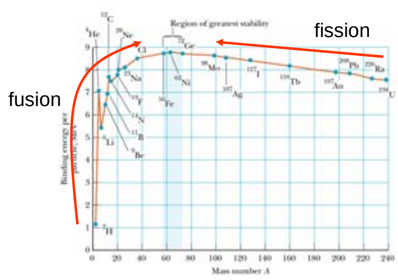
Final Exam

- Wed 3/17 from 3:00pm-5:59 York 2622
- Will cover all the course material including the last week
- 25 questions –multiple choice.
- You are allowed to bring 2 sheets of paper with equations on both sides.
- Bring a scantron form and a picture id.

Nuclear Fission
Nuclear Fusion

Curve of the Binding Energy



Energy can be released by Fusion and Fission

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)

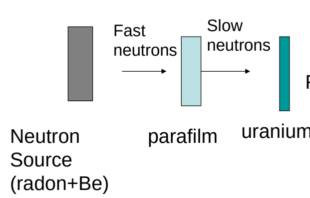
$$^{2}_{1}D + ^{2}_{1}D \longrightarrow ^{3}_{1}T + ^{1}_{1}H \quad + \text{Energy}$$

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

Fermi (1936)



Bombard uranium with neutrons

Found induced radioactivity

"Transuranium elements"

Fission of Uranium

Strassman and Hahn (1939)

Irradiated Uranium with neutrons
Detected Barium
Conclude Uranium nuclei splits into smaller fragments

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

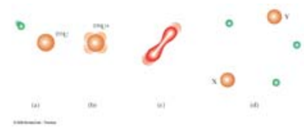
Liquid Drop model-

Lise Meitner

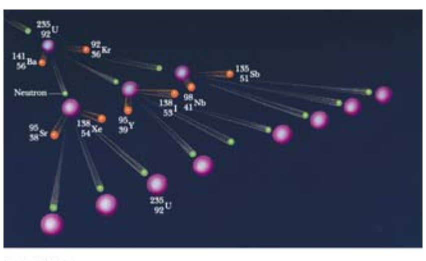
Explained fission due to the instability
of the higher larger nucleus.

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

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

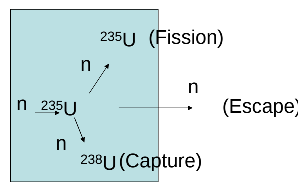


Nuclear Chain reaction



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

Critical Condition



Nuclear reactor

Reproduction constant
K = no. of product neutrons that result in another fission

K=1 (self –sustained 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

Centrifuge separation of isotopes

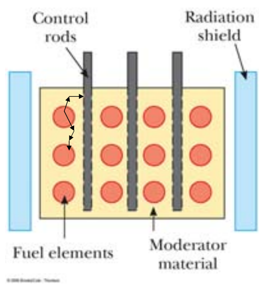
centrifugal separation gaseous UF_6

Nuclear reactor

fast neutrons must be slowed down to react efficiently.

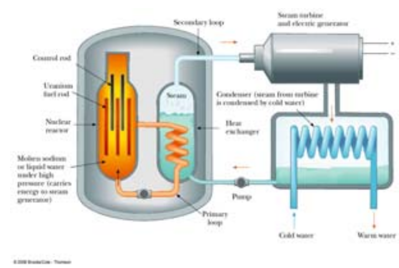
Moderator- slows neutrons to thermal velocities.

Control rods- neutron absorbers to control the level of neutrons



Critical condition. – When each neutron released initiates a new reaction.

Nuclear reactor



Plutonium

Plutonium is a fissionable material created in a nuclear reactor.

$$^{238}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{239}_{94}\text{Pu} + 2e^{-}$$

^{239}Pu can be made into nuclear bombs.

Pu can be chemically separated from U in spent fuel rods from nuclear reactors.

Nuclear Fusion

Fusion of small nuclei releases energy

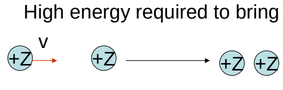
$$^{2}_{1}\text{D} + ^{2}_{1}\text{D} \longrightarrow ^{3}_{2}\text{He} + ^{1}_{0}\text{n} \qquad Q= 3.27\ \text{MeV}$$

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

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

Nuclear Fusion

High energy required to bring charged nuclei close together



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

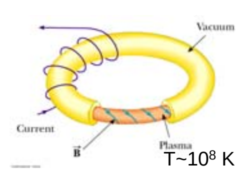
High density (n) for long time (τ)

Lawson Criterion

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

Plasma Fusion
Magnetic Confinement

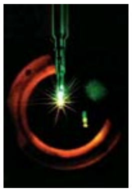
Plasma is a gas of ionized atoms
Heated to high temperature
Confined by magnetic forces



long times
low density

Princeton Tokomak

Laser fusion- Inertial Confinement



Deuterium pellet

Lawrence Livermore Lab
Nova Laser

Short times
High density

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
  - Limited supply of easily mined uranium
- Nuclear fusion reactions promise an unlimited source of energy.
  - Controlled fusion reactions are not yet possible.

Energy and Society

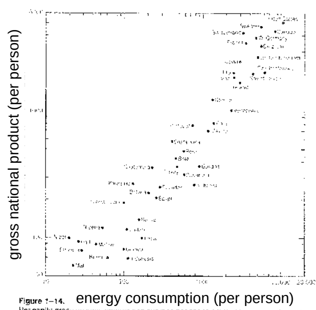
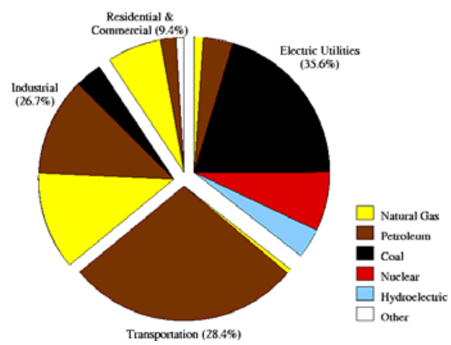


Figure 1–14. Per capita gross national product and average per capita power consumption for various countries of the world in 1971. This does not include the energy of the food that is consumed.

Energy Use USA



Oil Production in the US has peaked

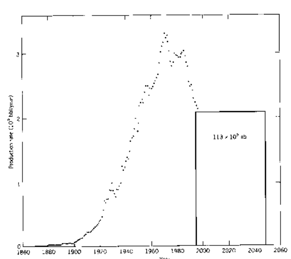
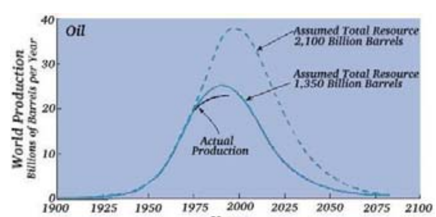
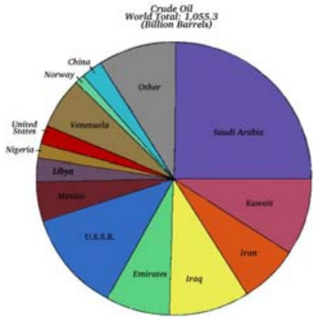


Figure 2.2 Annual petroleum production in the United States, including Alaska, since 1860. The rectangle at the right has an area representing the 113 billion barrels estimated to be remaining for future production.

World production is close to peaking



World Oil Resources



Alternatives to oil

Coal

Nuclear Energy

Hydroelectric

Wind

Solar

Biomass

One of the challenges in the future will be to find alternative sustainable sources of energy.