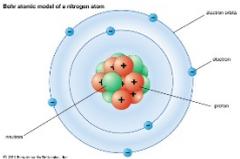# Physics 4.4 Atomic structure

4.4.1	Atoms and isotopes
4.4.1.1 **The structure of an 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 < **1/10 000** 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).
4.4.1.2 **Mass number, atomic number and isotopes**	In an atom the **number of electrons = 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) 23 (Atomic number) 11 Na Atoms of the **same element** can have **different numbers of neutrons**; these atoms are called <u>isotopes</u> of that element. Atoms turn into **positive ions** if **they lose one or more** outer **electron**(s).
4.4.1.3 **The development of the model of the atom (common with chemistry)** 	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. This suggested that the **ato**m 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 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.
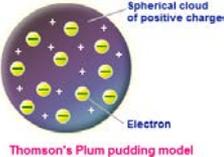
4.4.2	Atoms and nuclear radiation
4.4.2.1 **Radioactive decay and nuclear radiation** 	Some atomic nuclei are u**nstable**. The nucleus **gives out radiation** as it changes to become more stable. This is a random process called radioactive decay. Activity is the rate at which a source of unstable nuclei 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 <u>alpha particle (α)</u> – this consists of **two neutrons and two protons**, it is the same as a helium nucleus. **Least penetrating**, **most ionising** • a <u>beta particle (β)</u> – a **high speed electron** ejected from the nucleus as a neutron turns into a proton. Medium penetration and ionisation • a <u>gamma ray (γ)</u> – **electromagnetic radiation** from the nucleus. Most penetrating, least ionising. • a **neutron (n).**
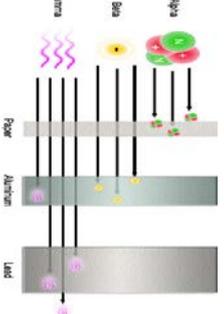
4.4.2.2 **Nuclear** **equations**	Nuclear equations are used to represent radioactive decay. In a nuclear equation an alpha particle may be represented by the symbol: $_2^4He$ and a beta particle by the symbol: $_{-1}^{\,0}e$ The emission of the different types of nuclear radiation may cause a change in the mass and /or the charge of the nucleus. For example: $_{86}^{219}radon \longrightarrow {}_{84}^{215}polonium + {}_2^4He$ So **alpha decay** causes both the **mass and charge of the nucleus to decrease**. So **beta decay** does not cause the mass of the nucleus to change but does cause the **charge of the nucleus to increase.** $_6^{14}carbon \longrightarrow {}_7^{14}nitrogen + {}_{-1}^{\,0}e$ The emission of a **gamma ray does not cause** the **mass** or the **charge** of the nucleus **to change.**
4.4.2.3 **Half lives and the** **random nature of** **radioactive decay**	Radioactive decay is **random**. The <u>half-life</u> 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.
4.4.2.4 **Radioactive** **contamination**	**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.
4.4.3	Hazards and uses of radioactive emissions and of background radiation (physics only)
4.4.3.1 **Background** **radiation**	**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 **fallou**t 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)
4.4.3.2 **Different half-** **lives of** **radioactive** **isotopes**	Radioactive isotopes have a very wide range of half-life values. This affects their uses
4.4.3.3. **Uses of nuclear** **radiation**	Nuclear radiations are used in medicine for the: • exploration of internal organs • control or destruction of unwanted tissue, such as cancers

	Evaluate the use of radioactive isotopes in this way.
4.4.4	Nuclear fission and fusion (physics only)
4.4.4.1 **Nuclear fission** 	**Nuclear fission** is the **splitting** of a **large** and **unstable nucleus** (eg **uranium** or **plutonium**). Spontaneous fission is rare. Usually, 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. All of the fission products have **kinetic energy**. 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**.
4.4.4.2 **Nuclear fusion**	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 of radiation.