

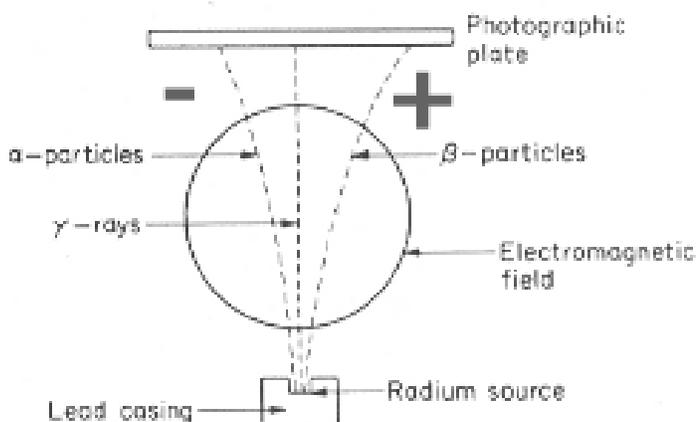
## TOPIC 13: Nuclear Chemistry

**1. When the atomic nucleus of one element is changed into the nucleus of a different element, the reaction is called *transmutation*.**

- **Stability of a Nucleus:** Any element containing an atomic number greater than 83 is considered an unstable element (aka a radioactive element)

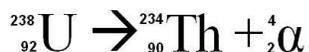
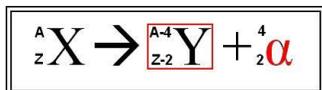
**2. Radioisotopes or radioactive isotopes** emit radioactive particles. Such as

- **Alpha Particles:** A helium nucleus composed of two protons and two neutrons.  ${}^4_2\text{He}$  or  ${}^4_2\alpha$  (they are positively charged particles and have low penetrating power) Alpha particles are released through *alpha decay*.
- **Beta Particles:** An electron that comes from a nucleus through *beta decay*.  ${}^0_{-1}e$  or  $\beta^-$  (they are negatively charged particles and have moderate penetrating power)
- **Positron Emission:** A particle that is identical to a beta particle except it is positively charged.  ${}^0_{+1}e$
- **Gamma Rays:** Almost all nuclear decay releases some energy in the form of gamma rays  ${}^0_0\gamma$  which are similar to x-rays but have greater energy and penetrating power (contains the greatest penetrating power out of all radioactive particles)

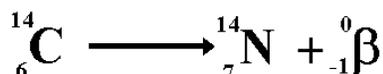


### 3. Decay Modes

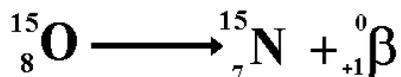
- **Alpha Decay:** Decay process that involves the emission (production) of alpha particles



- Atomic number (protons) of parent nucleus decreases by 2
  - Number of neutrons of parent nucleus decreases by 2
  - Atomic Mass overall of parent nucleus decreases by 4
- **Beta Decay:** Decay process that involves the emission (production) of beta particles



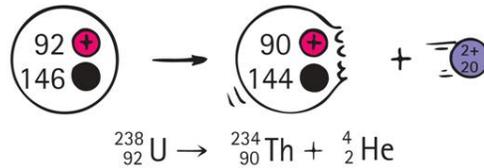
- Atomic number of parent nucleus increases by 1
  - There is no effect on the number of neutrons/atomic mass
- **Positron Emission:** Decay process that involves the emission (production) of a positron



- Atomic number (protons) of parent nucleus decreases by 1
- Atomic mass stays the same while number of neutrons increases by 1 due to the number of protons decreasing. This can be checked using this formula (atomic mass - atomic # = #neutrons) for each element.

