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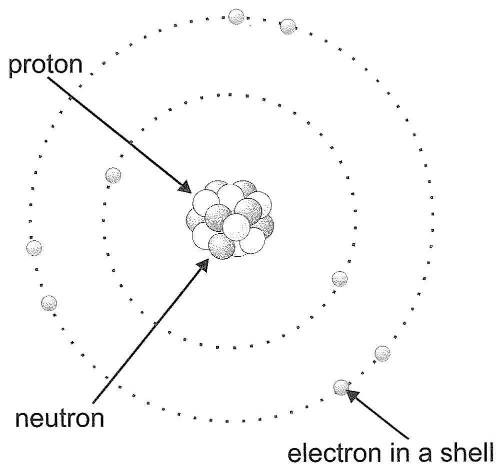
Atomic Structure

What Are **Atoms** Like?



1) Atoms are made up of **three** types of **subatomic particle**: **protons**, **neutrons** and **electrons**.
2) In the **centre** of all atoms is a **nucleus** containing **neutrons** and **protons**.
3) Almost all of the **mass** of the atom is contained in the **nucleus** which has an overall **positive** charge. The positive charge arises because each of the **protons** in the nucleus have a **+1** charge.
4) The **neutrons** in the nucleus have a very similar **mass** to the protons but they are **uncharged**.
5) **Electrons** are much **smaller** and **lighter** than either the neutrons or protons. They have a **negative charge** (**–1**) and **orbit** the nucleus in **shells** (or energy levels).
6) There's an **attraction** between the **protons** in the nucleus and the **electrons** in the shells.
7) The nucleus is **tiny** compared with the total volume occupied by the whole atom.
8) The **volume** occupied by the **shells** of the electrons determines the **size** of the atom.

Here's a round up of the **properties** of the subatomic particles:

Particle	Relative Mass	Relative Charge
Proton	1	+1
Neutron	1	0
Electron	$\frac{1}{2000}$	–1

What is the **Charge** on an Atom?

The overall charge on an atom is **zero**.

This is because each **+1** charge from a **proton** in the nucleus is **cancelled out** by a **–1** charge from an **electron**.
If an atom **loses** or **gains** electrons it becomes **charged**. These charged particles are called **ions**.

EXAMPLE: How many electrons has an Al^{3+} ion lost or gained?

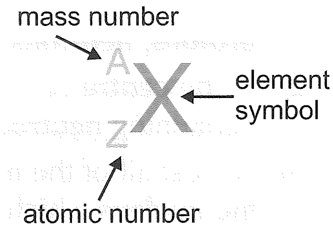
The Al^{3+} ion has a charge of **+3**, so there must be **3 more protons** than **electrons**.
Ions are formed when **electrons** are lost or gained, so Al^{3+} must have **lost 3 electrons**.

Neutrons are the perfect criminals — they never get charged...

1) Which subatomic particles are found in the nucleus?
2) What is the charge on an ion formed when an atom loses two electrons?
3) What is the charge on an ion formed when an atom gains two electrons?

Atomic Number, Mass Number and Isotopes

Atomic and Mass Numbers



1) If you look at an element in the periodic table, you'll see it's given **two numbers**. These are the **atomic number** and the **mass number**.
2) The **atomic number** of an element is given the symbol **Z**. It's sometimes called the **proton number** as it represents the number of **protons** in the nucleus of the element.
3) For **neutral** atoms the number of **protons equals** the number of **electrons**, but you need to take care when considering ions as the number of electrons changes when an ion forms from an atom.
4) The **mass number** of an atom is given the symbol **A**. It represents the **total** number of **neutrons** and **protons** in the nucleus.
5) **Subtracting Z** from **A** allows you to calculate the number of **neutrons** in the nucleus.

EXAMPLE: Use the periodic table to complete the following information about sodium.

Element	Symbol	Z	A	No. Protons	No. Neutrons	No. Electrons
Sodium			23			

The periodic table tells you that the **symbol** for sodium is **Na** and **Z** is **11**.
The number of **protons** in sodium is the same as the **atomic number**, which is **11**.
You work out the number of **neutrons** by **subtracting** Z from A: 23 – 11 = **12**.
The number of **electrons** is the **same** as the number of protons, which is **11**.

Isotopes

1) Atoms of the same **element** always have the same number of **protons**, so they'll always have the same **atomic number**, but their **mass numbers** can **vary** slightly.
2) Atoms of the same **element** with different **mass numbers** are called **isotopes**.
3) Isotopes have the same number of **protons** but different numbers of **neutrons** in their nuclei.

EXAMPLE: Copper has an atomic number of 29. Its two main isotopes have mass numbers of 63 and 65. How many neutrons does each of the isotopes have?

The ^{63}Cu isotope has 63 – 29 = **34 neutrons**.
The ^{65}Cu isotope has 65 – 29 = **36 neutrons**.

Finding the number of neutrons — it's as easy as knowing your A – Z...

1) Use the periodic table to work out how many neutrons are in a neutral phosphorus atom.
2) In terms of the numbers of subatomic particles, state two similarities and one difference between two isotopes of the same element.
3) Three neutral isotopes of carbon have mass numbers 12, 13 and 14. State the numbers of protons, neutrons and electrons in each.

