Raze X

- Lumea noastră este electromagnetică (și gravitațională)
- Forțele "tari" – energia nucleară
- Forțele "slabe" – dezintegrări

Bază: Sarcina electrică

electron e (–), proton p (+), nucleu

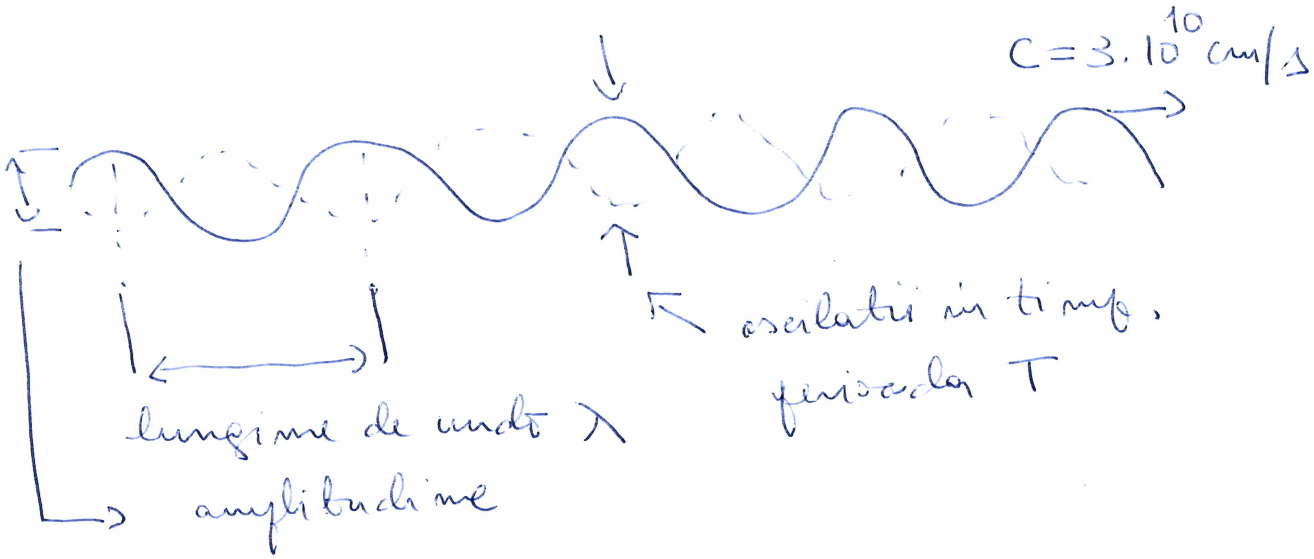
- Sarcina electrică în repaus – câmp electric (forță) (static)
- Sarcina electrică în mișcare – curent

Mișcare uniformă – câmp magnetic (forță, static)

Mișcare accelerată – câmp electromagnetic (time)

↓ Distanțe mari – radiație (unde)

