and O^{17} by the fact that the outside nucleon can be bound more strongly by a blown-up O^{16} cluster. In addition, one notes that here, one only needs one quantum of excitation rather than the two quanta of excitation needed to obtain the 6.06-Mev state in O^{16}. If we now estimate ΔE by this assumed structure, we indeed get a positive quantity in complete accord with the experimental situation. Furthermore, it was found[9] that this level in O^{17} does not exhibit stripping in the (d, p) reaction, thus further supporting our assumption about the structure of this level which we inferred from the study on the Coulomb energy behavior.

From the above discussion, we therefore conclude that by studying the sign and the order of magnitude of the excitation energy difference of mirror levels, valuable information can be obtained about the cluster structure of these levels. In some of the examples which we have mentioned, objections might be raised in that we have compared a bound state to a state in the continuum. Those examples are the comparisons of the mirror $(\frac{1}{2}-)$ state in O^{17} - F^{17} and the $(\frac{1}{2}+)$ levels in C^{13} - N^{13}. One might argue that since the nature of the external wave function describing clusters at large distances is quite different for a resonant state than for a bound state, any conclusion drawn from such comparisons might be rather doubtful. However, one must also note that for the decay of the $(\frac{1}{2}-)$ state in F^{17} and the $(\frac{1}{2}+)$ state in N^{13} the outside protons must penetrate through the Coulomb potential barrier; therefore, the wave function also decays exponentially in this region. Thus, in essence, those states behave very much as if they were indeed bound.

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OBSERVATION OF THE HYPERFINE STRUCTURE SPLITTING OF MUONIUM BY USE OF A STATIC MAGNETIC FIELD*

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The discovery of muonium through the observation of its characteristic Larmor precession frequency[1] may make possible a precision measurement of the hyperfine structure interval $\Delta\nu$ in the ground $1\,^2S_{1/2}$ state of muonium in a microwave experiment. As a preliminary to such an experiment in order to obtain a rough measurement of $\Delta\nu$ and to confirm further the expected behavior of muonium, the effect of a static magnetic field on the polarization of muons has been studied. The type of experiment described here has already been done for muons stopping in solids.[2]

The principle of the experiment can be understood by considering the Breit-Rabi energy level diagram[3] of the ground state of muonium. The direction of the applied static magnetic field H, which is also the direction of the axis of quantization, is taken along the direction of the incoming muon beam. If muonium is formed by a polarized muon capturing an electron from a gas atom at weak magnetic field, the hyperfine structure magnetic substates $(F, m_F) = (1,-1)$, $(1,0)$, $(0,0)$, and $(1,+1)$ will be populated in the relative amounts 1/2, 1/4, 1/4, and 0, respectively, where F is the quantum number for total atomic angular momentum and m_F is the associated magnetic quantum number.[4] In the substates $(1,0)$ and $(0,0)$ the muon is unpolarized, whereas in the substate $(1,-1)$ it retains its initial polarization. If muonium is formed at strong magnetic field, where the magnetic quantum numbers m_μ and m_J for the muon and electron are good quantum numbers, then the magnetic substates $(m_\mu, m_J) = (-1/2,-1/2)$, $(-1/2,+1/2)$, $(+1/2,+1/2)$, and $(+1/2,-1/2)$ will be populated in the relative amounts 1/2, 1/2, 0, and 0, and hence the muon will retain its initial polarization. The angular distribution of the decay positrons is related to the muon spin direction by the proportionality

$$N_{e^+}(\theta)\, d\Omega \propto (1+PA\cos\theta) d\Omega, \tag{1}$$

where P is the muon polarization, A is the asymmetry parameter, and θ is the angle between the directions of the muon spin and of the positron emission.[5] Specifically, the resultant polarization for muons forming muonium depends on the values of the magnetic field and of the hyperfine structure separation $\Delta\nu$ according to the equation

$$P = \tfrac{1}{2} + \tfrac{1}{2}\left(\frac{x^2}{1+x^2}\right), \tag{2}$$

where $x = (g_J - g_\mu)\mu_0 H/\Delta W$, and g_J = electron g value ($\approx +2$); g_μ = muon g value; μ_0 = electron Bohr magneton; ΔW = hyperfine structure splitting ($\Delta W/h = \Delta\nu = 4500$ Mc/sec); H = external magnetic field. Equations (1) and (2) indicate that $\Delta\nu$ can be measured in principle by observing the number of positron counts as a function of the magnetic field H.

The experimental arrangement is shown in Fig. 1. The counter array consists of five counters placed in an external meson beam of the Nevis synchrocyclotron. A large solenoid provides a longitudinal magnetic field. The target is a stainless steel tank containing purified argon gas at a pressure of 55 atmospheres, and sufficient absorber is placed between counters 1 and 2 so that only muons stop in the gas target. A stopped muon is signified by a $12\bar{3}$ coincidence and a decay positron by a $34\bar{2}$ coincidence. Decay positrons are counted from 0.2 μsec to 3.2 μsec after a muon enters the target, and the positron counts are recorded as a function of the magnetic field which is varied from 100 to 5800 gauss. Since the magnetic field influences the trajectories of the charged particles, it was necessary to obtain data with a dummy target consisting of an identical stainless steel tank containing aluminum sheets and having equivalent stopping power and geometry to the gas target. Effects due to muonium formation could then be distinguished since it is known that muons are not depolarized in aluminum.

