Announcements

1. Schedule –

   Today: Wrap-up of nuclear physics

   Wednesday: Review

   Tuesday: 5/6/03 2PM Final exam

2. Additional –

   HW sets 31 & 32 due Wednesday 4/30/03

   Problem solving session Tuesday 4/29/03 6 PM

   Additional student presentations?

   Additional review sessions?

   Open or closed book final.

Summary of previous discussions

Radiation dose: Amount of radiation absorbed/unit mass

1 Gy = 1 J/kg of absorbed radiation = 100 rad

1 Sv = RBE x (dose in Gy units) = 100 rem

RBE ← relative biological effectiveness

Nuclear reactions:

Total A (number of nucleons (Z+N)) is conserved

Total charge is conserved

protons and neutrons can convert to each other

$n \rightarrow p + e^- + \bar{\nu}$ ← antineutrino

$p \rightarrow n + e^+ + \nu$ ← neutrino

e^+ ← positron

Energy applications of nuclear physics

$$\sum_i {}^{A_i}_{Z_i} N \rightarrow \sum_f {}^{A_f}_{Z_f} N$$

$$Q = \sum_f M\left({}^{A_f}_{Z_f} N\right) - \sum_i M\left({}^{A_i}_{Z_i} N\right)$$

Energy available to generate electricity

Two basic approaches:

- Fission n + "heavy nucleous" → smaller nuclei
- Fusion 2 small nuclei → larger nucleus

Fission: Some history –

1932 James Chadwick (England) discovered neutron

Enrico Fermi (Italy) discovered that neutrons could be absorbed by nuclei to form new elements

Lise Meitner, Otto Hahn, Fritz Strassmann, Otto Frisch (Germany) discovered fission of U

Example:

$$n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr + 2n$$

$${}^{140}_{54}Xe \rightarrow {}^{140}_{55}Cs \rightarrow {}^{140}_{56}Ba \rightarrow {}^{140}_{57}La \rightarrow {}^{140}_{58}Ce$$

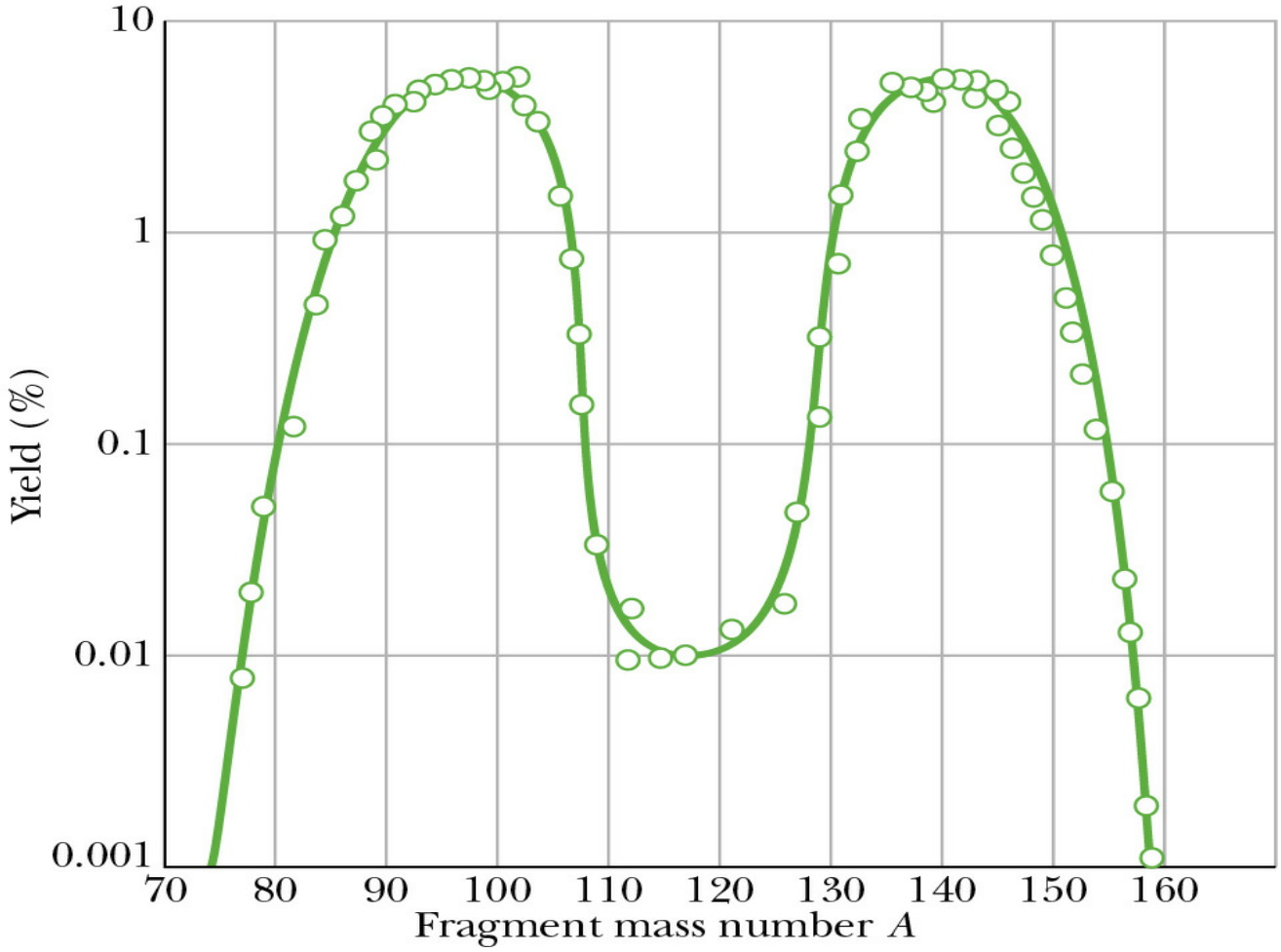
$$(14\text{s}) \quad (64\text{s}) \quad (13\text{d}) \quad (40\text{h}) \quad (\text{stable})$$

