quadratics. The lowest multiplet level of Pr splits up into two triply degenerate and one non-degenerate level. Agreement with experiment is obtained when the nonmagnetic, single level is placed lowest. The lowest multiplet level of Nd splits up into two quadruply degenerate and one doubly degenerate level, and here the doubly degenerate level must be placed lowest. The results agree satisfactorily with the measurements of Gorter and de Haas.[2] The over-all splitting produced by the crystal field is about 360 cm^{-1} for Pr and 840 cm^{-1} for Nd.

Calculations have also been made for Ni. Here the separation of energy levels due to the crystal field is much larger than the multiplet separation. The close equality of the observed principal susceptibilities suggests that the field is nearly cubic. If we neglect the spin, the ground state is split by the cubic field into one nonmagnetic and two magnetic levels; the nonmagnetic level must, for agreement with experiment, lie so far below the others that it alone is a normal state. The orbit-spin interaction is incapable of splitting this level which now has three coincident components. Thus the spin remains entirely free, and the susceptibility is rigorously proportional to $1/T$. The orbit-spin interaction, however, introduces an orbital contribution, so that the magneton number has a value intermediate between the Bose-Stoner value $[4S(S+1)]^{1/2}$ and the Laporte-Sommerfeld value $[4S(S+1)+L(L+1)]^{1/2}$. From the known value of the magneton number, we deduce an over-all separation of some 20,000 cm^{-1} due to the cubic field. If now a rhombic term is introduced into the Hamiltonian, the degeneracy of the lowest level is removed, the separation being of the order of a few wave numbers, and it is possible to explain the small differences in the principal susceptibilities. The dependence on temperature is now of the form $\chi=C_1/T+C_2/T^2+\cdots$ with different values of C_1, C_2, and Δ for the three axes. The average Δ is zero down to very low temperatures, in agreement with the very small observed value.

We have also considered Cu. Here the principal susceptibilities are so different as to preclude a cubic field. On the basis of a rhombic field producing a splitting large compared with the multiplet width, it is found that the law $\chi=C/T$ is obeyed by the susceptibility down to very low temperatures (cf. the experiments of de Haas and Gorter[3]). Thus the rhombic field alone does not introduce a correction to Curie's law, although it gives different Curie constants for the three axes.

These quantitative results are in general agreement with the qualitative predictions of Van Vleck (Quantum Theory of Electric and Magnetic Susceptibilities, Oxford University Press, Chap. XI), the chief difference being that the crystal fields are usually more nearly cubic than was there supposed, and also that the condition given for the spin to be free, namely (orbit-spin interaction)^2/(crystal field separation)$\ll kT$, is often too stringent.

The experimental material indicates that substances of high magnetic dilution, as for example the hydrated sulphates, have smaller values of Δ than the corresponding anhydrous salts. In these latter substances of very low magnetic dilution the effect of crystal fields on the deviation from Curie's law is probably subordinate to the influence of coupling between the angular momentum vectors of neighboring atoms, which will also give rise to a term Δ.

Further computations are in progress on cerium, cobalt and iron. Details of the work will be published shortly.

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[2] Gorter and de Hass, Leiden Com. 218b.

[3] de Haas and Gorter, Leiden Com. 210d.

The Production of Multiple Secondaries in Lead by Cosmic Radiation

Recently Rossi[1] has shown that triple coincidences occur in three G.M. counters placed out of line if these are surrounded by lead. We have observed a similar phenomenon with two G.M. counters arranged as shown in the accompanying diagram, Fig. 1.

Coincident discharges of the two counters were recorded on a telephone message register, operated by circuits soon to be described. The resolving time of the circuits was such that the accidental coincidences amounted to only two or three per hour and hence could be

[1] Bruno Rossi, Phys. Zeits. **33**, 304 (1932).

entirely neglected. At the spacing used the real coincidences averaged 1.71 per minute with a probable error of ± 0.03 per minute

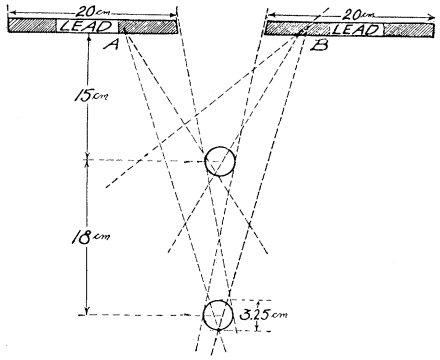

Fig. 1.

over a counting time of 1568 minutes. When blocks of lead $20\times32\times1$ cm were placed on either side of the counters in positions such that straight line paths through both counters were impossible for secondary rays originating in the lead, then the counting rate *increased* to 1.84 ± 0.03 over a counting time of 1312 minutes. The difference in the counting rates of 0.13 ± 0.04 must be attributed to some process by means of which the same primary ray ejects two or more secondaries from the lead at slightly different angles, some of these passing through one counter and others through the other counter. These secondaries may arise from the spraying out of distingegration products from a single nucleus as illustrated at *A* in the figure or they may be emitted as recoil electrons or protons at different points along the path of the primary ray as illustrated at *B*.

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April 25, 1932.

The Crystal Structure of Insulin

It has been known for some time that insulin exhibited certain optical properties of a true crystal.[1] Although numerous attempts have been made by Freudenberg[2] and others, no x-ray diffraction pattern could be obtained beyond the usual ring due to the 3.5A spacing common to proteins. Work of this kind employing the usual lengths of x-radiation, (copper $K\alpha$, 1.54A) has been done in this laboratory over a period of two years.

Recently insulin has been investigated by means of long wave x-rays, using the $K\alpha$ radiation of magnesium and aluminum. The method employed was essentially the same as previously used,[3,4] but a new type of apparatus was designed for the purpose.

The spacings found for insulin by this method are approximately 130, 100, and 80A, giving an axial ratio of 4/3:1:4/5. With the aid of microscopic data the crystal form was found to be monoclinic, with one angle between 88 and 90 degrees, the individual crystals frequently assuming a pseudo hexagonal form. The crystals were positive.

On the basis of the approximate molecular weight of 35,000 proposed by DuVigneaud,[5] and checked by others,[2] and the density of 1.315 determined by Freudenberg[2] and checked by us, the number of molecules per unit cell was found to be 26.

More complete data will be prepared for publication in the very near future, and the method will be applied to other proteins.

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K. E. CORRIGAN
Chemistry Department,
University of Illinois,
May 2, 1932.

[1] E. B. Mathews, Reported by Wintersteiner, DuVigneaud, and Jensen. Jour. Pharm. and Exp. Therapeutics **31,** 84 (1927).

[2] Freudenberg, Hoppe-Seyler's Zeits. f. physiol. Chem. **204,** 233 (1927).

[3] Clark and Corrigan, Radiology **15,** 117 (1930).

[4] Clark and Corrigan, Jour. Ind. and Eng. Chem. **23,** 815 (1931).

[5] DuVigneaud Jour. Bio. Chem. **70,** 393 (1927).

Erratum: Dissociation of the Carboxyl Group in Amino Acids and Related Substances, Produced by Absorption of Ultraviolet Light

Three typographical errors occurred in the printing of the above mentioned letter to the Editor (Phys. Rev. **40,** 115 (1932)). To correct these the word "cystine" should replace