Atoom- en kernfysica

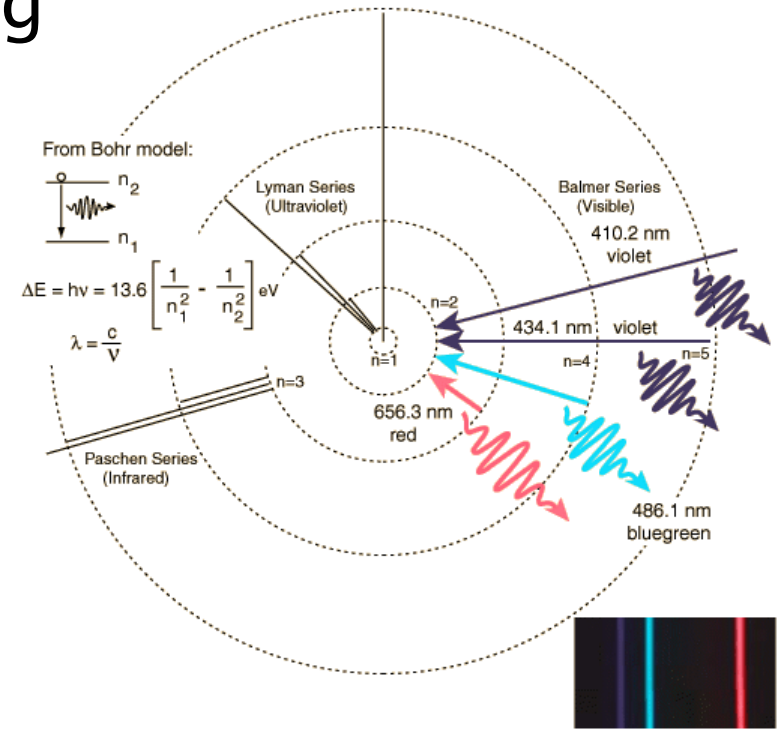
Cursus Stralingsveiligheid CD 2023-2024

M.A. Hofstee,
mariet.hofstee@maastrichtuniversity.nl

Hoofdstuk 4

Overzicht

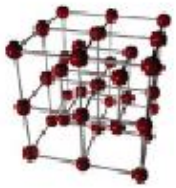
- Opbouw van een atoom
- Electronen in “schillen”
- Atomaire straling
- Electromagneitsche straling
- De kern van het atoom



