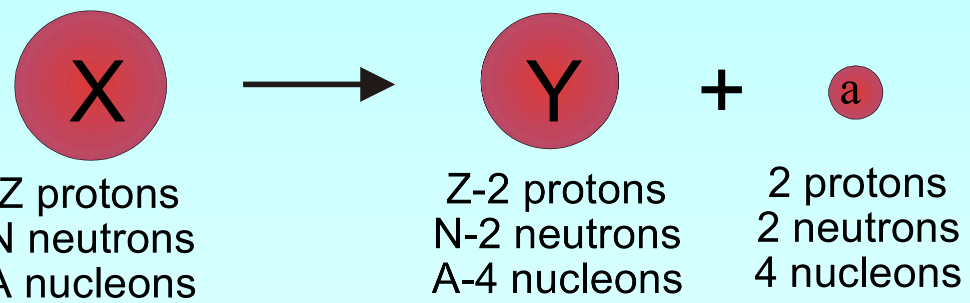
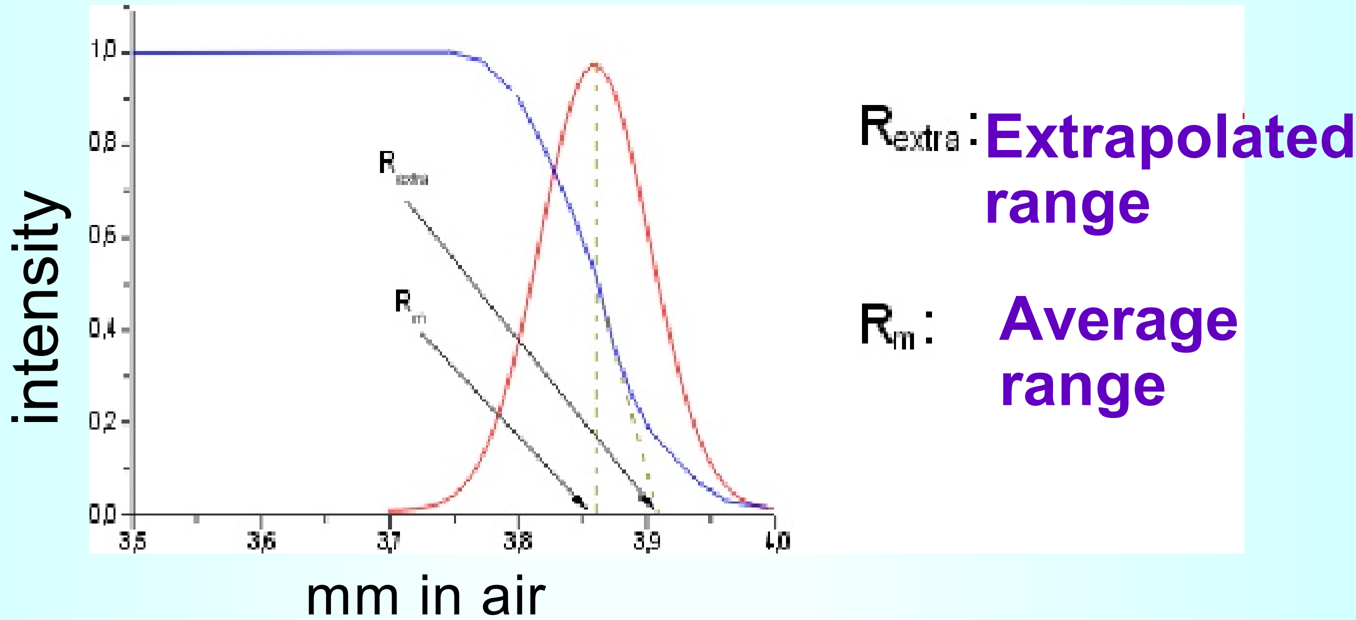
α-disintegration (rep)



- An α-particle is a ^{4}He-ion, consisting of 2 protons and 2 neutrons.
- Two-particle process
- The decaying nucleus gets 4 atomic mass units lighter.
  - In other words: $A_{after} = A_{fbefore} - 4$.
- The decaying atoms is transformed into a new element containing Z-2 protons.
- The α-particles are monoenergetic and have typical energy between 2 and 7 MeV.
- An α-particle is easily slowed down and eventually becomes a neutral He-atom (after picking up two electrons).