$${}^{94}_{38}Sr \rightarrow {}^{94}_{39}Y \rightarrow {}^{94}_{40}Zr$$

$$(75\text{s})(19\text{min})(\text{stable})$$

Q≈200 MeV

Other decay products for $n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U$



Mechanism for power plant

Heat → mechanical energy → generator → electricity

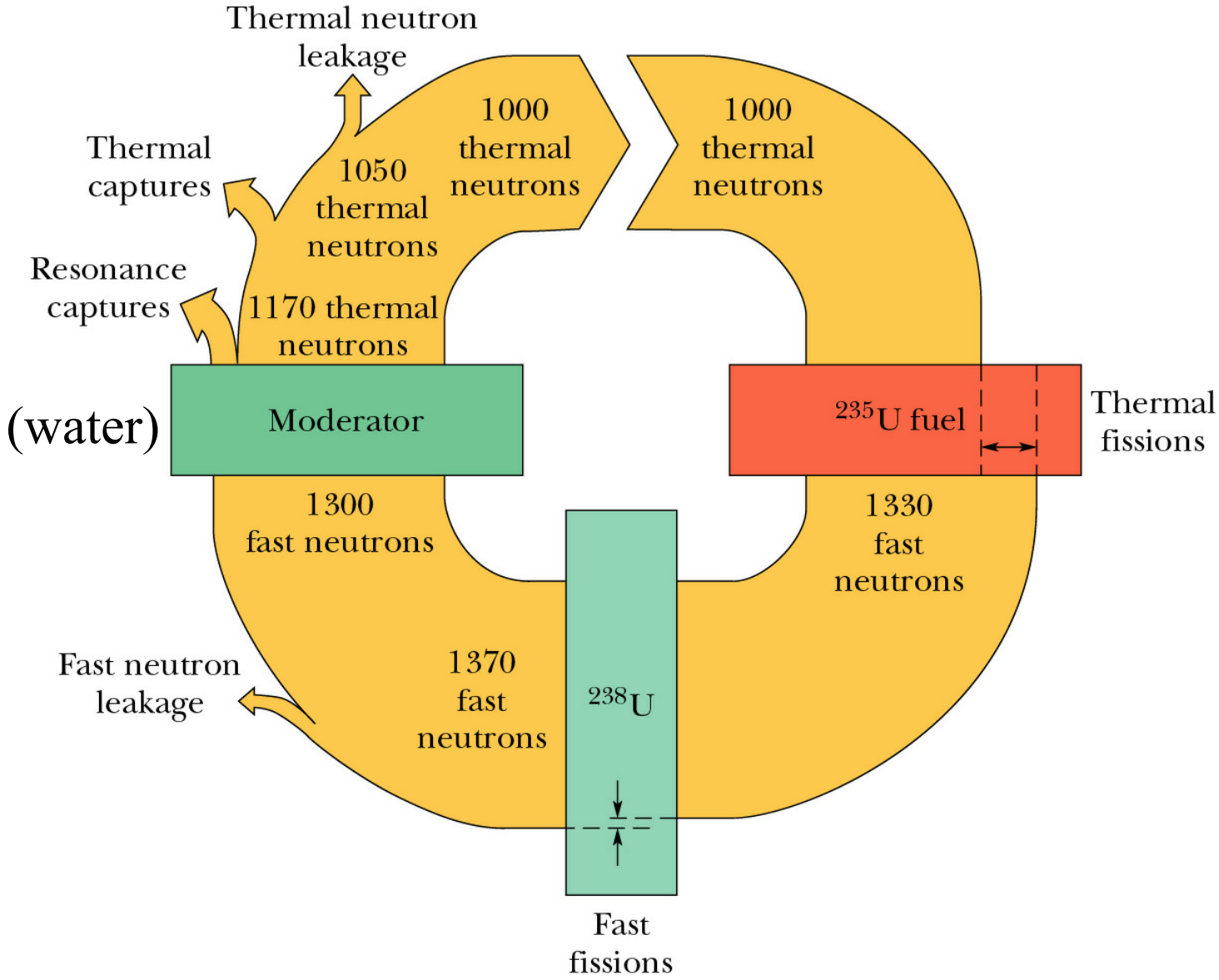
Heat sources:

