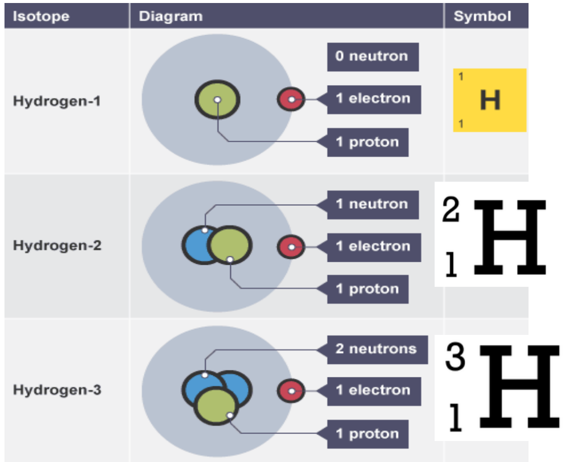
P4: Atomic structure

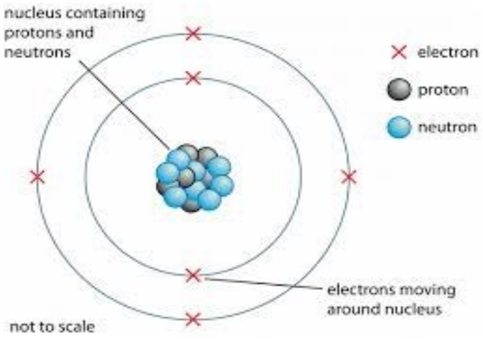
Section 1a: Atomic structure

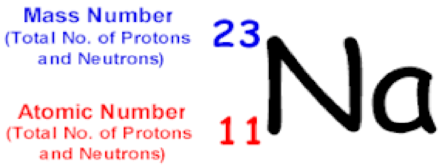
Isotopes:
Isotopes are the atoms of an element with different numbers of neutrons. They have the same proton number, but different mas numbers
Three isotopes of Hydrogen:



1b. Atoms are very small. Atoms have a radius of about 0.1nm (0.000 000 0001m, 1 x 10^{-10}m). Atoms have a central **nucleus** which contains protons and neutrons. The nucleus is surrounded by electrons. The electrons move around the nucleus in **energy levels**, or **shells**. The nucleus is tiny compared to the size of the atom as a whole. The radius of the nucleus is less than 1/10 000th of that of the atom (1 x 10^{-14}m). The size difference in size between a nucleus and an atom is equivalent to a pea placed in the middle of a football pitch. The nucleus contains protons and neutrons. These are much heavier than electrons. This means that most of the mass of the atom is contained in the tiny nucleus in the middle.

Section 1c: Atomic structure





The number of electrons in an atom is always the same as the number of protons, so atoms are electrically neutral overall. Atoms can lose or gain electrons. When they do, they form charged particles called **ions**:

If an atom **loses** one or more electrons, it becomes a **positively charged ion**
If an atom **gains** one or more electrons, it becomes a **negatively charged ion**

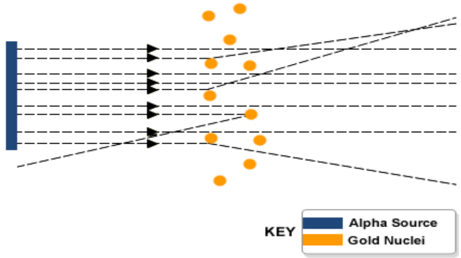
Section 2a: Discovery of the electron

The plum pudding model:

An early model - scientific idea - about the structure of the atom was called the **plum pudding model**. In this model, the atom was imagined to be a sphere of positive charge with negatively charged electrons dotted around inside it like plums in a pudding. Scientific models can be tested to see if they are wrong by doing experiments. An experiment carried out in 1905 showed that the plum pudding model could not be correct.

Section 2b Discovery of the electron

2b. Alpha particle scattering experiment:
Early in the 20th century scientists realised that all matter is made up of atoms. As a result of an experiment carried out by his assistants, Hans Geiger and Ernest Marsden, Ernest Rutherford suggested a model for the atom.