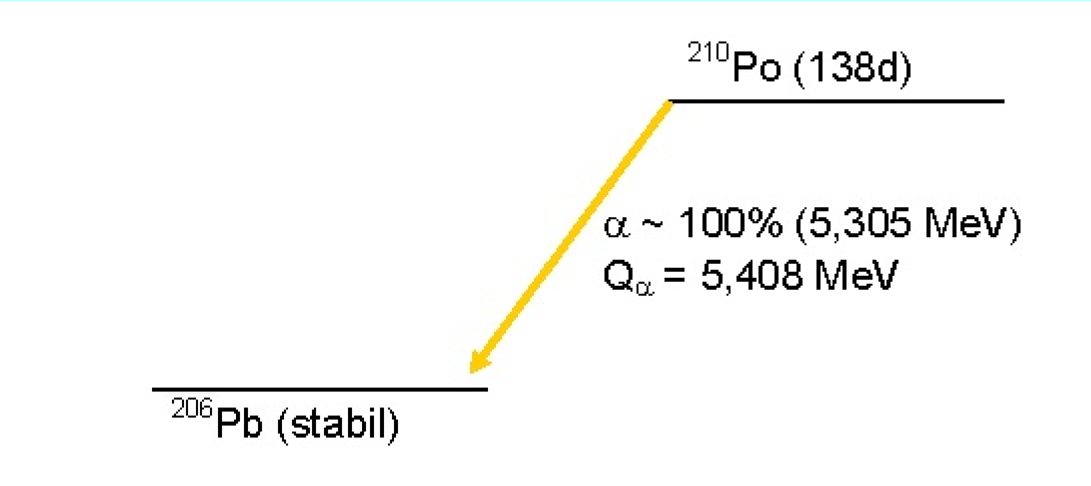
α-disintegration

- Range in air: 3.5 cm
- Range in water, 50-80 μm
- LET: approx. 100 keV/μm
- Sharp range

