

Cambridge GCSE Notes  
5054 Physics

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# 1 Electricity and magnetism

## 1.1 Simple magnetism and magnetic fields

## 2 Nuclear physics

### 2.1 The nuclear model of the atom

#### 2.1.1 The atom

The atom consists of a positively charged nucleus. Negatively charged electrons orbit in “shells” around this nucleus.

Alpha particles are very massive<sup>1</sup> and positively charged. When these particles were fired at a thin piece of gold foil at very high speeds, it is seen that most particles pass straight through the gold, barely deflected. However, some do bounce back toward the source of radiation and other directions. This is a result of the positively charged alpha particles being repelled by the like charge of the nuclei of the gold atoms. Most alpha particles continue on their path as atoms are mostly empty space and they travel through that empty space.

#### 2.1.2 The nucleus

The nucleus of an atom consists of two types of subatomic particles: the neutron and proton. Protons are positively charged and it is because of them nuclei gain their positive charge. Neutrons have zero charge but have a mass equal to that of a proton. Electrons orbiting the nucleus have the same charge as a proton, only negative. In atoms with zero charge, the number of protons equals the number of electrons. The negative and positive charges cancel out.

The loss of electrons from an atom causes the protons to be in surplus, resulting in a positively charged atom. The gain of electrons in an atom causes the electrons to be in excess, resulting in a negatively charged atom. Note that these charged states of atoms, called ions, are caused by absence or presence of electrons, the protons cause not charged atoms, as they do not move.

The nucleon number of an atom, also called the mass number, is the number of particles in the nucleus of an atom, in other words, the number of neutrons plus the number of protons. The atomic number or proton number of an atom is simply the number of protons in that atom.

$$A = Z + N$$

where  $A$  is the mass number,  $Z$  is the proton number and  $N$  is the neutron number of an atom. Seeing this equation we can find the number of protons or neutrons from the mass number of an atom given we have at least two of all three values.

For any particle, we can use the following notation to denote its nucleon number and proton number:

$${}^A_Z\text{X}$$

where X is the symbol of the particle.

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<sup>1</sup>They are only massive in the atomic scale, they still weigh next to nothing

An element is a substance with a unique number of protons. It is its number of protons that defines an element. Atoms may exist of the same element with different mass numbers, yet the same number of protons in the nucleus. This is a result of there being a different number of neutrons in that particular atomic nucleus. Such atoms with the same proton number as the element but a different neutron number is said to be an isotope of that element. The number of neutrons for the same element's vary, and so do the number of isotopes per element.

## 2.2 Radioactivity

### 2.2.1 Detection of radioactivity

Radioactivity is caused by release of radiation. This may be in the form of alpha ( $\alpha$ ) or beta ( $\beta$ ) particles or gamma ( $\gamma$ ) radiation. To detect this radiation, we can may use a Geiger-Muller tube and counter which detects radioactive particles and records the rate of particles detected per unit time, known as the count rate. It is measured in counts per second or minute. Cloud chambers may also be used to detect alpha radiation, by seeing the streaks formed in the gas inside the chamber. Spark counters may be used where sparks are formed whenever radioactive particles pass through electrified metal gauze.

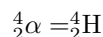
Background radiation is the radiation from the environment to which we are exposed all the time. It comes from many sources, such as the radioactive gas, radon which is in the air, rocks and buildings containing radioactive materials from the earth, our food and drink as what we eat has taken in nutrients from the ground which contains radioactive materials and finally cosmic rays which come from space, mostly from space.

Before detecting radiation, we must first measure the background radiation in that area. Once we have done so we will measure the radiation and subtract the background radiation from the reading gotten as that is the value of the radiation actually being measured.

### 2.2.2 The three types of emission

Emission of radiation is spontaneous, in that it is unpredictable when it will occur or in which direction it will occur.

Alpha particles consist of a pair of neutrons and a pair of protons. They are positively charged with a magnitude of two (+2). They are identical to the nuclei of helium atoms.



above is the nuclide representation of an alpha particle. Alpha particles are not particularly penetrating, and they stop movement within only few centimetres of atmospheric air. It is very ionising<sup>2</sup> because of its large size and relatively slow speed.

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<sup>2</sup>The ability to knock electrons out of orbit, causing absence of electrons, forming ions

Beta particles are high speed electrons that come from the nucleus, they have a mass of zero and a charge of -1.

$${}^0_{-1}\beta = {}^0_{-1}e$$

Beta particles are more penetrating than alpha particles, because of their higher speed. They are also smaller in size and hence collision with a particle is less likely, as a result they are less ionising than alpha particles.

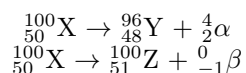
Gamma radiation is a high frequency electromagnetic wave. Gamma waves are very fast and hence they are least likely to interact with a particle, making them the least ionising. But they are the most penetrating of the three for the same reason.

In an electric field, positively charged alpha particles are attracted to the negative charge, and beta particles, being negatively charged are attracted to the positive charge. Alpha particles are less deflected than the beta particles because of its higher mass and hence higher momentum. The both are deflected in opposite directions. The uncharged gamma radiation are unaffected.

The charged alpha and beta particles form a current (rate of movement of charge) when they move. As a result, a force affects these particles when they move through an magnetic field. This force causes deflection of the particles, and it followings the left hand rule. Note that, current is opposite the direction of electron flow. The alpha particles are deflected less, again because of their higher mass. The gamma radiation is unaffected.

### 2.2.3 Radioactive decay

Radioactive decay is the change in an unstable nucleus resulting in the emission of one of the three types of radiation. This decay can be shown using decay equations, where the nucleon numbers for each of the elements sum up to be equal on both sides of the equation, and the same applies for proton numbers. Given below are two decay equations, showing the release of alpha and beta radiation from a nuclide:  ${}^{100}_{50}\text{X}$  into other two nuclides, Y and Z:



### 2.2.4 Fission and fusion

Fusion is the formation of a larger nucleus from the combination of two smaller nuclei, with release in energy. Fusion is the process by which energy is released in stars.

Fission occurs when a nucleus recieves a neutron and splits into two or more daughter nuclei, alongside release in energy.