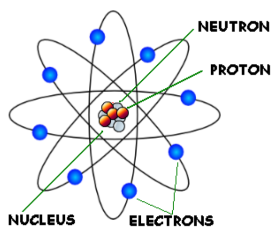
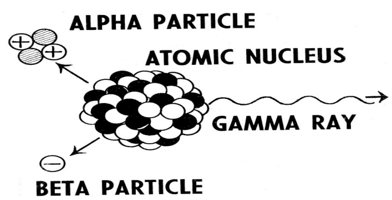
L07 - Nuclear Physics - Radioactivity

Agenda:
- The Periodic Table
  - > Atomic Number, Neutron Number, Atomic Mass, and Isotopes
- The Strong Force and other Fundamental Forces
- Alpha, Beta⁺, Beta⁻, and Gamma Decay
- Radiation and Magnetic Fields

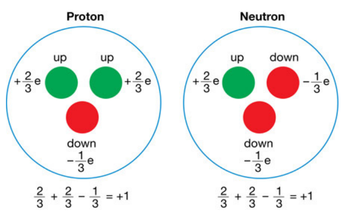
L07 - The Periodic Table



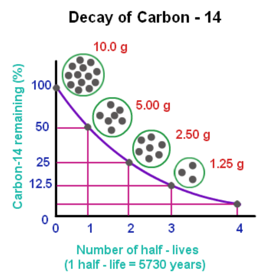
L07 - Radioactive Decay



L07 - Radioactive Decay



L08 - Radioactive Decay Formula



L08 - Radioactive Decay Formula

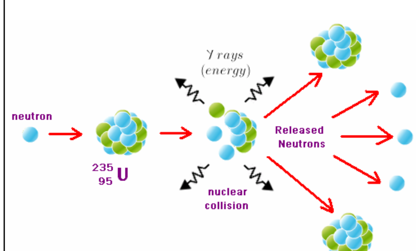
$$A = A_0 \cdot \left(\frac{1}{2}\right)^{t/h}$$

- A — final amount
- A_0 — initial amount
- t — time
- h — half-life
- $\left(\frac{1}{2}\right)$ — This is the split factor... After a half-life, one pound becomes ½ pound.

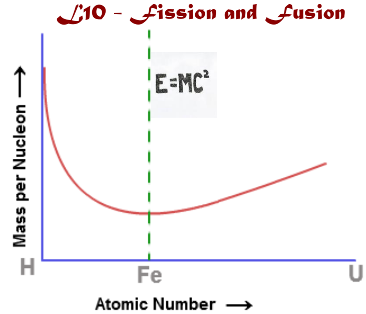
L09 - Worksheet

- Periodic Table
- Alpha, Beta(s), and Gamma Decay
- Radiation and Magnetic Fields, Cloud Chambers
- Half-life graphs and equations

L10 - Fission and Fusion



L10 - Fission and Fusion



The Periodic Table

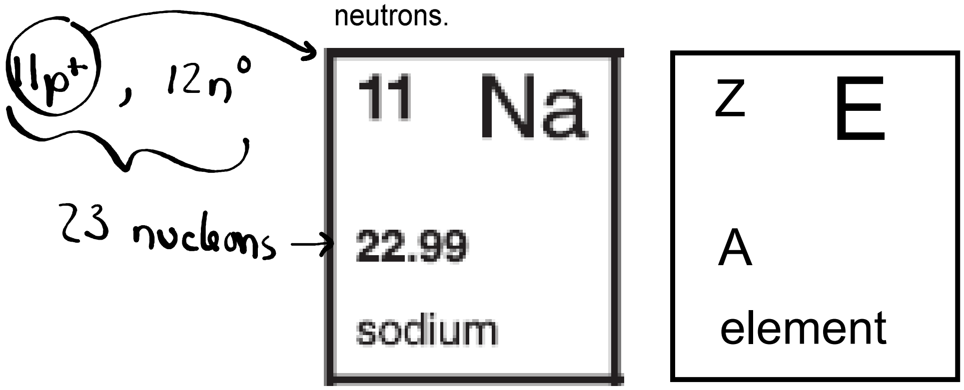
Key Terms

Atomic Number, Z: The number of protons in a nucleus

Neutron Number, N: The number of neutrons in a nucleus

Atomic Mass Number, A: The number of nucleons (protons + neutrons)

Isotopes: Elements have the same number of protons but different numbers of neutrons.



