Radioactive Materials

Dr. Khalid M. Salih

Definitions

Atomic number (Z) is the number of protons within the atom's nucleus and is equal to the number of electrons in the neutral (non-ionized) atom.

Mass number (A) is the number of nucleons (both protons and neutrons) in the nucleus of an atom.

Isotopes are variants of a particular chemical element which differ in neutron number, but have the same number of protons in each atom.

The term isotope is derived from Greek word ***isos*** (equal) and ***topos*** (place), meaning different isotopes of a single element occupy the same position on the periodic table.

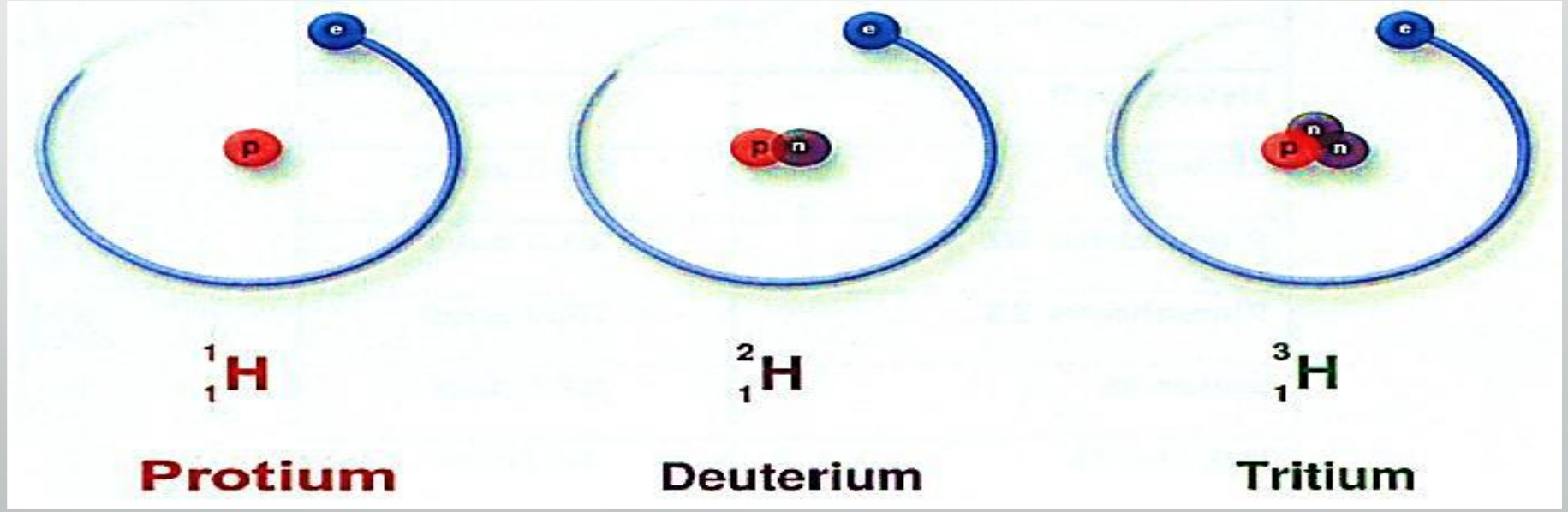
Isotopes

- **There are three isotopes in carbon element:**

  Carbon-12 (Z=6, A=12, neutron=6), **Carbon-13** (Z=6, A=13, neutron=7), **Carbon-14** (Z=6, A=14, neutron=8)

