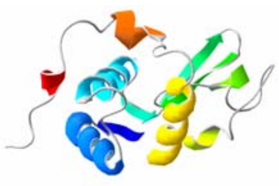
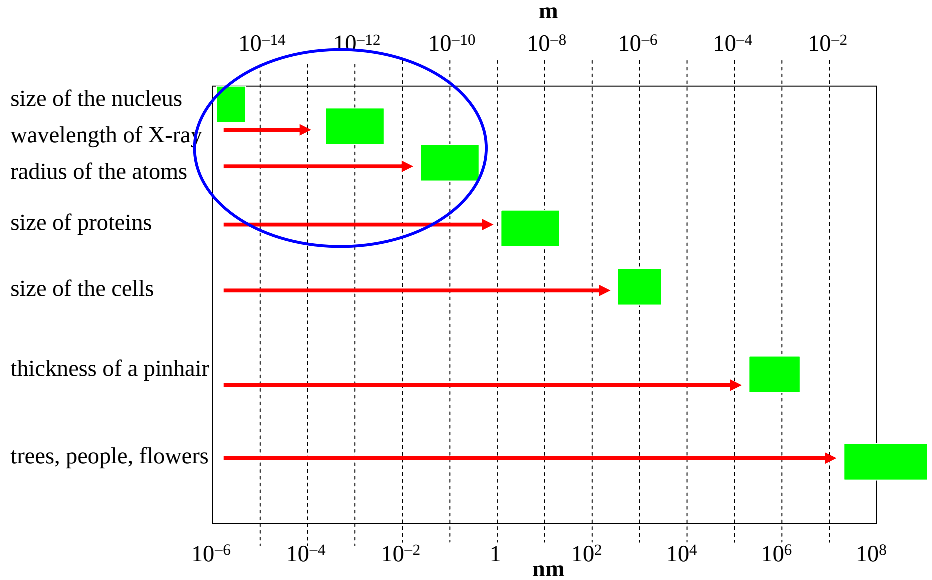
The microscopic world

atom, atomic nucleus, electron, foton

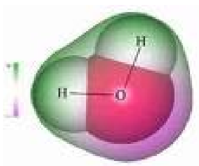
Irén Bárdos-Nagy



Length scale of the nature



macroscopic world ⇄ microscopic world



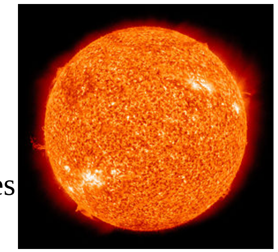
What is common, what is different?
Are the rules the same?
Is there any difference?

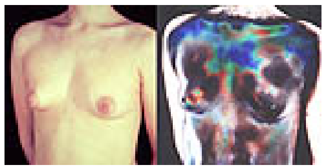
Thermal radiation

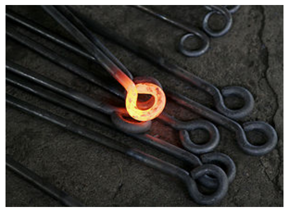
electromagnetic radiation

every material emits it, if T > 0 K

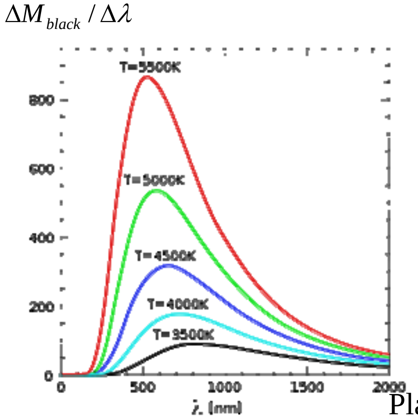
the origin of it is the thermal motion of particles







Characteristics of thermal radiation



Stefan – Boltzmann law:

$M_{black}(T) = \sigma T^4$

$E = At\,\sigma T^4$

Wien's displacement law:

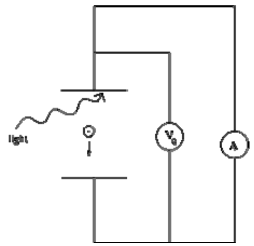
$\lambda_{max} T = const$

Planck's law of black body radiation:

