

Bragg reflection :determining the lattice constants of monocrystals

Objectives:

- 1-Investagating Bragg reflection at NaCl monocrystal
- 2-determinig the lattice constant a_0 of NaCl .

Theory:

Bragg's law of reflection describes the diffraction of plane waves at a monocrystal as the selective reflection of the waves at a set of lattice planes within the crystal .Due to the periodicity of the crystal, the lattice planes of a set have a fixed spacing d .An incident wave with the wavelength λ is reflected with maximum intensity when the Bragg condition is fulfilled .

$$n\lambda=2d \sin \theta \quad \text{eq.1}$$

n : diffraction order.

λ : wavelength.

d : spacing of lattice planes.

θ : the angle of the incident and reflected waves with respect to the lattice planes.

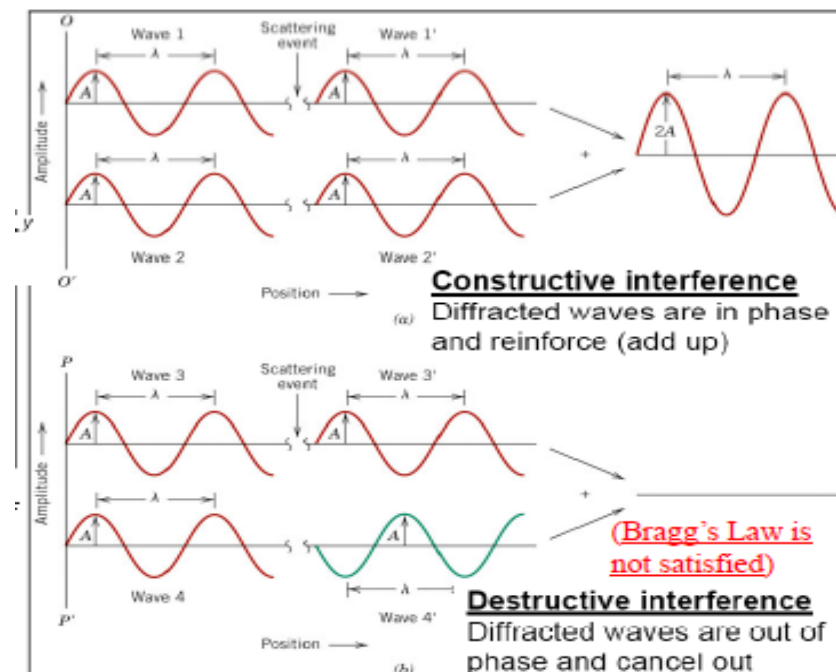


Fig.2 reflections must be in phase for a detectable signal i.e. for diffraction to occur ,x-rays scattered off adjacent planes must be in phase.

In Cubic NaCl crystal (Fig.1), the lattice planes run parallel to the surface of the crystal's unit cell .Their spacing d corresponds to one half of the lattice constant.

$$d = \frac{a_0}{2} \quad \text{eq.2}$$

substituting equation 2 in equation 1

$$n \lambda = a_0 \sin \theta \quad \text{eq.3}$$

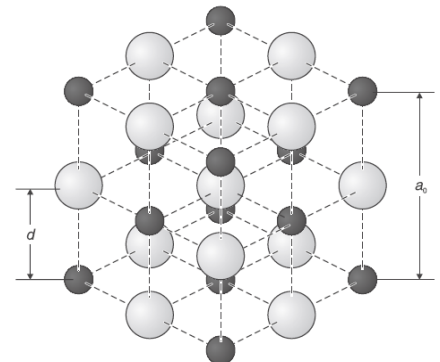


Fig.1 Three -dimensional representation of the structure of NaCl

In other words, to determine a_0 we need to measure the glancing angle θ for a known wave length λ and diffraction order n . This method is more precise when the glancing angles are also measured in higher diffraction orders.

In this experiment, the molybdenum x-rays are used as radiation of a known wavelengths , $k_\alpha=71.08 \text{ pm}$ and $k_\beta=63.09 \text{ pm}$.

