

# Medical Nuclear Physics

## Lecture 2

### Lecture 2: Radioactive Decay

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For Third-year Students

# Lecture Outline

- 1 Introduction
- 2 Methods of Radioactive Decay
- 3 Alpha Decay
- 4 Beta Decay
- 5 Gamma Decay
- 6 Decay Scheme Example
- 7 Multiple Choice Questions (MCQs)

Radioactivity is a natural phenomenon in which unstable nuclei emit radiation in order to reach stability.

## **Radioactive decay results in:**

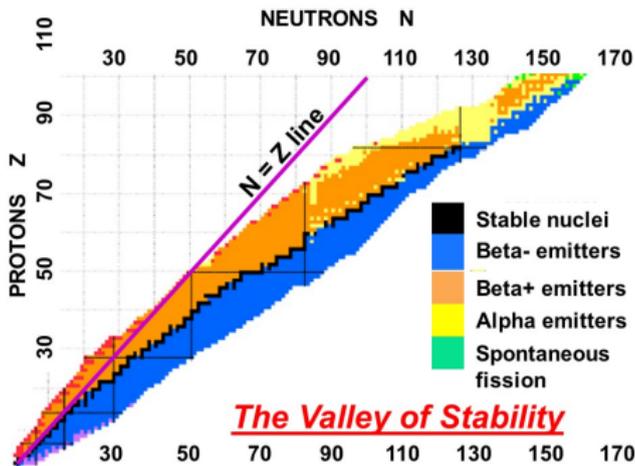
- Transformation into another nucleus
- Release of particles and/or gamma photons
- Reduction of nuclear energy

# Nuclear Stability Curve

The stability of a nucleus depends on the ratio of neutrons to protons:

- Light nuclei:  $N \approx Z$
- Heavy nuclei:  $N > Z$

Unstable nuclei decay until they reach the **stable region**.



# Main Methods of Radioactive Decay

Radioactive decay occurs through several mechanisms:

## Particle Emission

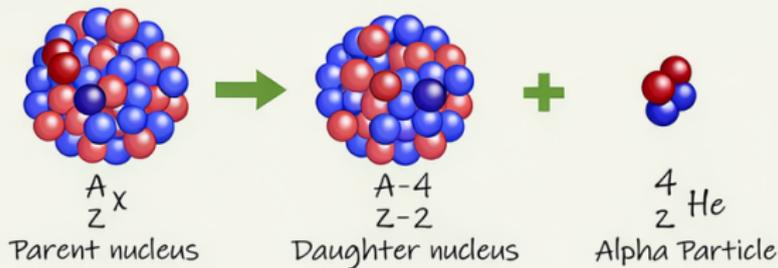
- Alpha decay ( $\alpha$ )
- Beta-minus decay ( $\beta^-$ )
- Beta-plus decay ( $\beta^+$ )

## Other Processes

- Electron capture
- Gamma emission ( $\gamma$ )
- Spontaneous fission

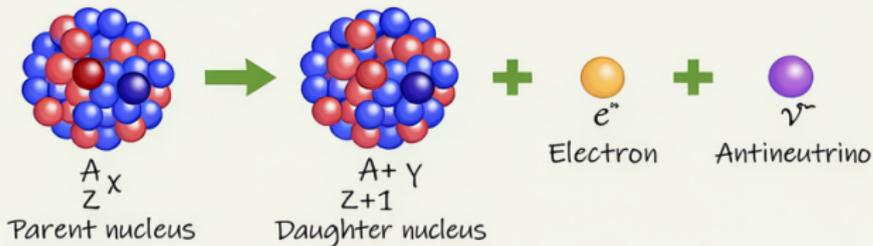
# Decay Types Figure

## ALPHA DECAY



## BETA DECAY

### BETA-MINUS DECAY



### BETA-PLUS DECAY

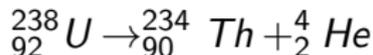


Alpha decay occurs mainly in heavy elements (Uranium, Radium).

**Alpha particle:**



Example:



**Effect:**

- $A$  decreases by 4
- $Z$  decreases by 2

Beta decay happens when the nucleus has an imbalance of neutrons and protons.

Three types:

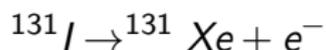
- 1 Beta-minus emission ( $\beta^-$ )
- 2 Beta-plus emission ( $\beta^+$ )
- 3 Electron capture

# Beta-minus Decay ( $\beta^-$ )

A neutron converts into a proton:



Example:



**Result:**

- Atomic number increases
- Mass number unchanged

# Beta-plus Decay ( $\beta^+$ )

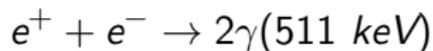
A proton converts into a neutron:



Example:



**Positron Annihilation:**

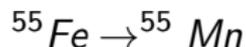


# Electron Capture

The nucleus captures an orbital electron:



Example:



**Observed emissions:**

- X-rays
- Gamma rays

Gamma decay occurs when the nucleus releases excess energy as photons.

