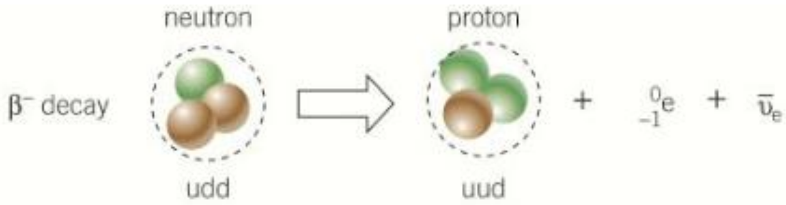
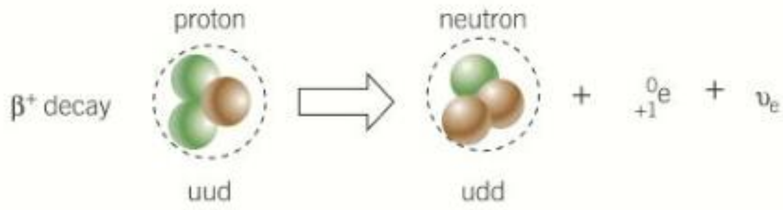
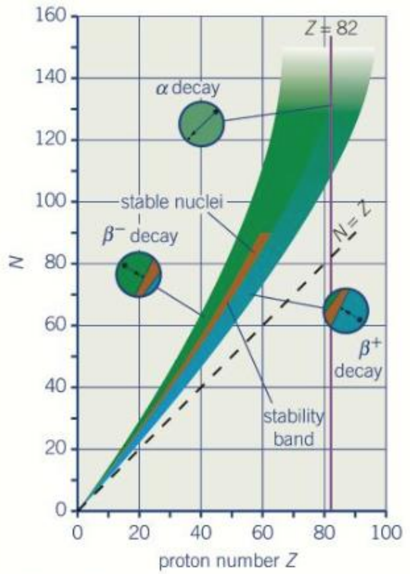
Nuclear Decay Summary

Type of decay	Δ Proton no.	Δ No. Of neutrons	Δ Nucleon (mass) no.	Occurs when
Beta-minus	+1	-1	0	Too many neutrons. Cause is weak nuclear force.
	$^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e + \bar{\nu}_e$ parent nucleus, daughter nucleus • strontium-90: $^{90}_{38}Sr \rightarrow {}^{90}_{39}Y + {}^{0}_{-1}e + \bar{\nu}_e$ • helium-6: $^{6}_{2}He \rightarrow {}^{6}_{3}Li + {}^{0}_{-1}e + \bar{\nu}_e$			 $d \rightarrow u + {}^{0}_{-1}e + \bar{\nu}_e$
Beta-Plus	-1	+1	0	Too many protons. Cause is weak nuclear force.
	$^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e + \nu_e$ parent nucleus, daughter nucleus • potassium-37: $^{37}_{19}K \rightarrow {}^{37}_{18}Ar + {}^{0}_{+1}e + \nu_e$ • fluorine-17: $^{17}_{9}F \rightarrow {}^{17}_{8}O + {}^{0}_{+1}e + \nu_e$			 $u \rightarrow d + {}^{0}_{+1}e + \nu_e$
Alpha	-2	-2	-4	A low ratio of protons to neutrons. This is generally for heavy elements with > 82 protons.
	$^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$ parent nucleus, daughter nucleus			
Gamma	Fission so no change	Fission so no change	Fission so no change	High energy nucleus is de-excited. This maybe following alpha or beta emission.
	$^{A}_{Z}X \rightarrow {}^{A}_{Z}X + \gamma$ Wavelengths usually < 10^{-13}m (high-energy)			

In nuclear reactions: Nucleon number and atomic number (Z) are always conserved. However, Albert Einstein showed, mass and energy are interchangeable - energy released from nuclear reactions is produced from mass.

Radiation	Range in air
Alpha	Very short due to high mass and charge means they are strongly ionising. **Few cm of air** OR **Thin paper**
Beta	Smaller charge and mass so larger range in air (**1m of air). 1-3mm of aluminium** completely absorbs them.
Gamma	No charge so not as ionising as beta or alpha. Huge range in air. **Few cm of lead** to absorb significant amounts of gamma rays.

Patterns for stability



▲ **Figure 3** *N–Z plot of nuclei*

Figure 3 shows a graph of number of neutrons *N* against proton number *Z*. All stable nuclei lie on a very narrow band known as the stability band (brown). The ratio of neutrons to protons in stable nuclei gradually increases as the number of protons in the nuclei increases. Only nuclei with proton numbers less than about 20 are stable with an equal number of protons and neutrons. Most nuclei have more neutrons than protons.

The stability band is surrounded by possible unstable nuclei. You can determine the likely decay of an unstable nucleus from its position relative to the stability band.

- Nuclei with more than 82 protons are likely to decay by emitting alpha particles.
- Nuclei to the right of the band have too many protons (proton-rich) and will likely decay by beta-plus.
- Nuclei to the left of the band have too many neutrons (neutron-rich) and will likely undergo beta-minus decay.

1 The only stable isotope of aluminium is $^{27}_{13}Al$. State and explain whether the isotope $^{29}_{13}Al$ is proton-rich or neutron-rich.

2 The only stable isotope of phosphorus is $^{31}_{15}P$. There are six other phosphorus isotopes with nucleon numbers ranging from 28 to 34. List all six of these isotopes and identify whether they are likely to be β^+ or β^- emitters.

Nuclear reactions are accompanied by a decrease in mass. Overall, total mass-energy is conserved for any system. Since energy is released in radioactive decay, there must be a decrease in mass.

E.g. during alpha decay, the alpha particle and daughter nucleus produced have kinetic energy. The principle of conservation of energy can't explain this, you must use the conservation of mass-energy.