Chemical burning: oxygen + coal, oil, etc.

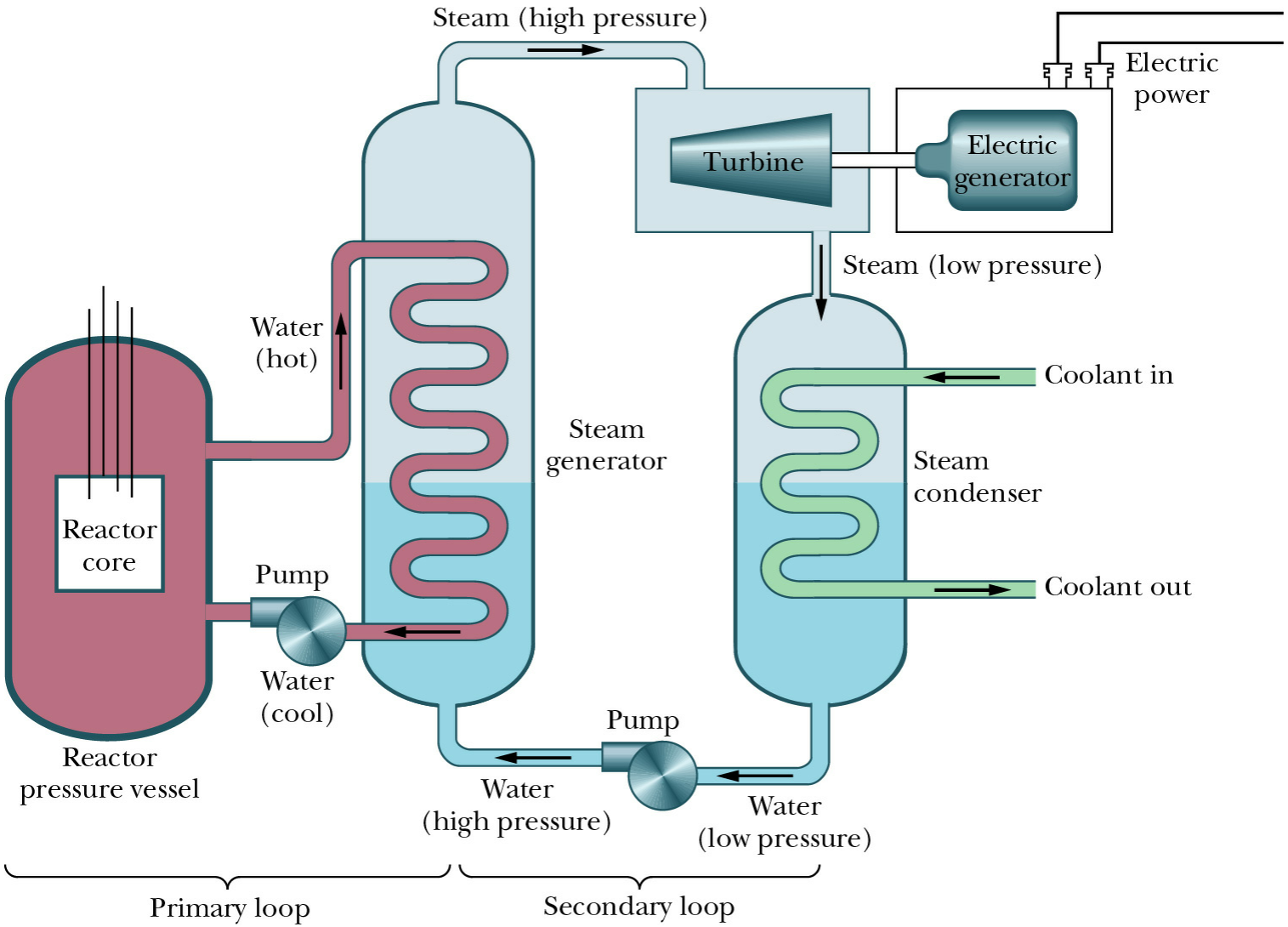
Nuclear burning: n + $^{235}_{92}U$

neutrons generated in the