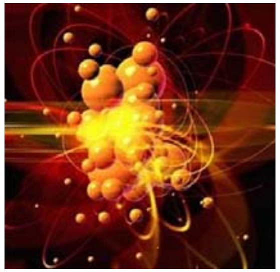
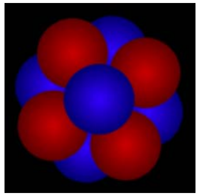
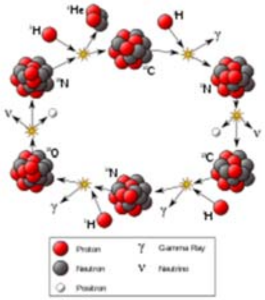
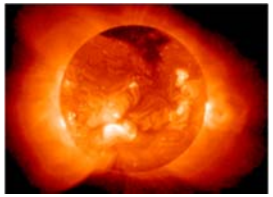




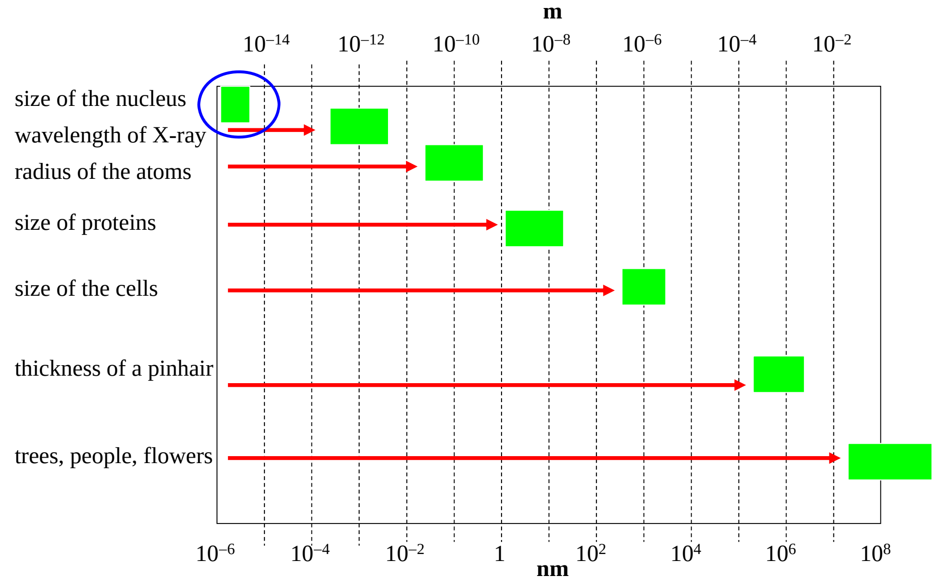
The microscopic world

atomic nucleus, radioactive decays



Irén Bárdos-Nagy

Length scale of the nature

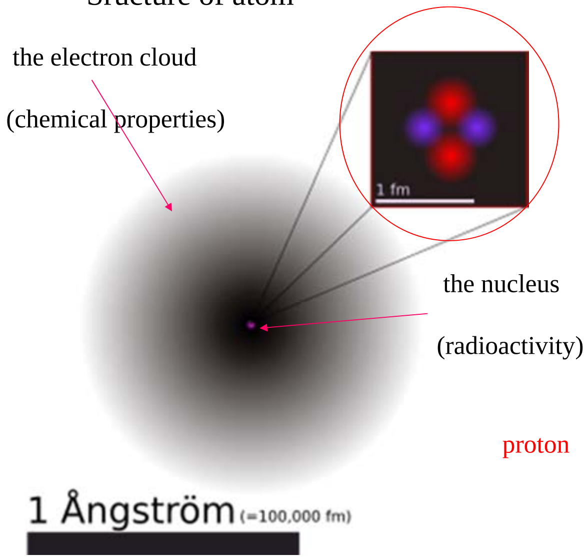


Building elements of atomic structure:

name/where	charge (elementary)	mass (kg)	atomic mass unit
electron/outside the nucleus	-1	$9{,}1 * 10^{-31}$	0,0005486
proton/inside the nucleus	+1	$1{,}66 * 10^{-27}$	1,007277
neutron/inside the nucleus	0	$1{,}67 * 10^{-27}$	1.008665

