symmetric tops the linear Stark effect is quite pronounced. The frequency shift $J, K, P \rightarrow J+1, K, P$, is $\nu=\nu_0+\Delta\nu$ where $\nu_0$ is the unperturbed frequency and[3]

$$\Delta\nu=\frac{\mu E}{h}\left(\frac{2KP}{J(J+1)(J+2)}\right)$$

plus higher order terms, and is independent of frequency. Here the "external quantum number" $P$ determines the quantization with respect to the external field $E$, and $\mu$ is the dipole moment. For low quantum numbers the multiplet components are separated by several megacycles for fields as low as 100 volts per cm or less. By applying the d.c. field parallel to the a.c. field, the selection rule $\Delta P=0$ applies, and no further complications arise in the spectrum.[1]

Since both quantum numbers $K$ and $P$ can range from $-J$ to $+J$, each component of a multiplet has several rotational terms contributing to its statistical weight $G$. Those multiplet components near the undisturbed frequency (low $|K|$ and $|P|$) and the extreme ends of the band (high $|K|$ and $|P|$) however contain sufficiently few terms so that useful intensity relations can be obtained. Table I shows the composition of the three lowest and two highest values of $|\Delta\nu|$ in columns 1, 2, 3, and 4. Columns 5 and 6 show specific values for the $J=3$ to $J=4$ transition of $CHCl_3$, occurring near 27,000 megacycles. A dipole moment of 1.05 e.s.u.[4] and spin $I$ of 5/2 (questionable)[5] are assumed.

For $J=3, 6, \cdots$ it is seen that the ratio of the $|KP|=J^2$ to $|KP|=1$ lines gives $S/W$ directly. By maintaining a fixed value of $\Delta\nu$ and varying $E$ to bring successive lines to this frequency, it should be possible to make accurate intensity comparisons. The intensities of course will be low, the intensity ratio of the $|KP|=1$ and $|KP|=J^2$ lines to the unresolved line being $2/(2J+1)^2$ (ignoring nuclear spins), or 0.041 for the $J=3$ line under consideration.

The above method depends on the use of a uniform d.c. field which is difficult to achieve using wave-guide technique.[1] A less sensitive method, perhaps only useful for low spin numbers, and $J=1$ or 2 spectrum lines, consists in comparing the intensities at the unperturbed frequency $\nu_0$ without field and with a field large enough to sweep out all terms for which $\Delta\nu\neq 0$. The intensity ratio is

$$\frac{3S/W+4}{3S/W+2}\text{ for } J=1 \quad\text{and}\quad \frac{5S/W+20}{5S/W+4}\text{ for } J=2.$$

TABLE I. Frequency shifts and statistical weights of Stark effect multiplets for rotational spectra of 3 homonuclear symmetric tops, with values for $J=3$ to 4 transition of $CHCl_3$ for field of 100 volts per cm.

| $\|KP\|$ | $\|K\|$ | $\|P\|$ | $G$ | $\Delta\nu$ $CHCl_3$ (mc) | $G/W$ $CHCl_3$ |
|---|---|---|---|---|---|
| 1 | 1 | 1 | $2W$ | 1.8 | 2 |
| 2 | 1<br>2 | 2<br>1 | $4W$ | 3.6 | 4 |
| 3 | 1<br>3 | 3<br>1 | $2W+2S$ | 5.4 | $2\left(1+\frac{38}{35}\right)$ |
| $J(J-1)$ | $J-1$<br>$J$ | $J$<br>$J-1$ | $2W+2S$[a] or $4W$[b] | 10.8 | $2\left(1+\frac{38}{35}\right)$ |
| $J^2$ | $J$ | $J$ | $2S$[c] or $2W$[d] | 16.2 | $2\left(\frac{38}{35}\right)$ |

[a] $J$ or $J-1$ divisible by 3.
[b] Neither $J$ nor $J-1$ divisible by 3.
[c] $J$ divisible by 3.
[d] $J$ not divisible by 3.

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## Energy Levels in the Nucleus $Mn^{56}$

A. B. MARTIN
*Yale University, New Haven, Connecticut*
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A NUMBER of investigators[1] have observed the energy levels in nuclei of low and medium mass number which are exhibited in the process of $d,p$ reactions. The energy level spacing observed in practically all cases was of the order of 1 Mev or greater, for excitations up to about 5 Mev above the ground state. When these results are compared with the 5-kev to 100-kev level spacings predicted by theory,[2] the influence of strong selection rules is indicated.

In order to shed more light on the nature of the selection rules operating, a study has been made of the energy levels resulting from a $(d,p)$ process in an element of medium atomic weight; i.e., a nucleus containing a sufficient number of particles to render the statistical approach of the theory at least reasonably valid. The excitation obtained extended to 4.3 Mev above ground. The results show that, while there are probably many other energy levels in the $Mn^{56}$ nucleus, a certain type of level (that associated with the $(d,p)$ reaction) seems to persist at an average spacing of about 0.85 Mev.

The reaction studied was:

$$Mn^{55}+H^2\rightarrow Mn^{56}+H^1.$$

The assignment of levels is unique, since only one isotope is involved.