Relative Atomic Mass

Calculating the **Relative Atomic Mass**

1) The average mass of an element is called its **relative atomic mass**, or A_r.
2) When you look up the **relative atomic mass** of an element on a **detailed** copy of the periodic table, you'll see that it isn't always a **whole number**. This is because the value given is the **average** mass number of two or more **isotopes**.
3) The **value** of the relative atomic mass is further complicated by the fact that some isotopes are **more abundant** than others. It's a **weighted average** of all the element's different isotopes.
4) You can use the **relative abundances** and **relative isotopic masses** (the mass number of a single, specific isotope) of each isotope to work out the **relative atomic mass** of an element.
5) Relative abundances of isotopes are often given as **percentages**. To work out the **relative atomic mass** of an element, all you need to do is multiply **each isotopic mass** by its **relative abundance**, add all the values together and divide by **100**.

EXAMPLE: What is the relative atomic mass of chlorine given that 75% of atoms have an atomic mass of 35 and 25% of atoms have an atomic mass of 37?

Average mass = (abundance of ^{35}Cl × 35 + abundance of ^{37}Cl × 37) ÷ 100
= [(75 × 35) + (25 × 37)] ÷ 100
= (2625 + 925) ÷ 100
= 3550 ÷ 100
= **35.5** (You can check your answer against a periodic table to see if it's right.)

Calculating the **Relative Formula Mass**

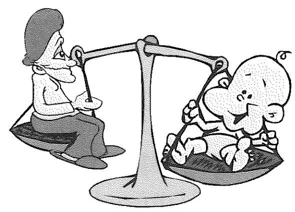
If you **add up** the relative atomic masses of all the atoms in a chemical formula, you get the **relative formula mass**, or M_r, of that compound.

(If the compound is molecular, you might hear the term relative molecular mass used instead, but it means pretty much the same.)

EXAMPLE: Calculate the relative formula mass of $CaCl_2$.

Ca has an atomic mass of 40.1 and Cl has an atomic mass of 35.5.

M_r = (1 × 40.1) + (2 × 35.5)
= **111**

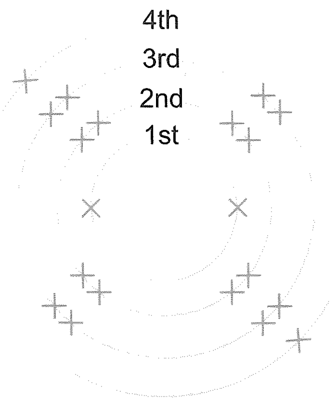


Together, my brother and I weigh 143 kg — it's our relative mass...

1) Find the relative atomic mass of lithium if its composition is 8% ^{6}Li and 92% ^{7}Li.
2) Find the relative atomic mass of carbon if its composition is 99% ^{12}C and 1% ^{13}C.
3) Find the relative atomic mass of silver if its composition is 52% ^{107}Ag and 48% ^{109}Ag.
4) Find the relative formula mass of sodium fluoride, NaF.
5) Find the relative formula mass of chloromethane, CH_3Cl.

Electronic Structure

*Electrons are Arranged in **Energy Shells***



1) Electrons orbit the nucleus in **shells** (also called **energy levels**).
2) You can draw concentric **circles** to represent the different **shells**. Then add **crosses** to represent the **electrons** at each level.
3) For example, this diagram shows the energy levels, for an atom with 20 electrons, filling up with electrons. It has two electrons in the first shell, eight in the second shell, eight in the third shell and two in the fourth shell.
(Remember you should always **start** filling the **innermost levels** first.)

Here's another way to show electron arrangements using simple notation:

An atom with 6 electrons:	2, 4
An atom with 11 electrons:	2, 8, 1
An atom with 20 electrons:	2, 8, 8, 2

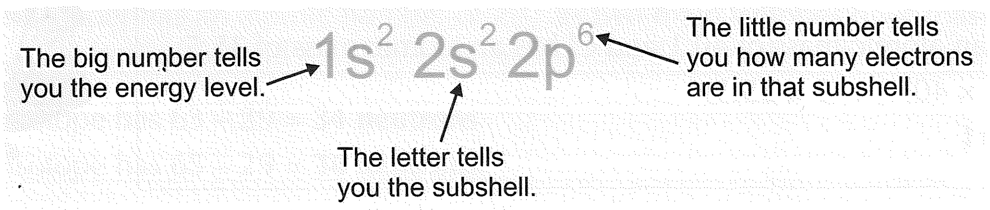
The first number tells you how many electrons are in the first shell, the second number tells you how many electrons are in the second shell, and so on.

*Energy Levels are **Split** into **Subshells***

1) Energy levels can be **split** into **sub-levels** called **subshells**. The first three subshells are called '**s**', '**p**' and '**d**'. They can each hold a different **number** of electrons.
2) The first energy level has **one subshell** — an 's' level. So the first energy level can contain up to **2 electrons**.

