MOMENTUM OF ELECTRONS IN SOLIDS

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INTRODUCTION

Monochromatic radiation after scattering consists of two components one of the same wavelength (Rayleigh) and one of increased wavelength (Compton).

Wavemechanical calculations show that when the scattering occurs on bound electrons the Compton line broadens into a band. This has been qualitatively described as a Doppler effect due to the motion of the electrons.

The profile of the Compton band depends on the velocity distribution of the electrons. The connection between the states of the electrons, both initial and final, should be simple in the case of monovalent metals, under the assumption that only valence electrons contribute to the Compton scattering.

As mentioned in the First Annual Report the ratio of the number $Z_{eff.}$ of effective valence electrons to the total number Z of valence electrons depends on the scattering angle φ and starting from the value zero gradually increases to a value $Z_{eff.} / Z = I$, which is reached at a certain scattering angle φ_0, which can be easily calculated. A theoretical investigation shows that the profile of the Compton band will be different on both sides of φ_0. For angles larger than φ_0 the profile is parabolic whereas for small angles the profile will be distorted on its slope towards the primary wavelength.

The experimental investigation of the form of the Compton profile is the subject of the present investigation.

EXPERIMENTAL PART

The spectrometer that analyzes both the initial radiation and the scattered radiation has been extensively described in the First Annual Report (Fig,I). The evaluation of the curves obtained by measurements is complicated by the fact that the initial X-ray line is not exactly monochromatic but has a natural width . The experimental line appears further broadened due to experimental reasons (astigmatism of the spectrometer, width of the slit of the detector e.t.c.).

During the initial experiments Cu_{K_β} radiation was used because Cu antikathodes can withstand high loads and because this radiation is not absorbed strongly in air.The counting rates obtained have a satisfactory intensity but the large natural width of this line (5,3 eV) produces an overlapping of the Rayleigh band and the Compton band to such a degree that they cannot be separated with any accuracy.A better solution is the use of Cr_{K_β} radiation which has much smaller natural width 3eV.The use of Cr radiation however has the disadvantage of giving a much smaller intensity.To this we will return later. As Cr_{K_β} radiation is absorbed in air losing half its intensity in 2I cm,the major paths of the rays were in evacuated tubes closed with thin mylar windows.

Up to present time as a scatterer we used mainly metallic Li.This is a monovalent metal which should follow the crude theory and which should give a stronger Compton band than the other alkali metals.It is essential that the scattering sample should be very pure,because small impurities would increase the absorption coefficient considerablyand hence decrease the quantity of Li participating in the scattering.

In the range of the scattering angles φ which are of theoretical interest the shift of the Compton band is small so that it cannot be separated from the Rayleigh line.In order to obtain a separation,a dummy experiment has to be devised,which will give the form of the Rayleigh line .If the form of the Rayleigh line is thus known,we can draw it in the plot of the scattering experiments (dotted line in fig.2) and thus obtain the profile of the Compton band by substraction.

The profile thus obtained cannot be directly compared to the theoretical profile because the theory refers to a strictly monochromatic primary radiation whereas in the scattering experiments the initial radiation has a finite width.

In principal various dummy experiments could be thought of. A first one would consist in exchanging the scattering material by another which would giye a strong Rayleigh line and a negligible Compton line.The use of Cu for a dummy experiment was not satisfactory because of the strong absorption of the Cr radiation in it.The use of Cr filings as a scatterer gave very intensive spectrum.This can be ascribed to the small absorbtion of radiations near the Cr_{K_β} line in Cr as this region is on the long wave side of the absorption edge(in contrast to Cr radiation in Cu).The intensity is probably increased also by the fluorescence radiation excited in Cr by the hard region of the X-rays spectrum.

The dummy experiment with Cr however was not satisfactory ,as a relatively intensive Compton band showed up as well.In a second type of dummy experiment the initial radiation was used in order to obtain the form of the Rayleigh line.This was done by setting the focus of the X-rays tube at the position of the scatterer thus directly illuminating the spectrometer.This methcd will be accurate if distortions of the spectrometer curve due to astigmatism were the same in the dummy experiment as the scattering experiment.This was found not to be so.We offer as an explanation the fact that in the scattering experiments the illuminating source(surface of the scatterer) is infinite whereas in the direct illumination the illuminating source has the form of a line(focus of the tube).

