (117)
- oganesson (118).

Since 2017, teams of scientists in Japan and in Russia have been trying to create element 119.

CAMBRIDGE
Cambridge University Press & Assessment
978-1-009-22964-7 — Cambridge Chemistry VCE Units 1&2
Brett Drummond , Simon Maaser , Lauren Angley , Scott Fraser , Rebecca Greaves , Trent Lucas , Zhen Wang
Excerpt
More Information

EXPLAIN

Key chemical terms

Before beginning to explore key chemical ideas in greater depth, there are some key terms that you need to be familiar with.

VIDEO 1A–1 ATOMS, IONS AND ISOTOPES

Atoms

Atoms are the building blocks of everything (Figure 1A–3). Your own DNA, cells, the food you eat, fragrances you smell, materials you use every day and the fuel used for transportation are all made of atoms.

Subatomic particles

Subatomic particles determine the characteristics of each type of atom. Figure 1A–3 and Table 1A–1 indicate the different subatomic particles within atoms, the charge they carry and their location.

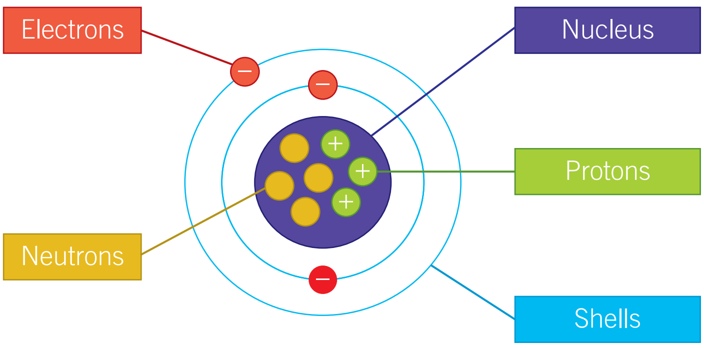


Figure 1A–3 A generalised representation of the structure of an atom, containing the location of the different subatomic particles

Table 1A–1 Subatomic particles and their location within an atom

Subatomic particle	Charge	Location	Relative mass (amu)
Proton	Positive	Nucleus	1
Neutron	Neutral		1
Electron	Negative	Shells	0.0005

You will notice from the table that protons and neutrons have similar relative masses. The actual values of their mass are:

$$\text{Proton} = 1.673 \times 10^{-24} \text{ grams}$$

$$\text{Neutron} = 1.675 \times 10^{-24} \text{ grams}$$

As these are such small values, we use the relative mass – in atomic mass units (amu) – of 1 to represent these. You will also notice that an electron is significantly smaller than each of these, in fact $\frac{1}{1840}$th the size.

Elements

Elements are made of only one type of atom and therefore are referred to as pure substances. Each element is made of its own unique atoms determined by the number of protons in its nucleus. Depending on the material that an element's atoms form, their **chemical** and **physical properties** are very different.

Atom the smallest piece of an element that retains the properties of that element

Subatomic particle a particle that is present within an atom; includes protons, neutrons and electrons

Proton a positively charged subatomic particle present within the nucleus of an atom

Neutron an uncharged subatomic particle present within the nucleus of an atom

Electron a negatively charged subatomic particle that moves around the nucleus of an atom

Element a pure substance made of only one type of atom

Chemical property the behaviour of an element or substance when it reacts with another element or substance

Physical property the features of an element or substance that can be measured without altering the chemical composition of that substance

CAMBRIDGE
Cambridge University Press & Assessment
978-1-009-22964-7 — Cambridge Chemistry VCE Units 1&2
Brett Drummond , Simon Maaser , Lauren Angley , Scott Fraser , Rebecca Greaves , Trent Lucas , Zhen Wang
Excerpt
More Information

1D CRITICAL ELEMENTS AND RECYCLING PROCESSES LINK
2A REPRESENTING COVALENT COMPOUNDS LINK
3A STRUCTURE AND PROPERTIES OF METALS LINK

Monoatomic an element that consists of only one atom; the prefix *mono* means 'one'

Diatomic a element that consists of two atoms; the prefix *di* means 'two'

Compound a substance formed from two or more different types of atoms in a fixed ratio

For example:

- Non-metallic elements like helium and neon are **monoatomic**, whereas other non-metallic elements, like chlorine and nitrogen, form molecules that are **diatomic** (Figure 1A–4).
- Other non-metallic elements, like carbon, can form giant networks or layers of atoms, creating substances such as diamond or graphite.
- Metallic elements, like sodium, form strong organised lattices made up of many cations, which form as a result of atoms losing electrons.

