# 8.701

Introduction to Nuclear and Particle Physics

Markus Klute - MIT

9. Nuclear Physics

9.7 Fission

# Spontaneous Fission

---

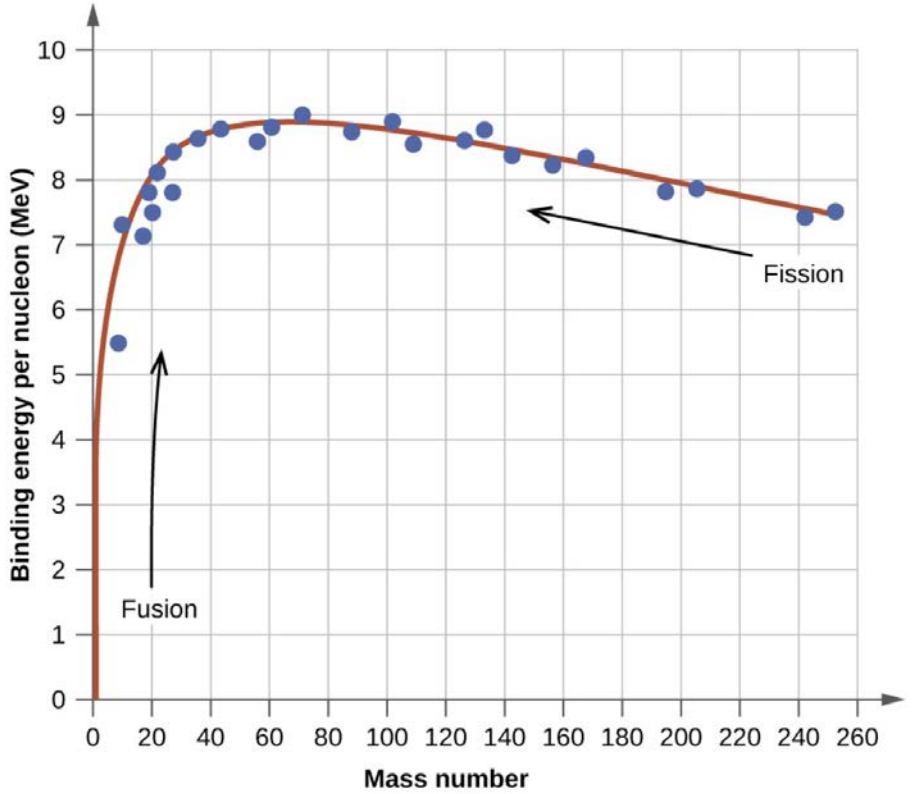
Occurs for very heavy nuclei

Parent nucleus breaks into two daughter nuclei

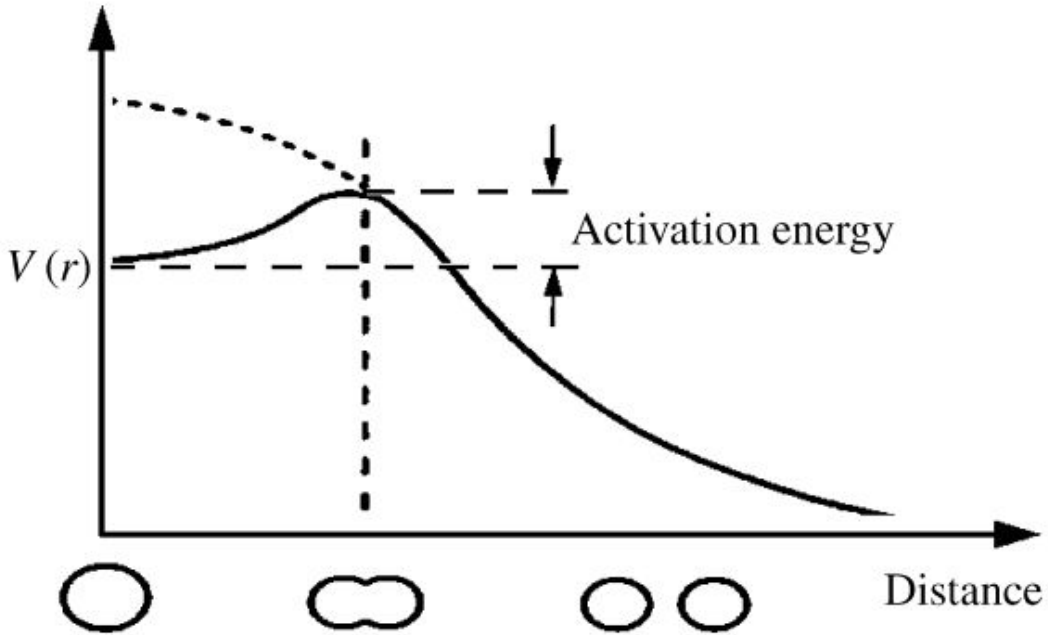
Semi-empirical mass formula predicts maximum energy for daughter nuclei of roughly equal mass