- **There are three isotopes in hydrogen element:**

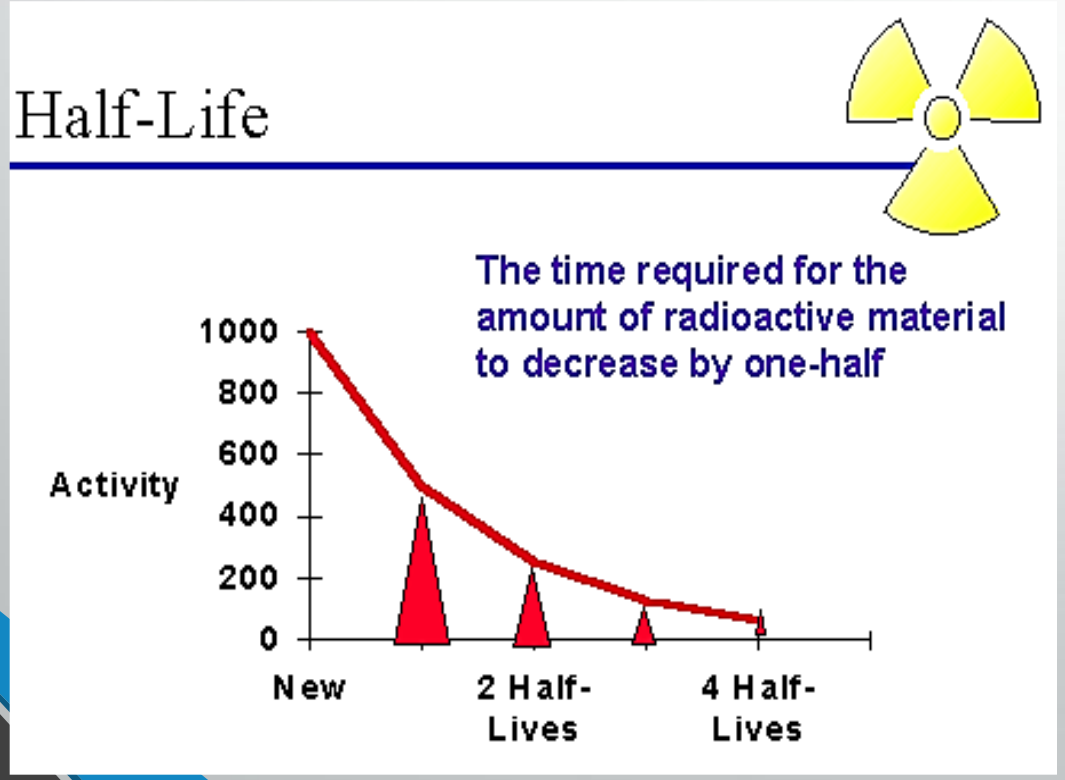
- **Protium** (Z=1, A=1, neutron=0), **Deuterium** (Z=1, A=2, neutron=1), **Tritium** (Z=1, A=3, neutron=2)



Radioactivity & Half-life

Radioactivity is a natural & spontaneous process by which the unstable atoms of an element emit or radiate excess energy in the form of particles or waves collectively called ionizing radiations.

Half-life is the time required for a given amount of some radioactive material to be reduced to one-half of its original activity.



Radioisotope	Half-Life
Hydrogen-3	12.3 years
Carbon-14	5730 years
Phosphorus-32	14.3 days
Phosphorus-33	25.3 days
Sulfur-35	87.6 days
Iodine-125	60.1days

Radioactive isotope (radionuclide)

- It is an atom that has excess nuclear energy, making it unstable unless emit this excess energy from the nucleus as new ***radiation, or particle,*** or transfer this excess energy to one of its ***electrons***, causing it to be ejected and then becomes more stable.
- Naturally occurring radionuclides fall into three categories:

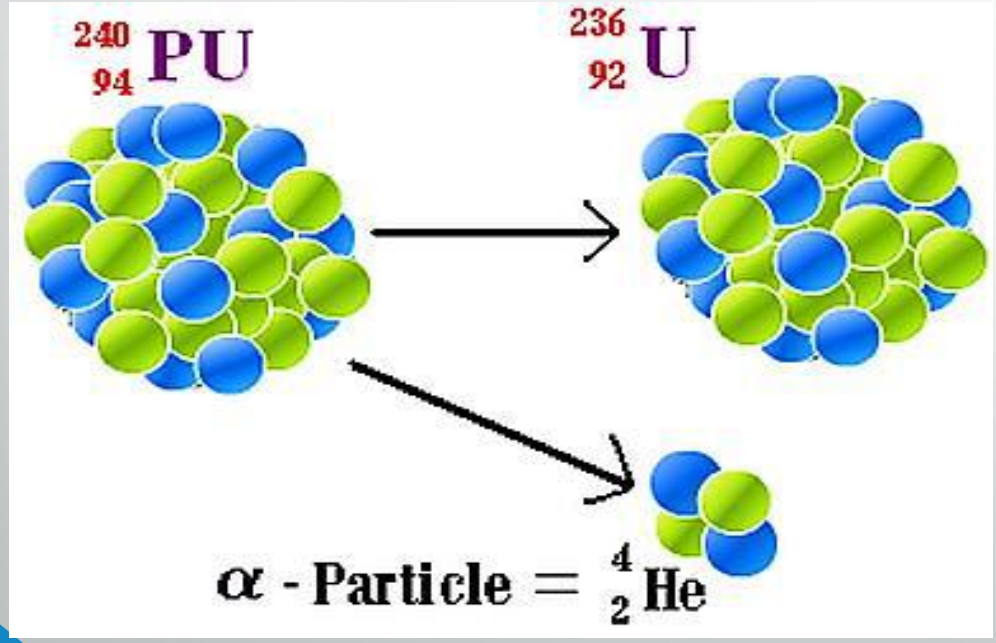
1. ***Primordial radionuclides*** originated from interior of stars which are not yet completely decayed because their half-lives are so long (uranium & thorium)
2. ***Secondary radionuclides*** derived from decay of primordial radionuclides and have shorter half-lives such as radiogenic isotopes.
3. ***Cosmogenic isotopes*** are continually being formed in atmosphere due to cosmic rays (carbon-14)

