

The microscopic world

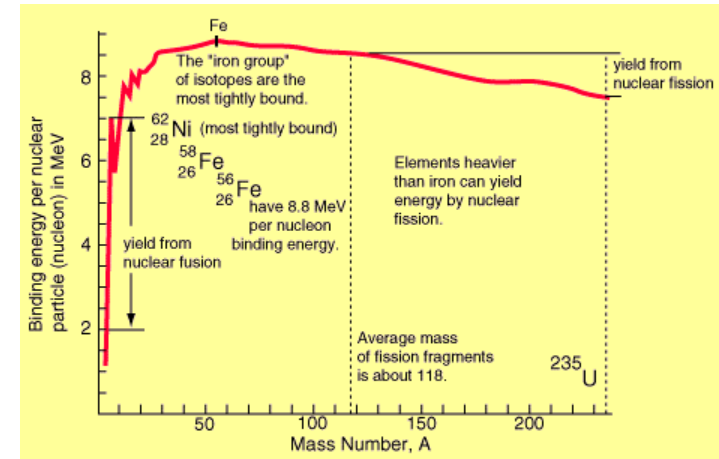
Characteristics of the radioactive decays



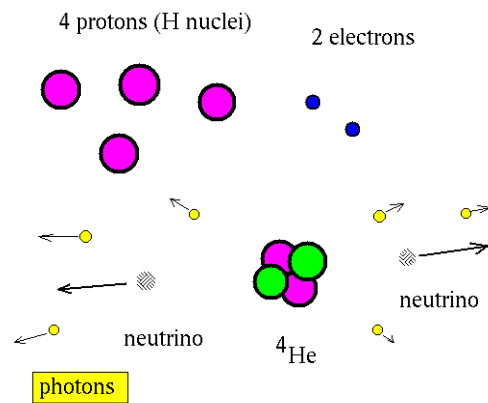
Irén Bárdos-Nagy



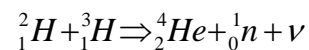
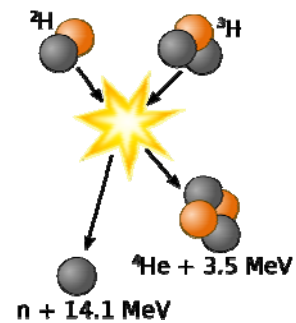
Nuclear binding energies of the different elements



