Modes of Radioactive Decay II

RTT4220 – LECTURE #3

KEDREE PROFFITT

WSU

09/02/2025

Review of Last Lecture

Gotta gotta get it

Types of Radiation (by particle type)

Alpha Emission ($\alpha, {}^{4}_{2}\mathrm{He}$)

- Massive
- Charged (+2)
- Low penetration

Beta Emission (β^{-}, β^{+})

- Low weight
- Charged (± 1)
- Medium penetration (very energy dependent)

Gamma Emission (γ)

- Massless
- No charge
- High Penetration

Types of Radiation (by mode)

Fission	One heavy nuclide → 2 or more fission products + energy Q
Fusion	Two light nuclei → 1 heavier nuclide + energy Q
Alpha Emission	Emission of helium with energy ~ 8-10 MeV, externally safe, heavy and neutron rich
Beta Emission	Emission of electron or positron, spectrum of energies, light and proton rich/deficit
Internal Conversion	Attempted gamma emission → electron emission, set energy
Excited State Gamma/Isomeric Transition	Emission of photon
Electron Capture	K-shell electron consumed by nucleus and proton, competitive with positron, vacancy

Radioactive Nuclides in Context

Wait, we make it for a reason?

Methods of Increasing Stability

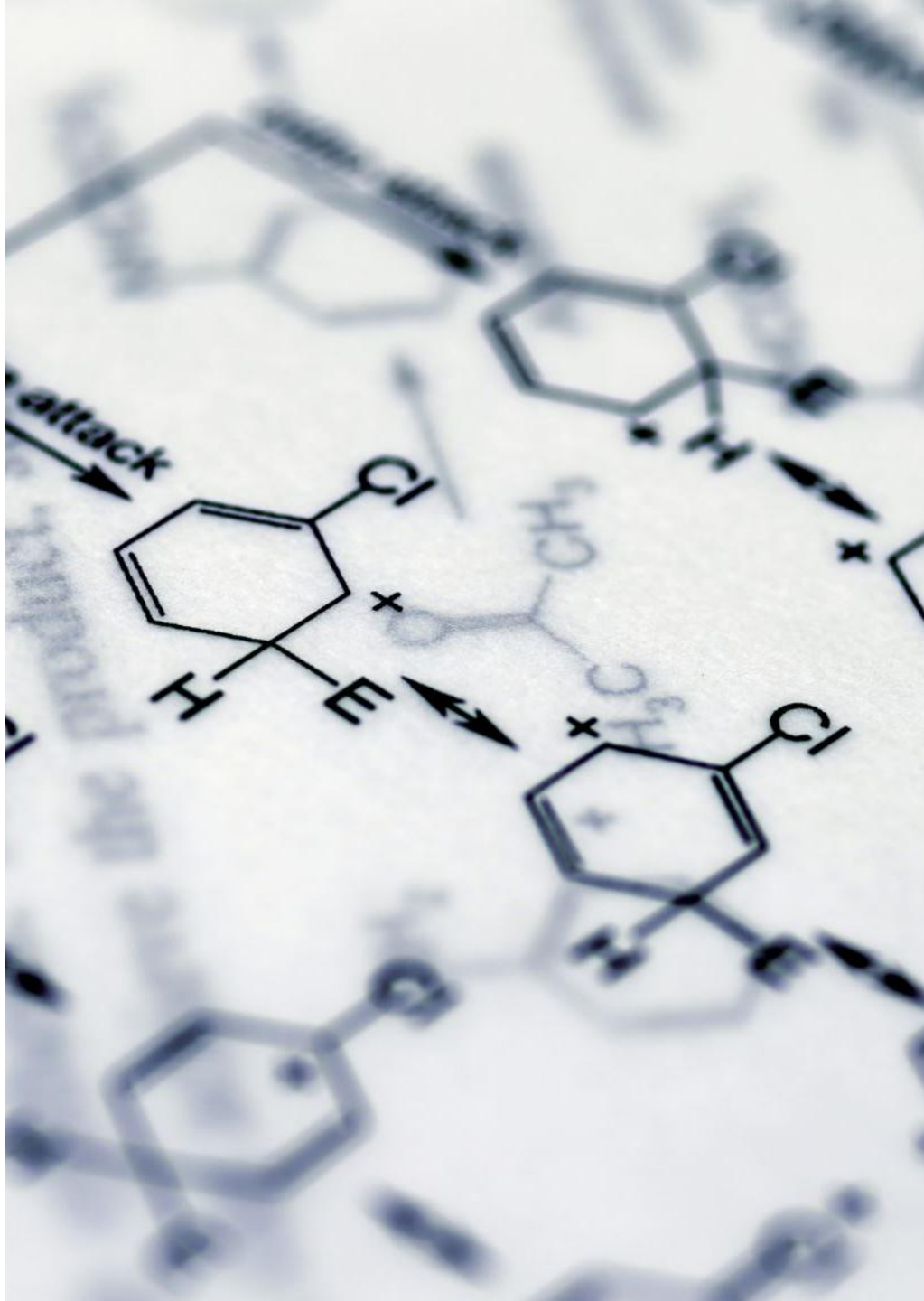
- Nuclei tend toward more favorable energy states (least potential energy)
- Many possible ways that nuclei obtain the above:
  - Nuclear Fission (heavy elements)
  - Nuclear Fusion (lighter elements)
  - Radioactive Decay