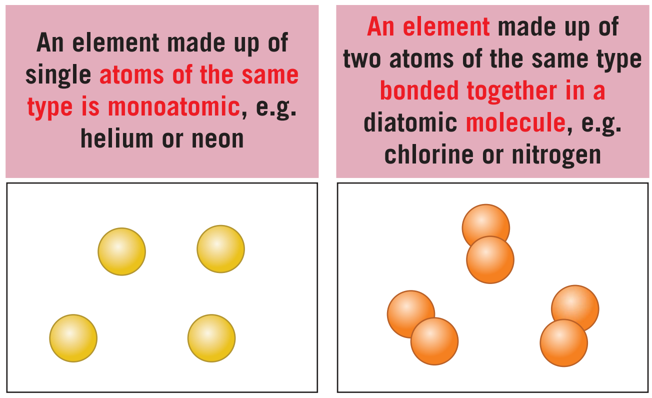


Figure 1A–4 Monoatomic (left) and diatomic (right) elements are made of only a single type of atom.

You will explore more of these properties across different chapters in Unit 1.

Compounds

Compounds are formed when two or more different types of atoms combine in fixed ratios to form a new substance (Figure 1A–5).

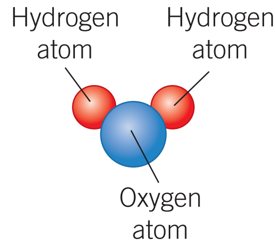


Figure 1A–5 A water molecule is a compound that is formed from two different elements in a fixed ratio. Two hydrogen atoms are covalently bonded to one oxygen atom.

Check-in questions – Set 1

1. Define the following terms: monatomic, diatomic, compound.
2. Using a fully labelled diagram, identify the charge and location of the different subatomic particles.

Atomic notation

There are currently 118 discovered elements, each with a unique name and chemical symbol. The first letter of each chemical symbol is always capitalised, and any subsequent letters, if present, are always lowercase (Table 1A–2).

Table 1A–2 Examples of different elements and their chemical symbols

Element	Chemical symbol
Carbon	C
Hydrogen	H
Sodium	Na
Mercury	Hg

One or two letters where the first letter is capitalised and the subsequent letter is always lowercase

Scientists have a uniform set of rules they follow for communicating their understanding of the representation of different elements. This includes being able to determine the:

- chemical symbol
- atomic number
- mass number.

Cambridge University Press & Assessment
978-1-009-22964-7 — Cambridge Chemistry VCE Units 1&2
Brett Drummond , Simon Maaser , Lauren Angley , Scott Fraser , Rebecca Greaves , Trent Lucas , Zhen Wang
Excerpt
More Information

An example of this is shown in Figure 1A–6.

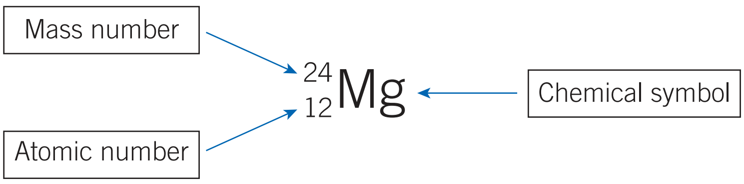


Figure 1A–6 The atomic notation representing the element, magnesium

Atomic number

The **atomic number** represents the number of protons present in the nucleus of an atom. Each element is unique and based on its number of protons (Figure 1A–7).

The atomic number is usually written as a *subscript* before the chemical symbol in atomic notation. As shown in Figure 1A–6 above, the atomic number of magnesium is 12. Therefore, it has 12 protons.

Similarly, the atomic number of lithium is 3, and its atomic notation is most commonly represented as $^{7}_{3}Li$. Therefore, we know that it has three protons, as represented in Figure 1A–7.

Atomic number the number of protons present in the nucleus of an atom

NOTE

On a *periodic table*, the atomic number is usually *above* each chemical symbol and is the smaller of the two numbers, as it does not include any neutrons.

