NUCLEAR CHEMISTRY

Radioactivity

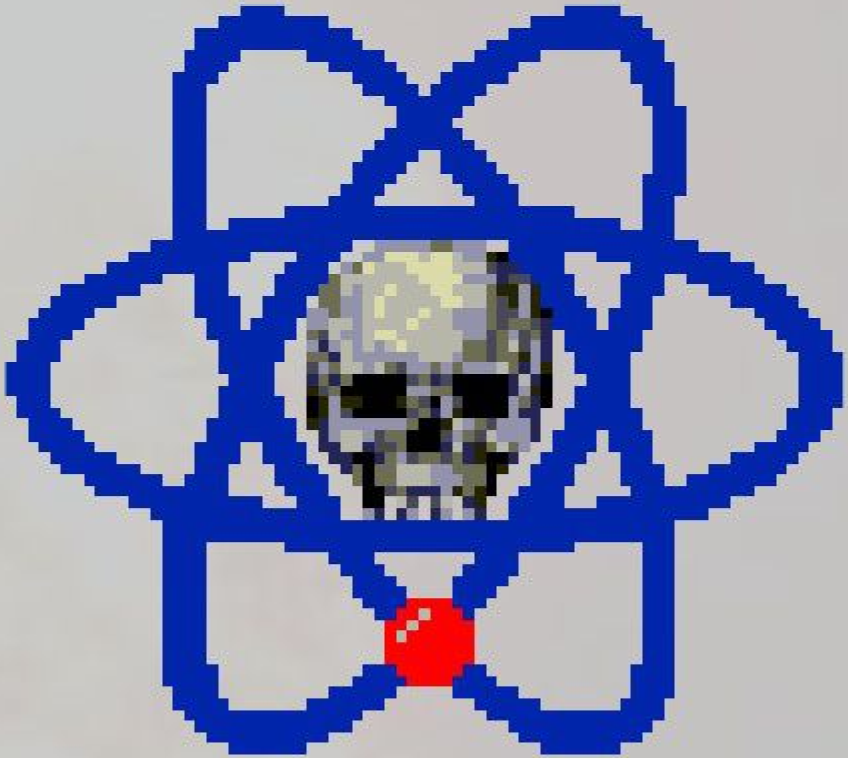
Radioactivity was 1st discovered by Antoine Becquerel, when a photographic plate never exposed to sunlight in his lab had become exposed. The only possible culprit was a nearby uranium salt sitting on the bench top.

History of Radioactivity

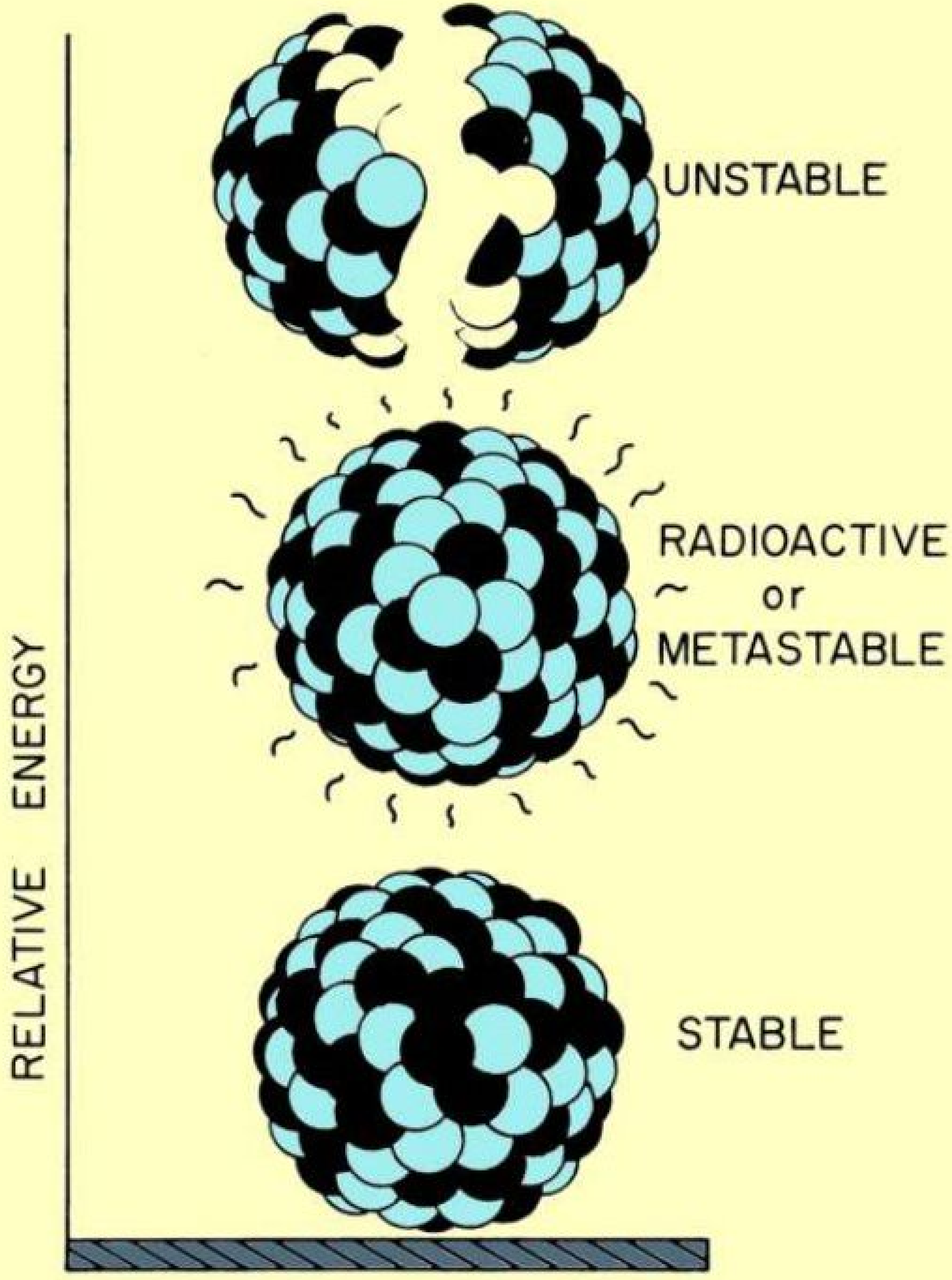
The term **radioactivity** was 1st used by **Marie Curie** in 1898. Curie and her husband, Pierre, found that radioactive particles were emitted as either electrically negative which were called beta particles (β) or positive particles called alpha particles (α).

Nuclear Chemistry

Nuclear reactions are reactions that affect the **nucleus** of the atom.



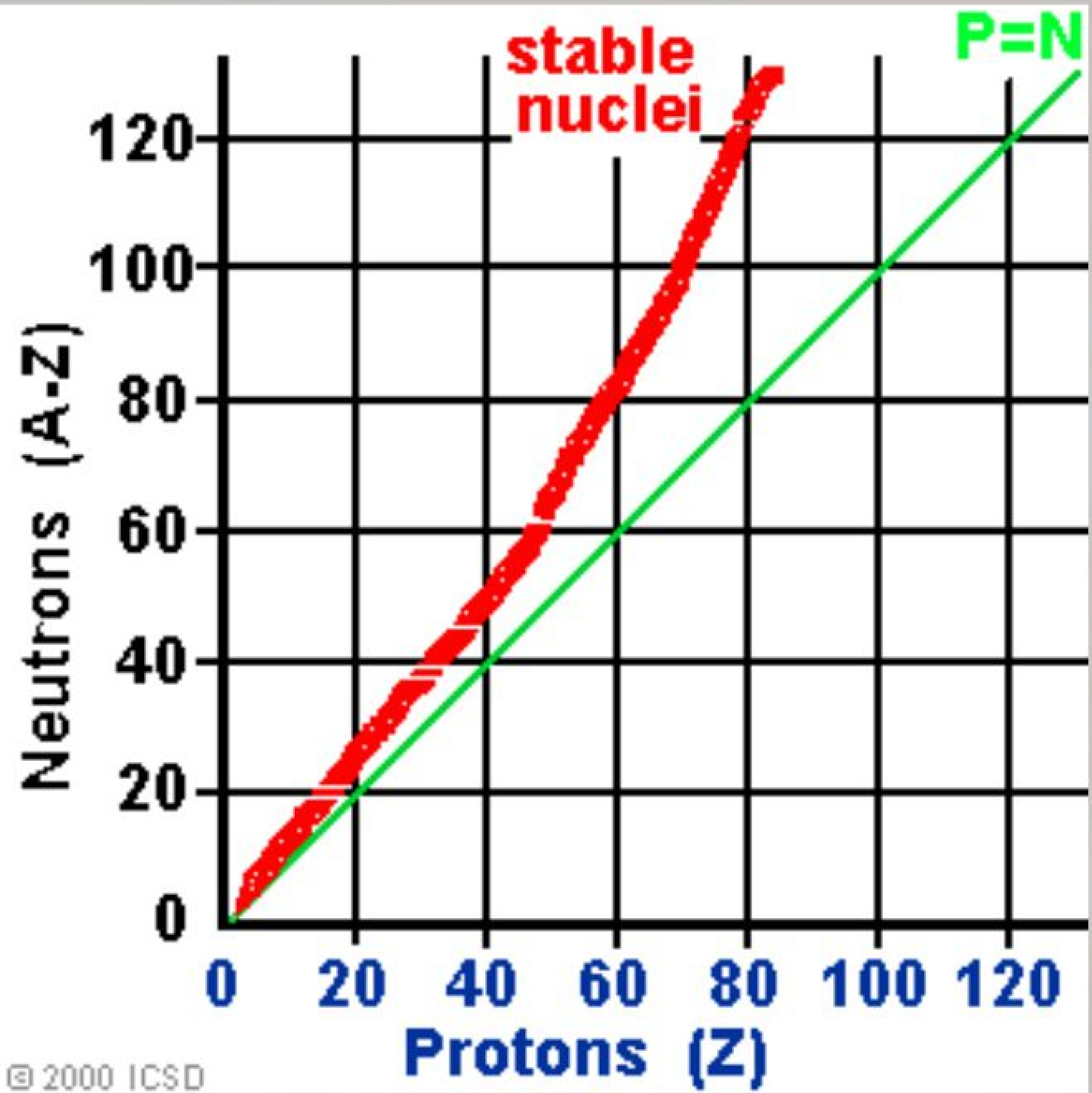
Radioactivity is the phenomenon of radiation (particles and/or energy) being ejected **spontaneously** by an unstable nucleus until it reaches a more stable arrangement.