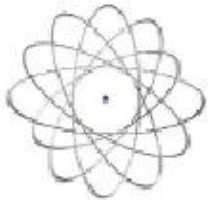
De schaal der dingen

Matter: 10^{-1}m

Crystal: 10^{-9}m



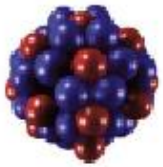
Atom: 10^{-10}m



Nucleus: 10^{-14}m

Interdisciplinary Research with Ions Beams

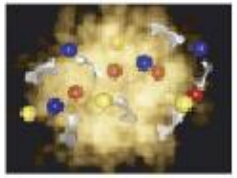
Nucleon: 10^{-15}m



Dense Plasma Research

Quark-Gluon Plasma

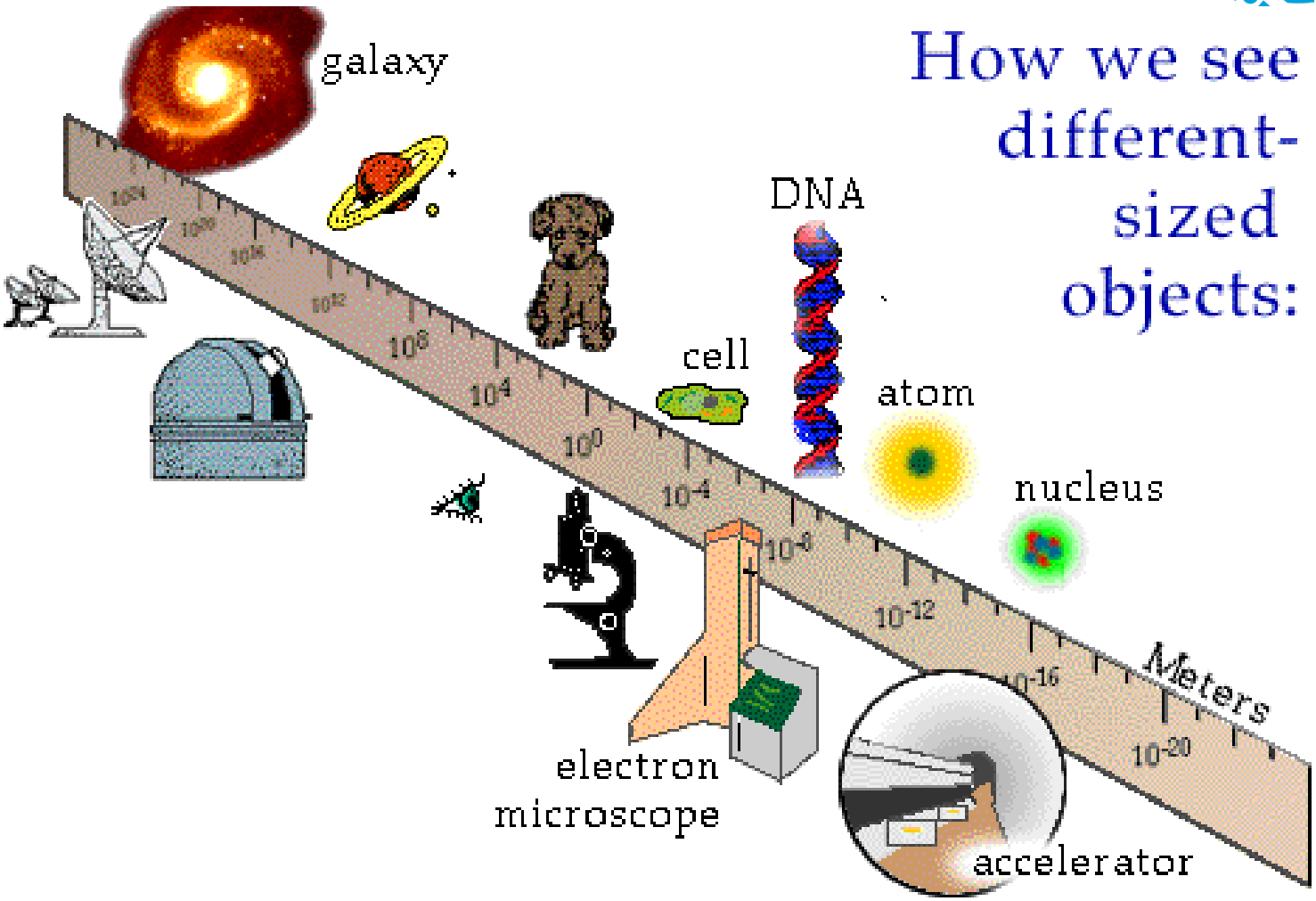
Nuclear Structure and Astrophysics



Hadron Structure and Hadronic Matter Research

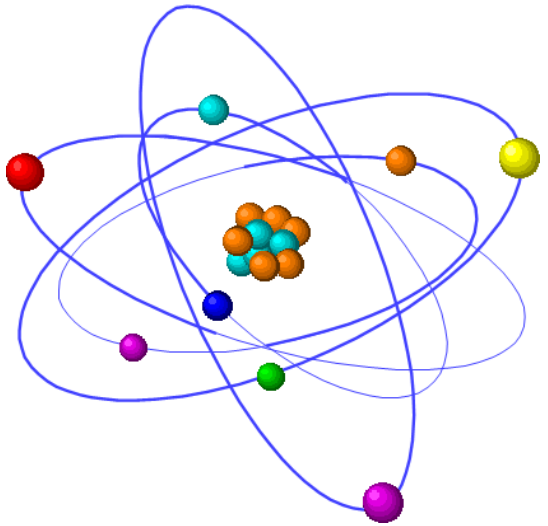
Quark Matter Research

Waarnemen


How we see different-sized objects:
galaxy
DNA
cell
atom
nucleus
electron microscope
accelerator
Meters
10^{8}
10^{4}
10^{0}
10^{-4}
10^{-8}
10^{-12}
10^{-16}
10^{-20}

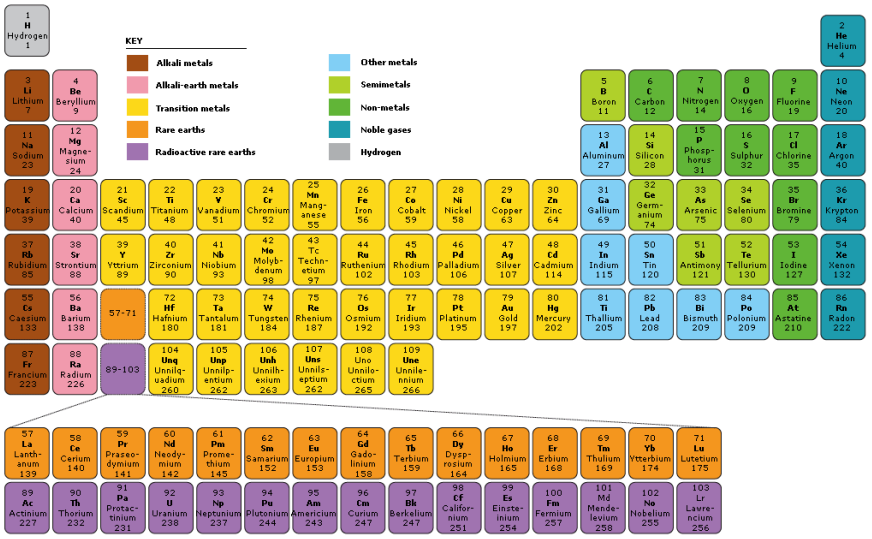
Het Atoom

- Primitief model
- Erg leeg
- kern met protonen (Z) en neutronen (N)
- wolk elektronen (ook Z)
- Z bepaald chemisch element
- A = Z+N bepaald massa

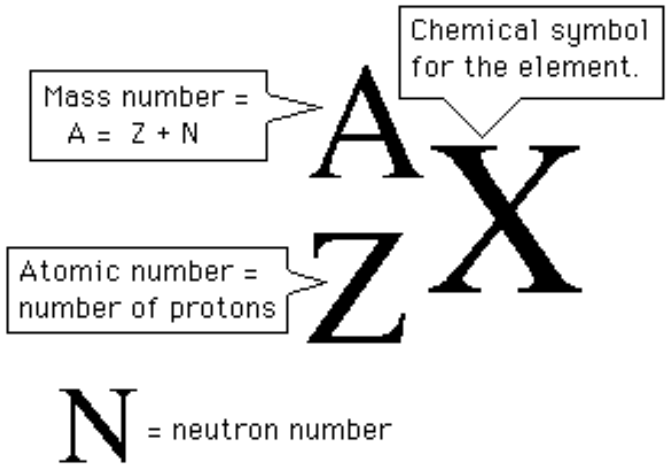


Notatie en termen

- Element (unieke Z)
- Nuclide (unieke A & Z)
- Nucleonen $A = Z + N$
- Isotopen (zelfde Z)
- Isobaren (zelfde A)
- Isomeren (zelfde A & Z)



- ^{13}C of kompleet $^{13}_{6}C_{7}$
- C-13

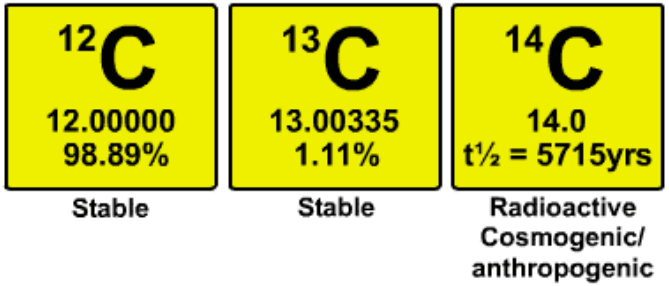


Grootheden

- Massa
  - atomaire massa eenheid 1u = 1.66 x 10^{-27} kg
  - Massagetal A
  - constante van Avogadro N_A = 6.022 x 10^{23}
  - 1 mol = A gram
- Lading
  - e = 1.602 x 10^{-19} C
- Energie
  - electronvolt eV = 1.602 x 10^{-19} J
- Afmetingen
  - atomen 0.1 nm = 10^{-10} m
  - kernen 1–10 fm = 10^{-15} – 10^{-14} m