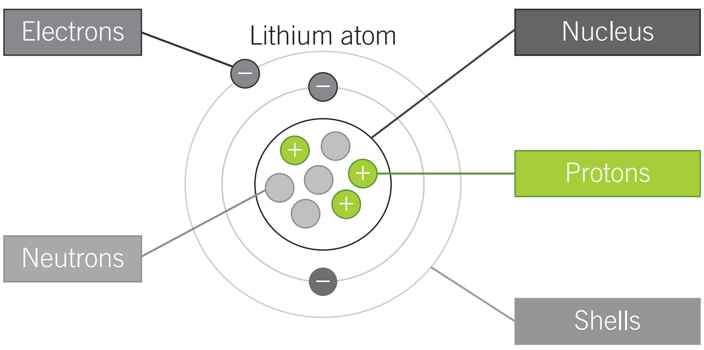


Figure 1A–7 Model of a lithium atom, highlighting the location of its three protons, where the number of these determines the *atomic number* and hence the type of element

Mass number

The **mass number** represents the total number of protons and neutrons present in the nucleus of an atom (Figure 1A–8). The mass number (or atomic mass) is usually written as a *superscript* before the chemical symbol.

Mass number the total number of protons and neutrons present in the nucleus of an atom

Mass number = number of protons + number of neutrons

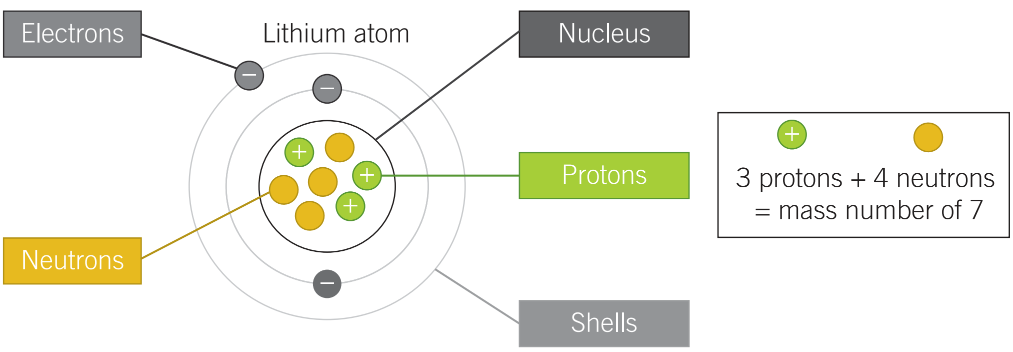


Figure 1A–8 A model of a lithium atom, highlighting the location and number of its three protons (green) and four neutrons (yellow), which add together to give the *mass number* of 7

Relative atomic mass
the average of the relative masses of all atoms for an element based on the isotopes for an element and their natural percentage abundances. Also known as relative atomic weight or standard atomic weight

Isotope
an atom of the same element with the same number of protons (same atomic number) but a different number of neutrons (different mass number)

3A STRUCTURE AND PROPERTIES OF METALS LINK

4A FORMATION AND NAMING OF IONIC COMPOUNDS LINK

You will also notice by looking at most periodic tables that the mass number for an element is not always an exact whole number. This is actually because what is shown is the **relative atomic mass**, not the mass number.

Relative atomic mass (or relative atomic weight or standard atomic weight as used on the IUPAC periodic table from 2022) is fractional, as it is the average of the relative mass of atoms, taking into account the fact there are isotopes for each element. **Isotopes** have differing numbers of neutrons, and each isotope for an element is present in different percentages, or abundances, in natural samples.

As you can see from the atomic notation of an element, the number of protons and neutrons can be determined. However, there is no reference to the number of electrons. This will be explored later in this chapter and again in Chapters 3A and 4A.

Check-in questions – Set 2

1 After locating the following elements on the periodic table, use their atomic numbers and relative atomic masses (rounded to the nearest whole number to estimate the mass number) to determine the number of all subatomic particles present in each.

Element	Atomic number	Mass number	Number of protons	Number of neutrons
Carbon (C)				
Germanium (Ge)				
Titanium (Ti)				

Isotopes

Isotopes are atoms of the same element with the same number of protons (the same atomic number) but a different number of neutrons, which gives each isotope a different mass number. A representation of this is shown for nitrogen in Figure 1A–9.