How are Radioactive Elements Made?

- Naturally occurring:
  - Products of nuclear fission from heavy elements made in supernovae
  - More commonly heavy, long half-lived elements like radium, occasionally lighter elements like carbon-14 due to other events like cosmic rays interacting with nitrogen in the atmosphere
  - Anything with $Z > 82$ is radioactive, man-made or natural
- Man-made:
  - Created by cyclotrons (proton excess)
  - Byproduct or created in nuclear reactors (neutron excess)
  - Common examples: O-15, F-18, Cs-137, Mo-99

Use of Radioactivity

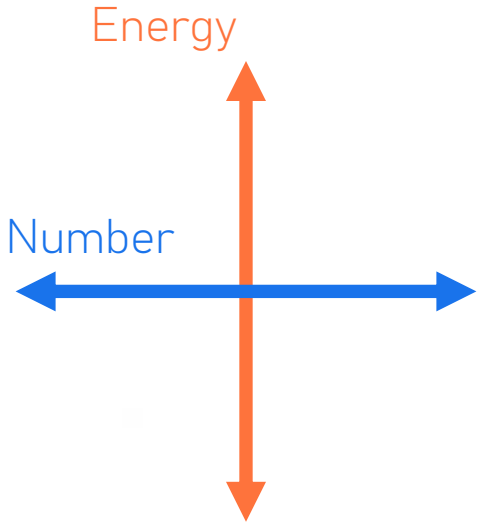
- Smoke detectors (Amercium-241)
  - There are electronic ones too! Research it!
- Carbon Dating
  - Carbon sinks (plants and animals) take in carbon until death,
  - C-14 has long half-life, can predict when it stopped taking in carbon (DEATH)
- Sterilization (Co-60)
- Radioactive Tracers (F-18 and more)
  - Medicinal and Industry
- Cancer Treatment!
  - You should definitely know that already

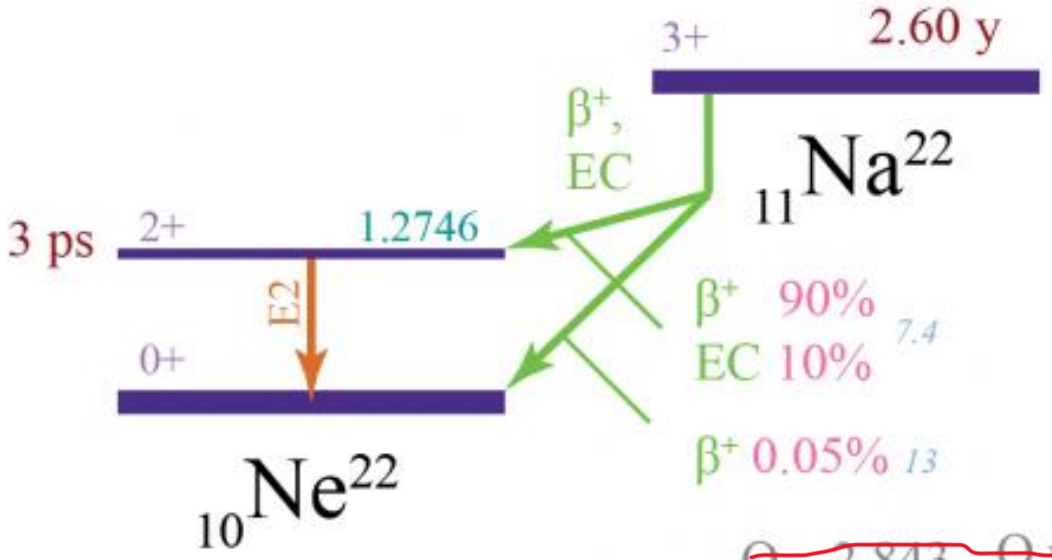


Decay Scheme Diagrams

STICK WITH ME.