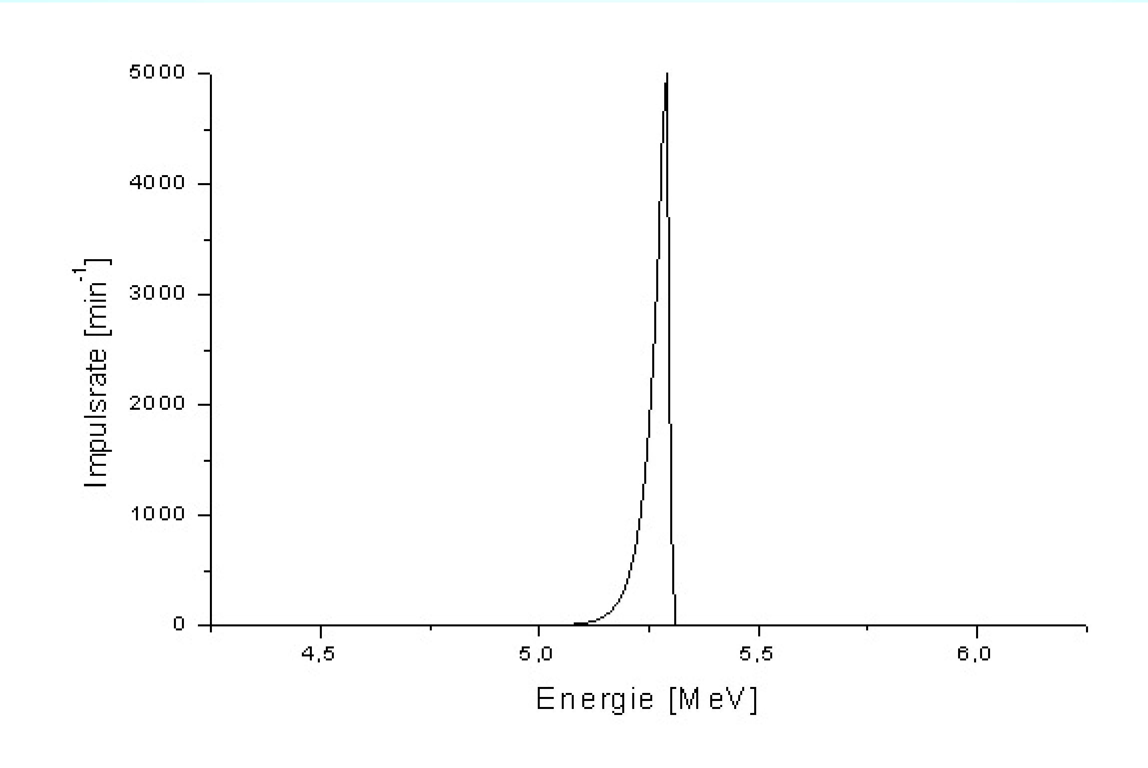


Lage variation in half-life from some nano-seconds up to10^{15} years
Litttle variation in energy (2,5 - 9 MeV)

α-disintegration

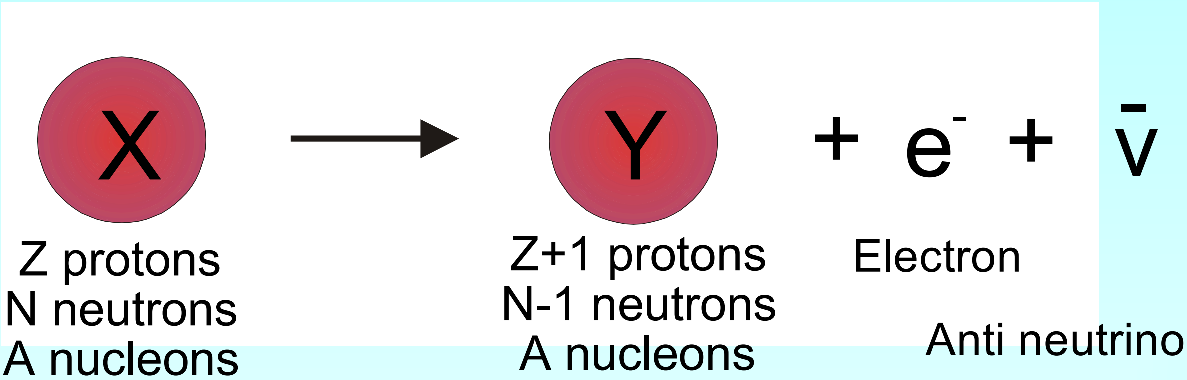


α-disintegration gives line spectrum



$$\ln \lambda = -a \cdot E_\alpha^{-1/2} + b$$

β^--disintegration (rep.)