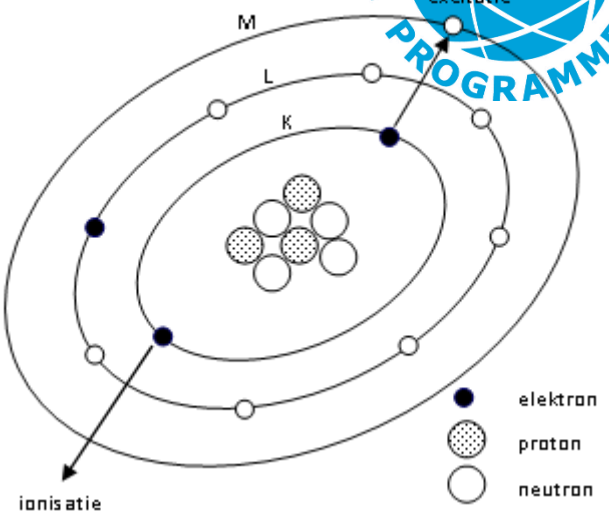
Enkele getallen

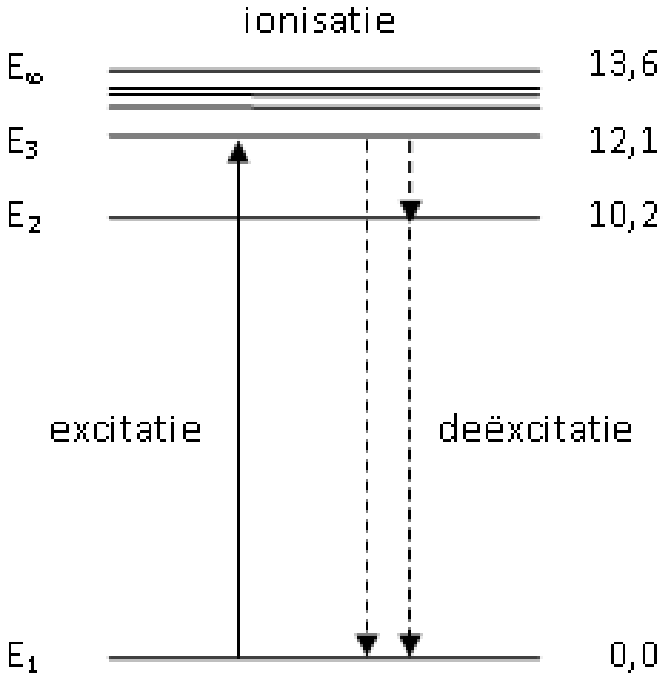
Object	kg	u	MeV/c²
electron	9.109 382 15(45)×10-31	0.000 548 579 909 46(22)	0.510 998 910(13)
proton	1.672 621 777(74)×10−27	1.007 276 466 812(90)	938.272 046(21)
neutron	1.674 927 351(74)×10−27	1.008 664 916 00(43)	939.565 378(21)
^{1}H atom	1.672 353 … ×10−27	1.007 825 04(7)	938.78....
^{12}C/12	1.660 … ×10−27	1 (exact)	931.494 060(21)



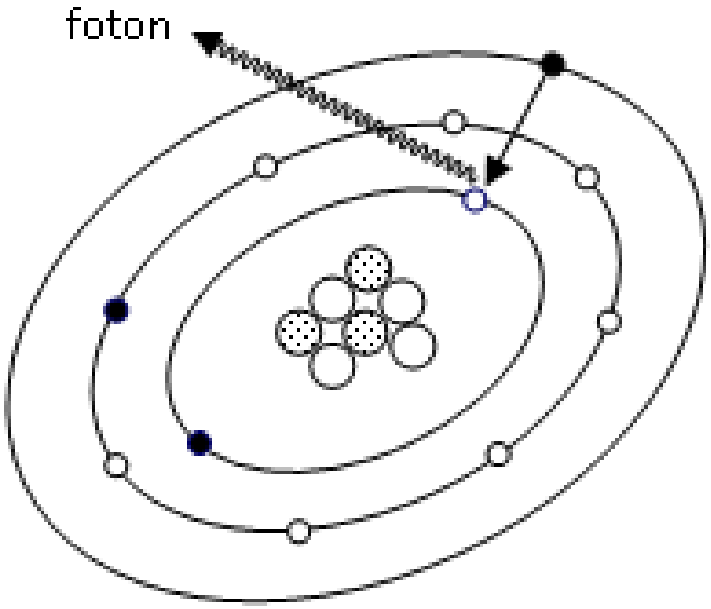
Atomaire Elektronen

- zitten in schillen: K, L, M, N … (gerekend vanaf de kern)
- per schil $2n^2$ elektronen
- vult op van binnen naar buiten
- Bindingsenergie
- alleen bepaalde energiën mogelijk, welke verschilt per atoom (vingerafdruk)
- Excitatie: atoom heeft een bepaalde hoeveelheid extra energie

