Nuclear Chemistry

1. **Quickly reviewing atomic notation and isotopes**
    a. Atomic Notation – commonly used to specify the number of protons and neutrons in the atom

Mass number

Atomic number $^{235}_{92}U$ Atomic symbol

    b. Isotopes – atoms of an element that have different number of neutrons.
    c. All atoms of a particular element have the same number of protons in their nucleus.

1. **Radioactive isotopes**
    ~100 Elements
    ~300 nature accruing isotopes
    1000+ are Artificial
    a. Many are unstable - Spontaneously disintegrate releasing high energy
    b. Nuclear Radiation – particles and energy released
        Move to more stable arrangements
    c. Radioactive Isotopes – isotopes that undergo radiation

2. **Common Forms of Radioactivity**
    i. alpha particle – 2 protons and 2 neutrons, +2 charge, 5-10% speed of light, helium nucleus, slow due to its mass, low penetration

$^{4}_{2}\text{He}$ or $^{4}_{2}\alpha$

    ii. beta particle – electron, -1 charge, 90% of speed of light, n → e + p, moderate penetration power

$^{0}_{-1}\beta$ or $^{0}_{-1}e^{-}$

    iii. positron – positive "electron", +1 charge, 90% speed of light, p → n+ β, moderate penetrating power

$^{0}_{+1}e$ or $^{0}_{+1}\beta$ $\quad$ $^{1}_{1}\text{p} \rightarrow {}^{0}_{+1}\text{e} + {}^{1}_{0}\text{n}$

    iv. Electron Capture – outer shell electron captured by nucleus, -1 charge

$^{0}_{-1}\beta$ or $^{0}_{-1}e^{-}$ $\quad$ $^{1}_{1}\text{p} + {}^{0}_{-1}\text{e} \rightarrow {}^{1}_{0}\text{n}$

v. gamma ray – electromagnetic radiation, no charge, light speed.

$${}^{0}_{0}\gamma$$

$${}^{0}_{+1}e + {}^{0}_{-1}e \rightarrow 2{}^{0}_{0}\gamma$$

3. Nuclear Equations

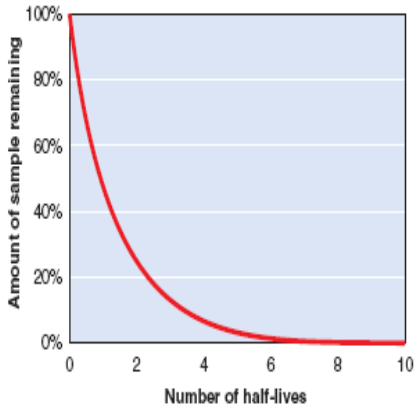
a. Elements may change
b. Balance Reactant mass # = product mass #s
c. Balance Reactant atomic # = product atomic #s
d. Practice Problems

Write a balanced equation for the following:

- Radium (Ra)-226 decays by alpha emission.
- Plutonium-239 emits an alpha particle when it decays.
- Protactinium (Pa)-234 undergoes beta decay.
- Sodium-24 undergoes beta decay.
- Gold (Au)-188 decays by positron emission.
- Carbon-11 emits a positron when it decays.
- Carbon-11 undergoes electron capture.
- Argon-37 undergoes electron capture.

4. Quick review of half-life

a. Radioactive decay is first order decay
b. Half-life is independent of sample size
c. Shorter the half-life, the more the radioactivity
d. Half-life is a characteristic of each isotope
e. Practice problems



- Rubidium-84 has a half-life of 33 day. How many milligrams of a 10.0 mg sample of this radioisotope remain after 99 days?
- How many days are required for a 1.00 mg sample of Rb-84 to decay to 0.0625?

5. Isotopic Dating

a. Radioactive isotopes are used to estimate the age of various items
i. Age of rock – U-235 – half-life of 4.5 billion years
ii. Organic materials in archeological sites – C-14 – half-life of 5730 years
iii. Age of wines – H(T)-3 – half-life of 12.26 years

b. Carbon – 14

i. 99.9% ^{12}C

ii. Produce ^{14}C in upper atmosphere

iii. Useful for dating objects between 500 and 50,000 years old

iv. After 50,000 years objects don't have enough of the isotope left for accurate measurements

v. Past uses

1. Shroud of Turin
    a. Alleged burial shroud of Jesus Christ
    b. First documented in Middle Ages
    c. Carbon-14 dating done in 1988, three separate labs
    d. Shroud ~800 years old
    e. Unlikely to be burial shroud

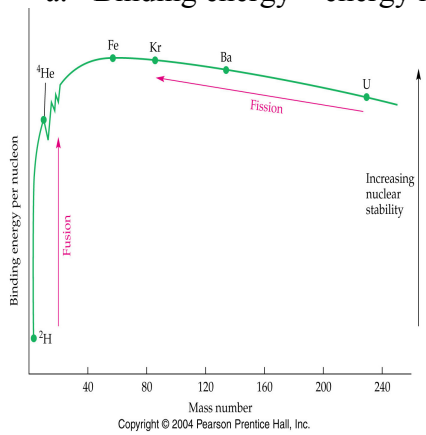
2. Dead Sea Scrolls
    a. Carbon-14 dating
    b. Scrolls 2000 years old

c. Practice problems

- **A piece of fossilized wood has carbon-14 activity one-eighth that of new wood. How old is the artifact? The half-life of carbon-14 is 5730 years.**
- **How old is a piece of cloth that has carbon-14 30% activity compared to that of new cloth fibers? The half-life of carbon-14 is 5730 years.**

6. Fusion and Fission

a. Binding energy – energy holding nucleus together



b. Fe is most stable

c. Smaller than Fe – fusion – atoms comes together to form larger atoms

d. Larger then Fe – fission – atoms break apart

7. Transmutation (Artificial) changes one element into another

   When potassium-39 is bombarded with neutrons, chlorine-36 is produced. What other particle is emitted?

   Technetium(Tc)-97 is produced by bombarding molybdenum(Mo)-96 with a deuteron (hydrogen-2 nucleus). What other particle is emitted?