Anatomy of a Decay Scheme Diagram



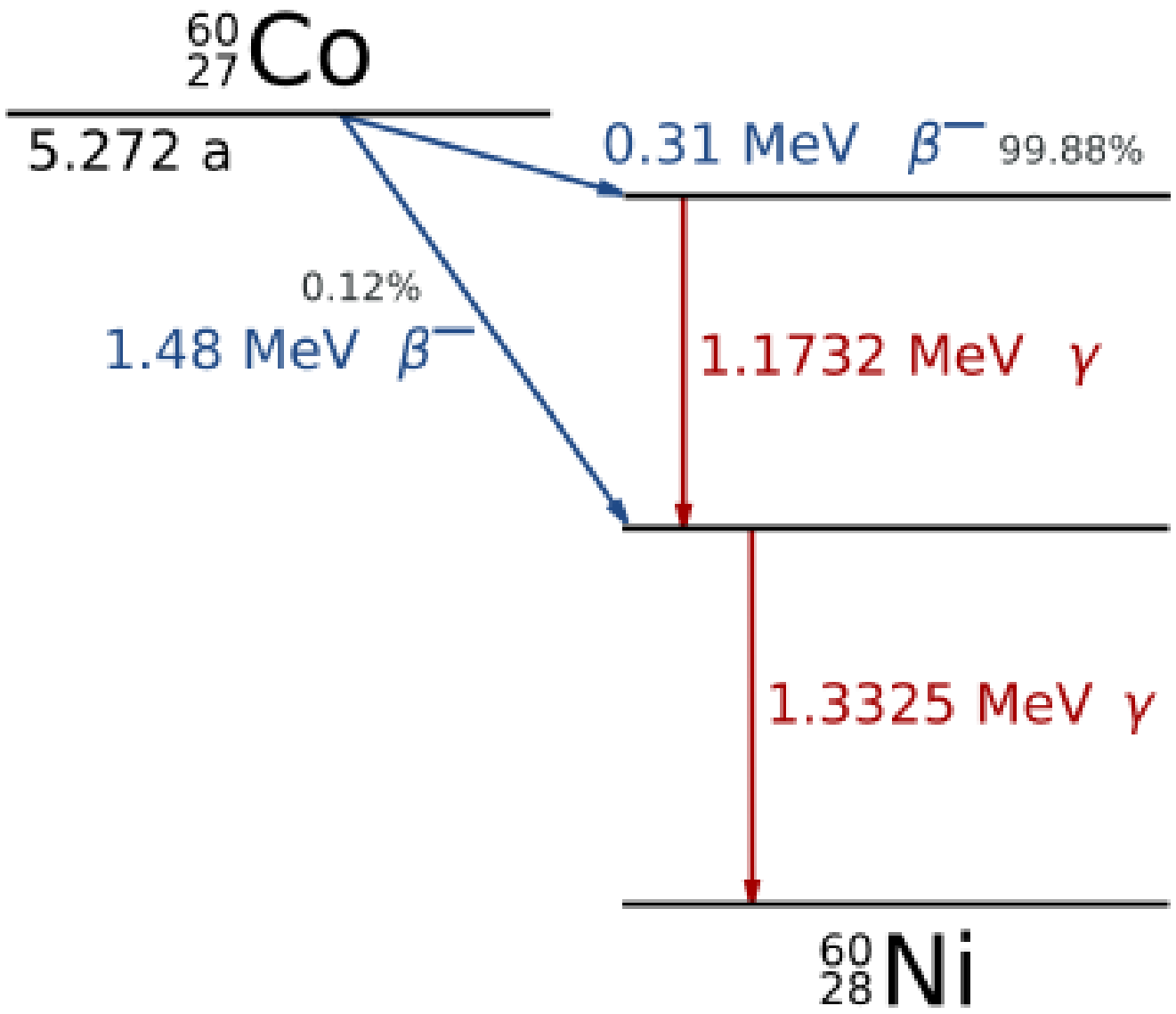


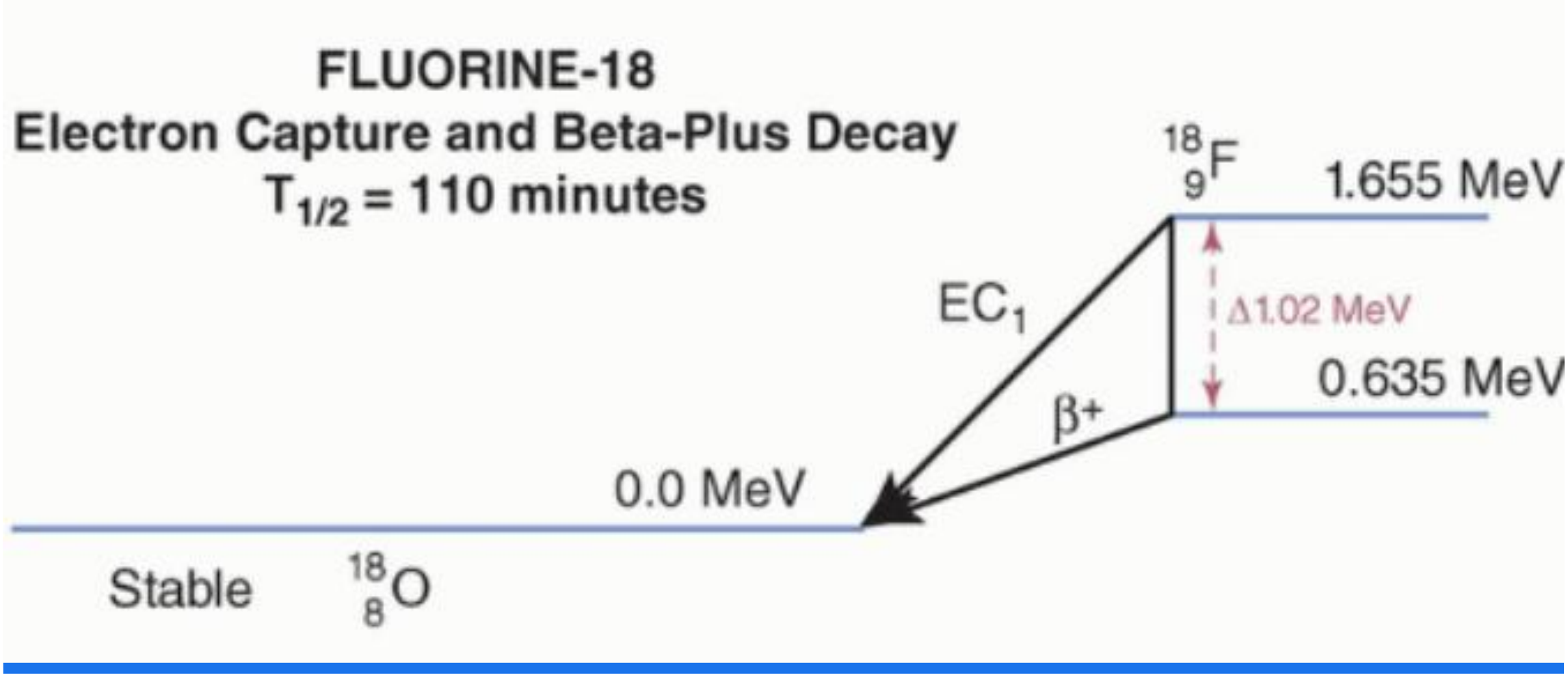
- Isotope
- Energy Levels
- Decay Processes
- ~~Nuclear Energy Transitions~~
  - ~~E# are electric~~
  - ~~M# are magnetic~~
- Energy (in MeV)
- Half-life
- ~~Nuclear Excitation State~~
- Relative probability of decay
- ~~"ln(ft)" value ∝ decay~~ rate

~~Q_{EC} 2.843 Q value [ΔE, MeV]~~
~~(MTW) (citation)~~

Scheme Diagram Example

- What is the Parent and Daughter?
- What are the decay modes?
- Is Co-60 gaining or losing atomic number?
- What is the relative ratio of probabilities?