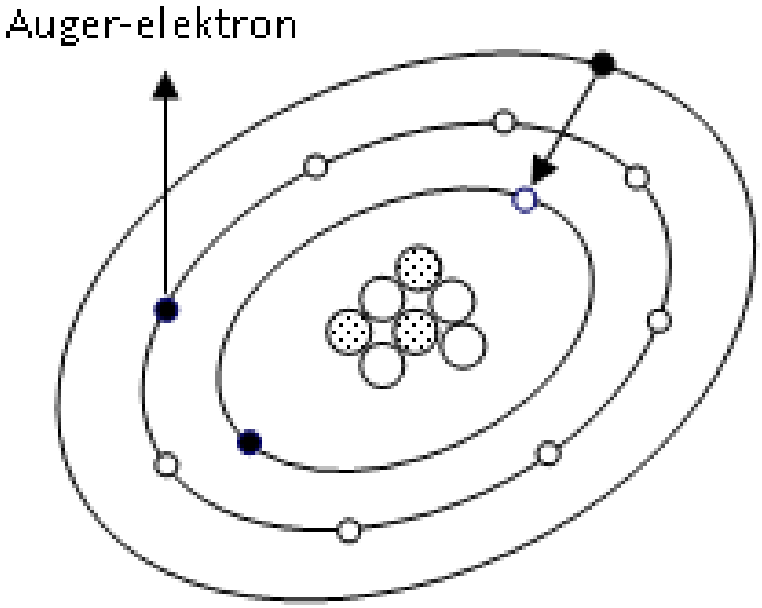




Atomaire straling

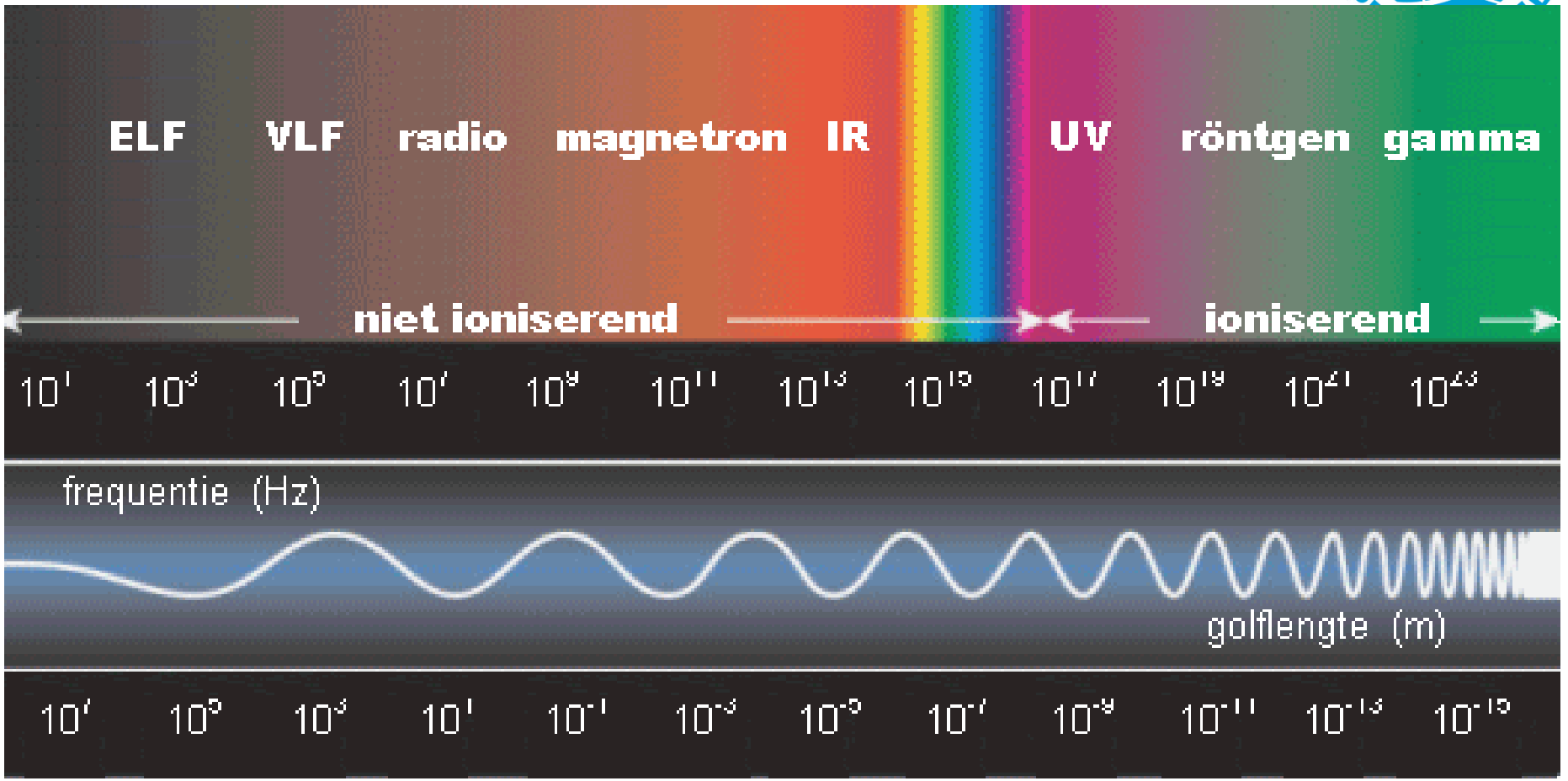


Röntgenstraling



Auger-elektron

Electromagnetische straling

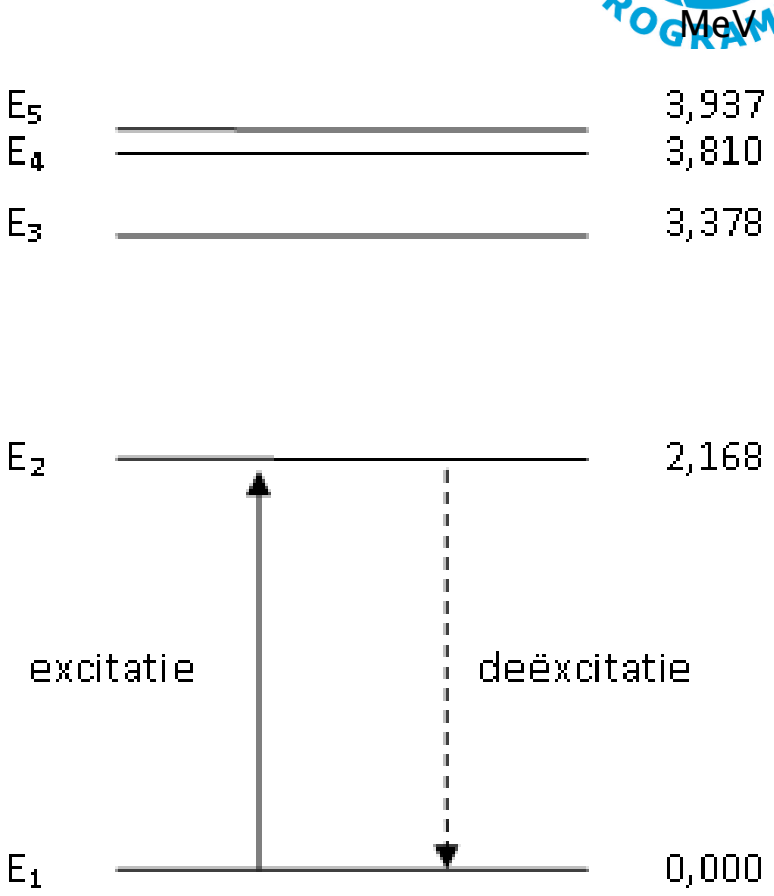


$$E = h\upsilon = \frac{hc}{\lambda}$$

$h = 6{,}626 \pm 10^{-34}$ J s
$c = 3 \pm 10^{8}$ m s^{-1}

Atoomkernen

- protonen (Z) bepalen chemisch element
- neutronen als ‘lijm’
- discrete energie niveaus
- Bindingenergie in MeV
- Lage massa Z = N
- Hoge massa Z < N