MEASUREMENTS

Initially the bent quartz crystal (I340) was held in a large crystal holder with an opening of 20mm X IO mm.It was found to give half widths of the initial radiation of IO eV against the natural width of 3.5 eV. By using a smaller surface 5mmXIOmm lines of 3.5 eV width were obtained which is satisfactory. The initial slit width of Imm had to be decreased to 0,4 mm in order to obtain the above values.

Preliminary measurements with Cr radiation showed that the counting rate under the above conditions would be relatively small so that Cu_{K_β} radiation was tried. The spectrometer curves obtained were very intensive but the relatively large natural width 6.3 eV on the one hand and the small shift of the Compton band due to the larger energy of the photons resulted in a strong overlapping as seen in fig.2. We therefor decided to return to the Cr_{K_β} radiation, which however will need measurements of long duration due to the small intensities. Up to this time two such measurements have been carried out at $\varphi = 38°$ and $\varphi=32°$. In the first, $\varphi = 38°$, the scattering angle is very near to the angle φ_0 from which on all the valence electrons contribute to Compton scattering, This curve hence does not have any theoretical interest. The second curve, $\varphi = 32°$, is plotted in fig.3. The Compton band is quite strong and could be accurately separated from the total spectrum if a satisfactory dummy experiment had been devised.

A criterium for a good dummy experiment is the constancy of the ratio $\frac{I_{scat.}}{I_{DE}}$ for the points on the right slope of the Rayleigh line. The symbols $I_{scat.}$ resp. I_{DE} describe the counting rates in the scatteringresp. dummy experiments after substracting the continuous spectrum. On the right slope the Compton component cannot be appreciable and therefor the right slopes of the two curves should coincide after suitable reduction. The ratio $\frac{I_{scat.}}{I_{DE}}$ of the points of the right slope would, in the case, give a constant reduction factor with which to multiply all counting rates of the dummy experiment, if they are to be considered as representing the Rayleigh line in the scattering experiment.

FUTURE WORK

It is most important to find a better dummy experiment. We intend to replace the Li scatterer by a slab of Cr filings and to illuminate it in such a direction so that the undesirable Compton band will be shifted to such a distance from the Rayleigh line where it will no longer disturbe.

The scattering experiments on Li will be continued towards smaller scattering angles where the main theoretical interest lies. The decreasing intensities will demand measurements of longer duration and we are therefor constructing the device for automatic advance of the monochrometer screw and an automatic recorder of the number of counts.

PERSONNEL

A. Theodossiou	I2 months
P. Euthymiou	I2 months

OTHER INFORMATION

Total man hours : 7 hours X 6 days weekly X 52 weeks= = 2184 hours.

Expenses for materials : $ I957.50

Important property: Scintillation counting system.

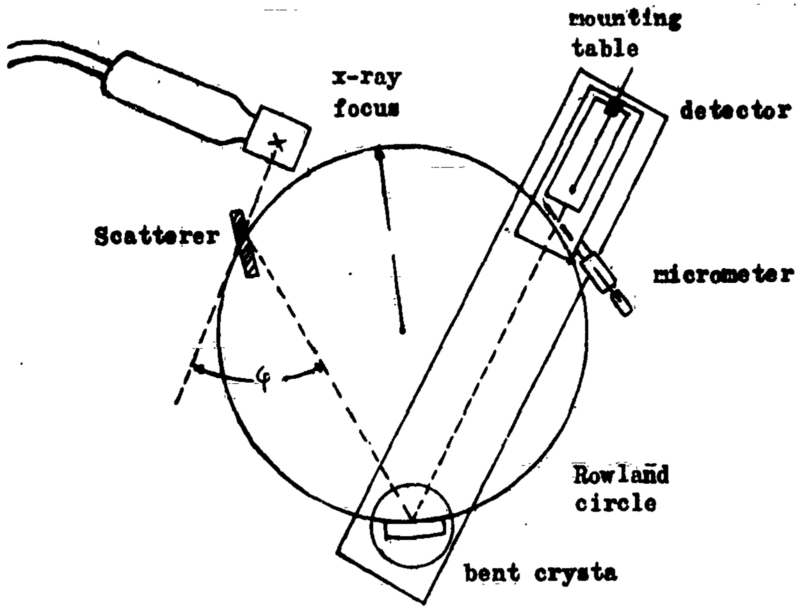

Fig. 1

Experimental Set-up. Radius of Rowland circle 50cm. (Quartz 1340).

