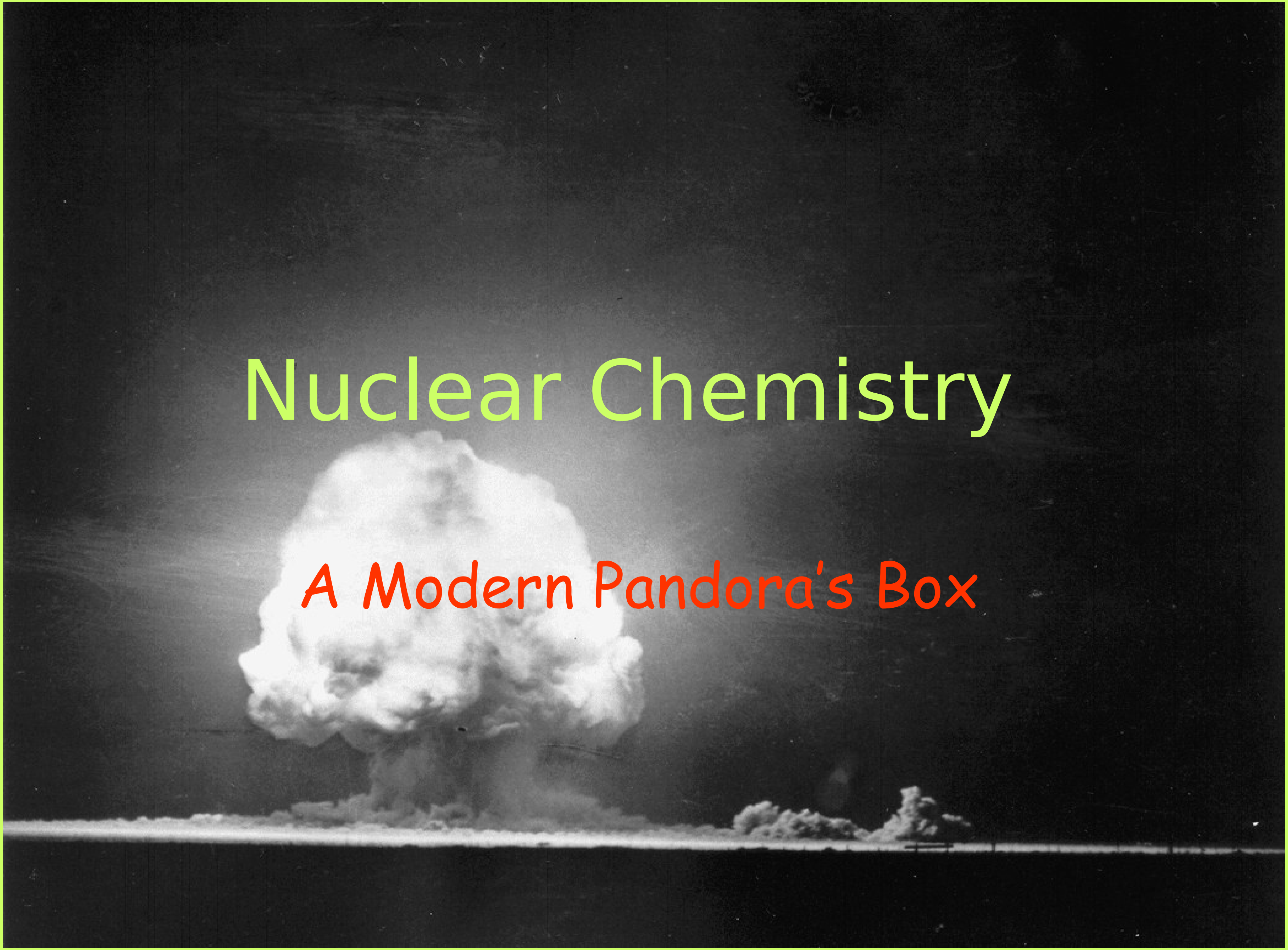
Nuclear Chemistry

A Modern Pandora's Box



Noo – clee - ar

Nuke---you---LAR

- Processes that take place in the nucleus of an atom. Its at the heart of it all.

At the heart of it all

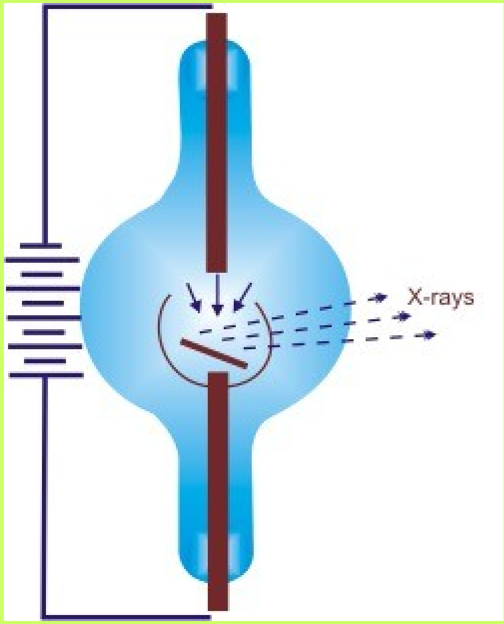
- Nucleus
  - protons
  - neutrons
- Isotope
  - same number of ___________
  - different number of __________
  - so either heavier or ___________

The discovery of the electron

- But wait there's more

The discovery of the electron

- As the electrons strike the metal anode the can eject X-rays
- (a potentially damaging form of radiation)



X-rays (light with enough energy to pass through matter)