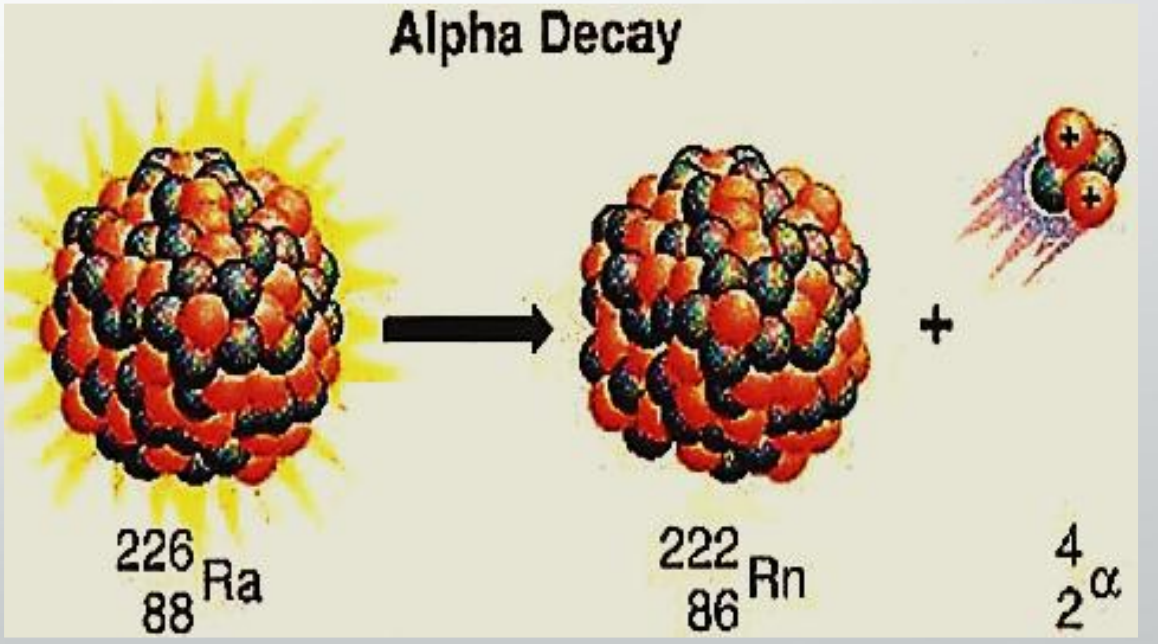
Types of Radioactive Decay

1. Alpha Particles
2. Beta particles
3. Gamma ray
4. X-ray
5. Neutrons

1. Alpha Particles

- A particle with (**2 neutrons & 2 protons**) is ejected from the nucleus of a radioactive atom which are rich in neutrons (radium, radon, polonium).
- Alpha particles are very heavy, very energetic & have two positive charge.





