tube with tungsten anode seems to be produced at high voltage across the tube mostly by secondary electrons knocked out from the levels of the tungsten atom. The probability that an absorption takes place in any level is a function of the voltage applied to the tube, it reaches a maximum and decreases nearly to zero for energies of primary electrons exceeding that of the level by about 40 times. What happens for the absorption of a primary electron must happen for the emission of the characteristic quantum also, because each absorption process of an electron in any level corresponds to the emission of a characteristic ray. Therefore, we have to expect that the intensity of any characteristic series due to the knocking out of electrons of an atom must increase first and then decrease with increasing voltage across the x-ray tube.

The writer desires to thank Professor Duane for his many helpful suggestions and his valuable criticism while this investigation has been in progress.

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ABSOLUTE X-RAY WAVE-LENGTH MEASUREMENTS

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As a result of their work on the diffraction of x-rays by a ruled grating, Compton and Doan (*Proc. Nat. Acad. Sci.*, **11**, 598 (1925)) made the statement that they saw "no reason why measurements of the present type may not be made fully as precise as the absolute measurement by reflection from a crystal, in which the probable error is due chiefly to the uncertainty of the crystalline grating space." Work has been in progress with the view of getting more precise measurements by this method than is at present possible by the crystal method. The method used follows closely that of Compton and Doan, rather than that of Thibaud (*Rev. d'Op.*, **5**, 105, 1926; *Phys. Zeit.*, May, 1928, and elsewhere).

With the small glancing angles (large angles of incidence) used, the usual formula for wave-length in optical work becomes:

$$n\lambda = D\left(\alpha\theta + \frac{1}{2}\alpha^2 - \text{4th degree terms}\right)$$

where D is the grating space, n is the order of diffraction, θ is the glancing angle, α is the angle between the zero order and the nth order. It was found unnecessary to use the 4th degree terms. Very accurate determinations of α and θ are thus required for a precise determination of the wave-length.

The experimental arrangement is shown diagrammatically in figure 1. The particular line to be measured was reflected from a calcite crystal C and collinated by the slit S_2 before reaching the grating G. The grating was so aligned that the x-ray beam would be reflected first in one position, then in a position approximately 180° from it. The dotted line DG is the direct beam; $G + 0$ the reflected beam from the face of the grating as shown, called positive zero for short; the dot-dash line $G - 0$ the reflected beam in the second position, called negative zero.

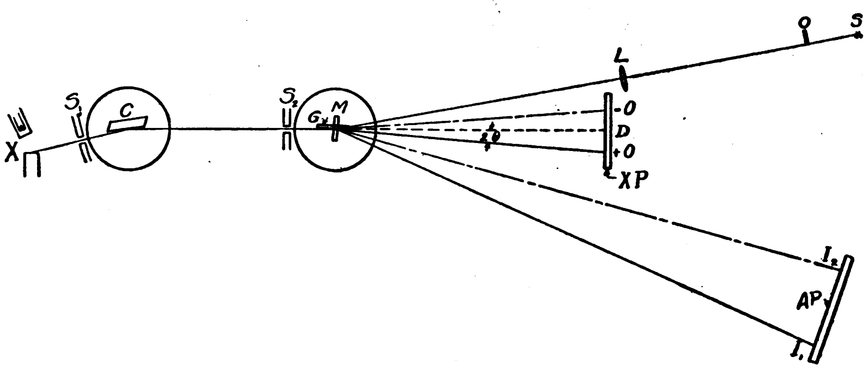

FIGURE 1

In order to obviate the necessity of measuring the indeterminate distance from the plate to the effective part of the grating for the purpose of determining the glancing angle, a plane parallel mirror M was mounted on the grating table so as to move as an integral part of it and the image of a straight edge O brought to a focus on the plate AP, I_1 corresponding to $+0$, I_2 to -0. With this arrangement no negative order was necessary for determining the glancing angle.