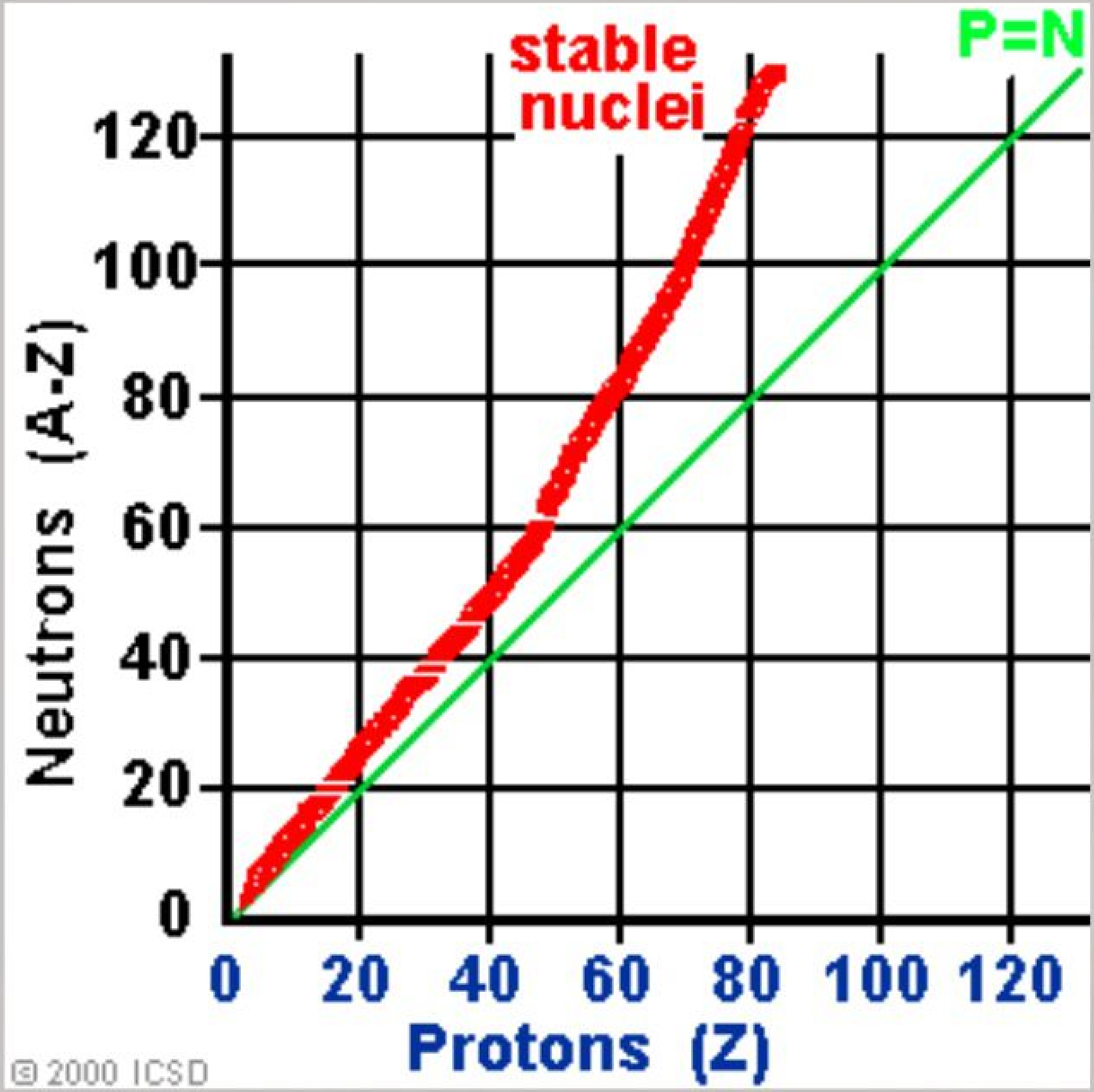
Nuclear Stability is determined by the **ratio** of protons to neutrons in the nucleus.

Radioactive decay is the process by which the unstable nuclei lose mass and/or energy by emitting radiation.

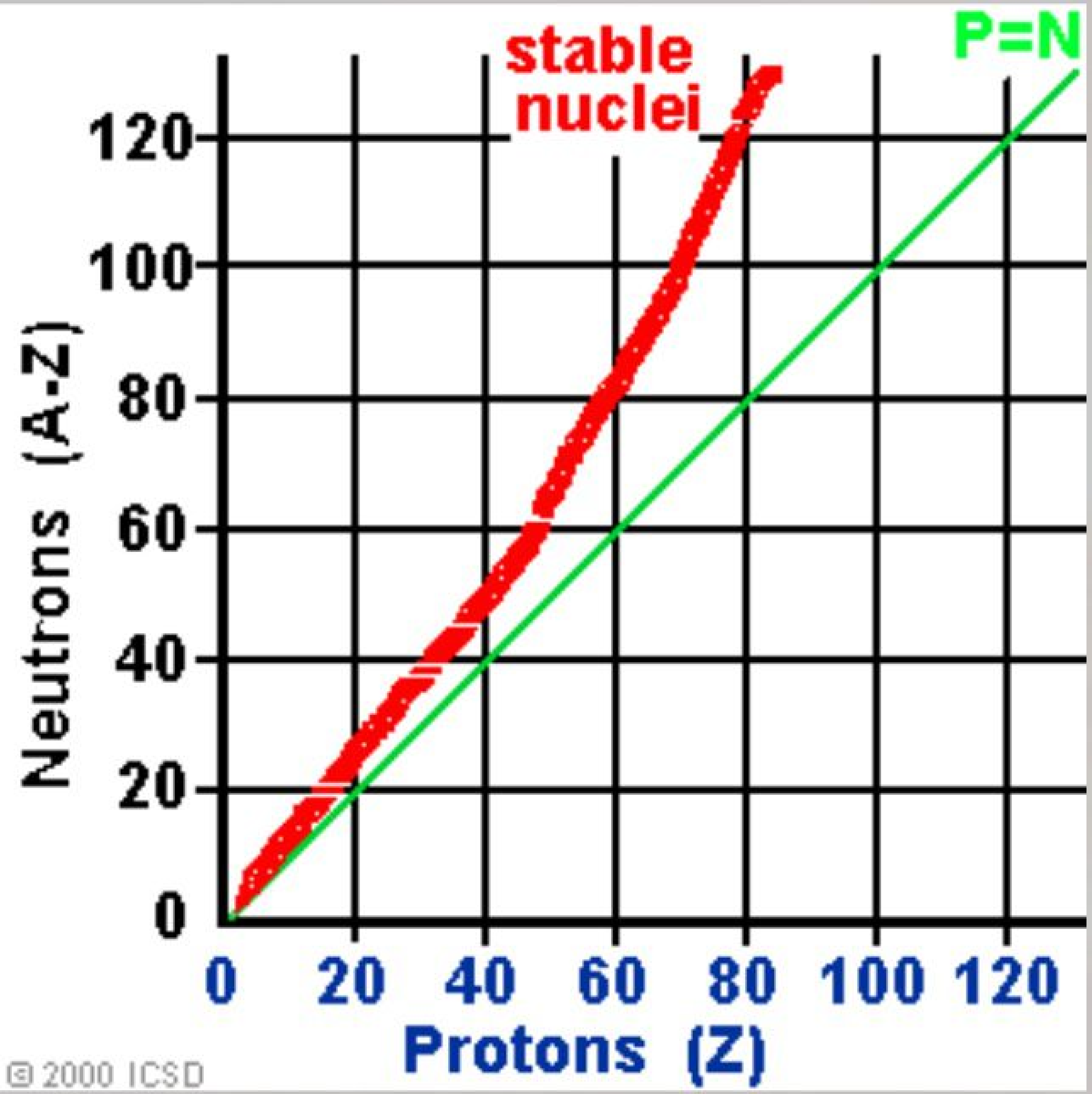
Eventually unstable nuclei achieve a more stable state when they are transformed into atoms of a **different element**.



