Inorganic Pharmaceutical Chemistry

Radio-pharmaceutics

Lecture 3

Radio-pharmacy = Nuclear Pharmacy

Nuclear pharmacy is a specialty area of pharmacy practice refers to the compounding and dispensing of radioactive materials for use in nuclear medicine procedures.

- **Atomic Mass Number, A** : Number of Protons + Neutrons
- **Atomic Number, Z** : Number of Protons or Electrons.
- **Neutron Number**, N : Number of Neutrons = A – z

Type of Nuclides:

- ISOTOPE: same Z differing N ; $^{8}{}_{5}B$ $^{10}{}_{5}B$ $^{12}{}_{5}B$
- ISOBAR: same A ; ^{14}C, ^{14}N , ^{14}O
- ISOTONE: same N ; ISOTONE: same N ; $^{12}_{6}C$, $^{13}_{7}N$, $^{14}_{8}O$

What is the Radioactivity?

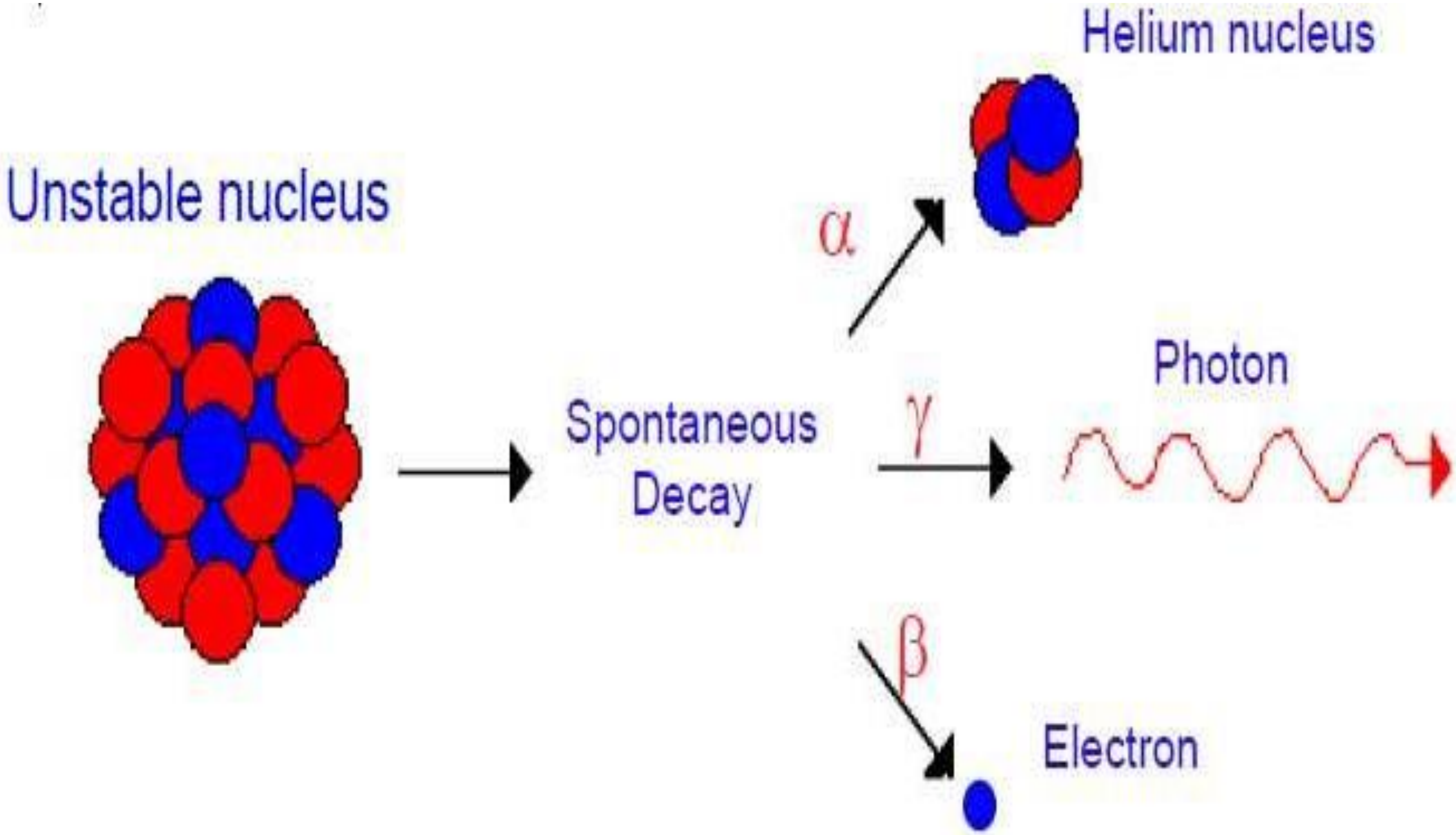
- The elements that are contain a stable nucleus, under normal conditions, these elements remain unchanged forever. They are not radioactive.
- In contrast, the elements that are contain an unstable nucleus (they are radioactive). The unstable nucleus is actually in an excited state that cannot be continued forever therefore will decay to reach a more stable state.
- Decay occurs spontaneously and lead to transform the nucleus from a high energy to new one that is lower energy by releases energy. The energy is emitted from the unstable nucleus as radiation.
- (i.e) ***Radioactivity:*** is the process in which an unstable isotope undergoes changes until a stable state is reached and in the transformation emits energy in the form of radiation (alpha particles, beta particles and gamma rays).