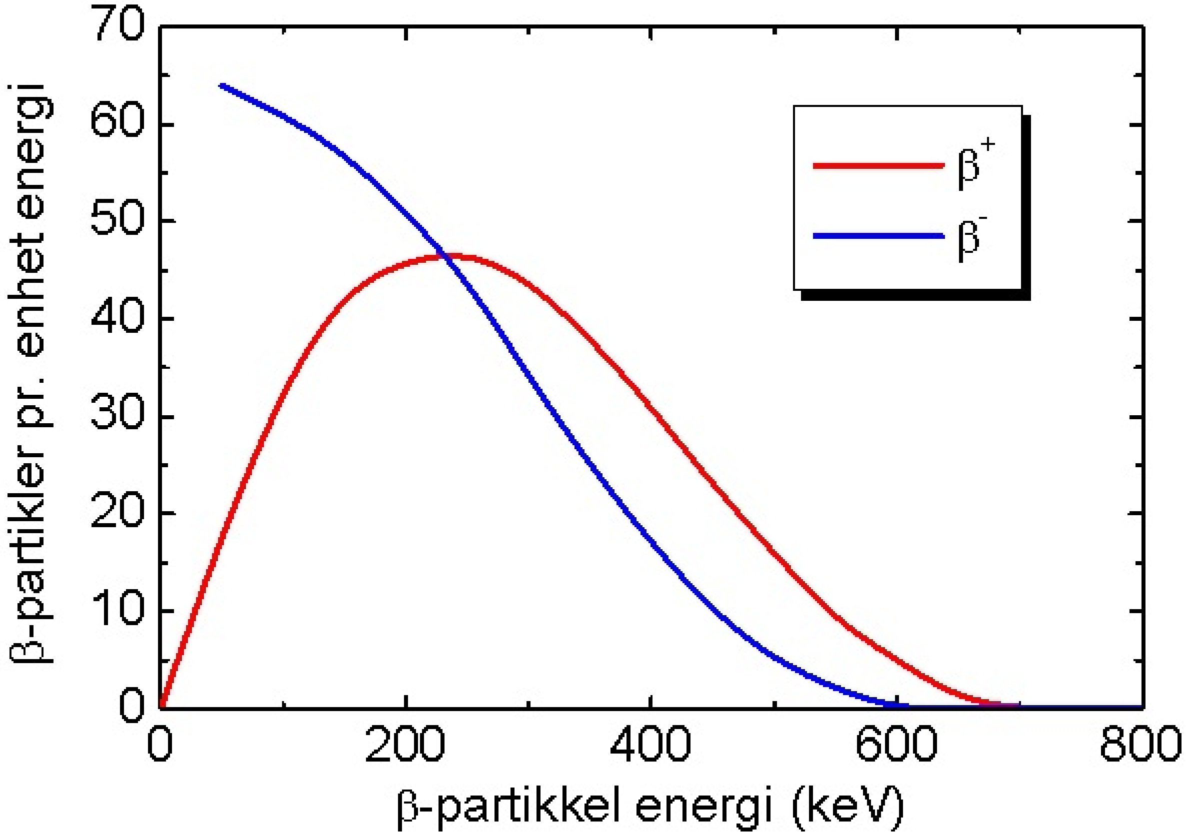


- β^--particles are highly energetic electrons with negativ charge
- β^- particles are not mono-energetic, like the α-particles, but may have energies between 0 and $E_{\beta,max}$. Their average energy is 1/3 of the energy liberated in the disintegration.
- β^--particle emission is always accompanied by the emission of an antineutrino.
  - The antineutrino is without mass and charge
  - Antineutrinos practically do not interact with matter and will “disappear” without leaving a trace (with very few exceptions).

Conservation laws.

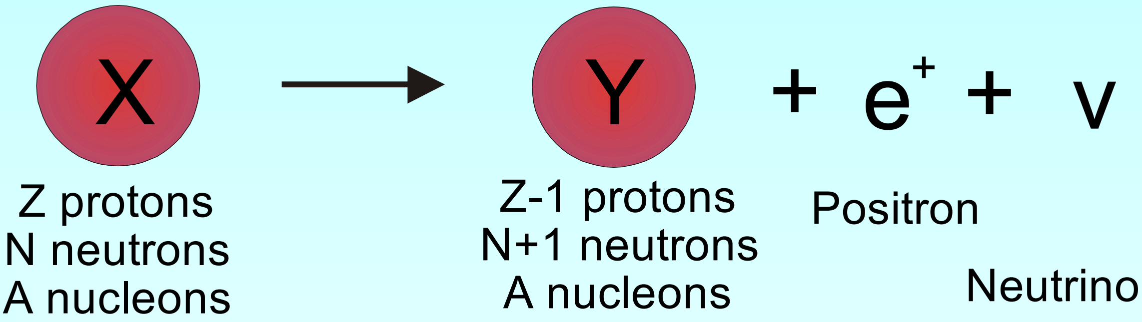
Correct disintegration:

$n \Rightarrow p + e^- + \bar{\nu}$



Explains continuous β-spektrum

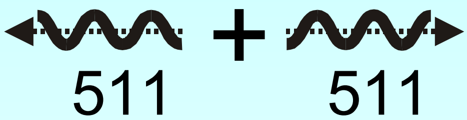
β^+-disintegration



β^+-particles are highly energetic positrons (positive charge)
Like the β^--particles,β^+-particles are not monoenergetic.
Also for β^+-disintegration an additional particle is emitted, the neutrino.
β^+-particles may therefore also have energies between 0 og $E_{\beta,max}$. Their average energy is 1/3 of the energy liberated in the disintegration.
The neutrino is the antiparticle of the anti-neutrino and behaves correspondingly.

β^+-disintegration

$e^+ + e^- \longrightarrow$



- A positron is an "anti-particle" and is not stable.
- After loosing its kinetic energy it will react with an electron. The total restmass will be emittet as two electromagnetic quants.
- The quants have the energy 511 keV, one electron mass.
- The quants are emitted in opposite directioon due to the conservation of momentum.

Electron capture

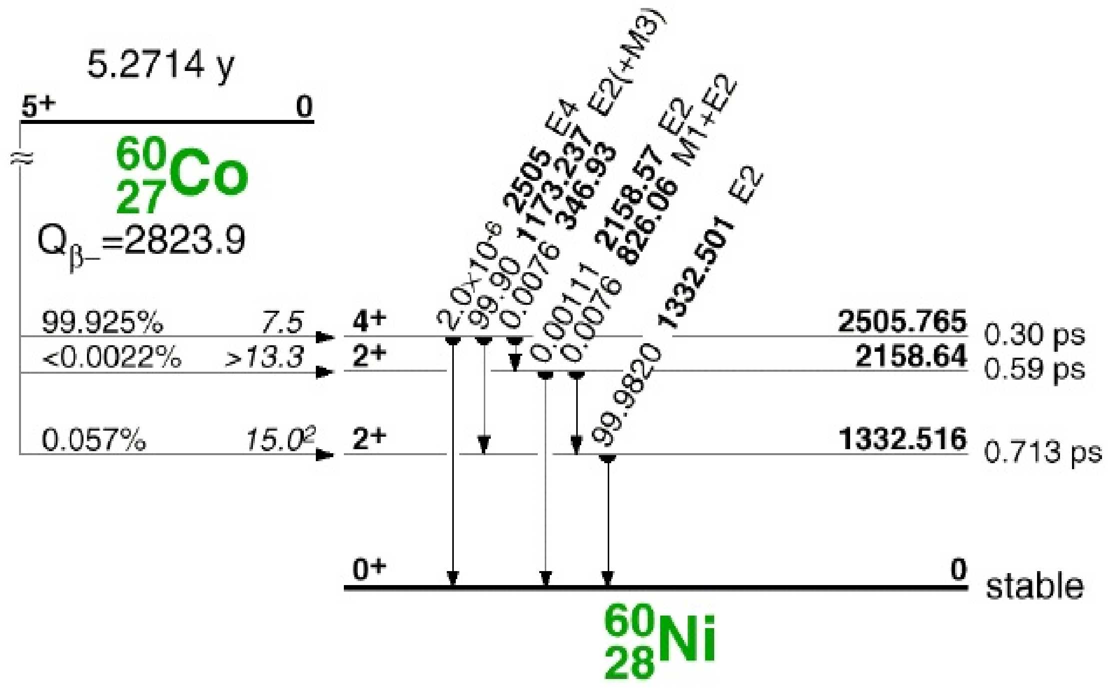
$$X + e^{-} \longrightarrow Y + \nu$$

X: Z protons, N neutrons, A nucleons

Y: Z-1 protons, N+1 neutrons, A nucleons

ν: Neutrino

- Electron capture is considered to be a type of β-disintegration (weak process)
- Instead of sending out a positron, an electron is captured by the nucleus.
- One gets the same product as for β^{+}-disintegration, but theren is no emission of electron/positron, just a (mono-energetic) neutrino.
- Characteristic X-rays are emitted when the electron structure is rearranged.