Why does Carbon have an Atomic Mass Number of 12.01?

http://phet.colorado.edu/en/simulation/build-an-atom

What does it mean when we refer to "*Carbon-14 dating*"?

http://phet.colorado.edu/en/simulation/radioactive-dating-game

11 Na	Z E
22.99	A
sodium	element

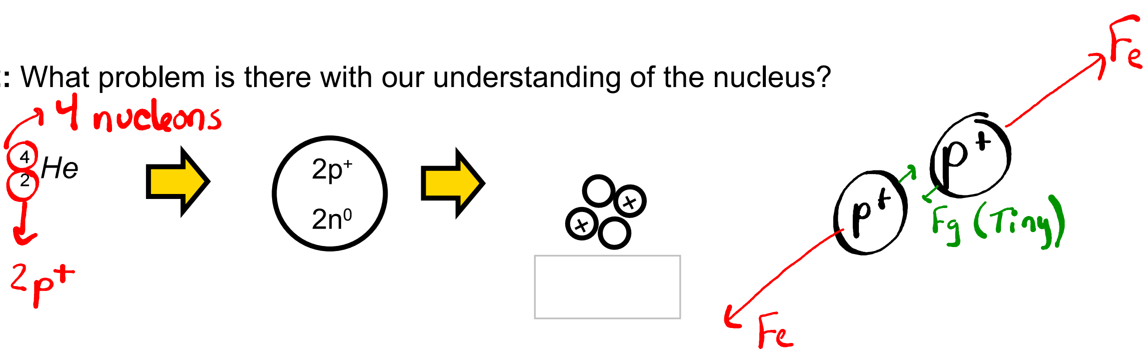
Q1: Identify the number of protons, neutrons and nucleons in $^{197}_{79}Au$.

Think of $^{197}_{79}Au$ as $^{A}_{Z}E$.

Gold - 197

$79p^+$
$118n^0$ } 197 nucleons

Q2: What problem is there with our understanding of the nucleus?



Strong Nuclear Force: Also called *nuclear force*, the short-range attractive force between baryons (protons, neutrons) that holds together the nucleus of the atom.

The Strong Force (Video #1 of 2)

The Strong Force (Video #2 of 2)

The Strong Force - Understood?

bcrowell #21 Sep 12, 2010

Staff Emeritus
Science Advisor
Insights Author
Gold Member

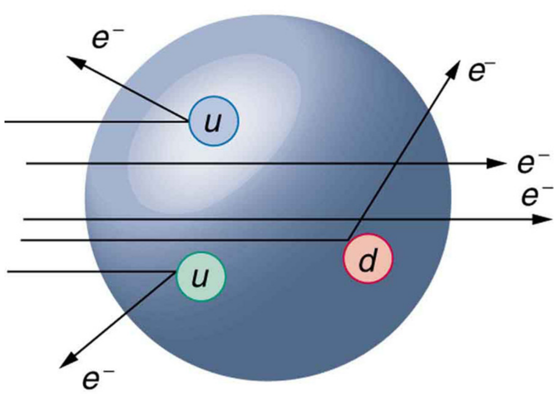
FAQ: Is the force between nucleons always attractive?