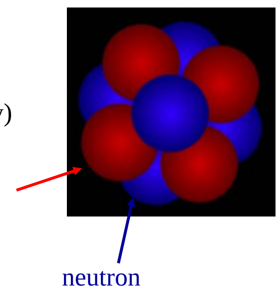
the charge of the electron: $1{,}6 * 10^{-19}$ C

Sructure of atom



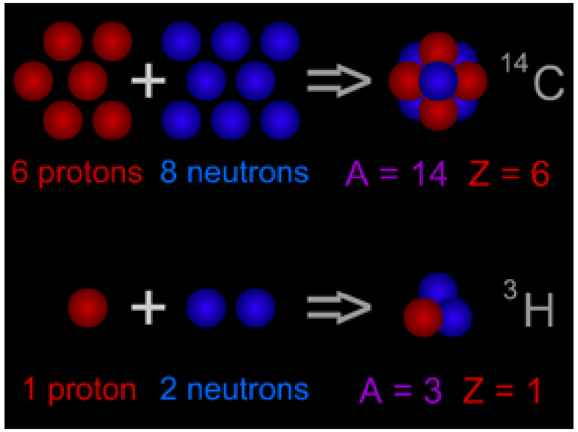
The figurative depiction of the He-4 atom

Structure of nucleus



Proton and/or neutron = nucleon

The atomic and the mass number



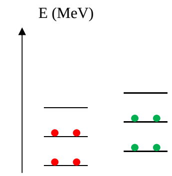
Z atomic number A mass number

Stability of the nucleus

Coulomb force: electrostatic repulsion between the positively charged protons

Nuclear force: very strong attractive force
act only on short - range (10^{-14} m)
do not depend on the charge

The nucleons have definite energy levels (MeV scale)

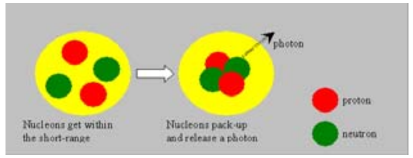


Quantized energy for the nucleus

Binding energy:

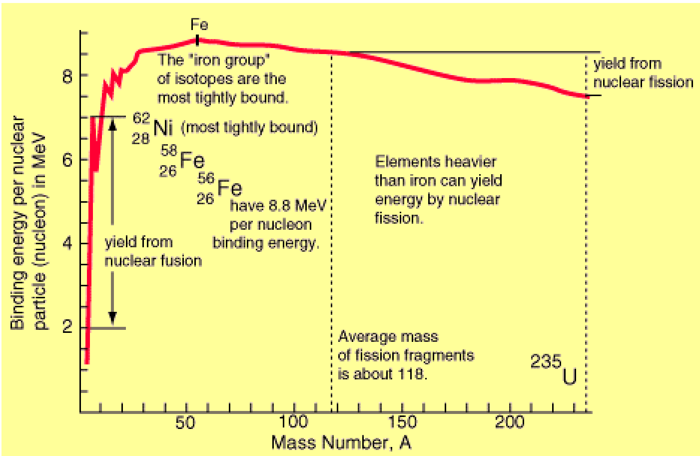
Total mass of 2 protons:	2.01456 amu
Total mass of 2 neutrons:	2.01732 amu
Total mass of nucleons:	4.03188 amu
Mass of the He atom:	4. 00153 amu
Mass defect (Δm):	0.03035 amu
Binding energy of $^{4}_{2}He$:	28.3 MeV