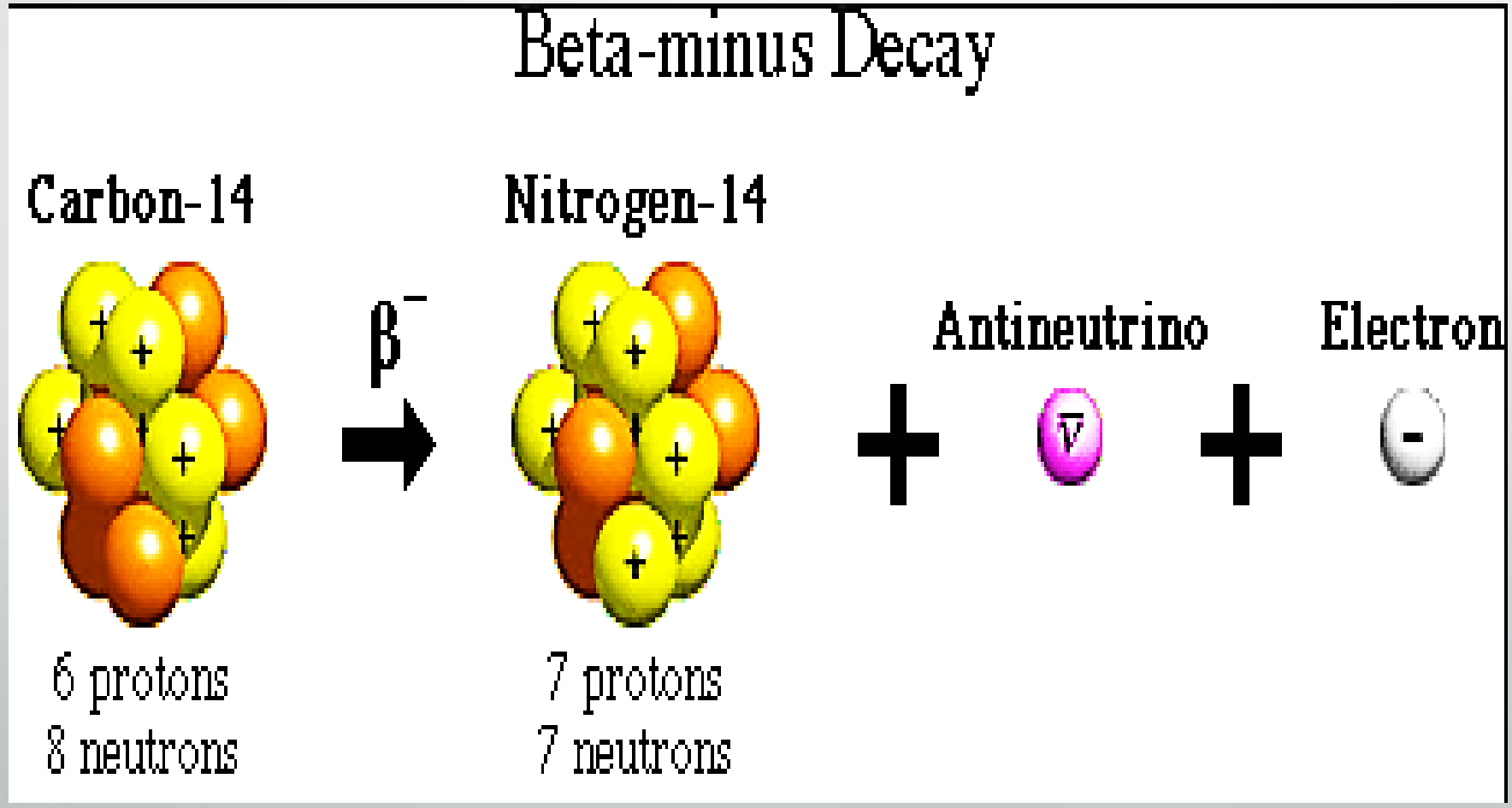
2. Beta Particles

- An **electron** is emitted from the nucleus of a radioactive atom (neutron rich) along with an unusual massless particle called (**antineutrino / neutrino)** that carries away some of the energy from the decay process.
- Because this electron is from the nucleus of the atom, it is called a beta particle to distinguish it from the electrons which orbit the atom.
- There are two types of beta decay:

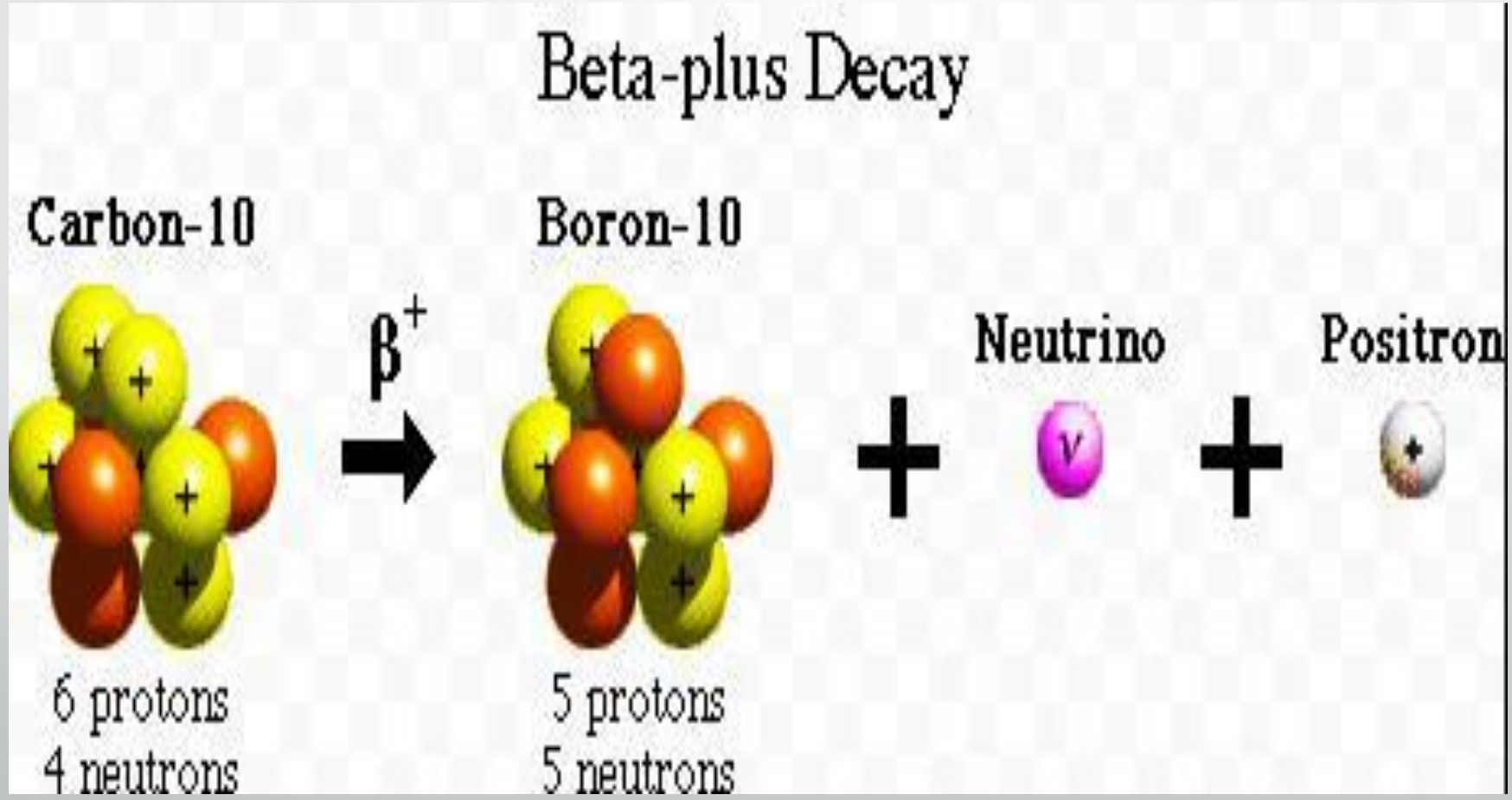
A. Beta-minus (β-) radiation

B. Beta-plus (β+) radiation

A. Beta-minus (β-) radiation

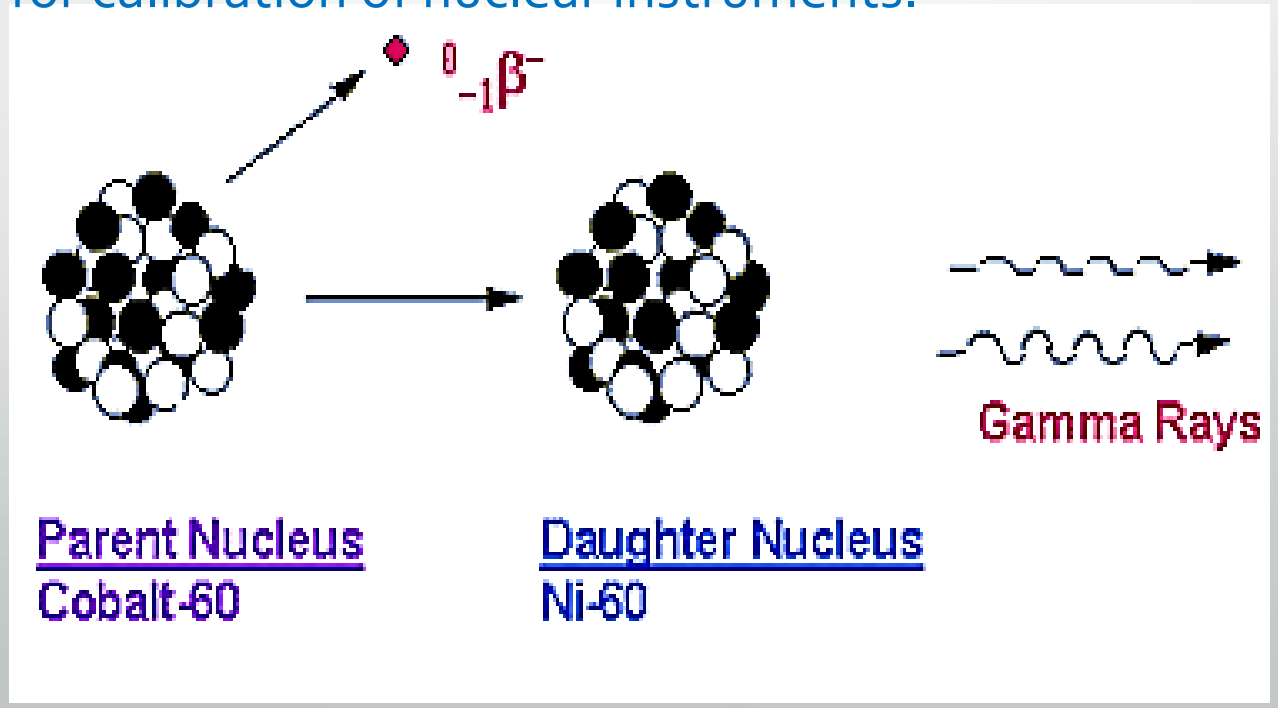


B. Beta-plus (β+) radiation



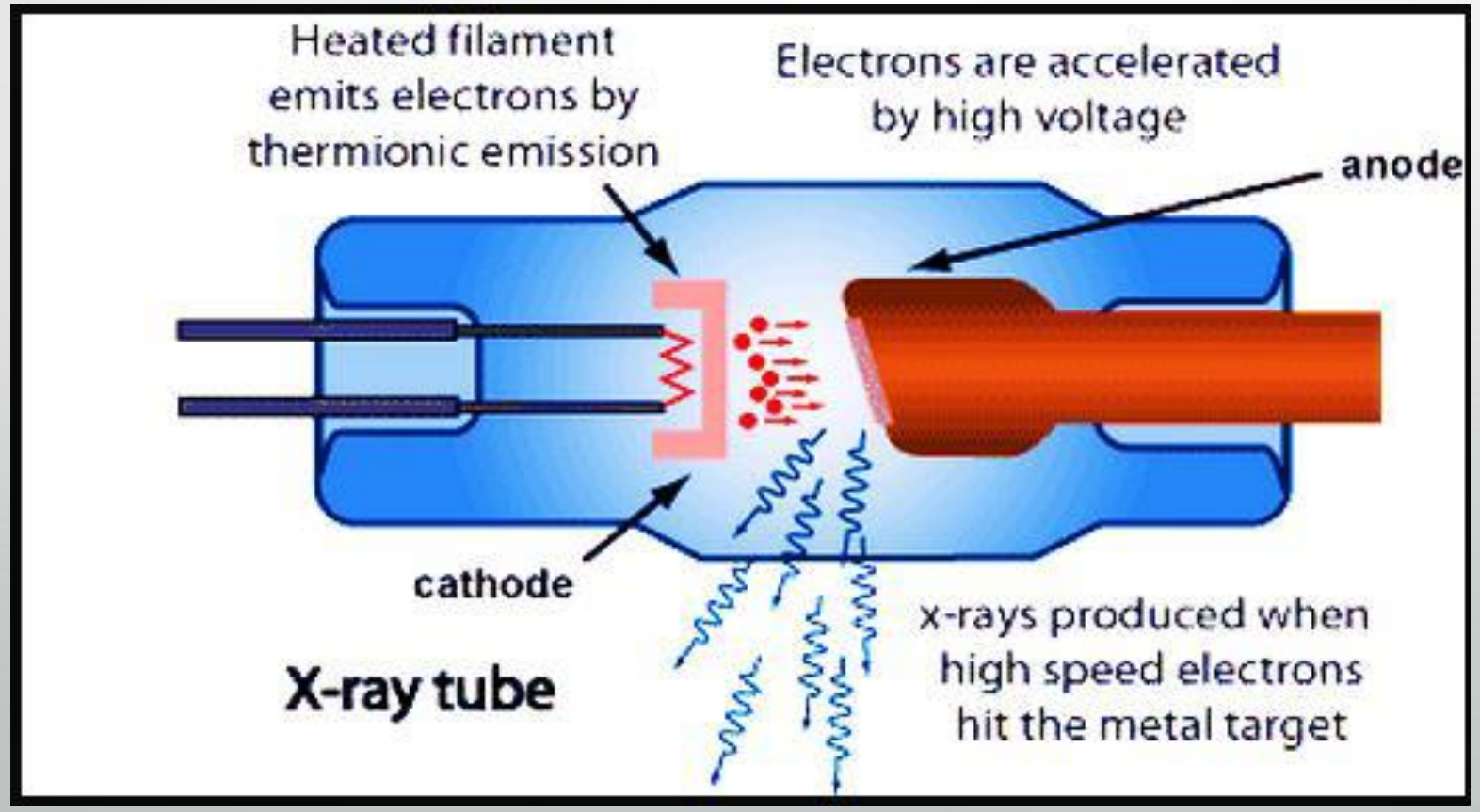
3. Gamma ray

- Gamma (γ) radiation consists of **photons** without mass or charge that emitted as a result of:
  - ✓ beta decay
  - ✓ nuclear reactions or absorption of a thermal neutron
- Gamma emitters include
  - ✓ technetium-99m & cobalt-60 used in nuclear medicine
  - ✓ cesium-137 used for calibration of nuclear instruments.



4. X-ray

- Electromagnetic waves of **photons** normally emitted by energy changes in electrons either in electron orbital shells that surround an atom or in the process of slowing down such as in an X-ray machine (***Crooke's tube)*** discovered by Roentgen.