Subshell	Maximum electrons
s	2
p	6
d	10

3) At GCSE you learnt that the second energy level can contain up to **8 electrons**. It's actually split into **2 sub-levels**. **Two** of the electrons are in an '**s**' level and the remaining **six** are in a '**p**' level. If you combine the 2 's' electrons with the 6 'p' electrons you get a total of 8.
4) Electrons generally start by filling the **energy level** with the **lowest energy**. So the **first** energy level will be completely **filled** before any electrons go into the **second** energy level. Within an energy level, electrons will fill the **subshells** in the order s, then **p**, then **d**.
5) As well as telling you how many electrons are in each **shell**, the **electron configuration** of an atom also tells you what **subshells** the electrons are in. For an atom with 10 electrons:



I'm trying to be calm, but my energy level is too high...

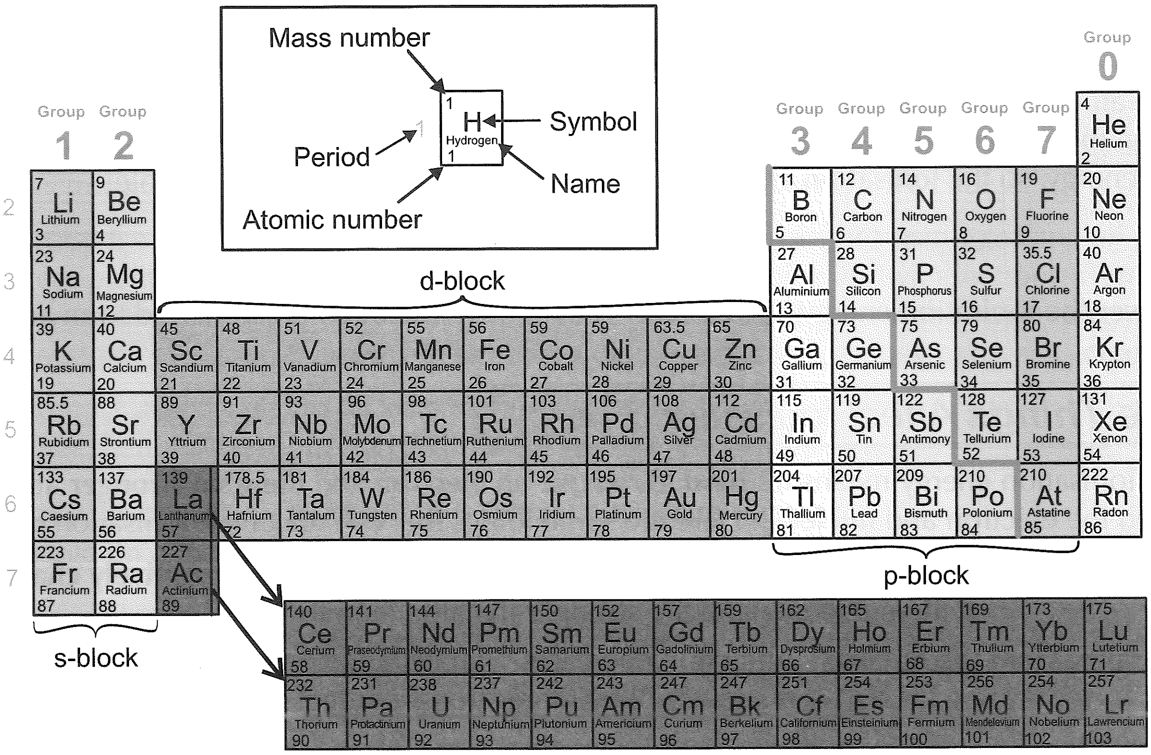
1) Draw diagrams to show the electron arrangements of the following elements: carbon, fluorine, magnesium, sulfur.
2) Use the simple notation shown above to write the electron arrangements of these elements: lithium, sodium, potassium, beryllium, magnesium, calcium.
3) Give the electron configurations of oxygen and chlorine.

The Periodic Table

The *Periodic Table*

The periodic table contains:

- All of the elements in order of atomic number.
- Vertical groups of elements which have similar properties.
- Horizontal rows of elements called periods.



What Are Groups *and* Periods?

Chemical reactions involve atoms **reacting** to gain a **full outer shell** of electrons.
All of the elements in a group have the same **number** of **electrons** in their **outer shell**.
As a result, the elements in a group **react** in a **similar** way.

The properties of elements in the same **period change gradually** as you move from one side of the periodic table to the other.

The Periodic Table *is Split into* Blocks

1) As well as being split into groups and periods, the periodic table has four **blocks**. You only need to worry about two of them at the moment though — the '**s**' block and the '**p**' block.
2) Groups **1** and **2** are called the **s-block** elements. Their outer electrons are in energy levels called **s subshells**. S subshells can accommodate up to 2 electrons (see page 4).
3) Groups **3** to **0** are called the **p-block** elements. Their outer electrons are in energy levels called **p subshells**. P subshells can accommodate up to 6 electrons (see page 4).

The mystery of the periodic table? It's elementary, my dear Watson...

1) Sort the following elements into a table to show which ones are from the s-block, and which are from the p-block: caesium, potassium, phosphorus, calcium, aluminium, barium and sulfur.
2) Give one similarity between elements that are in the same group.