Letters to the Editor.

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The Crossed-Orbit Model of Helium.

THE spectrum formula

$$\nu = N\left[3 - \frac{7}{4^n}F\left(\sin\frac{i}{2}\right)\right], \quad . \quad . \quad . \quad (a)$$

proposed for helium in my letter of March 1 (NATURE of April 28, p. 567), was shown to yield, for $-\cos i = \frac{1}{2}$, the correct ionisation potential and, for $\frac{1}{5}$, $\frac{3}{8}$, $\frac{5}{8}$, $\frac{5}{9}$, the four Lyman lines; with that corresponding to the former as the limit. The deduction of this formula (on lines by no means classical) and the attitude to be taken with regard to the "negative" results obtained in the meantime by Dr. Kramers by means of classical mechanics (*Zeits. f. Physik*, 13, 312) have been fully explained in a paper appearing in the June issue of the *Astrophys. Journal*, and need not be repeated here. The purpose of this letter is to point out some further peculiarities of the formula (*a*) as such, which will be seen to bring order into the apparently queer correlation given before.

If the simple rational values of $-\cos i$ are ordered in descending magnitude, namely,

$$\frac{4}{5}\ (\tfrac{3}{4})\ \tfrac{3}{5}\ (\tfrac{5}{8})\ \tfrac{3}{5}\ (\tfrac{4}{7})\ \tfrac{5}{9}, \quad . \quad . \quad . \quad (b)$$

every second, bracketed one, covers no observed line, while the others represent orderly the first four members, $m = 1$, etc., of the Lyman series $o\mathrm{S} - m\mathrm{P}$. Extrapolating the regular sequence of the last three fractions by

$$(\tfrac{6}{11})\ \text{and}\ \tfrac{7}{13},$$

one would expect the former to cover no line and the latter to represent the line $o\mathrm{S} - 5\mathrm{P}$, which, though hitherto not observed, can be expected with confidence. Now, with Lyman's $o\mathrm{S}$ and the usual 5P, this line should lie at $\lambda_5 = 512{\cdot}1$, while formula (*a*) gives, for $\cos i = -7/13$, $\lambda = 512{\cdot}3$. Again, turning to the left-hand end of the sequence (*b*), the next fraction $\frac{5}{8}$ naturally suggested itself as worth trying. For this value of $-\cos i$ ($i/2 = 73{\cdot}221°$, $\mathrm{F} = 2{\cdot}6642$) formula (*a*) gives $\lambda = 601{\cdot}2$, which is very close indeed to the "single line at $600{\cdot}5 \pm 0{\cdot}3$," repeatedly obtained by Lyman. As I understand from Prof. Lyman himself, he feels reasonably certain that it is genuine and that it belongs to the spectrum of helium. Moreover, from the semi-empirical point of view, the "combination" line $o\mathrm{S} - 1\mathrm{S} = 198{,}300 - 32{,}033$ would lie at $\lambda = 601{\cdot}3$, which is still closer to our result.

Thus, gathering the scattered items, we have, as an extension of (*b*), the following correlation (in which the bracketed numbers cover no observed lines):

$\frac{5}{9}$	$\frac{4}{5}$	$(\frac{3}{4})$	$\frac{3}{5}$	$(\frac{5}{8})$	$\frac{3}{5}$	$(\frac{4}{7})$	$\frac{5}{9}$ $(\frac{6}{11})$ $\frac{7}{13}$ . . . $\frac{1}{2}$.
$o\mathrm{S}-1\mathrm{S}$	λ_1		λ_2		λ_3		λ_4 λ_5 λ_∞

(*c*)

Notice that, according to Prof. Lyman, the arc spectrum of He contains no lines in addition to those here covered. The regular intermittency of (*c*), so far as the members $o\mathrm{S} - m\mathrm{P}$ are concerned, is manifest. The position of $o\mathrm{S} - 1\mathrm{S}$—the "queer" line, as Dr. Compton of Princeton called it—is correspondingly queer. Yet even this, though only a combination line, fits into the further remarkable regularity of the whole sequence (*c*), to wit, that the differences between the successive fractions are all of the form $1/np$, thus $5{\cdot}5 - 4{\cdot}6 = 1$, $4{\cdot}4 - 3{\cdot}5 = 1$, $3{\cdot}3 - 4{\cdot}2 = 1$, and so on. This curious feature was first noticed by my friend Prof. A. S. Eve of Montreal only after the whole array (*c*) was spread over the black-board in a recent lecture at the Bureau of Standards. It may thus be said to have grown out spontaneously, and certainly did not influence the writer in constructing the proposed formula.

So long as intra-atomic dynamics is awaiting its final shaping from modern groping attempts at a suitable modification of ordinary mechanics, every such regularity of correlation, no matter how "magical" in appearance, seems worthy of noticing, as a possibly helpful hint how to alter the old laws for intra-atomic purposes. LUDWIK SILBERSTEIN.

129 Seneca Parkway,
Rochester, N.Y., May 15.

Symmetry of Calcium Thiosulphate Hexahydrate.

CALCIUM thiosulphate hexahydrate, $CaS_2O_3 . 6H_2O$, is usually quoted in works on crystallography as an example of the triclinic asymmetric class, C_1^1—perhaps as the only known crystal which definitely represents this type of structure. It is described in Tutton's "Crystallography" (new edition, p. 280, old edition, p. 285), and, in more detail, in Groth's "Chemische Krystallographie," vol. 2, p. 676. In the latter we read

$$CaS_2O_3 . 6H_2O. \quad \text{Asymmetric.} \quad \text{Sp. gr. } 1{\cdot}872.$$
$$a : b : c = 0{\cdot}7828 : 1 : 1{\cdot}5170.$$
$$\alpha = 72° 30', \quad \beta = 98° 34', \quad \gamma = 92° 45\tfrac{3}{4}'.$$

The process by which symmetrical crystals are built up from less symmetrical material has been recently described by Sir William Bragg ("The Significance of Crystal Structure," Trans. Chem. Soc., 1922, vol. 121) and G. Shearer ("The Relation between Molecular and Crystal Symmetry as shown by X-ray Crystal Analysis," Proc. Phys. Soc., February, 1923). In the latter paper the author suggests that Nature never uses more molecules than are absolutely necessary for the purpose; that is, no more than N asymmetrical molecules will be used in the construction of a crystal of "symmetry-number" N, or, if the symmetry of the molecules be that of some class n, then no more than N/n will be used. Up to the present this hypothesis seems to be justified. In all organic crystals that have been examined in Sir William Bragg's laboratory not one has yet been found to contradict it. In all cases there has been no evidence to show that polymers of chemical molecules have been used, but, on the contrary, abundant evidence to show that the ultimate structural bodies correspond to the simple chemical molecules. Furthermore, it has been shown that, in general, the symmetry of a crystal is of a higher type than that of the molecules from which it is built—a rule which seems to be almost universally true. Especially with complex molecules does Nature resort to the device of combining a molecule with its digonal or its enantiomorph before using them to construct a Bravais lattice.

In view of these considerations it seemed very probable that, should a truly asymmetric crystal be obtained, its space-lattice would be found to be constructed of asymmetric groups of atoms corresponding to single chemical molecules; that is, it would be found to contain only one molecule per fundamental cell. Such a case seemed to be presented by $CaS_2O_3 . 6H_2O$, and, indeed, it was expected that X-rays would show it to be a simple triclinic lattice of single asymmetrical molecules, obeying, of course, the law of rational indices, but exhibiting no symmetry operation beyond that of identity.