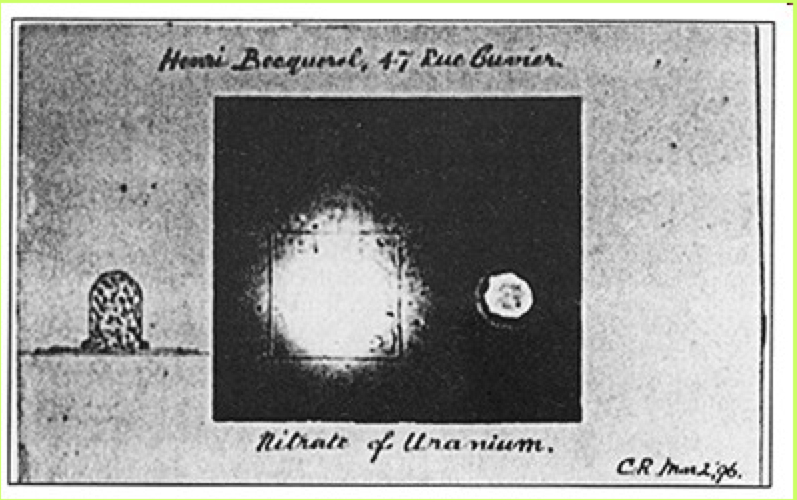
- Roentgen 1895
- something from cathode ray tube emits a form of light that can pass through matter.
- X-rays
- X = unknown algebra

Natural Radioactivity

- Becquerel (photographer liked minerals)

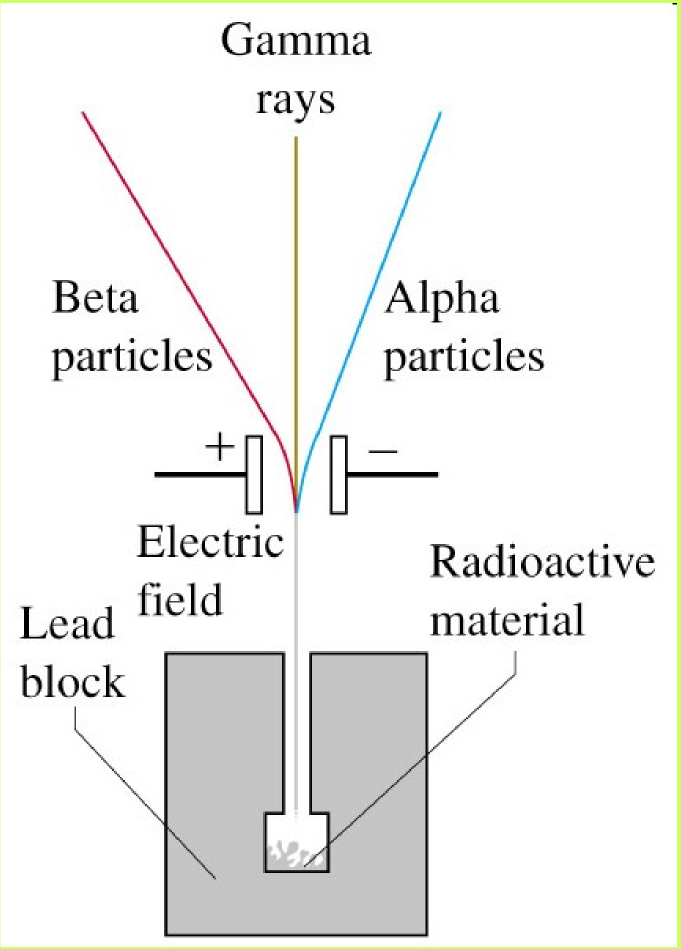
Natural Radioactivity

- Becquerel
- Uranium released
- something that could expose film sealed in a leather case.



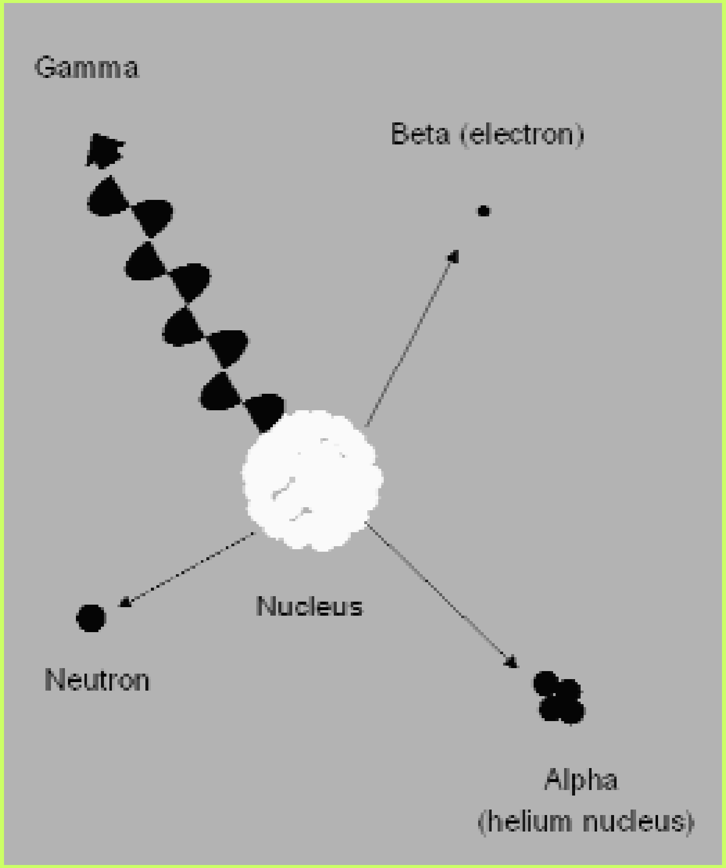
Rutherford/Radioactivity

- The release of energy and particles by the nucleus is called radioactivity.



