Alpha Decay
L11-III
Discovery of Radioactivity

Radioactivity was discovered by Becquerel in 1896. Experiments soon established that radiation consisted of at least three different types, called \( \alpha \), \( \beta \), and \( \gamma \) radiation, depending on how easily they penetrated matter.
## Types of Radioactivity

<table>
<thead>
<tr>
<th>emission</th>
<th>charge</th>
<th>mass</th>
<th>identity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>$+2e$</td>
<td>$4m_p$</td>
<td>He nucleus</td>
</tr>
<tr>
<td>$\beta$</td>
<td>$-e$</td>
<td>$m_e$</td>
<td>electron</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0</td>
<td>?</td>
<td>EM radiation</td>
</tr>
</tbody>
</table>

![Diagram of radioactive source with emissions](image)
Alpha Decay

**Generic Decay Equation**

\[ \frac{AX}{Z} \rightarrow \frac{A-4}{Z-2}Y + \frac{4}{2}\text{He} \text{ or } \frac{AX}{Z} \rightarrow \frac{A-4}{Z-2}Y + \frac{4}{2}\alpha \]

**Energetics**

It is found experimentally that \(\alpha\) particles are emitted with energies in the range from about 4 MeV to 9 MeV. (All \(\alpha\) particles from the same nuclide have the same energy.)
Alpha-particles of energy 8.6 MeV scattering off U-238 nuclei are readily described by the Rutherford scattering formula (Coulomb scattering), so the potential energy curve must be Coulombic, and yet $\alpha$ particles of energy 4.2 MeV are emitted by U-238 as it transforms to Th-234! How do these lower-energy emitted particles overcome a potential barrier of at least 8.6 MeV?
Example 1. Alpha Decay of Polonium-212

Polonium-212 decays by alpha emission with a half-life of 0.3 μs. The energy of the emitted α-particle is measured to be 8.9 MeV. We wish to model the emission of the α-particle.
Example 1.

(a) Write down the decay equation for Po-212 using full isotopic notation.
Example 1.

(b) Find an approximation to the height of the Coulomb barrier potential, $U_0$. 

http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html
Example 1.

(c) Find the width of the barrier, $a$, that must be penetrated by the 8.9 MeV alpha particle in order to escape the nucleus.
Example 1.

(d) What is the approximate speed of the alpha particle within the nucleus?
(e) What is the frequency with which the confined alpha particle strikes the potential barrier?
(f) Find an approximation for the probability of transmission of the alpha particle through the potential barrier.

Tipler, Chapter 6:

\[ P_T \approx \frac{16E}{U_0} \left(1 - \frac{E}{U_0}\right) e^{-2ka} \quad \text{if } ka \gg 1 \]

where

\[ k = \frac{\sqrt{2m(U_0 - E)}}{\hbar} \]

\[ u(x) \]

\[ u_0 \]

\[ a \]
Example 1.

(g) What is the probability per second for the emission of an alpha particle?

(h) What is the approximate value for the half-life of the alpha emission from Po-212 under the assumptions of this model? What do you conclude about the model? What improvements could be made?