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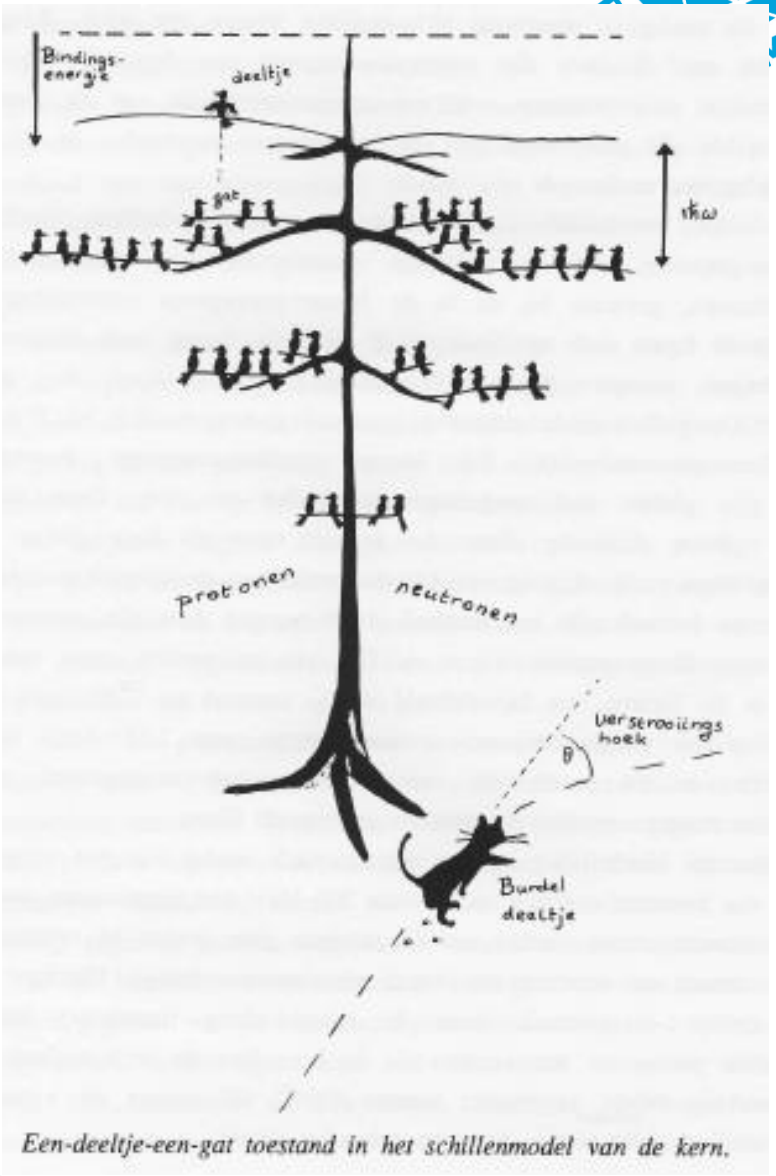
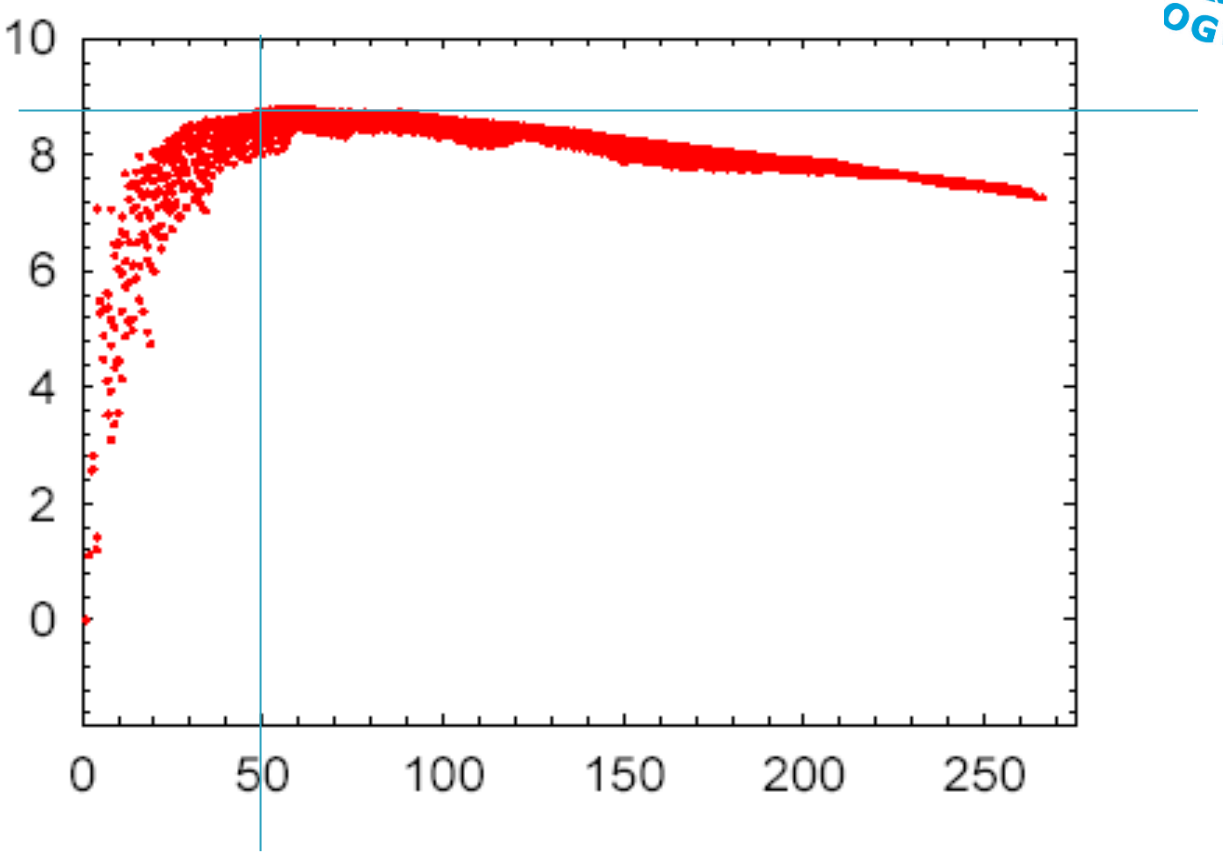


Een-deeltje-een-gat toestand in het schillenmodel van de kern.