Unde



$$\lambda = cT$$

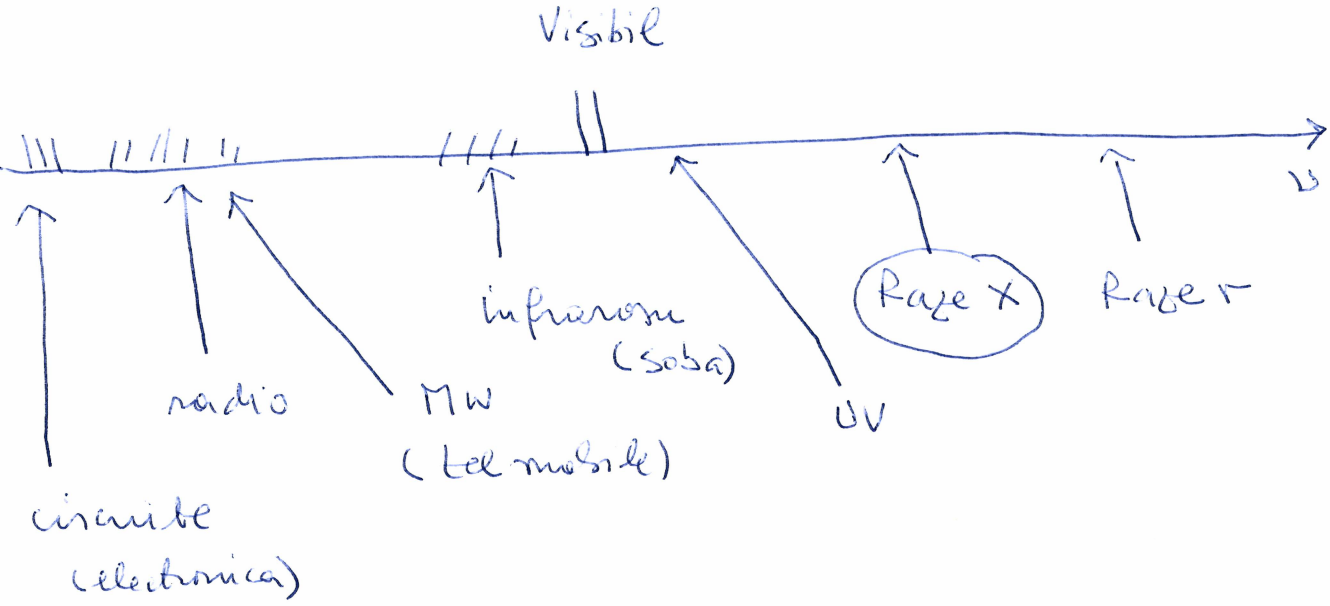
- frecventa $\nu = \frac{1}{T}$ ($\frac{1}{s}$, Hz)
- polarizare (directie in spatiu; transversale)
- Cimpul em - suprapunere de unde

  Intensitate

Ce masuram?

- La frecvente mici si intensitati mari → → cimpul (+ energia)
- La frecvente mari si intensitati mici → → energia

Spectrul electromagnetic



- Vizibil $1\mu = 10^{-4}$ cm $(0.4-0.7)$ $\nu \sim 10^{14}\ s^{-1}$

  Infrarosu $\sim 10^{13}$

  10^{12} – THz.

  MW – 1 – 100 GHz.

- Radio 1 KHz – 100 MHz ($k = 10^3$, $M = 10^6$)

Raze X $\lambda = 0.1 - 100\ \text{Å}$; $1\ \text{Å} = 10^{-8}$ cm (atom)

$\nu = 10^{16} - 10^{19}$ Hz

$\mathcal{E} = 100$ eV – 100 keV

Raze γ $\nu > 10^{19}\ s^{-1}$ (cosmic radiation)

$\lambda < 10^{-9}$ cm (sub-atomic)

Structura cuantică a câmpului electromagnetic

- "Grăunțe" de energie, impuls (fotonul)

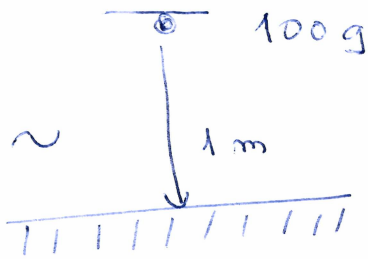
$$\mathcal{E} = h\nu \quad , \quad h = 6.62 \cdot 10^{-27} \text{ erg} \cdot \text{s}$$

$$p = \frac{h}{\lambda} = \frac{h\nu}{c} = \frac{\mathcal{E}}{c}$$

- Intensitatea $\sim$ N de fotoni

Energy unit

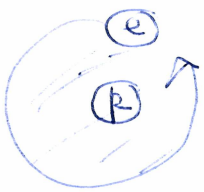
$1 eV = 1.6 \cdot 10^{-19} J$ $\quad (1 erg = 10^{-7} J)$

