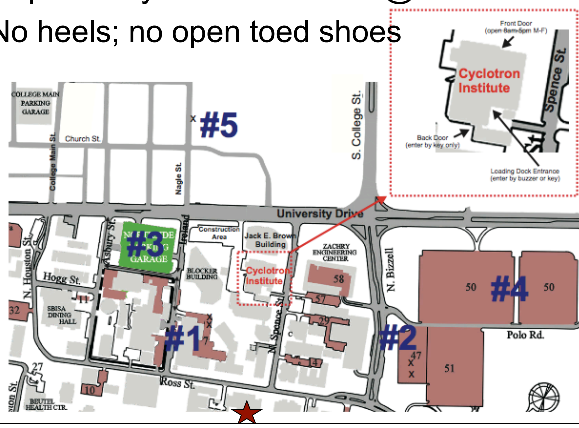
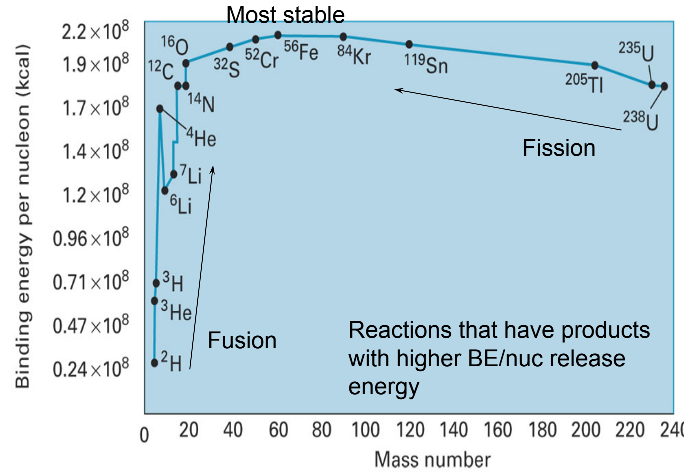
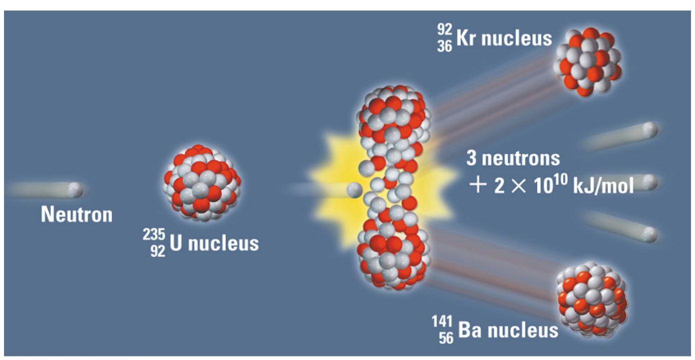
Cyclotron Tour Friday

