
STRAND-JDYLL Á LA RÖNTGEN

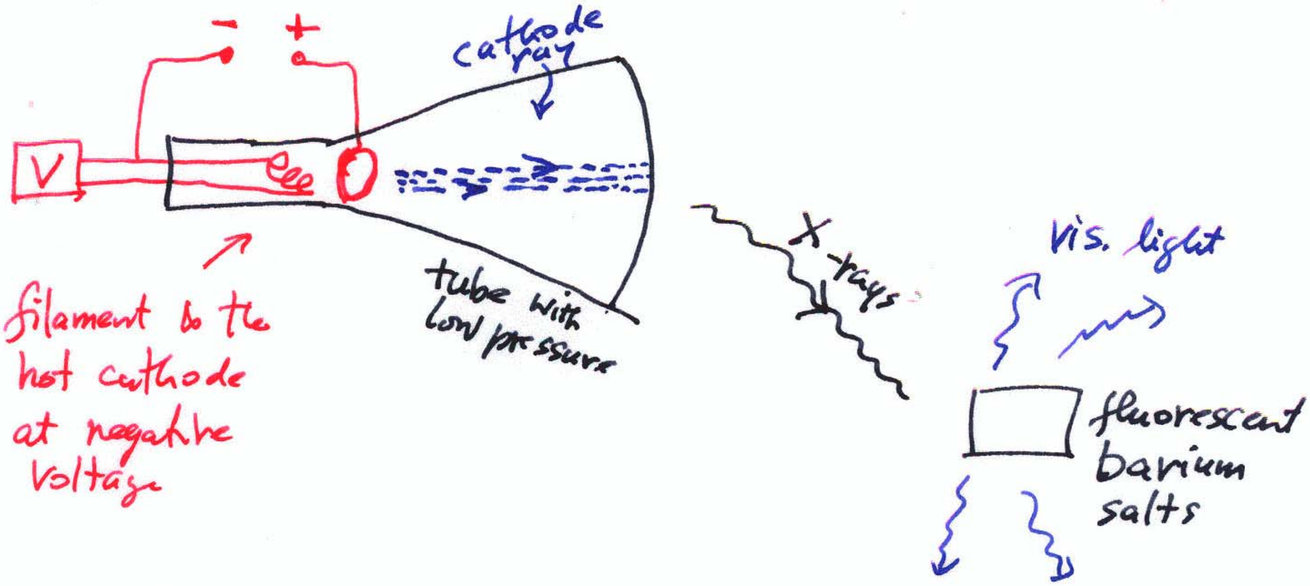
9. The Discovery of X-rays

Khare & Swarup, Secs. 1.17 – 1.23

X-rays were discovered in 1895 by Wilhelm Roentgen.

He was studying gas discharges in a cathode-ray tube; and noticed that fluorescent materials would emit light when placed near the C.R.T.

Even if the C.R.T. was blocked by cardboard, the "X-rays" produced effects.



In 1897 J J Thomson showed that a cathode ray is a stream of identical particles, which he named "electrons".

Here are some properties of X-rays C1/2
observed by Roentgen:

- X-rays penetrate low-Z materials
- X-rays will ionize a gas
  /an X-ray beam will discharge a charged electroscope/
- X-rays cause fluorescence
- X-rays expose a photographic plate
- X-rays are electrically neutral
- X-rays are blocked by high-Z materials
  /the radiologist can … picture of your …

Roentgen's hand

⇒ X-rays are a penetrating …

Later History

JJ Thomson argued that X-r… short-wavelength electro…

1899: Haga and Wind observed single-slit diffraction with X-rays; estimated $\lambda \sim 0.1$ nm $= 10^{-10}$ m

1906: Barkla observed polarization of X-rays by scattering from surfaces

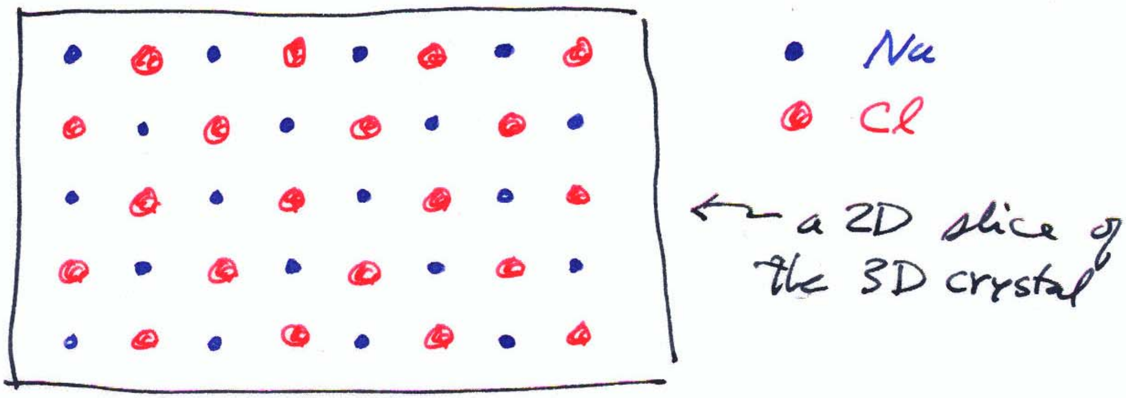
Observations of X-ray spectra

The wavelengths are very short, so measuring them is difficult.