reaction are also used to fuel the reaction

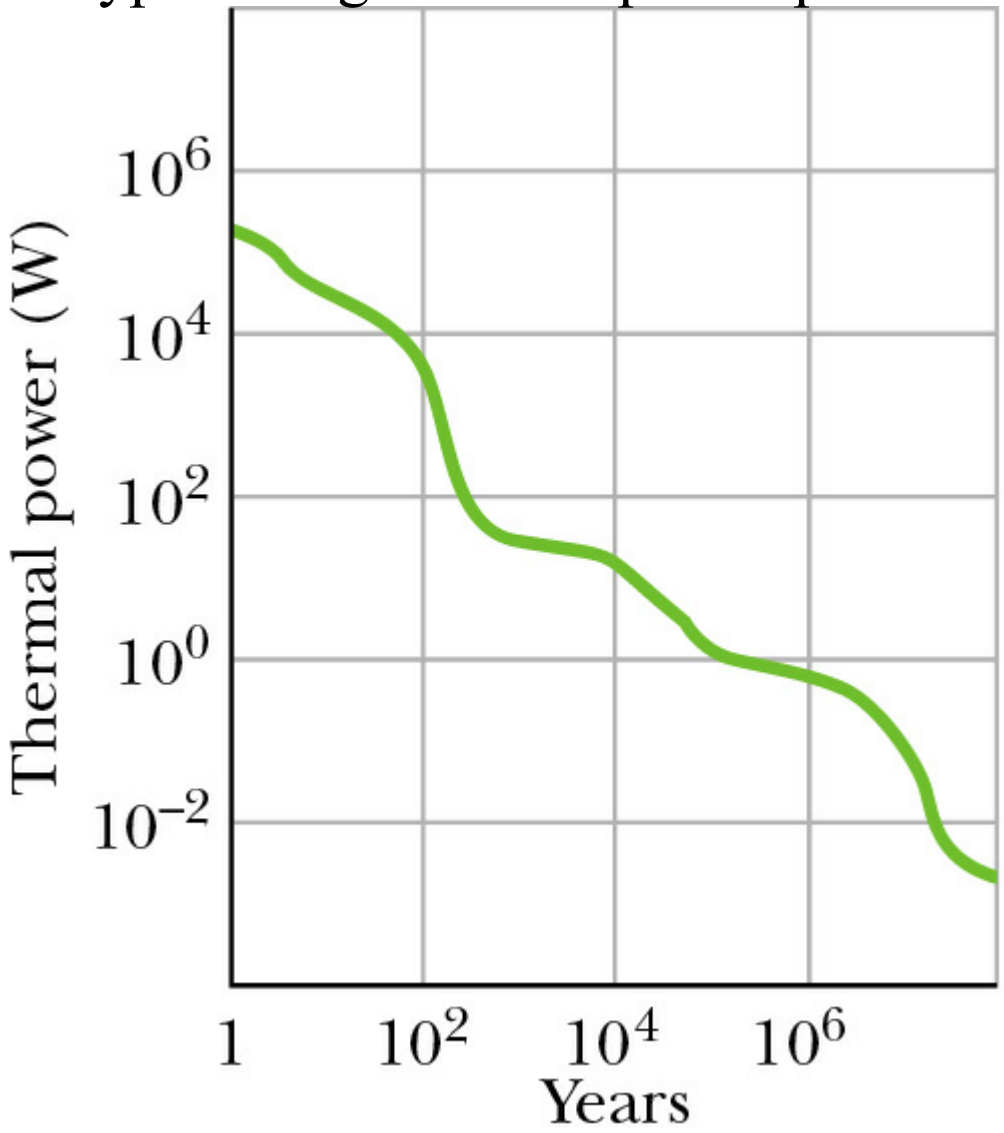
Model for nuclear reactor – accounting for 1000 neutrons



