Radioactivity 05/11/2022

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GCSE…

What is radioactivity?

Unstable nuclei decaying into more stable atoms.

What are the forms of radioactivity?

- **Alpha α: 2p2n^{2+}, stopped by paper, most ionising**
- **Beta β: high-speed electron, e$^-$, stopped by aluminium, middle-most ionising**
- **Gamma γ: E.M. wave, stopped by lead and concrete, least ionising**

What is half-life?

Amount of time it takes for the half of the total number of radioactive nuclei to decay to their daughter nuclides

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$$

How can we express half-life?

$$\frac{1}{2^n} \times n$$

$$\frac{1}{2^5} \times n = \frac{1}{32} \times n$$

$$\leftrightharpoons$$

$$\log_2(32) = 5$$

Equations:

α: $^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}X + {}^{4}_{2}\alpha$

β: $^{A}_{Z}X \rightarrow {}_{Z+1}{}^{A}X + {}^{0}_{-1}\beta$

γ: $^{A}_{Z}X \rightarrow {}^{A}_{Z}X + {}^{0}_{0}\gamma$

Beyond GCSE…

γ - Why?

Gamma radiation occurs after alpha or beta decay because the atom has excess energy after the decay that must be expelled to return to a ground state.

Isomer = Atom with excess energy, this means it's in an excited state and needs to return to the ground state.

β - Why?

Beta radiation changes the atomic number of an atom due to an underlying physical process. This process is the reason why beta decay actually occurs and is measurable.

In the nucleus of an unstable atom, a neutron changes to a proton, electron and electron antineutrino.

$^{A}_{Z}X \rightarrow {}_{Z+1}^{A}X + {}_{-1}^{0}e + {}_{0}^{0}\overline{\nu}_{e}$ **= normal equation**

$n^{0} \rightarrow p^{1+} + e^{1-} + \overline{\nu}_{e}{}^{0}$ **= in the nucleus**

This change means that the mass number remains unchanged and the atomic number increases by one.

Radioactivity - Why?

Nuclear binding energy = force that holds the nucleus together.

Two forces act upon the nucleus= nuclear binding energy (strong nuclear force) + electromagnetism

Strong nuclear force = holds the nucleus together

Electromagnetism = breaks the nucleus apart

If the strong nuclear force is stronger or weaker than electromagnetism then the nucleus falls apart.

Other decay modes:

- **Proton (p + 2p) = a proton rich nucleus spits out a proton**
- **Neutron (n + 2n) = a neutron rich nucleus spits out a neutron**
- **Beta-plus (β^+) = proton decays to a neutron, releasing a positron and an electron neutrino**
- **Electron Capture (EC, ε + εε) = A deficit of electrons is made up for as the atom captures a neighbouring electron**
- **Spontaneous Fission (SF) = nucleus is too large so splits into two**
- **Cluster Decay (CD) = a large nucleus emits a particle larger than an alpha-particle**

Calculating mass number of stable nuclides:

For early nuclides the neutron number is almost equal to the atomic number. However, for later nuclides there are many more neutrons to protons.