Protons and neutrons are referred to collectively as nucleons. Nucleons interact via the strong nuclear force, and unlike the electric and gravitational interactions, this interaction can't be expressed by any simple equation. The reason is that nucleons are not fundamental particles. They're actually clusters of quarks. All we have are models of the force, and just because two models differ, we can't conclude that one is right and one is wrong. They are simply fits to the data, with their forms chosen for convenience for a certain purpose, and often with lots of adjustable parameters. The description of the strong nuclear force is also complicated because it depends on both the spins of the nucleons and on the particular combination of neutrons and protons (although it stays the same when the identities of neutrons and protons are swapped).

Since nuclei are bound, and the electrical interactions in a nucleus are repulsive, we conclude that the nuclear force is at least sometimes attractive. It is not possible, however, to infer simply from the fact that nuclei don't collapse that the nuclear force is sometimes repulsive. In fact the main reason that nuclei don't collapse is the zero-point motion required by the Heisenberg uncertainty principle; this is exactly analogous to the reason that the hydrogen atom doesn't collapse, even though the interaction between the proton and electron is purely attractive. There are some models of the nuclear force, such as the one-pion exchange potential (OPEP), that are purely attractive, and that predict roughly the right sizes for nuclei.

Relatively sophisticated models of the nucleon-nucleon interaction do usually include repulsion under certain circumstances, e.g., there may be a "hard core" in the potential at short ranges. The fact that all such models seem to do a better job of reproducing certain data when the repulsive features are turned on suggests that this repulsive feature is model-independent.

