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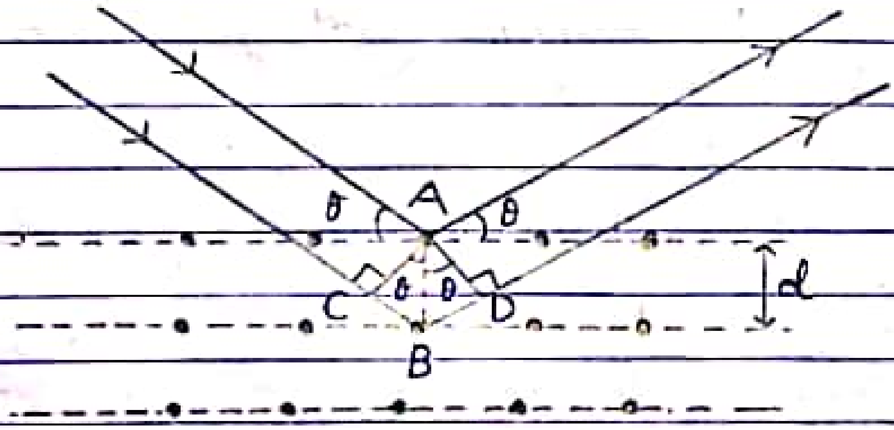
Bragg's Law (Q-2. Subs.)

Waves show diffraction effects when they are broken up by regularly-spaced scattering points with seperation of the order of the wavelength. X-rays are electromagnetic waves of the order of 1 Å. Such short waves cannot be diffracted by optical gratings which are too coarse for them.

Laue, in 1912, pointed out that crystals have geometrically-regular, periodic arrangements of atoms in space, with seperations comparable to the X-ray wavelengths. Hence crystals could act as natural three-dimensional grating for X-rays. Laue's students actually obtained a diffraction pattern by passing X-rays through a crystal of rock-salt.

William Bragg used the crystals as reflection gratings. He supposed that X-rays striking a crystal are scattered in all directions by each atom of the crystal. As the atoms are arranged in a regular pattern, in certain directions the scattered waves interfere constructively while in others they interfere destructively. Hence a diffraction pattern is formed.

In fig. is shown a particular set of cleavage planes in a crystal, the dots representing the atoms.



Let d be the interplanar spacing. Suppose a parallel X-ray beam is incident at glancing angle θ. It is scattered by the atoms A and B in random directions. Constructive interference takes place only between those scattered waves which are parallel and have a path difference of $n\lambda$, where λ is the X-ray wavelength and n is an integer. It is seen that for such rays the scattering angle is equal to the glancing ~~ge~~ angle θ. The path difference is $CB + BD = d\sin\theta + d\sin\theta = 2d\sin\theta$.

