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Introduction

Nuclear transformations accompanied by the (1) emission of electrons.
(2) Some nuclei emit positrons
(3) Sometimes the nucleus captures one of the orbital electrons, mostly from the shell closest to it, the K-shell.

Note - K-Capture is energetically more favourable than the positron emission, it also depends on overlap of the nuclear wave function with the K-electron wave function.

☆ Unlike the line spectrum of α-rays the spectrum of β-rays happens to be continuous.

This continuous nature of β-ray spectrum gave rise to serious difficulties in understanding β-decay

Problem:-
Just like the α-decay, β decay also is an energy transition between two definite energy states (fig. 1)

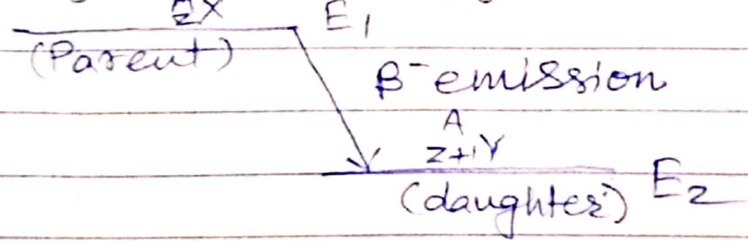

Fig. 1

Thus monoenergetic β-rays (forming a line spectrum) is expected. However observed cont. spectrum implies that electrons emitted during β-decay process do not have the same K.E.

β Radiation -

The portion of the radiation emitted from a radioctive source, that was strongly deflected by perpendicular magnetic field was termed as β-radiation

Modes of β radioactivity:-

1. Negatron Emission (β^- emission)
2. Positron Emission (β^+ emission)
3. Orbital Electron Capture (EC)

* For β decay there is no change in mass no.
* But the product nucleus has atomic no. greater by one unit (for β^- emission)
* β ~~decay~~ Rays are easily distinguished from α-particles by their considerable greater range in matter.
* Product nucleus has atomic number one unit less than of the parent nucleus. (for β+ emission)

β^- process (Negatron Emission)

When a radioactive element emits a β- particle, the product has the same mass no. as the parent, but its atomic no. is greater by one unit.

$$ {}^{A}_{Z}Mc^2 = {}^{A}_{Z+1}M^+c^2 \text{ (positive ion)} + m_0c^2 + Q_{\beta^-} $$

β^- process increases the nuclear charge by one unit with number of

atomic electrons unchanged.
If B be the Binding energy of the last atomic electron, then we have

$$ {}^{A}_{Z+1}Mc^2 = {}^{A}_{Z+1}M^{+}c^2 + m_0c^2 - B $$

$$ \boxed{Q_{\beta^-} = {}^{A}_{Z}Mc^2 - {}^{A}_{Z+1}Mc^2 - B} $$

β^+ process (Positron Emission)
when a positron is emitted the mass number is still unchanged but the atomic number of product is one unit less than that of the ~~prod~~ parent.

$$ {}^{A}_{Z}Mc^2 = {}^{A}_{Z-1}M^{-}c^2 \text{ (negative ion)} + m_0c^2 + Q_{\beta^+} $$

β^+ process decreases the nuclear charge by one unit. The rest energy of the negative ion formed is given by

$$ {}^{A}_{Z-1}M^{-}c^2 = {}^{A}_{Z-1}Mc^2 + m_0c^2 - B $$

$$ \boxed{Q_{\beta^+} = {}^{A}_{Z}Mc^2 - {}^{A}_{Z-1}Mc^2 - 2m_0c^2 + B} $$

EC Process :-
When the ratio of neutrons to protons is low, another type of decay known as orbital electron capture process has been found to occur.
In this process electrons from the first (usually) or any other atomic quantum level is captured by the nucleus which combines immediately with a proton to form a neutron.
The product of this type has the same mass number as its parent but its atomic number would be one unit lower as in the case of β^+ process.

$$ {}^{A}_{Z}Mc^2 = {}^{A}_{Z-1}M^*c^2 \text{ (neutral but excited)} + Q_{EC} $$

The Q value of EC process

$$ Q_{EC} = {}^{A}_{Z}Mc^2 - {}^{A}_{Z-1}Mc^2 - E_B + B $$

E_B is the ionisation/binding energy of the atomic captured electron.

Qu. How do we acquire beta decay with the hypothesis that nuclei contain only neutrons and protons

It is imagined that the electron are created at the time of emissions (similar to photons) from excited states. Then the 3 modes of beta radio activity can be shown as :-

$$ {}_0n^1 \rightarrow {}_{+1}p^1 + {}_{-1}e^0 \quad (\beta^- \text{ emission}) $$

$$ {}_{+1}p^1 \rightarrow {}_0n^1 + {}_{+1}e^0 \rightarrow (\beta^+ \text{ emission}) $$

$$ {}_{+1}p^1 + {}_{-1}e^0 \rightarrow {}_0n^1 \quad (\text{EC process}) $$

Above eqs. emphasize that the protons and neutrons can be treated as different states of single particles, known as nucleon, and the electrons play a photons like role.