Nuclear Fission

Nuclear Fusion

Natural radioactivity

Many elements found in nature are unstable and decay emitting radioactivity.

These include Uranium, ^{238}U , Radon ^{224}Ra and Potassium ^{40}K. Carbon ^{14}C,

The half lives of natural radio-isotopes are long.
Not useful as sources for power.
Low Power output.

Induced Nuclear reactions

Can result in short half lives- fast reactions-high energy density

Combining nuclei (Fusion)

$$^{2}_{1}D + {}^{2}_{1}D \longrightarrow {}^{3}_{1}T + {}^{1}_{1}H \quad + \text{Energy}$$

Neutron reactions (Fission)

$$^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n \quad + \text{Energy}$$

Fission of Uranium

Strassman and Hahn (1939)

Irradiated Uranium with neutrons
detected Barium
conclude Uranium nuclei splits

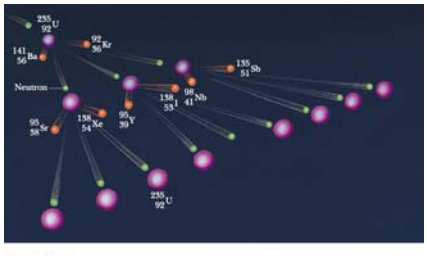
$$^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{141}_{56}Ba + \text{other\_products}$$

Meitner Liquid drop model

$T_{1/2} \sim 10^{-12}$ s

$$^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{236}_{92}U \longrightarrow Ba + \text{products} \quad +\text{neutrons} \quad +\text{energy}$$

Nuclear Chain reaction



Chain Reaction
binding of 1 neutron releases ~3 neutrons
Each neutron can initiate another reaction

Enriched ^{235}U

Natural Uranium is a mixture of ^{235}U (0.7%) and ^{238}U(99.3%)

^{238}U is does not undergo the fission process but acts as an absorber for neutrons. (neutron capture)

Most Uranium nuclear reactors use uranium enriched in ^{235}U. (2-3%)

Nuclear weapons used highly enriched ^{235}U. (~90%)

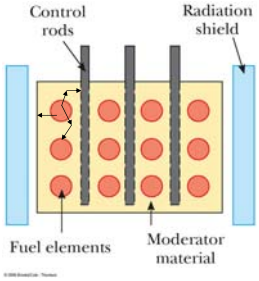
Enrichment done by mass separation.
Gaseous diffusion
Centrifuge process.
Laser separation

Nuclear reactor

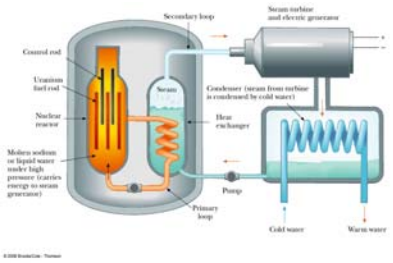
fast neutrons must be slowed down to react efficiently.

Moderator- slows neutrons to thermal velocities.

Control rods- neutron absorbers to shut down the reaction.



Nuclear reactor



Nuclear Fusion

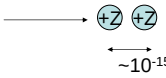
Fusion of small nuclei releases energy

$^{2}_{1}D + {}^{2}_{1}D \longrightarrow {}^{3}_{2}He + {}^{1}_{0}n$ Q= 3.27 MeV

$^{2}_{1}D + {}^{2}_{1}D \longrightarrow {}^{3}_{1}T + {}^{1}_{1}H$ Q= 4.03 MeV

$^{2}_{1}D + {}^{3}_{1}T \longrightarrow {}^{4}_{2}He + {}^{1}_{0}n$ Q=17.6 MeV

Nuclear Fusion



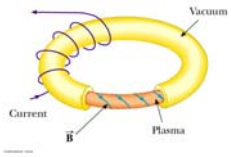
Requirements for fusion
High Temperatures (T~ 10^8 K)

High density (n) for long time (τ)

Lawson Criterion

$n\tau > 10^{14}$ s/cm^3

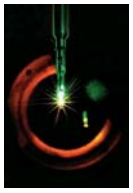
Plasma Fusion Magnetic Confinement



long times
low density

Princeton Tokomak

Laser fusion- Inertial Confinement



Deuterium pellet

Short times
High density

Lawrence Livermore Lab
Nova Laser

Prospects

- Nuclear energy by fission is currently a source of much of the electrical power (~15% USA).
- The problems with nuclear energy
  - Radioactive waste disposal
  - Atomic bomb threats
- Nuclear fusion reactions promise an unlimited source of energy.
  - Controlled fusion reactions are not yet possible.