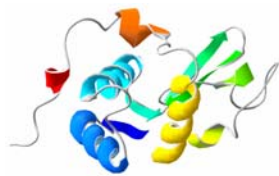


The microscopic world

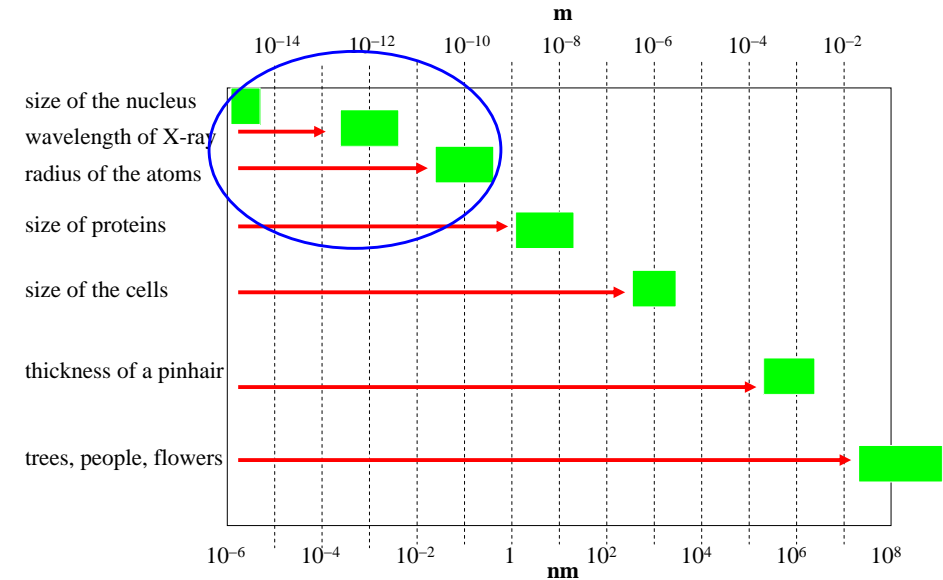
atom, atomic nucleus, electron, foton



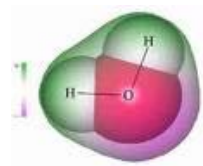
Irén Bárdos-Nagy



Length scale of the nature



macroscopic world \longleftrightarrow microscopic world



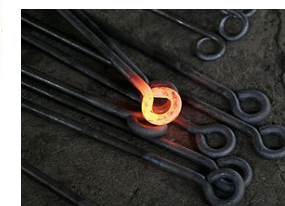
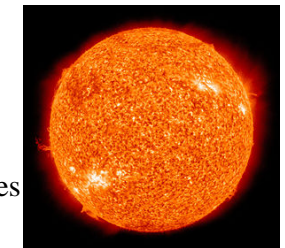
What is common, what is different?
Are the rules the same?
Is there any difference?

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:

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

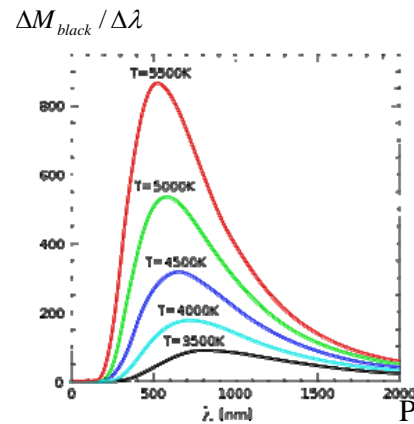
$$E = A \sigma T^4$$

Wien's displacement law:

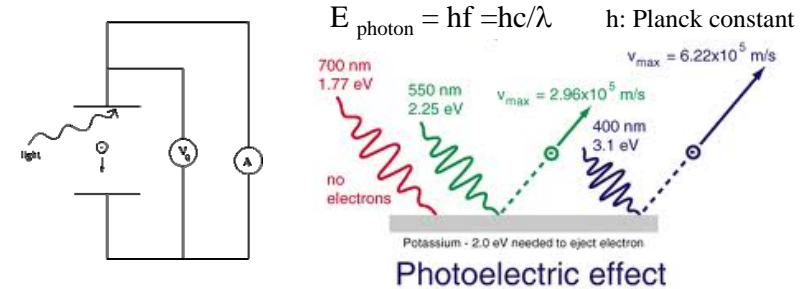
$$\lambda_{\text{max}} T = \text{const}$$

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

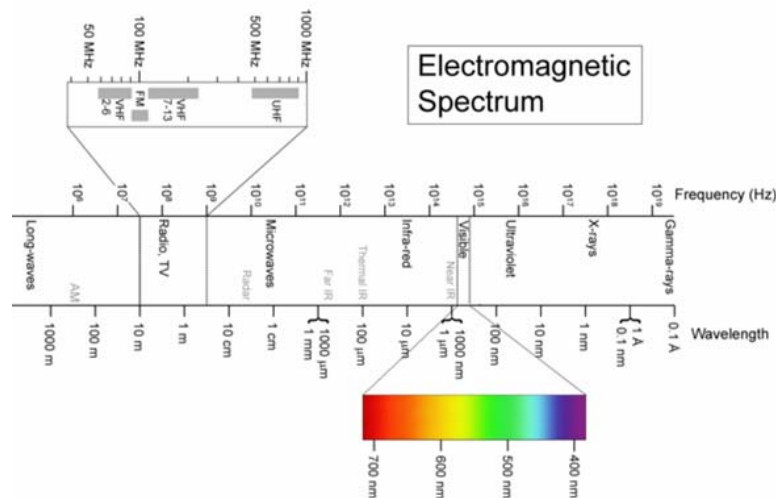


The photons behave as particles: $E_{\text{kin}} = hf - W_{\text{em}}$

dual nature of light

- wave**: interference, diffraction
- particle**: thermal radiation, photoelectric effect

