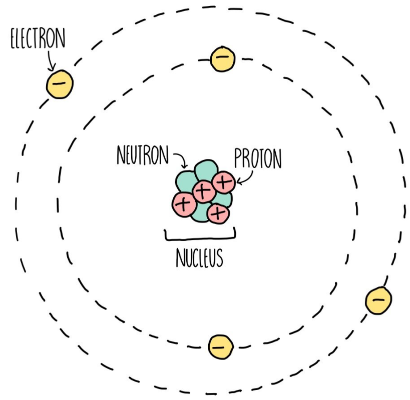
Atomic structure and isotopes

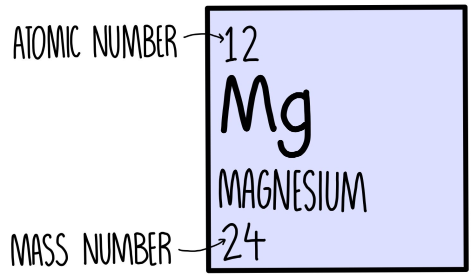
Atomic structure

- The **nucleus** is made up of protons and neutrons — this is where most of an atom's weight comes from.
- **Electrons** weight practically nothing.
- **Protons** are positively charged.
- **Neutrons** are neutral.
- **Electrons** are negatively charged and orbit the nucleus — there's an attraction between the positive nucleus and its electrons.
- In a neutral atom, the number of protons is **equal** to the number of electrons.



Atomic number and mass number

- **Atomic number** = the number of **protons**. In a neutral atom, this also tells you the number of electrons.
- **Mass number** = the number of both **protons and neutrons** in the nucleus.
- **Isotopes** are atoms of an element with the same number of protons but different numbers of neutrons.



Isotopes

- Isotopes are atoms that have the **same number of protons** but **different numbers of neutrons**.
- So they have the **same atomic number** but a **different mass number**.
- For example, two isotopes of chlorine are chlorine-35 and chlorine-37, in which chlorine-37 has two additional neutrons in its nucleus.

The actual mass of an atom is so small that it's more useful to compare its mass to another atom and express this as a relative mass. The mass of an atom is always compared to the mass of **carbon-12**.

- **Relative atomic mass**, Ar, is the weighted **mean mass** of an atom of an element, compared to **1/12th** of the mass of an atom of **carbon-12**.
- **Relative isotopic mass** is the mass of an **atom of an isotope** compared with **1/12th** of the mass of an atom of **carbon-12**.

Mass numbers in the periodic table are an **average** of all the masses of all **isotopes** of a particular element. We call this the **relative atomic mass** (RAM) and can be calculated using the following formula:

$$\frac{(\text{MASS NO. OF ISOTOPE 1} \times \text{\% OF ISOTOPE 1}) + (\text{MASS NO. OF ISOTOPE 2} \times \text{\% OF ISOTOPE 2})}{100}$$

Mass spectrometry

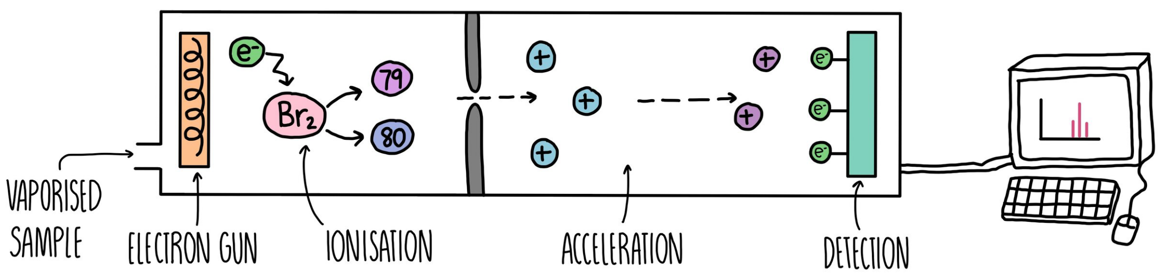
We can use mass spectrometry to provide information about **which isotopes are present** in a sample. Mass spectrometry takes place in the following steps:

1. **Ionisation** – the sample is ionised when **high energy electrons** are fired at it from an '**electron gun**'. The electron gun is made up of a hot wire filament with a current running through it which emits electrons, forming **1+ ions**. The 1+ ions are attracted to a **negatively charged electric plate** where they are **accelerated**.