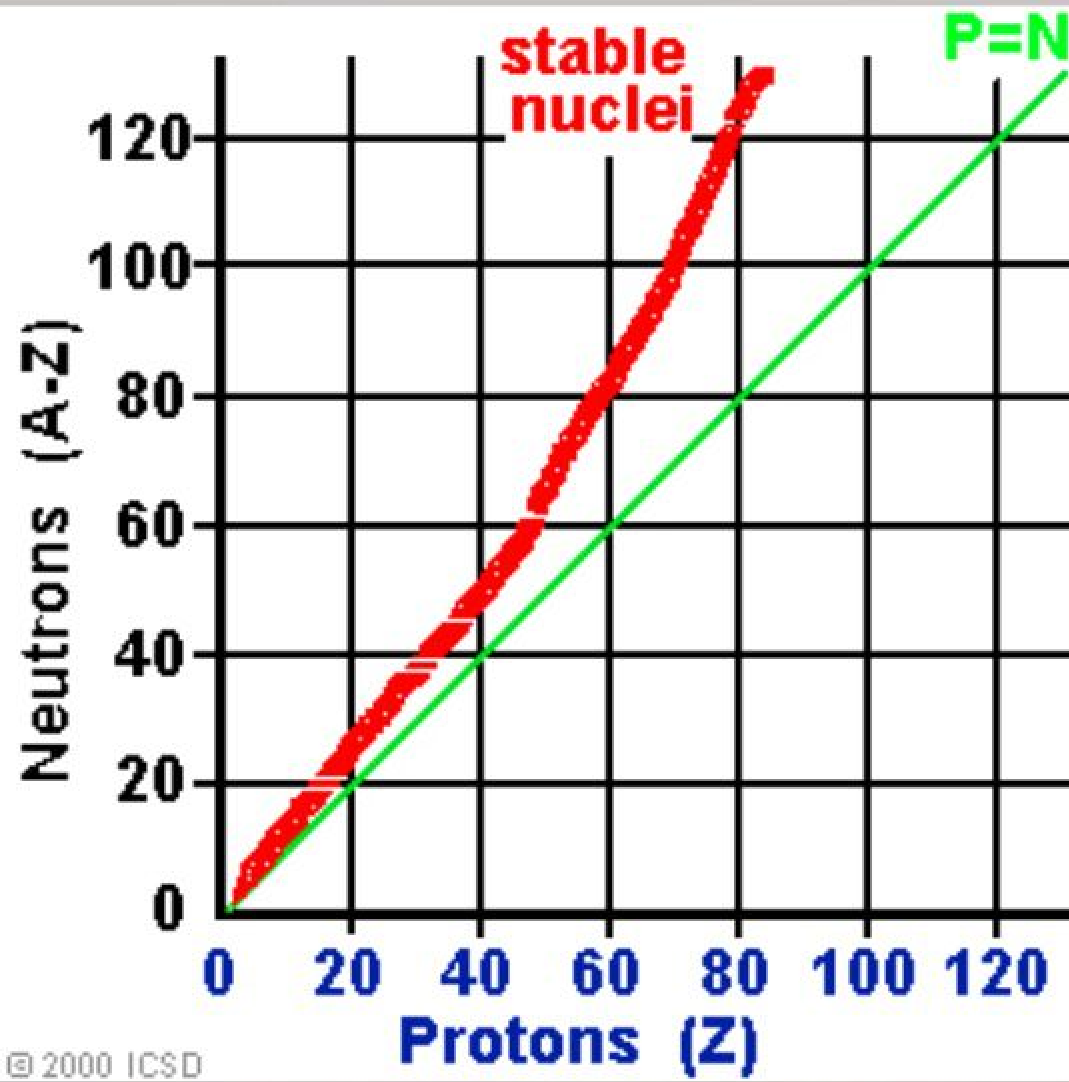
This graph shows the stable nuclei in **red**. There are several things to notice:



- There are no stable nuclei with an atomic number higher than **83** or a neutron number higher than **126**.



- The more **protons** in the nuclei, the more neutrons are needed for stability. Notice how the stability band pulls away from the **P=N** line.



•Stability is favored by **even** numbers of protons and even numbers of neutrons. 168 of the stable nuclei are even-even while only 4 of the stable nuclei are odd-odd.

Types of Radioactive Decay

When unstable nuclei decay, the reactions generally involve the emission of a **particle** and or **energy**.

For each type of decay, the equation is **balanced** with regard to atomic number and atomic mass. In other words, the total atomic number before and after the reaction are equal. And the total atomic mass before and after the reaction are also **equal**.

Transmutation

<u>α - decay</u>

$$^{239}_{94}Pu \rightarrow ^{235}_{92}U + ^{4}_{2}He$$

<u>β - decay</u>

$$^{14}_{6}C \rightarrow ^{0}_{-1}e + ^{14}_{7}N$$

<u>γ - decay</u>

$$^{99m}_{43}Tc \rightarrow ^{99}_{43}Tc + \gamma$$

When particles break down in the nucleus in an atom of an element (radioactive decay), the element changes into another element. This is called **<u>transmutation</u>**.

TYPES OF RADIATION

Gamma emission is the high energy electromagnetic radiation given off in most nuclear reactions. **GAMMA RAYS ARE NOT MATTER, THEY ARE ENERGY**. Therefore, they are not involved in balancing the nuclear equation. They are very damaging and difficult to shield against.

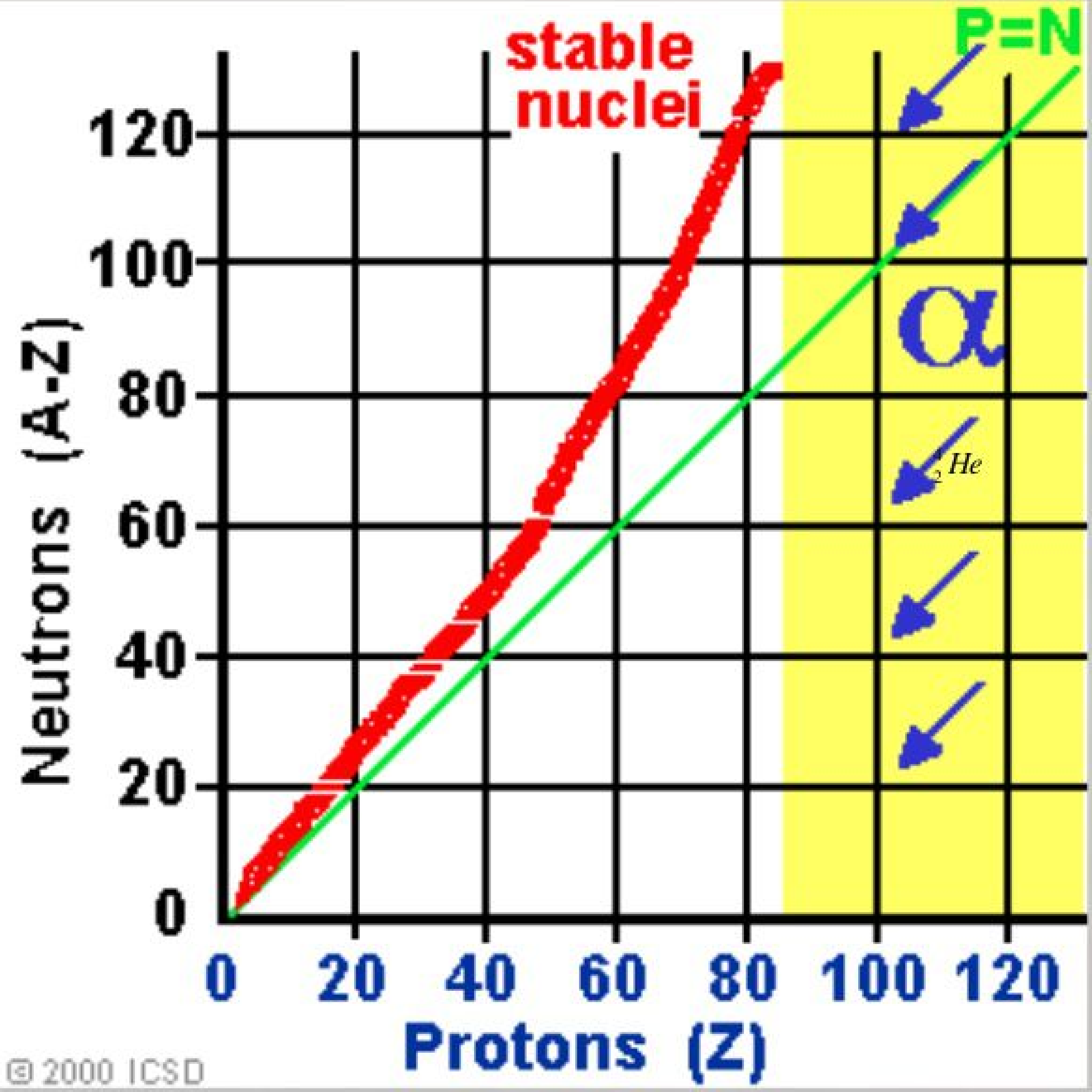
Types of nuclear reactions

1. Radioactive decay - emission of the following particles:
   - Gamma
   - Alpha
   - Beta
   - positron
2. Nuclear disintegration - emission of a proton (p^+) or a neutron (n^0)
3. Fission - splitting of the nucleus
4. Fusion - combining of nuclei

Gamma Emission (γ)

Generally accompanies other radioactive radiation because it is the energy lost from settling within the nucleus after a change.

Alpha Particle Emission (α)

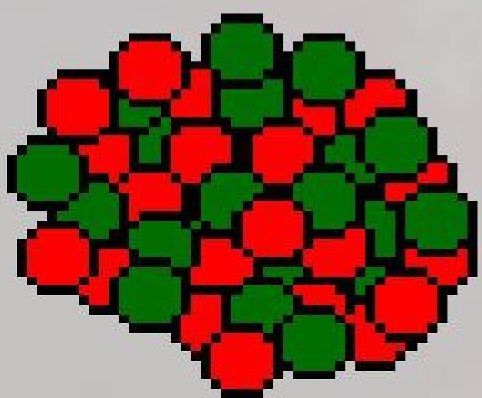


Happens when the atomic number is greater than 83 The 2 p+ 2n ($^4_2$He) loss brings the atom down and to the left toward the belt of stable nuclei.