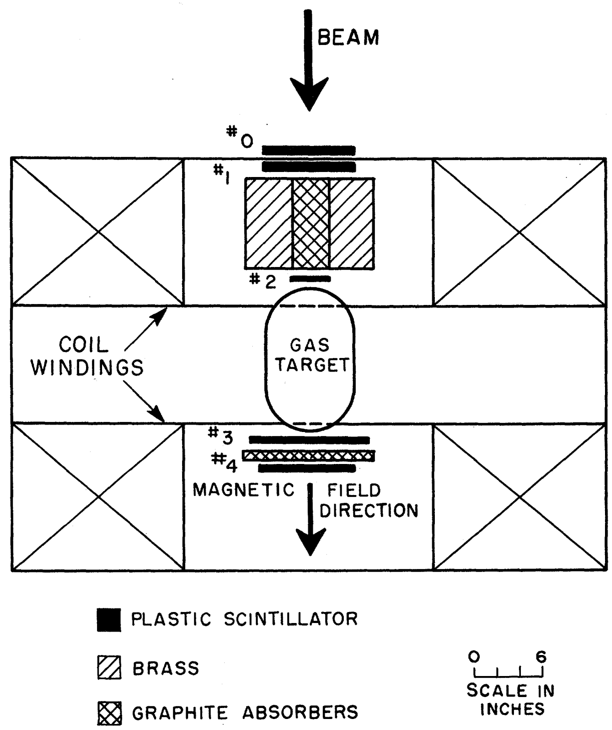

FIG. 1. Experimental arrangement.

The results of the experiment are shown in Fig. 2. The quantity R is the ratio of the positron counting rate for the dummy target to the positron counting rate for the gas target with both rates normalized to 1 at $H = 0$. The data points are indicated together with their error bars which represent plus or minus one standard deviation. The solid curve is the theoretical curve which corresponds to the expected theoretical value of $\Delta\nu = 4500$ Mc/sec, whereas the two dashed curves correspond to $\Delta\nu = 2250$ Mc/sec and $\Delta\nu = 9000$ Mc/sec. The theoretical curves are drawn on the assumption that all the muons stopped in the argon gas form muonium, which is supported

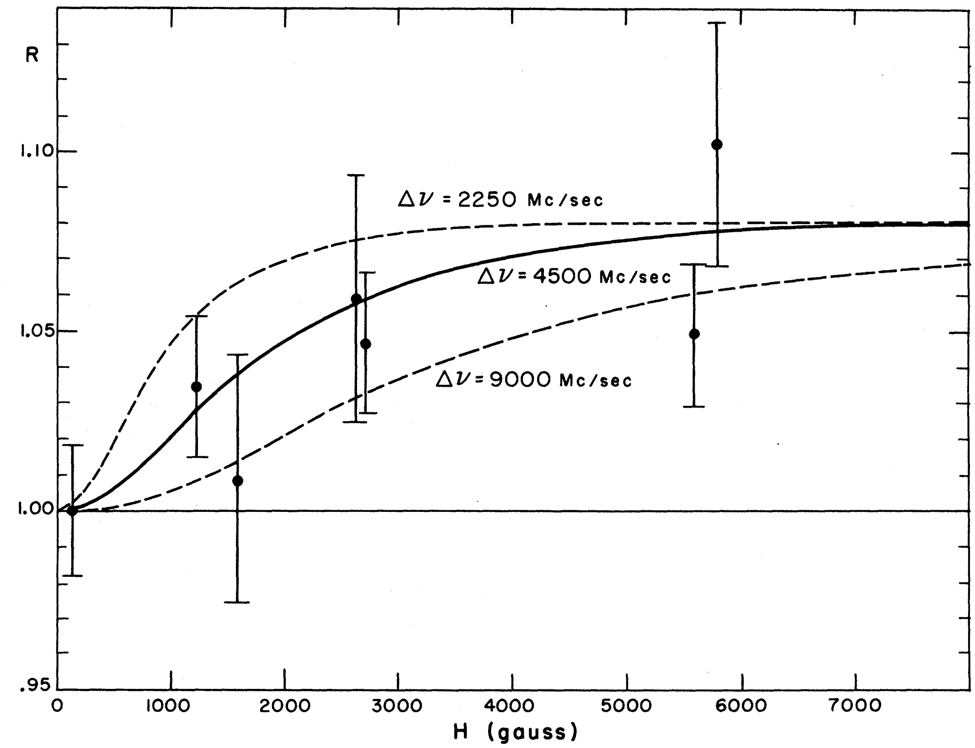

FIG. 2. Experimental data and theoretical curves for the quantity R versus the magnetic field H.

by evidence from the earlier experiment.[1] The data are consistent with the assumptions that $\Delta\nu = 4500$ Mc/sec and that all the muons form muonium, and indeed indicate that $\Delta\nu$ lies between 2250 Mc/sec and 9000 Mc/sec.

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