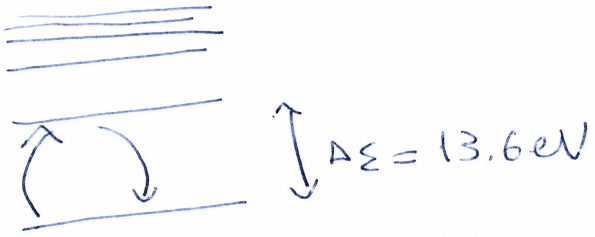


1°C - water - 4.19 J (cal)

Nivele atomice

- H :





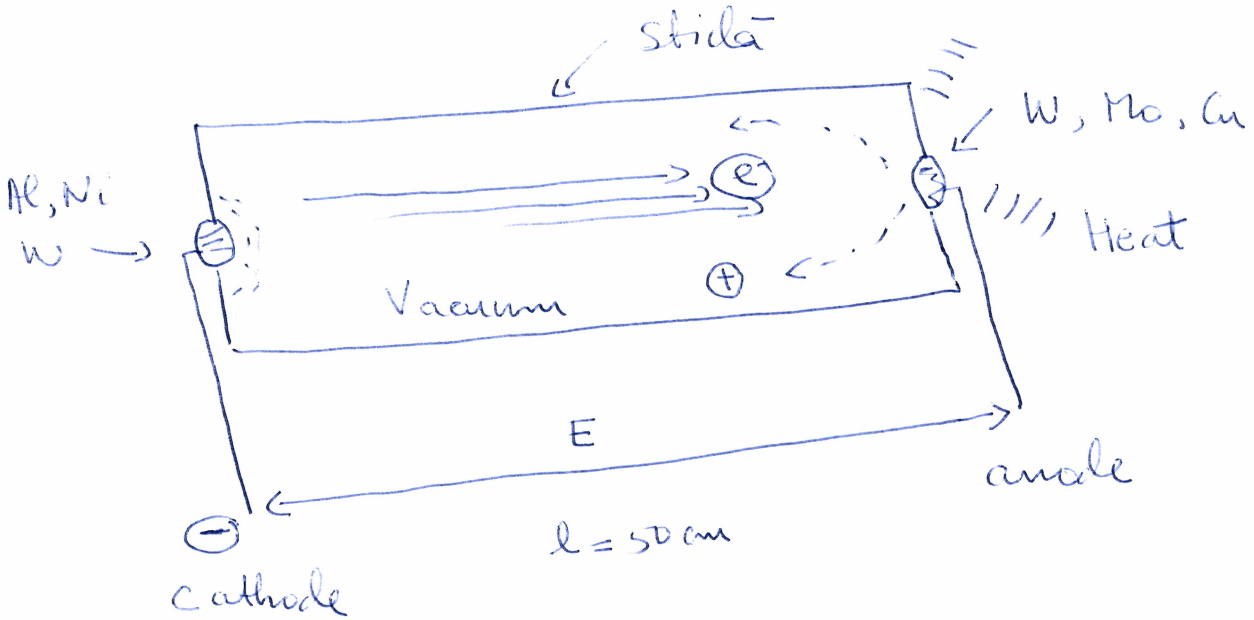
excitation - dezexcitation

$$\lambda = \cancel{\nu} \, cT = \frac{c}{\nu} = \frac{hc}{\Delta E} = 0.1 \mu \; (\rightarrow UV)$$

- Atomi grei ΔE - mare, λ mică,
  frecvența mare $\longrightarrow$ raze X
- Molecule ΔE - mică, λ ~~mică~~ mare,
  frecvența mică $\longrightarrow$ spectroscopia moleculară
  (Raman, infraroșu)

Raze X (Roentgen 1895)