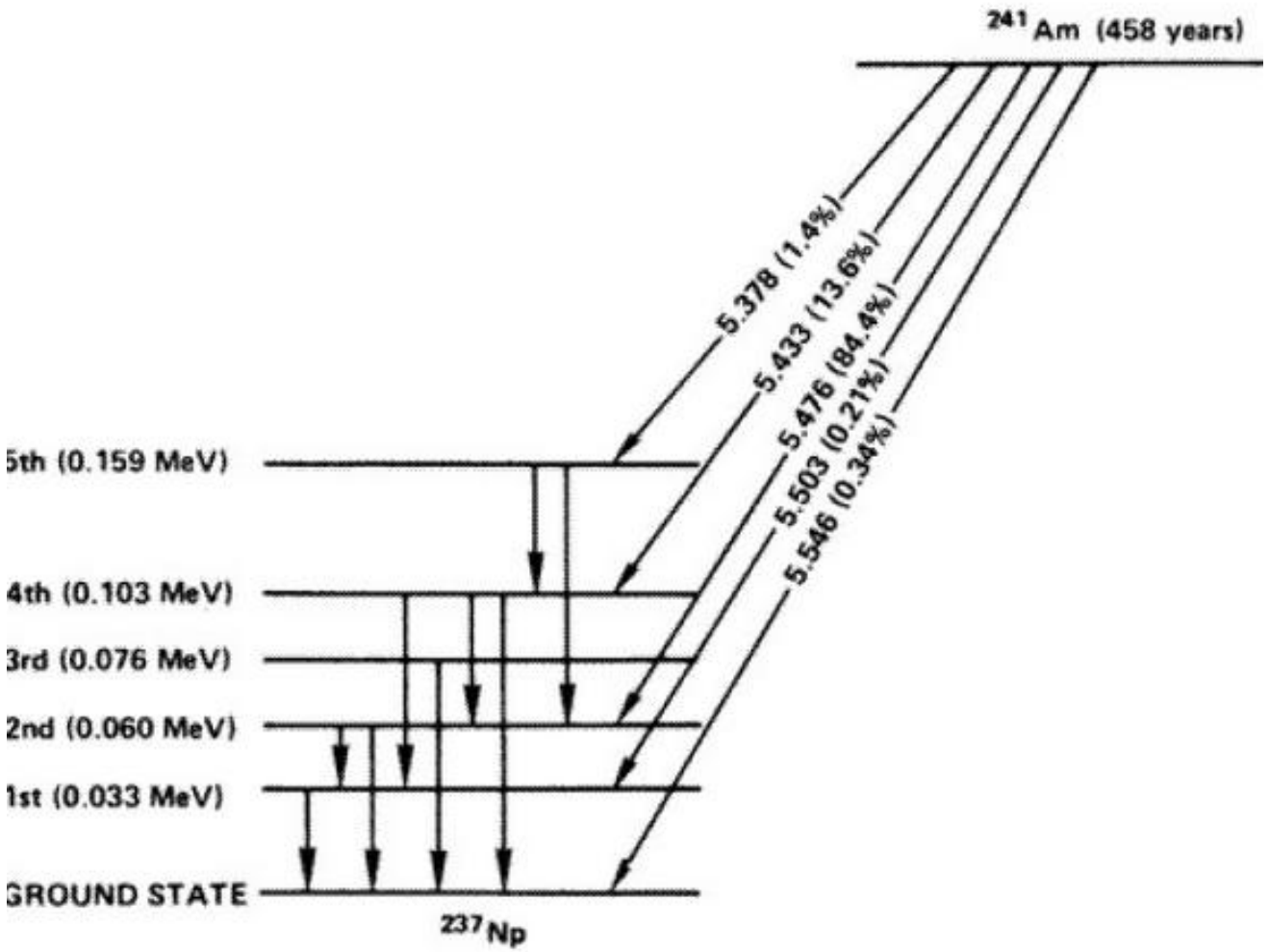


Yet Another Please

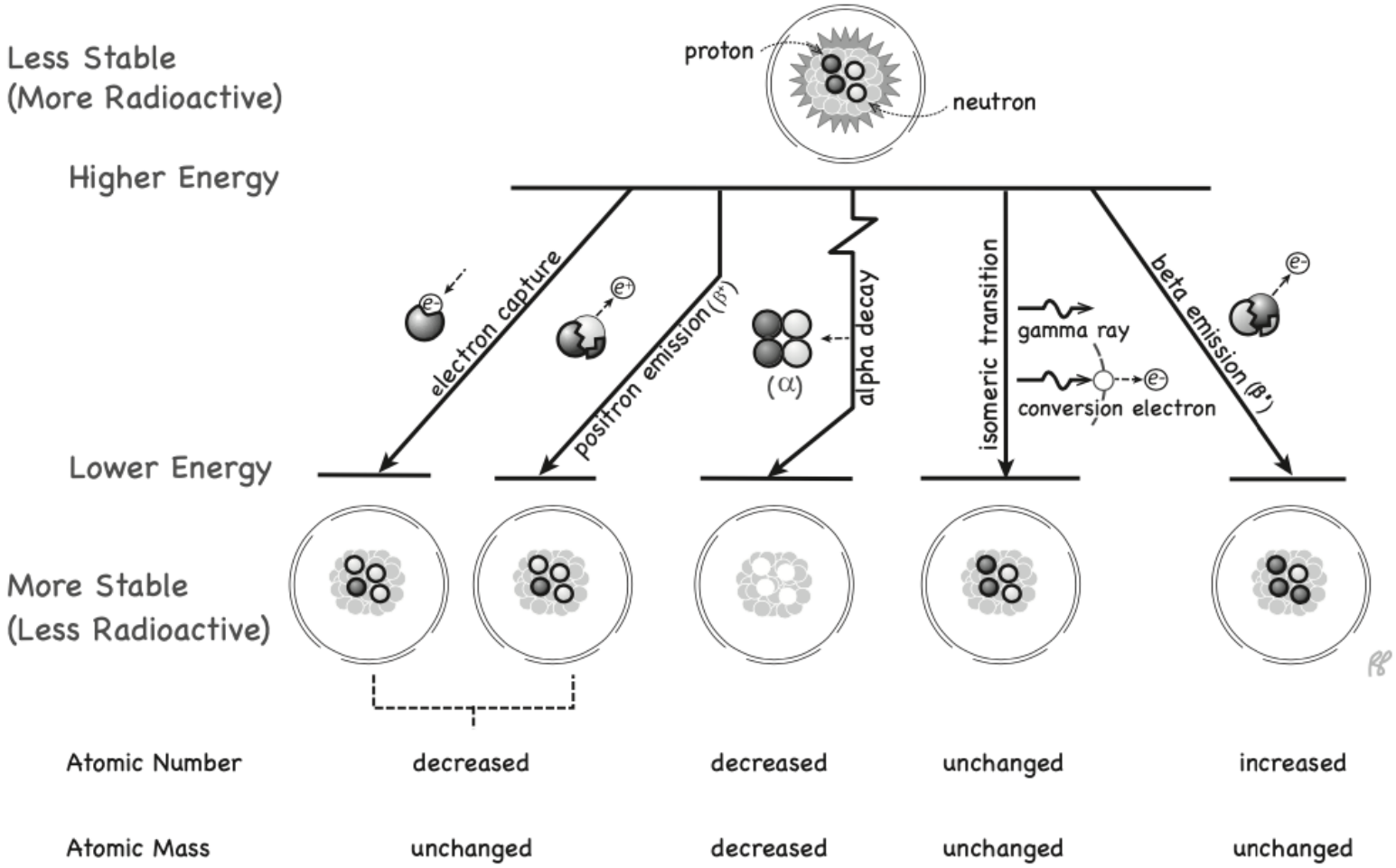
- What is the energy released during EC?
- Why are there two arrows?
- Why does one have a vertical line with 1.022 MeV?

I Swear, Last One

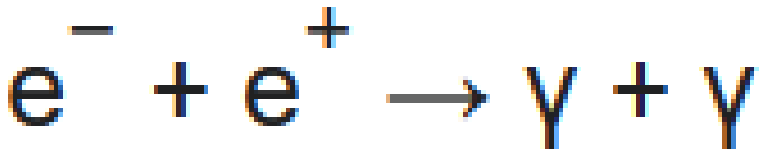
FOR NOW...