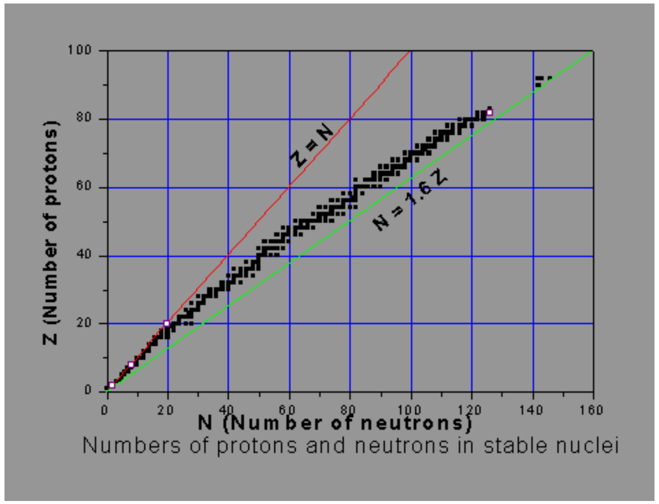
($\Delta E=\Delta m*c^2$)



$^{4}_{2}He$ nucleus

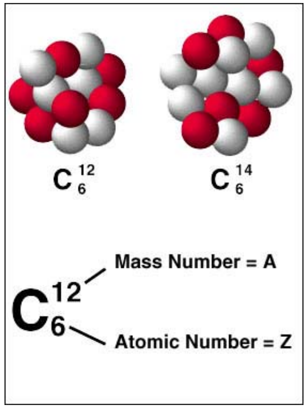
Nuclear binding energies of the different elements

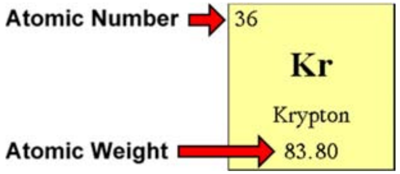




Isotopes:

number of protons is the same   number of neutrons is different

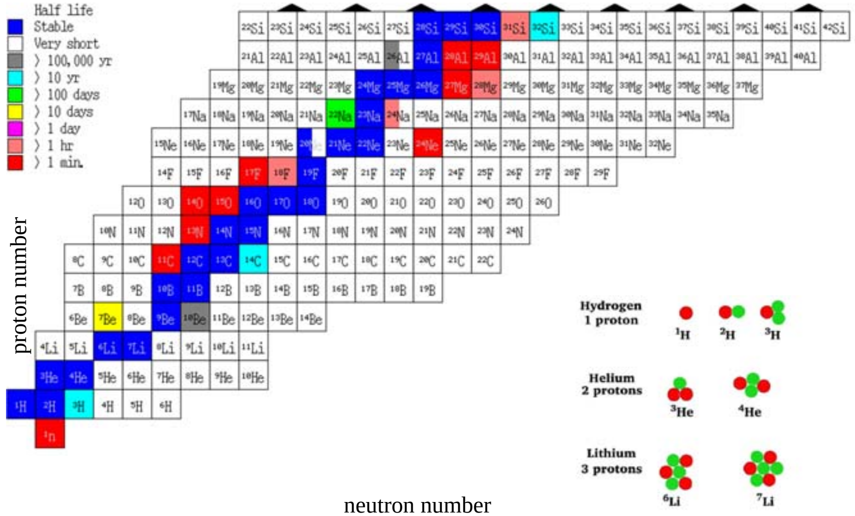




mass number → atomic weight

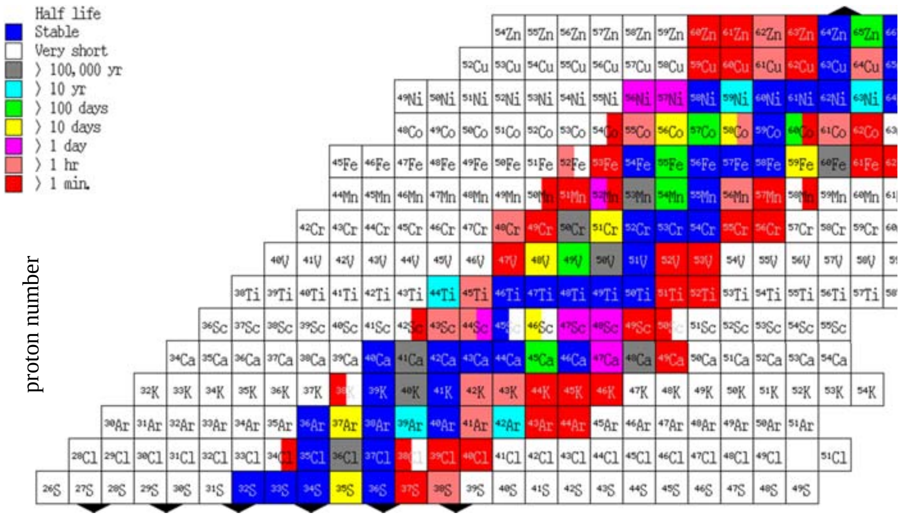
The chemical properties are the same!!

Table of isotopes



neutron number

Table of isotopes

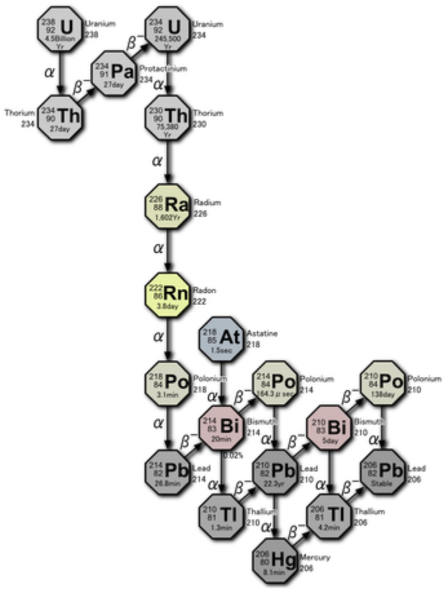


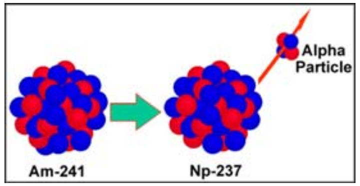
neutron number

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)

The α decay



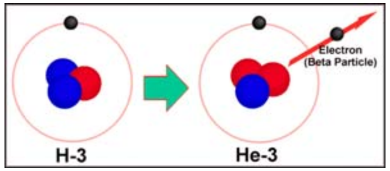


$$ {}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha $$

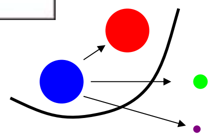
The energy of the emitted α particle is constant in the case of a given nuclid:

line spectrum (MeV)

The β^- decay

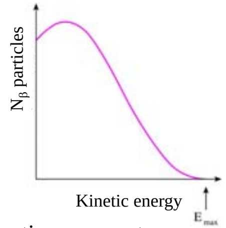


$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + \beta^- + \overline{\nu} $$



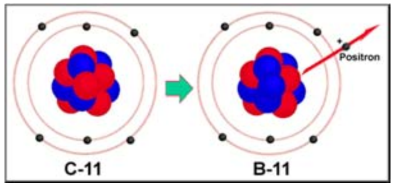
Examples:

$$ {}^{14}_{6}C \rightarrow {}^{14}_{7}N + \beta^- + \overline{\nu} $$
$$ {}^{40}_{19}K \rightarrow {}^{40}_{20}Ca + \beta^- + \overline{\nu} $$
$$ {}^{59}_{26}Fe \rightarrow {}^{59}_{27}Co + \beta^- + \overline{\nu} $$
$$ {}^{131}_{53}I \rightarrow {}^{131}_{54}Xe + \beta^- + \overline{\nu} $$