Evidence for Quarks



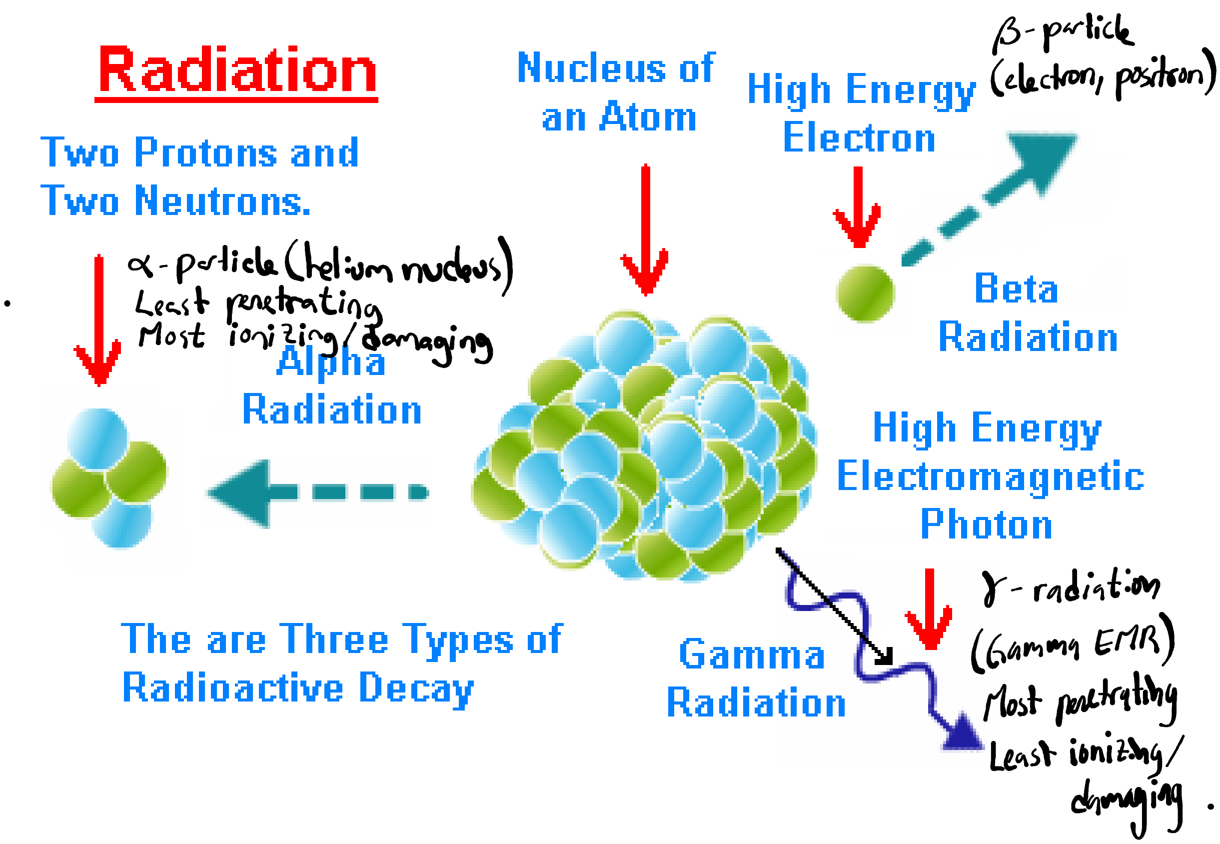
Proton

Scattering of high-energy electrons from protons produces evidence of three point-like charges consistent with proposed quark properties.

This experiment is analogous to Rutherford's discovery of the small size of the nucleus by scattering α particles.

High-energy electrons are used so that the probe wavelength is small enough to see details smaller than the proton.

Types of Radiation

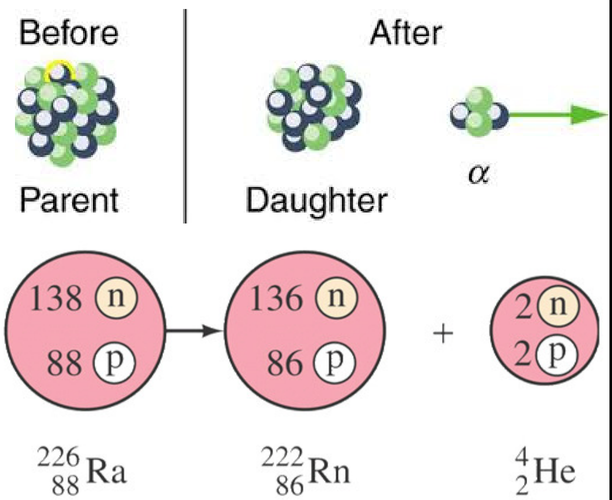


Radioactive Decays (Alpha and Gamma)

Alpha Decay (α): Emission of a helium nucleus from an atomic nucleus.

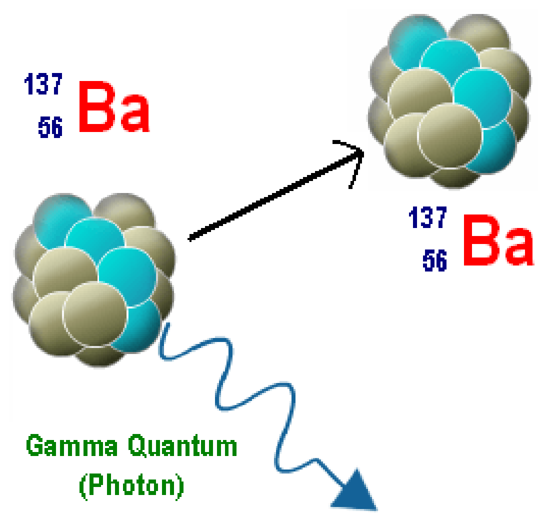
Gamma Decay (γ): Gamma rays produced during gamma decay are produced in conjunction with other forms of radiation such as alpha or beta rays, and are produced after the other types of decay occur. An excited nucleus can decay by the emission of an α or β particle. The daughter nucleus that results is usually left in an excited state. It can then decay to a lower energy state by emitting a gamma ray photon, in a process called gamma decay. Gamma rays are ionizing radiation, and therefore are biologically hazardous.

