much current as a surface which had been well degassed. Thus the efficiencies found for such surfaces were of the order of 5 percent and 2 percent for Ne and A respectively.

Photoelectric currents obtained with Hg discharges were relatively very small and sufficiently in accord with the known values of the efficiency of the normal photoelectric effect in the general region of λ2500A (taken to be of the order of 0.1 percent or 0.2 percent for metals like Ni.) The present results may also be compared with the maximum efficiencies reported for the total currents in the selective effect in the case of sensitive films of the order of 1 percent or 2 percent.

Preliminary experiments with He have yielded values of the efficiency comparable with those in Ne. The experimental conditions were not, however, as favorable in He as in the other cases and the evidence was not as clear that the action of metastable atoms was unimportant.

The experiments are being continued and extended to surfaces of different work functions. Details will be given in a later paper.

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October 29, 1931.

Zeeman Effect in Solids

J. Becquerel,[1] Freed and Spedding,[2] and others have reported that the absorption lines of the rare earth spectra split into doublets of enormous separation when a magnetic field is applied. Both Becquerel and ourselves have stated that some lines under certain conditions resolve into more components; however, both emphasized that the doublets were the most striking facts observed. In a letter to the Physical Review of March 15, 1931, I announced that all lines of the Gd^{+++} ion spectra were complex in a magnetic field and that the doublets really consisted of several components, and that they appeared as doublets only on account of the low resolving power of the instrument used.*

Since that time I have combined the prism from a Hilger E2 spectrograph with a large three-meter Hilger (*L* mounting) and obtained in effect a three-prism instrument which gives a dispersion of 1.3A per mm at the 2700A band of the Gd^{+++} ion.

While unfortunately only three plates were obtained at this dispersion before it became necessary to have the magnet rebuilt, nevertheless the results were so interesting that a report of them now seems advisable. In all three cases the bands between 2700A and 2800A were photographed, the light passing through the crystal parallel to the *b* axis of the monoclinic $GdCl_3 \cdot 6H_2O$ crystal. In plates 1 and 2 the field was parallel to the *a* axis, the fields being 17.5 and 18.5 kilograms, respectively. In plate 3 the field of 18.5 kilograms was parallel to the *c* axis.

All the lines of the bands, which were separated from each other so that they did not overlap when the field was applied, split into nine lines of approximately equal spacing with an overall separation of 16 times the normal Larmor precession.

The intensities of these lines varied greatly; In some cases the outer components were very intense while the inner three or five were barely visible, thus giving rise to an apparent doublet under low dispersion. In other instances the inner components were the more intense giving the appearance of a single, unaffected or slightly widened line under low dispersion. Frequently the intense components in plates 1 and 2 were the faint ones in plate 3. For a few lines the nine components were intense in all three plates.

A Paschen-Back effect was clearly discernible in most of the lines, being small in plate 1 and fairly pronounced in plates 2 and 3. With increased Paschen-Back effect the lines tended to widen and blur and the dissymmetries in intensities became very pronounced. The dissymmetries in position were not so great, especially in overall separation. They did tend to make the intervals between the lines more irregular. These irregularities in the intervals, with two exceptions where the lines in question were close together, were never greater

* Note: J. Becquerel for some time has stated that many of the doublets in the case of other rare earths are actually quartets. It appears, however, from the following work they are really even more complex.

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[1] Many papers. Leiden Comm. 1906–1931.

[2] Freed and Spedding. Phys. Rev. **35**, 1408 (1930); ibid. **38**, 670 (1931).

than 20 percent, on any of the plates investigated.

In the exceptions mentioned, lines 2788–9A and 2790–5A, while they gave the nine lines distinctly in plates 1 and 2 did not in plate 3. Also line 2790–5A did not seem to have an overall splitting of 16 ω (ω being the Larmor precession). However, the Paschen-Back effect here was pronounced so that the lines were badly blurred. In addition weak components may have been present.

The lines upon which the splitting could be observed were as shown in Table I.

TABLE I.

Line	Plate 1	Plate 2	Plate 3
A	Field 17.5 K.G.	18.5 K.G.	18.5 K.G.
	parallel to a		parallel to c
2793.07	9 c ?	9 c ?	9 o.f.
2790.49	9	9	9 ? blurred
2788.90	9	9	9 ? blurred
2786.68	9 f	9 o ?	9 c ?
2766.47	9 c.f.	9 c ?	9 c
2764.29	9	9	9 o.f.
2745.57	9 c.f. blurred	9 c ?	9 o.f.
2743.54	9 c.f. blurred	9 c ?	9

c = center compounds
f = faint but definitely present
o = outside components
? = doubtful

In my last letter[3] I called attention to the fact that many investigators have shown the basic level of Gd^{+++} ion in solids must be a $4f^7$; $^8S_{7/2}$ level, which is not split apart appreciably by the electric field of the crystal and which is free to take all orientations in a magnetic field. This level would then split into eight equally spaced levels of 2ω separation when a magnetic field is applied. Of course as Kramers[3] showed there would be a slight second order splitting due to the crystal field, so that the spacings would be distorted somewhat depending on the magnitude of the effect, but it is certainly small.

