BETA AND GAMMA DECAY

Lecture 11-IV
Three types of beta decay

There are three decays which change the atomic number $Z$ by 1, while leaving the mass number unchanged:

- $\beta^-$ decay: nucleus emits an electron, $Z \rightarrow Z + 1$

- $\beta^+$ decay: nucleus emits a positron, $Z \rightarrow Z - 1$

- Electron capture: nucleus captures a (usually inner shell) electron, $Z \rightarrow Z - 1$
Energetics of beta decay

Q value
The energy difference between the parent nucleus and decay products is denoted by Q.

$$Q = [m_p - (m_d + m_e)]c^2$$

For beta decay to occur, the mass of the decay products must be less than the mass of the parent.

$$m_p > (m_d + m_e)$$

Source: Montemayor
Energetics of beta decay

Beta decay of copper

Source: Montemayor
Conservation of momentum in beta decay

Beta decay of He-6
Fundamental processes

\[ n \rightarrow p + \beta^- + \bar{\nu}_e \quad \beta^- \text{ decay} \]

\[ p \rightarrow n + \beta^+ + \nu_e \quad \beta^+ \text{ decay (for bound proton)} \]

\[ p + e^- \rightarrow n + \nu_e \quad \text{electron capture} \]
\( \quad \text{(for bound proton)} \)
All particles* have a corresponding “anti-particle”, symbolized by placing a bar over the particle symbol.

<table>
<thead>
<tr>
<th>Particle</th>
<th>Symbol</th>
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<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>proton</td>
<td>$p$</td>
<td>antiproton</td>
<td>$\bar{p}$</td>
</tr>
<tr>
<td>neutron</td>
<td>$n$</td>
<td>antineutron</td>
<td>$\bar{n}$</td>
</tr>
<tr>
<td>electron</td>
<td>$e^-$</td>
<td>positron</td>
<td>$e^+$</td>
</tr>
<tr>
<td>neutrino</td>
<td>$\nu$</td>
<td>antineutrino</td>
<td>$\bar{\nu}$</td>
</tr>
</tbody>
</table>

*The jury is still out for neutrinos, which may be their own antiparticle.
Gamma decay

After emission of an alpha or beta particle, a nucleus is often left in an excited state. The nucleus can return to the ground state via emission of a photon.

Generic equation:

\[ \frac{AX}{Z}^* \longrightarrow \frac{AX}{Z} + \gamma \]
Example: Gamma decay

Do a quick “back-of-the-envelope” calculation to make a rough estimate of photon energies emitted in atomic and nuclear transitions.

**Typical sizes**
atom: $10^{-10}$ m
nucleus: $10^{-15}$ m

\[
\Delta p_x \Delta x \approx \frac{\hbar}{2}
\]

\[
\Delta p_x^2 = p^2 - \bar{p}^2
\]

Result: $E \sim 5$ MeV