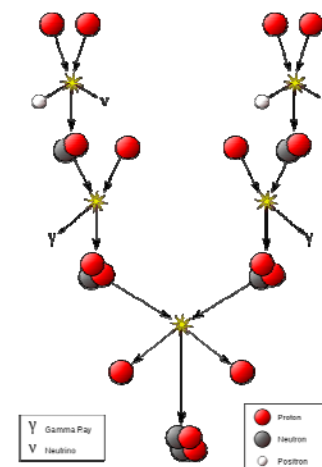
Nuclear fusion



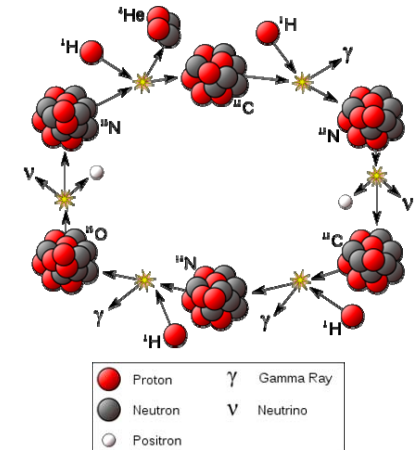
26 MeV energy/fusion



Nuclear fusion in the stars

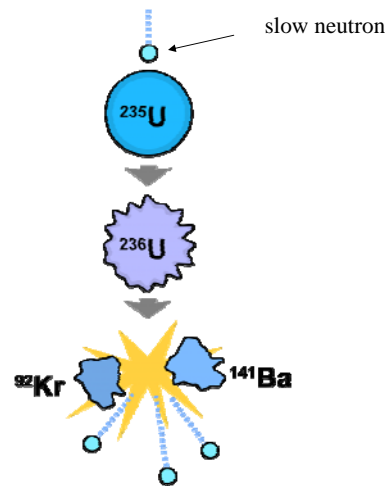


proton – proton chain in the Sun

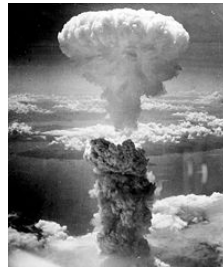


CNO cycle in the stars heavier than the Sun

Nuclear fission



~ 200 MeV/fission event



Radioactive decays and particles

decay	particles
α	α particle = ^4_2He nucleus
β^-	β^- particle = electron
β^+	β^+ particle = positron
K – electron capture	characteristic X – ray photon
Isomeric transition	γ – radiation (photon)

Characteristics of radioactive decays in general

- energy of the particles \rightarrow characterises the radiation
- half life \rightarrow depends only on the type of the isotope
characterises the time process of the decay
- activity \rightarrow characterises the radioactive source

α particle:	constant energy, line spectrum
β particles:	different energies continuous spectrum
γ photon:	definite energy, line spectrum

The half life of the isotopes

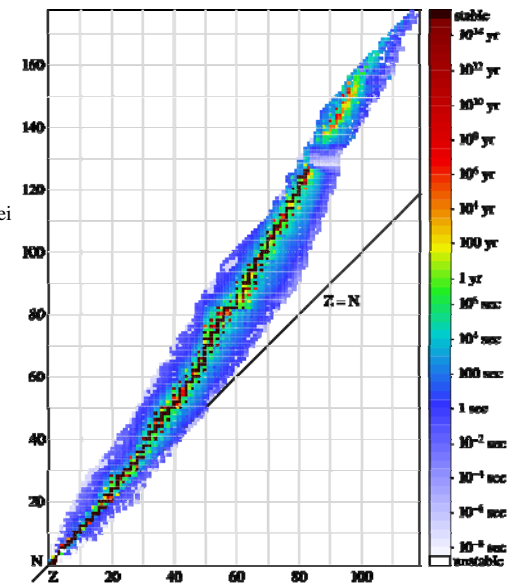
half life:

$$T_{1/2} = T \Rightarrow N = \frac{N_0}{2}$$

N_0 the original number of radioactive nuclei

mean lifetime:

$$\tau \Rightarrow N = \frac{N_0}{e}$$



Activity

number of undecayed nuclei

The number of decays at a unit time.

$$\Lambda = A = \left| \frac{dN}{dt} \right| = \left(\left| \frac{\Delta N}{\Delta t} \right| \right)$$

unit: Becquerel (Bq)
1 Bq = 1decay/s

time

kBq MBq GBq TBq

level of natural activity

activity applied in the in vivo diagnostics

carefull work with it

activity applied in the therapy

Radioactive decay law

number of undecayed nuclei

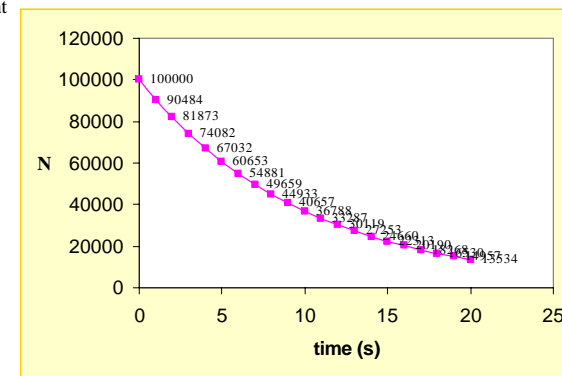
number of undecayed nuclei when t=0

$$\frac{dN}{dt} = -\lambda \cdot N \longrightarrow N(t) = N_0 \cdot e^{-\lambda \cdot t}$$

time

decay constant
(unit: 1/s)