what is the radiation?

- Radiation is the emission or transfer of energy in the form of waves (photon) or particles (mass) through space or material medium.
- Waves are including an electromagnetic radiation, such as radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma radiation.
- Particles are including the alpha, beta.

The Nature (type)of Radiation (Types of radioactive decay):

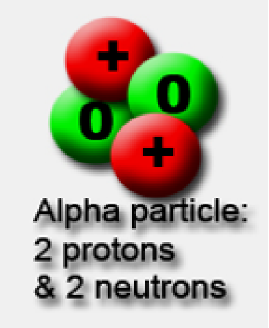
- The energy emitted by an unstable nucleus is in specific forms which is one of three types, called: alpha (α), beta (β) and gamma (γ) radiations.


Unstable nucleus
Spontaneous
Decay
α
Helium nucleus
γ
Photon
β
Electron

1- Alpha particle decay:

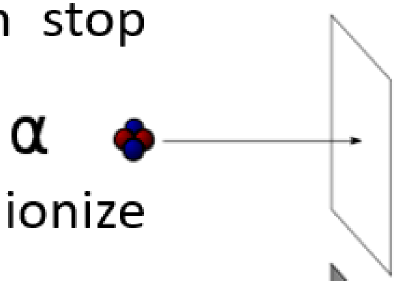
- Alpha particles are made of **2 protons and 2 neutrons.**
- We can write them as $^{4}_{2}\alpha$, or $^{4}_{2}He$, because they're the same as a helium nucleus.

- This means that when a nucleus emits an alpha particle, its **atomic number decreases by 2 and its mass number decreases by 4.**