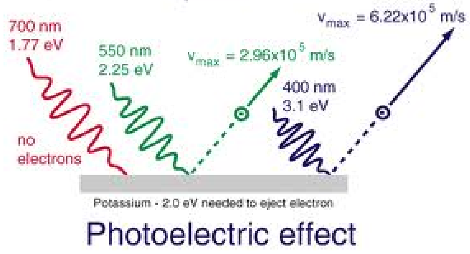
the energy is emitted in discrete units

the photon is the energy (light) quanta

The photoelectric effect and the explanation of it



$E_{photon} = hf = hc/\lambda$ h: Planck constant



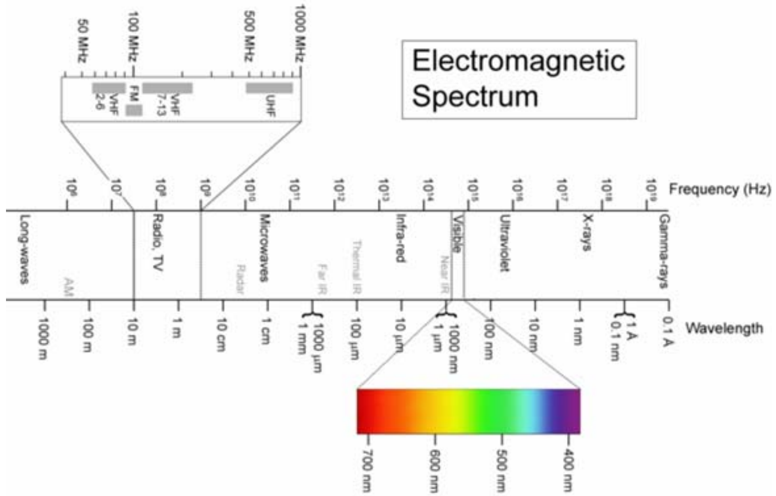
The photons behave as particles: $E_{kin} = hf - W_{em}$

dual nature of light

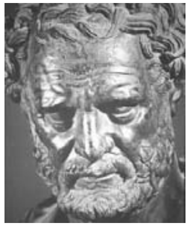
wave
interference
diffraction

particle
thermal radiation
photoelectric effect

The dual nature is characteristic not only for the light, but the complet electromagnetic spectrum



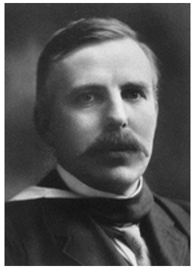
History of the atom



Democritus (BC 406)
idea of "atoma"

Dalton (1808)
all matter is bilt up
from tiny spheres

Joseph J. Thomson (1904)
the plum pudding model



Ernest Rutherford (1910)
central nucleus with
positive charge

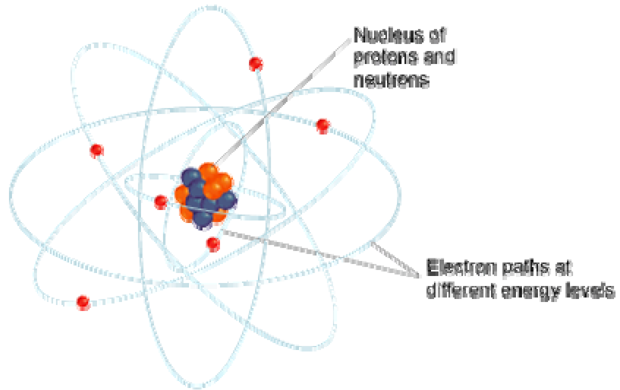
Niels Bohr (1913)
definite electron orbitals

Building elements of atomic structure:

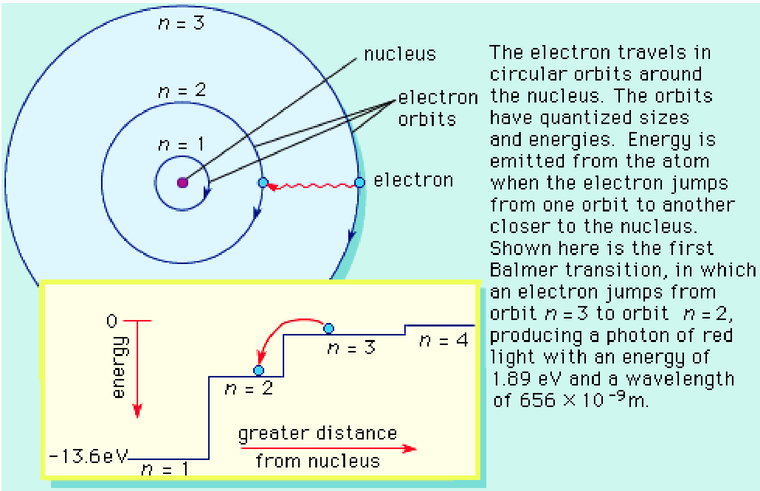
name/where	charge (elementari)	mass (kg)	atomic mass unit
electron/outside the nucleus	-1	$9,1*10^{-31}$	1/1800
proton/inside the nucleus	+1	$1,66*10^{-27}$	1,0076
neutron/inside the nucleus	0	$1,67*10^{-27}$	1.0086

