Chapter 25
Nuclear Chemistry

Chemical vs. Nuclear Reactions	
Chemical Reactions	**Nuclear Reactions**
1. Bonds are broken and formed 2. Atoms may rearrange, but remain unchanged 3. Involve only valence electrons 4. Small energy changes 5. Reaction rate is influenced by temperature, pressure, concentration, and catalysts.	1. Nuclei emit particles and/or rays. 2. Atoms are often converted into atoms of another element 3. May involve protons, neutrons or electrons 4. Large energy changes 5. Reaction rate not usually affected by temperature, pressure, or catalysts

Radioisotopes

Isotopes of atoms with unstable nuclei.

They emit radiation to attain more stable configurations in a process called radioactive decay

During radioactive decay, unstable atoms lose energy.

$^{12}_{6}C$ $^{14}_{6}C$

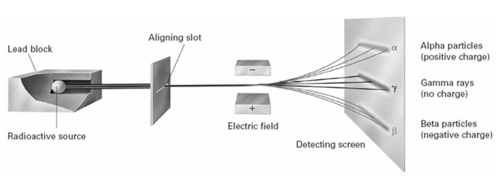
Types of Radiation

During radioactive decay, unstable atoms lose energy by emitting one of several types of radiation.

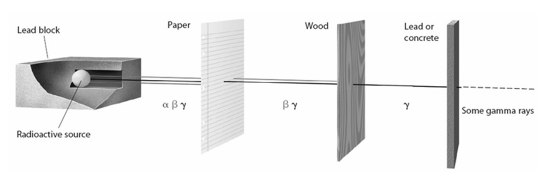
The 3 most common types are:

1. Alpha
2. Beta
3. Gamma

Charge of Radiation



Penetration of Radiation



Characteristics of Radiation

Table 25.1

Characteristics of Some Types of Radiation

Property	Alpha radiation	Beta radiation	Gamma radiation
Composition	Alpha particle (helium nucleus)	Beta particle (electron)	High-energy electro-magnetic radiation
Symbol	α, ${}^{4}_{2}He$	β, ${}^{0}_{-1}e$	γ
Charge	2+	1−	0
Mass (amu)	4	1/1837	0
Common source	Radium-226	Carbon-14	Cobalt-60
Penetrating power	Low (0.05 mm body tissue)	Moderate (4 mm body tissue)	Very high (penetrates body easily)
Shielding	Paper, clothing	Metal foil	Lead, concrete (incompletely shields)

Alpha Radiation

Alpha radiation consists of helium nuclei that have been emitted from a radioactive source. These emitted particles, called **alpha particles**, contain two protons and two neutrons and have a double positive charge.

- *Note: In a nuclear decay equation, mass and charge are conserved!*

$$ {}^{238}_{92}U \xrightarrow[\text{decay}]{\text{Radioactive}} {}^{234}_{90}Th + {}^{4}_{2}He \ (\alpha \text{ emission}) $$

Uranium-238 — Thorium-234 — Alpha particle

Beta Radiation

Beta particles are fast moving electrons emitted from the neutron of an unstable nucleus

The mass number stays the same, but the proton number increases by 1, therefore changing the element.

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

Beta Radiation

The neutron changing into a beta particle and a proton.

$$ {}^{1}_{0}n \longrightarrow {}^{1}_{1}H + {}^{0}_{-1}e $$

Neutron — Proton — Electron (beta particle)

Gamma Radiation

A high-energy photon emitted by a radioisotope is called a **gamma ray.** The high-energy photons are electromagnetic radiation.

The emission of gamma rays does not change the mass number or the atomic number.

Alpha and/or beta radiation usually accompany gamma rays

$$ {}^{230}_{90}Th \longrightarrow {}^{226}_{88}Ra + {}^{4}_{2}He + \gamma $$

Thorium-230 — Radon-226 — Alpha particle — Gamma ray

Nuclear Stability

Nucleons: protons and neutrons

The stability of a nucleus can be correlated to the neutron:proton ratio.

Atoms that do not have the proper ratio may undergo radioactive decay to achieve stability.

All atoms with atomic number greater than 83 are considered radioactive.

Types of Radioactive Decay

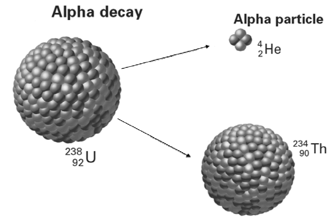
Alpha Decay: All nuclei with more than 83 protons

- The neutrons and protons must decrease to achieve a stable nuclei.

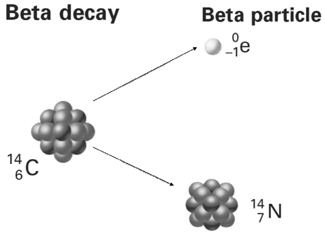
Beta Decay: Occurs when a radioisotope has too many neutrons

- Carbon-14 has too many neutrons, therefore undergoes beta decay and becomes a stable nitrogen atom.

Alpha Decay



Beta Decay



Balancing Nuclear Equations

Mass
Atomic

$$^{230}_{90}Th \rightarrow {}^{226}_{88}Ra + {}^{4}_{2}He$$

All elements with atomic numbers greater than 83 are radioactive. As you can see, Thorium decayed producing Radium and Helium.