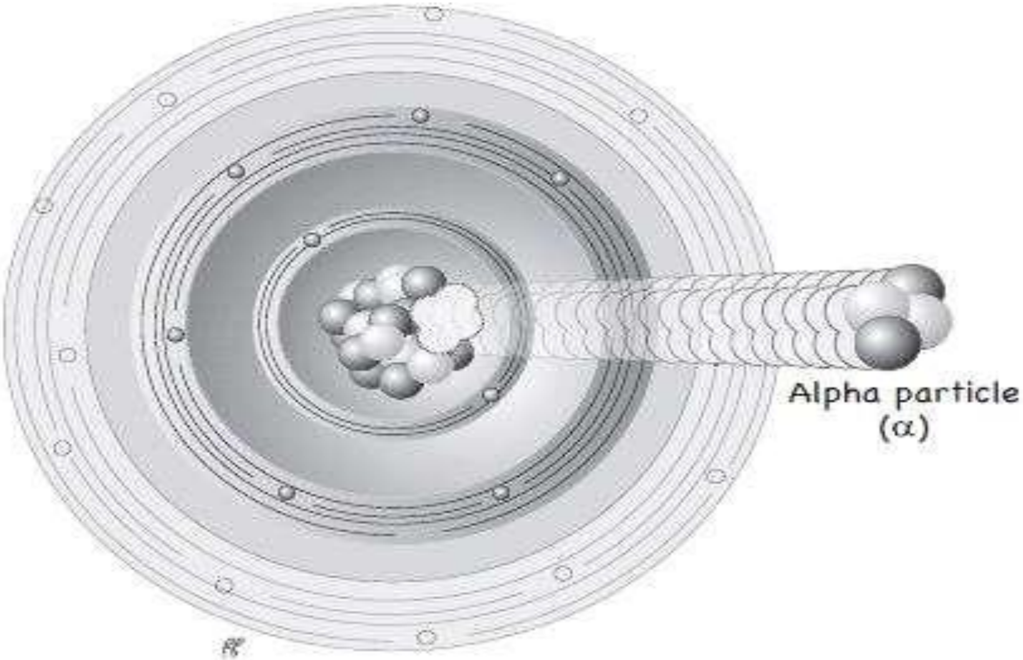
- Alpha particles are relatively **slow** and **heavy.**

- They have a **low penetrating power** - you can stop them with just a sheet of **paper**.



- Because they have a large charge, alpha particles ionize other atoms strongly.
- Alpha-decay occurs in very heavy elements, for example, Uranium and Radium.

Alpha-decay



Alpha decay.

$$^{226}_{88}\mathrm{Ra} \xrightarrow[T_{1/2}=1602\ \mathrm{a}]{} {}^{222}_{86}\mathrm{Rn} + \alpha$$

and

$$^{222}_{86}\mathrm{Rn} \xrightarrow[T_{1/2}=3.82\ \mathrm{d}]{} {}^{218}_{84}\mathrm{Po} + \alpha$$

- **Alpha** decay of Uranium-235.

$$^{235}_{92}U \rightarrow ^{4}_{2}He + ^{231}_{90}Th$$

2- Beta particle decay:

- They are **fast**, and **light**.
- Beta particles have a **medium penetrating power** - they are stopped by a sheet of **aluminum**.

There are two types:

A- Beta Minus Decay:

This means that beta particles are **the same as an electron.**

We can write them as β^- or e^-, because they're the same as an electron.

Beta minus decay causes the atomic number of the nucleus to increase by one and the atomic mass number remains the same.

In beta minus decay, one of the neutrons in the nucleus suddenly changes into a proton, causing an increase in the atomic number of an element, but the atomic mass number does not change .

$$^{60}_{27}\text{Co} \xrightarrow[T_{1/2}=5.26\ \text{a}]{} {}^{60}_{28}\text{Ni}^{*} + e^{-} + \overline{\nu}_e$$