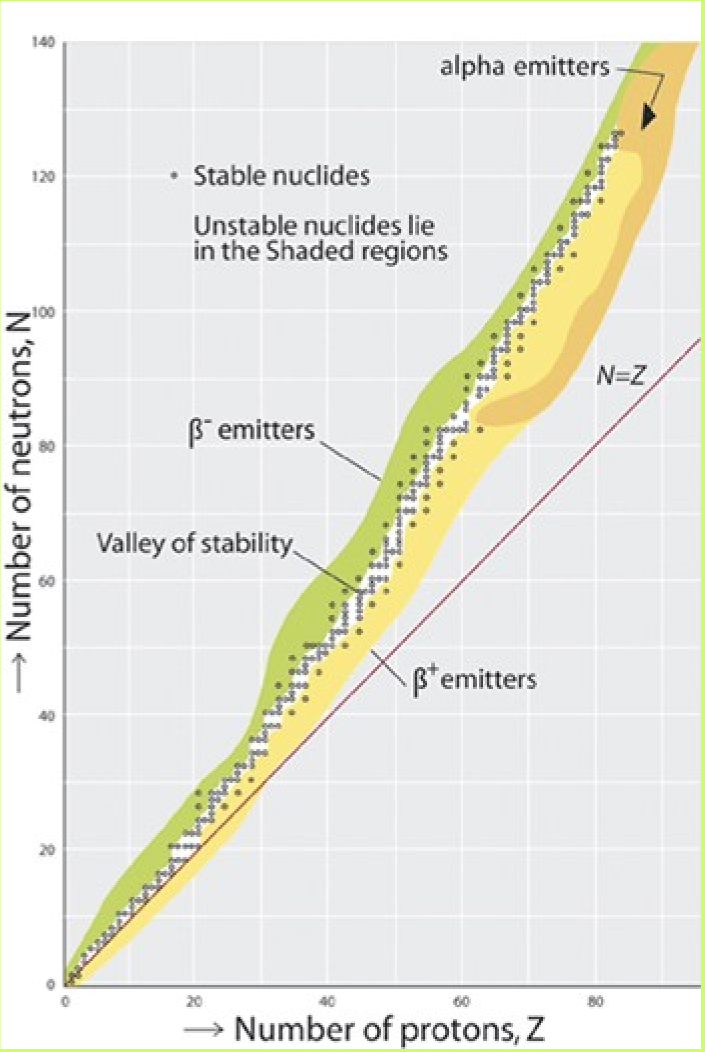
Gaining stability (losing energy and particles to gain more stability)

Unstable isotopes release of energy and particles from their nuclei to get stable. This is called radioactivity.

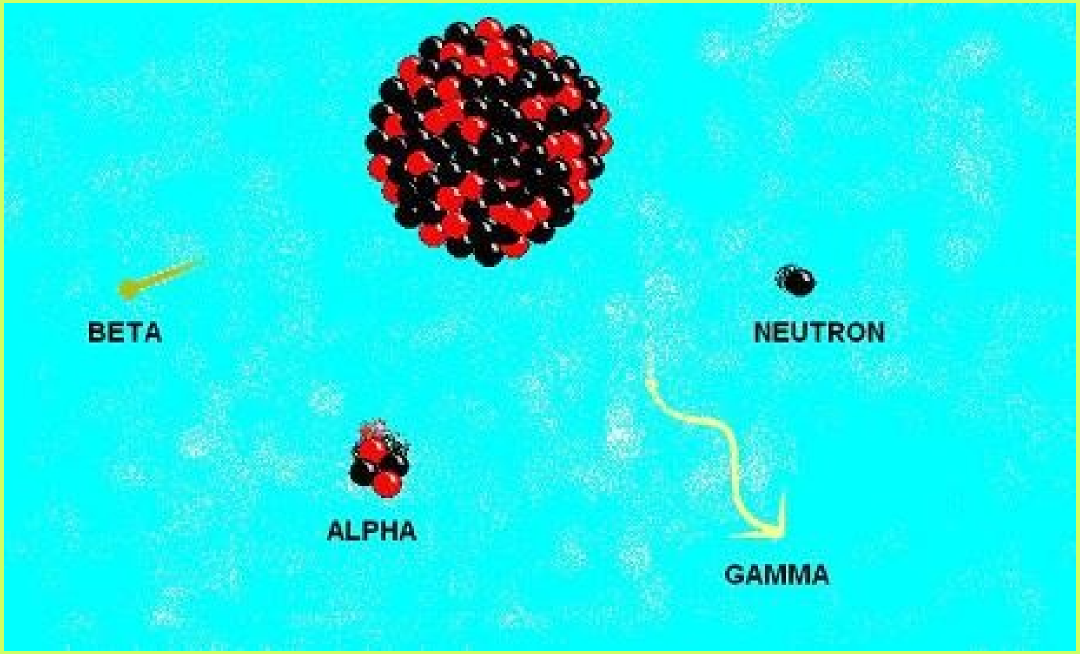


Not all isotopes are unstable

- Neutron/proton number increases to help keep nucleus stable.
- Job of neutron help insulate protons
- Approximately 2000 isotopes, 279 non-radioactive.



Decay? Or Change?



- Law of Conservation of Mass
- Law of Conservation of Charge
- Must be obeyed

Ionizing radiation (ionizes your cells.....bad!!!??)

- Alpha (α) : $^{4}_{2}He$
- Beta (β-) : $^{0}_{1}e-$
- Gamma (γ) : high, high energy photon, no mass, no charge, just pure energy
- Neutron $^{1}_{0}n$ (not discovered til 1930's) (but that's another story)

Ionizing radiation (ionizes your cells.....bad!!!??)