## Important properties:

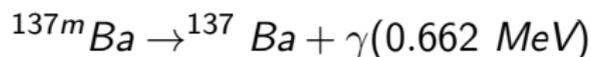
- No change in  $A$
- No change in  $Z$
- Only nuclear energy decreases

# Caesium-137 Decay Scheme

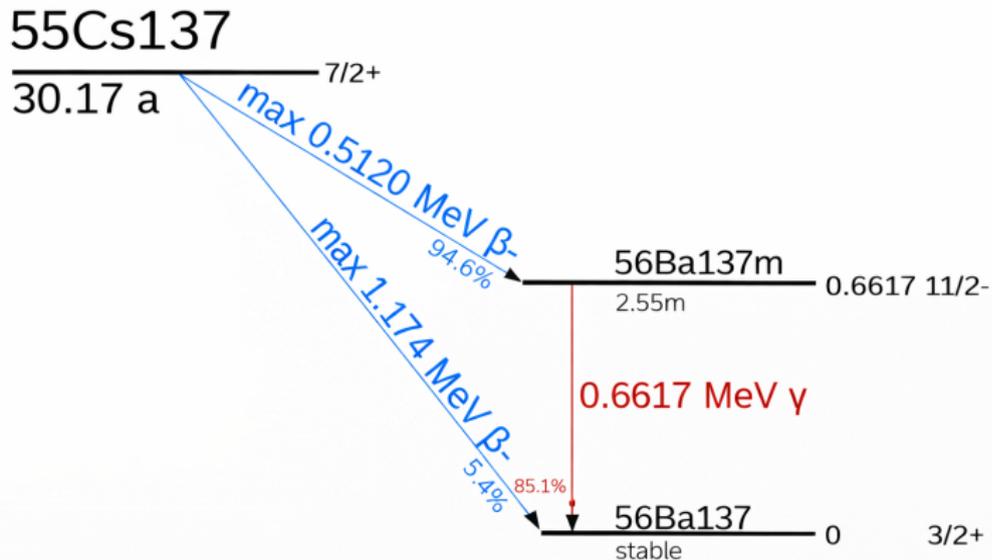
Caesium-137 is widely used in medical physics calibration.



Then metastable barium emits gamma:



# Decay Scheme Diagram



● Proton   ● Neutron   ● Electron   ● Positron   ● Antineutrino



Radioactive decay is best described as:

- ① A. A chemical reaction between atoms
- ② B. Emission of particles/energy from an unstable nucleus
- ③ C. Fusion of two nuclei into one
- ④ D. Rearrangement of electrons in atomic shells
- ⑤ E. None of them

Which of the following quantities is always conserved in radioactive decay?

- ① A. Mass only
- ② B. Atomic number only
- ③ C. Energy and charge
- ④ D. Electron configuration
- ⑤ E. None of them

In alpha decay, the nucleus emits:

- ① A. One electron
- ② B. One positron
- ③ C. Two protons and two neutrons
- ④ D. One neutron only
- ⑤ E. None of them

After alpha decay, the atomic number of the nucleus:

- ① A. Increases by 2
- ② B. Decreases by 2
- ③ C. Remains unchanged
- ④ D. Decreases by 4
- ⑤ E. None of them

Beta-minus decay occurs when:

- ① A. A proton converts into a neutron
- ② B. A neutron converts into a proton
- ③ C. The nucleus emits an alpha particle
- ④ D. The nucleus emits gamma rays only
- ⑤ E. None of them

In beta-plus decay, the emitted particle is:

- ① A. Electron
- ② B. Neutron
- ③ C. Positron
- ④ D. Alpha particle
- ⑤ E. None of them

Electron capture happens when:

- ① A. A nucleus emits a gamma photon
- ② B. A proton captures an inner orbital electron
- ③ C. A neutron escapes the nucleus
- ④ D. Two nuclei combine together
- ⑤ E. None of them

Gamma decay is characterized by:

- ① A. Change in atomic number
- ② B. Emission of charged particles
- ③ C. Emission of electromagnetic radiation only
- ④ D. Loss of mass number by 4
- ⑤ E. None of them

Caesium-137 decays into metastable barium-137m mainly by:

- 1 A. Alpha decay
- 2 B. Beta-minus decay
- 3 C. Beta-plus decay
- 4 D. Electron capture
- 5 E. None of them

The gamma ray emitted from Ba-137m has an energy close to:

- ① A. 0.140 MeV
- ② B. 0.511 MeV
- ③ C. 0.662 MeV
- ④ D. 1.25 MeV
- ⑤ E. None of them