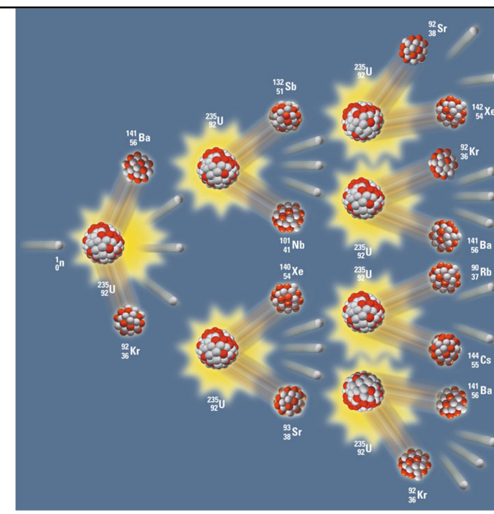
Report to cyclotron for class @ 10:20

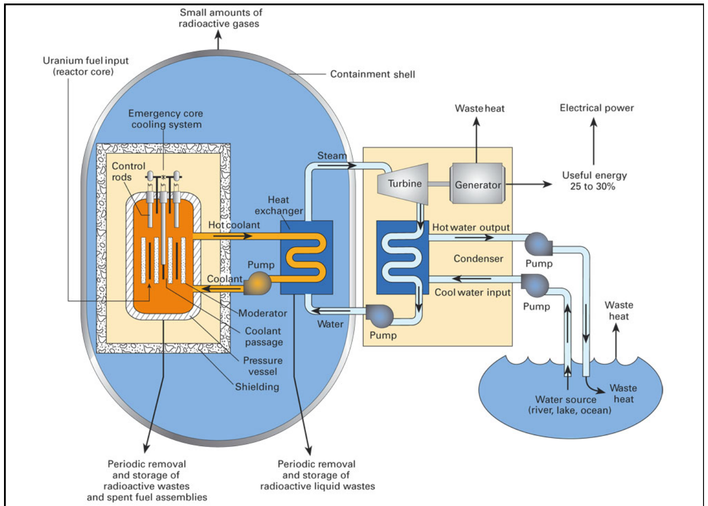
No heels; no open toed shoes







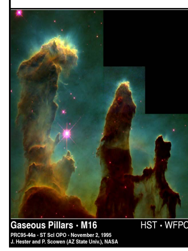


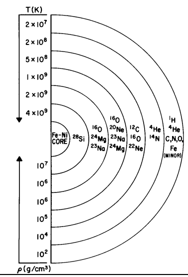


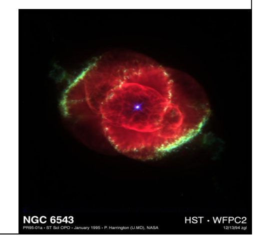
The Origin of the Elements (Nuclear Cosmochemistry)

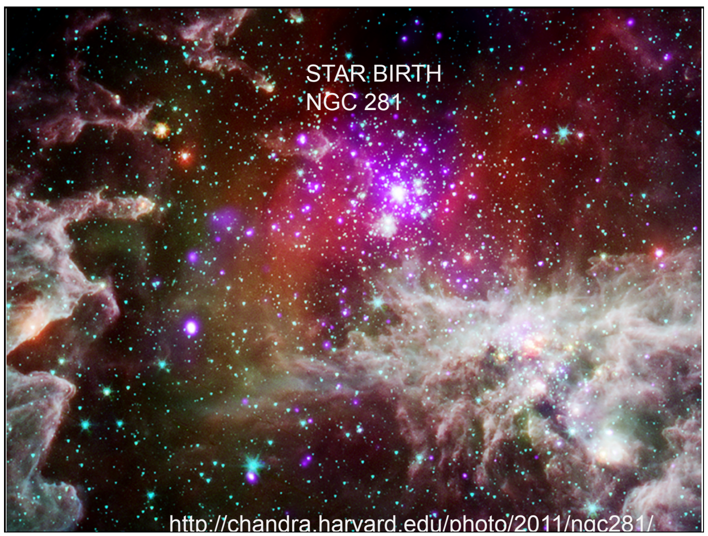
"We are all made of star stuff," said Carl Sagan.

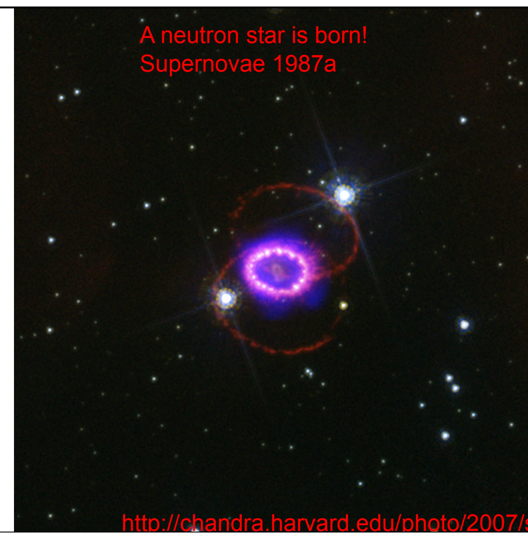
The elements that make up everything that we see around us were made by nuclear reactions and decays. These processes also produce the energy that makes the stars shine, including the nearest star, our sun. We depend on this energy for our very existence.











Stellar nucleosynthesis

- expansion and cooling from big bang
- local inhomogeneities in expansion -> galaxy formation
- within these regions condensation can occur
- subsequent heating provides environment for star formation

Element formation in stars like our sun

- Proton gas
  - gravitation attraction
  - electrostatic repulsion
- Hydrogen burning
  - $^{1}H + ^{1}H \rightarrow ^{2}H + \beta^{+} + \nu$
  - $^{2}H + ^{1}H \rightarrow ^{3}He$
  - $^{3}He + ^{3}He \rightarrow ^{4}He + 2\ ^{1}H$
- Quasi-Equilibration