Apparatus:

X-ray apparatus (shown in figure 3)-Geiger-Muller counter tube -NaCl monocrystal - Pc with X-ray apparatus program.

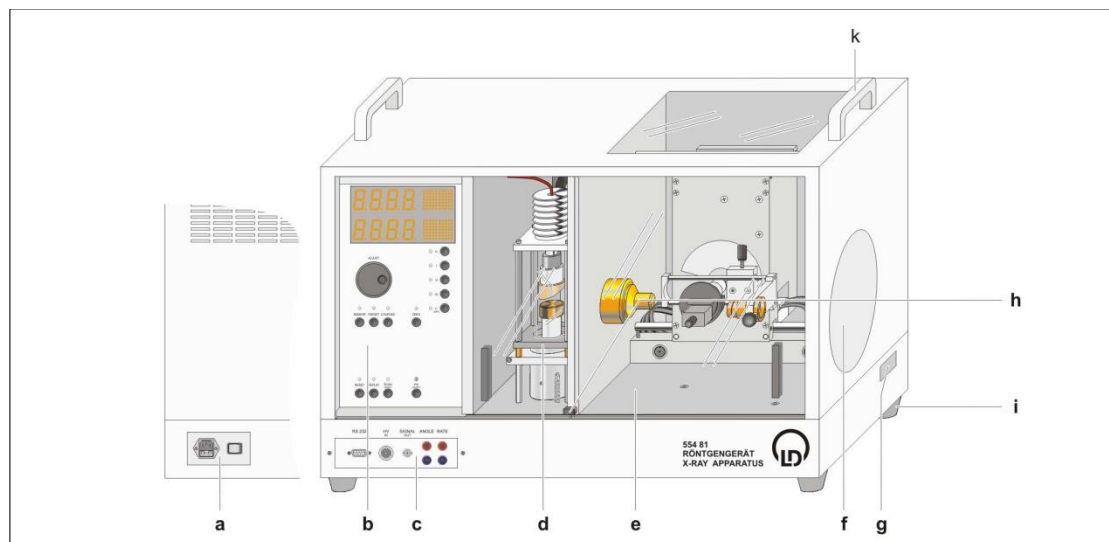


Fig. 3 X-ray apparatus

- | | | |
|----------------------------|--|---------------------------|
| a Mains Power panel | d Tube chamber (with X-ray tube Mo) | g Free channel |
| b control panel | e Experimental chamber (here with goniometer) | i Feet |
| c Connection panel | f Fluorescent screen | K Carrying handles |

procedure:

1-start the software "X-ray apparatus", and clear any existing data.

2-set the high voltage $U=35$ kV , the emission current $I =1$ mA ,the measuring time per angular step $\Delta t=10$ s and the angular step width $\Delta\beta = 0.1^\circ$

3-Press the COUPLED key to activate 2θ coupling of target and sensor and set the lower limit of the target angle to 4° and the upper limit to 22° .

4-start measurement and data transfer to the PC by pressing the SCAN key.

5--when you have finished measuring save the measurement.

6-in each diffraction diagram use the left mouse button ,mark the "full width "of each peak and write down the centre values in a table as the glancing angle.

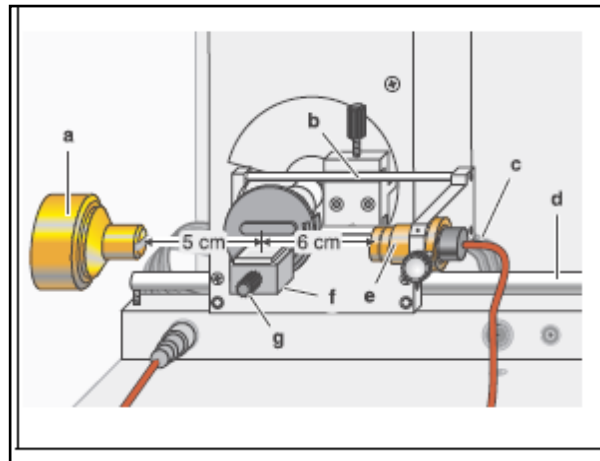


Fig.4 experiment setup.