Bindingsenergie

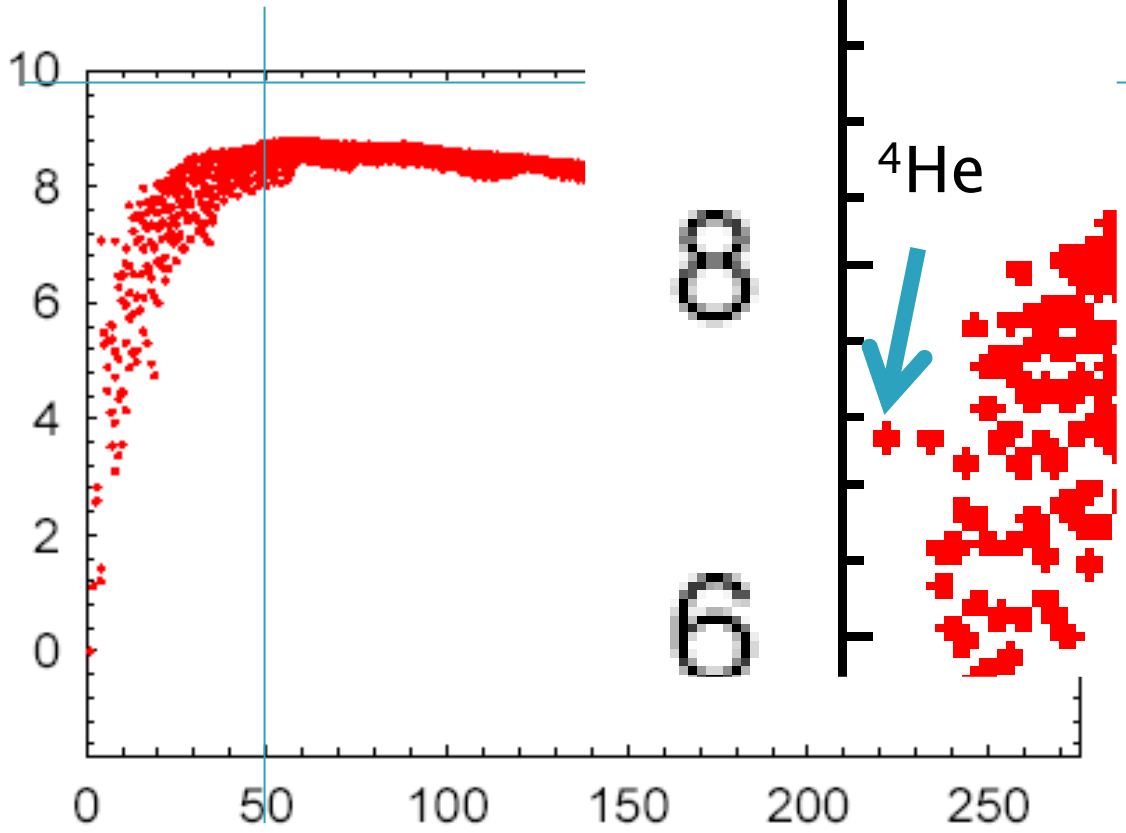
BE/A

(MeV)

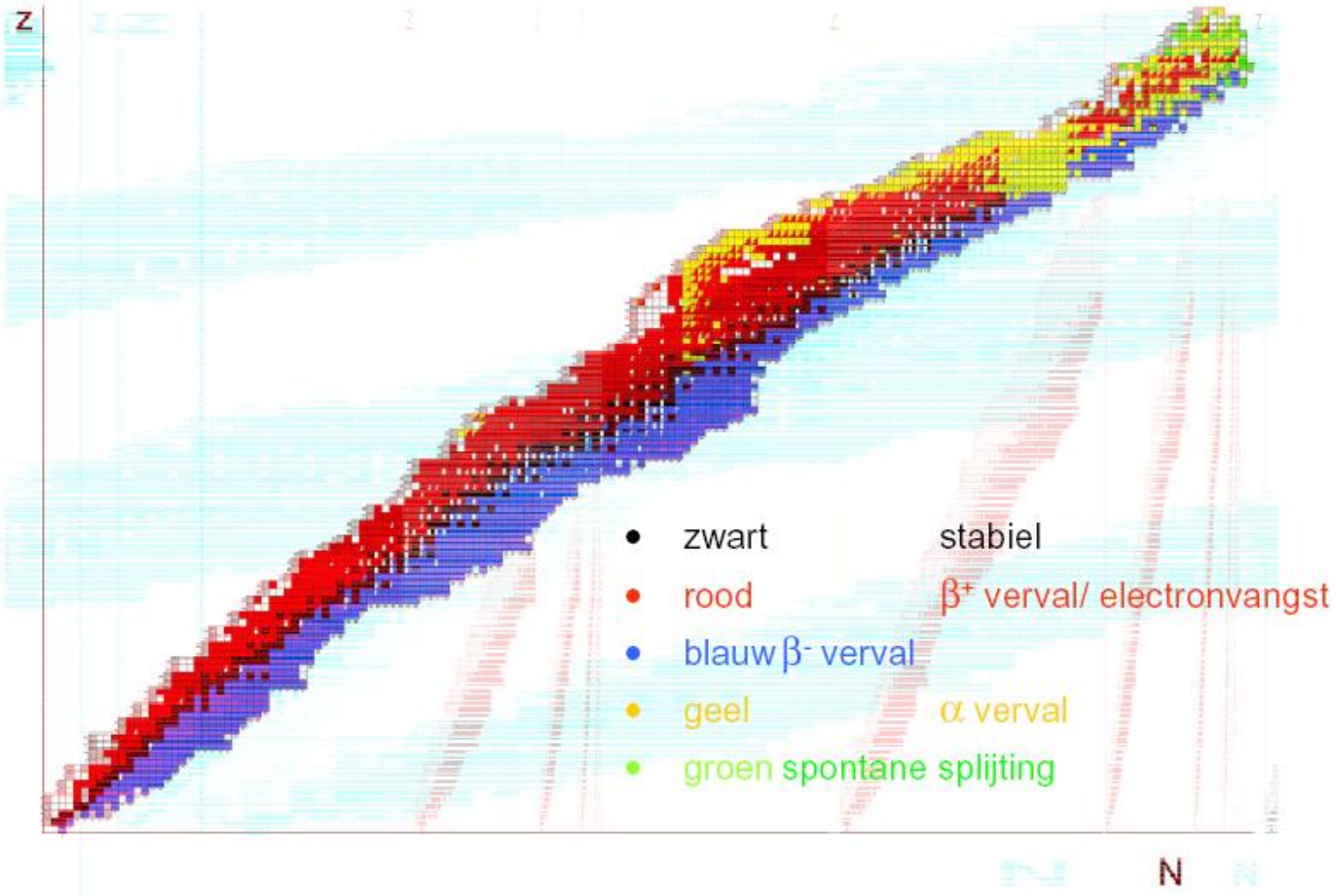


$$\hat{E}_{binding} \cdot \mathrm{A} = \mathrm{Z}\, m_p + \mathrm{N}\, m_n - m\left({}^{\mathrm{A}}_{\mathrm{Z}}\mathrm{X}\right)$$

