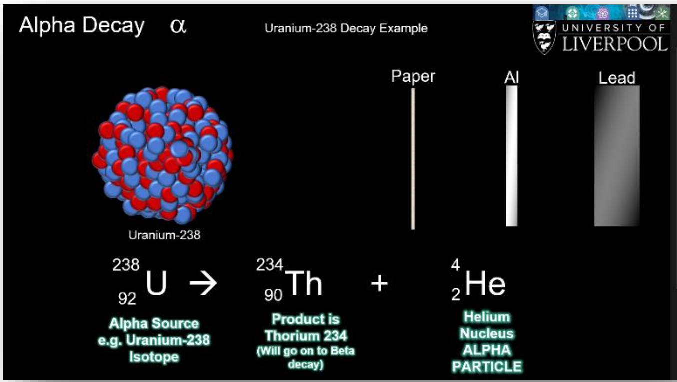
Alpha decay: Uranium – 238 example. (Click to progress animations)

Here is the HUGE Uranium – 238 isotope which we will use to demonstrate alpha decay.

238 nucleons made up of 92 protons and 146 neutrons are tightly packed together in this large nucleus which will undergo an alpha decay into Thorium – 234 like so…



We can see the alpha particle, which is in fact a helium nucleus, being emitted and only travels a short distance in air and can be stopped by thin and light shielding such as paper or skin.

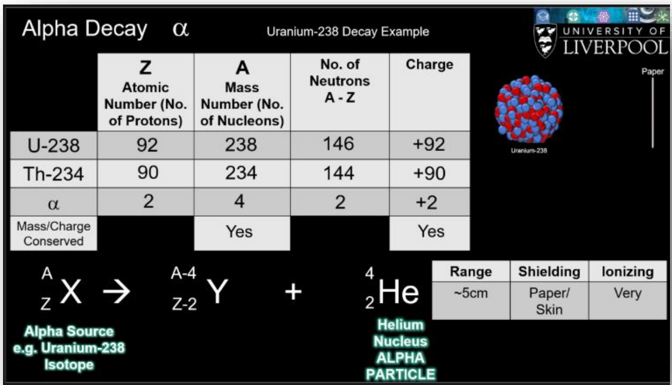
If the alpha particle does encounter another atom, it can ionise it which means knocking electrons free from their orbit leaving the atom with a non-zero net charge due to the imbalance of numbers of protons versus number of electrons.

This can be dangerous if it happens in living cells however this is unlikely even at a relatively close distance to the source.

But what if an alpha source was ingested? The decay would happen inside the body making it almost certain that there would be cell damage.

NEXT SLIDE

Let's check that mass and charge are conserved in this decay…



First, we can see that the atomic number, Z, has changed where 2 protons left the nucleus in the alpha particle.

Now we should verify that the mass has been conserved by checking that the number of nucleons of the products added together match the original Uranium nucleus.

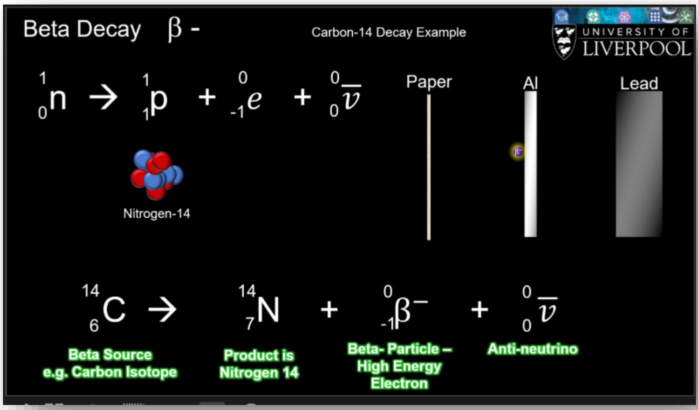
We can also see that the number of neutrons, which we find by subtracting the atomic number Z from the mass number A, has gone down by 2 also with these leaving the nucleus in the alpha particle.

Finally, we can check that charge has been conserved by looking at the charge of the nuclei before and after the decay. He atomic number Z is the number of protons which as we know have a positive charge. We can see that the Uranium lost +2 charge when it decayed into Thorium which is accounted for in the alpha particle.

Here is the general formula for an alpha decay.

Beta - decay: Carbon – 14 example.

Here is the Carbon – 14 isotope which has 6 protons and 8 neutrons making up the 14 nucleons of this nucleus and we will look at an example of this undergoing a Beta – decay.