Alpha Particle Emission (α)

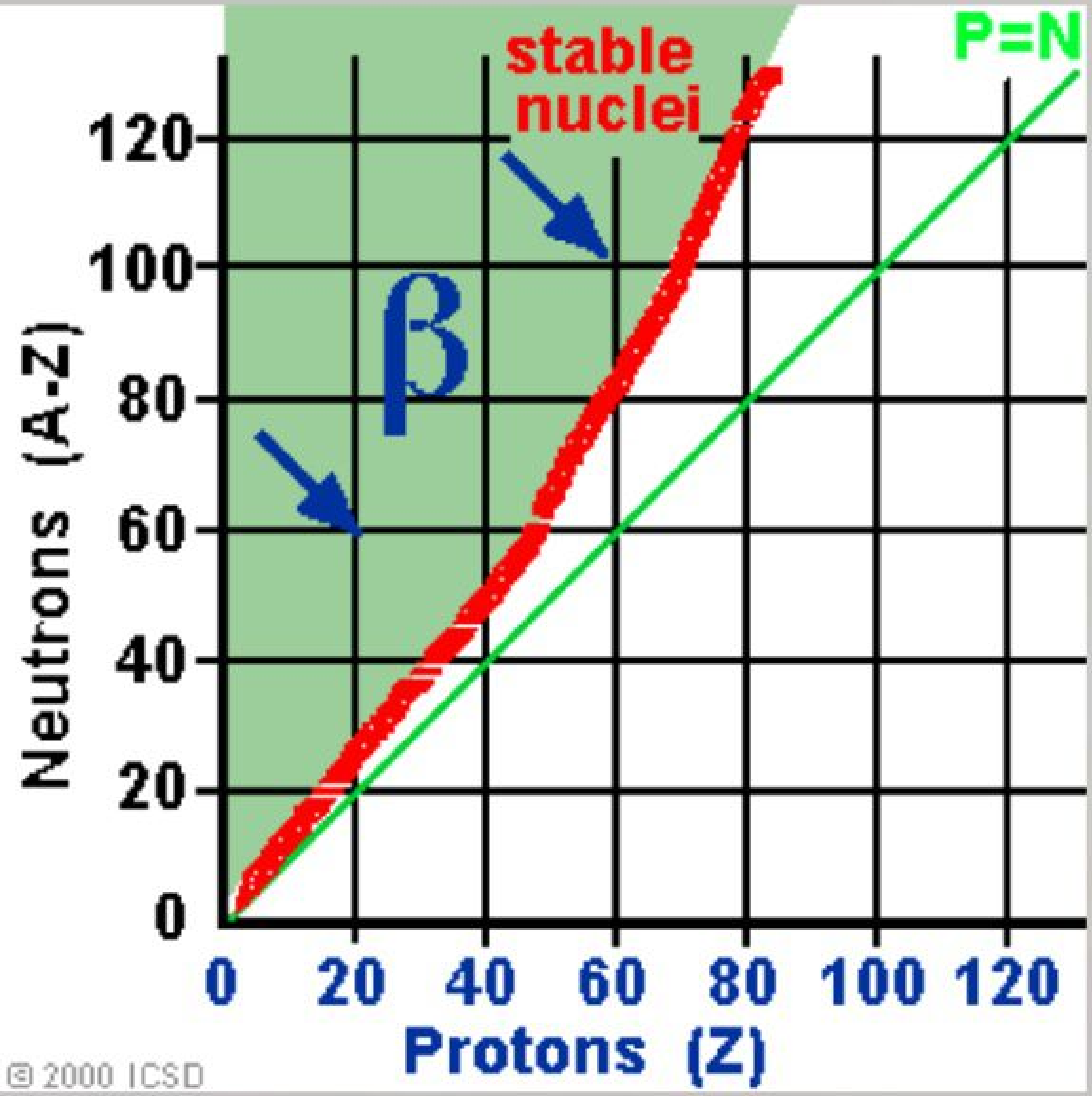
$$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$$

Uranium - 238 | Thorium - 238 | Alpha Particle (α)

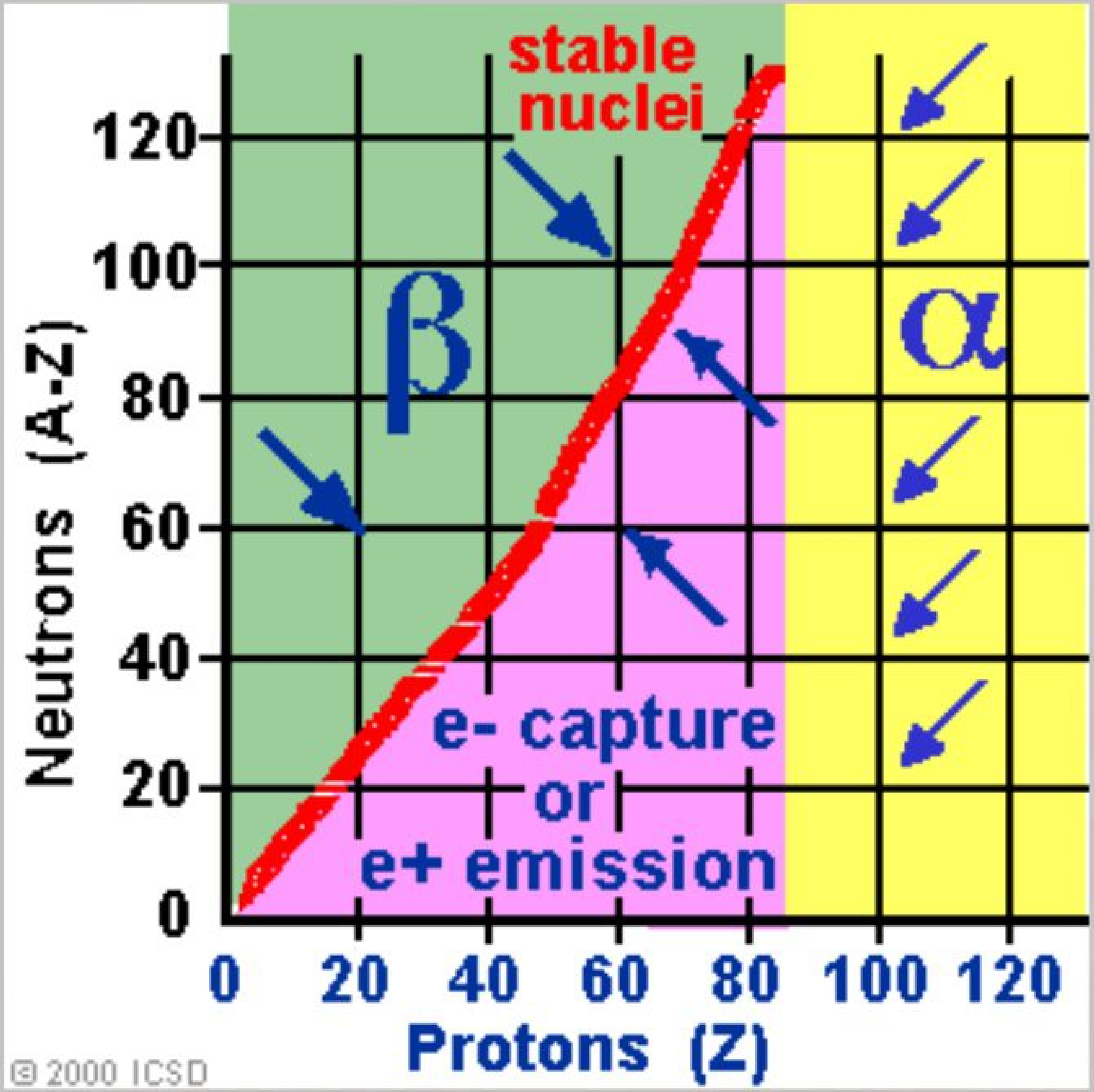


$$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$$

Beta Particle Emission (β)

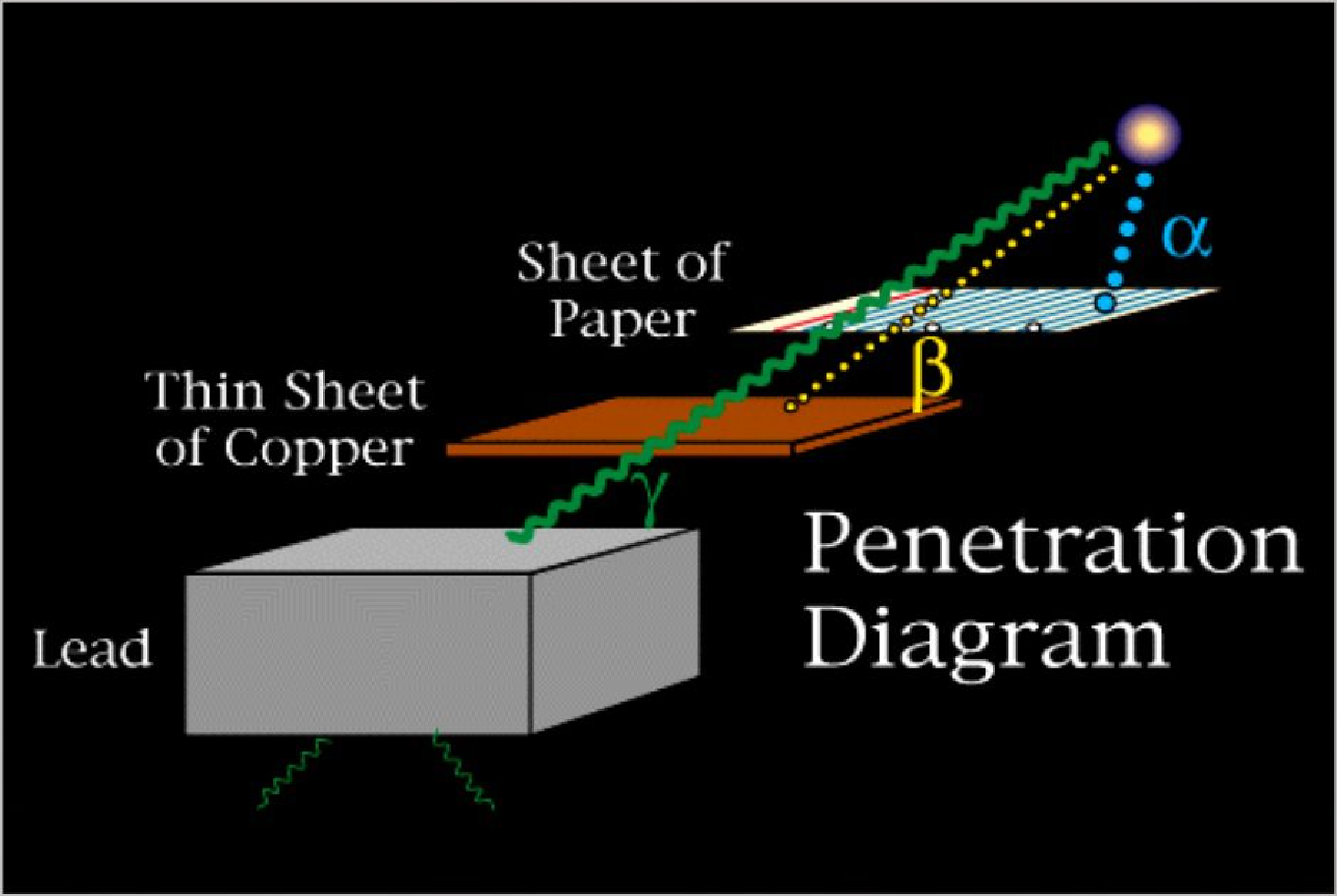


- Happens to nuclei with high neutron:proton ratio
- A neutron becomes a proton causing a shift down and to the right on the stability graph