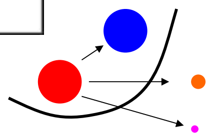


continuous spectrum

The β^+ decay



$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + \beta^+ + \nu $$

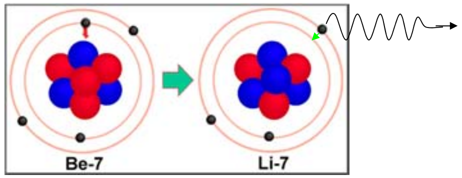


Examples:

$$ {}^{11}_{6}C \rightarrow {}^{11}_{5}B + \beta^+ + \nu $$
$$ {}^{13}_{7}N \rightarrow {}^{13}_{6}C + \beta^+ + \nu $$
$$ {}^{52}_{26}Fe \rightarrow {}^{52}_{25}Mn + \beta^+ + \nu $$
$$ {}^{18}_{9}F \rightarrow {}^{18}_{8}0 + \beta^+ + \nu $$

continuous spectrum

K – electron capture (inverse β^- decay)



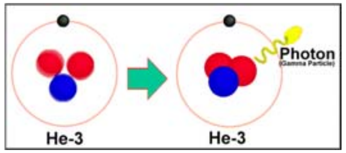
$$ {}^{1}_{1}p + \beta^- \rightarrow {}^{1}_{0}n + \nu $$

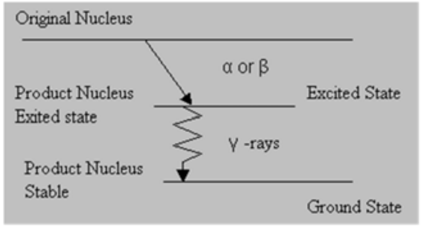
Examples:

$$ {}^{40}_{19}K + \beta^- \rightarrow {}^{40}_{18}Ar + \nu $$
$$ {}^{51}_{24}Cr + \beta^- \rightarrow {}^{51}_{23}V + \nu $$
$$ {}^{123}_{53}I + \beta^- \rightarrow {}^{123}_{52}Te + \nu $$

The γ decay

Prompt γ decay





There is no change of the number of protons and neutrons

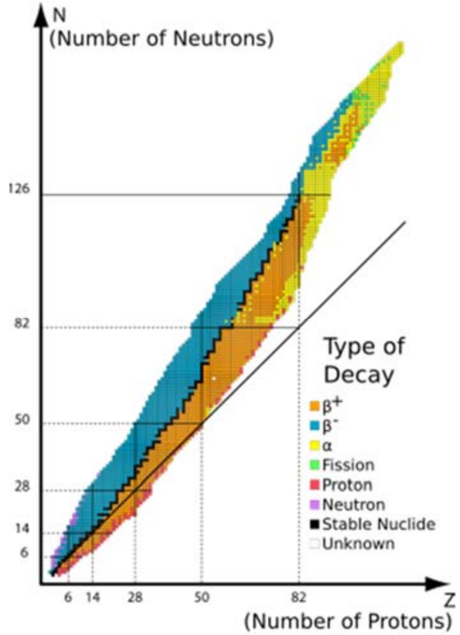
Isomeric transition

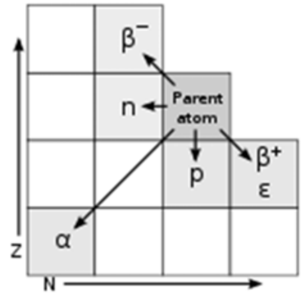
$$^{99}_{42}Mo \xrightarrow{\beta^-} {}^{99m}_{43}Tc \xrightarrow{\gamma} {}^{99}_{43}Tc$$

66 hours 6 hours

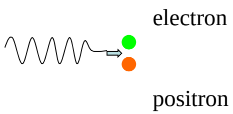
opportunuty for separation

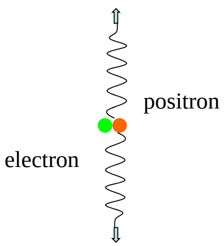
Summary





Pair production ↔ annihilation





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

$\downarrow$ ~ 1MeV

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

$\downarrow$ ~ 0.5 MeV