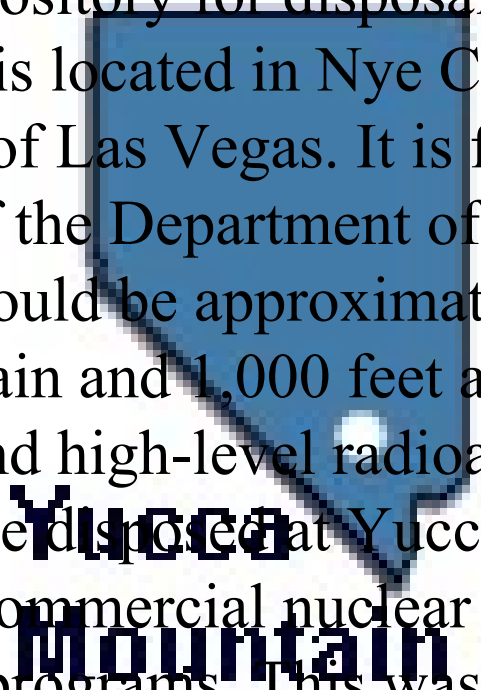
Simplified model of nuclear power plant



Thermal power release by radioactive wastes from one year's operation of a typical large nuclear power plant

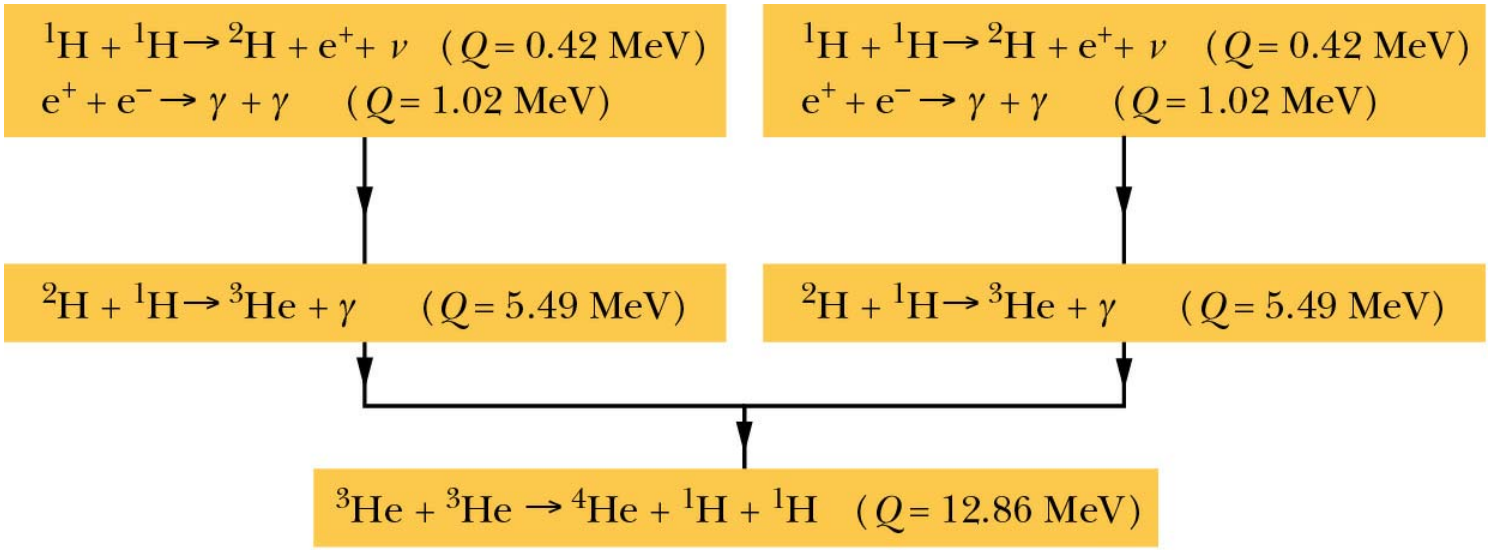


Nuclear waste depository at Yucca Mountain, Nevada. -- Yucca Mountain is the Department of Energy's potential geologic repository designed to store and dispose of spent nuclear fuel and high-level radioactive waste. If approved, the site would be the nation's first geological repository for disposal of this type of radioactive waste. The site is located in Nye County, Nevada, about 100 miles northwest of Las Vegas. It is federally owned land on the western edge of the Department of Energy's Nevada Test Site. The repository would be approximately 1,000 feet below the top of the mountain and 1,000 feet above the ground water. Spent nuclear fuel and high-level radioactive waste make up most of the material to be disposed at Yucca Mountain. About 90% of this waste is from commercial nuclear power plants; the remaining is from defense programs. This waste is currently stored at facilities in 43 states.



