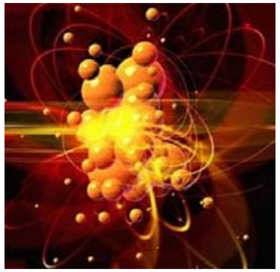
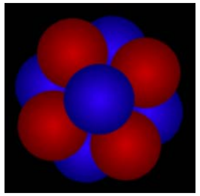
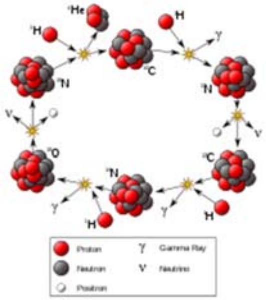
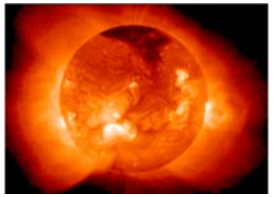






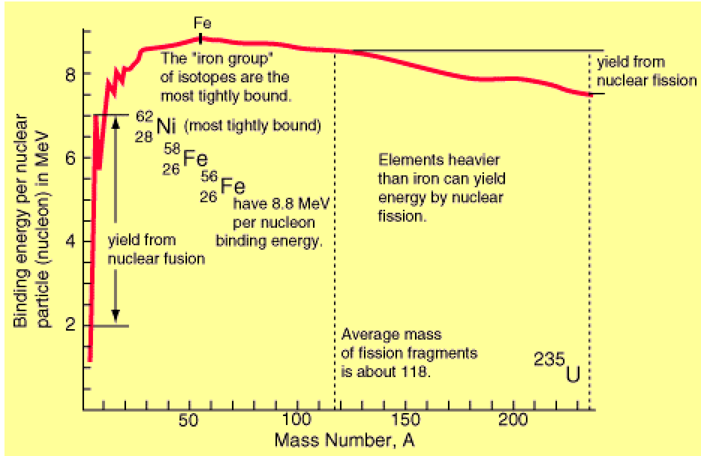
The microscopic world

Characteristics of the radioactive decays

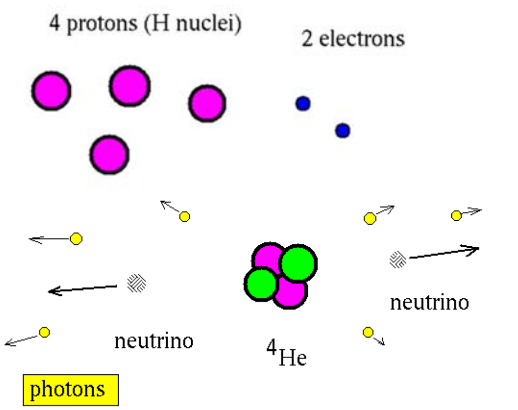


Irén Bárdos-Nagy

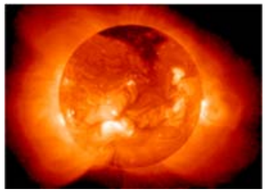
Nuclear binding energies of the different elements