I also pointed out that the excited level most probably arises from one of these electrons jumping out through the completed $5s$ and $5p$ shells, giving rise to a configuration such as the $4f^6 5d$.†

I showed there, that one might expect the six $4f$ electrons to couple with Russell-Saunders coupling to give a ^7F term, and that the external electron would be coupled more loosely due to the partial shielding action of the completed $5s$ and $5p$ shells. The external electron would have its orbit coupled strongly with the electric field of the crystal[5] (Case II Bethe)[6] so that it could not orient in a magnetic field. The magnetic moment set up by this orbit however would tend to couple with the moment of the ^7F term inside and the energy of the coupling would presumably be strong enough to prevent the orientation of this core in a magnetic field.

The spin of the external electron, however, would be very loosely coupled as its resonance effect with the other electrons would be small due to the partial shielding action of the completed $5s$ $5p$ shells, and would be of the order of magnitude of the coupling energy of a single electron. It would therefore orient in the

† $4f^7$ electrons give rise to only one octet term, $^8S_{7/2}$ as Pauli's exclusion principle excludes all others. Therefore, for the electron to remain under the influence of the shielding effect of the completed $5s$, $5p$ shells, it would be necessary for a spin to reverse itself when Δn and Δl are 0, giving rise to a sextet term. Reversals such as these rarely occur in atomic spectra. Also the energy involved would probably be large.

[3] F. H. Spedding. Phys. Rev. **37,** 777 (1931).

[4] Kramers. Proc. Amst. Acad. **33,** No. 9 (1930).

[5] E. C. Stoner, in order to account for the magnetic susceptibilities of the iron group has suggested that the orbits are bound and only the spins are free to orient in a magnetic field. Phil. Mag. **8,** 250 (1929).

[6] Bethe. Ann. d. Physik **3,** 133 (1929).

fields obtainable in the laboratory, giving rise to two levels with a separation of 2ω.

Bethe[6] has shown that in crystals the ordinary selection rule of $\Delta m = \pm 1$ does not hold, but that new selection rules apply which permit large jumps in m. These depend on the symmetry of the fields, etc., and in this case are rather uncertain; however, if one assumes all transitions are possible between the levels, exactly nine equally spaced lines are obtained with an overall separation of 16ω. This is true regardless of the term of the upper level.

If the magnetic field splitting becomes of the order of magnitude of the splitting due to the crystal field, then a Paschen-Back effect will be observed and the lines will first blur and then resolve into two components. Also if the coupling of the basic term with the crystal field is large enough so that the magnetic field is not strong in comparison with it, the pattern will be destroyed, and thirdly, if the coupling energy of the spin in the upper term is of the same magnitude as the applied field, again the pattern will not be obtained.

From the above results it seems that the spin of the external electron is very weakly coupled with the orbit, also that the splitting of the basic level due to the crystal field is small.

It seems probable that the excited levels of the rare earths are of the type $((^7F_0d)_2)_{5/2}$, $((^7F_1g)_4)_{9/2}$,[7] which are split apart due to the various coupling of the external electron orbit with the field of the crystal.

I hope shortly to resume these investigations, studying the polarization of the lines and the effect of various field strength on their splitting. Mr. G. Nutting and myself have investigated the effect of crystal symmetry on the splitting of these terms and expect to publish the results very shortly in the Journal of the American Chemical Society.

F. H. Spedding
National Research Fellow in Chemistry,
University of California, Berkeley,
November 5, 1931.

[7] Professor R. T. Birge very kindly suggested this type of nomenclature for the terms in question.

Comparison of Viscosity and Molecular Arrangement in Twenty-two Liquid Octyl Alcohols

In my recent article just published (Phys. Rev. **38,** 1575 (1931)), the values of viscosity for approximately 0°C were used, whereas the x-ray observations were taken between 20° and 30°C. But the rate of change of the viscosity with temperature is of approximately the same order of magnitude in all cases so that the comparison between x-ray diffraction and viscosity is essentially correct if regarded as referring to same temperature conditions. As a matter of fact, the comparison would be slightly improved by using the viscosity at 25°C. The values of viscosity are those obtained by Bingham and Darrell (Rheology **1,** 174 (1930)).

G. W. Stewart

University of Iowa,
Iowa City, Iowa,
November 5, 1931.

Measurement of Nuclear Spin

Hyperfine structures of spectral lines and alternating intensities of band spectra constitute at present the only available means of determining angular momenta of atomic nuclei. We wish to point out another means of finding nuclear spins. It is well known that the Stern Gerlach experiment allows one to determine the angular momentum of an electronic configuration. If the atom has an angular momentum $j(h/2\pi)$ there are $2j+1$ lines in the Stern Gerlach pattern for conditions where the velocity of the atomic beam is sharply defined. It is also obvious that if the inhomogeneous magnetic field used in the experiment is not too strong, the coupling of the electrons to the nucleus will not be destroyed. There will now be $(2j+1)$ $(2i+1)$ distinct states in a magnetic field, where $i(h/2\pi)$ is the angular momentum of the nucleus. It is possible, in some cases, to observe the pattern due to these states and to follow the transition to the strong field condition with $2j+1$ lines.

The number of Stern-Gerlach lines observed in a weak field, their positions, and the magnetic field strength necessary to bring about a partial transition to the strong field pattern will be seen to determine the value of the nuclear spin.

As an example consider an atom in a state