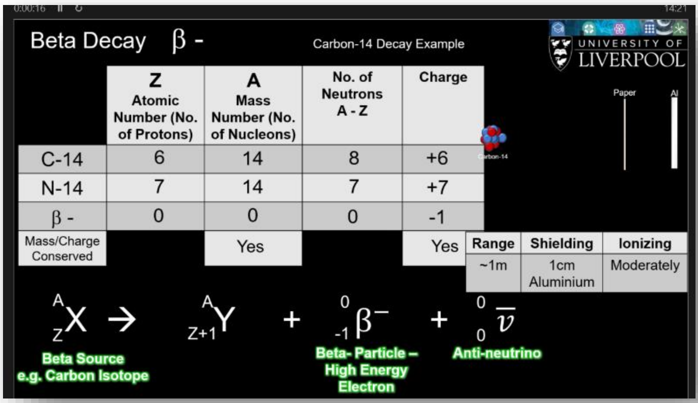
Unlike alpha decay where nucleons left the nucleus, Beta decay involves a nucleon transforming in this case a neutron changes into a proton. The atomic number is what decides what element an atom is so when Carbon gains a proton in the beta – decay it changes into Nitrogen.

The beta – particle that is emitted is in fact a high energy electron which has negligible mass but carries away a negative charge following its creation during the neutron transformation.

The beta - particle is accompanied by an anti-electron neutrino, also created in the nucleon transformation which has no mass or charge and are extremely difficult to detect.

NEXT SLIDE

The range of the beta – particle is about 1 meter; it can be stopped by 1 cm aluminium shielding and it is moderately ionizing.



Let's check that mass and charge are conserved. The atomic number has changed but not due to nucleons leaving the nucleus. The mass number has not changed so mass is conserved and if we account for the -1 charge taken away by the Beta – particle we can see that charge is also conserved since the total charge before the decay was +6 and after is +7-1=+6.

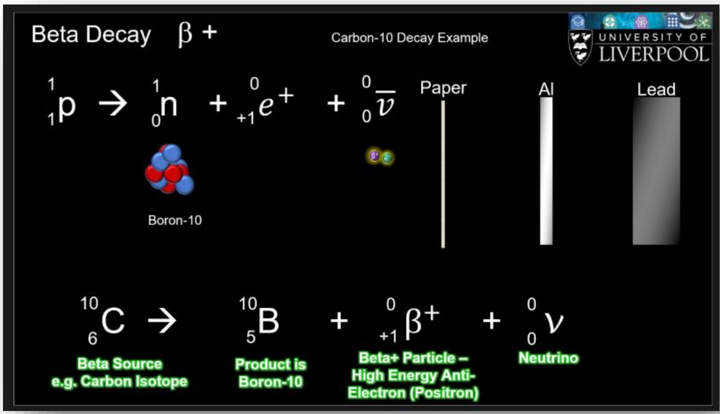
Here is the general formula for Beta- decay.

Beta + decay: Carbon – 10 example.

Here is the Carbon – 10 isotope which has 6 protons and 4 neutrons making up the 10 nucleons of this nucleus and we will look at an example of this undergoing a Beta + decay.

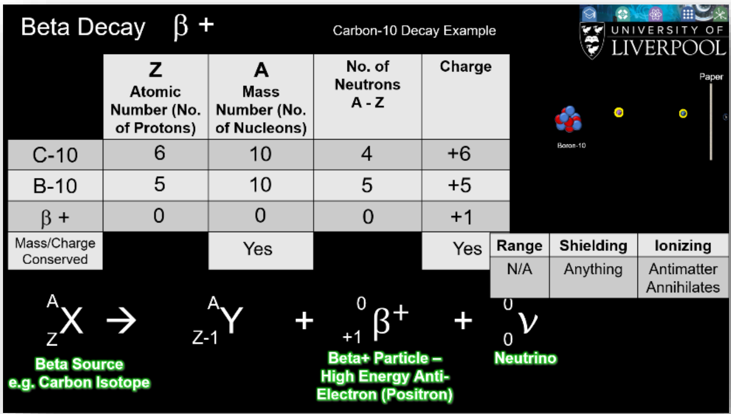
Similarly to Beta- decay, no nucleons leave the nucleus but opposite to beta- decay, Beta+ decay involves a proton transforming into a neutron producing the Beta + particle and an electron neutrino. Due to the atomic number changing the atom becomes Boron-10.

