reaction $B^{10}(d, \alpha)Be^8$ which has been the subject of extensive measurements with a magnetic spectrograph.[1] The calculations were for the 16.62-MeV state in Be^8 with a 12-MeV deuteron beam and the detector at a laboratory angle of 30°. For an isotropic breakup of the Be^8, the energy of P_1 was shifted down by about 9 keV. With angular correlation patterns such as have been observed in a similar reaction,[8] the negative energy shift varied from about 7 to 10 keV. This is the same order of magnitude as is caused by the interference between the two Be^8 states.[1,2] When final-state Coulomb interaction effects are likely to be important, one should report the detector angle and beam energy along with the energy level parameters, as has been done by Kroepfl and Browne.[9]

The negative energy shift can be understood by consulting Fig. 1 again. If P_2 moves rapidly away with a large angle θ, particle P_1 gains less energy from electrostatic repulsion because of the charge carried away by P_2. When the intermediate nucleus is Be^8, the symmetry of the nucleus limits the effective θ to 90°. Even though the negative shift is small, it overpowers the larger positive shift in the integrated curve because of the $\sin\theta$ factor.

Our experiments were not sufficiently precise to allow a measurement of the negative energy shift. Because of its importance in determining the location of energy levels, this measurement should be made as soon as possible. One might expect the classical calculation to be better for the negative shift since it depends only on P_1 and P_2 being far apart and does not require precise localization.

A proper quantum mechanical treatment of the final-state Coulomb interaction which included angular-momentum effects should give a quantitative description of the peak shapes to be expected. If this theory were checked once with a high-precision coincidence experiment, it could then be used to calculate corrections for the Coulomb shifts in all other experiments.

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NUCLEAR SPIN FILTER*

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A "spin filter" for selecting metastable hydrogen, deuterium, or tritium atoms with a given nuclear spin magnetic quantum number (m_I) has been built and tested. With the device installed in the Los Alamos "Lamb-shift" polarized-ion source, we have obtained a deuterium negative-ion beam with ~55% spin-state purity for $m_I = 1$, 0, or −1. An improved magnetic field homogeneity in the apparatus is expected to increase the purity to ~75%.

In connection with the development of a "Lamb-shift"-type source of polarized negative hydrogen, deuterium, or tritium ions,[1] we have developed and tested a device through which metastable atoms with a particular nuclear spin orientation (m_I) may be transmitted while the remaining atoms are quenched to the ground state. The device exploits the "three-level interaction" phenomenon which was discovered by Lamb and Retherford[2]; a rather complete discussion of the relevant theory has been given in a report.[3]

In this method, a longitudinal rf electric field is used to connect the α $(2S_{\frac{1}{2}}, m_J=\frac{1}{2})$ and the e $(2P_{\frac{1}{2}}, m_J=\frac{1}{2})$ atomic states while a transverse dc electric field simultaneously connects the e state to the β $(2S_{\frac{1}{2}}, m_J=-\frac{1}{2})$ state. This must take place in a magnetic field near that for which the β and e lines "cross," i.e., in the range 500-650 G. The nuclear-spin quantum number has a particular value for the α, β, and e state considered; that is, the selection rule $\Delta m_I = 0$ holds. When the rf frequency corresponds to the α-β separation for a particular m_I, an equilibrium α-β mixture is established. Metastable atoms with other m_I values are quickly quenched by the rf field.

In a practical polarized-ion source, one is interested primarily in α-state atoms, since β-state atoms are easily quenched by collisions or by electric fields. The equilibrium mixture formed by the rf field (strength R) and the dc field (strength V) satisfies the condition $a/b \propto V/R$, where a and b are the α- and β-state amplitudes. Thus, if the particle beam sees an rf field which rises slowly (and falls slowly) as it enters (and leaves) the cavity, the equilibrium mixture at either end will correspond to pure α atoms, and the condition $a/b \propto V/R$ can be maintained as the beam traverses the cavity. In this way, the α-state transmission can be optimized. The large openings in the ends of the cylindrical cavity accomplish this purpose (see Fig. 1). The cavity is operated at a frequency of 1608 MHz in the TM_{010} mode. The overall length of the present model is 34 cm; note that it is split into four sectors to allow the application of the required dc field. Selection of different m_I values is accomplished by varying the magnetic field.

In Fig. 2 we show, as a function of magnetic field, the polarization and relative intensity of a deuterium negative-ion beam produced with the use of this device in the Los Alamos Scientific Laboratory source.[4] These data were obtained via the reaction $\mathrm{T}(d,\alpha)n$ with the deuterons accelerated to 70 keV. The upper part of the figure shows the tensor polarization (P_{33}) as computed from the relation $fP_{33} = 4(R-1)/(1.799R+1)$. R is the observed ratio of the 90° to the 165° $\mathrm{T}(d,\alpha)n$ cross section; f, the analyzing reaction "efficiency," was assumed to be 0.9. About 55% spin-state purity was obtained at each of the three peaks. The lower part of Fig. 2 shows the yield of negative deuterium ions versus magnetic field with the spin filter operating (upper curve) and with the rf power greatly increased so that all metastable atoms are quenched (lower curve). An rf power level of about 1 mW (~7 V/cm) and a dc field of about 20 V/cm was used for spin selection; about 200 mW of rf power was used for quenching. The declining yield with increasing magnetic field is associated with the extraction of the negative-ion beam from the field region, and is not related to the spin-filter performance.

