that is required of an electron orbit in such a model is that it shall have the proper energy value and be of the right order of magnitude for atomic dimensions. It may well be that pendulum orbits which satisfy these conditions will still prove useful in atomic theory.

[1] J. W. Nicholson,, *Phil. Mag.*, **45**, 804 (1923).

[2] This fact was first called to the attention of the present writer by Prof. A. E. Ruark.

[3] A. Sommerfeld, *Atombau und Spektral linien*, 3rd German ed., page 735.

[4] E. S. Bieler, *Proc. Roy. Soc.*, **105**, 434 (1924).

[5] B. F. J. Schonland, *Proc. Roy. Soc.*, **113**, 87 (1926).

[6] E. Schrödinger, *Ann. Physik*, **79**, 371 (1926). The number l here used corresponds to n in the paper referred to, in conformity with more recent usage.

MEASUREMENT OF THE MO.K DOUBLET DISTANCES BY MEANS OF THE DOUBLE X-RAY SPECTROMETER

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The doublet which should be present in the $K\beta$ radiation has only been observed in the case of a few elements; between $Z = 41$ and $Z = 50$.[1] Their separation is so small that they appear as a single line except with an instrument of high resolving power.

We have recently found that the double X-ray spectrometer possesses high resolving power when properly arranged. We have obtained a considerable separation of the $K\beta$ doublet of Mo as shown in figure 3.

The geometry of the arrangement used will be easily understood from figure 1. The two slits between the X-ray tube and the crystal Z are quite wide (1.5 mm.) so that a divergent beam comes through to crystal A. Crystal A may be regarded as the collimator and crystal B as the analyzer. If these crystals are nearly perfect, such as split calcite, only one wave-length is reflected at a given angle of incidence. This is not strictly true as it has been found from previous experimental work that some energy is reflected at about $4''$ of arc each side the proper angle for reflection of a given wave-length, λ.

A radiation of certain wave-length, say λ_1 represented by full lines in figure 1, falls on crystal A at proper angle θ for reflection. Any other wave-length proceeding along same path will not be reflected. But radiation of another wave-length such as λ_2 of the figure coming through the slits at a different angle $(\theta + d\theta)$ will be reflected at its proper angle from crystal A to crystal B. That is if two radiations slightly differing in wave-length are present two parallel beams will strike crystal B at slightly different angles of incidence. These two beams λ_1, λ_2 represent in these experiments the Kα doublet in one instant and the Kβ doublet in the other.

The position of crystal B that will reflect λ_1 is shown by the full line in the figure. At this position the λ_2 radiation will not be reflected from B. If now the crystal be rotated through an angle $2d\theta$ to position represented by the broken lines, the λ_2 radiation will be reflected and not the λ_1. The angle $2d\theta$ represents the difference of the angles that the two beams make with surface of crystal B. If $d\theta$ is not too small separate rocking curves are obtained for each radiation (λ_1, λ_2). If the angle $d\theta$ is too small, that is, if λ_1 and λ_2 are too nearly of same wave-length, the two rocking curves merge into one curve of greater width.

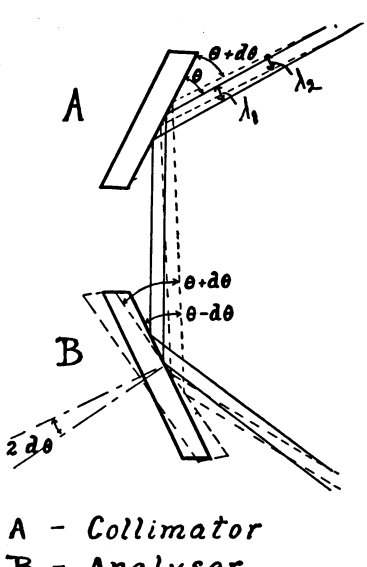
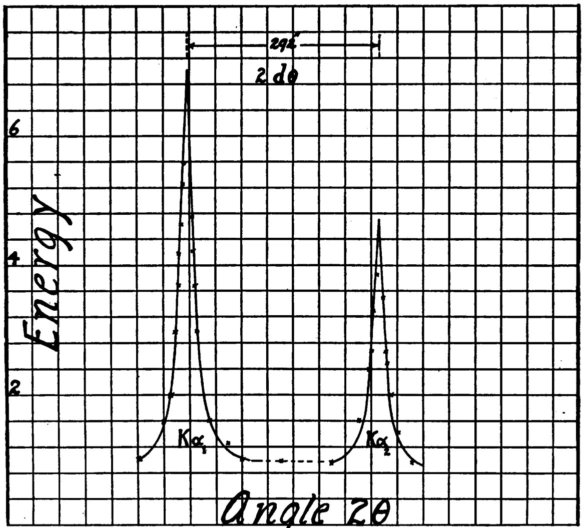


FIGURE 1

Crystal A was mounted in the usual manner at the center of the spectrometer table. Crystal B was provided with a lever arm and tangent screw that permitted small angles of turn to be measured to one-half second of arc. The slits were quite wide, 1.5 mm. or more. The distance between slits was 50 cm. It was found that the width of rocking curve was closely independent of horizontal slit width. An important matter, however, was the vertical height of slits. With slits a centimeter or more in height the rocking curves were quite wide, but their width progressively decreased as vertical height decreased. The vertical height finally used was 1.75 mm. That is, the cross-section of beam falling on A was 1.5 mm. by 1.75 mm. This property that the horizontal slit width does not affect the width of rocking curves is a useful one as sufficient intensity of radiation is obtained to permit quite accurate measurements.