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

Sructure of atoms based on Bohr model



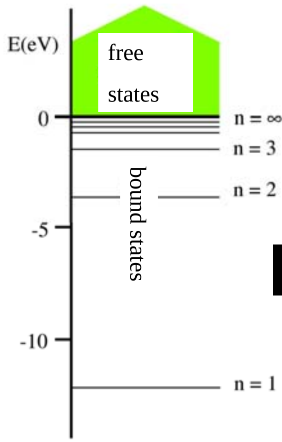
Sructure of atoms based on Bohr model



the radii of the orbitals and the energy levels are determined by the orbital numbers:

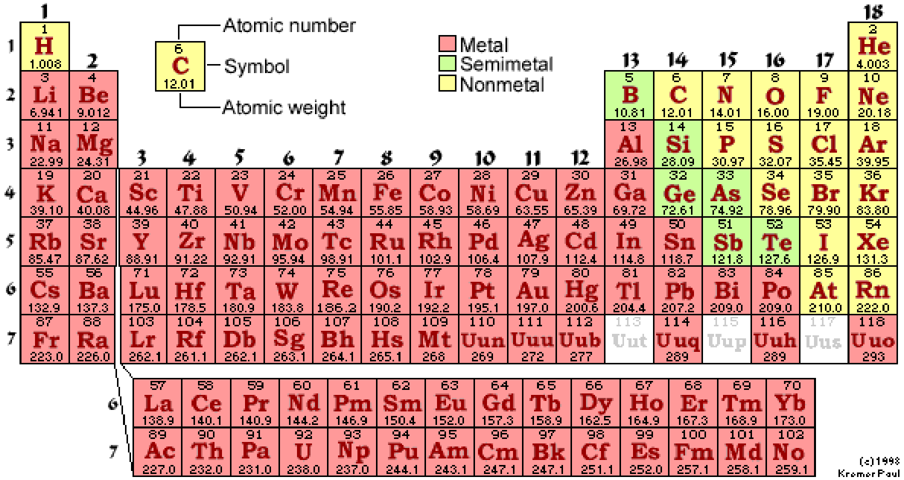
$r \sim n^2$ $E_{kin} \sim 1/n^2$

possible energy levels of the electron in the H atom



emission spectrum of the H atom

The periodic system based on the Bohr model



Further improvement: Quantum mechanics


V.de Broglie (1923)


J. Davisson and L. H. Germer (1927)


G. P. Thomson (1928)

The wave nature and a certain wavelength have to be associated to every material mass

$$\lambda = \frac{h}{m \cdot v} = \frac{h}{I}$$

h ← Planck constant (6.63×10^{-34} J/s)

I ← momentum of the particle


E. Schrödinger (1926)
Scrödinger (wave) equation


W. Heisenberg (1930)
the Heisenberg uncertainty relation

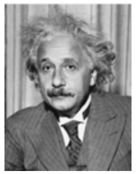
Further properties of quantized atomic electron states:

azimuthal (l) and magnetic (m_l) quantum numbers



O. Haas and W. Gerlach (1922)

the spin (s) quantum number



A. Einstein and J. W. de Haas


Pauli exlusion principle

W. Pauli (1925)


Hund principle

H. Hund (1925)

The Bohr model and the quantum mechanical atomic structure

Bohr model	quantum mechanical aspects
circular orbitals	there is no orbital, only probability (electron cloud)
one energy level (n) to characterise the orbital	four quantum numbers n, l, m_l, s to characterise the energy levels
energy quanta	energy quanta
the orbitals have no overlapping	the orbitals have overlapping (chance for energy levels)
photon absorption/emission	photon absorption/emission

Electron clouds based on the quantum mechanical calculations