BRAGG REFLECTION

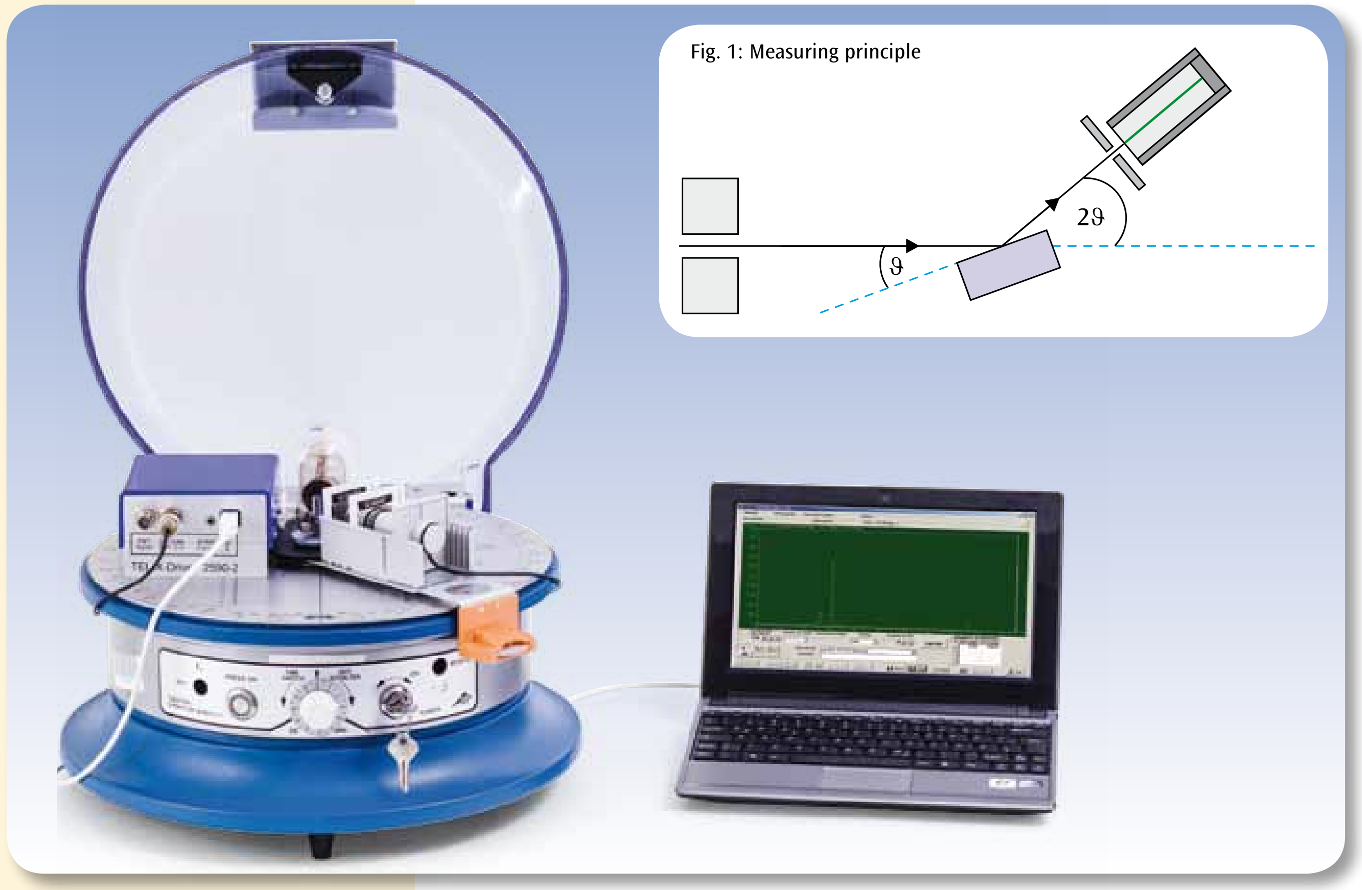

Fig. 1: Measuring principle

EXPERIMENT PROCEDURE

- **Record diffraction spectra of the X-rays produced by a copper anode upon passing through crystals with a salt-like structure.**
- **Determine the lattice constants and make a comparison with the size of the crystals' components.**

OBJECTIVE

Determine the lattice constants for crystals with a structure similar to salt (NaCl)

SUMMARY

Measurement of Bragg reflection is a key method for investigating monocrystals using X-rays. It involves X-rays being reflected by the various lattice planes, whereby the secondary waves reflected by individual layers undergo constructive interference when the Bragg condition is fulfilled. If the wavelength of the X-rays is known, it is possible to calculate the separation between lattice planes. In this experiment, various crystals which share the structure of salt (NaCl) are investigated and compared.

REQUIRED APPARATUS

Quantity	Product	Number
1	X-Ray Apparatus (230 V, 50/60 Hz)	1000657 or
	X-Ray Apparatus (115 V, 50/60 Hz)	1000660
1	Basic Set Bragg	1008508
1	Crystallography Accessories	1000666
1	Bragg Drive	1012871

BASIC PRINCIPLES

A key method for investigating monocrystals using X-rays was devised by *H. W.* and *W. L. Bragg*. They developed an interpretation of how atoms or ions were arrayed in a crystal which took the form of parallel layers in a structure containing the component atoms of the crystal lattice. Incoming plane waves of X-rays would then be reflected from these layers but the wavelength of the X-rays would remain unaffected.

The direction of the incident and reflected rays, parallel to the wave fronts, would be expected to meet the condition "angle of incidence = angle of reflection". The secondary waves reflected from the various lattice layers would also be expected to interfere with one another, whereby the interference would be constructive when the path difference Δ between the secondary waves is an integer multiple of the wavelength λ.