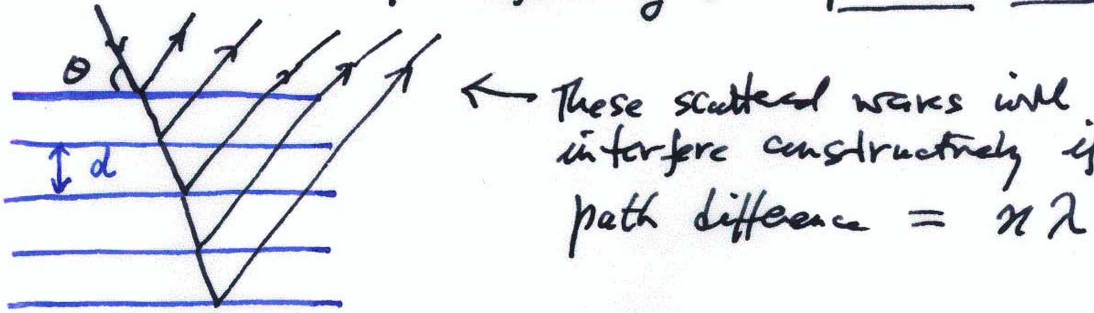
1913 : von Laue used a crystal as a diffraction grating for X-rays

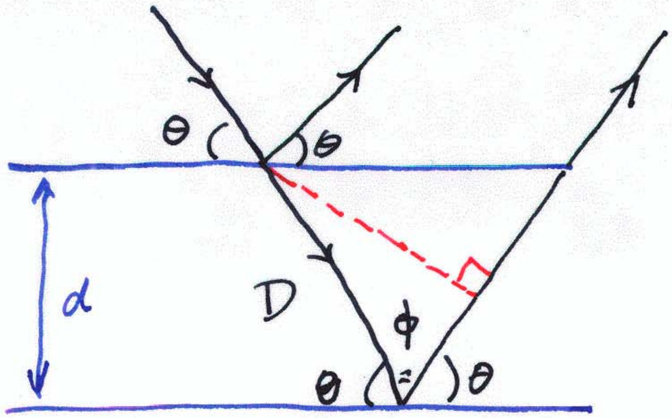
Bragg Scattering (Wm. Lawrence Bragg & Wm. Henry Bragg)
(son) (father)

As an example, consider a NaCl crystal



So consider X-rays reflecting from parallel lattice planes





Path Difference = $D + D\cos\phi$

hypotenuse = $D = \frac{d}{\sin\theta}$

$\phi = \pi - 2\theta$

$\cos\phi = -\cos 2\theta$

$$P.D. = \frac{d}{\sin\theta} + \frac{d}{\sin\theta}\left(2\sin^2\theta - 1\right)$$

$$P.D. = 2d\sin\theta$$

d = distance between atomic planes

__Bragg's Law__ $\quad 2d\sin\theta_n = n\lambda$

$(n = 1\ 2\ 3\ 4 \ldots)$

θ = angle between the incident ray and the lattice plane reflecting the waves

If $\theta = \theta_n$ there is constructive interference between reflected waves from different (parallel) lattice planes. ⇒ High intensity of scattered X-rays in that direction

Bragg's Law : $2d \sin\theta_n = n\lambda$

$(n = 1, 2, 3, \ldots)$

Two ways to use Bragg's law

(1) knowing θ_n and λ determines d

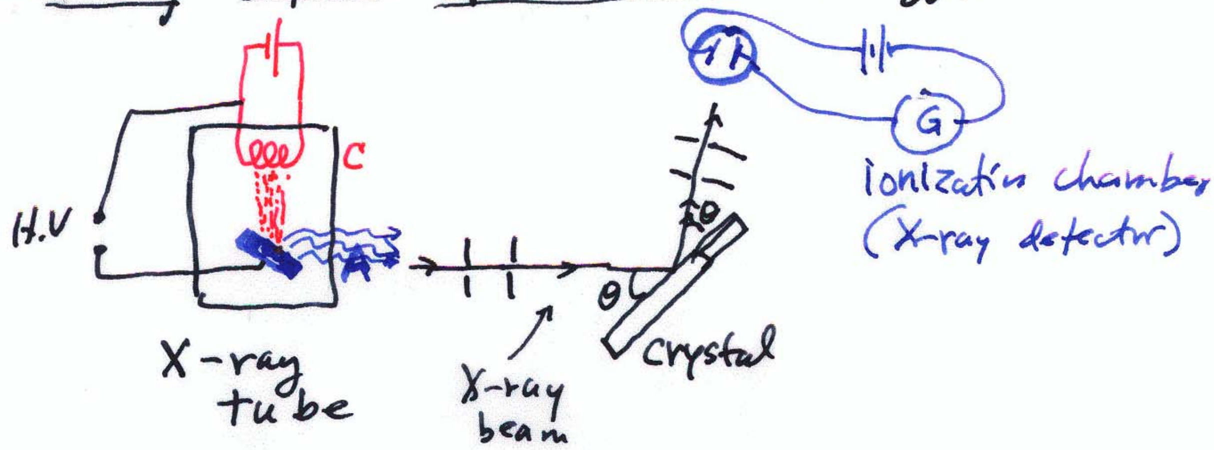
X-ray crystallography to determine crystal structure