Tubul catodic



- Emisie termo-ionică
- Emisie electrică
- Curent catodic

$$E = 100\ kV/m = 10^5\ V/m$$

$$a = \frac{2E}{m} \cong \frac{1.6 \cdot 10^{-19} \cdot 10^5}{10^{30}} \cong 10^{16}\ m/s^2$$

$$V = a\tau, \quad l = \frac{a\tau^2}{2}$$

$$\tau = \sqrt{\frac{2l}{a}} = 10^{-8}\ s \quad , V = 10^8\ m/s\ (\sim c!)$$

$$\mathcal{E} = \frac{mv^2}{2} \cong 10^4\ eV\ (10\ kV)$$

Curentul de tub

- Energia $qEa \cong 1{,}6 \cdot 10^{-19} \cdot 10^{5} \cdot 10^{-10} = 10^{-24}\,J =$

$= 10^{-5}\,eV$ (!)

- Lucrul de extractie $W = 2-3\,eV$

Probabilitatea de ionizare

$$P = \frac{qEa}{W} \sim 10^{-5}$$

- Cati electroni ies din catod ?

$$N = n \cdot S \cdot a \cdot P = 10^{22} \cdot 1\,cm^2 \cdot 10^{-8} \cdot 10^{-5} = 10^{9}$$

- Curentul

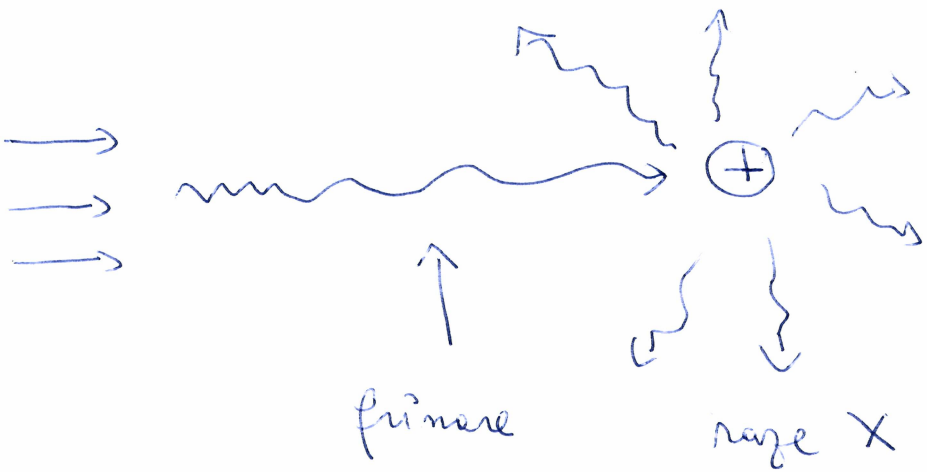
$$I = \frac{qN}{t} = \frac{10^{-19} \cdot 10^{9}}{10^{-8}} = 10^{-2}\,A\ (mA)$$

$$P \cong 10^{5} \cdot 10^{-2} = 1\,kW$$

- Fluxul de electroni $\frac{N}{St} \cong 10^{17}\,/cm^2 \cdot s$ (!)

Ce se întîmplă la Anod ?

- Radiația de frînare (Bremsstrahlung)



Randament ~ 1% (restul căldură)

$\lambda \gtrsim 1$ Å

$\varepsilon \lesssim 10$ keV (10 kV, uzual)

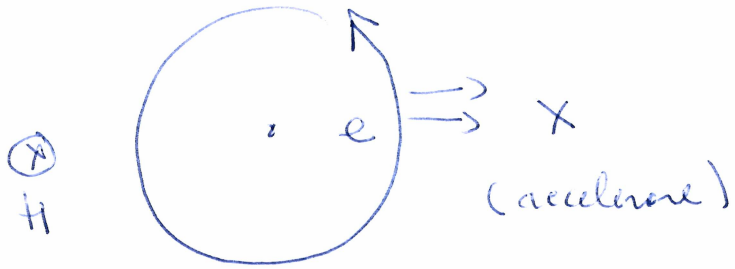
$\varphi \sim 1\ ph/cm^2 \cdot s \times 10^3$ ($\sim 1/R^2$)

(spectru continuu)