The path difference can be deduced with the help of Fig. 1, where it can be seen that

(1) $$\Delta = 2 \cdot d \cdot \sin\vartheta.$$

d: interplanar distance

ϑ: angle of incident and reflected rays

This means the condition for constructive interference is

(2) $$2 \cdot d \cdot \sin\vartheta_n = n \cdot \lambda.$$

Therefore, if monochromatic X-rays of known wavelength are used, the interplanar distance d can be found by measuring the angles.

In practice, this is done by turning the crystal by an angle ϑ with respect to the angle of incidence, while at the same time moving the Geiger-Müller detector by an angle of 2ϑ, see Fig. 2. Condition (2) is therefore precisely met when the Geiger counter registers maximum intensity.

This experiment uses the characteristic X-rays produced by an X-ray tube with a copper anode. This produces K_α radiation of wavelength $\lambda = 154$ pm and K_β radiation of wavelength $\lambda = 138$ pm. Use of a nickel filter allows much of the K_β radiation to be suppressed, since the absorption edge of nickel lies between the two aforementioned wavelengths. In addition to their characteristic radiation, all X-ray tubes also emit "bremsstrahlung" (literally braking radiation) distributed over a continuous spectrum. This is evident as background beneath the peaks in the measured curves, which represent the characteristic lines.

This experiment investigates cubic monocrystals which have been sliced parallel to their (100) face. This makes the lattice planes which are relevant for Bragg reflection easy to identify. In order to improve the accuracy of the measurement, multiple orders of diffraction are considered.

The crystals provided include LiF and NaCl crystals. Supplementary measurements can also be made using KCl and RbCl crystals. All of these have the same crystal lattice structure, in which the two varieties of atom occupy alternating positions in the lattice. The interplanar distance d is therefore equal to half of the lattice constant a.

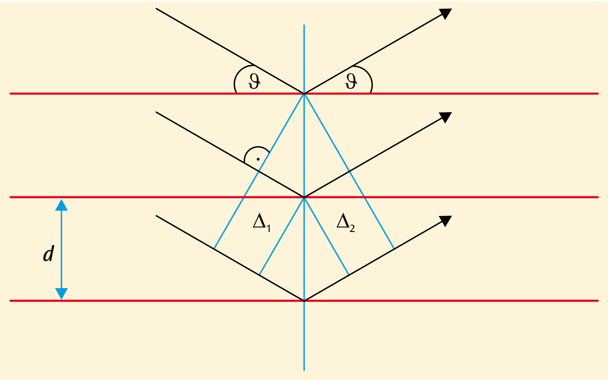

Fig. 2: Diagram showing derivation of Bragg condition

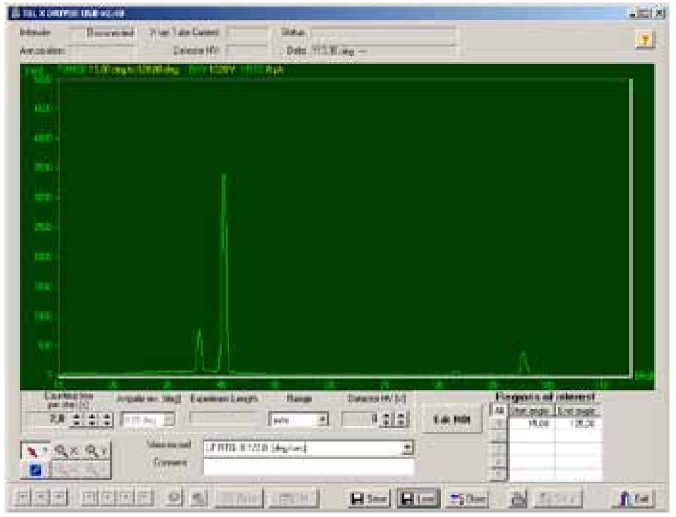
Fig. 3: Bragg curve for NaCl

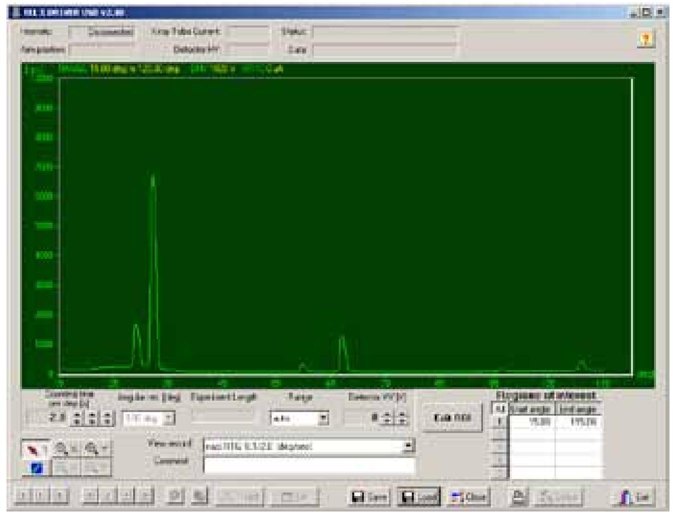
Fig. 4: Bragg curve for LiF

EVALUATION

Using equation (2) the following equation can be derived for determining the lattice constants:

$$a = 2 \cdot d = \lambda_{K\alpha} \cdot \frac{n}{\sin\vartheta_n}$$

A comparison between the values obtained for NaCl, KCl and RbCl indicates that the lattice constant correlates with the size of the alkali metal ions. The lattice constants for LiF and NaCl also differ because the component atoms of the crystal are of different sizes.


Fig. 5: NaCl crystal