exponential decrease

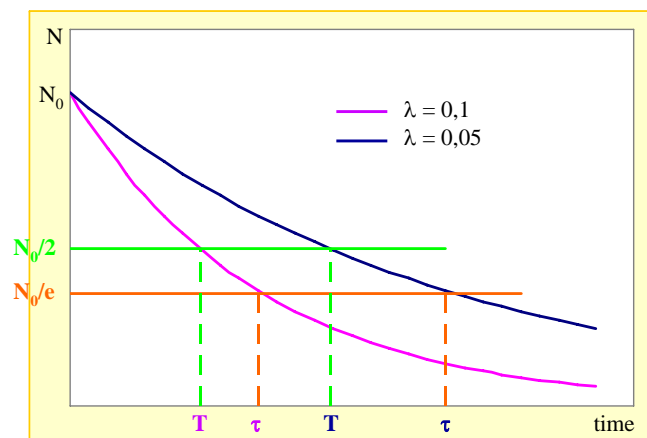


Radioactive decay law

$$N(t) = N_0 \cdot e^{-\lambda \cdot t} = N_0 \cdot e^{-\frac{t}{\tau}} = N_0 \cdot 2^{-\frac{t}{T}}$$

$$N(t) = \frac{N_0}{e} \Rightarrow t = \tau$$

$$N(t) = \frac{N_0}{2} \Rightarrow t = T$$



$$\lambda = \frac{\ln 2}{T} = \frac{0,693}{T}$$

$$T = \frac{\ln 2}{\lambda} = \frac{0,693}{\lambda}$$

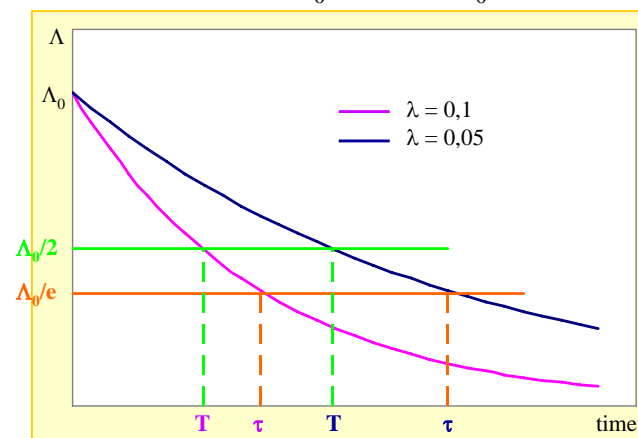
N theoretically **never** decreases to zero!

Decrease of activity as a function of time

$$N(t) = N_0 \cdot e^{-\lambda \cdot t}$$

$$\Lambda = \lambda \cdot N$$

$$\Lambda(t) = \Lambda_0 \cdot e^{-\lambda \cdot t} = \Lambda_0 \cdot e^{-\frac{0,693}{T} \cdot t} = \Lambda_0 \cdot 2^{-\frac{t}{T}}$$



Λ decreases on the same mode as N!

Λ theoretically **never** decreases to zero!

During about 10 T, the original activity decreases about to its 1/1000.

Absorption of radiations

Reminder energy changes in the micro – world

- energy difference between the outer shell atomic orbitals: $\sim \text{eV}$
(light photons)
- energy difference between the inner shell atomic orbitals: $\sim \text{keV}$
(X-ray photons)
- energy difference between the nuclear energy levels: $\sim \text{MeV}$
(radioactive particles,
 γ photons)

absorption of radioactive radiations: **depend on the type of radiation**

α
 β^-
 β^+

particles with electric charge

γ
X-ray

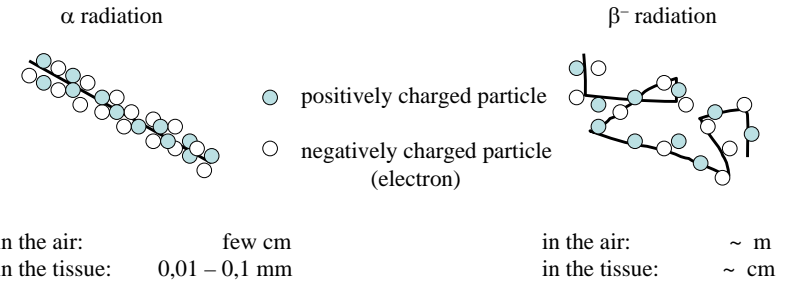
photons, having no electric charge (electromagnetic radiations)