This graph shows all the trends of decay and the band of stable nuclei

Penetrating Power of Radiation



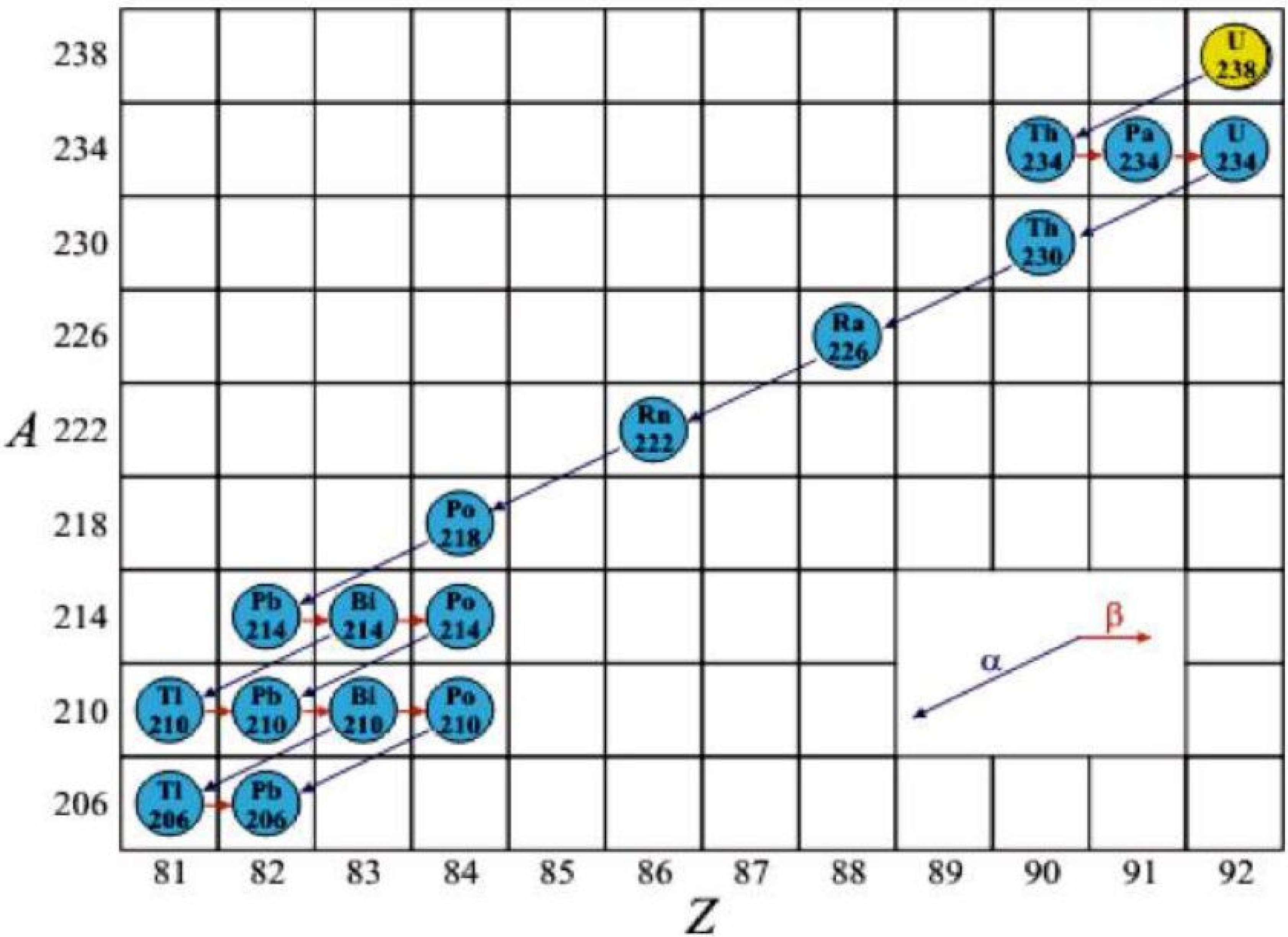
Nuclear Chemistry

Name	Symbol	Particle Emitted	Mass	Atomic Number	What is Happening?	Blocked By
Alpha	$^{4}_{2}He$	Helium Nucleus	Decrease by 4	Decrease by 2	Helium nucleus is given off	Paper
Beta	$^{0}_{-1}\beta$	High Speed Electron	No Change	Increase by 1	Neutron changes to Proton	Metal
Gamma	$^{0}_{0}\gamma$	High Speed Photon	No Change	No Change	Accompanies Alpha & Beta Decay	Partially by Lead & Concrete

Decay Series

- A series of radioactive nuclides produced by successive radioactive decay until a stable nuclide is reached.

Decay Series for Uranium - 238

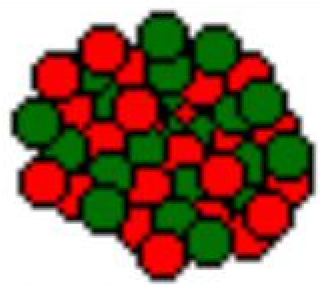


BETA EMISSION (β)

A beta particle (a high energy electron, charge of -1) is emitted from the nucleus as a neutron is converted into a proton.

Carbon - 14 | Nitrogen - 14 | Beta Particle

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$$



$$^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}e$$

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Positron Emission

A positron is an antimatter particle that has the same mass as an electron but has a positive charge. A positron is emitted from the nucleus as a proton is converted to a neutron.

$$^{18}_{9}F \longrightarrow ^{18}_{8}O + ^{o}_{+1}e$$

Fluorine - 18 **Oxygen - 18** **Positron**

Positron Emission

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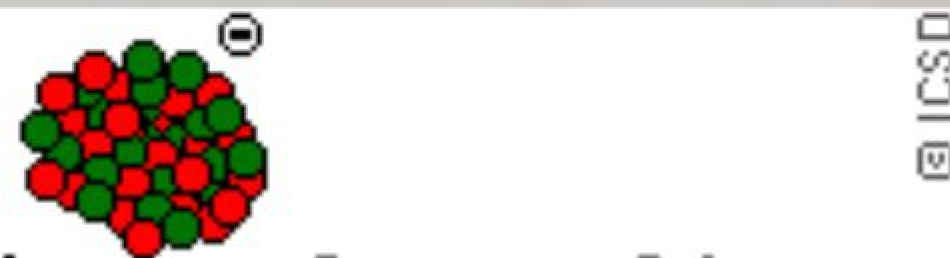
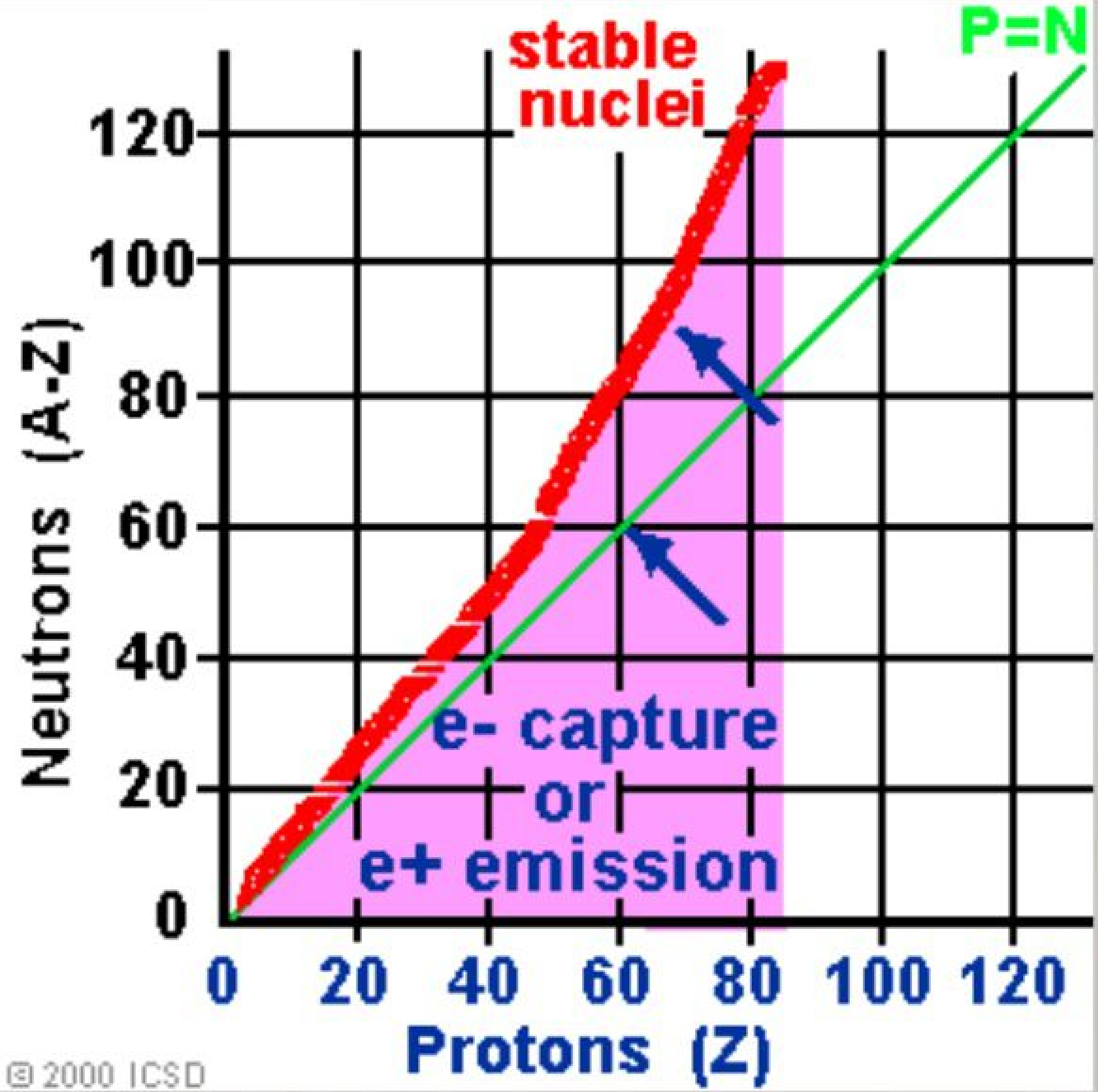


