Confirming Bragg's Law using X-Ray Diffraction from NaCl

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Abstract

1 Introduction

The arrangement of atoms or ions in crystals can be understood as an array of parallel lattice. These lattices will form planes in which waves can be scattered, creating a spherical wavelet. In this situation, our wavelength λ of the incident wave is unchanged and

Bragg's law states that the glancing angle θ is related to an integer multiple of the incident wavelength λ in the following way

$$n\lambda = 2d \sin\theta \qquad (1)$$

In essence, this means that with a fixed λ there exists some θ that depends on d, the distance between objects in the lattice, in which we have that the angle of incidence is equal to the angle of reflection.

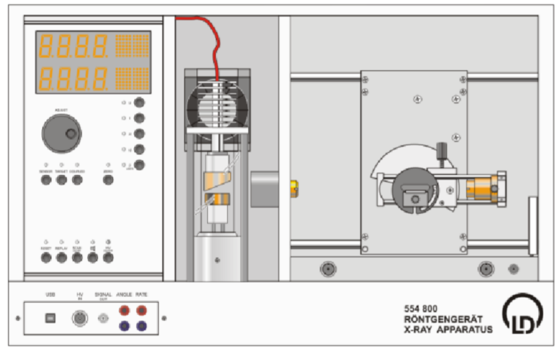
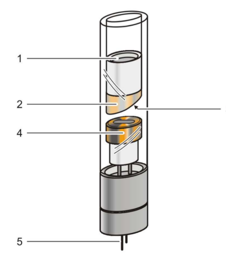
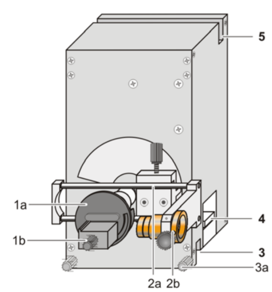


Figure 1: Visualization of the Lehr-und Didaktiksysteme X-ray Apparatus 554 800



(a) Labeled visualization of the x-ray tube. Numbered components are as follows: **(1)** Thread for heat sink; **(2)** Copper block; **(3)** Molybdenum anode; **(4)** Hot cathode; **(5)** Pin socket Base



(b) Labeled visualization of the goniometer. Numbered components are as follows: **(1)** Target arm; **(2)** Sensor arm; **(3)** Bottom guide groove; **(4)** Terminal pin connector; **(5)** Top guide groove

Figure 2: Descriptions of x-ray tube and goniometer

2 Experimental Procedure

2.1 Apparatus

We will use the Lehr-und Didaktiksysteme X-ray Apparatus 554 800 (Figure 1) with serial number 469703. A visualization of this apparatus is seen in Figure 1. This apparatus is equipped with a built in X-ray tube, goniometer, and Geiger-Müller counter, We will detail the exact specifications and use of each of these components below. The X-ray tube(Figure 2a) uses a molybdenum anode in a copper block whose purpose is to dissipate heat. This molybdenum has $K_\alpha = 17.4$ keV and $K_\beta = 19.6$ keV. This goniometer (Figure 2b) is a self-contained unit for mounting the crystal sample and the detector. It is internally calibrated so that the GM Counter will move twice the angle of the sample for each rotation in order to maintain the Bragg angle. The goniometer has unlimited angle range with an angular resolution of 0.1°. We will utilize a self-quenching Geiger-Müller counter with a thin mica window $d = 12 - 15$ mm with a filling of neon, argon, and halogen gas. This will be used to detect the x-ray radiation scattering off the crystal. The NaCl crystal we will use is a 25 by 25 by 4 millimeter NaCl crystal with the spacing of lattice planes being 282 pm. This crystal has theoretical reflection angles of 7.24° for K_α and 6.43° for K_β from the molybdenum x-ray tube.