Deuterons having a mean energy of 3.68 Mev were obtained from the Yale cyclotron and the energy of the emitted protons was determined by absorption in air and Al foils. The proton counting system included two each proportional counters, capacity-neutralized preamplifier

TABLE I.

| Proton range (cm air) | Proton energy (Mev) | $Q$ (Mev) | Levels (Mev) | Spacing (Mev) |
|---|---|---|---|---|
| 22.9 | 3.98 | 0.38 | 4.38 | |
| | | | | 0.77 |
| 30.8 | 4.73 | 1.15 | 3.61 | |
| | | | | 1.13 |
| 44.7 | 5.85 | 2.28 | 2.48 | |
| | | | | 0.71 |
| 54.4 | 6.55 | 2.99 | 1.77 | |
| | | | | 0.70 |
| 64.7 | 7.23 | 3.69 | 1.07 | |
| | | | | 1.07 |
| 82.3 | 8.29 | 4.76 | 0 | |

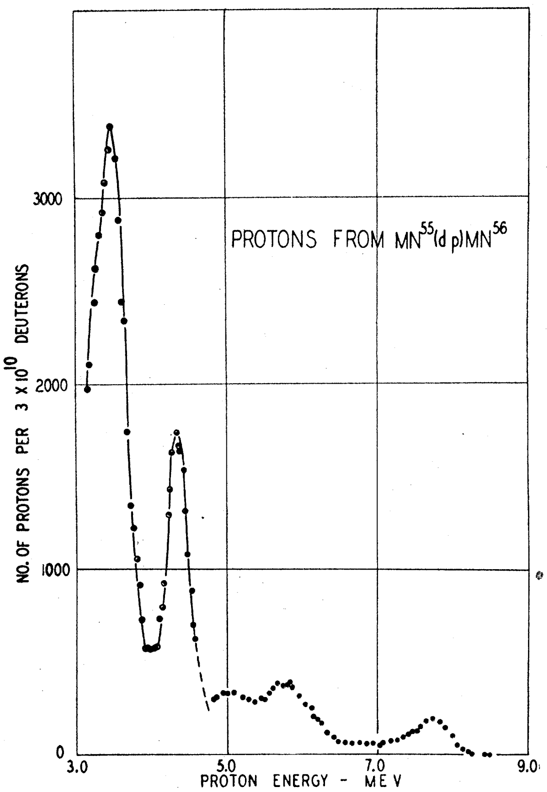


FIG. 1. Proton groups from the reaction $Mn^{55}(d, p)Mn^{56}$. The number of protons counted per unit deuteron beam is plotted against the proton energy.

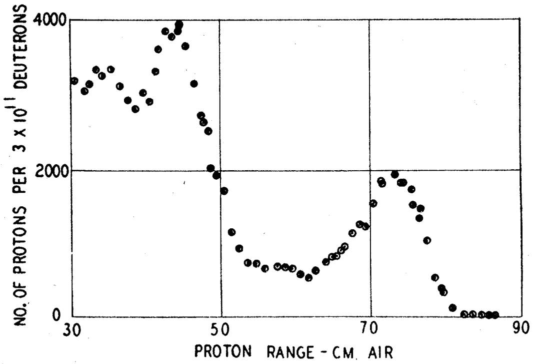


FIG. 2. Proton groups of ranges greater than 30 cm from the reaction $Mn^{55}(d, p)Mn^{56}$, plotted to an expanded scale. The number of protons counted is plotted against the proton range. (Averaged data for 11 runs.)

units and linear amplifiers, a coincidence circuit and a slightly modified Higinbotham scale-of-64 circuit. The over-all resolution of the method for the accurate determination of proton ranges is placed at 0.3 Mev.

Figure 1 shows the results obtained over the range of proton energies investigated. The total number of counts used to plot the two prominent groups between 3 and 5 Mev is to be obtained by dividing the ordinate by three.

Figure 2 shows the groups having ranges greater than 30 cm of air (4.66 Mev) on an expanded scale. A total of 21 separate runs were made over this interval, all of which are useful for analysis purposes, although only 11 were used to form the averages shown on this graph. On this curve, the total number of counts taken to determine a particular point is given by the ordinate in each case.

The $Q$-values shown in Table I below are calculated from the average values of the proton ranges obtained from several plots, each plot representing the averaged results from several runs.

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## Propagation of Spherical Shock Waves in Water

R. H. COLE* AND J. S. COLES**
*Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.*
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IN a recent paper in this journal,[1] Osborne and Taylor have reported comparative measurements of shock wave pressures in water at distances of 1 ft. and 31.3 ft. from No. 6 blasting caps (containing approximately 0.3 g of explosive). Their results showed a larger decrease in initial (or peak) pressure of the steep fronted shock wave than predicted from the theory of infinitesimal, spherically diverging waves, but gave no detectable increase in duration of the wave at the larger distance. As Osborne and Taylor show, the attenuation in excess of an inverse first power decrease with distance is a natural consequence of the non-linear propagation and steep fronts of finite amplitude waves. The failure to observe a significant broadening of the decaying pressure profile behind this front as the wave spreads out is, however, puzzling, as this effect is also to be expected both from the hydrodynamical properties of the medium and from results of other experimental work.

Measurements made at the Underwater Explosives Research Laboratory[2] with high explosive charges over a large range of charge weights and distances leave no doubt that both the increased attenuation and spreading of the wave profile predicted by theory are realized to a significant extent. The shock wave pressure decays very nearly exponentially in time at a given point in space until the pressure has fallen to roughly one-third its initial value. In the initial stages, the pressure $P$ at a given point as a function of time $t$ can therefore be characterized by a peak pressure $P_m$ and time constant $\theta$ in the formula $P(t)=P_m \exp(-t/\theta)$. At a distance of 20 ft. from a 300-lb. charge of TNT the peak pressure $P_m$ has been measured with tourmaline crystal piezoelectric gauges to be 6000 lb./in.$^2$. At a distance of 500 ft., a value of 160 lb./in.$^2$ is