$$^{81}_{37}Rb + ^{0}_{-1}e \rightarrow ^{81}_{36}Kr$$

$$^{18}_{9}F \longrightarrow ^{18}_{8}O + ^{o}_{+1}e$$

Fluorine - 18 | Oxygen - 18 | Positron

Positron Emission

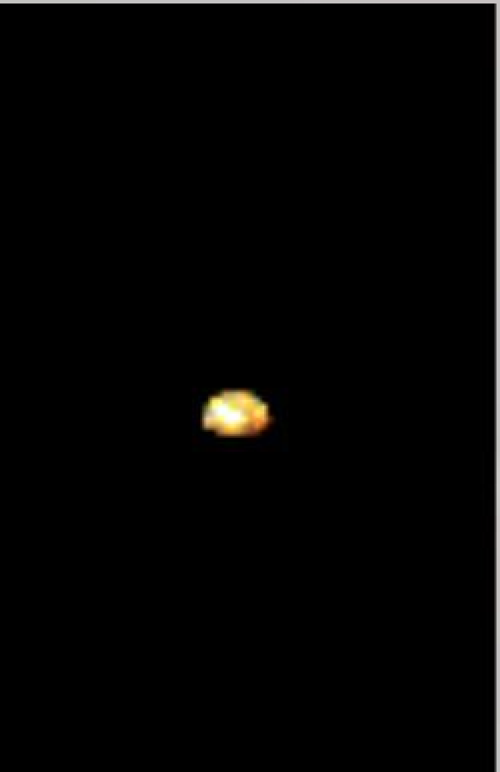


Happens to nuclei with a low neutron:proton ratio

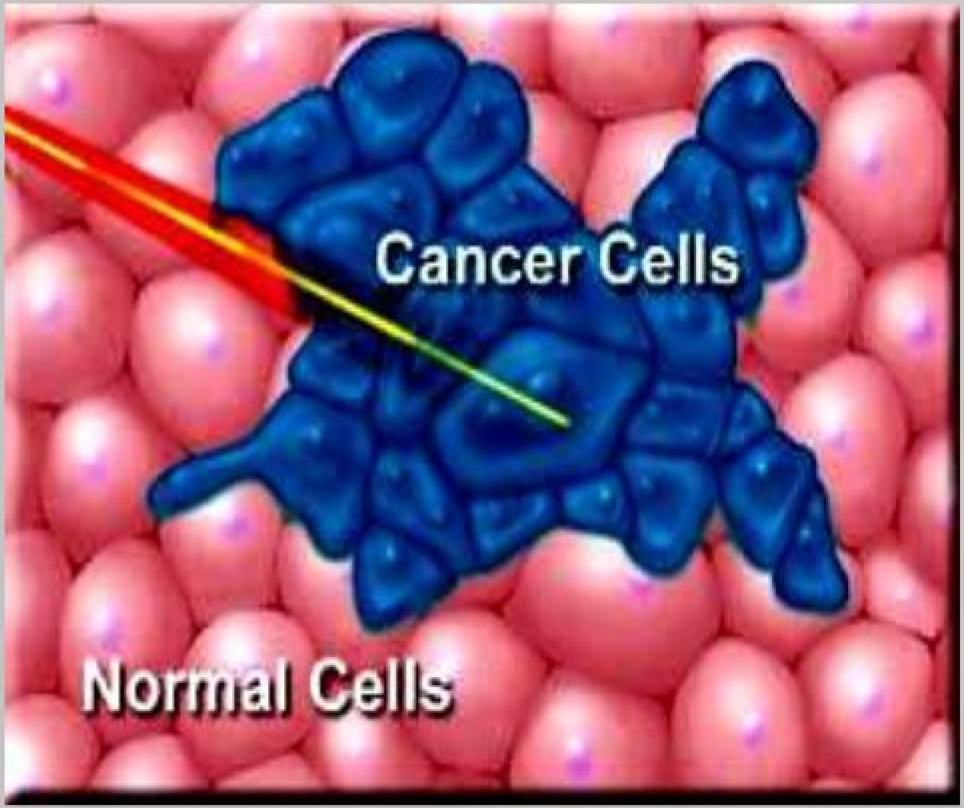
A proton becomes a neutron causing a shift up and to the left

Uses for Nuclear Radiation

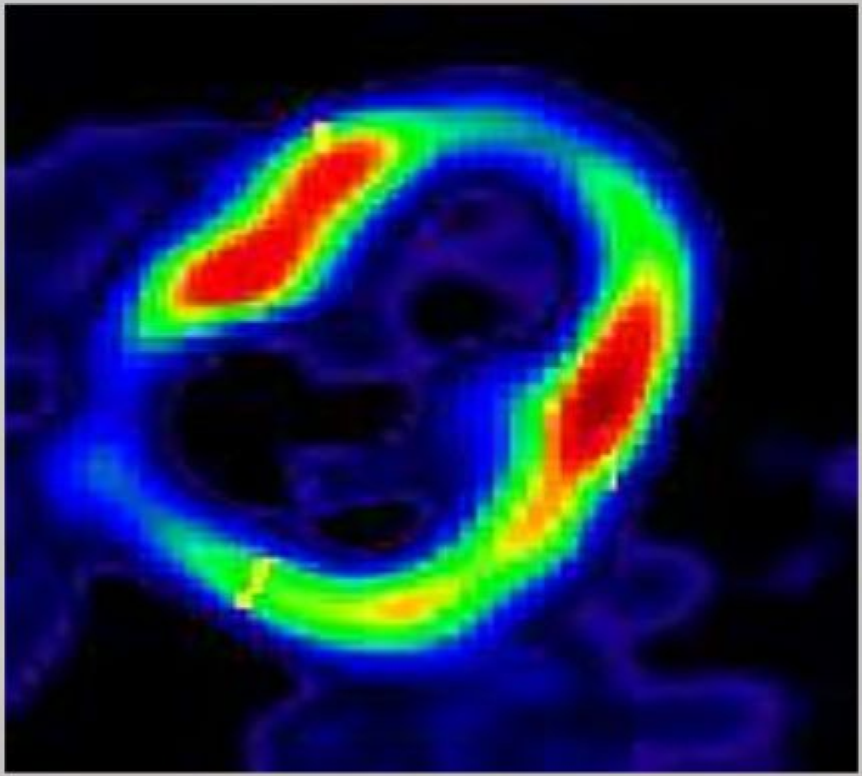
Since the physical and chemical properties of radioisotopes of an element are the same as stable ones, many uses for radioactive nuclides are possible.



In medicine radioactive nuclides are used to destroy cancer cells and as tracers to tract substances through the body or identify cancer and other diseases.