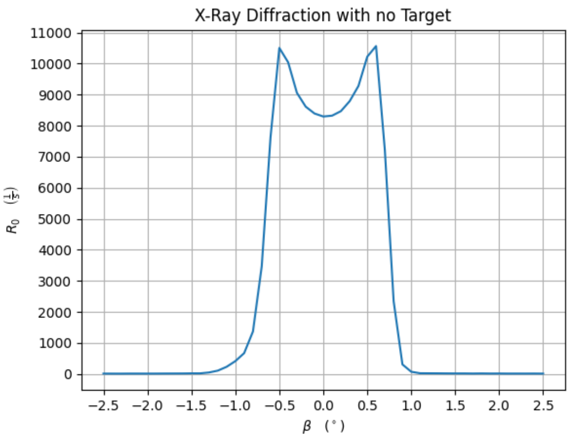


Figure 3: X-ray count data without a sample

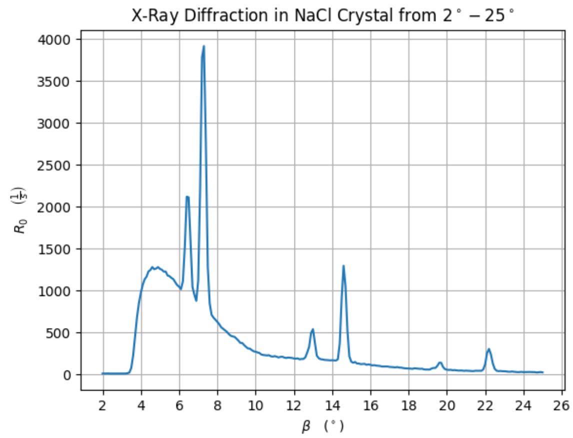


Figure 4: Graph of count rate versus angle

2.2 Data Collection

Data collection will be done using the Geigar-Müller counter to measure the number of incident X-rays and the goniometer to measure the angle of the sample. The built in scan mode of the apparatus will be used to scan through the angles of 2° and 25°. The Geigar-Müller counter will take counts of how many X-ray photons per second it detects at that angle. The data can be collected directly from the device utilizing its built in software. We will then plot the count rate as a function of angle in which we should see defined peaks at each Bragg for each value of n for Mb K_α and K_β emissions. We expect there to be six defined peaks, one for the 3 values of n for each emission spectrum. We will then fit a curve to these emission peaks in order to find the angle in which they are maximized, which will be our Bragg angle for that emission line.

3 Data Analysis

The first step in taking data is to see the expected counters of the GM counter without a sample to diffract off of. The purpose of this is to determine the shape of the expected peak that will be superimposed on the X-ray emission spectrum of molybdenum. Our results for this baseline can be seen in Figure **??**. The dip in the peak of the curve is most likely due to the fact that there is a lip on the sample rest and this caused the x-rays to scatter abnormally. Otherwise, we have a curve that fits very similarly to a Gaussian, so we will utilize a Gaussian fit for each peak in our experimental data.

With our fit determined, we will now analyze the data of the full scan. The graph of the full gamut of data is seen in Figure **??**

4 Results and Conclusions

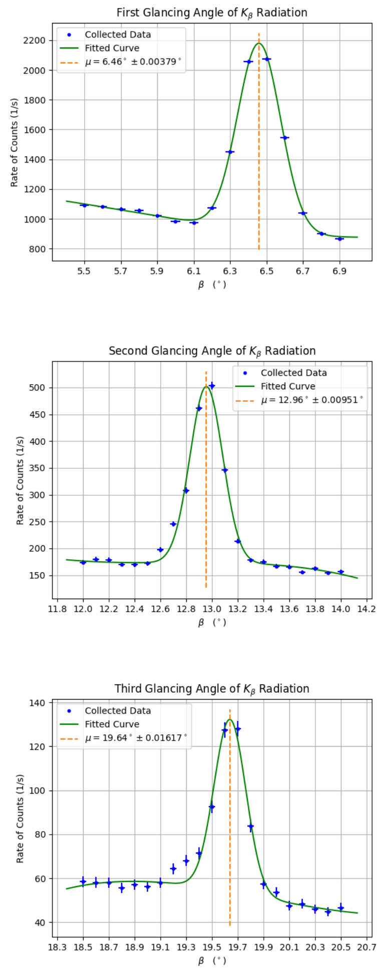


Figure 5: Graphs of each peak of the Mb K_β emission.

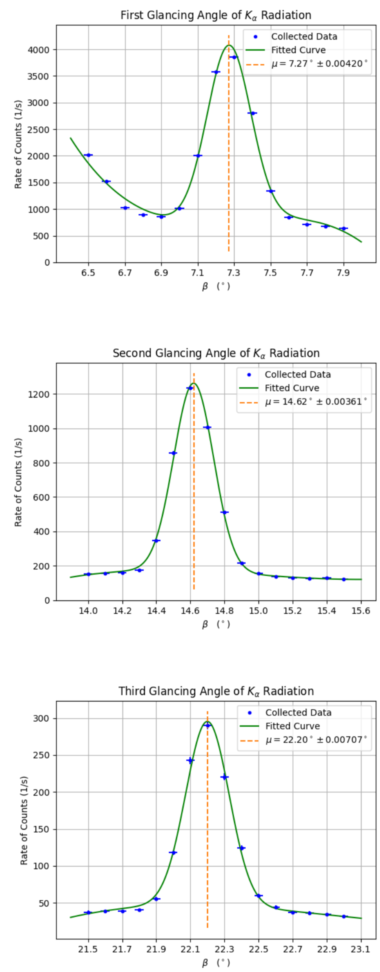


Figure 6: Graphs of each peak of the Mb K_α emission.

References