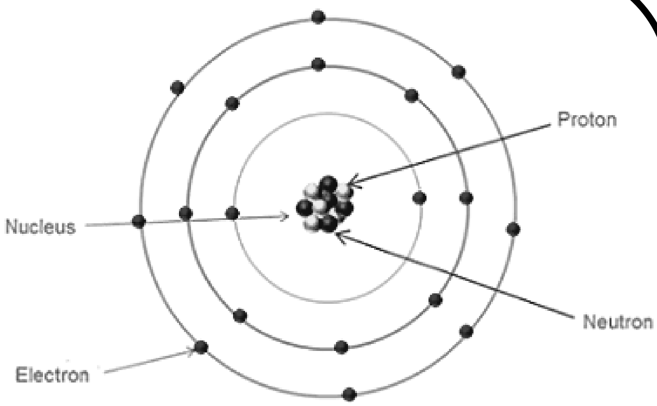
Structure of the Atom

Atoms are very small, having a **radius of about 1 × 10^{-10} metres**.



The basic structure of an atom is a **positively charged nucleus** composed of **both protons and neutrons** surrounded by negatively charged electrons.

The radius of a nucleus is less than 1/10000 of the radius of an atom.

Most of the mass of an atom is concentrated **in the nucleus**.
The **electrons** are arranged at **different distances from the nucleus** (different energy levels).

The **electron arrangements may change** with the absorption of electromagnetic radiation (move further from the nucleus; a higher energy level) or by the emission of electromagnetic radiation (move closer to the nucleus; a lower energy level).

Mass number, Atomic number and Isotopes

In an atom the **number of electrons is equal to the number of protons** in the nucleus.
Atoms have **no overall electrical charge**.

All atoms of a particular element have the **same number of protons**.
The **number of protons** in an atom of an element is called its **atomic number**.
The **total number of protons and neutrons** in an atom is called its **mass number**.

Atoms can be represented as shown in this example:

(Mass number) (Atomic number) $^{23}_{11}Na$

Atoms of the **same element can have different numbers of neutrons**; these atoms are called **isotopes** of that element.

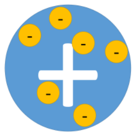
Atoms turn into **positive ions** if they **lose** one or more outer **electrons**.

P4 The development of the model of the atom

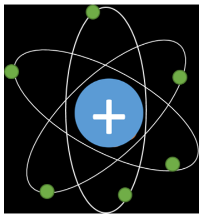
New experimental evidence may lead to a scientific model being changed or replaced.

Before the discovery of the electron, **atoms were thought to be tiny spheres that could not be divided**.

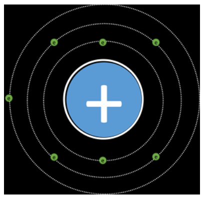
The discovery of the electron led to the **plum pudding model** of the atom. The plum pudding model suggested that the atom is a **ball of positive charge** with **negative electrons** embedded in it.



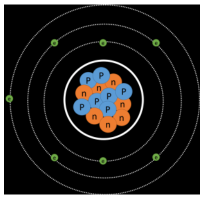
The results from the **alpha particle scattering experiment** led to the conclusion that the **mass of an atom was concentrated at the centre** (nucleus) and that the **nucleus was positively charged**. This nuclear model replaced the plum pudding model.



Niels Bohr adapted the nuclear model by suggesting that **electrons orbit the nucleus at specific distances**. The theoretical calculations of Bohr agreed with experimental observations.



Later experiments led to the idea that the positive charge of any **nucleus could be subdivided into a whole number of smaller particles**, each particle having the same amount of positive charge. The name proton was given to these particles. The experimental work of James Chadwick provided the evidence to show the **existence of neutrons within the nucleus**. This was about 20 years after the nucleus became an accepted scientific idea.



P4 Radioactive decay and Nuclear Radiation

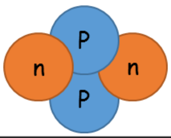
Some atomic nuclei are unstable. The nucleus **gives out radiation as it changes to become more stable**. This is a random process called **radioactive decay**.

Activity is the **rate at which a source of unstable nuclei decays**. Activity is measured in **becquerel** (Bq)

Count-rate is the **number of decays recorded each second** by a detector (eg Geiger-Muller tube).

The nuclear radiation emitted may be:

- an **alpha particle** (α) – this consists of **two neutrons and two protons**, it is the same as a helium nucleus
- a **beta particle** (β) – a **high speed electron** ejected from the nucleus as a neutron turns into a proton
- a **gamma ray** (γ) – **electromagnetic radiation** from the nucleus
- a **neutron** (n).

Type of radiation	What is it made of?	What does it look like? (Sketch it)	How big is it?	How much air can it get through?	What material stops it?
Alpha	2 protons 2 neutrons		Small (nucleus of an atom)	About 5-10 cm	A few sheets of paper
Beta	Electron		About 8000 times smaller than alpha	Around 1-2 m	A few mm of aluminium
Gamma	Electromagnetic wave		massless	Many meters	A few cm of lead

P4 Nuclear Equations

Nuclear equations are used to represent radioactive decay.
In a nuclear equation an alpha particle may be represented by the symbol:

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

and a beta particle by the symbol:

$$^{0}_{-1}\text{e}$$

The emission of the different types of nuclear radiation may cause a change in the mass and /or the charge of the nucleus.

For example:

$$^{219}_{86}\text{radon} \longrightarrow {}^{215}_{84}\text{polonium} + {}^{4}_{2}\text{He}$$

So **alpha decay causes both the mass and charge of the nucleus to decrease**.

