Radioactive Decay and Radiometric Dating

Extra credit: chapter 7 in Bryson

See online (link fixed) or moodle

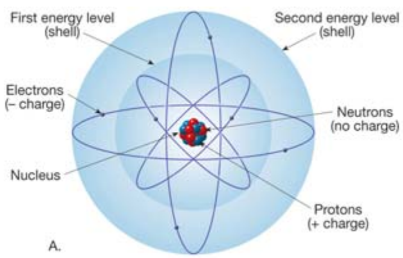
Radioactivity and radiometric dating

- Atomic nucleus
- Radioactivity
- Allows us to put numerical ages on geologic events

Atomic structure

- Nucleus—composed of protons and neutrons
- Orbiting the nucleus are electrons – negative electrical charges

Atom model



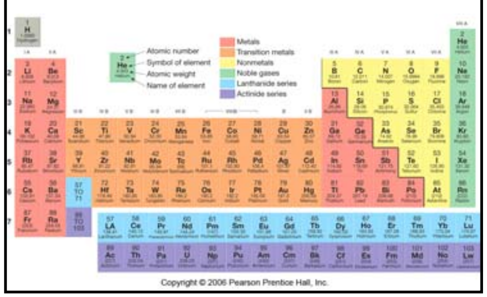
Atomic number

- Identifying number
- Number of protons
- Determines the properties

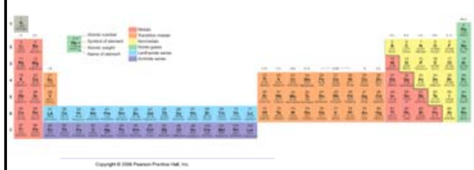
Mass number

- Protons + Neutrons
- Nucleons
- Not the same as Atomic Mass

Periodic Table



Series in Periodic Table



Isotope

- Same number of protons
- Different number of neutrons
- Different mass number than another isotope of the same element
- Variant atom of the same element
- Say “Gold 188” for Au-188

Radioactivity

Spontaneous breaking apart (decay) of atomic nuclei

Nucleus

- Very small—10^{-15} to 10^{-14} m radius
- “Strong interaction” binds nucleons
- Protons repel one another
  - Neutrons counteract this
  - More neutrons than protons in larger atoms

Nuclear forces

- Very strong at small distances (10^{-15} m)
- Weakens at 10X that distance (10^{-14} m)
- Elements at. # 82 + are unstable, because they are big
- “Radioactive”

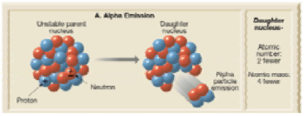
Radioactive decay

- Parent atom– an unstable isotope
- Daughter products
  - Formed from the decay of a parent atoms
  - Different element because of nuclear changes

Types of radioactive decay

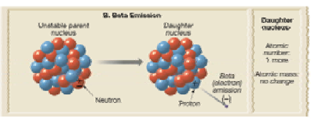
- Alpha emission α
- Beta emission β
- Gamma radiation γ

Alpha emission α



- 2 N + 2 P^+
- Positive charge
- Large→ non-penetrating

Beta emission β



- Negative charge—electron
- N→ $P^+ + e^-$
- Small, but low energy—minor penetration

Gamma radiation γ

- Penetrating, energetic photons
- Lower energy of excited daughter nucleus
- No charge, less mass than electron

Nuclear Decay Equation Alpha Decay

- Ra-226→Rn-222+α

Total nucleons stays same,
but on daughter (product) side

Alpha decay α removes $2N^o$ and $2P^+$

Nuclear Decay Equation
Beta Decay

- H-3 → He-3 + β

Total nucleons stays same

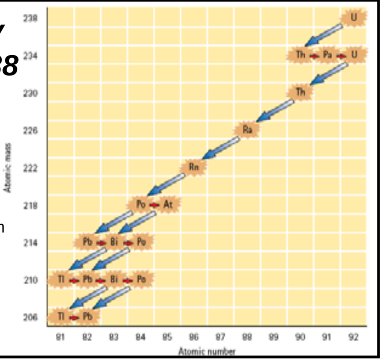
Beta decay β $N^o \rightarrow P^+ + e^-$

Balancing Nuclear Equations

- P^+ (protons) + e^- (electrons) = N^o (neutrons)
- Keep track of protons: elemental symbol
- α decay decreases by two by releasing them with two neutrons…so atomic number goes down by 2, atomic mass goes down by 4
- β decay increases protons by releasing electron…so atomic number goes up by 1, atomic mass stays the same

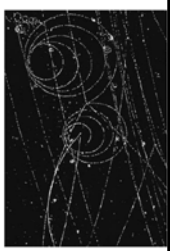
Decay of U-238

NAMES--
Pa: protactinium
Th: thorium
Ra: radium
Rn: radon
Po: polonium
At: astatine
Pb: lead
Bi: bismuth
Tl: thallium



Measuring Radioactivity

- Radioactive decay strips electrons from atoms
- Ions created
- Geiger counter--charged wire, results in 'clicks' of counter
- Others rely on visual reactions of ions



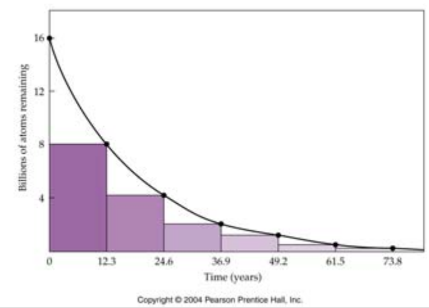
Half Life

Decay is random for any radioactive atom

BUT: Predictable for mass of material

- One half of unstable parent material → daughter product: HALF LIFE: $L_{1/2}$
- Decay rate constant, unaffected by external conditions

Parent to daughter ratios of H-3



Half Life equation

Amount remaining can be calculated by

$$R = I\frac{1}{2^n}$$

R remaining   I initial   n number of half-lives

Calculate amount from half-life

- Start with 400 mg of Co-60
- Half life is 5.25 years
- How much is left after 15.75 years?
- To use equation at right,
- First calculate how many half lives
  3 half-lives

$$R = I\frac{1}{2^n}$$

$$15.75\ years \div \frac{5.25\ yr}{halflife} = 15.75\ years \cdot \frac{halflife}{5.25\ yr} =$$

Calculate amount from half-life

- 400 mg of Co-60
- Half life is 5.25 years
- How much is left after 3 half-lives?
- Calculate amount

$$R = (400mg)\cdot\frac{1}{2^3} = 50mg$$