The Beta+ particle is a positron, an anti-electron which will not move very far as it will certainly encounter a normal electron which will result in a matter/antimatter annihilation producing gamma rays.



NEXT SLIDE

Let's check that mass and charge are conserved.



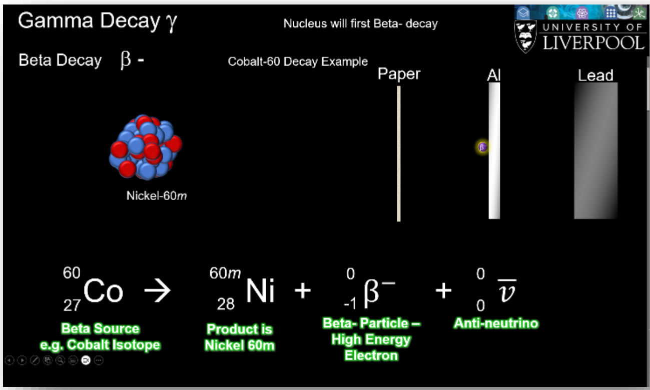
The atomic number has changed because 1 proton transformed into a neutron. The mass number has not changed so mass is conserved and if we account for the +1 charge taken away by the Beta + particle we can see that charge is also conserved since the total charge before the decay was +6 and after is +5+1=+6.

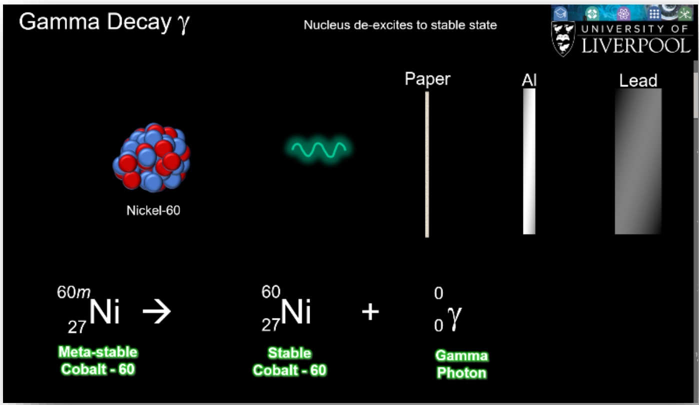
Here is the general formula for Beta+ decay.

Gamma decay: Nickel m metastable to stable state.

Gamma decay is different from the other decay processes in that no particles are emitted from the nucleus but instead electromagnetic radiation. Gamma decay will usually happen following a previous decay in this example, Cobalt-60 decays via beta – decay to Nickel– 60.

The Nickel nucleus is left in an excited state known as metastable which is what the 'm' next to its mass number indicates, sometimes this may be shown as an asterisk.

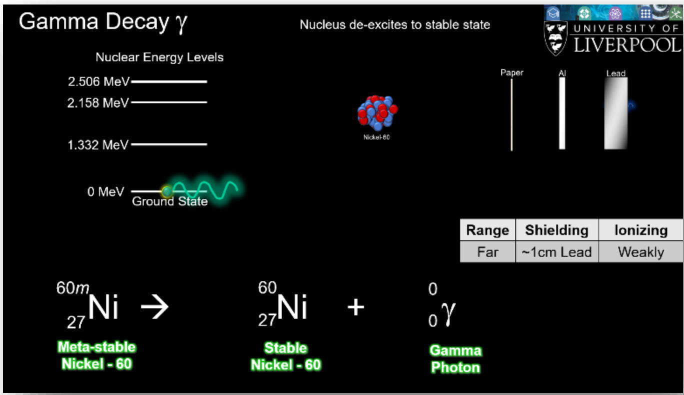




Similarly to the way electrons can enter an excited state then subsequently de-excite releasing EM radiation in the form of X-Rays, nuclear de-excitation releases Gamma rays.

We can see the particles in the metastable Nickel moving very quickly and then slow down with the energy being taken away by the gamma photon.

Gamma radiation travels very far and can pass through most shielding however much can be stopped by about 1 cm of lead, but some will also pass straight though.



There is no need to verify conservation of mass and charge in this case as no nucleons have changed but rather lost energy so we can say that energy is conserved. Again, this energy has come from the nucleons themselves which were left in an excited state following the Beta – decay. Their de-excitation can be seen on this energy level diagram, note the huge amount of energy between the excited states and the ground state are in MeV compared to electron energy levels which are in eV.