Nuclear decay not magic, must follow rules

- Conservation of mass and energy
- Do charge and mass balance first, then fill in blanks.
- Recall Z the atomic number is the number of protons. It must always match the chemical symbol
- $^{238}_{92}U$ $^{235}_{92}U$

92 = U, U=92

Sample Decay reactions

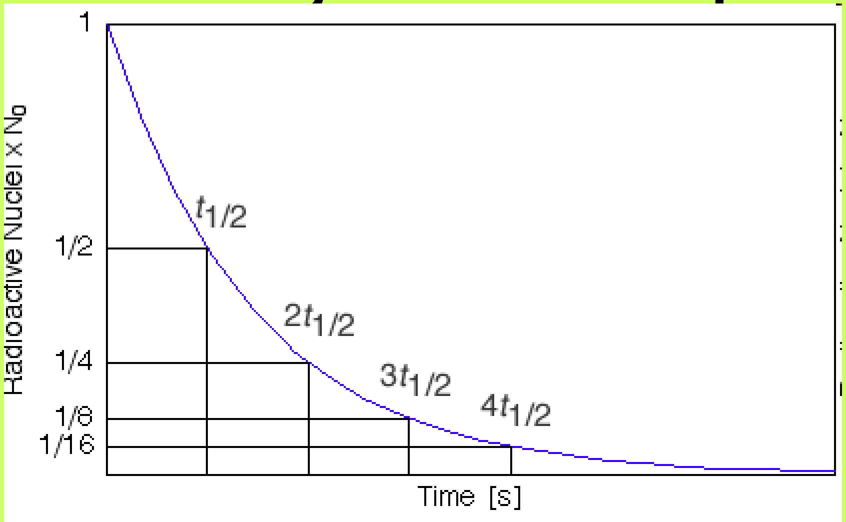
- $^{227}_{89}Ac$ --> $^{227}_{90}Th$ + ______
- $^{13}_{7}N$ --> $^{13}_{6}C$ + _____
- $^{210}_{84}Po$ --> $^{206}_{82}Pb$ + ______

Not So Elementary my dear Watson

- Through the addition and subtraction of particles, elements transmute from one to another.
- Stars build elements by a variety of nuclear processes

Get a life well half-life anyway

- Half-life: amount of time required for 1/2 of the original nuclei to decay into another element. This is a fixed number for a given isotope.



Age Dating example

- A piece of charred sinew from a mummy has 1/4 of the $^{14}_{6}C$ that living things have. The half-life of $^{14}_{6}C$ is 5,730 years. How many years before present was the mummy killed.

Dating example

- 1/4 = 1/2 x 1/2 so 2 half-lives have passed.
- 2 x 5,730 = 11,460 year before present

Mass Defect not a gene for weight gain

- The difference between the mass of an element, and the mass of the parts needed to make the element.
- Somehow when we put the parts of an atom together they weigh less

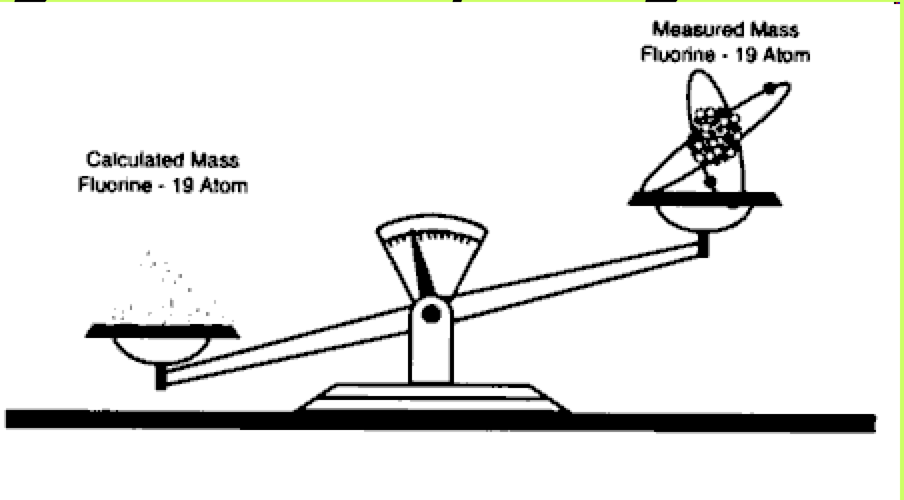
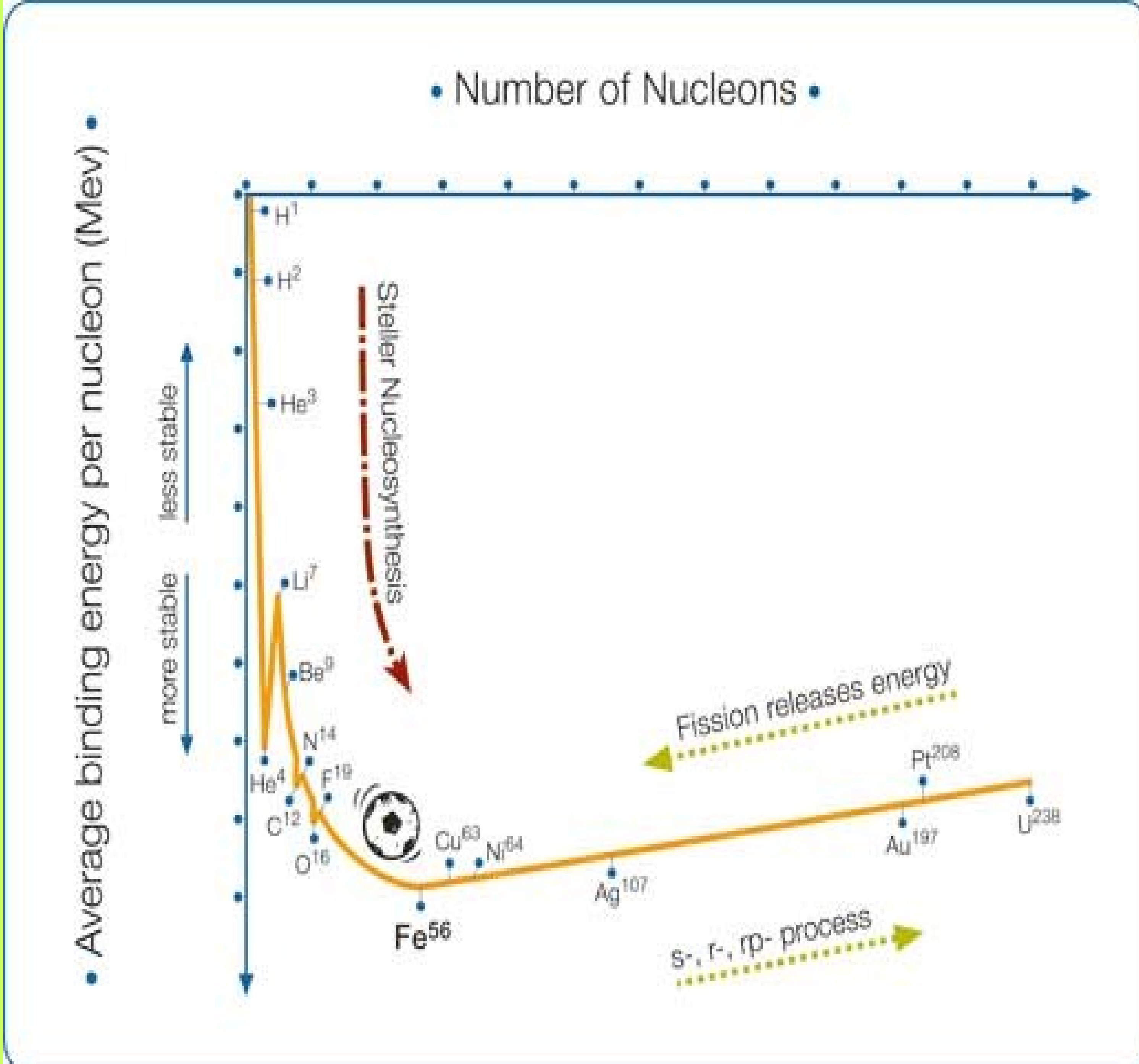


