Nucleons

Protons and Neutrons make up the nucleus. They have a mass of 1 relative to each other but an actual mass of 1.67×10^{-27}kg.

The proton carries a charge of **$+1.6 \times 10^{-19}$C**. In certain calculations you must use the actual values.

Electrons

Are negatively charged

1.6×10^{-19}C

and have a opposite charge to that of a proton.

Specific Charge

When we think about an ion, atom or particle it has what is called a specific charge.

This is a simple idea of the charge C/mass kg so should come out in Ckg^{-1}. So the specific charge on a magnesium ^{24}Mg ion is found by adding all nucleon masses which is **$24 \times 1.67 \times 10^{-27}$kg**. Then the overall ion charge which is **3.2×10^{-19}C** and dividing to produce a value of **$8.04 \times 10^{6} CKg^{-1}$**. You don't add all the charges as they cancel out.

Periodic Table

In the periodic table all atoms have a symbol…

A = mass or protons + neutrons in relative form

i.e. 1+2 = lithium.

Z = proton number.

You must learn these terms!

Probing The Nucleus

Rutherford did an experiment to investigate the nucleus. He fired alpha radiation at the nucleus and found that most went through and a few returned deflected at 180° or near to.

The conclusion was that the nucleus was very small and very positive with a lot of empty space around it

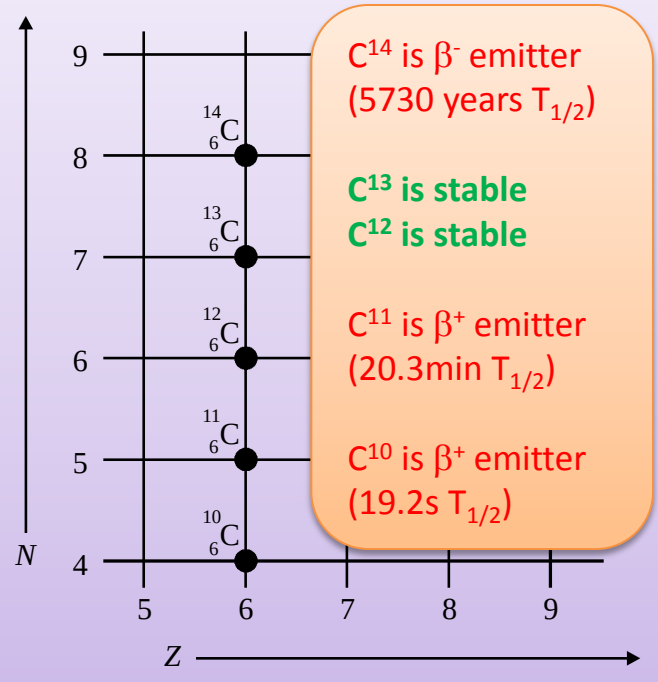
Isotopes

Isotopes are simply elements with more or less neutrons.

This means that they can be more unstable than the ones usually found in the periodic table.

Often Isotopes appear in small % so effect the relative mass of a sample.

Radioactive Carbon



C^{14} is β^- emitter ($T_{1/2}$ = 5730 years)

C^{13} is stable
C^{12} is stable

C^{11} is β^+ emitter ($T_{1/2}$ = 20.3min)

C^{10} is β^+ emitter ($T_{1/2}$ = 19.2s)

Ions

Of course ions will be more tricky at A level. Instead of thinking of the removal of an electron as - -1 or the atoms charge becomes +1 to form a +1 ion i.e. Na^+. Now we think about ions as….

1.6×10^{-19}C -> +1
3.2×10^{-19}C -> +2
4.8×10^{-19}C -> +3

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Strong Force

Acts on nucleons **only** as they contain quarks. It keeps the nucleus stable; short-range attraction to about 3 fm, very-short range repulsion below about 0.5 fm.
This balance causes nucleons to be happy at the distance to make a stable atom.

Electrostatic Force

All charged particles i.e. protons, electrons, positrons, muons etc.. either attract or repel each other.

The force gets very large at small separations.

Alpha Decay

This is where 4 nucleons (2p &2n) split from the nucleus of an atom to make the atom more stable. Z & N become Z-2 & A-4.

Alpha always have the same energy for a particular atom i.e. 5MeV.

Beta (β-) Decay

An atom has a nucleon decay via the weak interaction. A neutron converts to a proton and emits a β^- particle (or e-) and an electron anti-neutrino.
There is symmetry for charge before and after. The particle and anti-particle share the energy of the decay differently for each emission.

