in the measurements. We thank Dr. Gaines for helpful correspondence and for sending us his T_1 data for H_2 at 4.2°K.

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NUCLEAR POLARIZATION OF NEGATIVE DEUTERIUM IONS PRODUCED BY CHARGE EXCHANGE*

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In 1950 Lamb and Retherford[1] pointed out that hydrogen atoms in the $2s$ (metastable) state could be polarized by passage through a magnetic field of 575 G crossed by a weak electric field. Since then there has been interest[2] in using this technique to produce a beam of polarized nuclei for injection into accelerators, and experiments along this line were carried out by Madansky and Owen.[3] However, in these experiments the beam of ions arising from metastable atoms was masked by a larger beam of ions arising from ground-state atoms.

Recently Donnally and Sawyer[4] have carried out an experiment in which it appears that this difficulty can be overcome. They produced a metastable beam by charge exchange in cesium vapor and converted it to negative ions in an argon gas cell. These negative ions are of particular value for injection into tandem Van de Graaff accelerators. They found that at a velocity of 3.1×10^7 cm/sec (500 eV for protons or 1000 eV for deuterons), the negative-ion current emerging from the argon gas cell decreased by a large factor ($\gg10$) when the metastable atoms incident on the argon were quenched to the ground state by application of an electric field. However, no attempt was made in their experiment to measure the nuclear polarization obtainable.

In this Letter we wish to report a measurement of the tensor polarization of deuterons in D^- ions made by this method.

A schematic diagram of the apparatus is shown in Fig. 1. The 1-keV β ($m_J = -\frac{1}{2}$) metastable atoms were quenched to the ground state in the polarizing region P. The neutral beam leaving the polarizing region consisted of α ($m_J = +\frac{1}{2}$) metastables, together with ground-state atoms arising partially from charge exchange in the cesium and partially from quenching of the β's. The electronic polarization was transferred to the deuterons in a transition region T. The purpose of the transition region was to minimize nonadiabatic transitions among magnetic substates of the metastable atoms.

The neutral beam from the transition region then passed through the argon cell. Some of the metastables made charge-changing collisions with argon atoms to produce D^- ions in the electronic ground, ${}^1S_0$, state (any other states excited would presumably be short lived and decay before being detected). The tensor polarization P_{33} of the deuterons made by ionization of an α metastable was computed to equal -0.327.

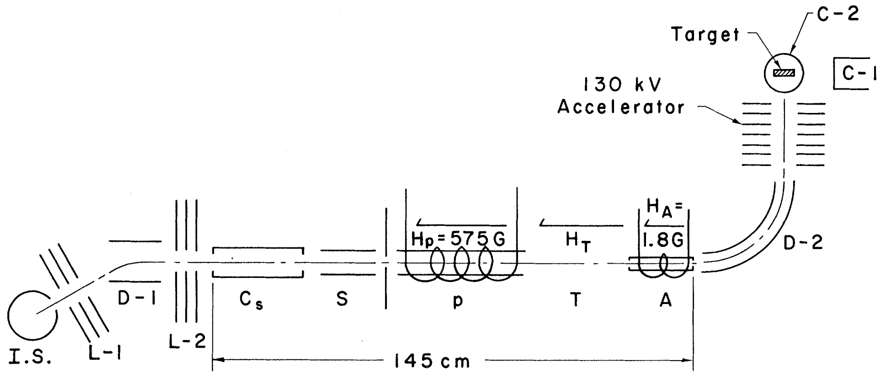

FIG. 1. Diagram of the apparatus. $I.S.$ is the ion source; L-1 and L-2 are focusing lenses; D-1 is a 15° deflecting system; Cs is the cesium cell (25 cm long, 1 cm diameter); S is an ion removal field (13.5 V/cm); P is the polarizing region, a 575-G longitudinal magnetic field and a 6.7-V/cm transverse quenching electric field; T is the transition region of exponential decrease of magnetic field; A is the argon cell (25 cm long, 1 cm diameter); D-2 is a 90° electrostatic analyzer. The 130-keV accelerator and tritiated titanium target are as shown.

(It would be $-\frac{1}{3}$ if the magnetic field in the argon cell were zero.) The net tensor polarization of all the deuterons emerging as negative ions from the argon cell should be less than this because some of the negative ions arise from ground-state atoms.

The negative ions emerging from the argon cell were selected by a 90° electrostatic analyzer D-2. The deuteron tensor polarization was measured by observing the neutron asymmetry in the reaction $t(d,n)\alpha$ at 130 keV.[5] The instrumental asymmetry was measured by increasing the magnetic field in the argon chamber to 50 G, thus reducing the deuteron tensor polarization effectively to zero.

With no cesium or argon in the exchange cells, and with all sweep and magnetic fields turned off, the positive-ion current emerging from the argon cell was 1.5×10^{-7} A, which yielded 1.8×10^{5} counts per minute in either of the counters.

The current of negative ions due to metastables was obtained by taking a quenching curve as shown in Fig. 2. As a measure of the metastable current we took the difference between the counting rates with quenching voltage 0 and 200 volts.