- γ-disintegration, transition between two levels in the same nucleus, usually rapid, ~10^{-15} s.
- Transition between two levels without change in nucleon number or proton number
- Isomeric γ- disintegration, long half-life
  - White indications in the chart of nuclides
- Isomers arise due to changes of nuclear spin with many units (≥3)
- F.ex $^{99m}Tc \Rightarrow {}^{99}Tc + \gamma(142\ keV)$ (6.0 h) (213 000 år)

Gamma spectra

- The photons from radioactivity induced transitions are in the region from ~10 keV to ~6 MeV
- The spectrum from ^{60}Co has two distinct lines (1173 and 1332 keV) and looks as below in two different types of detectors (Ge and NaI types)

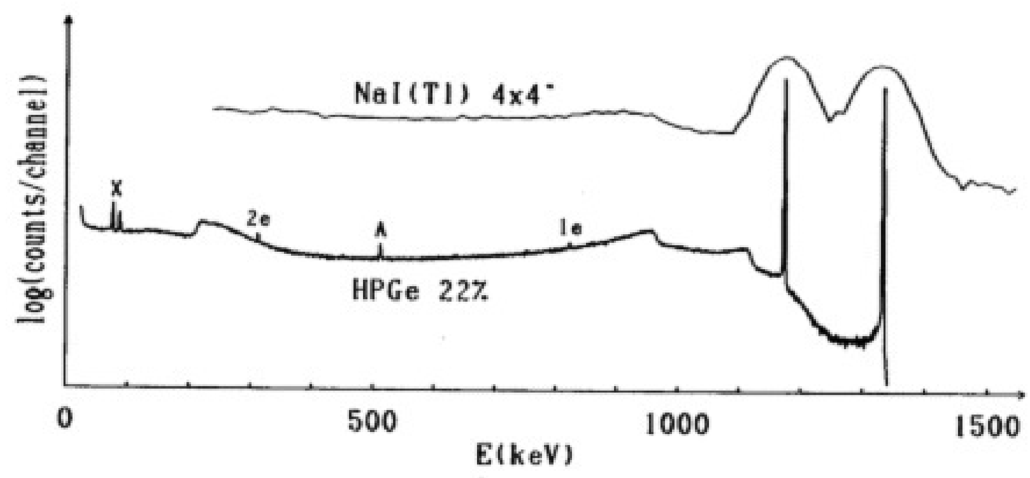
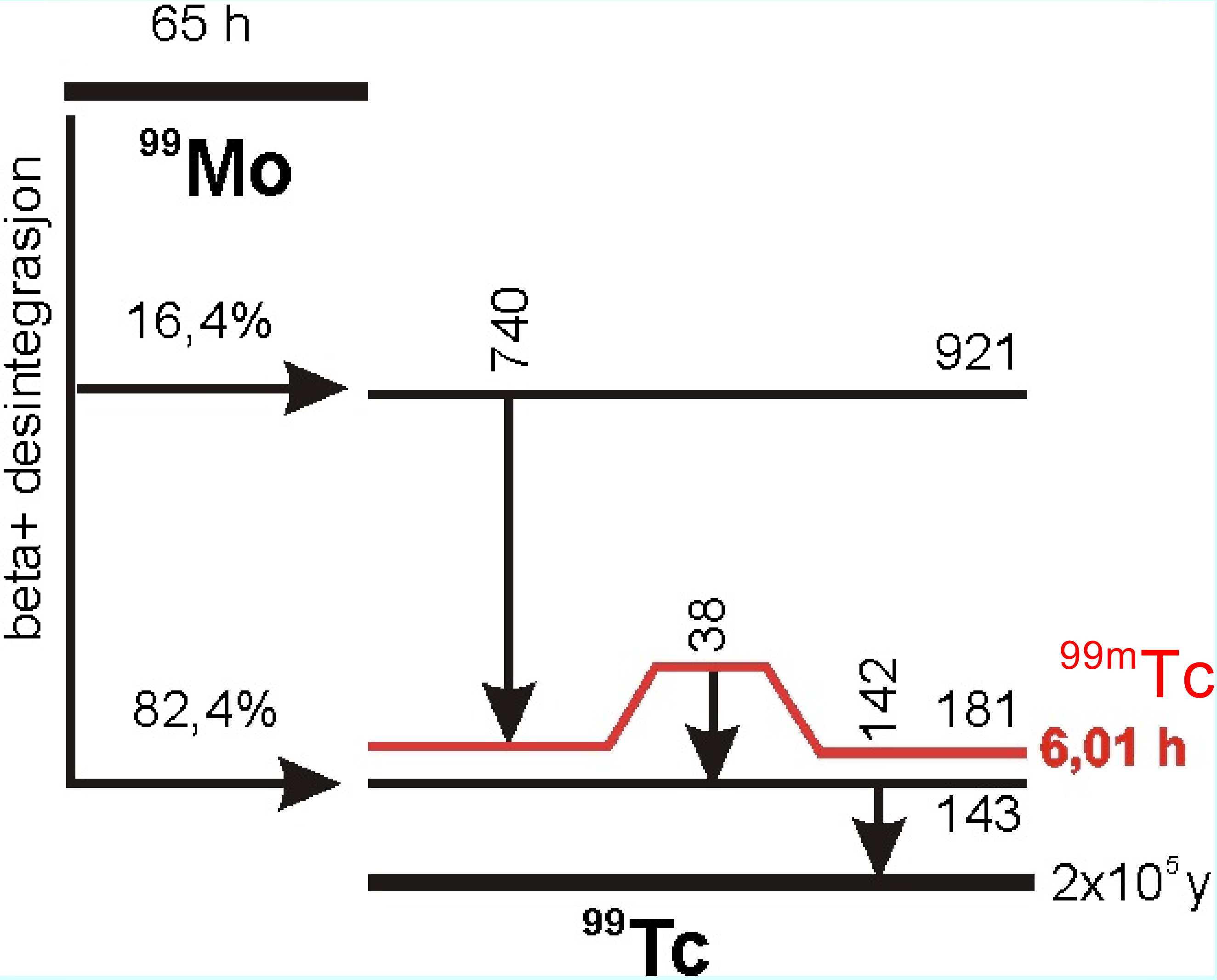