Beta (β+) Decay

This is the same process as Beta (β^-) but opposite as a proton converts to a neutron and emits a beta + particle (or e+ positron) and an electron-neutrino.

There is symmetry for charge before and after. The particle and anti-particle share the energy of the decay differently for each emission.

Gamma Decay

A Gamma ray (γ) is emitted from the atom.

It has no charge or mass.

Neutrinos

These are produced in the Sun by the weak interaction (**β+** or **β-** decay).

They have no charge or mass and are not affected by strong or EM force. They are fundamental particles.

Neutrino Flavour

There are three types, or "flavours", of neutrinos: electron neutrinos, muon neutrinos and tau neutrinos.

Each type also has a corresponding antiparticle, called an antineutrino with an opposite chirality.

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EM Waves

Electromagnetic Waves This is energy in the form of waves. The formula to express the speed that an EM wave travels in a vacuum is **$c=f\lambda$.**

The speed is always **$3.00 \times 10^{8} ms^{-1}$**. We often use the suffix of nm for the wavelength visible light i.e. **500nm** or **$500 \times 10^{-9} m$**

Photons

EM waves are produced when a **charged** particle such as an electron collides with atomic electrons to make electrons change shells or very fast electrons are slowed down in matter to produce x-rays. Photons have **zero mass** but carry both **energy** and **momentum.**

Laser Beams

A laser beam is simply a lot of photons all discharged at the same time and in phase with each other. This is a property called coherence. We mean all the ups and down happen at the same time and they are of the same frequency. The power of a laser beam of energy **$E = hf$**..... **$P = nhf$** where n is the number of photons.

Electron Volt

The electron volt is a very simple way of expressing a little quantity of energy. It saves us using tricky figures i.e. **$3.32\ 10^{-19} J = 2.07 eV$.** What we do is simply divide the energy in Joules by the value of the charge on the electron or **$1 \times 10^{-19} JeV^{-1}$.**

Particles

You should know that for every type of particle, there is a corresponding antiparticle.

The positron, the antiproton, the antineutron and the antineutrino are the antiparticles of the electron, the proton, the neutron and the neutrino respectively.

Matter v Antimatter

They have the same mass but opposite charge (if charged).

In the case of hadrons this is because they are made up of anti-quarks.

When matter and antimatter meet they annihilate.

Rest Energy

Sometimes we talk of the rest energy of a particle. This is the energy it takes to form a particle.

Units used are Joules or electron volts. However, we often use MeV or GeV which are 1×10^6eV or 1×10^9eV respectively.

Annihilation

In which a particle and a corresponding antiparticle **collide** and **anni hilate** each other, producing two photons of total momentum and total energy equal to the initial momentum and energy of the particle and antiparticle, including their combined rest energy $2mc^2$.

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Pair Production

In which a high-energy photon produces a particle and its antiparticle.

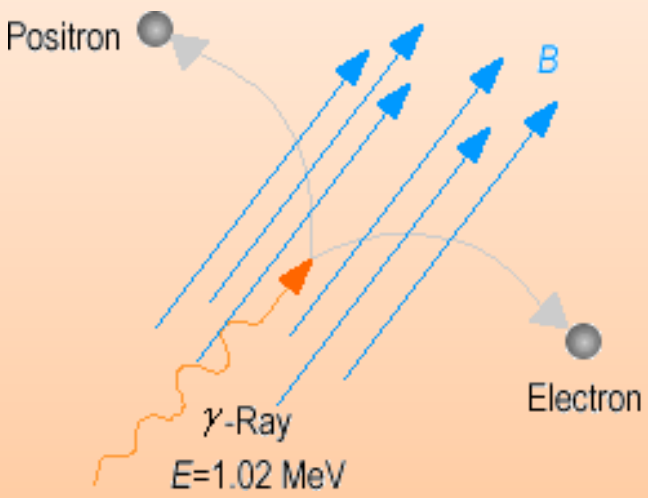
This can only occur if the photon energy **E= hf = hc/λ** is greater than or equal to $2mc^2$, where m is the mass of the particle, with rest energy mc^2 for each particle of the **pair produced**.

Cloud Chambers

These chambers show us charged particles by creating droplets in a saturated gas. The particles can be deflected by a magnetic field and show momentum and charge +/- to an observer.