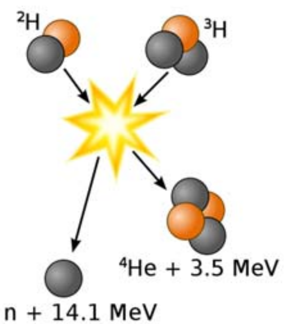


Nuclear fusion



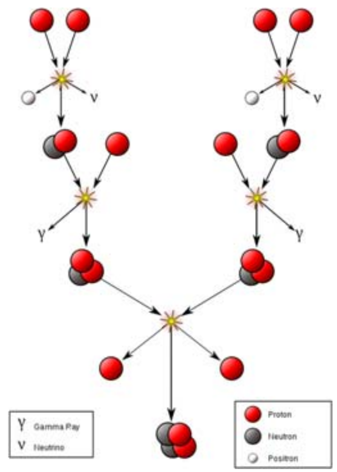
26 MeV energy/fusion



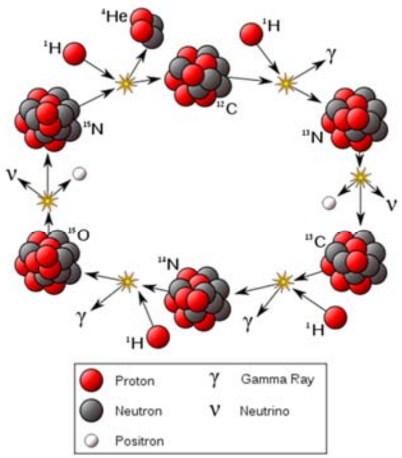


$$^2_1H + ^3_1H \Rightarrow ^4_2He + ^1_0n + \nu$$

Nuclear fusion in the stars

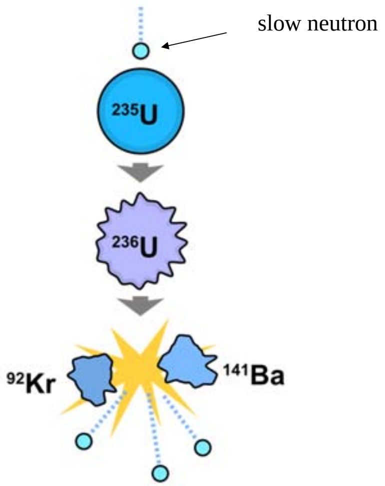


proton – proton chain in the Sun



CNO cycle in the stars heavier than the Sun

Nuclear fission



~ 200 MeV/fission event

Radioactive decays and particles

decay	particles
α	α particle = ${}^{4}_{2}He$ 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 → characterises the radiation

- half life → depends only on the type of the isotope; characterises the time process of the decay

- activity → 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

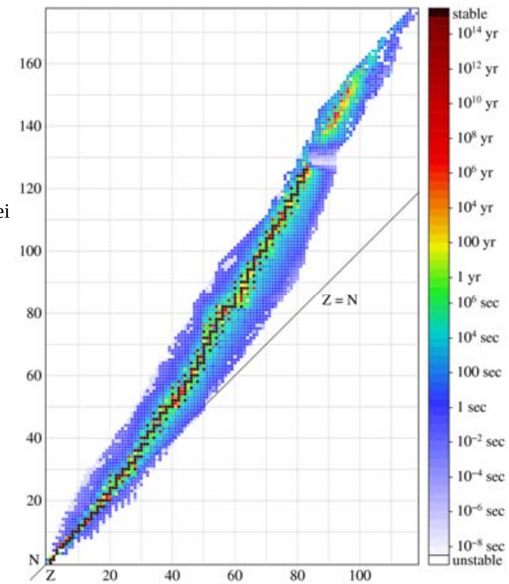
half life:

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

N_0 the original number of radioactive nuclei

mean lifetime:

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



Activity

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

number of undecayed nuclei (N)

time (t)

The number of decays at a unit time.

unit: Becquerel (Bq)

1 Bq = 1decay/s

kBq — level of natural activity

MBq — activity applied in the in vivo diagnostics

GBq — carefull work with it

TBq — activity applied in the theraphy

Radioactive decay law

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

number of undecayed nuclei (N)

time (t)

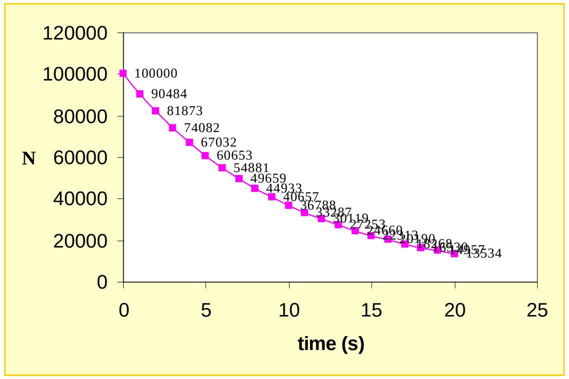
decay constant (λ)

(unit: 1/s)

number of undecayed nuclei when t=0 (N_0)

exponential decrease

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



Radioactive decay law

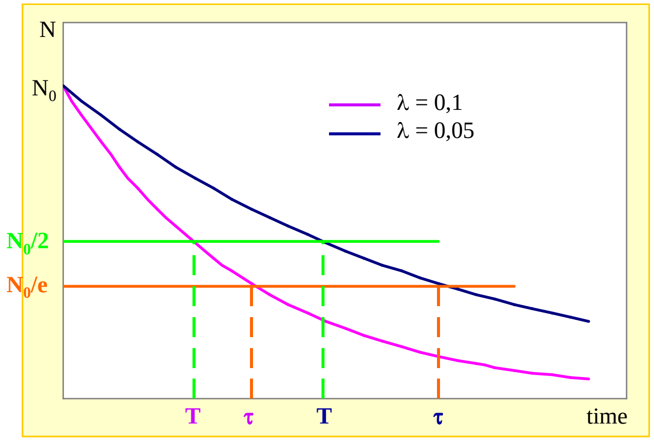
$$N(t) = N_0 \cdot e^{-\lambda \cdot t} = N_0 \cdot e^{-\frac{t}{\tau}} = N_0 \cdot 2^{-\frac{t}{T}}$$