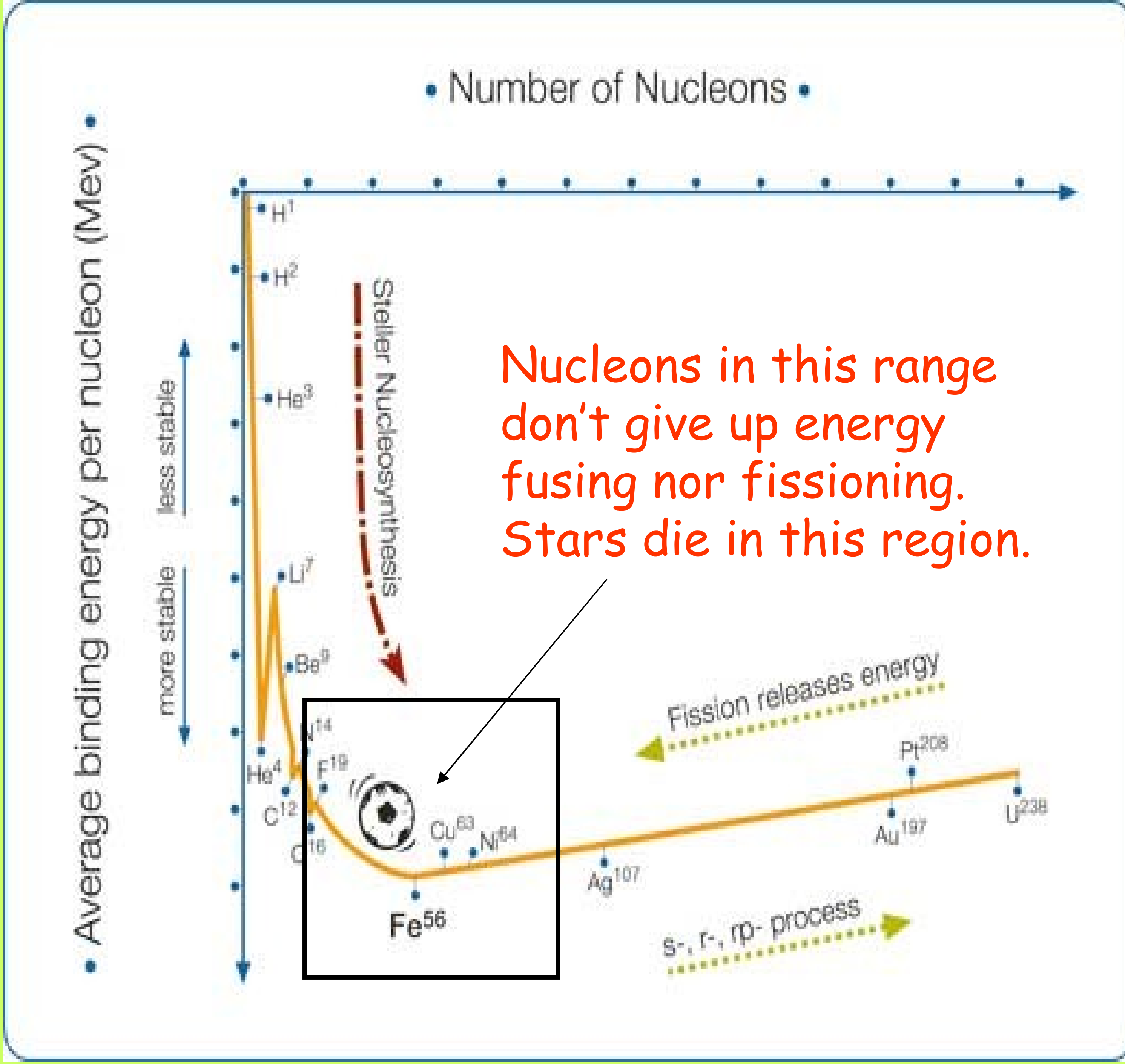
Figure 2-V. Illustration of a Mass Defect

Mass Defect not a gene for weight gain

- The reverse relationship is true of heavy isotopes. The heavy isotopes are heavier than the sum of their parts, so if you split them.
- Viola… you get a mass defect…
- $E=mc^2$ and go boom!