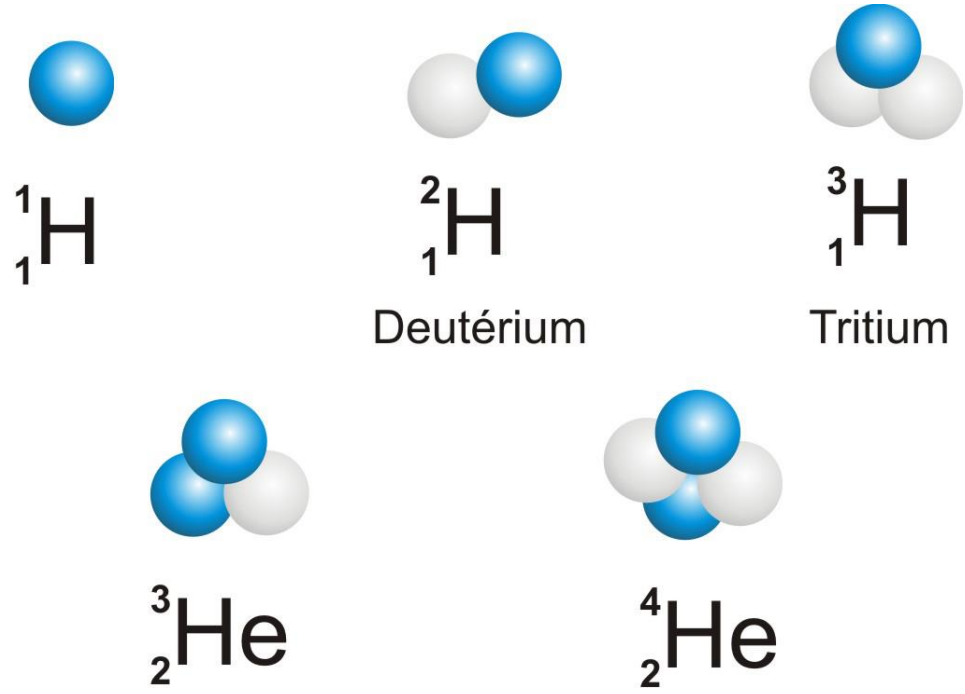
Bindingsenergie

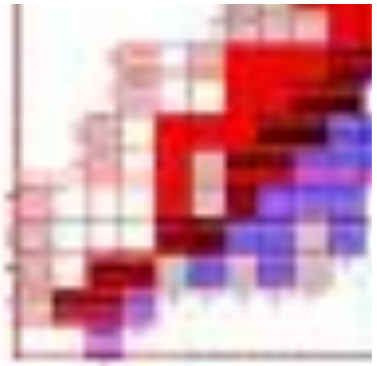


Nuclidenkaart

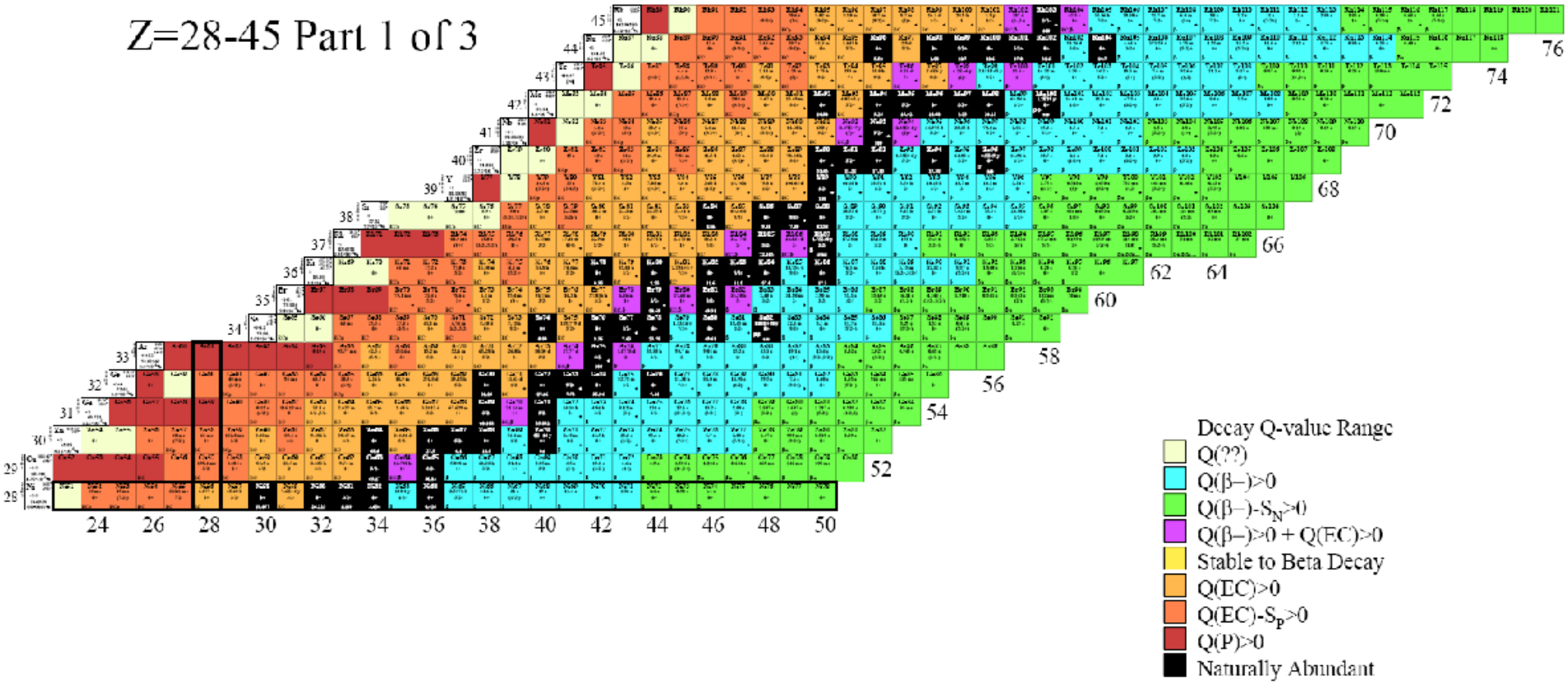


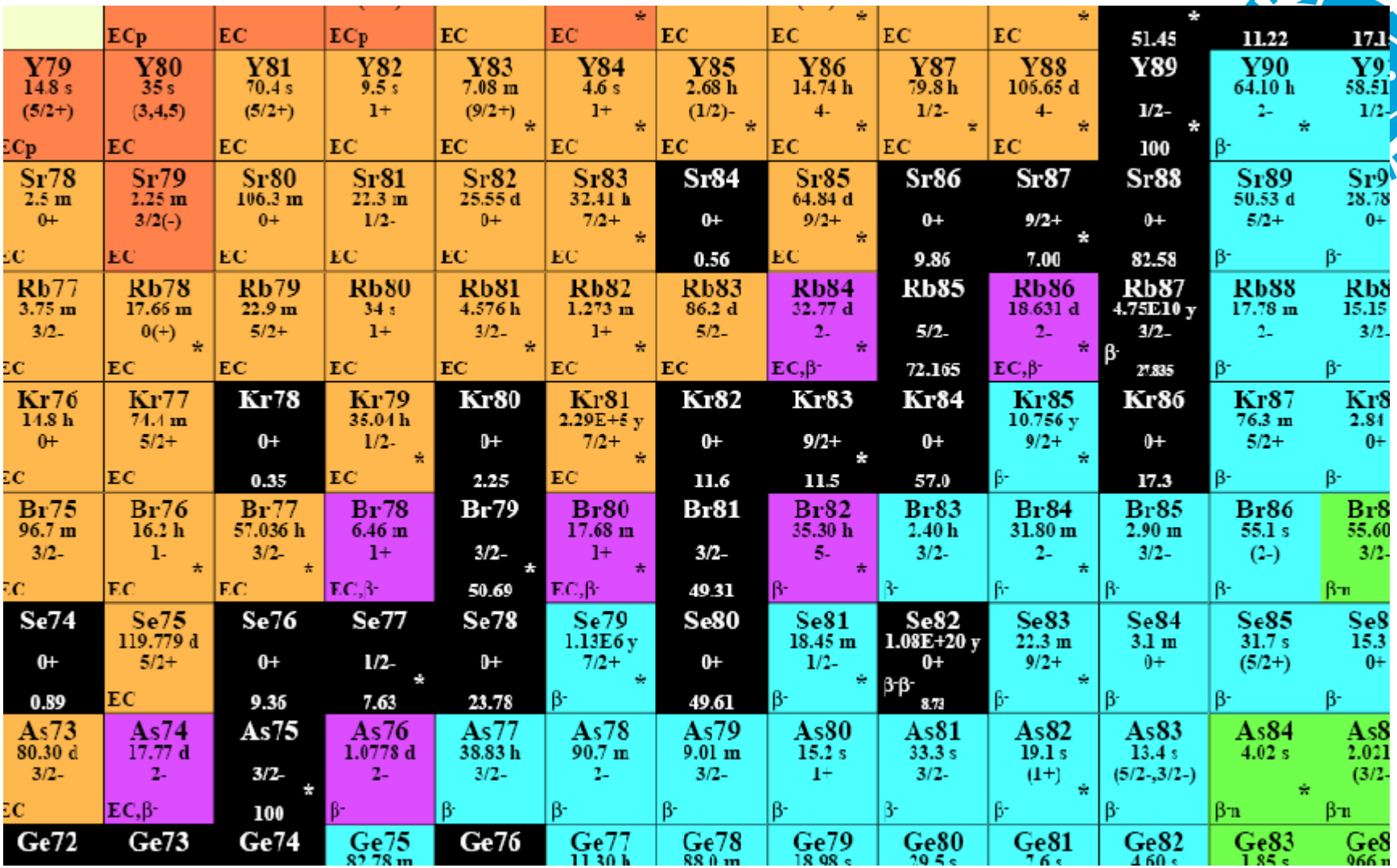
Een paar voorbeelden



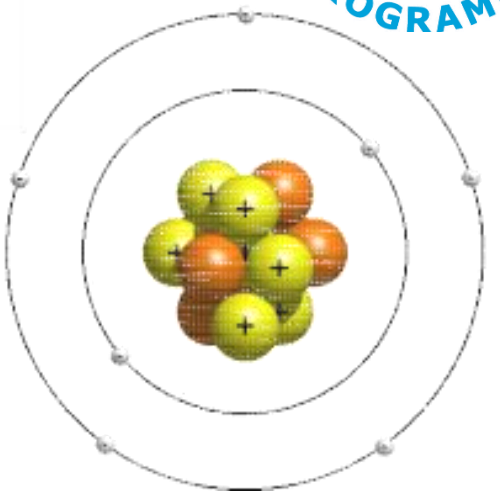


Z=28-45 Part 1 of 3




ECp
EC
ECp
EC
EC
EC
EC
EC
EC
51.45
11.22
Y79 14.8 s (5/2+) ECp
Y80 35 s (3,4,5) EC
Y81 70.4 s (5/2+) EC
Y82 9.5 s 1+ EC
Y83 7.08 m (9/2+) EC
Y84 4.6 s 1+ EC
Y85 2.68 h (1/2)- EC
Y86 14.74 h 4- EC
Y87 79.8 h 1/2- EC
Y88 105.65 d 4- EC
Y89 1/2- 100
Y90 64.10 h 2- β-
Sr78 2.5 m 0+ EC
Sr79 2.25 m 3/2(-) EC
Sr80 106.3 m 0+ EC
Sr81 22.3 m 1/2- EC
Sr82 25.55 d 0+ EC
Sr83 32.41 h 7/2+ EC
Sr84 0+ 0.56
Sr85 64.84 d 9/2+ EC
Sr86 0+ 9.86
Sr87 9/2+ 7.00
Sr88 0+ 82.58
Sr89 50.53 d 5/2+ β-
Rb77 3.75 m 3/2- EC
Rb78 17.66 m 0(+) EC
Rb79 22.9 m 5/2+ EC
Rb80 34 s 1+ EC
Rb81 4.576 h 3/2- EC
Rb82 1.273 m 1+ EC
Rb83 86.2 d 5/2- EC
Rb84 32.77 d 2- EC,β-
Rb85 5/2- 72.165
Rb86 18.631 d 2- EC,β-
Rb87 4.75E10 y 3/2- β- 27.835
Rb88 17.78 m 2- β-
Kr76 14.8 h 0+ EC
Kr77 74.4 m 5/2+ EC
Kr78 0+ 0.35
Kr79 35.04 h 1/2- EC
Kr80 0+ 2.25
Kr81 2.29E+5 y 7/2+ EC
Kr82 0+ 11.6
Kr83 9/2+ 11.5
