Shell structure

when the number of protons or neutrons is

2, 8, 20, 28, 50, 82, 126

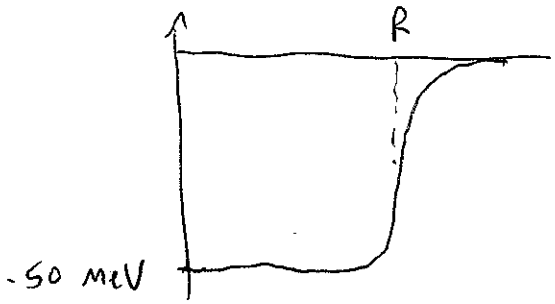
the nucleus is more stable against decay.

these are 'magic numbers'

if both are 'magic' then nuclei are particularly stable

this is a signature of 'shell structure'

Assume a nuclear Independent Particle Approximation with potential



R ~ nucleus size

Calculate numerically the energy levels

for each l (s, p, d, f ..)

n can take on any value $n = 1, 2, 3, \ldots$

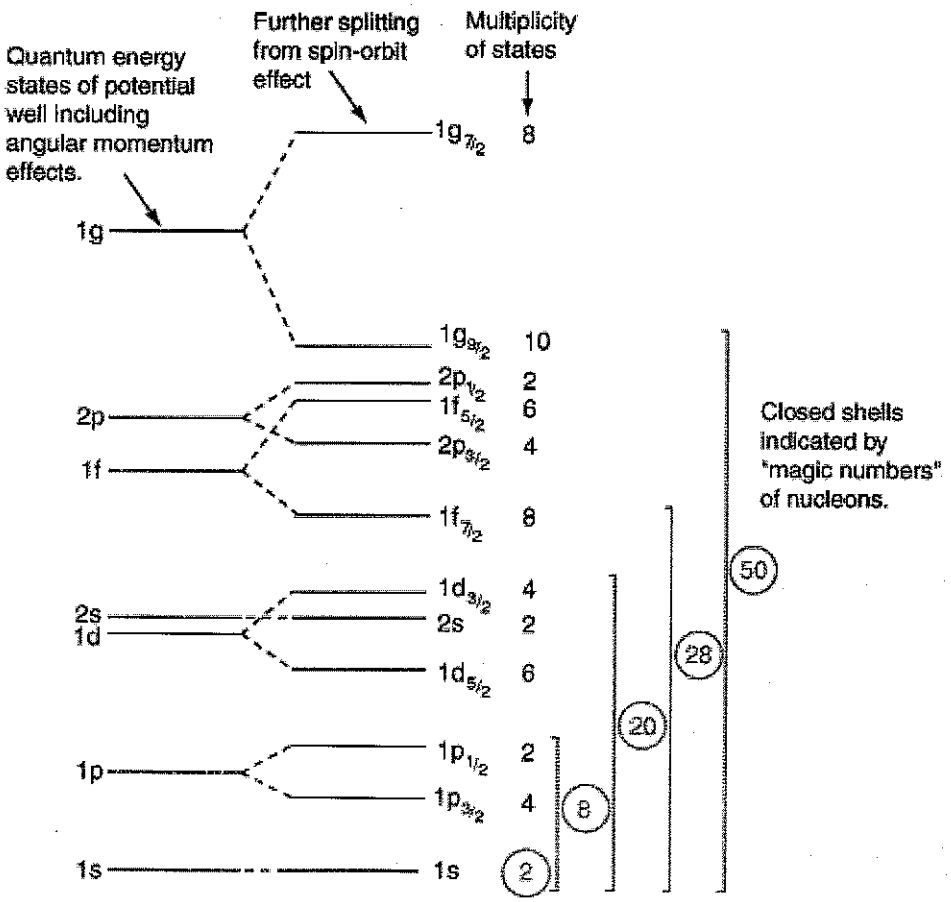
example - we can have 1p state.

The strong force gives rise to a spin-orbit interaction

Energy levels are split by value of $\tilde{J}$

$$\tilde{J} = \tilde{L} + \tilde{S}$$

calculated levels with splitting



alpha decay

$$Q = (M_P - M_D - m_\alpha)c^2$$

M_P: mass parent, M_D: mass daughter, m_α: mass alpha

$Q > 0$ for alpha decay

momentum conservation

$$p_D = p_\alpha = p$$

energy conservation

$$Q = \frac{p^2}{2M_D} + \frac{p^2}{2m_\alpha}$$

$$\frac{p^2}{2m_\alpha} = E_K = \frac{Q(A-4)}{A}$$ ← Kinetic energy of α

Beta decay

electron emitted is β^- decay

$$n \rightarrow p + e^- + \bar{\nu}_e$$

$\bar{\nu}_e$: electron anti-neutrino

$$p \rightarrow n + e^+ + \nu_e$$

e^+: positron, ν_e: electron neutrino

not possible for a free proton from energy conservation

Gamma Decay

Nucleus is left in an excited state after a decay

$$^{Z}_{A}N^{*} \longrightarrow {}^{Z}_{A}N + \gamma$$

$^{Z}_{A}N^{*}$: excited nucleus

$^{Z}_{A}N$: ground state nucleus

$E_\gamma \sim MeV$

Electron Capture

$$^{231}_{93}Np_{138} + e^{-} \longrightarrow {}^{231}_{92}U_{139} + \nu_e$$

Results leave an empty electron orbit in inner shell. Electronic transition gives off x-ray, or ejects electron - Auger electron

Four Radioactive series starting from

Thorium	^{232}Th	^{208}Pb
Neptonium	^{237}Np	^{209}Bi
Uranium	^{238}U	^{206}Pb
Actinium	^{235}U	^{207}Pb
	↑ Parent	↑ end product