BETA DECAY SPECTROMETER

**Purpose:**
We will measure electron energy spectrum for two radioactive beta emitters, Sr90 and Tl204. The average $Q$ and endpoint energy will be observed. The spectrum is not monochromatic, but is characteristic of a 3-body decay where the beta may take on a spectrum of energies.

\[ P \rightarrow D + e^- + \nu \quad \text{Parent} \rightarrow \text{Daughter} + \text{beta}^- + \text{neutrino} \]

The $Q$-value of the decay is the total kinetic energy available to the decay products.

\[ Q = M(P) - M(D) - M(e) - M(\nu) \]

$Q$ is shared equally amongst the three decay products, so

\[ <Q> = Q/3 \]

The maximum $T_{max}$ a decay product may receive is $Q$!

\[ T_{max} = Q \text{ (endpoint)} \]

Thus by measuring the electron's kinetic energy spectrum of we can determine $T_{max} = Q$.

![Energy spectrum of electrons emitted in the beta decay of Bi$^{115+}$](image)

**(1) HV Plateau** Before using the beta spectrometer with the GM tube you should find the GM tube operating voltage by moving the source to the zero +70° position and record the number of counts per 10-minute interval, each 100V between 300 V and 800V.

Graph the result and identify the plateau region. The Geiger tube voltage should be set to a value about 20% past the onset of the plateau.

<table>
<thead>
<tr>
<th>V</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>700</th>
<th>800</th>
<th>900</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
(2) Take counts per 10 minute interval each 10 degrees (0 to +90 degrees).

<table>
<thead>
<tr>
<th>Angle</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counts/10m</td>
<td></td>
<td></td>
<td></td>
<td></td>
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(3) Graph the number of counts above background per energy interval versus electron kinetic energy. \( dN/dE vs T \).

\[
\frac{dN}{dT} = \left( \frac{dN}{d\theta} \right) \left( \frac{d\theta}{dT} \right) \quad \text{with} \quad \left( \frac{d\theta}{dT} \right) \cdot \Delta \theta = \frac{5^0}{T(\theta + 2.5^0) - T(\theta - 2.5^0)}
\]

(See BetaCalculator.xls on web site.)

Determine the endpoint energy \( Q \) where the energy spectrum merges in to the background.

**Derivation of Kinetic Energy Equation**

\[
T = E - mc^2 \quad \text{and} \quad p = qBr = eBr \tan \left( \frac{\theta}{2} \right)
\]

\[
T = \sqrt{p^2c^2 + m^2c^4} = mc^2 \left( \frac{pc}{mc^2} \right)^2 + 1 - 1 = mc^2 \left( \frac{eBR}{mc \tan \left( \frac{\theta}{2} \right)} \right)^2 + 1 - 1
\]

with \( \frac{eBR}{mc} = 1.131 \)

\[
T = 0.511 \left( \frac{1.131}{\tan \left( \frac{\theta}{2} \right)} \right)^2 + 1 - 1 \text{ MeV}
\]