

give their assistance in any scientific capacity in the event of war coming despite their efforts to prevent it. Without trained technical assistance the warfare of the future will be impossible. If they wish to carry a rifle, by all means let them: they will not do much harm with a rifle. But a refusal to give their technical assistance would not only bring any war to a standstill, but would also be the strongest possible guarantee against it breaking out. If this measure is not taken, and promptly, we may well fear that the new order that rises from the ruins of the old will persecute science as whole-heartedly as ever did the rulers of the Middle Ages, and with better reason.

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The Heisenberg Theory of the Anomalous Zeeman Effect.

IN his theory for doublets Heisenberg (*Zeit. f. Physik*, 8, 273, 1922) assumes that the atom may be looked at as made of two parts: (1) the shell and (2) the valence electron. Expressing angular momenta in multiples of $\hbar/2\pi$ and choosing the direction of the angular momentum of the shell as positive, the electron is allowed to have angular momenta $I = \frac{1}{2}, \pm\frac{3}{2}, \pm\frac{5}{2}, \dots$ in the s, p, d, \dots states respectively, and the shell has in all of the states the angular momentum $\frac{1}{2}$. The observed Zeeman patterns show that $I = \frac{3}{2}$ in $2p_1$ and $I = -\frac{3}{2}$ in $2p_2$. The observed energy levels show that the energy in $2p_1$ is higher than in $2p_2$. The writer experienced the following difficulty in accounting for this relative position of energy levels.

Various hypotheses can be made as to the nature of the interaction between the shell and the electron. We may suppose, for example, that the magnetic field of the electron induces a precession in the shell in a manner analogous to that in which an external magnetic field induces a precession in the electronic orbit. We then suppose, too, that the field due to the shell produces a precession of the electron. The contribution to the kinetic energy of each of these precessions is $-\mu H \cos \vartheta$, where μ, H, ϑ are respectively the magnetic moment of the shell, the field at the shell due to the electron, and the angle between the positive directions of μ and H . The contribution of both is $-2\mu H \cos \vartheta$. The mutual energy of the magnetic fields is $+\mu H \cos \vartheta$. There is no contribution to the energy of the electric field because the radius of the orbits is unchanged (Sommerfeld, "Atombau und Spektrallinien," third edition, p. 380). The energy to be added to that coming from other sources is then $-\mu H \cos \vartheta$. On this hypothesis, therefore, the $2p_1$ state has the lower energy, while the reverse is actually the case.

If there were no induced precession in the shell, but if the electronic precession should be still hypothesised, the $2p_1$ and the $2p_2$ levels would coincide.

If the shell and the electron should be supposed to have no induced precession, the energy of the magnetic field becomes the only source for the energy of separation of the $2p_2$ levels. This energy is $+\mu H \cos \vartheta$ and thus makes the $2p_1$ level the state of higher energy, as it is actually observed to be.

It seems questionable, however, whether the hypothesis just made can be maintained, for it presupposes that the dimensions of the orbits of the valence and the shell electrons are the same in the $2p_1$ and the $2p_2$ state. This may be contrary to quantum conditions if the energy of the magnetic field is considered as kinetic energy. If two electrons should be constrained to move on the opposite ends

of a diameter of a circle of variable radius (as in Bohr's first helium model), the kinetic energy becomes of the form:

$$\frac{m_1 v_1^2}{2} + \frac{m_2 v_2^2}{2} + M_{12} v_1 v_2 = (m_1 + M_{12}) v_1^2,$$

where m_1, m_2, v_1, v_2 are respectively the masses and velocities of the electrons and $M_{12} v_1 v_2$ is the mutual energy of their magnetic fields. The case is formally analogous to the hydrogen atom, and a substitution in well-known formulas shows that the total energy becomes decreased if M_{12} is increased. The reason for this is traceable to a decrease in the radius of the orbit. Thus again the effect on the $2p_1$ level is opposite to that observed.

The matter of the sign of the energy in the doublet terms thus does not appear to the writer to be sufficiently clear.

The same question of sign is present in the case of triplet terms. In addition to this the $2p_2$ term of triplets does not seem to be accounted for properly by Heisenberg. His arrangement of angular momenta accounts for the energy level of the $2p_2$ state. I obtain, however, a different result for the Zeeman resolution. On going through Heisenberg's calculation his lines 5, 6, counted from the bottom of page 292 and leading to the equation $\cos \theta = m/p_{12}$ do not appear obvious. His p_{12} is the projection of a vector in the direction J , m is the projection of the same vector in the direction H , and θ is the angle between J and H . The above equation is then $\cos(JH) = \cos(AH)/\cos(AJ)$, which does not appear to be generally valid. It becomes correct, however, if A and J are the same. They are the same for doublets and for the $2p_1, 2p_3$ terms of triplets, but not for the $2p_2$ term.

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Thunderstorms and Ozone.

THE question—What chemical changes, if any, are associated with atmospheric electrical discharges?—does not appear hitherto to have received a definite answer. Nitrogen peroxide and ozone are both referred to in scientific literature, although neither appears to have been satisfactorily identified, and their presence has been perhaps inferred from the phenomena observed while "sparking" air by artificial means.

No reliance can be placed upon observations made with guaiacum or starch-potassium iodide papers, and the work of the more serious investigators on ozone in the air (Pring, *Proc. Roy. Soc.*, 1914, 90a, 204; Hayhurst and Pring, *Jour. Chem. Soc.*, 1910, 868; Kaiser and McMaster, *Am. Chem.*, July 1, 1908, 39, 96; Henriot and Bonissy, *Comp. rend.*, 1908, 146, 977; and the older work of Houzeau, Schöne, H. de Varigny, Hached and Arny, and Thierry) has thrown no light on this subject.

Unexpectedly clear evidence on the above point was obtained by me in connexion with the severe thunderstorm which passed over the metropolis from south to north, during the early hours of July 10 last. The lightning on this occasion was generally described in the London press as the most vivid and prolonged display in living memory (*vide* NATURE, July 21, p. 113).

I have for some time been measuring the proportion of certain variable gaseous constituents in London and country air, and succeeded last spring in working out an improved method of estimating ozone, in