For constructive interference, we must have

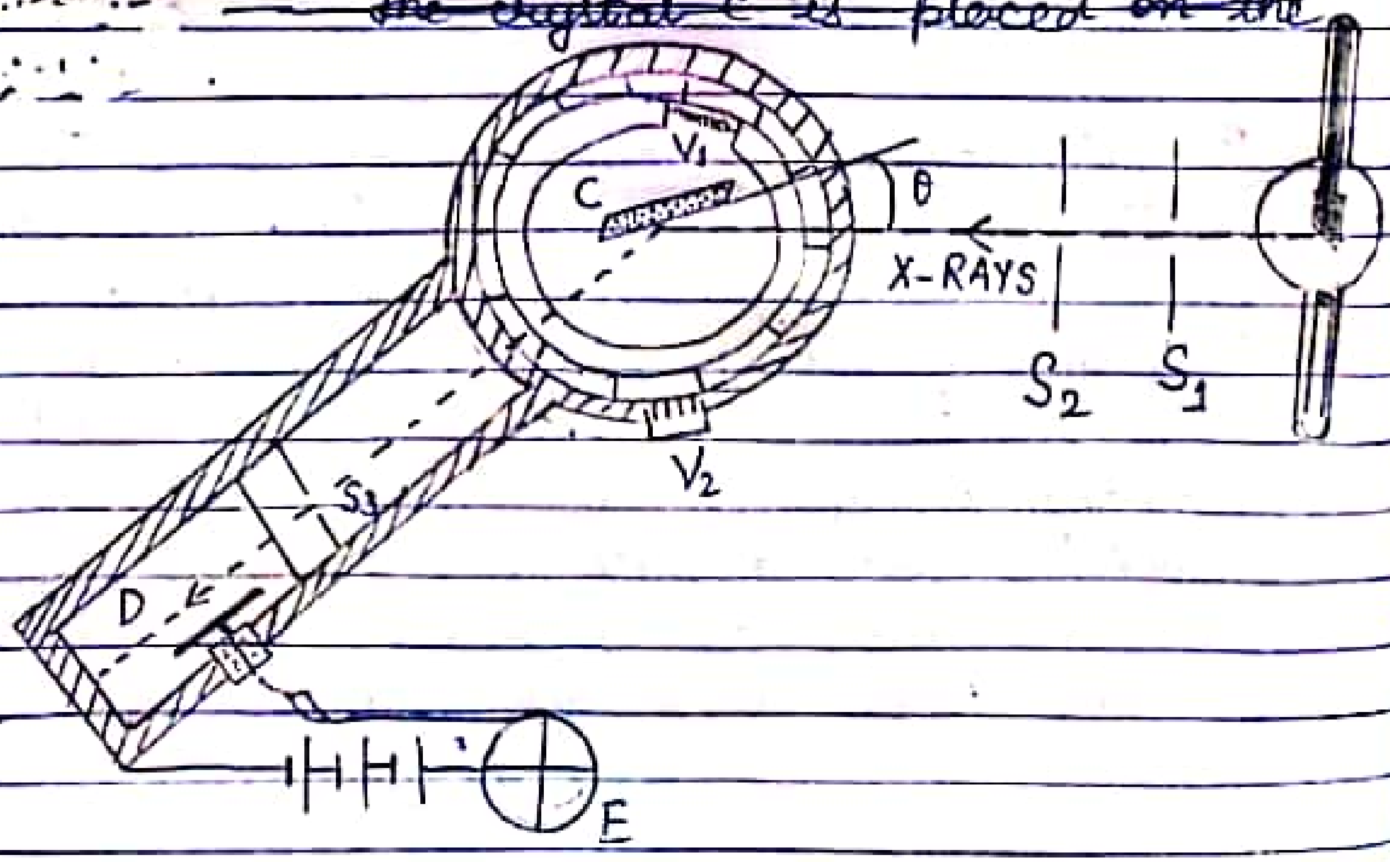
$$2d \sin\theta = n\lambda \qquad n = 1, 2, 3, \ldots$$

This is Bragg's equation. It shows that for given values of λ and d, there are a no. of permitted directions defined by θ (for $n = 1, 2, 3, \ldots$) in which mirror-like reflections will occur. images obtained in these directions are the first, second, third, ... order diffraction images.

If the incident X-ray beam consists of several wavelengths, a number of spectra are obtained.

Bragg's X-ray Spectrometer — It is shown in fig. . X-rays from a tube pass through fine slits S_1 and S_2 which collimate in into a fine pencil. This pencil falls on a crystal C mounted on a circular table capable of rotation about a vertical axis. The position of the table can be read on a graduated scale with a vernier V_1. The reflected beam after passing through slit S_3 enters the ionisation chamber D, filled with methyl iodide which absorbs X-rays strongly. The chamber is mounted on an arm which can be rotated about the same axis as the crystal. Its position can be read by a second vernier V_2. The gas in the chamber is ionised by the X-rays. The resulting ionising current, which is measured by the electrometer E, is a measure of the intensity of X-rays reflected by the crystal.

~~The crystal C is placed on the~~



Working — The crystal C is placed on the table such that the face from which the X-rays are to be reflected contains the axis of rotation. The crystal is rotated through small angles, and also the ionisation chamber through double the angles, and the ionisation current is measured each time. It is found that as the glancing angle θ is varied, the ionisation in the chamber also varies. Maximum ionisation occurs for values of θ given by Bragg's law.

Determination of Wavelength — For a particular wavelength λ, we have

$$2d \sin\theta = n\lambda.$$

or

$$\frac{\lambda}{d} = \frac{2\sin\theta}{n}$$

By observing those value of θ at various orders n which sharp reflection occurs, a mean value of λ/d is determined. Now, if the spacing of crystal planes, d, is known, the wavelength λ of X-rays can be calculated.