Alpha



$$ {}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha $$

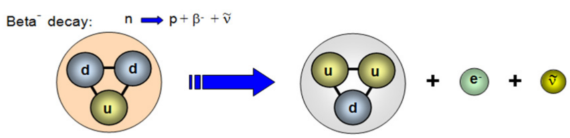
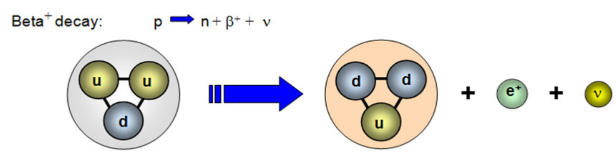
Gamma

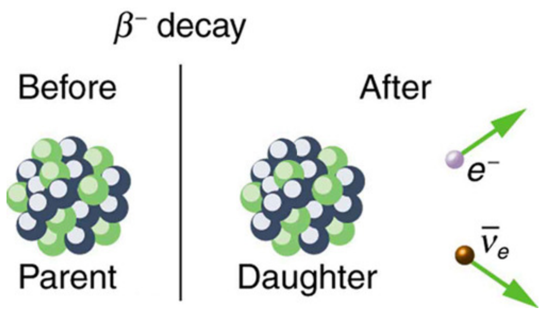


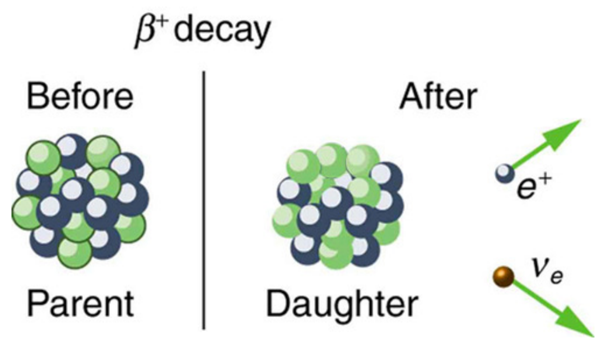
$$ {}^{12}_{5}B \rightarrow {}^{12}_{6}C^{*} + {}_{-1}^{0}\beta + \bar{\nu} $$
$$ {}^{12}_{6}C^{*} \rightarrow {}^{12}_{6}C + \gamma $$

Radioactive Decays (Beta-minus and Beta-plus)

Beta Decay (β): A proton is transformed into a neutron, or vice-versa, inside an atomic nucleus. This process allows the atom to move closer to the optimal ratio of protons and neutrons. As a result of this transformation, the nucleus emits a detectable beta particle (electron or positron).

Beta-negative / Beta-minus	Beta-positive / Beta-plus
	





β⁻ (-1 charge, 0 nucleons)

Conservation of Nucleons

$${}^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$$

$${}^{23}_{12}Mg \longrightarrow {}^{23}_{11}Na + {}^{0}_{1}e + {}^{0}_{0}\nu$$

Conservation of Charge

$${}^{A}_{Z}x \longrightarrow {}^{A}_{Z+1}y + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}_e$$

$${}^{A}_{Z}x \longrightarrow {}^{A}_{Z-1}y + {}^{0}_{+1}e + {}^{0}_{0}\nu_e$$

Conservation of Charge

Anti-neutrino

In terms of Quarks?

Beta-negative decay

$${}^{1}_{0}n \rightarrow {}^{1}_{+1}p + {}^{0}_{-1}\beta + \bar{\nu}$$

In terms of Quarks?