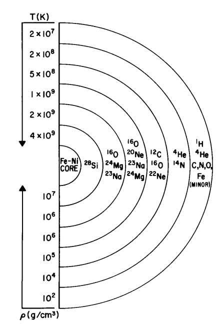
  (Coulomb prevent He from burning)

Helium burning : Red Giants

- 3α reaction
  - $^{4}He + ^{4}He \rightarrow [^{8}Be]$
  - $^{8}Be + ^{4}He \rightarrow ^{12}C + \gamma +$ Energy
- O,N
  - $^{12}C + ^{4}He \rightarrow ^{16}O + \gamma$
  - $^{16}O + ^{4}He \rightarrow ^{20}Ne + \gamma$

C+C and O+O cannot occur due to Coulomb

Exothermic Fusion



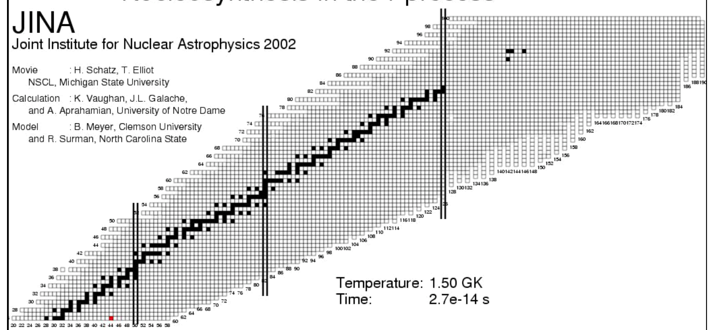
- Carbon and Oxygen burning
  - $^{12}C + ^{12}C$; $^{16}O + ^{16}O$
  - ^{20}Ne, ^{24}Mg, ^{28}Si, ^{4}He, Energy
- Silicon burning
  - $^{28}Si + ^{4}He \rightarrow ^{32}S +$ g
  - $^{32}S \rightarrow ^{36}Ar \rightarrow ^{40}Ca \rightarrow$ ..... ^{56}Fe

  (burning of envelopes)
- end of exothermic charged particle reactions

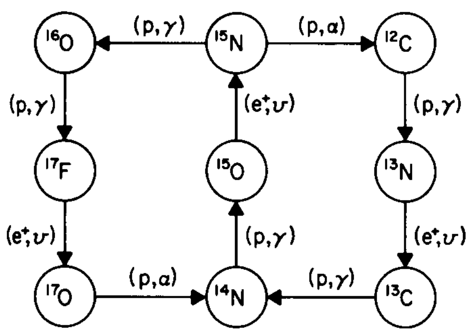
r-process : supernovae

- fast gravitational collapse
- Core: neutron generation
  - $^{56}Fe \rightarrow 26\ ^{1}H + 28\ n$
- Envelope : heavy element synthesis
  - $^{56}Fe + n \rightarrow {}^{57}Fe + n \rightarrow {}^{58}Fe$...... (A increases)
  - $^{79}Fe \rightarrow {}^{79}Co + \beta^- + \bar{\nu}$ .... (Z increases)
  - terminal once fission possible (A=270)
- Cyclic process - later generations enrich mixture of nuclides

Nucleosynthesis in the r-process



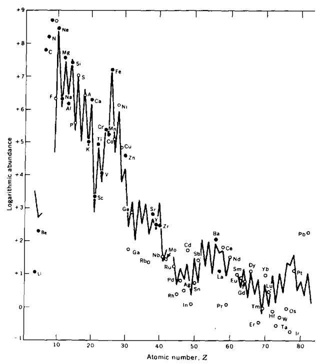
2nd generation stars (CNO cycle)

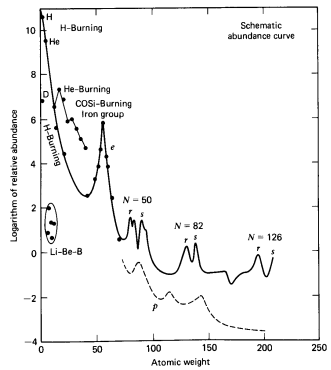


2nd generation Red Giants (s-process)

- slow neutron generation
  - $^{17}O + {}^{4}He \rightarrow {}^{20}Ne + n$
  - $^{13}C(\alpha,n)$, $^{21}Ne(\alpha,n)$
- Beta decay occurs at 1st unstable nucleus - not the n drip line
- Termination at ^{209}Bi