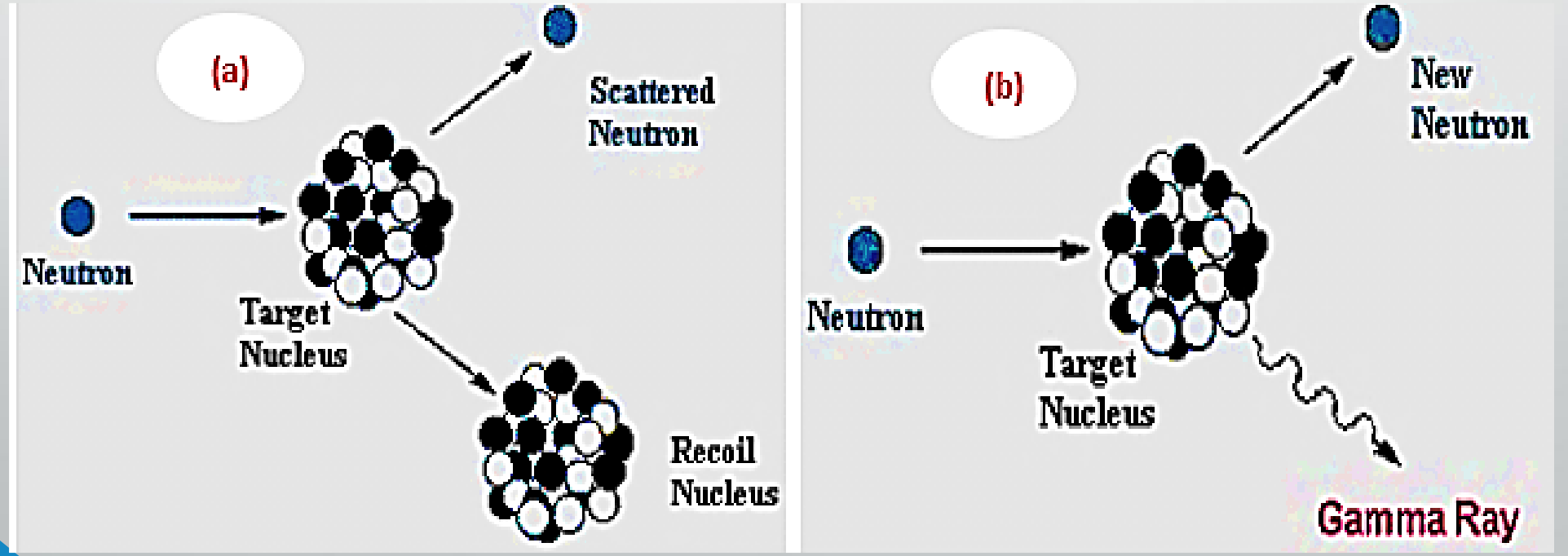
5. Neutron Radiation

- Neutrons are **neutral** particles with same mass of proton emitted during spontaneous or induced:
  - ✓ **nuclear fission**
  - ✓ **nuclear fusion**
  - ✓ **other nuclear reactions**
- Neutrons are not directly ionizing radiation, but produce secondary events that occur as collisions with matter called:
  1) **Scattering events**
  2) **Capture events**

1) Scattering events (high speed & energy neutrons)

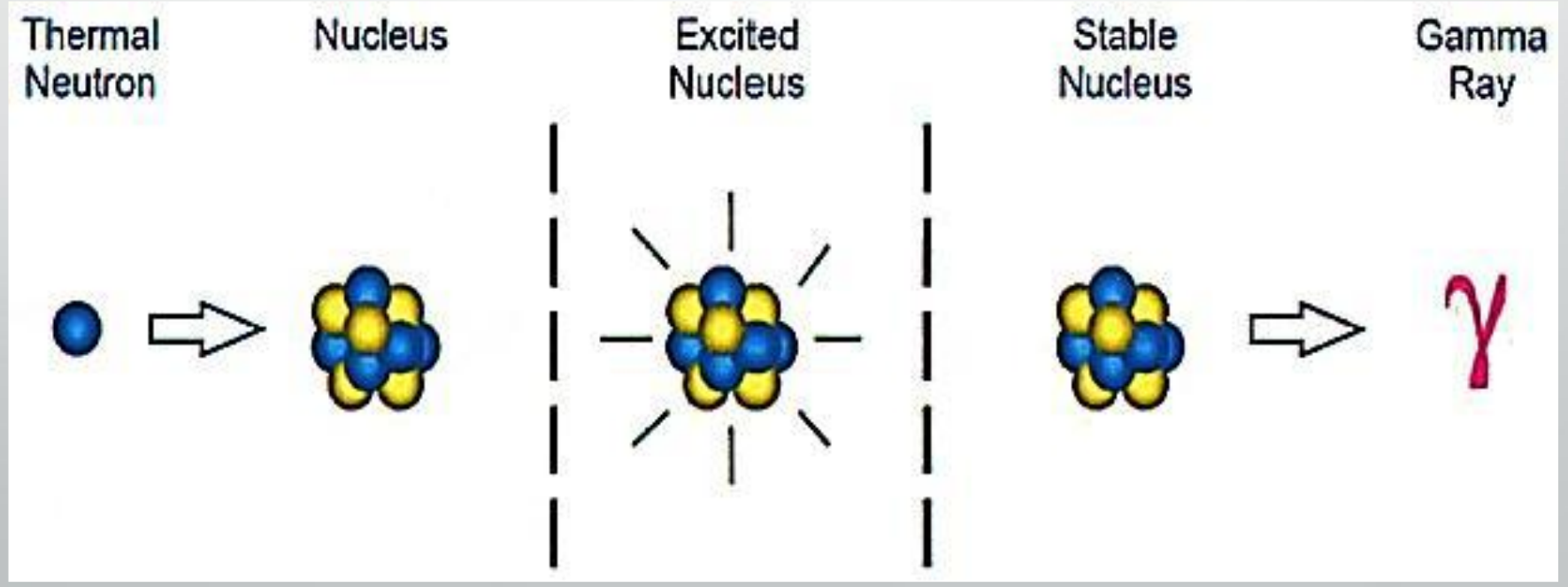
a) ***Elastic scattering event*** (neutron **collides** with target nucleus) (scattered away) (**recoil nucleus** causing excitation and ionization events).