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



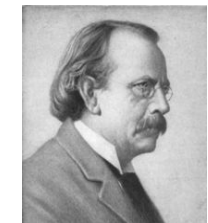
History of the atom



Democritus (BC 406)
idea of "atoma"



Dalton (1808)
all matter is built 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

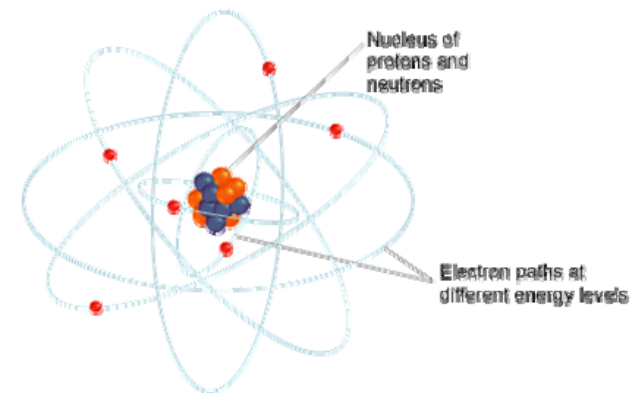


Building elements of atomic structure:

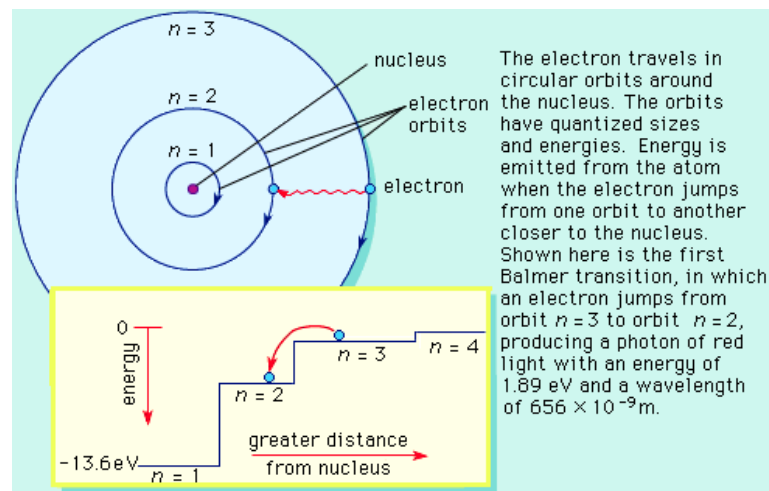
name/where	charge (elementari)	mass (kg)	atomic mass unit
electron/outside the nucleus	-1	$9,1 \cdot 10^{-31}$	1/1800
proton/inside the nucleus	+1	$1,66 \cdot 10^{-27}$	1,0076
neutron/inside the nucleus	0	$1,67 \cdot 10^{-27}$	1.0086

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

Structure of atoms based on Bohr model



Structure of atoms based on Bohr model

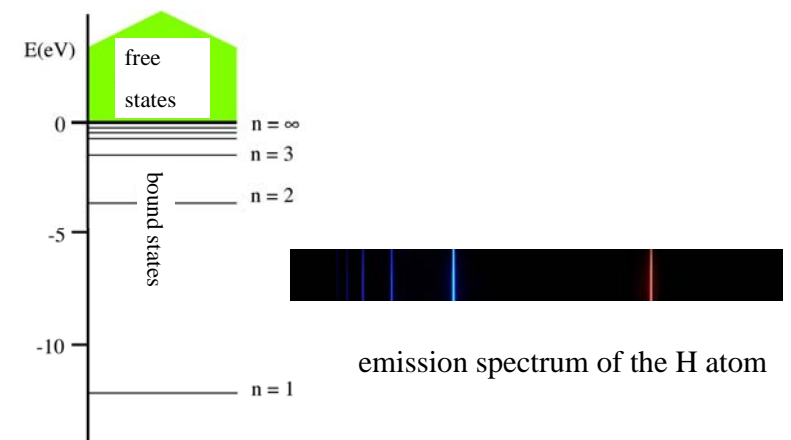


the radii of the orbitals and the energy levels are determined by the orbital numbers:

$$r \sim n^2$$

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

possible energy levels of the electron in the H atom



emission spectrum of the H atom

The periodic system based on the Bohr model

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008	2 He 4.003																
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98.91	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm 144.9	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0		
87 Fr 223.0	88 Ra 226.0	89 Ac 227.0	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu 244.1	95 Am 243.1	96 Cm 247.1	97 Bk 247.1	98 Cf 251.1	99 Es 252.0	100 Fm 257.1	101 Md 258.1	102 No 259.1		

Atomic number
Symbol
Atomic weight

Metal
Semimetal
Nonmetal

(c) 1998
Kremer Paul

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

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

Planck constant
(6.63x10⁻³⁴ J/s)
momentum of the particle



E. Schrödinger (1926)
Schrödinger (wave) equation



W. Heisenberg (1930)
the Heisenberg uncertainty relation

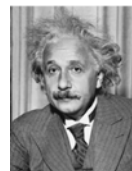
Further properties of quantized atomic electron states:

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



W. Pauli (1925)

Pauli exclusion principle



H. Hund (1925)

Hund principle

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
energy quanta

four quantum numbers n, l, m_l, s
to characterise the energy levels
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

