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.

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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

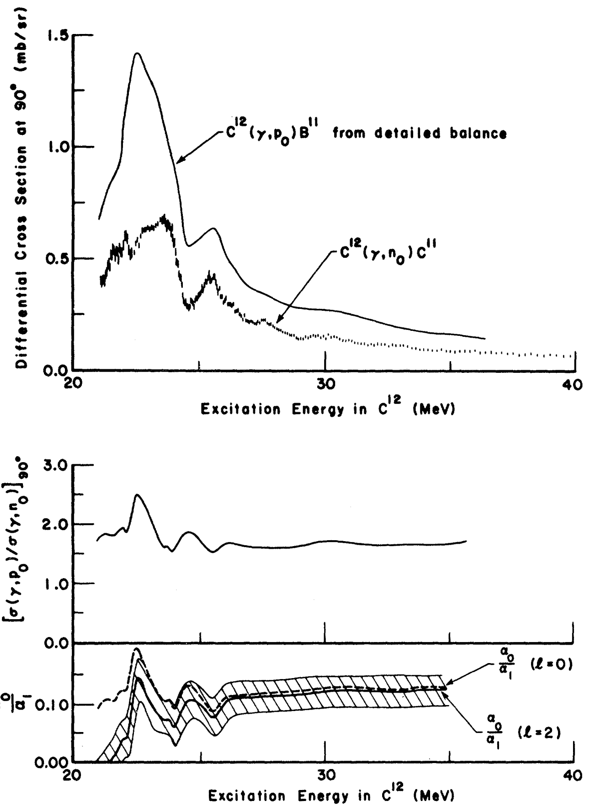

FIG. 1. The observed $C^{12}(\gamma,n_0)C^{11}$ differential cross section at 90° compared with the $C^{12}(\gamma,p_0)B^{11}$ data deduced from detailed balance analyses using the $B^{11}(p,\gamma_0)C^{12}$ results of Allas et al. (Ref. 11) up to 28 MeV and Brassard, Scholz, and Bromley (Ref. 12) above 28 MeV. The ratio of the amplitudes a_0/a_1 is shown for penetration factors corresponding to $l=0$ and $l=2$ particle emission. The cross-hatched region indicates the error due to statistics: The absolute $C^{12}(\gamma,n_0)C^{11}$ cross section has a systematic uncertainty of 20 % which is not included in the above diagrams.

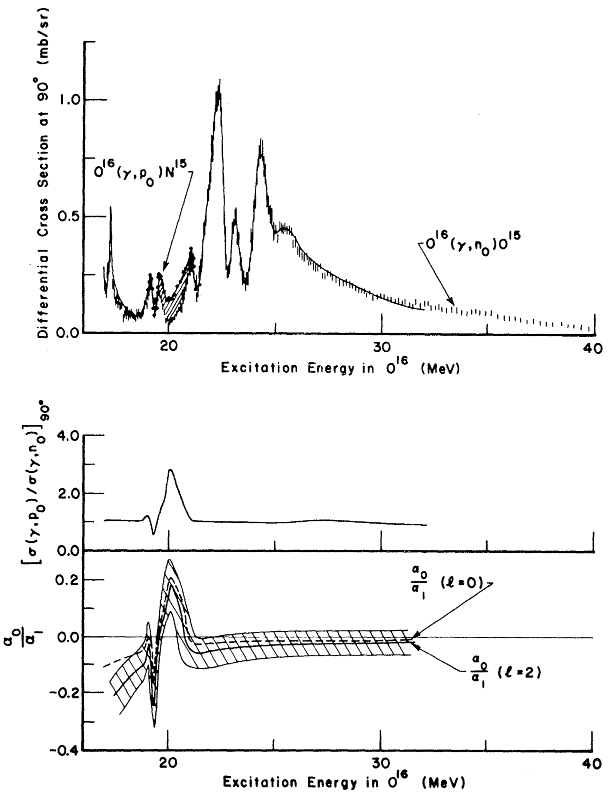

FIG. 2. The observed $O^{16}(\gamma,n_0)O^{15}$ differential cross section at 90° compared with the $O^{16}(\gamma,p_0)N^{15}$ data. The (γ,p_0) results are indicated by solid dots between 19 and 21 MeV and by a thin line elsewhere; Morrison's data (Ref. 15) are used between 17 and 22 MeV and between 25 and 32 MeV. In the region 22-25 MeV the (γ,p_0) data deduced from the $N^{15}(p,\gamma_0)O^{16}$ work of Tanner, Thomas, and Earle (Ref. 13) are used. The cross-hatched region indicates the error on a_0/a_1 due to statistics: The absolute $O^{16}(\gamma,n_0)O^{15}$ cross section has a systematic uncertainty of 10 % which is not included in the above diagrams.

the shape of the detector efficiency as a function of energy using a Monte Carlo method.