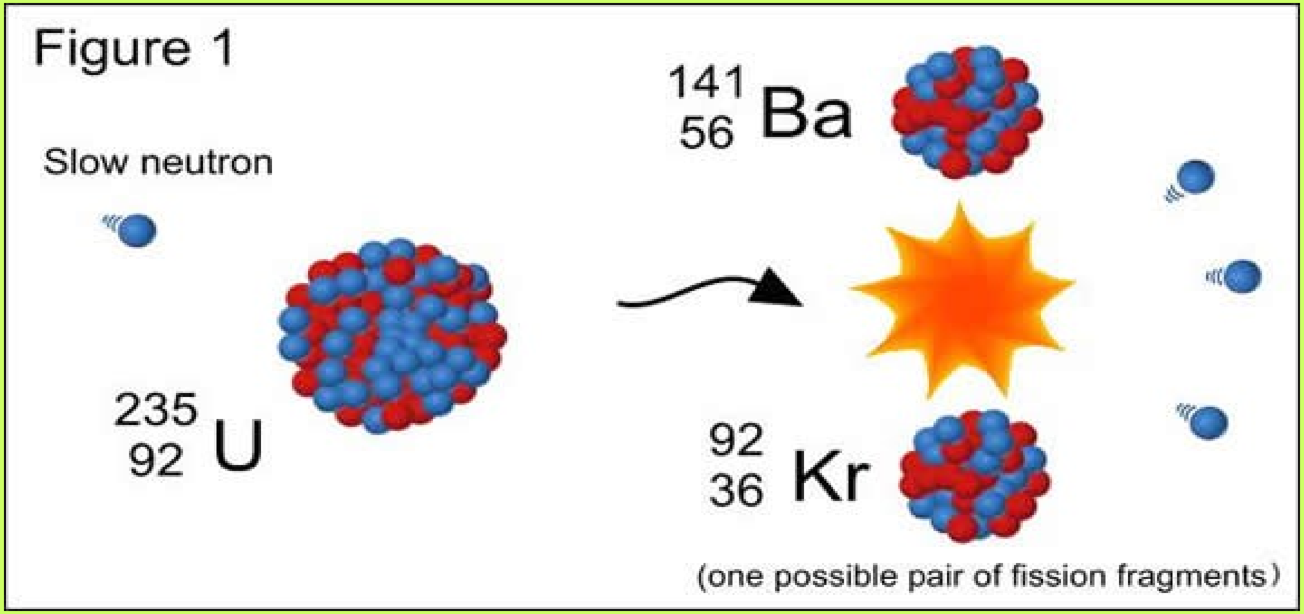


Number of Nucleons
Average binding energy per nucleon (Mev)
less stable
more stable
Steller Nucleosynthesis
Fission releases energy
s-, r-, rp- process
H1
H2
He3
Li7
Be9
He4
N14
C12
F19
O16
Fe56
Cu63
Ni64
Ag107
Au197
Pt208
U238



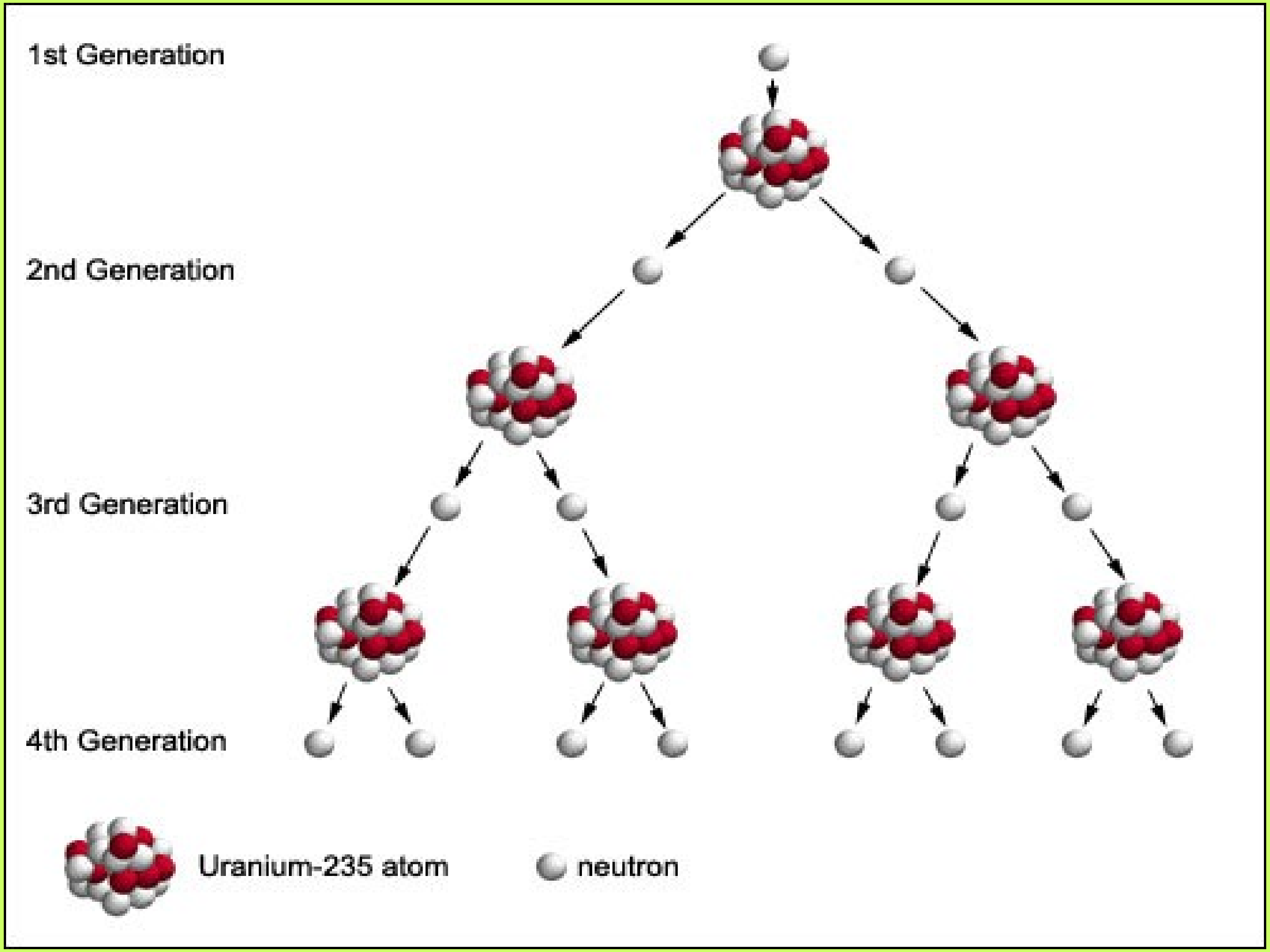
Number of Nucleons
Average binding energy per nucleon (Mev)
less stable
more stable
Steller Nucleosynthesis
Nucleons in this range don't give up energy fusing nor fissioning. Stars die in this region.
Fission releases energy
s-, r-, rp- process
H1
H2
He3
Li7
Be9
He4
N14
F19
C12
O16
Cu63
Ni64
Fe56
Ag107
Au197
Pt208
U238