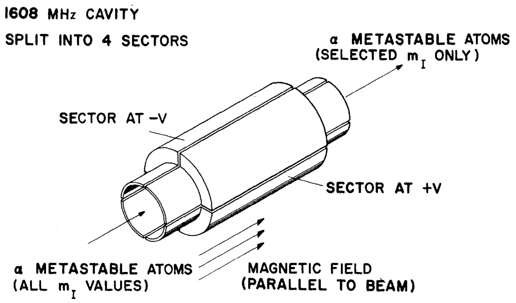

FIG. 1. Schematic diagram of the nuclear spin filter. The overall length of the device is 34 cm.

The above data were obtained with a magnetic field homogeneity of about ±1.5 G. This necessitated using higher dc fields than desirable, with the attendant increased quenching loss. Thus, only about 50% of the desired α states were

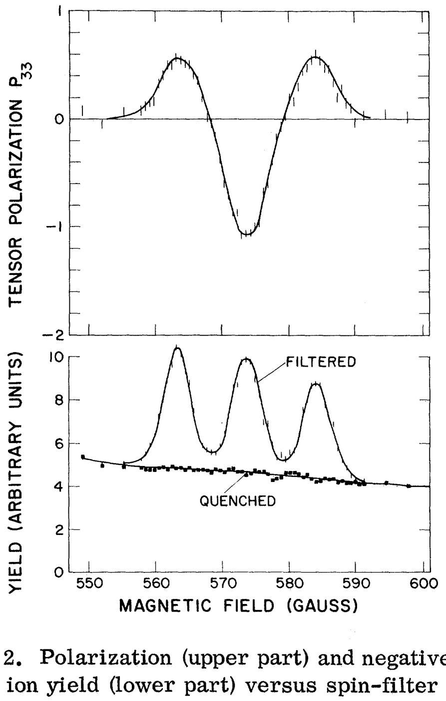

FIG. 2. Polarization (upper part) and negative deuterium ion yield (lower part) versus spin-filter magnetic field. The smooth curves are visual fits to the data. From left to right the peaks correspond to the selection of $m_I = 1$, 0, and -1, respectively.

transmitted. In a new solenoid, where the field homogeneity will be improved to ~± 0.2 G, we expect to achieve ~85% transmission. This improvement corresponds to an increase in spin-state purity from ~55 to ~75%. Further improvement in the polarization is possible only it the number of metastable atoms relative to the number of ground-state atoms can be increased. Curves of negative-ion current versus magnetic field have also been obtained for hydrogen beams. The polarization can be estimated from the ratio of the "filtered" and "quenched" currents; a polarization of ~60% has been observed. The magnetic field strengths which correspond to the two hydrogen-atom resonances are near 538 and 605 G.

We would like to thank Ralph Stevens, Jasper Jackson, Bob Watt, Donald Dodder, Leon Heller, and Joe Parker for discussions and help during the course of the development of this device. We would especially like to thank Charles Drake for drawing our attention to the three-level interaction phenomenon.

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ENERGY DEPENDENCE OF ISOSPIN MIXING IN THE GIANT-DIPOLE STATES OF C^{12} AND O^{16}

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A potentially powerful method of measuring isospin impurities in light nuclei is to compare certain partial photoproton and photoneutron cross sections for states excited by $E1$ photons.[1-3] In the case of a self-conjugate nucleus, the ratio of photoproton (γ,p) to photoneutron (γ,n) cross sections, leading to mirror levels in the residual nuclei, is related to the amplitudes of isospin components. For isolated states with single exit channels, Barker and Mann[2] deduce the expression

$$\frac{\sigma(\gamma,p)}{\sigma(\gamma,n)} \simeq \frac{P_p}{P_n}\left|\frac{\alpha_1+\alpha_0}{\alpha_1-\alpha_0}\right|^2, \tag{1}$$

where P_p and P_n are the proton and neutron penetrabilities, respectively, and α_0 and α_1 are the amplitudes of the $T=0$ and $T=1$ components of the excited-state wave function. In deriving Eq. (1), it is assumed that the transition probabilities may be expressed in terms of reduced widths[4] and that the proton and neutron angular distributions are identical. Now that calculations of photoproton and photoneutron widths are being attempted,[5-7] information on possible isospin mixing is required.[8] This is particularly true in C^{12} and O^{16}, where high-resolution data on the absolute 90° cross sections for emission of ground-state neutrons[9,10] are needed for comparison with (γ,p_0) results.[11-15]

We have therefore measured the 90° cross sections for the reactions $C^{12}(\gamma,n_0)C^{11}$ and $O^{16}(\gamma,n_0)O^{15}$ up to excitation energies of 40 MeV using the Yale electron linear accelerator and associated nanosecond time-of-flight spectrometer.[16]

The absolute cross sections are obtained by comparing the neutron yields with those from deuterium. For example, in the case of O^{16}, a measurement of the difference spectrum from "identical" targets of light and heavy water is made. The advantages of such a technique are these: (i) It is not necessary to know the shape of the bremsstrahlung spectrum; (ii) it is not necessary to know the absolute magnitude of the neutron detector efficiency as a function of energy—only the shape is required; (iii) systematic errors, such as those due to possible uncertainties in beam monitoring or due to uncertainties in our knowledge of experimental geometry, are eliminated; and (iv) the absolute cross section is simply related to that of deuterium which is known to an accuracy of better than ±10%.

In connection with item (ii), we have calculated