Kr84 0+ 57.0
Kr85 10.756 y 9/2+ β-
Kr86 0+ 17.3
Kr87 76.3 m 5/2+ β-
Br75 96.7 m 3/2- EC
Br76 16.2 h 1- EC
Br77 57.036 h 3/2- EC
Br78 6.46 m 1+ EC,β-
Br79 3/2- 50.69
Br80 17.68 m 1+ EC,β-
Br81 3/2- 49.31
Br82 35.30 h 5- β-
Br83 2.40 h 3/2- β-
Br84 31.80 m 2- β-
Br85 2.90 m 3/2- β-
Br86 55.1 s (2-) β-
Se74 0+ 0.89
Se75 119.779 d 5/2+ EC
Se76 0+ 9.36
Se77 1/2- 7.63
Se78 0+ 23.78
Se79 1.13E6 y 7/2+ β-
Se80 0+ 49.61
Se81 18.45 m 1/2- β-
Se82 1.08E+20 y 0+ β-β- 8.73
Se83 22.3 m 9/2+ β-
Se84 3.1 m 0+ β-
Se85 31.7 s (5/2+) β-
As73 80.30 d 3/2- EC
As74 17.77 d 2- EC,β-
As75 3/2- 100
As76 1.0778 d 2- β-
As77 38.83 h 3/2- β-
As78 90.7 m 2- β-
As79 9.01 m 3/2- β-
As80 15.2 s 1+ β-
As81 33.3 s 3/2- β-
As82 19.1 s (1+) β-
As83 13.4 s (5/2-,3/2-) β-
As84 4.02 s β-n
Ge72
Ge73
Ge74
Ge75
Ge76
Ge77
Ge78
Ge79
Ge80
Ge81
Ge82
Ge83

Samenvatting



- Atomen
  - Chemische eigenschappen hangen af van atoomgetal (Z)
  - Periodiek systeem
  - Electronen in schillen
- Kernen
  - Fysische eigenschappen hangen af van isotoop (Z en A, massagetal)
  - Energieniveaus
  - Bindingsenergie (ten opzichte van losse nucleonen)
  - Nuclidenkaart (https://www.nndc.bnl.gov/nudat3/)