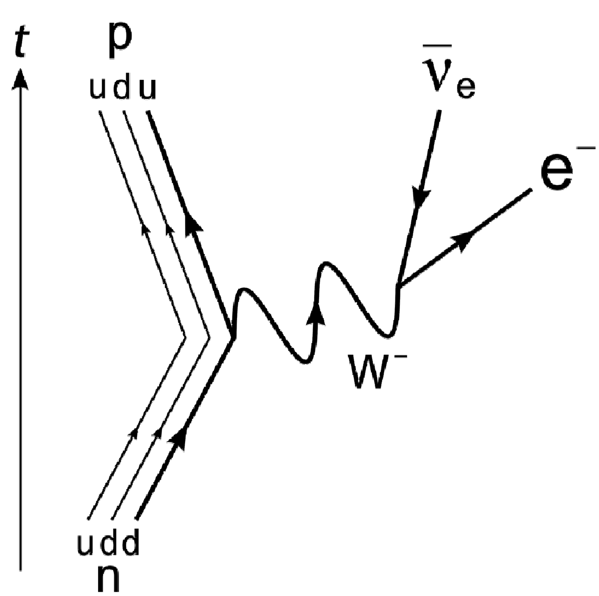
Beta-positive decay

$${}^{1}_{+1}p \rightarrow {}^{1}_{0}n + {}^{0}_{+1}\beta + {}^{0}_{0}\nu$$

Positron

Beta Decay Animation

Q2: What type of Beta-Decay is this? Positive or Negative?



Radioactive Decay Questions (Page 1 of 2)

Q3: Write the alpha decay of Uranium - 238.

$${}^{238}_{92}U \rightarrow {}^{4}_{2}\alpha + {}^{234}_{90}Th$$

$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$$

$${}^{A}_{Z}x \rightarrow {}^{A}_{Z+1}y + {}^{0}_{-1}e + {}^{0}_{0}\overline{v_e}$$

$${}^{A}_{Z}x \rightarrow {}^{A}_{Z-1}y + {}^{0}_{+1}e + {}^{0}_{0}v_e$$

Q4: Show Thallium - 208 beta negative decay

$${}^{208}_{81}Tl \rightarrow {}^{0}_{-1}\beta^{-} + {}^{208}_{82}Pb + \bar{v}$$

$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$$

$${}^{A}_{Z}x \rightarrow {}^{A}_{Z+1}y + {}^{0}_{-1}e + {}^{0}_{0}\overline{v_e}$$

$${}^{A}_{Z}x \rightarrow {}^{A}_{Z-1}y + {}^{0}_{+1}e + {}^{0}_{0}v_e$$

Q5: Show Nitrogen - 13 beta positive decay

$${}^{13}_{7}N \rightarrow {}^{0}_{+1}\beta^{+} + {}^{13}_{6}C + v$$

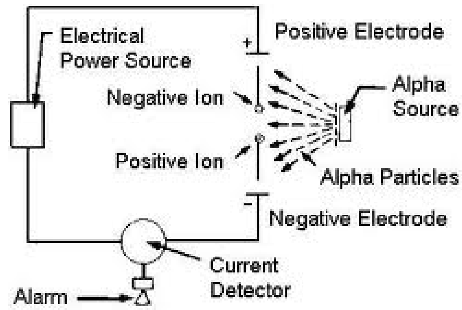
$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$$

$${}^{A}_{Z}x \rightarrow {}^{A}_{Z+1}y + {}^{0}_{-1}e + {}^{0}_{0}\overline{v_e}$$

$${}^{A}_{Z}x \rightarrow {}^{A}_{Z-1}y + {}^{0}_{+1}e + {}^{0}_{0}v_e$$

Radioactive Decay Questions (Page 2 of 2)

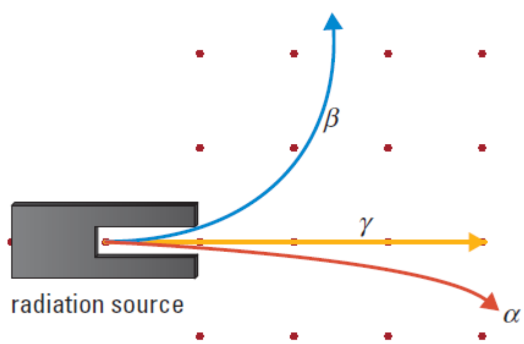
Q5: How do smoke detectors work?



