Radioactive decay

SACE says

- “Unstable Nuclei will undergo radioactive decay in which particles and/or electromagnetic radiation are emitted.”
- But, what does that all mean?
- Lets have a wander ... (right back to the start)

Nuclei

- Nuclei is the plural of Nucleus, the centre of an Atom
- Atoms;
  - A unit of matter; the smallest unit of a **chemical** element. Each atom consists of a nucleus, which has a positive charge, and a set of electrons that move around the nucleus. (dictionary.com)
  - Atoms have zero charge (number of protons = number of electrons)
  - Ions have a charge as a result of having more or less Electrons than Protons

Atoms are …

- Made of **Protons** and **Neutrons** in the Nucleus with Electrons in energy levels around it.
  - You knew them as ‘shells’ in year 10
- **Protons** and **Neutrons** are made of **Quarks**, a **fundamental** particle
- **Fundamental** means it is not made of other particles, not that in cannot be created or decay

So what is an ‘unstable nucleus’ ?

- In simple terms, it is any Nucleus that will spontaneously decay.
- Decaying is where
  - Atoms break into different (smaller) atoms
  - Or
  - Sub-atomic particles turn into different subatomic particles
- In both cases energy is released as part of the decay process

An example of an ‘unstable nucleus’ ?

- Some isotopes like He^2(no neutrons) have a half life of $10^{-9} seconds$, Uranium 236 U^{236}has a half life of $2 \times 10^7 years$, **both** are considered “unstable”
  - Remember, half life is how long it takes for half of the sample to decay.

Radioactive Decay

- **Radioactive decay** (also known as nuclear decay, radioactivity, radioactive disintegration or nuclear disintegration) is the process by which an unstable atomic nucleus loses energy by radiation. A material containing unstable nuclei is considered radioactive. (Wikipedia)

NOTE …

- Radioactive decay is all about ‘losing energy by radiation’
- NOT becoming somethings else or breaking up

- The two usually happen together, however, the term “radioactive” refers to radiation
- Dictionary definition;
  - *the emission of energy as electromagnetic waves or as moving subatomic particles, especially high-energy particles which cause ionization.*

Recap

- Radiation. The most common form of radiation is Electromagnetic Radiation.
- Visible light is part of the spectrum of Electromagnetic Radiation. So is gamma radiation, microwave radiation, radio waves, etc.

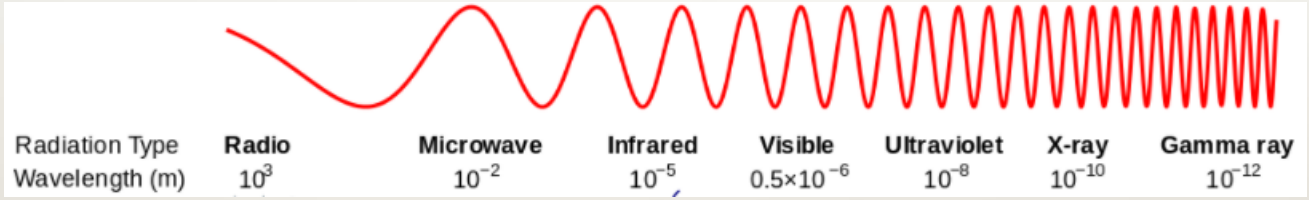


Image courtesy Inductiveload, NASA

There are 3 other ‘common’ types of radiation

- Alpha
- Beta plus
- Beta minus

- In Alpha decay, a nucleus spontaneously emits an alpha particle (2 protons and 2 neutrons). Equal to a helium nucleus.

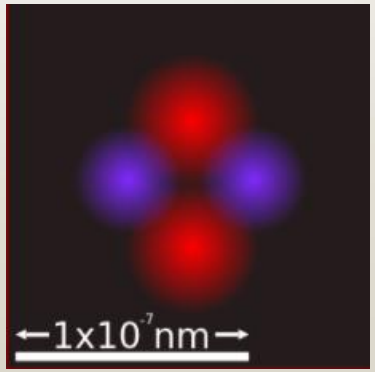


Image courtesy Furmanj

Beta decay (be careful)

- Beta minus decay
  - the Nucleus emits an Electron and an Anti-Neutrino in a process that changes a Neutron to a Proton

$$ {}^{1}_{0}n \rightarrow {}^{1}_{+1}p + {}^{0}_{-1}e + {}^{0}_{0}\overline{\nu}. $$

- Beta plus decay
  - the Nucleus emits a Positron and a Neutrino in a process that changes a Proton to a Neutron (also known as Positron emission).