Elemental Abundances

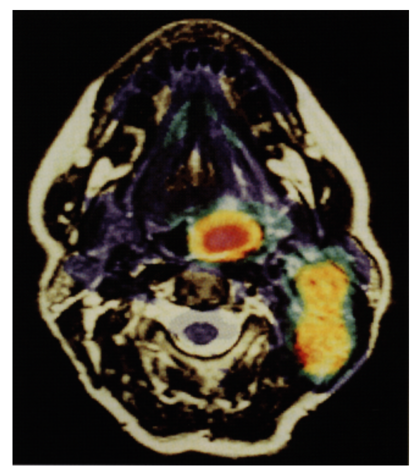




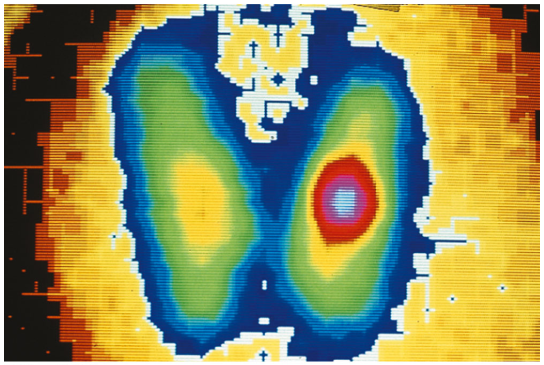
Diagnostic Nuclear Medicine: Positron Emission Tomography

"PET works by measuring gamma rays emitted by radioactive tracers attached to substances such as blood or glucose as they move through the target organ"
Science, vol 249

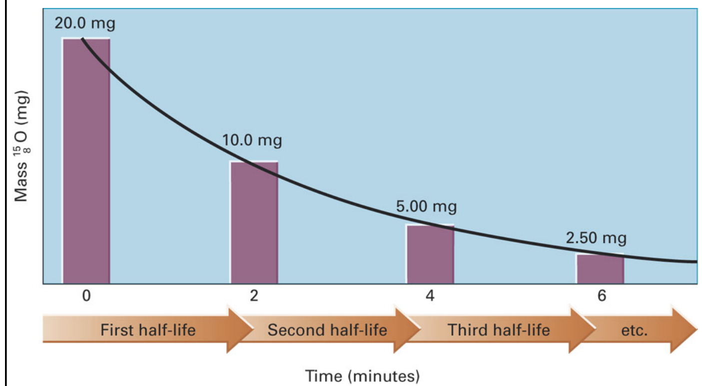
- inject/ingest molecule with beta$^+$ unstable nucleus into the body
- molecule travels through biological pathways
- positron (β^+) is emitted
- positron meets electron => annhilation
- 511KeV gamma rays produced (180^o)
- detect gammas to pinpoint where molecule was in body



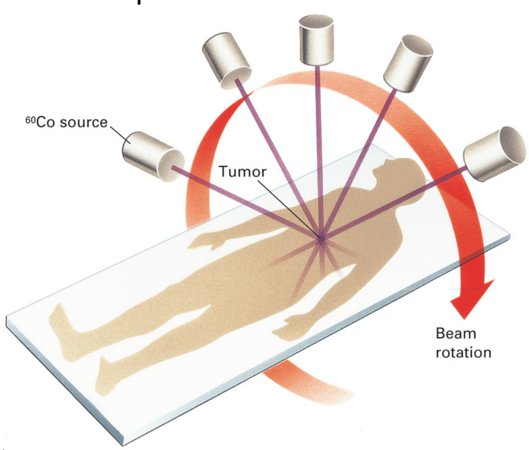
Diagnostic Nuclear Medicine: 99mTc scan

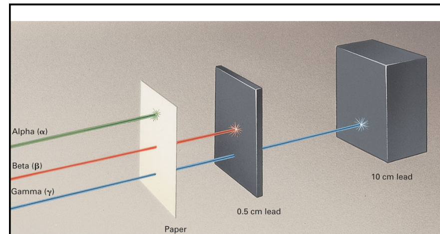


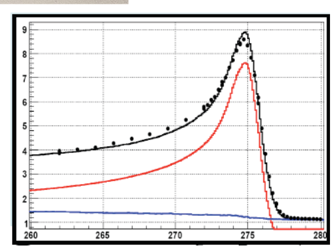
Radioactive decay follows first order kinetics

