MIE407 Nuclear Reactor Theory & Design

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Nuclear Stability:

- Stability of nucleus is the result of the balance between the strong nuclear force and the electromagnetic force.
- Range of the strong nuclear force is about $1\,\mathrm{fm}$ (femtometre, $10^{-13}\,\mathrm{cm}$)
- The strong nuclear force acts equally between protons and neutrons, but neutrons also reduce repulsions between protons by pushing them further apart from each other.
- Fermi approx: $r = R_0 A^{1/3}$ where $R_0 = 1.2\,\mathrm{fm}$
- The strong nuclear force is repulsive at very small distances, which contributes to the incompressibility of the nucleus.
- The strong nuclear force is insignificant at larger than around 4 proton diameters.

Nuclear Binding Energy:

- The binding energy of a nucleus can be found by calculating the mass defect of the nucleus compared to the mass of the unbound nucleons.

$$E_B = [Zm_p + (A - Z)m_n - m]c^2 \equiv \Delta M \times c^2 \tag{1}$$

- The binding energy is usually expressed as the average binding energy per nucleon $\varepsilon = E_B/A$.
- $1\,\mathrm{u}$=$931.5\,\mathrm{MeV/c^2}$

Compound nucleus decay modes:

- Neutron capture (n, γ): Nucleus decays to a lower energy state by emitting some gamma rays. $n +^A X \to^{A+1} X^* \to^{A+1} X + \gamma$
- Elastic scattering (n, n'): Neutron is re-emitted after leaving the nucleus in the ground state.
- Inelastic scattering $(n, n'\gamma)$: Neutron (usually high energy) is re-emitted at a lower energy, leaving the nucleus in an excited state. Then, the nucleus emits some gamma rays to return to the ground state.
- Fission (n, f): Nucleus splits into two fragments with approx. $2:3$ mass ratio.
- Particle emission $(n, \alpha), (n, p), (n, kn)$: A particle other than a neutron, or multiple neutrons are emitted. Only occurs with very high energy neutrons. Hence, only a small number of $(n, 2n)$ reactions occur in nuclear reactors.