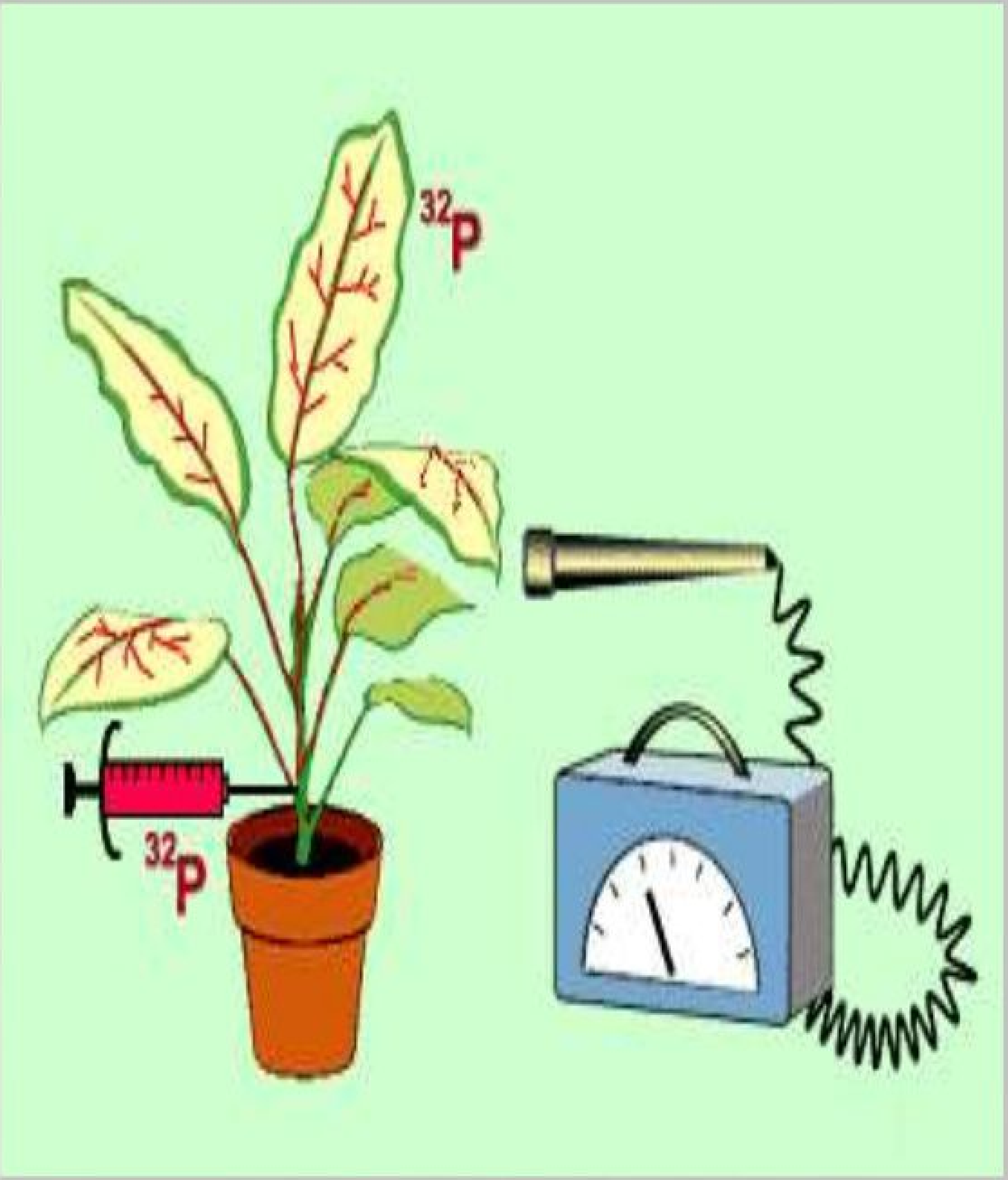


Cobalt - 60

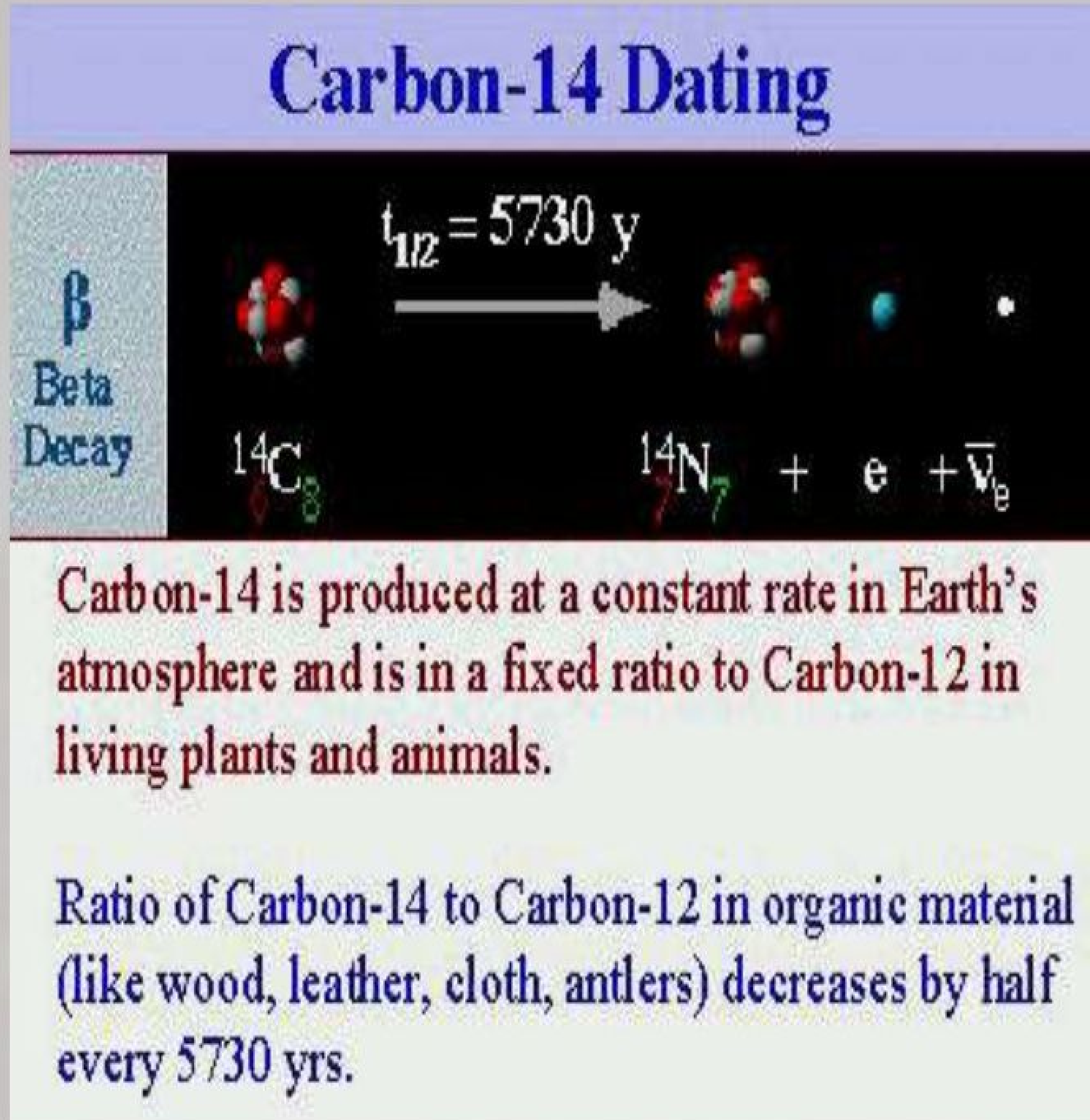


Radioactive Tracer

In agriculture, radioactive nuclides are used as tracers in fertilizer to determine the effectiveness or to prolong shelf life of food by irradiating to destroy microorganisms.



In dating radioactive nuclides are used to determine the age of objects. Example: Carbon -14 is used to date organic materials.



In energy production, currently nuclear fission is used to create energy. Example: Comanche Peak nuclear power plant in Glen Rose produces energy that is used by TXU Energy.

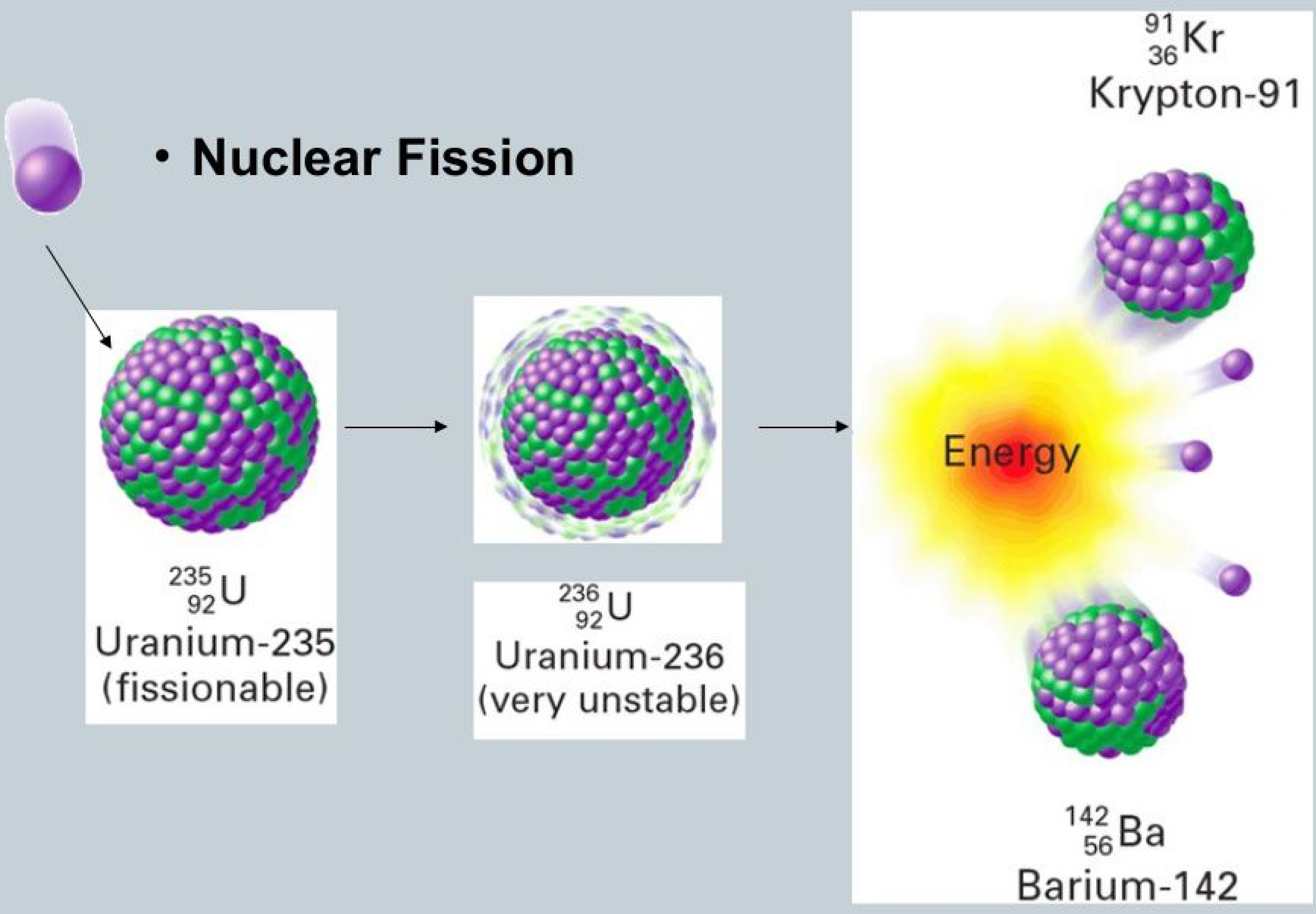
Fission and Fusion

Nuclear Fission

- **What happens in a nuclear chain reaction?**
  - **When the nuclei of certain isotopes are bombarded with neutrons, they undergo fission, the splitting of a nucleus into smaller fragments.**
  - **In a chain reaction, some of the neutrons produced react with other fissionable atoms, producing more neutrons which react with still more fissionable atoms.**