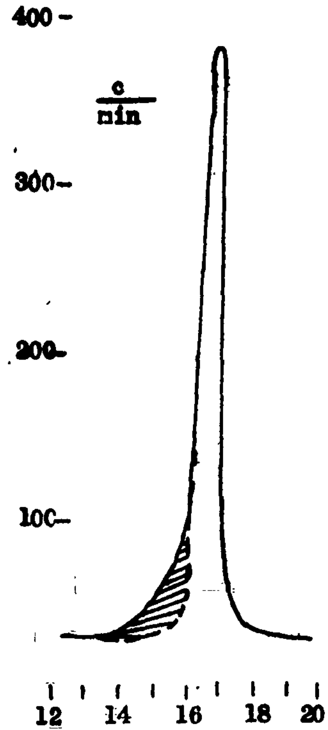

Fig. 2

Cu_β radiation (50kV, 18 mA) scattered on Li at $\varphi = 23^\circ$ Slit 0,1 mm., crystal dimensions $10X5\ mm^2$.

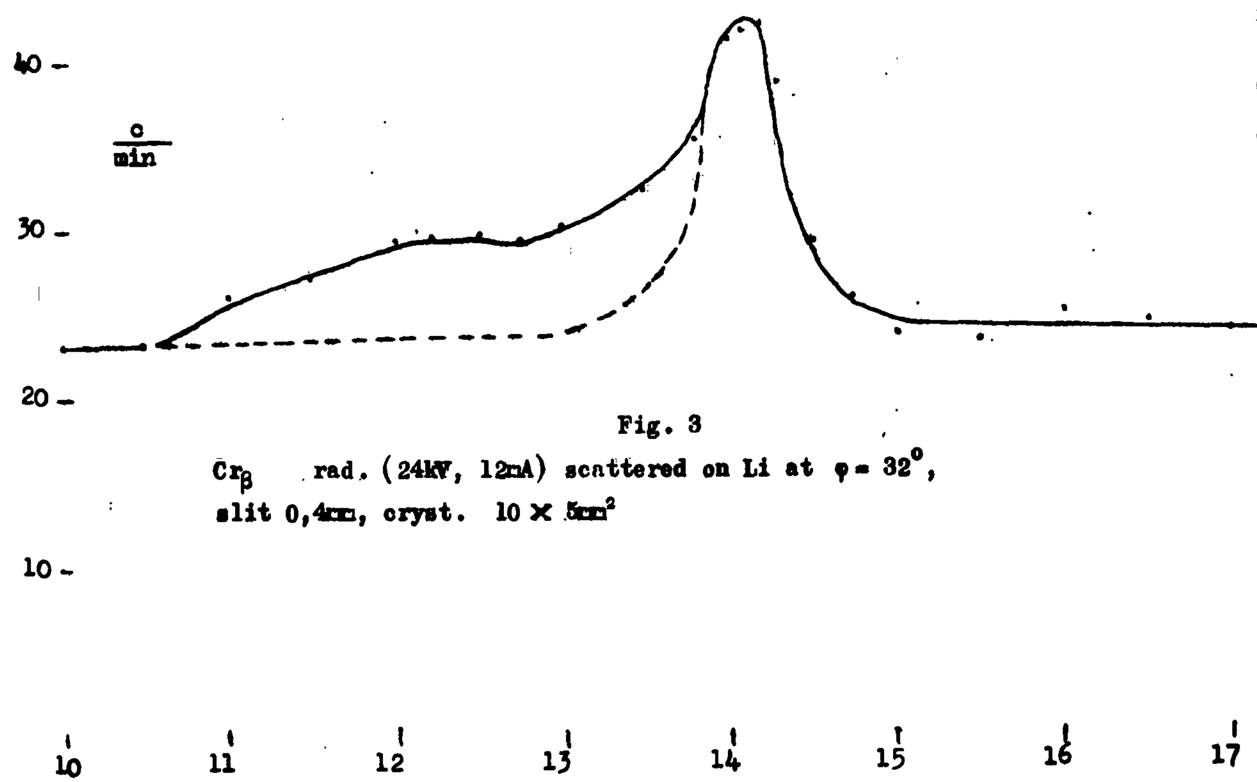

Fig. 3

Cr_β rad. (24kV, 12mA) scattered on Li at $\varphi = 32^\circ$, slit 0,4mm, cryst. $10 \times 5mm^2$