Example

$$^{238}_{92}\mathrm{U} \rightarrow {}^{145}_{57}\mathrm{La} + {}^{90}_{35}\mathrm{Br} + 3n$$



# Induced Fission



# Induced Fission

Neutrons with near zero kinetic energy can excite the compound nucleus.

For example, a zero-energy neutron entering $^{235}U$ forms a $^{236}U$ with 6.5 MeV excitation energy and quickly undergo fission.

Fission fragments carry away about 180 MeV per fission

Prompt neutrons are produced in addition to the fission fragments. For $^{235}U$ the number varies between 0 and 6 with an average of 2.5.

Fragments will often decay further releasing additional neutrons

# Chain Reaction

---

Sustained chain reaction possible

$$k \equiv \frac{\text{number of neutrons produced in the } (n+1)\text{th stage of fission}}{\text{number of neutrons produced in the } n\text{th stage of fission}}$$

k = 1  critical

k < 1  subcritical

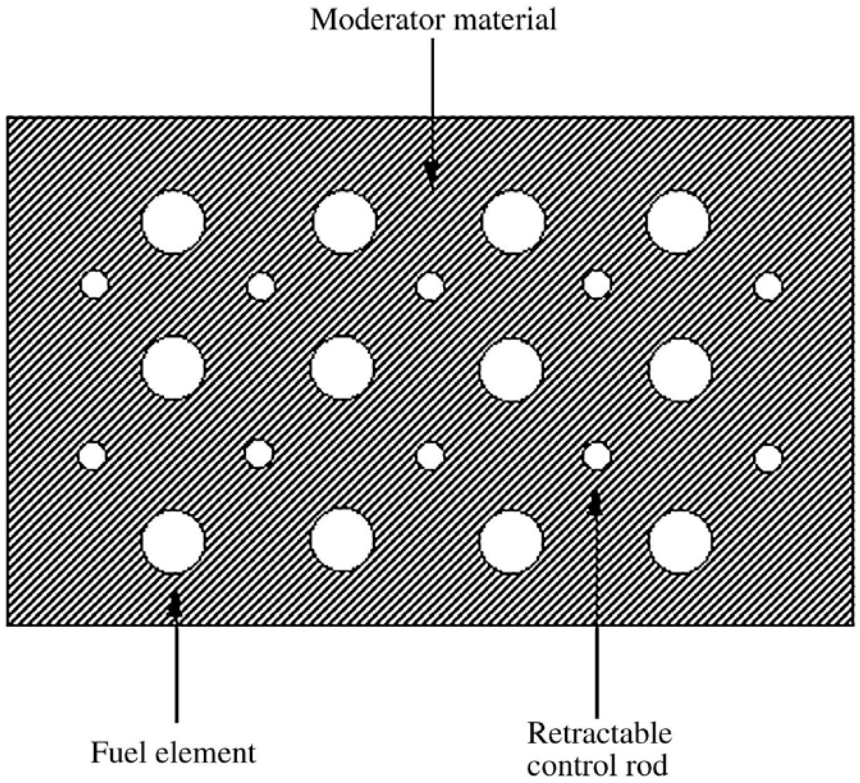
k > 1  supercritical

# Nuclear Fission Reactors

---

Several types of reactors have been developed

Thermal reactors use uranium as fuel and low-energy neutrons to establish the chain reaction



8.701 Introduction to Nuclear and Particle Physics
Fall 2020