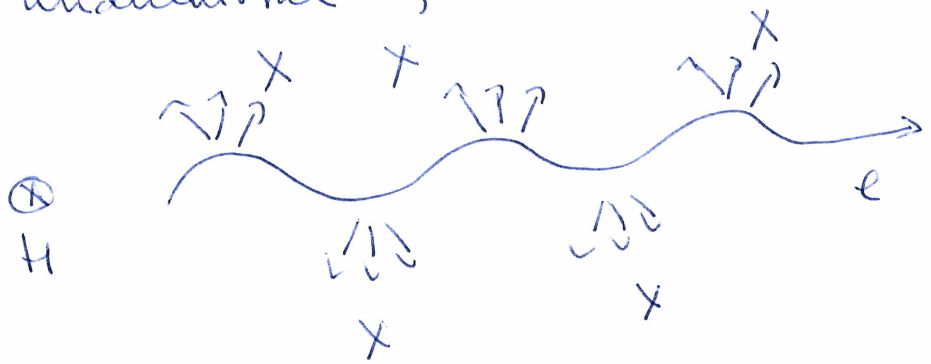
- Spectru raze X - caracteristic (excitații atomice)

Alte surse de raze X

- Radiatia de sincrotron



- Undulatorul , LINAC



- FEL (free electron laser) (tunabile)

XANES (X-ray abs near the edge str)

EXAFS (ext X- abs fine structure)

Proprietăți raze X

- Penetrabilitate (atenuare)

  ~ 10 - μ (10^{-3} cm)

  (depinde de masă, Z, energie)