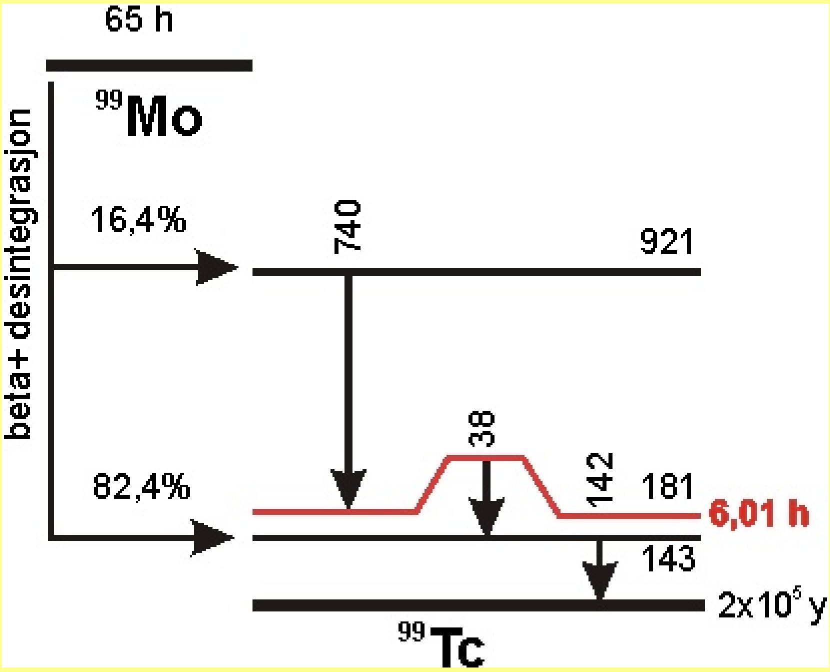
FIG. 8.15. Energy spectrum of ^{60}Co obtained with scintillation and HPGe detectors.