b) ***Inelastic scattering events*** (neutron **absorbed** by target nucleus) (gamma ray & less energetic neutron emitted from the target)



2) Capture event (low speed & energy neutron)

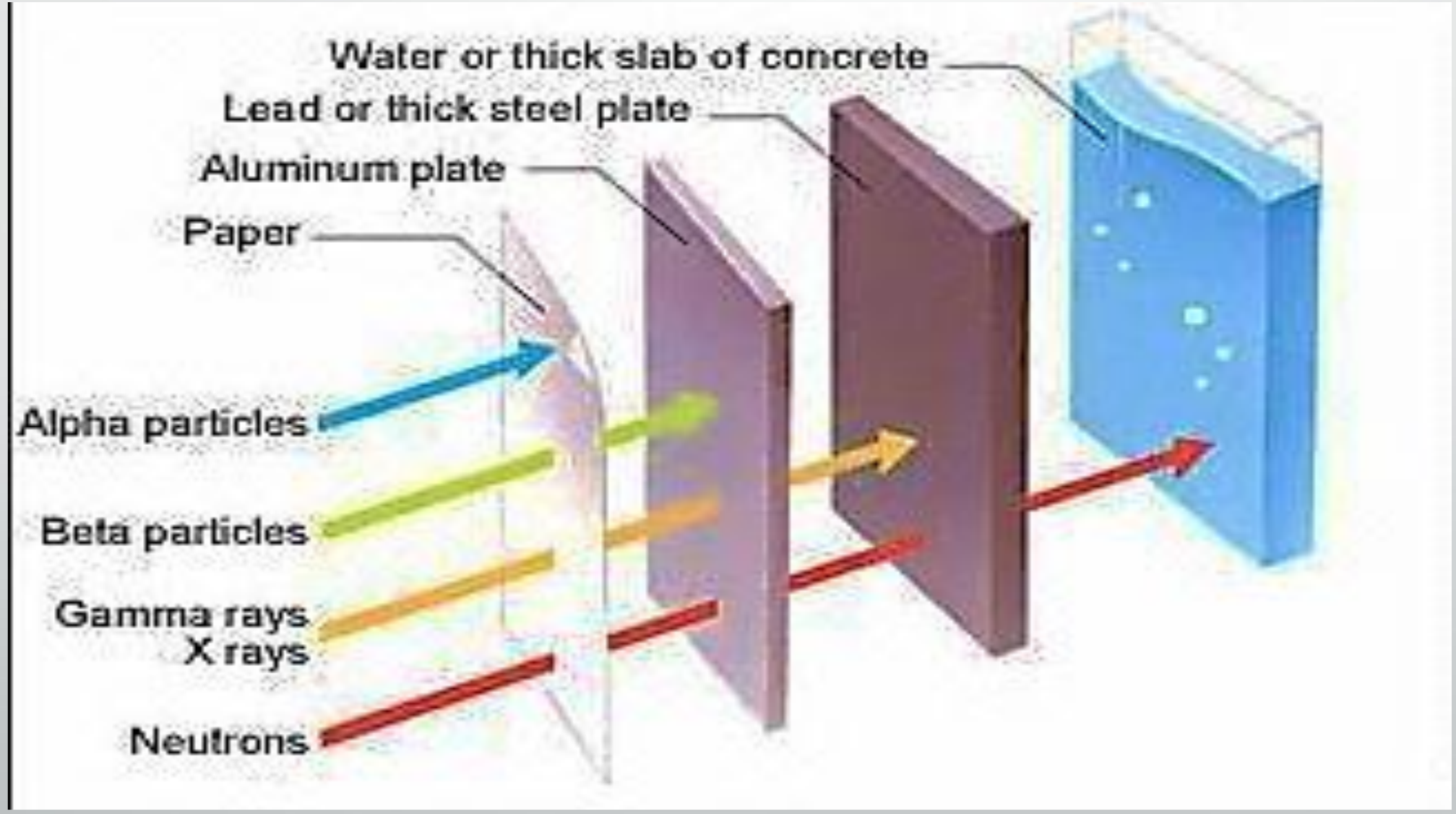
- It is called ***thermal neutron*** that may be absorbed by a target nucleus
- The mass number of new atom increases by one and become unstable, and emitting gamma ray to return to its stable status.
- Neutrons are the only type of ionizing radiation that can make other objects, or material, radioactive in a process called ***neutron activation.***



Properties of Ionizing Radiations

Radiation	Type of Radiation	Mass (AMU)	Charge	Shielding material
Alpha	*Particle*	*4*	*+2*	*Paper, skin, clothes*
Beta	*Particle*	*1/1836*	*±1*	*Plastic, glass, light metals*
Gamma & X-ray	*Electromagnetic Wave*	*0*	*0*	*Dense metal, concrete, Earth*
Neutrons	*Particle*	*1*	*0*	*Water, concrete, polyethylene, oil*

Properties of Ionizing Radiations




THANK YOU