Having aligned the apparatus photographically the following steps were taken. The grating was first moved out of the beam and a short exposure of the direct beam recorded on the plate XP. This place on the film was then protected from further immediate exposure with a strip of lead and the grating moved back to its position and a short exposure taken to record the negative zero order. The position of the grating was then recorded by an exposure on plate AP after which the grating was turned and the positive position recorded. Sufficient time was allowed for the recording of the positive zero order on plate XP, then the direct beam was uncovered and a lead frame placed in front of the film so that only the central portion was exposed to the action of the x-rays. When the exposure had been going for a time sufficient to record several orders of the spectrum and before the plate XP was removed, a check on the glancing

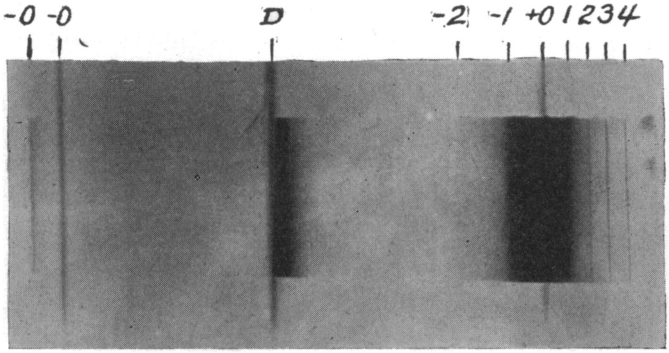

FIGURE 2

angle was obtained by putting another plate at AP, recording the position of the grating, then rotating back to get a second negative zero order, the position of which was also determined. The room temperature did not vary more than 1°C. during the exposure.

Figure 2 is an enlargement of a plate obtained at XP, and is typical. It was obtained for the $K\alpha_1$ line of Cu at a glancing angle of 21′ 19.5″ after an

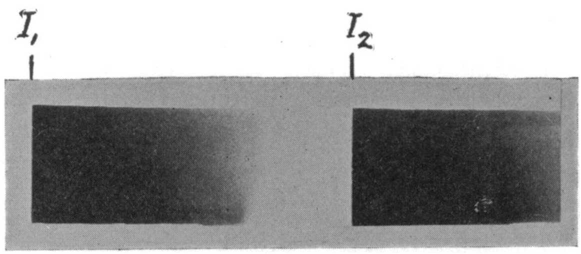

FIGURE 3

exposure of about 30 hours at a distance of approximately 1 meter. The tube was operated at about 30 kv. peak. The two negative zero orders are shown at -0, direct beam at D, positive zero order at $+0$, two negative diffracted orders at -2, and -1, and four of the six measurable positive diffracted orders at 1 to 4. The 6 positive orders are easily visible and measurable on the original negative. The broad beam beside D is that part of the direct beam which passed the grating. Figure 3 shows the type of plate obtained at AP, the distance MI_1 being about 2 meters.

If $I_1I_2 = c$, $MI_1 = d$, $D - 0 = a$, $D + 0 = b$, $\frac{c}{d} = m$ and $\frac{a}{b} = l$ then $\tan 2\theta = \frac{m}{l + 1}$, to the degree of accuracy required. Having determined θ it is an easy matter to determine $\theta + \alpha_n$ and hence α_n. Measurements of the plates XP and AP were made on two comparators on different days and results of different observers used. The only distances not measured on the comparator were MI_1 and the grating space. The former was measured by making fiducial marks on a steel tape and comparing the distance between these marks with a standard meter. The results obtained from measurements of some of the plates on hand are given below. In each case a speculum metal grating was used. Only 5 mm. were ruled, the length of the lines being 2 cm. The grating space as determined with a Geneva spectrometer using the green line of mercury was 2.0000×10^{-3} cm. The column at the right are the values taken from Siegbahn, "The Spectroscopy of X-Rays" (Ox. Univ. Press, 1925), p. 105.

Cu $K\alpha_1$	1.5374 ± 0.0006	1.53730 Å
Fe $K\alpha_1$	1.937 ± 0.004	1.93230 Å
Mo $K\alpha_1$	0.708 ± 0.002	0.70759 Å

The probable errors are those estimated from the errors in the measurements of the distances involved. The Cu wave-length is the weighted mean of measurements on the 1, 2, 3, 4, 6 positive orders of the plate of figure 2. That for Fe is the result of a calculation on only 1 positive order, and although the lines of the plate were not as sharp as on plates for Cu and Mo, the angles were of such a magnitude as to partly offset this circumstance. The Mo wave-length is the weighted mean of three measurements on first-order spectra only. The sharpness of the lines seems to warrant recording the result.

A continuation of the work is in progress. The writer wishes to thank Professor A. H. Compton for his keen interest and for the valuable suggestions he has made. Acknowledgment of the suggestions of Dr. J. A. Bearden is also made and indebtedness is due Dr. R. L. Doan who had designed a considerable part of the apparatus before the writer started work.