Radiation and Magnetic Fields

Concept Check

Figure 16.5 shows the paths that α, β, and γ rays take when passing through a magnetic field. What can you conclude about the electrical properties of these rays?



▶ **Figure 16.5** The paths of α, β, and γ rays in a magnetic field

Q6: What do we notice about the radius of curvature of each path? Why?

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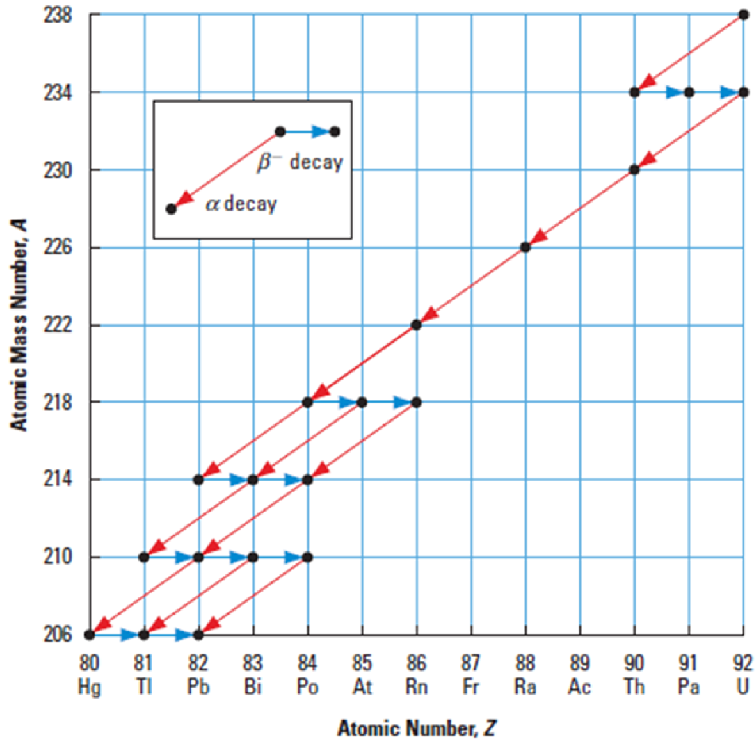
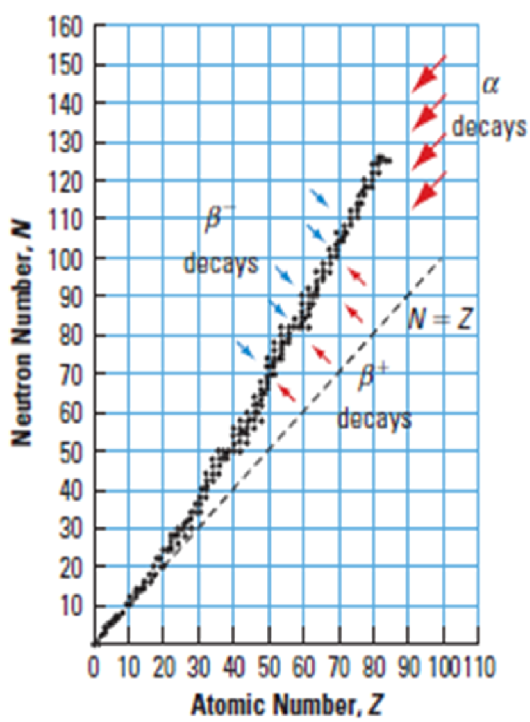
Radioactive Decay Series



$${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$$

$${}^{A}_{Z}x \longrightarrow {}^{A}_{Z+1}y + {}^{0}_{-1}e + {}^{0}_{0}\overline{\nu_e}$$

Band of Stable Isotopes



$${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$$

$${}^{A}_{Z}x \longrightarrow {}^{A}_{Z+1}y + {}^{0}_{-1}e + {}^{0}_{0}\overline{\nu_e}$$

Black dots represent stable isotopes.

$N \geq Z$