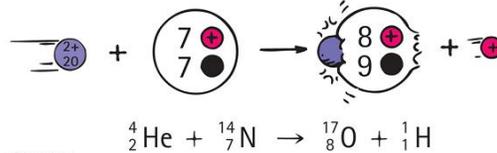
## 4. Transmutations: Natural VS. Artificial

- **Natural Transmutation-** Occurs spontaneously in nature
  - Reaction is spontaneous
  - Only one substance is on the left side of the nuclear equation
  - Alpha and beta decay and positron emission are natural transmutations that occur as a result of unstable neutron-to-proton ratios



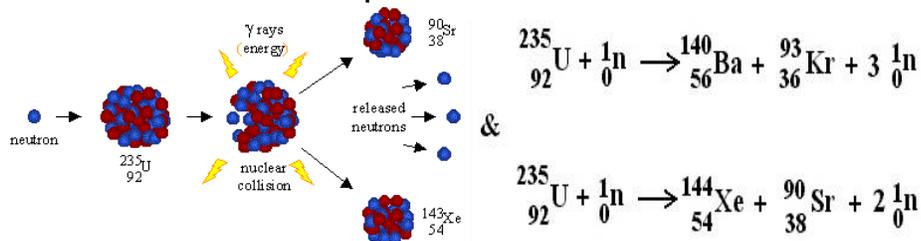
- Think about how things in **nature** happen spontaneously (on their own) just like **natural** transmutation.

- **Artificial Transmutation-** Does not occur spontaneously in nature
  - Reaction is nonspontaneous
  - Two substances on the left side of the equation
  - Bombarding a nucleus with high energy particles brings about the artificial transmutation

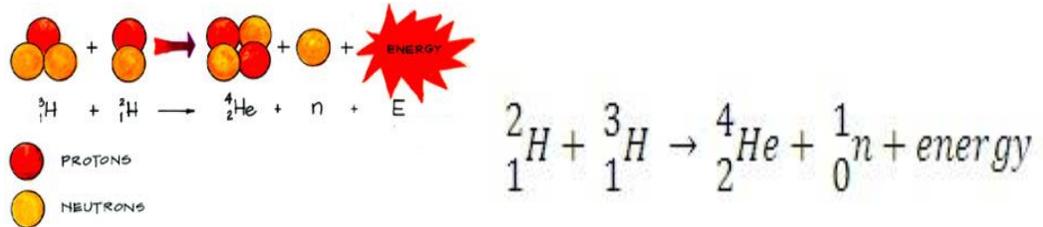


## 5. Types of Nuclear Reactions: Fission VS. Fusion

- **Fission:** Splitting of a heavy nucleus to produce lighter nuclei
  - ❖ Always has a neutron on the reactant side of the nuclear equation



- **Fusion:** Combination of two small nuclei to produce a heavy nucleus.
  - ❖ Hydrogen and Helium are always involved.
  - ❖ Produces more energy than fission and the products are not as radioactive as fission.

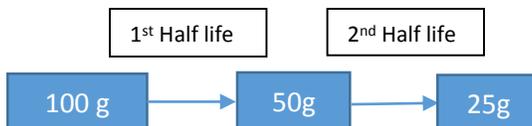


## 6. Conversion of Mass to Energy

- The mass loss in nuclear reactions is due to the conversion mass to energy.
- Mass can never be created nor destroyed BUT it can be converted to energy.
  - ❖ According to Albert Einstein  $E=mc^2$ . The mass that was converted into energy is called **mass defect**. (Total mass of the nucleus is less than the sum of the mass of the individual masses of the protons and neutrons.

## 7. Half Life

- The time it takes for the mass of a radioisotope to decrease by half.



- Half is independent of pressure, concentration, or temperature.

## 8. Uses and Dangers of Radioisotopes

- **Dating:** Carbon-14 (C-14) is used for dating living materials (organic materials). Uranium-238(U-238)/Lead-206(Pb-206) are used to date rocks and other geological formations

- **Chemical Tracer:** Any radioisotope used to follow the path of a material in a system.
  - Tracers are used to detect radioactive materials
  - Phosphorus-31(P-31) is present in fertilizers used on plants
- **Medical Applications**
  - Iodine-131(I-131) is used for detection and treatment of thyroid conditions
  - Cobalt-60(Co-60) is used to kill cancerous tumors as well as to destroy anthrax bacilli.
  - Technitium-99(Tc-99) is used given to patients to detect cancerous tumors
- **Radiation Risks:** High doses of radiation can and will cause SERIOUS illness and death