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

$$^{87}_{37}Rb \rightarrow {}^{87}_{38}Sr + {}^{0}_{-1}\beta$$

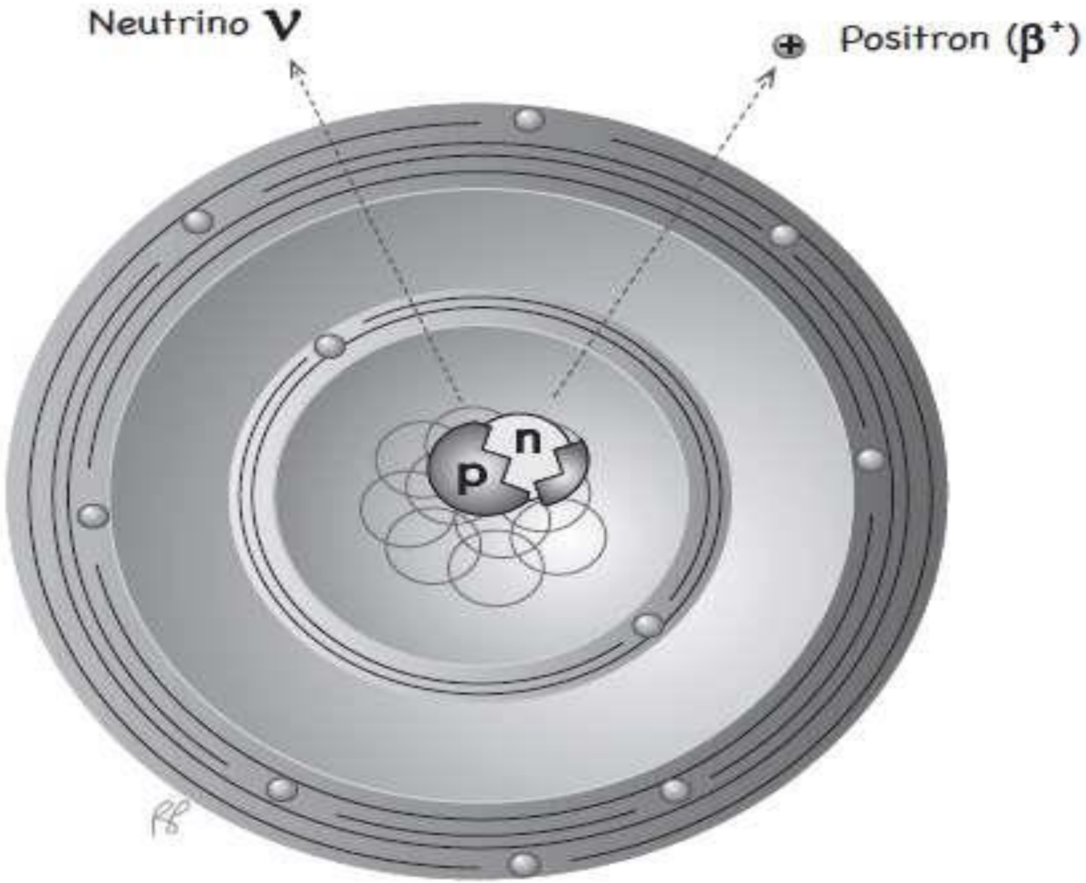
B- Beta Plus Decay:

Positron emission decay, beta plus decay, or β^+ decay

This type of beta decay decreases the atomic number of the nucleus because a proton changes into a neutron. This type of beta decay involves the release of a charged particle called a “positron” that looks and acts like an electron but has a positive charge.

(i.e)

Beta Plus Decay causes the atomic number of the nucleus to decrease by one and the atomic mass number remains the same.



β^+ (positron) decay.

$$^{18}_{9}F \xrightarrow[T_{1/2}=110\ \text{min}]{} {}^{18}_{8}O + e^+ + \nu_e$$

$$^{11}_{6}C \rightarrow \; ^{11}_{5}B + \, ^{0}_{1}\beta \cdot$$

Positron

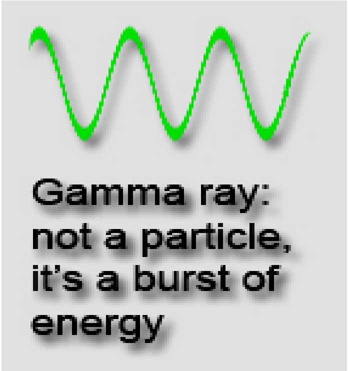
$$^{38}_{19}K \rightarrow \, ^{0}_{+1}\beta + \, ^{38}_{18}Ar$$

H.W. What is the effect of Beta Decay on atomic mass ? Why?

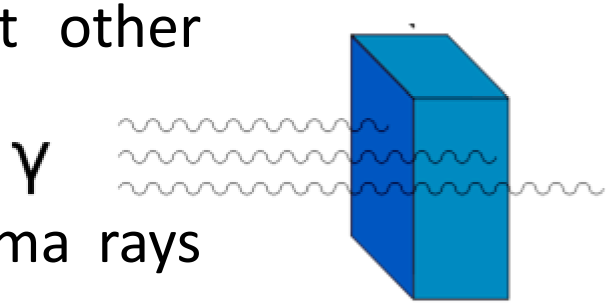
3- Gamma ray:

- Gamma rays are **waves, not particles**. This means that they have **no mass** and **no charge**.
- in Gamma decay:

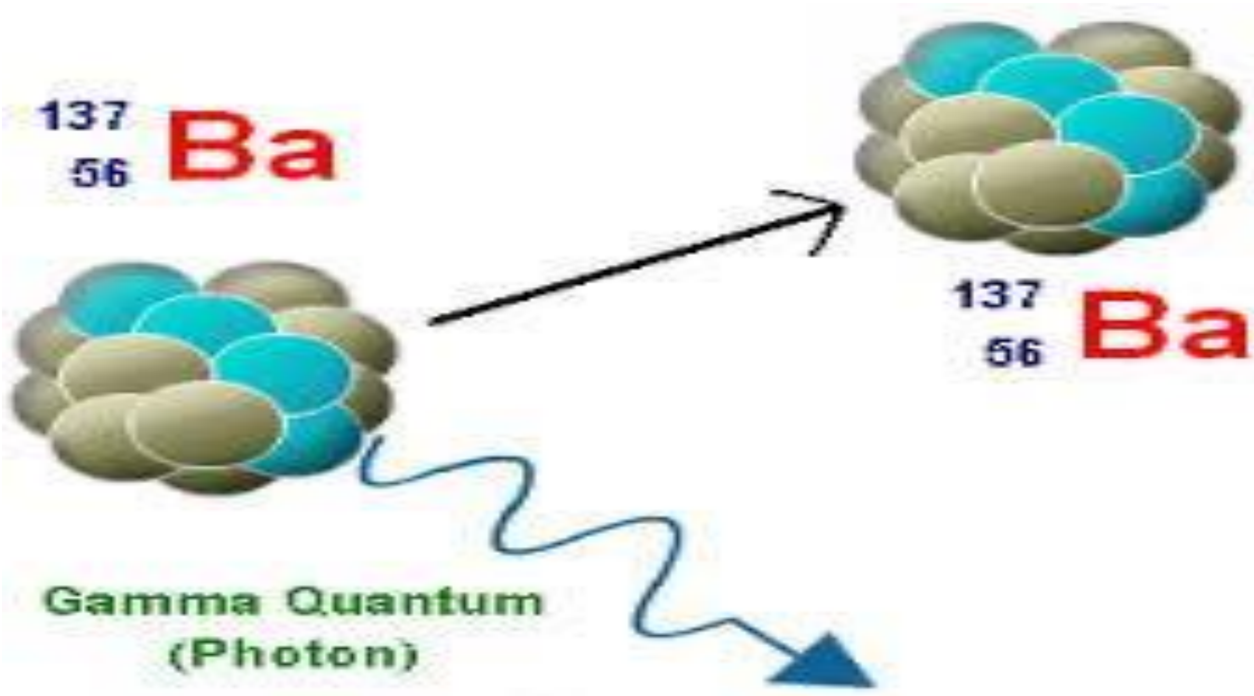
- atomic number unchanged
- atomic mass unchanged.



- Gamma rays have a **high penetrating power** - it takes a thick sheet of metal such as **lead** to reduce them.
- Gamma rays do not directly ionize other atoms, although they may cause atoms to emit other particles which will then cause ionization.



- We don't find pure gamma sources - gamma rays are emitted alongside alpha or beta particles.



137
56
Ba
137
56
Ba
Gamma Quantum
(Photon)

$$^{125}_{53}\mathrm{I}^{*} \longrightarrow \, ^{125}_{53}\mathrm{I} + \gamma$$

$$^{226}_{88}\mathrm{Ra} \longrightarrow \, ^{222}_{86}\mathrm{Rn} + \, ^{4}_{2}\mathrm{He} + \, ^{0}_{0}\gamma$$