Absorption of charged particles

ionization during the path \longrightarrow continuous decrease of the particle energy

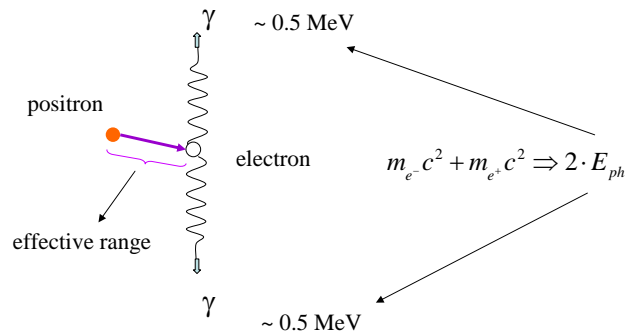
the energy after a given path length decreases to the thermal value

effective range



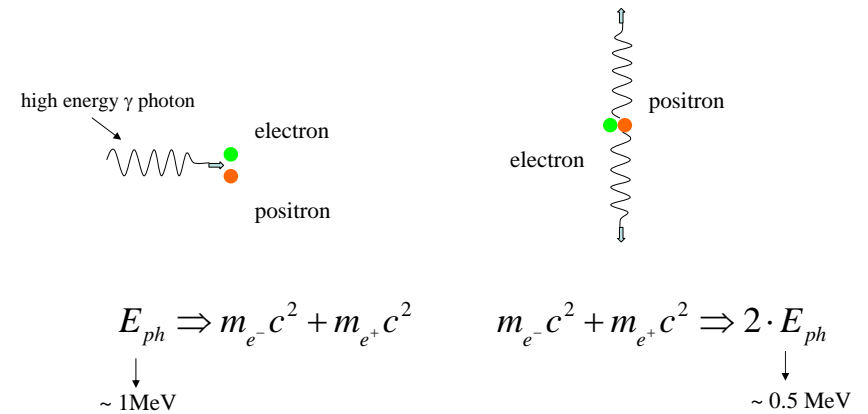
Absorption of β^+ radiation

annihilation

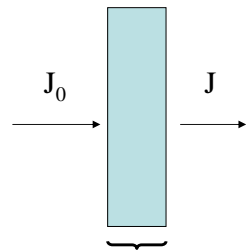


positron emission tomography (PET)

Pair production \longleftrightarrow annihilation



Absorption of γ radiation (and X-ray)



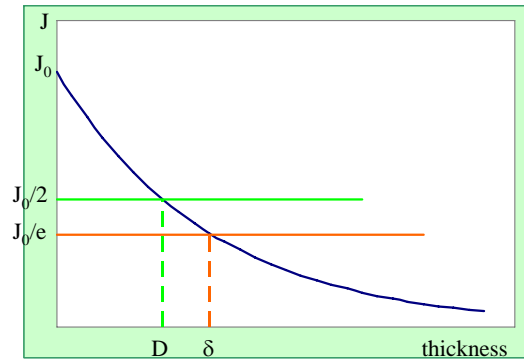
layer thickness (x)

there is no effective range

$$J = \frac{E}{A \cdot t} = \frac{n \cdot E_{ph}}{A \cdot t}$$

n : number of photons in the radiation
 E_{ph} : individual photon energy

n is changing during the absorption, E_{ph} is constant!



Chapters in the text book:

- II/2.2.1., II/2.2.2, II/2.2.3. (thermal radiation)
- I/1.1., I/1.1.2., I/1.1.3., I/1.2.3., I/1.3. (the structure of the atom)
- I/1.5. (the structure of the nucleus)
- II/3.2.1., II/3.2.2. (radioactive decays, radioactive decay law)
- II/1.1.3. (decrease in intensity)