Atomic structure

You need to know about the structure of an atom and the particles that make it up.

All atoms are made up of the same **3 basic particles**:

- **protons**
- **electrons**
- **neutrons**.

The only difference between one atom and the next is the number of these particles in the atom. That is enough to make things as different as gold and oxygen.

Neutrons and **protons** are heavy in comparison to electrons. In fact, a neutron or a proton weighs about 2000 times as much as an electron!

The other thing to remember is that **protons** have a positive charge, **electrons** have a negative charge and **neutrons** have no charge at all.

How are these particles arranged?

An atom is not a solid thing. In fact, quite the opposite. Atoms are nearly completely empty.

Protons and neutrons are tightly clumped together in the middle, in the nucleus, while electrons spin around them

To give you an idea of the proportions, imagine a full size football stadium. The nucleus would be equivalent to the size of an ant in the middle, with the electrons whizzing around the outskirts.

The central part of the atom is called the **nucleus**. That's where you find all the protons and **neutrons.**

As we said above, protons and neutrons are **heavy** compared to electrons, so you can see that all the mass is concentrated in the middle of the atom. Also, as all the protons are in the nucleus of the atom, the nucleus has a positive charge.

The **electrons** (negatively charged) orbit around the outside of the atom.

An atom is made up of mostly empty space.

Protons have a **positive** charge and a lot of mass.

Neutrons are neutral but are as heavy as protons.

Electrons are negative and are only about $\frac{1}{2000}$ of the mass of the others.

To help us to describe atoms and nuclei, we use numbers and letters. **Here is an example:**

$$^{4}_{2}He$$

The atom in the diagram is described by the numbers and letters shown next to it. All atoms of a certain element will have the same number of protons in the nucleus.

The top number is called the **mass number** or the **nucleon number**. It tells you how many particles are in the nucleus, i.e. how many protons and neutrons.

The bottom number is called the **proton number** or the **atomic number**. It tells you how many protons there are in the nucleus.

The letters give you a clue as to the name of the atom. This is an atom of **'helium', He.**

The number of **electrons** in an atom is the same as the number of **protons**. That makes the atom **neutral** overall (neither negative nor positive).

If the numbers are not equal, the atom becomes a charged particle. We call these charged particles ions.

Isotopes

The **number of protons** is the thing that decides how an atom is going to behave and therefore what element the atom belongs to. If you change the number of protons in an atom, you change the type of atom (it becomes an atom of another element.)

However, **you can change the number of neutrons** in an atom without changing the type of atom.

For example, hydrogen is an atom that contains only 1 proton. Atoms with more or less neutrons in them are called **isotopes**.

What is radioactivity?

Some isotopes of atoms can be unstable.

They may have:

a) Too much energy

or

b) The wrong number of particles in the nucleus.

We call these **radioisotopes.**

To make themselves more stable, they throw out particles and/or energy from the nucleus. We call this process **'radioactive decay'**. The atom is also said to **disintegrate**.

The atom left behind (the daughter) is different from the original atom (the parent). It is an atom of a new element. For example uranium breaks down to radon which in turn breaks down into other elements.

The particles and energy given out are what we call **'radiation'** or **'radioactive emissions'**.

Background radiation

There is a certain amount of radiation around us (and even inside us) all the time. There always has been – since the beginning of the Earth. It is called **Background radiation.**

Background radiation comes from a huge number of sources.

In most areas, Background radiation is safe. It is at such a low level that it doesn't harm you. You need to be exposed to many times the normal background level before you notice any symptoms.

However, some areas of the country have a higher level of background radiation than others because the rocks near the surface contain more radioactive isotopes (for example, Cornwall).

Ionisation

The radiation emitted by radioactive substances has a huge amount of energy, which is why it is so dangerous. The energetic radiation causes **ionisation.**

When radiation hits a neutral atom, some of the energy from the radiation is passed to the atom. This energy can cause an electron from the atom to escape, leaving the atom with a positive charge. This positively charged atom is called an **ion,** so the process is called ionization.

As the radiation travels along it ionises atoms that are close enough. The more atoms the radiation ionises the more energy the radiation gives away, until eventually there is no energy left. The radiation is then said to have been **absorbed**.

Detecting radiation

You will see in the following quick learn that there is more than one type of radiation, but each sort causes ionisation. This is how we are able to detect radiation.

It is hard to detect the actual particles or waves emitted by radioactive substances, but it is easy to detect the positive and negative ions produced by the ionisation they cause. A device called a **Geiger-Muller** tube collects the charged ions and can measure the amount of ionisation that is taking place in a certain time. The greater the amount of ionisation the more radiation there must be.