The ground-state contributions are deduced by measuring the photoneutron spectra as a function of bremsstrahlung end-point energy; typical increments are 2 MeV in C^{12} and 5 MeV in O^{16}. The use of thin targets ($\frac{1}{8}$-in. thick graphite and $\frac{1}{4}$-in. thick water) ensures that spurious effects due to resonant self-absorption of photoneutrons are negligible.

The observed $C^{12}(\gamma,n_0)C^{11}$ differential cross section at 90° is shown in Fig. 1, where it is compared with $C^{12}(\gamma,p_0)B^{11}$ data obtained by detailed balance from $B^{11}(p,\gamma_0)C^{12}$ results.[11,12] The ratio $[\sigma(\gamma,p_0)/\sigma(\gamma,n_0)]_{90°}$ is also shown together with the ratio α_0/α_1 obtained by assuming that only d-wave particles are emitted.[11] The cross-section ratio ranges from more than 2.5:1 at 22.5 MeV to 1.6:1 above 30 MeV. The overall energy dependence of the ratio α_0/α_1 follows the shape of the giant resonance; some detailed changes are observed, however, in the regions of fine structure.

The $O^{16}(\gamma,n_0)O^{15}$ and $O^{16}(\gamma,p_0)N^{15}$ results[15] are presented in Fig. 2 together with values of α_0/α_1. In contrast to C^{12}, the ratio is remarkably constant at a value of unity for energies above 21 MeV. Some departures from unity are seen, however, in the limited energy range between 19 and 21 MeV.

It is of interest to check, independently, the accuracy of the present differential cross sections. This is not presently possible, however, since the only published work (note Ref. 10) concerns the integrated-over-angles cross sections for the reactions $C^{12}(\gamma, n_0)C^{11}$ and $O^{16}(\gamma, n_0)O^{15}$.[17,18] We may obtain some indirect evidence concerning the present work, by assuming that the neutrons have the same angular distributions as the protons. In the latter cases, angular distributions are available from both the (p, γ_0)[11] and (γ, p_0)[19] reactions. Using these results we obtain the following integrated-over-angles cross sections:

$C^{12}(\gamma, n_0)C^{11}$, 6.6± 1.4 mb at 23.5 MeV;

$O^{16}(\gamma, n_0)O^{15}$, 9.1± 1.0 mb at 23.3 MeV.

These values are to be compared with those reported recently:

$C^{12}(\gamma, n_0)C^{11}$, 6.3 mb at 23.5 MeV (Ref. 17)

and

$O^{16}(\gamma, n_0)O^{15}$, 7.2 mb at 22.3 MeV (Ref. 18).

The agreement in the case of carbon is very good. However, in the case of oxygen, there is a discrepancy ~20%. The systematic error introduced in correcting the present work for the shape of the angular distribution and the lack of information on systematic errors in Ref. 18 make it difficult to assess the discrepancy quantitatively.

Unfortunately, the interpretation of the experimental results shown in Figs. 1 and 2 in terms of the true isospin mixing is not as straightforward as indicated in Eq. (1). For example, there is evidence from both angular distribution and polarization studies[20] that the dipole states in C^{12} and O^{16} emit s-wave as well as d-wave nucleons. Furthermore, possible damping of the mixing ratio α_0/α_1 due to the effects of continuum states has not been considered in detail. In the absence of a more complete theoretical analysis, we therefore conclude that the giant-dipole states of C^{12} contain appreciable admixtures of $T=0$ components (~5% in intensity at 22.5 MeV). A characteristic energy dependence is observed in the mixing ratio which may reflect a change from a compound to a direct reaction mechanism as the excitation energy increases from 20 to 30 MeV. In O^{16}, the major dipole states have a high degree of isospin purity. The ground-state cross sections not only have similar shapes above 21 MeV but also have similar magnitudes. In future calculations, it would be desirable to reproduce even the gross features of the effects reported here.

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