(e.g., NaCl in 1914 ; diamond in 1914)

(2) knowing θ_n and d determines λ

spectroscopy – measure intensity versus λ

X-ray crystal spectrometer (Bragg)



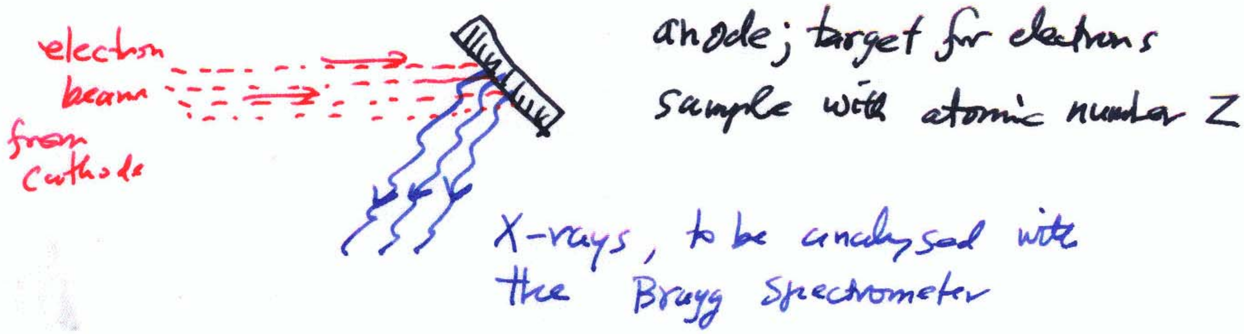
H.V. = 1 – 100's kV

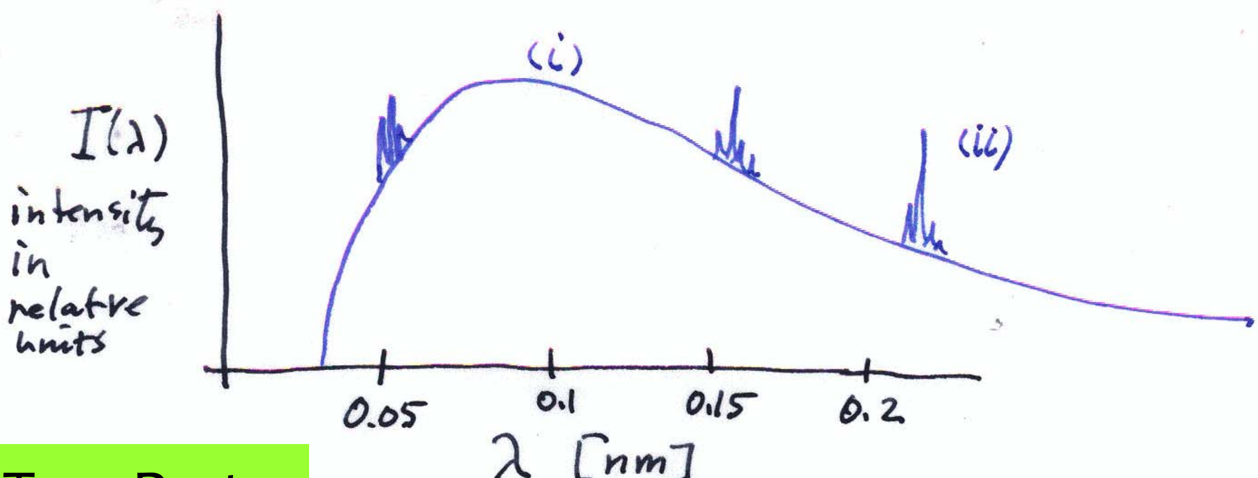
With a known crystal, one can measure intensity versus λ by varying θ and using Bragg's law.

Cathode rays (electrons) collide with the target, producing the X-ray spectrum of the material in the target.

The X-ray spectrum produced by an X-ray tube

Collingwood X-ray tube (1913)





Two Parts:

(i) Continuum Spectrum
→ approximately independent of anode material

(ii) Characteristic Spectrum (line spectrum)
→ unique for each element of the anode

We'll see Wednesday how the line spectrum depends on the energy levels of the atom.