Why is radiation harmful?

It is this process of ionisation that makes radioactive substances so dangerous. Living cells can be fatally damaged if molecules in the cell are ionised. This damage can kill cells or cause cancers to form. The greater the dose of radiation the more likely it is that cancer will occur.

Alpha, beta and gamma

There are three main types of radiation that can be emitted by radioactive particles. They are called **alpha**, **beta**, and **gamma**.

Dangers of handling radioactive substances

Each type of radiation that can be emitted can be absorbed by different materials and ionises different amounts. They are equally dangerous but for different reasons.

Alpha particles:

Although alpha particles cannot penetrate the skin, if it gets into the body it can ionise many atoms in a short distance. This makes it potentially extremely dangerous. A radioactive substance that emits just alpha particles can therefore be handled with rubber gloves, but it must not be inhaled, eaten, or allowed near open cuts or the eyes.

Beta particles:

Beta particles are much more penetrating and can travel easily through skin. Sources that emit beta particles must be held with long handled tongs and pointed away from the body. Inside of the body beta particles do not ionise as much as alpha particles but it is much harder to prevent them entering the body.

Gamma waves:

These waves are very penetrating and it is almost impossible to absorb them completely. Sources of gamma waves must also be held with long handled tongs and pointed away from the body. Lead lined clothing can reduce the amount of waves reaching the body. Gamma waves are the least ionising of the three types of radiation but it is extremely difficult to prevent them entering the body.

What is half-life?

Radioactive substances will give out radiation all the time, regardless of what happens to them physically or chemically. As they decay the atoms change to daughter atoms, until eventually there won't be any of the original atoms left.

Different substances decay at different rates and so will last for different lengths of time. We use the **half-life** of a substance to tell us which substances decay the quickest.

Half-life – is the time it takes for half of the radioactive particles to decay.

It is also the time it takes for the count-rate of a substance to reduce to half of the original value.

We cannot predict exactly which atom will decay at a certain time but we can estimate, using the half-life, how many will decay over a period of time.

The half-life of a substance can be found by measuring the count-rate of the substance with a Geiger-Muller tube over a period of time. By plotting a graph of count-rate against time the half-life can be seen on the graph.

Using radioactivity

Different radioactive substances can be used for different purposes. The type of radiation they emit and the half-life are the two things that help us decide what jobs a substance will be best for. Here are the main uses you will be expected to know about:

1. Uses in medicine to kill cancer – radiation damages or kills cells, which can cause cancer, but it can also be used to kill cancerous cells inside the body. Sources of radiation that are put in the body need to have a high count-rate and a short half life so that they are effective, but only stay in the body for a short period of time. If the radiation source is outside of the body it must be able to penetrate to the required depth in the body. (Alpha radiation can't travel through the skin remember!)

2. Uses in industry – one of the main uses for radioactivity in industry is to detect the thickness of materials. The thicker a material is the less the amount of radiation that will be able to penetrate it.

3. Alpha particles would not be able to go through metal at all, gamma waves would go straight through regardless of the thickness. Beta particles should be used, as any change in thickness would change the amount of particles that could go through the metal.

They can even use this idea to detect when toothpaste tubes are full of toothpaste!

4. Photographic radiation detectors – these make use of the fact that radiation can change the colour of photographic film. The more radiation that is absorbed by the film the darker the colour it will go when it is developed. This is useful for people working with radiation, they wear radiation badges to show them how much radiation they are being exposed to.

5. Dating materials – The older a radioactive substance is the less radiation it will release. This can be used to find out how old things are. The half-life of the radioactive substance can be used to find the age of an object containing that substance.

There are three main examples of this:

i) Carbon dating – many natural substances contain two isotopes of Carbon. Carbon-12 is stable and doesn't disintegrate. Carbon-14 is radioactive. Over time Carbon-14 will slowly decay. As the half-life is very long for Carbon-14, objects that are thousands of years old can be compared to new substances and the change in the amount of Carbon-14 can date the object.

ii)Uranium decays by a series of disintegrations that eventually produces a stable isotope of lead. Types of rock (igneous) contain this type of uranium so can be dated, by comparing the amount of uranium and lead in the rock sample.

iii) Igneous rocks also contain potassium-40, which decays to a stable form of Argon. Argon is a gas but if it can't escape from the rock then the amount of trapped argon can be used to date the rock.