potential energy for two nucleons

\[ V(r) = \frac{1}{2} \frac{\alpha}{r} + \frac{1}{2} \frac{\alpha}{r^2} \]

at large distances

\[ H = \frac{p^2}{2m} + V(r) \]

\[ p = \frac{\hbar}{2\pi} \]

\[ H \Psi(r, \theta, \phi) = \mathcal{E} \Psi(r, \theta, \phi) \]

\[ \Psi(r, \theta, \phi) = Y_l(m) Y_l(m) Y_l(m) \]

or

\[ \Psi(r, \theta, \phi) = Y_l(m) Y_l(m) Y_l(m) \]

\[ \mathcal{E}_{ijk} = (l+i+k+\frac{3}{2}) \hbar \omega - \mathcal{E}_0 \]

atomic physics:

\[ m = 1 \quad l = 0 \quad \text{lowest state} \]

\[ m = 0 \quad l = 1 \quad m = 0, 1, 2 \]

\[ m = 2 \quad l = 2 \quad m = -2, -1, 0, 1, 2 \]

nuclear physics:

\[ m = 1 \quad l = 1 \quad \text{same energy level} \]

\[ m = 1 \quad l = 2 \]

\[ m = 2 \quad l = 0 \]

\[ n = 1 \quad l = 3 \quad n = 2 \quad \mathcal{E} = 1 \]

\[ n = 2 \quad \mathcal{E} = 0 \]
Nucleus (possible nucleons in nucleus)

$m = 1, l = 0$ lowest energy level

up to 2 protons + 2 neutrons \(\rightarrow\) $^4$He

$m = 1, l = 1$ next energy level

+ up to 6 p + 6 n \(\rightarrow\) $^{16}$O

Another quantum number $j = \frac{1}{2}$ spin between antiparallel and parallel $s, l, J (J = 3)$

$^{12}$C

$\rightarrow$ magic number: 2, 8, 20, 28, 50, 82, 126

See nuclear level scheme graph

lead heaviest stable nucleus possible: 82 p, 126 n

Decays

$^{12}$C \(\rightarrow\) excited nucleus

absorption $^{12}$C bombarded with gamma ray $^{12}$C*

spontaneous emission of $^{12}$C emits a gamma ray

See graph, evidence for excited state

In decay of $^{232}$Th decay by $\beta$ decay to $^{232}$Pa which emits $\gamma$ emission
Excited state $\rightarrow \gamma$ emission

Fission

$\alpha$-Decay

Tunneling

In quantum mechanics there exists a probability particle can be found outside nucleus.

$\tau = \text{life time}$

$N = \text{number of Nucleons}$

\[ \frac{dN}{dt} = \frac{1}{\tau} N \]

\[ N(t) = N_0 e^{-t/\tau} \]