Fission not Fishin'



- Only about 4 of 2000 isotopes are fissionable. They split approximately in two if hit by a low energy neutron. They give off more neutrons. Hence more fissioning.

Chain fission reactions



Fission

- After a heavy nucleus is split, some "nuclear" glue is converted to energy. This mass defect is the m in $E= mc^2$
- For $^{235}_{92}U$ this energy release is approximately 26 million times more energy released than combustion of methane. This energy can be destructive...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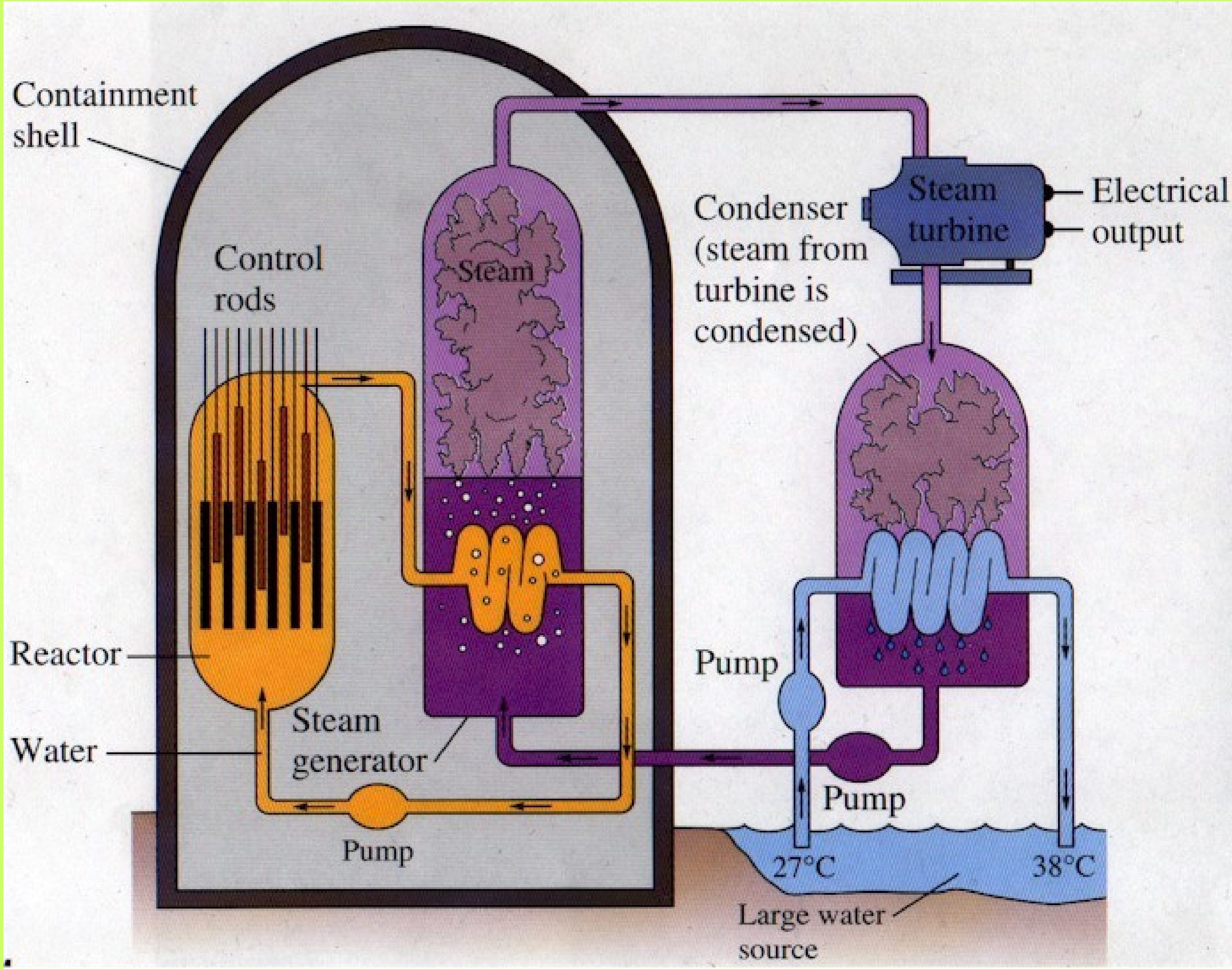
31

Or constructive...

Nuclear Steam Kettle



All this fissioning leads to WASTE

- The fission fragments are not all the same size, nor the same half-live, but the many daughters are radioactive.
- The shorter the half-life, the more radioactive, but no longer useful for fissioning.
- Sometimes heavier trans-uranics are produced.