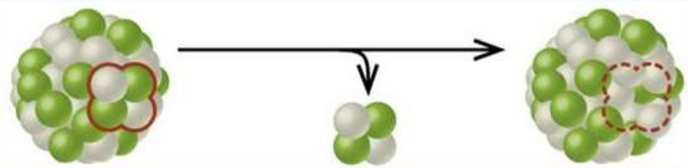
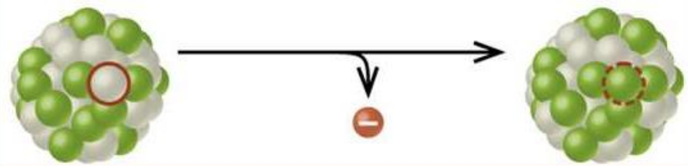
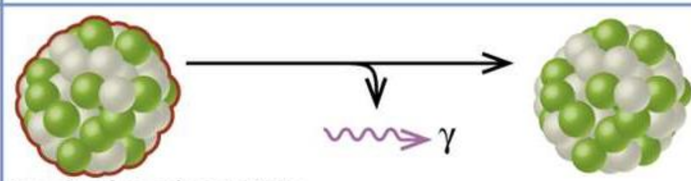
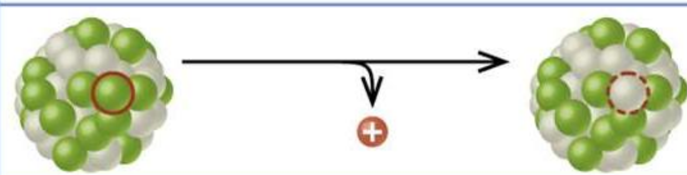
radium-226		radon-222		alpha particle		energy

-

- **Gamma** decay of Uranium-235.

$$^{235}_{92}U \longrightarrow ^{0}_{0}\gamma + ^{235}_{92}U$$

Summary of type of radiation

Type	Nuclear equation	Representation	Change in mass/atomic numbers
Alpha decay	$^{A}_{Z}X \rightarrow\ ^{4}_{2}He + ^{A-4}_{Z-2}Y$		A: decrease by 4 Z: decrease by 2
Beta minus Beta decay Electron Emission	$^{A}_{Z}X \rightarrow\ ^{0}_{-1}e + _{Z+1}^{\ \ A}Y$		A: unchanged Z: increase by 1 $(n^0 \rightarrow p^+ + e^-)$
Gamma decay	$^{A}_{Z}X \rightarrow\ ^{0}_{0}\gamma + ^{A}_{Z}Y$	 Excited nuclear state	A: unchanged Z: unchanged
Beta plus Positron emission	$^{A}_{Z}X \rightarrow\ ^{0}_{+1}e + ^{A}_{Z-1}Y$		A: unchanged Z: decrease by 1 $(p^+ \rightarrow n^0 + e^+)$

Types of radioactive decay:

Type of Radiation	Alpha particle	Beta particle		Gamma ray
		Minus	Plus	
Symbol	${}^{4}_{2}\alpha$ or ${}^{4}_{2}He$	β^-	β^+	γ
Charge	+2	-1	+ 1	0
Speed	slow	fast		Very fast
Ionizing ability	high	medium		0
Penetrating power	low	medium		high
Stopped by:	paper	aluminum		lead

Application of radiopharmaceuticals:

1- Treatment of disease: (therapeutic radiopharmaceuticals)

They are radiolabeled molecules designed to deliver therapeutic doses of ionizing radiation to specific diseased sites.

- *Chromic phosphate P32* for lung, ovarian, uterine, and prostate cancers
- *Sodium iodide I 131* for thyroid cancer
- *Samarium Sm 153* for cancerous bone tissue
- *Sodium phosphate P 32* for cancerous bone tissue and other types of cancers
- *Strontium chloride Sr 89* for cancerous bone tissue

2- <u>Aid in the diagnosis of disease (diagnostic radiopharmaceuticals)</u>

The radiopharmaceutical accumulated in an organ of interest emit gamma radiation which are used for imaging of the organs with the help of an external imaging device called gamma camera.

- Radiopharmaceuticals used in tracer techniques for measuring physiological parameters (e.g. ^{51}Cr-EDTA for measuring glomerular filtration rate).

-Radiopharmaceuticals for diagnostic imaging

(e.g.^{99m}TC-methylene diphosphonate (MDP) used in bone scanning).