Complete the Following

$$\_\_ \rightarrow {}^{181}_{77}Ir + {}^{4}_{2}He$$

$$^{230}_{84}Po \rightarrow {}^{4}_{2}He + \_\_$$

$$\_\_ \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$$

Complete the Following

$$^{184}_{74}W \rightarrow \_\_\_\_ + {}^{184}_{75}Re$$

$$\_\_\_\_ \rightarrow {}^{0}_{-1}e + {}^{120}_{51}Sb$$

$$^{42}_{20}Ca \rightarrow {}^{0}_{-1}e + \_\_\_\_$$

Complete the Following

$$^{115}_{49}In \rightarrow \, ^{115}_{49}In + \_\_\_\_\_$$

$$\_\_\_\_\_ \rightarrow \, ^{122}_{51}Sb + \, ^{0}_{0}\gamma$$

$$^{96}_{42}Mo \rightarrow \_\_\_\_\_ + \, ^{0}_{0}\gamma$$

Transmutation

The conversion of an atom of one element into an atom of another element.

Occur in two ways:

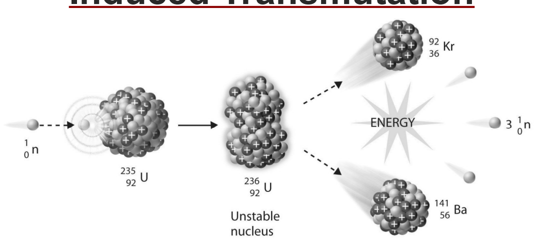
1. Induced Transmutations
2. Radioactive Decay

- Transmutation can occur **naturally** by radioactive decay.
  - a single nucleus undergoes decay
- Transmutation can also occur **artificially** when particles bombard the nucleus of an atom.
  - at least two reactants produce the target material

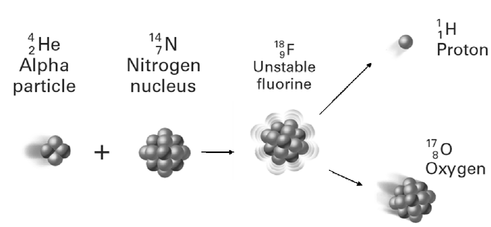
Induced Transmutation

- A nucleus is bombarded with high-energy particles to bring about a change.
- Two types:
  - Bombarding with charged particles: protons or alpha particles.
    - Particle accelerators use magnetic or electrostatic fields to accelerate particles towards the target.
      - Cern video
  - Bombarding with neutrons.
    - Neutrons are obtained as by-products of nuclear reactors.

Induced Transmutation



Induced Transmutation



Transuranium Elements

The elements following uranium on the periodic table

Have atomic numbers of 93 and greater.

Produced in the laboratory by induced transmutation

Transuranium Elements

$$^{238}_{92}\mathrm{U} + \mathrm{n} \rightarrow {}^{239}_{92}\mathrm{U} \rightarrow {}^{239}_{93}\mathrm{Np} + \mathrm{e}^-$$

Radioactive Decay Rates

All radioactive isotopes are continuously unergoing radioactive decay.

Half-life is used to measure radioactive decay.

Stable atoms have a long half-life

Unstable atoms have a short half-life.

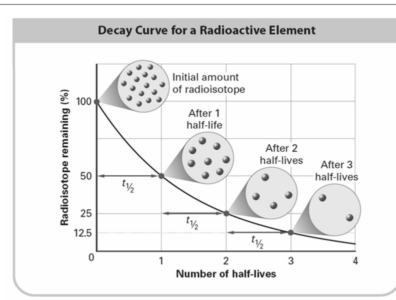
Using Half-Life

The time required fo one-half of a radioisotopes nuclei to decay into products.

The half-life of Strontium-90 is 29 years.

Using Half-Life

- If a 100 g sample has a half-life of 5 days:
  - After 5 days ½ (50g) will remain undecayed
  - After 10 days ¼ (25g) will remain undecayed
  - After 15 days 1/8 (12.5g) will remain undecayed
  - After 20 days 1/16 (6.25g) will remain undecayed
  - And so on…



Calculating Half-Life

The half-life of Strontium-90 is 29 years. Given 355.0-g, how much Strontium-90 remains after 116 years has passed?

(t=time elapsed, T=half life)

amount remaining = initial mass$(1/2)^{t/T}$

Calculating Half-Life

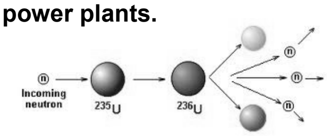
The half-life of Iron-59 is 44.5 days. How much of a 2.0 mg sample remains after 133.5 days.

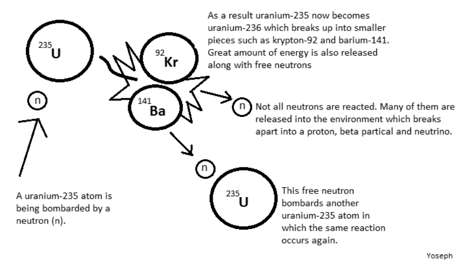
amount remaining = initial mass$(1/2)^{t/T}$

Nuclear Fission

The splitting of a nucleus into fragments

Used by nuclear power plants.





Nuclear Fusion

The combining of atomic nuclei.

Releases a large amount of energy.

The sun is powered by hydrogen atoms fusing to form helium.