- Dozimetry $D = \frac{\Delta \mathcal{E}}{\Delta m}$

1 Gray (Gy) = 1 J / 1 Kg (Sievert)

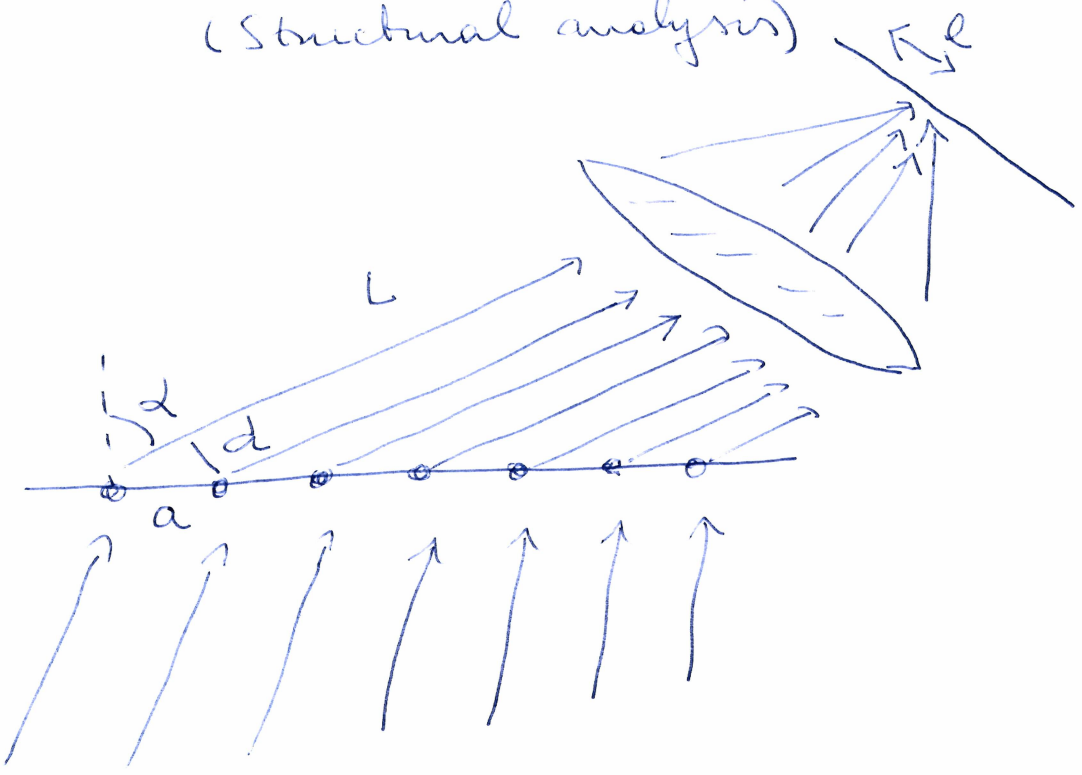
1 Roentgen = 1 erg / 1 g

rad = 100 erg/g

(Activity Becquerel 1/s; Curie $3.7 \cdot 10^{10}$/s)

X-ray diffraction

(Structural analysis)



$$\sin\alpha = \frac{d}{a} = \frac{n\lambda}{a} = \frac{\alpha}{L}$$

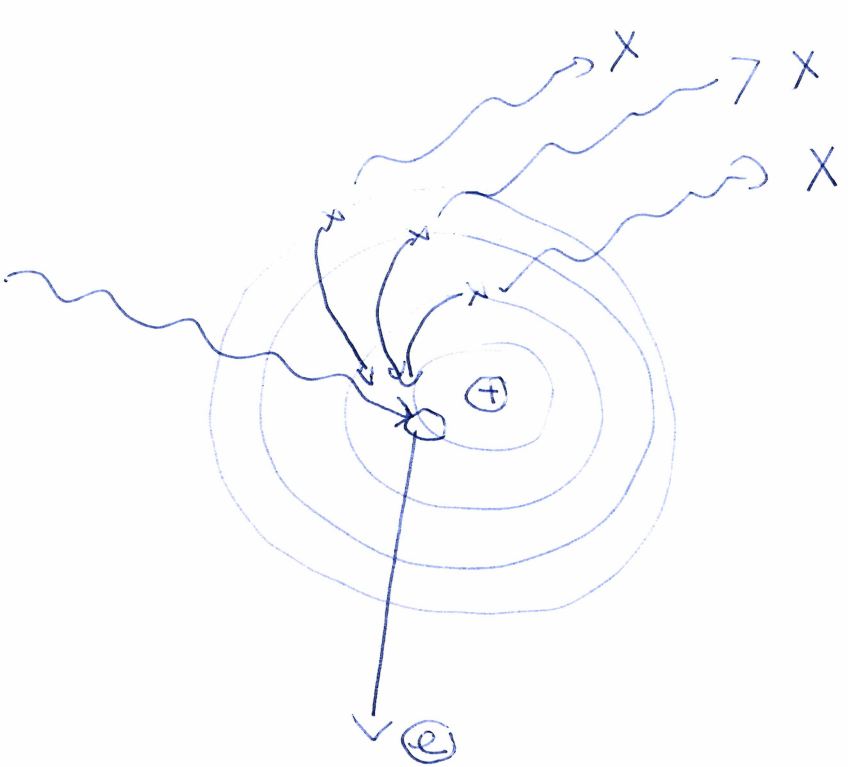
$$A \sim e^{i\varphi} + e^{i\varphi + i\Delta\varphi} \rightarrow 1 + e^{i\Delta\varphi}$$

$$A^2 \sim 2 + 2\cos\Delta\varphi$$

$$\Delta\varphi = 2\pi\frac{d}{\lambda} = 2\pi \cdot n$$

$$d = n\lambda$$

Fluorescență de raze X (XRF)



- Analiză elementală
- N ! (heavy elements)

Propunere mea

(1) XRF ! detecție selectivă, elementală

(2) Îmbunătățirea detecției sensibilității (diode)

(3) Transfer from the medical practice to security practice

Thermionic emission

(Richardson law)

- Cathode vaporization $Q \sim N \sim T$
- high T : ionization $\sim N \times N$ (interaction)
- Number of released electrons

$$\sim T^2 e^{-W/T}$$