The results from this alpha scattering experiment led to the conclusion that the mass of an atom was concentrated at the centre (nucleus) and that the nucleus was charged. The alpha scattering experiment led to the 'plum-pudding model' being replaced by the nuclear model.

Neils Bohr adapted the nuclear model by suggesting that electrons orbit the nucleus at specific distances. Later experiments led to the idea that the positive charge of any nucleus could be divided into a whole number of smaller particles, each particle having the same amount of positive charge. The name 'proton' was given to these particles.
In 1932, the experimental work of **James Chadwick** provided evidence that the neutron existed within a nucleus. This was about 20 years after the nucleus became an accepted scientific idea.

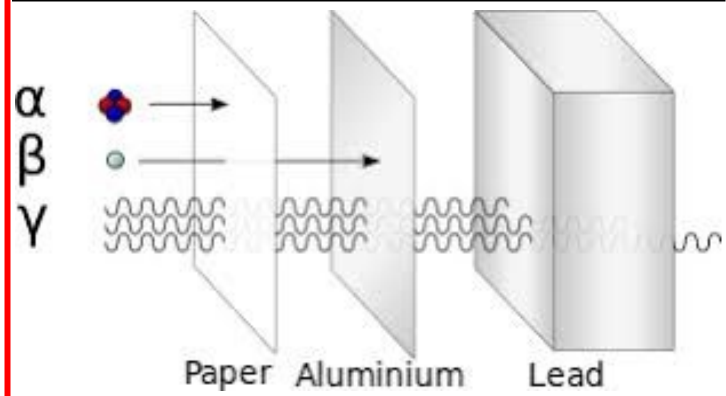
P4: Atomic structure

Section 3: Radioactive decay

Some atomic nuclei are unstable. The nucleus gives out ionising 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 and is measured in Becquerel (Bq).

	Radiation emitted from nucleus	Change in mass number	Change in atomic number
Alpha (α) decay	Helium nucleus $^{4}_{2}He$	-4	-2
Beta (β) decay	Electron $^{0}_{-1}e$	0	+1
Gamma (γ) decay	Electromagnetic waves	0	0
Neutron (n) decay	Neutron	-1	0

Section 4: The penetration of alpha, beta and gamma radiation



Alpha is blocked by paper, **Beta** is blocked by Aluminium and **Gamma** can penetrate both paper and aluminium but is blocked by lead.

Section 5: Nuclear decay equations

In a nuclear equation an alpha particle may be represented by the symbol: $^{4}_{2}He$

And a beta particle: $^{0}_{-1}e$

The emission of the different types of ionising radiation may cause a change in the mass and/or the charge of the nucleus. For example:

$$^{219}_{86}Rn \rightarrow ^{215}_{84}Po + ^{4}_{2}He$$

Alpha decay causes both the mass and charge of the nucleus to decrease:

$$^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e^{-}$$

Nuclear

decay is random so it is not possible to predict which individual nucleus will decay next. But with a large enough number of nuclei it is possible to predict how many will decay in a

Section 6: Half life

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 from a sample containing the isotope to fall to half its original level.

You will not need to remember these!

Half-lives of some

Isotope	Half-life
Potassium-40	1.3 billion years
Carbon-14	5700 years
Caesium-137	30 years
Iodine-131	8 days
Lawrencium-260	3 minutes
Nobelium-252	2.3 seconds

Section 7: Contamination and Irradiation

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 ionising radiation. The irradiated object does not become radioactive.

Source of dose	Effect of dose
Airport security scan, eating a banana, dental or chest x-ray, yearly dose from food	Low risk
Maximum yearly dose permitted for radiation workers, lowest annual dose where increased risk of cancer is evident.	Medium risk
Highly targeted dose used in radiotherapy (single dose)	High risk, but balanced by a likely cure of cancer
Extremely severe dose, received in a nuclear accident	Death probable within 6 weeks
Maximum radiation dose per day found at the Fukushima plant in 2011	Fatal dose; death within 2 weeks
10 minutes exposure to the Chernobyl reaction meltdown in 1986	Death within hours