$$N(t) = N_0/e \Rightarrow t = \tau$$

$$N(t) = N_0/2 \Rightarrow t = T$$

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

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

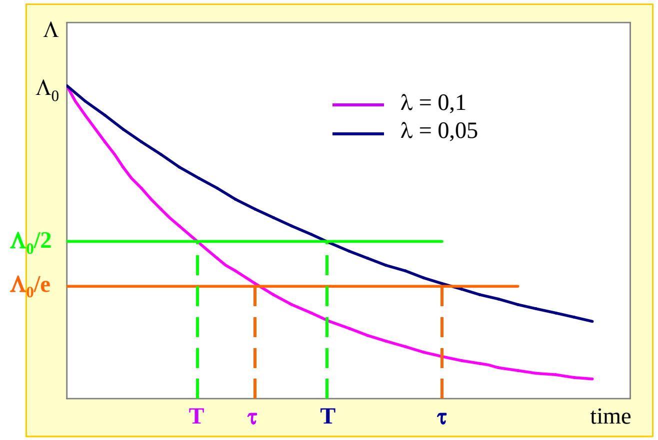


N theoretically **never** decreases to zero!

Decrease of activity as a function of time

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

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



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: ~ **eV** (light photons)
- energy difference between the inner shell atomic orbitals: ~ **keV** (X-ray photons)
- energy difference between the nuclear energy levels: ~ **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)

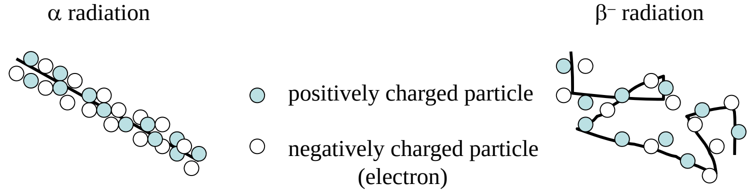
Absorption of charged particles

ionization during the path → continuous decrease of the particle energy

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

↓

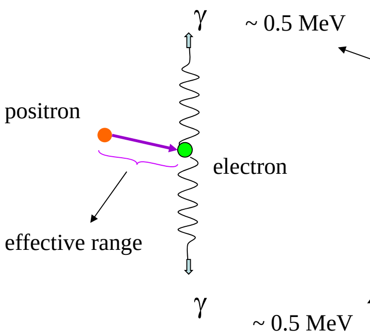
effective range



α radiation		β^- radiation	
in the air:	few cm	in the air:	~ m
in the tissue:	0,01 – 0,1 mm	in the tissue:	~ cm

Absorption of β^+ radiation

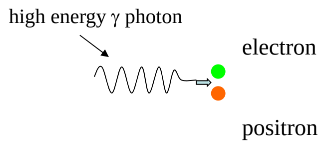
annihilation

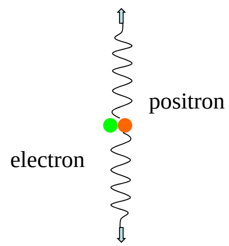


$$m_{e^-}c^2 + m_{e^+}c^2 \Rightarrow 2 \cdot E_{ph}$$

positron emission tomography (PET)

Pair production ↔ annihilation





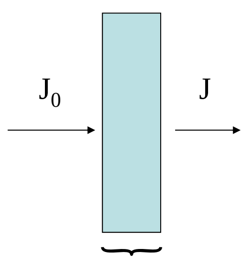
$$E_{ph} \Rightarrow m_{e^-}c^2 + m_{e^+}c^2$$

↓ ~ 1MeV

$$m_{e^-}c^2 + m_{e^+}c^2 \Rightarrow 2 \cdot E_{ph}$$

↓ ~ 0.5 MeV

Absorption of γ radiation (and X-ray)

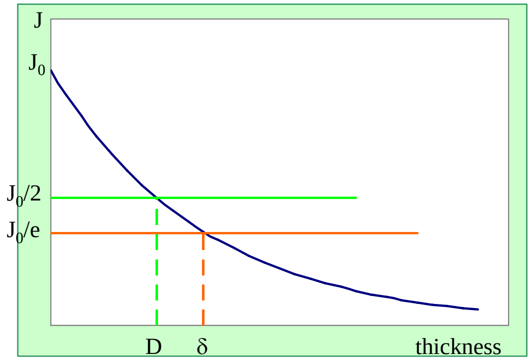


$$J = \frac{E}{A \cdot t} = \frac{n \cdot E_{ph}}{A \cdot t}$$

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

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

there is no effective range



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 stucture 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)