$$ {}^{1}_{+1}p \rightarrow {}^{1}_{0}n + {}^{0}_{+1}e + {}^{0}_{0}\nu. $$

Sound familiar? – Weak ~~force~~ interaction

- A Neutrino passes close to a Neutron in an unstable isotope and;
  - Becomes a W^+ boson and an Electron
  - The W^+ boson interacts with a Down Quark in the Nucleus and changes it into an Up Quark.
  - An Anti-Neutrino is created in the interaction to conserve spin and energy

So …

- W^+ boson is the weak force particle in Beta minus decay
- Yes read that again ..
- And
- W^- boson is the weak force particle in Beta **plus** decay

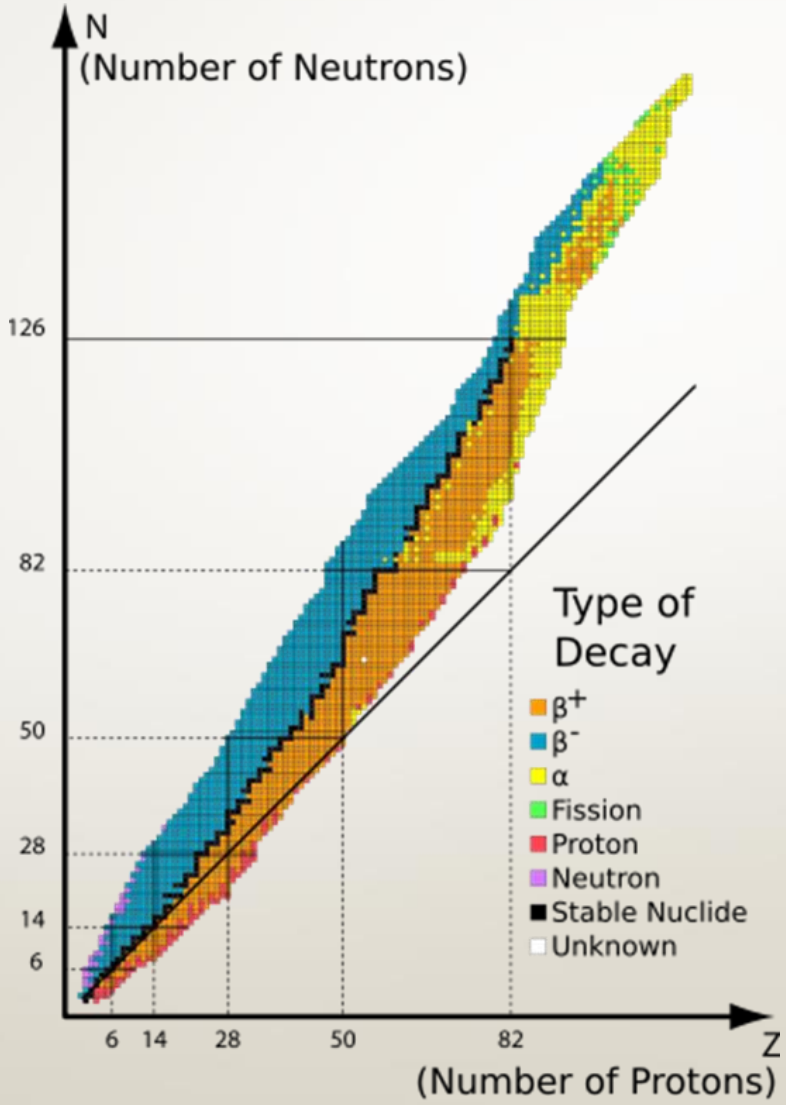
But there is more …

- **Neutron Emission**
  - extremely Neutron-rich Nuclei, lose energy by way of Neutron Emission, resulting in a change from one isotope to another of the same element.
- **Electron Capture**
  - the Nucleus captures an orbiting Electron, causing a Proton to convert into a Neutron in a process. A Neutrino and a Gamma ray is subsequently emitted.
- **Cluster Decay and Nuclear Fission**
  - a Nucleus heavier than an Alpha Particle is emitted.

Summary time

- Radioactive decay is where atoms decay (lose energy) either through;
  - Alpha decay
  - Beta^{+} or Beta^{-} decay
  - Neutron Emission
  - Electron Capture
  - Cluster Decay and Nuclear Fission

NZ Graph


N
(Number of Neutrons)
126
82
50
28
14
6
6
14
28
50
82
Z
(Number of Protons)
Type of Decay
β+
β-
α
Fission
Proton
Neutron
Stable Nuclide
Unknown