The lines are due to phoelectric absorption, the continuous part is due to Compton scattering. There are only two photon energies.

Nuclear Isomers

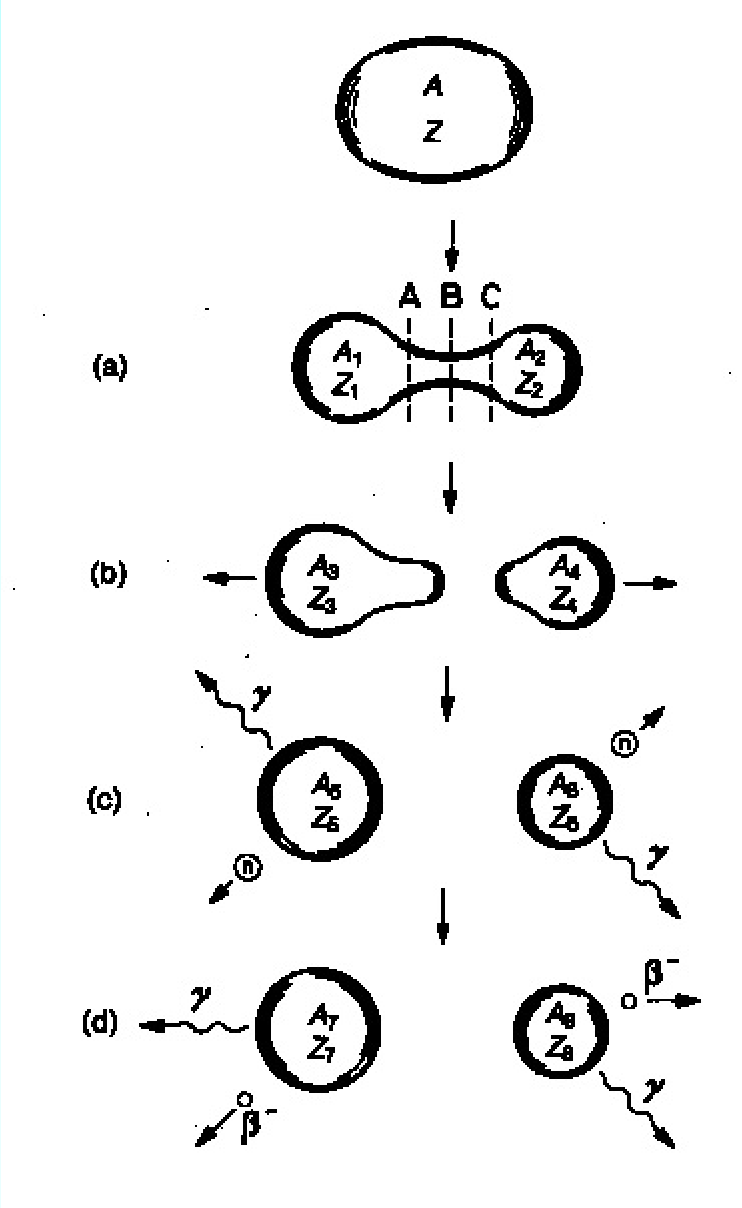
- Nuclear isomers are levels with extremely long half-life
  - Up to 10^{15} y (^{180m}Ta)
  - Normally 1s - some days
  - Lower limit, ~1μs (individual)





- Excited levels with long half-life are called *metastable*.
- Nuclei in thiese excited states are called metastable or isomers.
- This is marked by writing an “m” after the atomic number, in this case it is ^{99m}Tc.
- A metastable nucleus is exactly the same nucleus as in the ground state, but it has “extra” energy.
- Metastable nuclei need not emit γ, but may totally or partly disintegrate in other ways.

Spontaneous fission



Spontaneous fission is a mode of decay where the whole nucleus breaks up into two heavy fragments. (K.Petrzhak & G.Flerov 1940)

Spontaneous fission -yields