All this fissioning leads to WASTE

- $^{90}_{38}Sr$ $t_{1/2} = 29$ years
- $^{137}_{55}Cs$ $t_{1/2} = 30$ years

- These nuclides are both hot and will be incorporated in animals and people as Sr mimics Ca and Cs mimics K in biological processes.

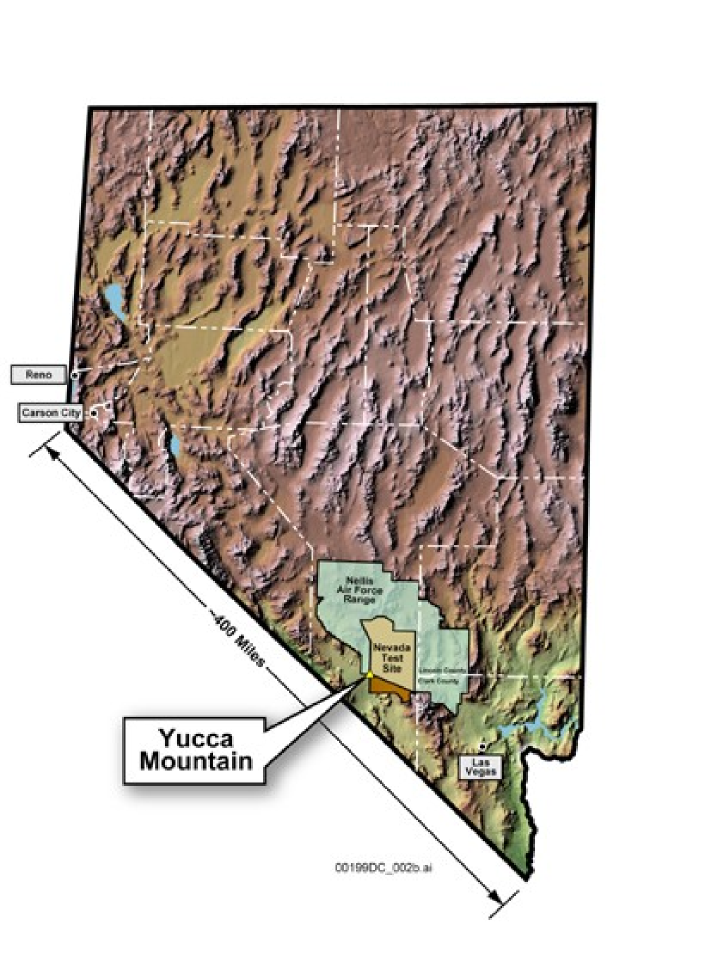
Nuclear Waste

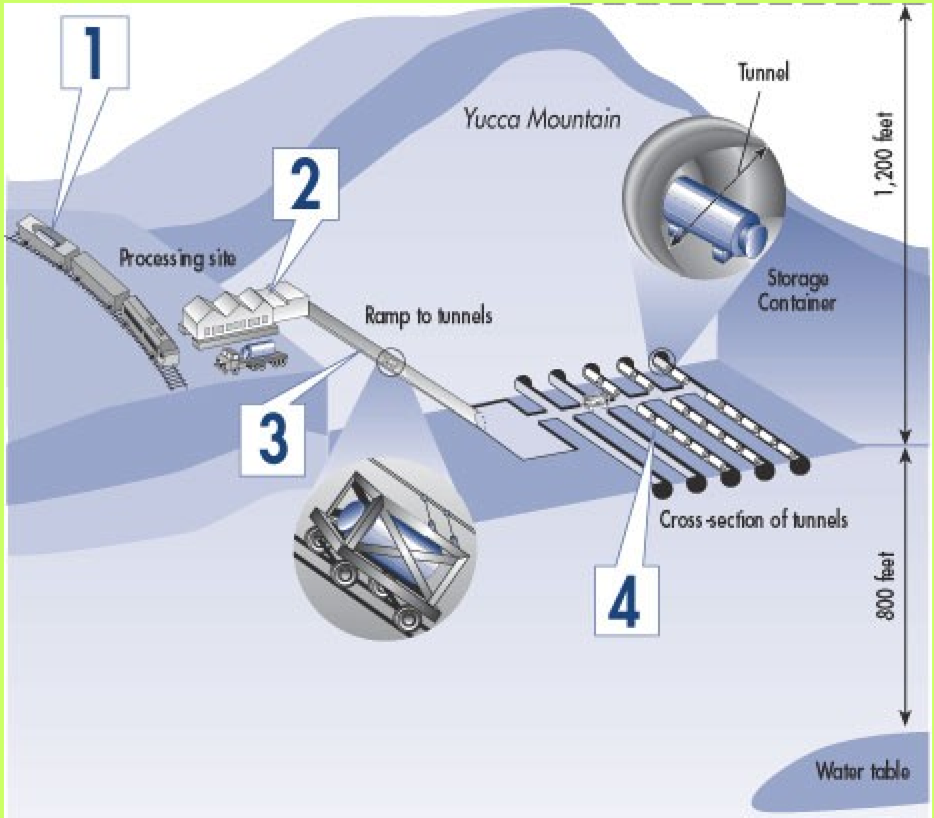
- Isolate: from biosphere, underground water sources.
  - Radioactivity itself tends to damage materials like steel and other metals.
  - Furthermore, a large quantity of radioactive matter tends to get very hot.
  - Incorporate waste in certain kinds of glass and ceramic materials.

Nuclear Waste

- Underground storage
- Shoot into space
- Do nothing.
- These seem like the major options

Yucca Mountain





Yucca Mountain

- Pros
  - Low population
  - Dry
- Cons
  - Geologic activity
  - Tranportation distance

Do Nothing?

- Continue to store waste at reactor facilities
  - near population
  - above water table
  - security?
  - never designed for long term storage