For example:

$$^{14}_{6}\text{carbon} \longrightarrow {}^{14}_{7}\text{nitrogen} + {}^{0}_{-1}\text{e}$$

So **beta decay** does not cause the mass of the nucleus to change but **does cause the charge of the nucleus to increase**.

The emission of a **gamma ray does not cause the mass or the charge of the nucleus to change**.

Half-lives and the random nature of radioactive decay

Radioactive decay is **random**.

The **half-life** of a radioactive isotope is **the time it takes for the number of nuclei of the isotope in a sample to halve**, or the time it takes for the count rate (or activity) from a sample containing the isotope to fall to half its initial level.

Radioactive isotopes have a very wide range of half-life values.
The **hazards** associated with radioactive material **differ according to the half-life** involved.

P4

Radioactive Containment

Radioactive contamination is the **unwanted presence of materials containing radioactive atoms** on other materials.

The **hazard** from contamination is **due to the decay** of the contaminating atoms.

The **type of radiation** emitted **affects the level of hazard**.

Irradiation is the process of **exposing an object to nuclear radiation**. The irradiated object does not become radioactive.

Suitable precautions must be taken to protect against any hazard that the radioactive source used in the process of irradiation may present.

Background Radiation (Triple only)

Background radiation is around us all of the time.

It comes from:

- **natural sources** such as rocks and cosmic rays from space
- **man-made sources** such as the fallout from **nuclear weapons** testing and **nuclear accidents**.

The level of background radiation and radiation dose may be affected by occupation and/or location.

Radiation dose is measured in **sieverts (Sv)**
1000 millisieverts (mSv) = 1 sievert (Sv)

P4 Uses of nuclear radiation (Triple only)

Nuclear radiations are used in medicine for the:

- exploration of internal organs
- control or destruction of unwanted tissue.

Radioactive sources can also be used by doctors to find out if different organs in our bodies are working properly. Doctors can inject a small amount of radioactive material into a patient's body. The radioactive substance is carried by the blood to the organ, eg the kidneys or the thyroid gland, that the doctor wants to examine. The radiation coming from the organ is measured. The measurements can be processed by a computer so that an image of the organ is displayed on the computer screen. The image helps the doctor to diagnose what is wrong with the organ.

Radiation can be used to kill cancerous body cells. Gamma radiation, for example, from a radioactive source can be directed so that it targets cancer cells.

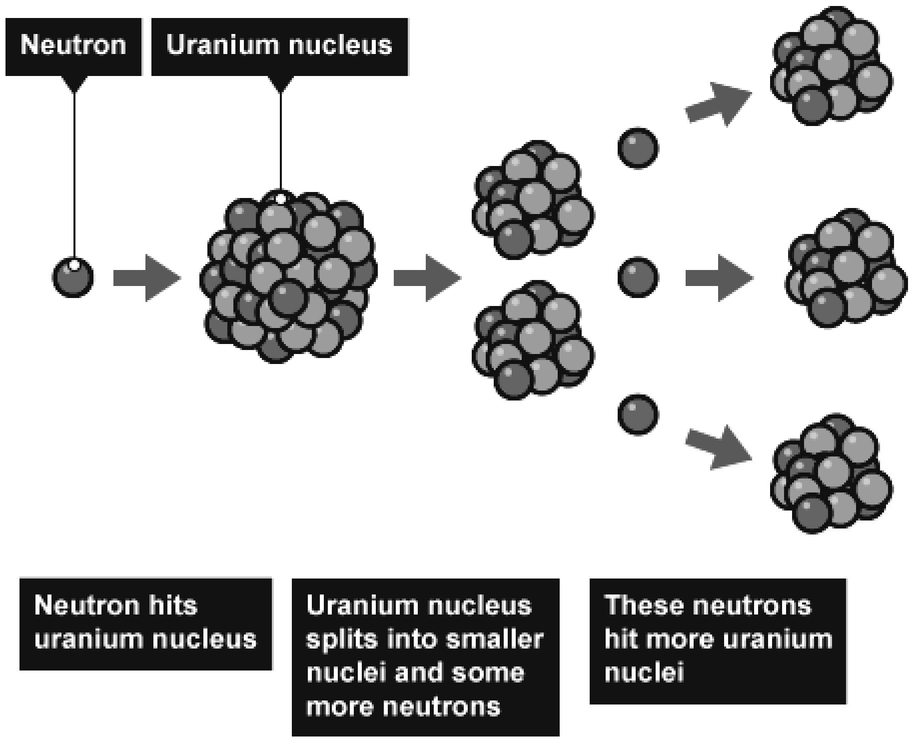
<u>Dangers</u>

A dose of radiation that exceeds normal levels can be dangerous. Radiation can affect the way in which the cells in our bodies operate and can cause the cells to become cancerous. We must act responsibly and take appropriate safety precautions when we are dealing with radiation.

P4 Nuclear fission and Nuclear fusion (Triple only)

Nuclear **fission** is the **splitting of a large and unstable nucleus** (eg uranium or plutonium).
Spontaneous fission is rare.
Normally, for fission to occur the unstable nucleus must first absorb a neutron. The nucleus undergoing fission splits into two smaller nuclei, roughly equal in size, and emits two or three neutrons plus gamma rays. Energy is released by the fission reaction.

The neutrons may go on to start a chain reaction.
The chain reaction is controlled in a nuclear reactor to control the energy released.
The explosion caused by a nuclear weapon is caused by an uncontrolled chain reaction.



Nuclear **fusion** is the **joining of two light nuclei to form a heavier nucleus**.

In this process some of the mass may be converted into the energy.