Carl Anderson found the positron by this method.

Pair Production



PET Scanning

"Positron Emission Tomography" is a process where a radioactive tracer is injected into the body. The body then metabolises the isotope at a certain rate. The isotope then decays and producing a position which decays into two gamma ray photons on hitting an electron. These photons are picked up and mapped to produce 3D images.

EM Force

The Electromagnetic force acts **only** between charged particles.

It is transmitted by the mass-less particle THE PHOTON.

Strong Interaction

Acts between nucleons (protons and neutrons) and is transmitted by the Gauge Boson called the GLUON.

Theory has predicted that there are 8 of them but you don't need to know this.

Weak Interaction

Acts over an even shorter range than the strong interaction. It acts on both Leptons and Hadrons and is transmitted by 3 bosons called; W+, W- and Z Bosons. It is often called "decay" as the particles which are effected by it change into something else.

Gravity

The gauge boson that transmits the gravitational force is the GRAVITON.

This has never as of yet been discovered and is predicted to have zero mass.

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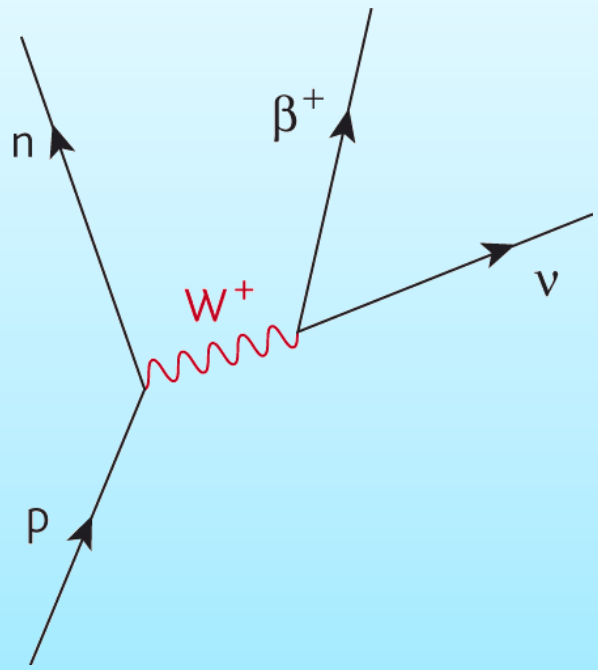
Feynman Diagrams

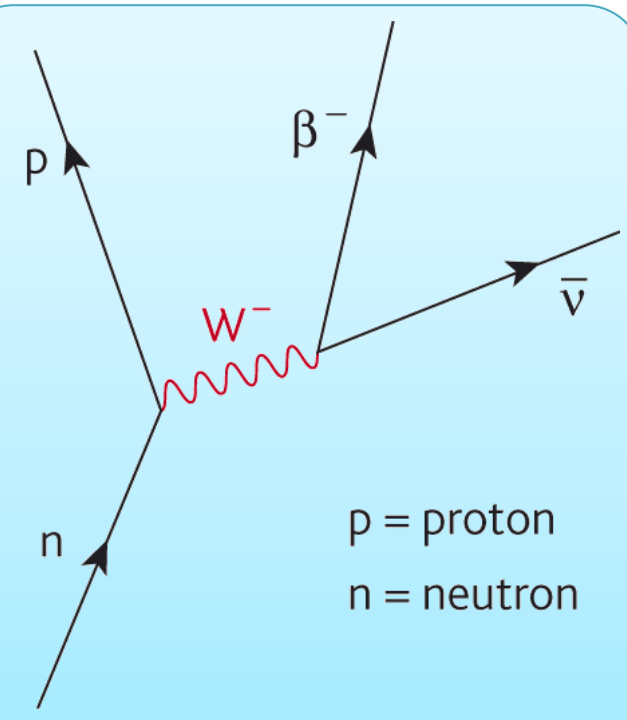
The eminent Physicist Richard Feynman invented a graphical method to represent interactions of particles.

The only thing that really means anything is the time and direction of the arrows. The angles are not significant.