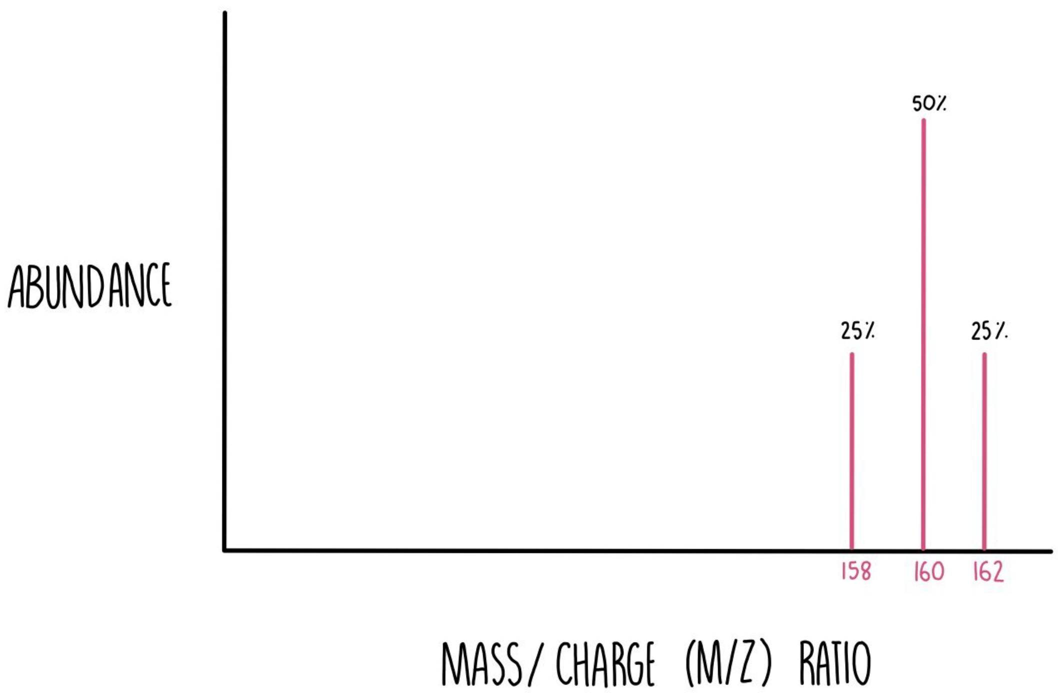
$$X_{(g)} + e^- \longrightarrow X^+_{(g)} + 2e^-$$

2. **Acceleration** – the positive ions are **accelerated** using an **electric field** so they all have the **same kinetic energy**.

3. **Detection** – positive ions hit a **negatively charged plate** and **gain electrons**. This generates a movement of electrons, therefore an **electric current** that is measured. The **size of the current** gives a measure of the **number of ions** hitting the plate.



Here's an example of a mass spectrum produced by a sample of bromine, which exists as bromine-79 and bromine-81 isotopes.



The y-axis gives the **abundance of ions** where the **height** of each peak is proportional to the **relative isotopic abundance** (so the taller the peak, the more of the isotope is present in the sample). The x-axis gives the **mass/charge ratio (m/z)** of the isotope. Given that the charge of the ions is always **+1**, the m/z is effectively the **mass** of each ion.

In the mass spectrum above, we can see that the sample consists of:

- 50% with a mass of 160 (from Br_2 consisting of both Br-79 and Br-81)
- 25% with a mass of 158 (from Br_2 consisting of 2x Br-79)
- 25% with a mass of 162 (from Br_2 consisting of 2x Br-81)

Relative formula mass

The **relative formula mass (Mr)** of a compound is the **sum** of the **relative atomic masses** of the atoms in the numbers shown in the formula.

E.g., the Mr of calcium carbonate, $CaCO_3$, is the sum of the atomic masses of all the elements in the compound. The mass number of calcium is 40, carbon is 12 and oxygen is 16, so the Mr for calcium carbonate is $40 + 12 + (16 \times 3) = 100$.