Measurements:

θ	$\sin \theta$	line	n	$n\lambda$ (pm)
		K_β	1	
		K_α	1	<u>اكتب المعادلة هنا</u>
		K_β	2	
		K_α	2	
		K_β	3	
		K_α	3	

Results:

Graph:

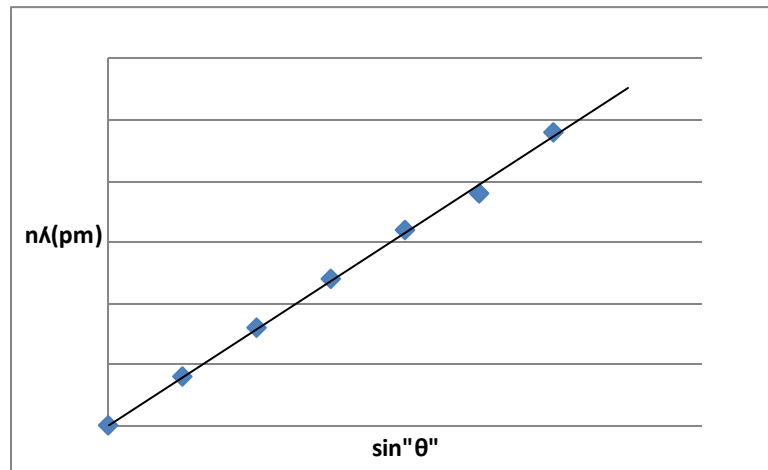
Plot $n\lambda$ versus $\sin\theta$

-Find the slope

-find $a_0 = \text{slope}$.

-find the percentage error

where $a_0 = 564.02 \text{ pm}$.



Background:

X-rays are a form of electromagnetic wave with the wavelengths ranging from 10^{-8} to 10^{-10} m. X-rays are created when fast-moving electrons are rapidly decelerated in matter. According to the laws of classical electrodynamics, this deceleration gives rise to electromagnetic radiation, which is mainly radiated perpendicular to the direction of acceleration for energies below 50 keV, i.e. for an X-ray tube, perpendicular to the direction of the electrons striking the anode. For historical reasons, this x-ray component is referred to as “bremsstrahlung” after the German word for the deceleration process by which it occurs. The bremsstrahlung has a continuous spectrum which extends to a certain maximum frequency ν_{\max} or a minimum wavelength λ_{\min} . If the energy of the electrons exceeds a critical value, the characteristic x-radiation is generated, which appears in the spectrum as individual lines in addition to the continuous bremsstrahlung spectrum. These lines are generated when high-energy electrons penetrate deep into the atomic shells of the anode material, and eject electrons from the innermost orbits by collision. The holes created in this process are filled by electrons from the outer orbits with emission of X-rays. The resulting X-radiation is characteristic of the anode material,

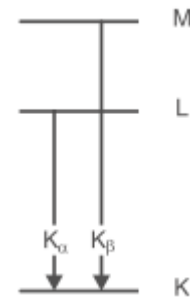


Fig.1. Simplified term diagram of an atom and definition of the K, L and M series of the characteristic X-ray radiations.

Figure 1 serves to illustrate the adopted orbital model of the atomic shell for the lines of the characteristic X-radiation: the individual orbits are characterized by a particular binding energy and are designated from the innermost to the outermost with the letters K, L, M, N, *etc.* Electrons can transit between the orbits in accordance with the laws of quantum mechanics; these transitions entail either the absorption or emission of radiation, depending on the direction of transitions. For example, radiation from transitions to the K-orbital occurs as a series of sequential lines designated K_{α} , K_{β} *etc.* In this experiment, the anode is made of Molybdenum (Mo). The K_{α} , and K_{β} radiations of Mo have the wavelengths of 7.11×10^{-2} nm and 6.32×10^{-2} nm, respectively.