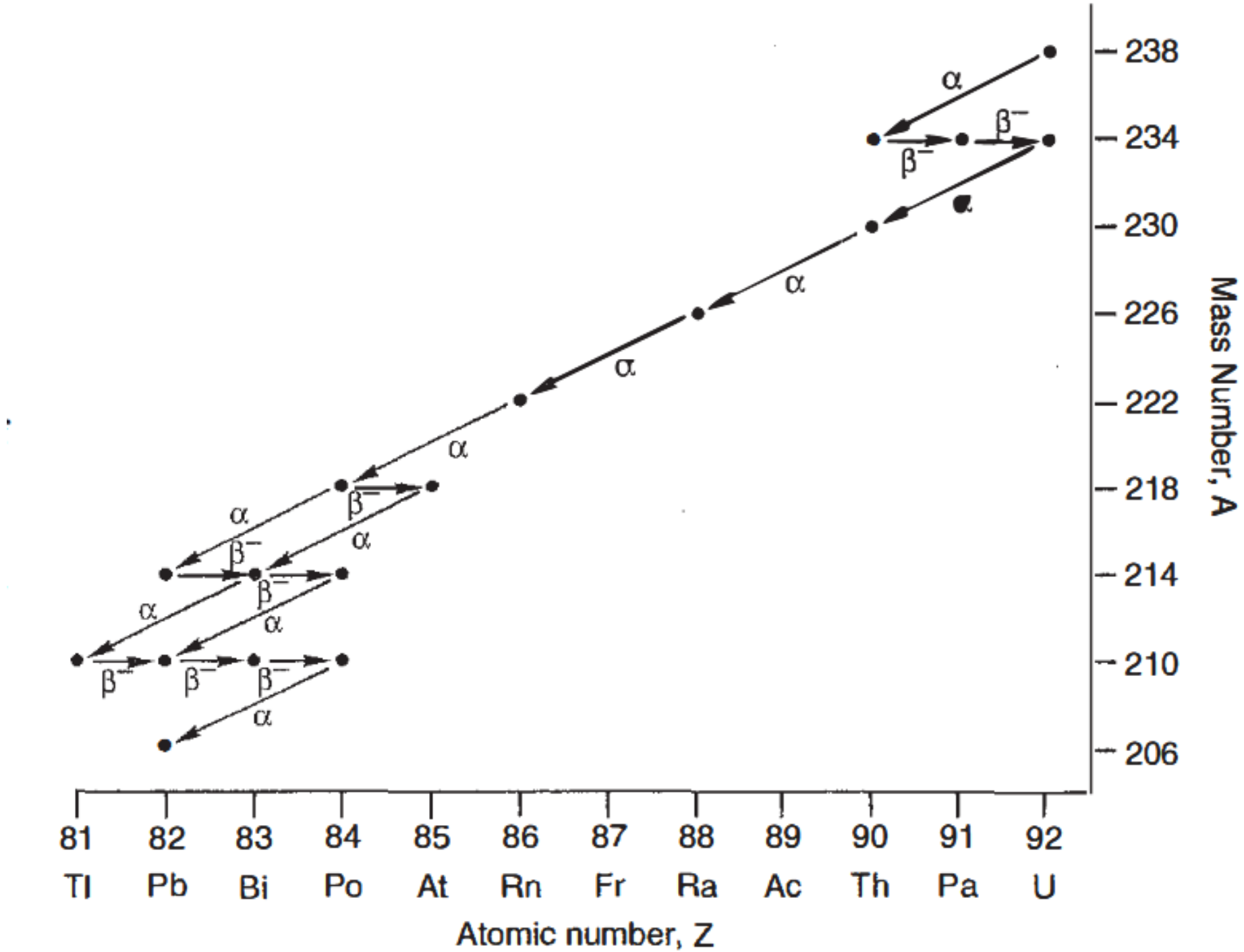
Decay Scheme Diagram Guide



Positron Annihilation



- Origin of the 1.022 MeV energy requirement
- When positron and electron meet → KABOOM electrons are converted into photons
- Matter-Antimatter reaction produces 2 photons
  - Conservation of linear momentum → must be two photons
  - Rest energy of an electron is 0.511 MeV
  - Most often occurs when positron comes to rest → 2x 180 degree opposed photons with 0.511 MeV each
- Basis of PET Imaging (Positron Emission Tomography)


238
234
230
226
222
218
214
210
206
Mass Number, A
α
β⁻
81 Tl
82 Pb
83 Bi
84 Po
85 At
86 Rn
87 Fr
88 Ra
89 Ac
90 Th
91 Pa
92 U
Atomic number, Z