Nuclear Fission

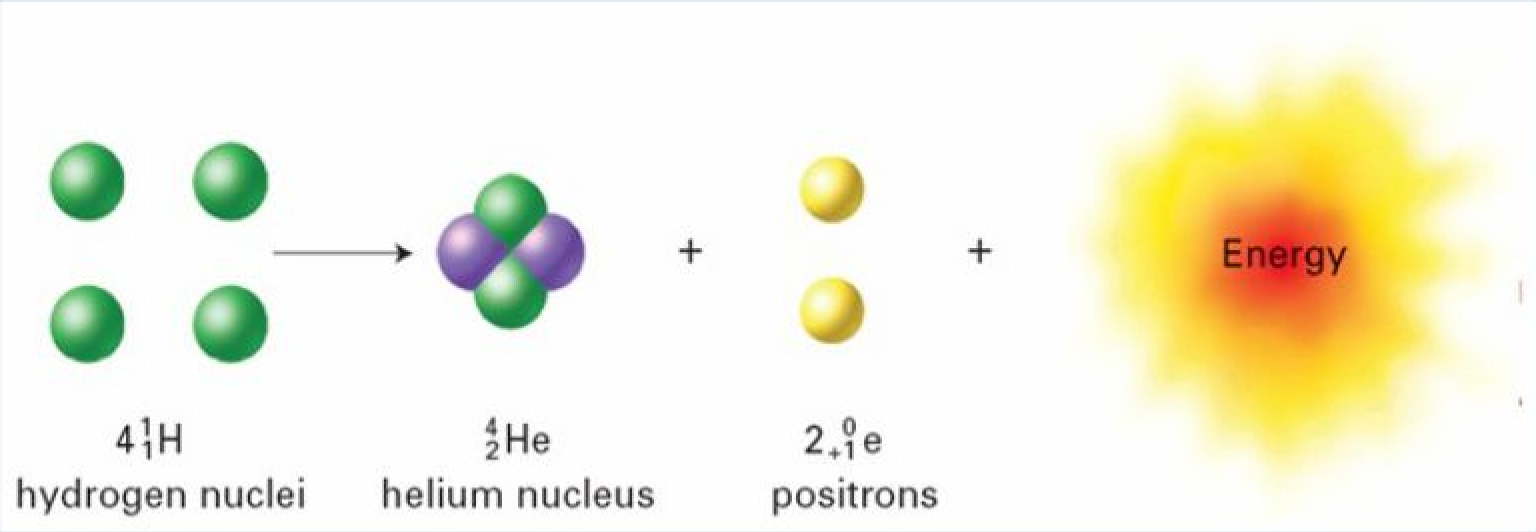
- **Nuclear Fission**



- **Nuclear fission can release enormous amounts of energy.**
  - **The fission of 1 kg of uranium-235 yields an amount of energy equal to that produced when 20,000 tons of dynamite explode.**
  - **Nuclear reactors used controlled fission to produce useful energy.**
  - **Reaction takes place within uranium-235 or plutonium-239 fuel rods.**
  - **Much of the energy produced is in the form of heat.**
  - **A fluid, usually liquid sodium or water, removes heat from the core (coolant).**
  - **The heated fluid is used to change water into steam, which drives a turbine that generates electricity.**

Nuclear Fusion

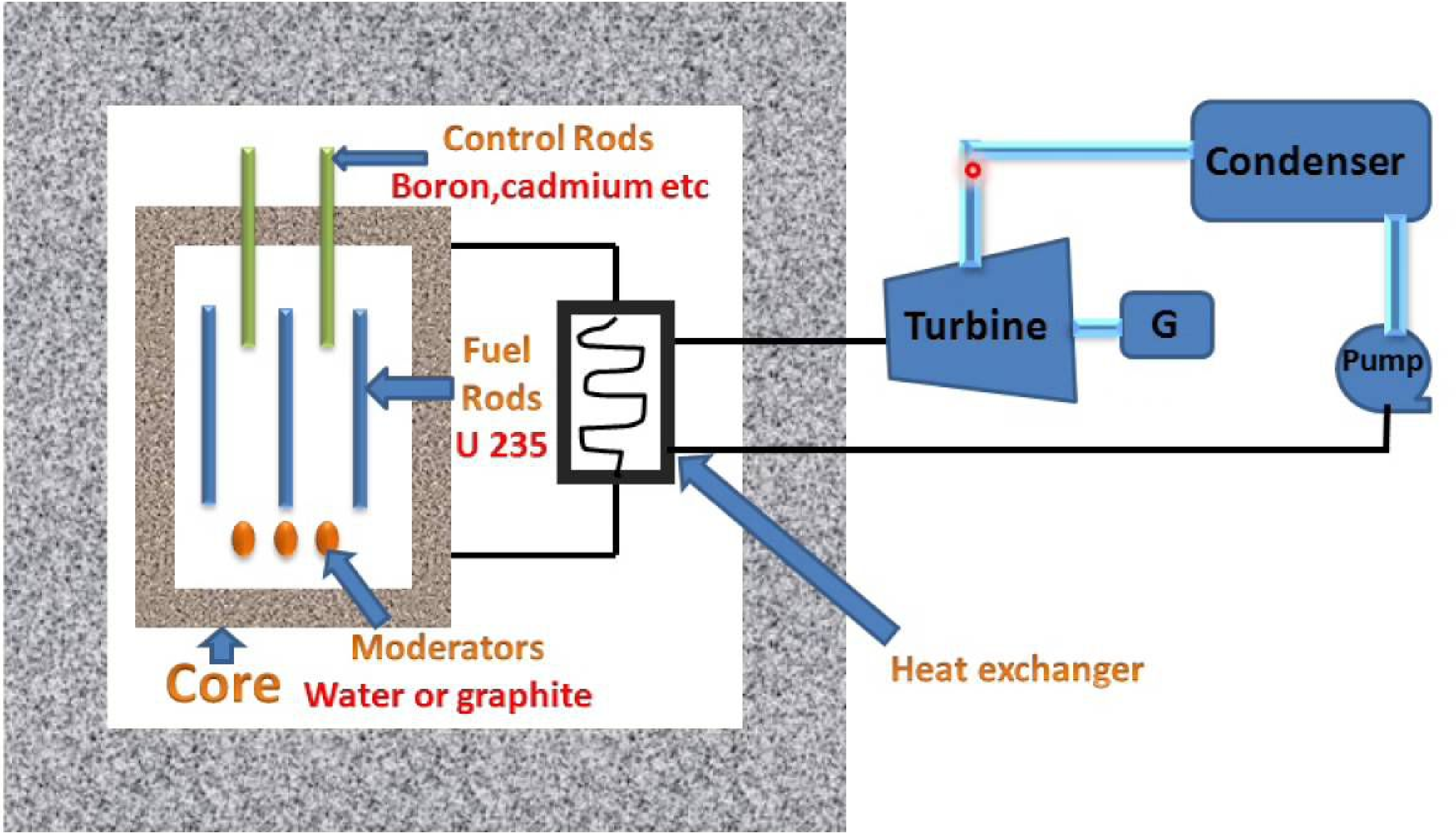
- **How do fission reactions and fusion reactions differ?**
  - **Fusion** occurs when nuclei combine to produce a nucleus of greater mass. In solar fusion, hydrogen nuclei (protons) fuse to make helium nuclei and two positrons.



- Fusion reactions, in which small nuclei combine, release much more energy than fission reactions, in which large nuclei split.
- The use of controlled fusion as an energy source on Earth is appealing.
    - The potential fuels are inexpensive and readily available.
    - Reaction of hydrogen-2 nucleus and hydrogen-3 combine to form a helium nucleus.
    - The problems with fusion lie in achieving the high temperatures necessary to start the reaction and in containing the reaction once it has started.

What is Nuclear Reactor?

- A nuclear reactor is a system that contains and controls sustained nuclear chain reactions.
- Reactors are used for generating electricity, moving aircraft carriers and submarines, producing medical isotopes for imaging and cancer treatment, and for conducting research.
- Fuel, made up of heavy atoms that split when they absorb neutrons, is placed into the reactor vessel (basically a large tank) along with a small neutron source. The neutrons start a chain reaction where each atom that splits releases more neutrons that cause other atoms to split .
- Each time an atom splits, it releases large amounts of energy in the form of heat. The heat is carried out of the reactor by coolant, which is most commonly just plain water. The coolant heats up and goes off to a turbine to spin a generator or drive shaft. Nuclear reactors are just exotic heat sources.



Control Rods
Boron,cadmium etc
Fuel
Rods
U 235
Moderators
Water or graphite
Core
Heat exchanger
Turbine
G
Condenser
Pump

Nuclear hazards

- Radioactive (nuclear) pollution is a special form of physical pollution related to all major life- supporting systems – air,water and soil.
- Radioactivity is the phenomenon of emission of energy from radioactive isotopes (i.e., unstable isotopes), such as Carbon- 14, Uranium- 235, Uranium- 238, Uranium- 239, Radium- 226, etc.
- The emission of energy from radioactive substances in the environment is often called as 'Radioactive Pollution'.

- Generally radiation hazards in envt. Comes from UV rays, cosmic rays, visible,microwave radiation.
- Among these X rays which produce out 95% of radiation exposure.
- Nuclear energy(power plants) is used to produce electricity .But fuel used in power plants is radioactive,which is very dangerous & waste matrls are hazardous.

Sources of nuclear hazards

1.Natural resources :

1) Cosmic rays from outer space. The quantity depends on altitude and latitude; it is more at higher latitudes and high altitudes.

2) Emissions from radioactive materials from the Earth's crust.

2.Man-made sources :

- Nuclear power plants.
- X-rays.
- Nuclear bombs.
- Nuclear accidents.
- Mining and processing of radioactive ores.
- Use of radioactive materials in nuclear weapons.

EFFECTS

- The biological effects of nuclear radiation can be divided into three groups

  (i) Short term recoverable effects(small effect which leads to loss of hair)

  (ii) long term irrecoverable effects and

  (iii) genetic effect

- Internal bleeding & blood vessel damage may show up as red spots on the skin.
- Cancer is considered to be major health problem from radiation exposure.
- Radiation can cause changes in DNA which is known as MUTATION.
- Acute exposures appears as burns & radiation sickness(nausea,hair loss, weakness …)

Safety Measures

- Monitoring radioactivity around the disposal sites.
- Prevention of erosion of radioactive waste disposal sites.
- Prevention of any drilling activity in and around the waste disposal site.
- Periodic and long- term monitoring of such disposal sites and areas of naturally occurring uranium rich rocks.