To obtain the same resolving power with a single X-ray spectrometer having slits 50 cm. apart would require very narrow slits, about 0.001 cm. The energy would be too small for accurate measurement. This arrangement of the double X-ray spectrometer increases the resolving power at least ten times over that of the single for the same energy received in the ionization chamber.

The rocking curves obtained are shown in figures 2 and 3. Figure 2 represents the $K\alpha_1\alpha_2$ doublet. The angular separation is about fourteen times the width of curve at half-maximum. The separation of $2d\theta$ = 292″ of arc is the angle read on crystal B. It is twice the separation for a single crystal. The better determination of the α_1, α_2 wave-lengths gives $d\lambda$ = 0.0043 Å. The angular separation corresponding to this is 147″. The above determination gives $^1/_2$(292″) = 146″. The agreement is well within the errors of measurement in both cases.



1 Division = 40 Seconds
FIGURE 2

The Kβ doublet and the Kγ line are shown in figure 3. The separation of $\beta - \gamma$ of $^1/_2$(760″) = 380″ agrees with that obtained from wave-length measurements. The β_1, β_2 doublet is separated by $2d\theta$ = 40″ or $d\theta$ = 20″. The corresponding wave-length separation is $d\lambda$ = 0.00058 Å. Recent reliable determinations of these wave-lengths give β_1, β_2 as 0.630791 Å and 0.631354 Å, respectively.[2] The corresponding doublet distance is 0.000563 Å.

The Kγ line is, of course, a doublet also, but it has not yet been separated. The Kγ curve is wider at half-maximum than the $K\beta_1$, which indicates it is not a single structure. Could the resolving power be increased this would undoubtedly be separated into a doublet.

A consideration of the geometry of the double reflection shows that it is possible to obtain a parallel beam of X-rays of a single wave-length selected out from the continuous X-ray spectrum. In this case a beam having wave-length lying between λ and $\lambda + d\lambda$ will be reflected from crystal A. But only radiation of a given λ will be selected out of this bundle by crystal *B*. This beam will be parallel and monochromatic within the tolerance angle of the crystal (about 4″).

A number of interesting effects have been observed in the case of the radiation from elements of lower atomic number, such as the effect of chemical combination on the structure of the absorption limit observed by Bergengren and Lindh as well as its effect on the structure of the emission lines.[3]

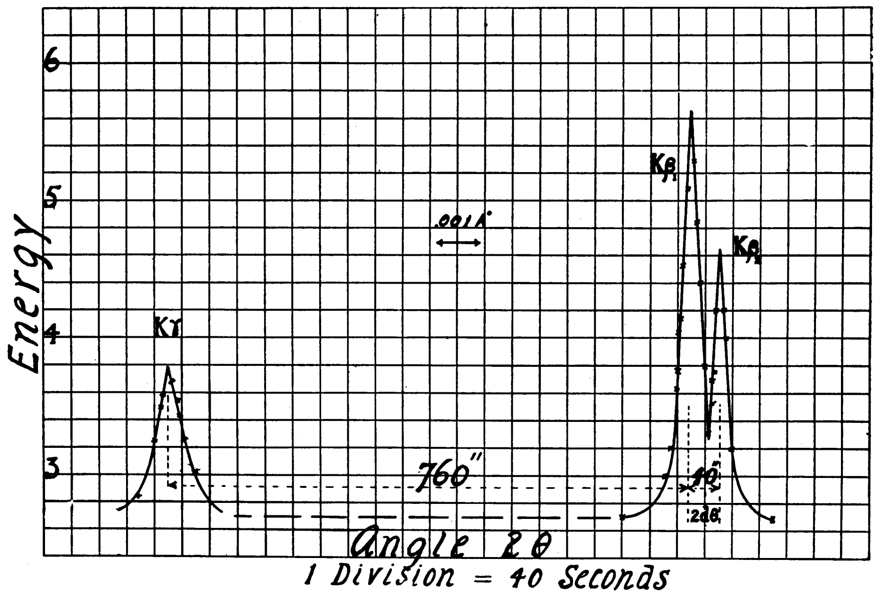


FIGURE 3

Another effect of considerable importance is the fine structure of the emission lines and its dependence on excitation voltage.[4] This arrangement of the double X-Ray spectrometer should make possible the investigation of these and other effects in the case of elements of higher atomic number.

[1] Compton, X-Rays and Electrons.

[2] Allison and Armstrong, *Phys. Rev.*, Dec., 1925.

[3] Siegbahn, *Spectroscopy of X-Rays*, p. 142 and p. 99.

[4] Siegbahn, *Ark. Mat. Ast. O. Fys.*, 18, No. 18.