It was found that at a fixed cesium temperature, a plot of the metastable signal as a function of argon pressure times length exhibited a peak at about 15 mTorr cm of argon. With the argon set at 15 mTorr cm, the metastable signal when plotted against the vapor pressure times length of cesium exhibited a peak at about 5 mTorr cm, with half-width at half-maximum of about 4 mTorr cm.

The peak counting rate corresponded to a deuteron current of 4×10^{-9} A leaving the argon cell, or about 2% of the positive-ion current measured at the output of the argon cell in the absence of cesium, argon, and all magnetic and sweeping fields. At this peak intensity the tensor polarization of the deuteron beam leaving the argon cell was measured to be -0.19

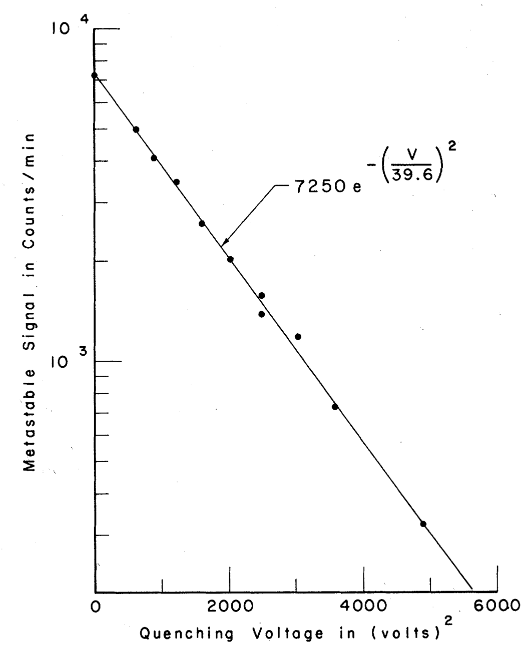

FIG. 2. Metastable quenching curve. The expected dependence on quenching voltage V is const$\times\exp(-V^2/Q^2)$ where Q is a constant computable from theory and geometric factors. The computed value is $Q=40$ V.

± 0.01. The error quoted is one standard deviation associated with counting statistics only. The figure of −0.19 was obtained from the neutron asymmetry with the magnets on and the quench field set at 6.7 V/cm. It includes the effect of negative ions made by ionization of ground-state atoms. If one takes instead the asymmetry after subtraction of the counting rate which obtains with the quench field set at 200 V, the resulting tensor polarization is that possessed by those deuterons which became negative ions via metastable atoms. This tensor polarization is −0.23 ± 0.01. The ratio of these two tensor polarizations is consistent with that expected from a measurement of the counting rate with all the metastables quenched.

It was found that the measured values of tensor polarization were insensitive to cesium and argon pressures. No change in tensor polarization was observed over a pressure range on either side of the signal maxima great enough to give a factor of two drop in the metastable signal.

The tensor polarization of −0.23 for those deuterons made via metastables is to be compared with the expected value of −0.33. It was found that turning off the exponential transition field reduced the measured tensor polarization to −0.04. This observation is in agreement with estimates of the depolarization introduced by the fringing field of the solenoid. However, it appears that either our practical approximation to an exponentially decreasing field was inadequate, or that our numerical estimates of the depolarization introduced by this field are unrealistic. Neither of these possibilities can be ruled out at the present time. In the near future we plan to eliminate the problem by ionizing at high magnetic field. A more highly polarized deuteron beam will be produced by a method involving radio-frequency fields.

Finally, it should be mentioned that cesium vapor is also an efficient converter of incident deuterons into negative ions. At 1 keV as much as 25% of the positive-ion current is converted into negative-ion current at 10 mTorr cm of Cs. This effect has also been observed by Donnally.[6]

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TRANSITION RATES IN B^{10} AND THE β DECAY OF C^{10}†

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A recent measurement[1] of the lifetime of the lowest $T=1$ level of B^{10} at 1.74 MeV is incompatible with the known beta decay[2] of C^{10}. The transition between the 1.74-MeV and 0.72-MeV levels of B^{10} is the gamma-ray analog of the beta transition from C^{10} to the lower level. A comparison of the relevant matrix elements shows that the measured gamma-ray lifetime[1] of $(1.52 \pm 0.24)\times 10^{-13}$ sec cannot be reconciled with the ft value[3] of 1000 for the C^{10} beta decay, unless there is a serious breakdown of isobaric-spin conservation. A specific calculation by Cohen and Kurath[4] predicts a gamma-ray lifetime 35 times shorter than the measured value. Measurements[1,5,6] have also been reported for the lifetimes of the levels of B^{10} at 2.15 and 3.59 MeV, but the large errors on the measurement[1] for the 2.15-MeV level warrant a remeasurement of the lifetime of this level; while the two measurements[5,6] for the 3.59-MeV level are in only fair agreement. The transition from the 2.15-MeV level to the 1.74-MeV level is the gamma-ray analog of the allowed but unobserved beta decay from C^{10} to the 2.15-MeV level.

The lifetimes of these three levels of B^{10} have been remeasured with the Doppler-shift-attenuation method using a Ge(Li) detector.