# 8.701

Introduction to Nuclear and Particle Physics

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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

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



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#### **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 <sup>4</sup>

## **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



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