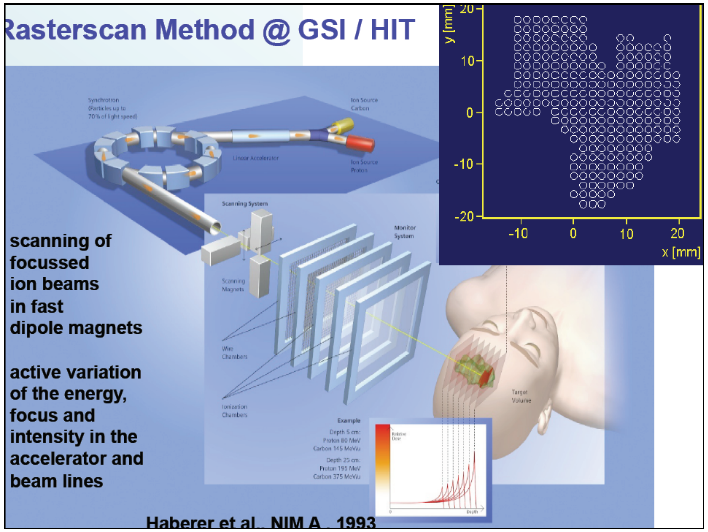


Therapeutic Nuclear Medicine



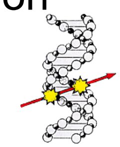






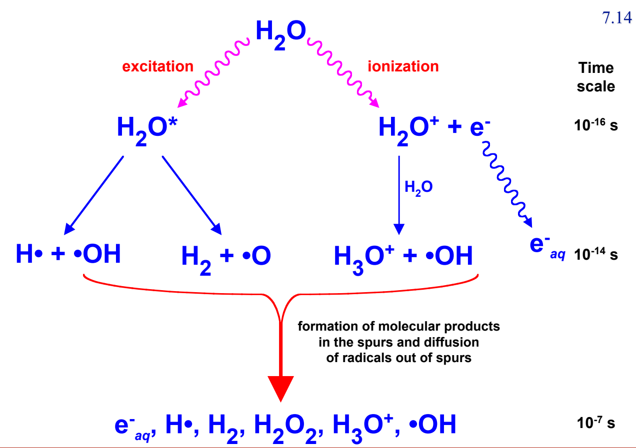
Stuff not covered in lecture

Effects of Ionizing radiation



- Produce free radicals.
- Break chemical bonds.
- Produce new chemical bonds and cross-linkage between macromolecules.
- Damage molecules that regulate vital cell processes (e.g. DNA, RNA, proteins).

RADIOLYSIS OF WATER



Natural Background Radiation

- **Natural Radioactivity in the Body**
  - tritium (H-3), carbon-14 (C-14), and potassium-40 (K-40)
- **Cosmic Radiation**
  - extremely energetic particles, primarily protons, which originate in the sun and other stars
- **Radioactivity in the Earth**
  - uranium and thorium and their decay products

Radiation Doses to the U.S. Population

Average annual whole body dose (millirem/year)

Natural:	Cosmic	29
	Terrestrial	29
	Radon	200
	Internal (K-40, C-14, etc.)	40
Manmade:	Diagnostic x-ray	39
	Nuclear Medicine	14
	Consumer Products	11
	All others (fallout, air travel, occupational, etc.)	2
	Average annual total	**360**

Tobacco (if you smoke, add ~280 millirem)

Average doses from some common activities

Activity	**Typical Dose**
Smoking	280 millirem/year
Dental x-ray	10 millirem per x-ray
Chest x-ray	8 millirem per x-ray
Drinking water	5 millirem/year
Cross country round trip by air	5 millirem per trip
Coal Burning power plant	0.165 millirem/year

Putting Risk into Perspective

Health Risk	**Estimated Life Expectancy Lost**
Smoking 20 cigarettes a day	6 years
Overweight by 15%	2 years
Alcohol (US average)	1 year
all accidents	207 days
All natural hazards	7 days
Occupational dose of 300 mrem/year	15 days

1 in a million chance of death

- Smoking 1.4 cigarettes in a lifetime (lung cancer)
- Eating 40 tablespoons of peanut butter (aflatoxin)
- Spending two days in New York City (air pollution)
- Driving 40 miles in a car (accident)
- Flying 2500 miles in a jet (accident)
- Canoeing for 6 minutes (drowning)
- Receiving a dose of 10 mrem of radiation (cancer)