Project 3: Proton emission

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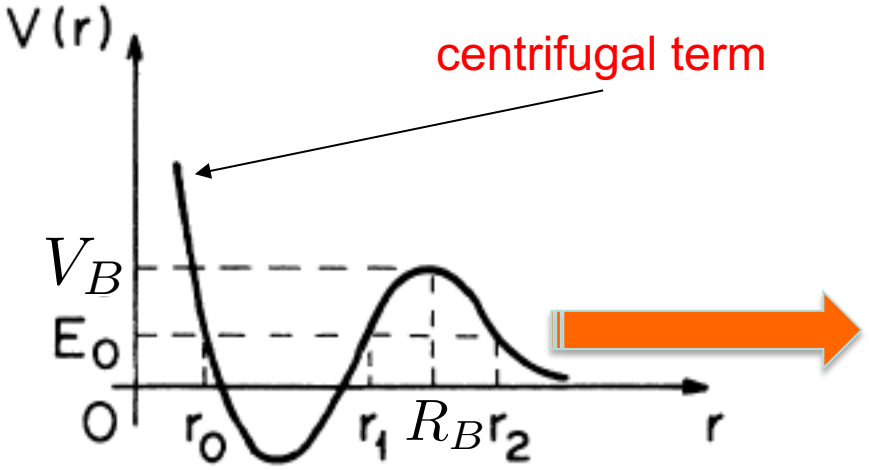

$$\Gamma = S_p \mathcal{N} \frac{\hbar^2}{4\mu} \exp\left\{-2\int_{r_1}^{r_2} |k(r)| dr\right\} \qquad T_{1/2} = \hbar \ln 2/\Gamma$$

proton spectroscopic factor

$$\hbar k(r) = \sqrt{2\mu[E_0 - V(r)]} \qquad \frac{1}{\mathcal{N}} = \frac{1}{2}\int_{r_0}^{r_1} \frac{dr}{k(r)}$$

The interaction between the odd proton and the core nucleus is given by the Woods-Saxon optical potential:

$$V(r) = V_{\rm WS} + V_{\rm Coul} + \frac{\hbar^2}{2\mu r^2}\ell(\ell+1)$$

$$V_{\rm WS} = -V_0 f_{\rm WS}(r) + V_{\rm so}\left(\frac{\hbar}{m_\pi c}\right)^2 \frac{2}{r}\left[\frac{d}{dr} f_{\rm WS}(r)\right](\vec{\ell}\cdot\vec{s})$$

$$f_{\rm WS}(r) = \frac{1}{1+\exp[(r-R)/a]}$$ Woods-Saxon form factor

$$V_{\rm Coul}(r) = \begin{cases} \frac{Ze^2}{r} & \text{for } r > R \\ \frac{Ze^2}{2R}\left[3 - \left(\frac{r}{R}\right)^2\right] & \text{for } r \le R \end{cases}$$

Take: $e^2 = 1.4399764\,\text{MeV fm},\ a = 0.7\,\text{fm},\ \left(\frac{\hbar}{m_\pi c}\right)^2 \approx 2.044\ \text{fm}^2$

Assume: $V_0 = 54\,\text{MeV} \quad R = 1.2A^{1/3}\,\text{fm},\ V_{\rm SO} = 0.2V_0$

1. Assuming S_p=1 compute partial decay half-lives for proton emission for the following cases:

Nucleus	Q_p (keV)	Orbit	$t_{1/2}^{exp}$
$^{109}_{53}I_{56}$	829 ±4	$1d_{5/2}$	(100 ±5) μs
$^{112}_{55}Cs_{57}$	823 ±7	$1d_{5/2}$	(500 ±100) μs
$^{113}_{55}Cs_{58}$	977 ±4	$1d_{5/2}$	(17 ±2) μs
$^{146}_{69}Tm_{77}$	1140 ±5	$0h_{11/2}$	(235 ±27) ms
	1210 ±5	$0h_{11/2}$	(72 ±23) ms
$^{147}_{69}Tm_{78}$	1071 ±3	$0h_{11/2}$	$(2.7\ ^{+2.4}_{-0.9})$ s
	1132 ±4	$1d_{3/2}$	(360 ±40) μs
$^{150}_{71}Lu_{79}$	1283 ±4	$0h_{11/2}$	$(40\ ^{+30}_{-20})$ ms

$$E_0 \approx Q_p,\ \mu = m_p$$

2. For ^{147}Tm, plot $T_{1/2}$ (in a $\log_{10}$ scale) as a function of Q_p-value for several values of l. Discuss the result.
3. Using computed and experimental half-lives, extract the spectroscopic factors
4. Compute the neutron decay width for a neutron in a $h_{11/2}$ shell in a nucleus with A=150 as a function of E_0. Discuss the result.