

valuable in estimating the relative probability of excitation to the various levels which are difficult to observe spectroscopically. I think sufficient resolving power could be obtained to separate the 4.7 volts and 4.9 volt levels. The method has the great advantage that the collisions take place in a completely field-free space.

The intensity of the 11.5 volt peak is surprising. If it is the result of two successive collisions as explained above, it should be less intense than the 4.7 volt, 4.9 volt, and 5.4 volt peak. No satisfactory explanation of its intensity has been found. Foard, in an abstract (*Bull. Am. Phys. Soc.*, Dec. 13, 1929), has described some similar experiments using a magnetic analysis. He seems to have obtained slightly higher resolution. He finds a peak at 7.7 volts, the  $1^2S_1$  energy level. This peak does not occur either in my experiments or in those of Whitney. Otherwise the same peaks were found.

In the present experiment, the electron gun could be rotated to give an angular distribution of the scattered electrons and some results have been obtained. They are not very accurate, and agree in general with those of Arnot (*Proc. Roy. Soc.*, vol. 125, p. 660), so nothing further need be said about them.

These experiments were made possible by the kindness of Prof. A. M. Tyndall in placing the facilities of the Wills Physical Laboratory at the University of Bristol at my disposal. The work was done while I held an 1851 Exhibition Senior Studentship.

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#### Glancing Angle of Reflection from Calcite for Silver ( $K\alpha_1$ ) X-Rays.

WE have measured the first order glancing angle at which the  $K\alpha_1$  line of silver is reflected from the cleavage planes of calcite by a method independent of any used by those who have obtained the most reliable results so far. The weighted mean value of fourteen independent observations reduced to 18° C. is  $5^\circ 17' 13.81'' \pm 0.06''$ .

This value was obtained from spectrograms taken on a new spectrometer specially designed to utilise the displacement method introduced by H. S. Uhler (*Phys. Rev.* [11], 11, 1-20; 1918). A full description of the method, instrument, and results will be given later.

The value of the wave-length corresponding to the above glancing angle is  $0.558238 \text{ \AA} \pm 0.000002 \text{ \AA}$ . obtained by using  $3.02904 \text{ \AA}$ . for the 'effective' grating space of calcite (Siegbahn, "Spectroscopy of X-Rays", 1924 edition).

The thermal coefficient of expansion at 18° C. for the grating space of calcite obtained from the most trustworthy sources, without approximations, is  $0.000102_3/^\circ \text{C}$ . This value differs by about 2 per cent from the generally quoted value originally given by W. Stenström (Dissertation, Lund, 1919) as a sufficient approximation.

It is interesting to note that our value of the glancing angle is 1.4" smaller than that given by G. Kellström (*Zeit. f. Phys.*, 41, 516; 1927) for the first order of calcite, namely,  $5^\circ 17' 15.2''$ . The probable error of the unweighted mean of Kellström's seven determinations for this order is  $\pm 0.04_5''$ . The unweighted mean of his four second order determinations is also larger than ours and has relatively four times this probable error. With such a difference existing, one wonders if the grating spaces of the crystal specimens used were the same. We employed an unusually selective piece of calcite which was

cleaved from an excellent specimen of Iceland spar contained in the Marsh collection of Yale University.

Our value is larger than those of K. Lang (*Ann. d. Physik*, 75, 489; 1924), A. Leide (Dissertation, Lund, 1925), and A. P. Weber (*Zeit. f. Wiss. Photo.*, 23, 149; 1925), although coming within  $0.11''$  of Lang's and  $0.36''$  of Leide's results when their probable errors are added to their respective mean values.

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#### The Nuclear Moment of Lithium.

THE fact that the hyperfine structures of spectral lines are so much narrower than the multiplets in the same spectrum is due principally to the fact that the latter are produced by the magnetic moment of the electrons, while the former originate from the magnetic moment of the nucleus, which is usually attributed to nuclear protons, and is, therefore, about 1840 times smaller.

The hyperfine structure of the  $\text{Li}^+$  spectrum, discovered by Schüler (*Zeit. f. Phys.*, 42, 487; 1927) is of the same order of magnitude, however, as the multiplet separations themselves. From this fact Heisenberg (*Zeit. f. Phys.*, 39, 516; 1926) drew the conclusion that the magnetic moment of the lithium nucleus was of the same order of magnitude as that of an electron, and therefore caused by electrons in the nucleus and not by protons. The experiments of Taylor (*Zeit. f. Phys.*, 52, 846; 1929) on the Stern-Gerlach effect with lithium atoms failed, however, to indicate the expected large magnetic moment for the nucleus.

In the following we will show that the nuclear magnetic moment is not very large, and that the wide hyperfine structure is caused by the presence of a single  $1s$  electron in the configurations considered.

In a recent letter to NATURE (125, 16; 1930), Fermi has given an expression for the interaction between the nuclear moment and the external electrons derived from quantum mechanics.<sup>1</sup> For an  $s$ -state in an hydrogenic atom the doublet separation ( $s$ -states have  $j=1/2$  and thus split into two levels) will be

$$\Delta\nu = \frac{8}{3} R\alpha^2 \frac{Z^3}{n^3} \cdot \frac{g(i)}{1840} \cdot (i + \frac{1}{2}).$$

In this expression we denote by  $g(i)$  the ratio between the magnetic and mechanical moments of the nucleus, its Landé  $g$ -value, but in units 1840 times smaller than used for electrons, in order to obtain the magnetic moment of a spinning proton as unity. Since the mechanical moment of a spinning proton is  $1/2$  quantum unit, its  $g(i)$  is thus 2. The mechanical moment of the nucleus is denoted by  $i$ .

Applied to doubly ionised lithium the lowest  $s$ -state would have a doublet separation of

$$\Delta\nu = 0.228 g(i) \cdot (i + \frac{1}{2}) \text{ cm.}^{-1}.$$

For the  $1s 2s$  and  $1s 2p$  configurations of  $\text{Li}^+$  we may assume that the hyperfine structure is mainly due to the presence of the  $1s$  electron. The added electron will have some screening effect on the  $1s$  electron, but as it is an outer electron this effect will be very small. Furthermore, the screening effect of the  $1s$  electron upon the  $2s$  or  $2p$  electron will be large, and as these

<sup>1</sup> The same expressions were known to us before from unpublished material of H. Casimir, presented at a meeting in Copenhagen last April. For a general state in an hydrogenic atom Casimir obtains for the interaction energy:

$$\Delta E = R\hbar c \alpha^2 Z^3 / n^3 (l + \frac{1}{2}) j(j+1) \cdot g(i) / 1840 \cdot ij \cos(i, j),$$