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

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 $16\omega$. 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.

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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)).

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## 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 with inner quantum number $j=\frac{1}{2}$ and nuclear spin $i$. The energy of the atom in a magnetic field is

$$W=-\frac{\Delta W}{2(2i+1)}\pm\frac{\Delta W}{2}\left(1+\frac{2m}{i+\frac{1}{2}}x+x^2\right)^{1/2};$$

$$x=\frac{g\omega}{\Delta W},\quad \omega=\frac{eh}{4\pi mc}\quad H=\mu_0 H$$

where $\Delta W$ is the separation between the two hfs components in the absence of a magnetic field, $g$ is the Landé $g$ factor for the electronic configuration (e.g. 2 for $^2S$ terms), $m$ is the magnetic quantum number and $H$ is the magnetic field. The force due to an inhomogeneous magnetic field is

$$F=-\frac{dW}{dH}\frac{\partial H}{\partial y}$$

where $dH/dy$ is the gradient of the magnetic field. Thus

$$F=\pm\frac{\dfrac{2m}{2i+1}+x}{2\left(1+\dfrac{4m}{2i+1}x+x^2\right)^{1/2}}\cdot g\mu_0\frac{\partial H}{\partial y}.$$

For

$$i=\tfrac{1}{2},\quad F=\pm\frac{x+m}{2(1+2mx+x^2)^{1/2}}\cdot g\mu_0\frac{\partial H}{\partial y}.$$

For

$$m=1,\ 0,\ 0,\ -1$$

$$F=\left(1,\frac{x}{(1+x^2)^{1/2}}-\frac{x}{(1+x^2)^{1/2}}-1\right)(g/2)\mu_0\frac{\partial H}{\partial y}.$$

In a weak field the Stern-Gerlach pattern should consist of three lines the central one having twice the intensity of the two deflected lines. In intermediate fields there are 4 lines and in strong fields (complete Paschen-Back effect for hfs) there are only two lines both of which are displaced. The weak field region may be said to correspond to $x<0.1$, the intermediate to $x=1$, and the strong to $x>3$. If $\Delta W$ measured in $\mathrm{cm}^{-1}$ is denoted by $\Delta\nu$ then $H$ in gauss is

$$H=2.14\times10^4\times(\Delta\nu)/g.$$

For the normal $^2S$ state of $Cs\Delta\nu=0.30\ \mathrm{cm}^{-1}$ and the low field region $x=0.1$ lies below 320 gauss while $x=3$ for $9.6\times10^3$ gauss. For $x=1/(8)^{1/2}=0.354$ the four lines will be equidistant. This corresponds to a field of $1.14\times10^{+3}$ gauss.

The nuclear spins of Cs and Rb are at present being investigated with this method by one of us (I. I. R.).

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November 10, 1931.