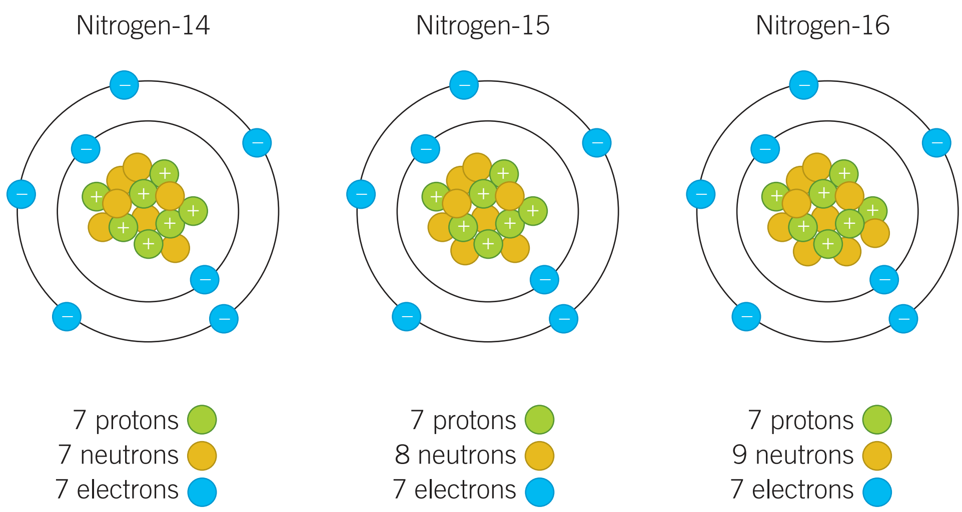


Figure 1A–9 Three of the isotopes of nitrogen, indicating the different numbers of subatomic particles within each. Note that each atom is still nitrogen, as it always has an atomic number of 7 (seven protons).

NOTE
Although not covered in VCE Chemistry Units 1&2, the stability of an isotope is determined by how likely it is to break down or decay into lighter (smaller) elements.

CAMBRIDGE
Cambridge University Press & Assessment
978-1-009-22964-7 — Cambridge Chemistry VCE Units 1&2
Brett Drummond , Simon Maaser , Lauren Angley , Scott Fraser , Rebecca Greaves , Trent Lucas , Zhen Wang
Excerpt
More Information

Number of electrons and the formation of ions

Recall that the atomic number is the number of protons in an element's atoms. The atomic number also provides information about the number of electrons in an atom of an element. In a neutral atom, the number of positive protons and negative electrons will always be equal.

Therefore, changing the number of electrons will not change the type of element. However, it will change the chemical properties of that element, often to become more stable. As you will see in Chapters 3A and 4A, changing the number of electrons results in the formation of **ions**.

Ions are versions of atoms that contain their normal number of protons but have more, or fewer, electrons. This gives them an overall electric charge. The atomic notation for an ion is represented in the same way as for any other atom; however, it includes either a superscript positive or negative charge and the size of this charge following the chemical symbol. This can be seen in Figures 1A–10 and 1A–11.

LINK 3A STRUCTURE AND PROPERTIES OF METALS
LINK 4A FORMATION AND NAMING OF IONIC COMPOUNDS

Ion
a positively or negatively charged atom that has either lost or gained electron(s)

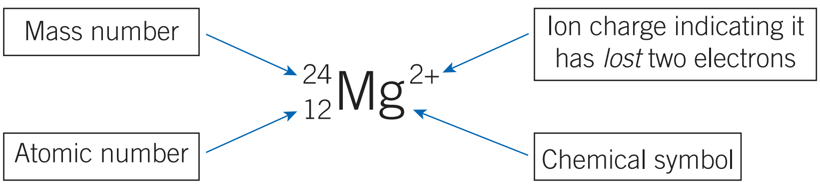


Figure 1A–10 The atomic notation representing a magnesium ion. The '2+' charge indicates that magnesium, a metal, has *lost* two electrons. Overall, it has 12 protons (atomic number) but only has 10 electrons.

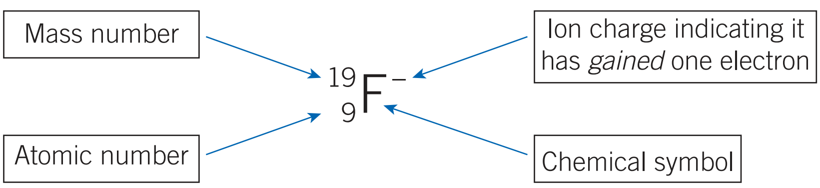


Figure 1A–11 The atomic notation representing a fluoride ion. The '–' charge indicates that fluorine, a non-metal, has *gained* one electron. Overall, it has nine protons (atomic number) but has 10 electrons.

Atoms will either gain or lose electrons based on how many electrons are present in their outer shell. This will be explored further in Chapter 1B.

LINK 1B ELECTRON CONFIGURATIONS

Check-in questions – Set 3

1 How many protons, neutrons and electrons does each of the atoms or ions below contain?
   a $^{19}_{9}F$
   b $^{65}_{30}Zn^{2+}$
   c $^{35}_{17}Cl^{-}$

2 Define the following key terms.
   a mass number
   b atomic number

3 Do isotopes of an element have a different atomic number or mass number?

WORKSHEET 1A–1 ATOMS AND SUBATOMIC PARTICLES