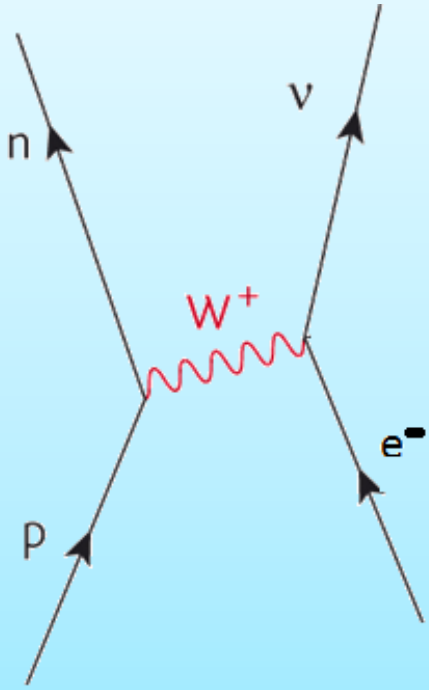
β^+ Decay



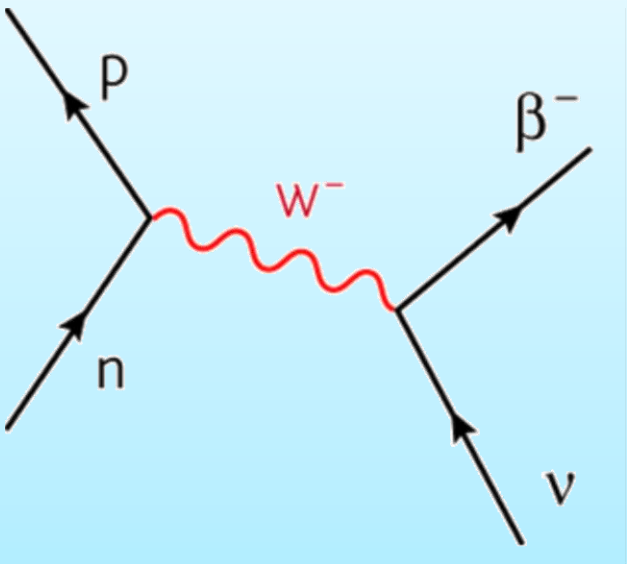
β^- Decay



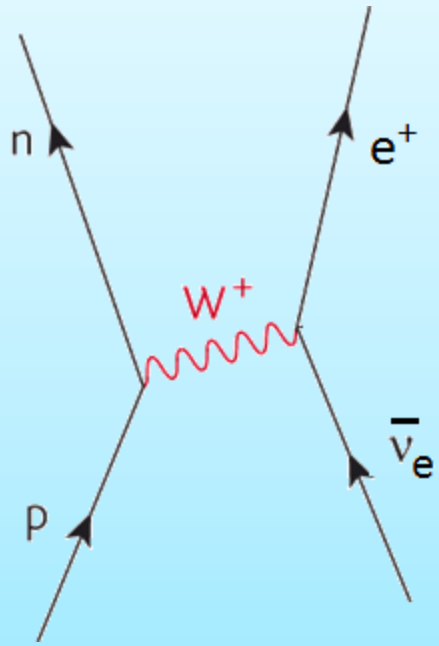
Electron Capture



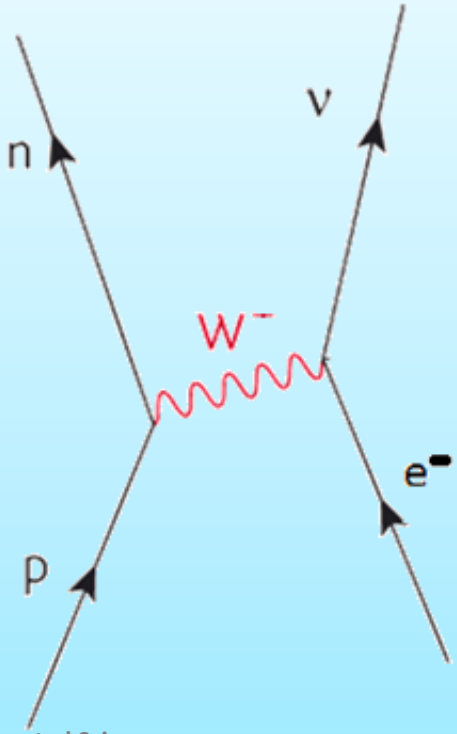
n - neutrino interaction



p - antineutrino interaction



Electron-Proton Collision



W^- / W^+ Boson

The W Boson is an exchange particle which has a very short life time 10^{-27}s so it does not travel very far.

It operates at a distance of 0.001fm.

W^+ / W^- Bosons are exchanged during interactions or decays.

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