Fusion reactions

Summary of reactions in the sun:



Total energy release for each event: 26.7 MeV

This process has been occurring for ≈ 5 x 10^9 years and is expected to last for 10^9 more years

Fusion reactions which might be possible on earth:

$^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + n$ (Q=3.27 MeV)

$^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{1}H$ (Q=4.03 MeV)

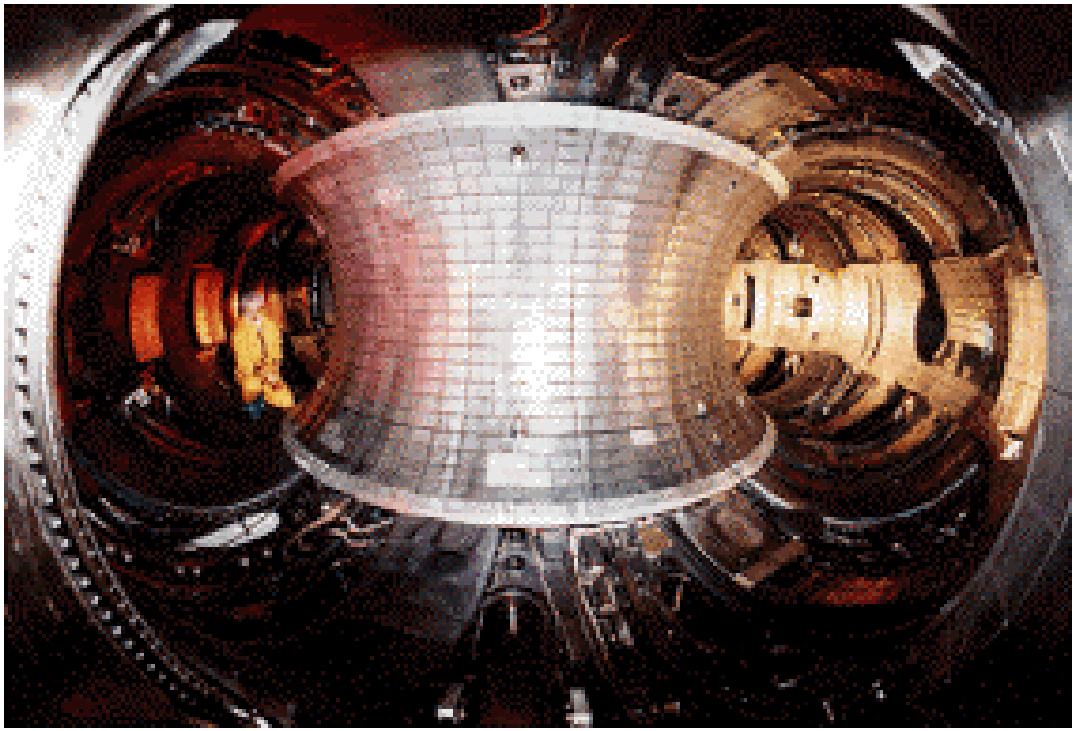
$^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + n$ (Q=17.59 MeV)

Technological challenge: How to control the energetic reactants to effect net energy gain???

Magnetic confinement – "tokamak" design

Laser confinement – high powered lasers focused on fuel put into solid form

Images from the Tokamak Fusion Test Reactor at Princeton



	Advantages	Disadvantages
Fission	Technology has been demonstrated	Nuclear waste
Fusion	Less dangerous nuclear waste	Technology has not yet been demonstrated