photoproton energy distribution[11] which shows the ground state to be favored by a factor of 4 or more.[12]

We conclude that the experimental evidence on $C^{12}(\gamma,p)B^{11}$ supports an independent-particle description of the giant resonance and suggests *LS* coupling as the more valid approximation.

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[1] We do not imply that only one excited state is involved. It is, however, convenient to discuss one resonance state corresponding to the gross resonance in the cross section around 22 Mev; in practice this gross state may well appear shared between several "fine structure" states of largely common parentage.

[2] At the giant resonance the respective proton energies are 5.5 Mev and 3.4 Mev. We may ignore transitions to other states of B^{11}; they are eliminated by the Coulomb barrier and also effectively by experimental considerations such as the target thickness.

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[12] It is only a limit that may be given from these experiments because identification of protons in the low-energy "tail" of the observed spectrum with a particular transition cannot be made with certainty. The assumptions involved in identification of the "tail" protons which resulted in the factor 4 were such as to make that value a lower limit.

(γ,p) and (γ,n) Yield Ratios from Self-Conjugate Nuclei

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It has been pointed out that the observed (γ,n) cross sections for light nuclei do not attain the sum rule limit.[1,2] Various interpretations have been given,[1,2] but in only a few cases are both (γ,p) and (γ,n) cross sections data available for comparison with the sum rule limit. In the cases of self-conjugate nuclei like Mg^{24} or Ca^{40}, however, calculation of the proton-to-neutron yield ratio on the basis of compound nucleus formation, can be made relatively safely since product nuclei from (γ,p) and (γ,n) reactions are mirrors of each other whose level structures are identical.

Calculation was made on the following basis: (1) The level density for the $4n+3$ residual nuclei was taken as $\omega(E)=C\exp(aE)$, where $a=d\log w/dE$ is taken to be a constant over the range of the residual energies involved. This assumption fits well with (p,p') data[3] on Al from 3- to 10-Mev excitation; it can be extrapolated to zero in good agreement with the density of known levels in Al^{27}. Values of a for different nuclear mass numbers A were obtained from the known levels of B^{11}, Na^{23}, and Al^{27} and also from (p,p') data[3] on Al, Ni, and Ag. A smooth curve was drawn through these points and values of a interpolated for arbitrary A. (2) For the barrier penetration factor, a formula $(1-kB/E_p)$ was used. Here E_p is the energy of the outgoing protons, B is the classical barrier height for $r_0=1.5\times10^{-13}$, and k is adjusted so that the penetration factor makes the best fit to the quantum-mechanically calculated value.[4] Then,

$$r_{pn}=\frac{\exp\{a(E_e-b_p)\}-1}{\exp\{a(E_e-b_n)\}-1}\rightarrow\exp\{a(b_n-b_p)\}$$

when E_e is large.

Here r_{pn} is proton-neutron yield ratio, E_e is the excitation energy of the compound nucleus, b_n is the neutron binding energy and b_p is the proton binding energy plus kB. The asymptotic values of r_{pn} are given in Table I. If we estimate the sum of integrated (γ,p) and (γ,n)[5] cross sections we obtain the results in Table I. Here the dipole sum rule is resumed except for very light nuclei.

TABLE I. Asymptotic value of r_{pn} and the sum of (γ,p) and (γ,n) integrated cross sections for certain self-conjugate nuclei.

							Dipole sum rule limit by Levinger and Bethe	
	C^{12}	O^{16}	Mg^{24}	Si^{28}	S^{30}	Ca^{40}	$x=0$	$x=1$
r_{pn}	1.6	1.9	3.6	4.4	5.6	9.7		
$\frac{A}{NZ}\int_{\text{giant resonance}}\{\sigma(\gamma,p)+\sigma(\gamma,n)\}dE$	0.046	0.054	0.047	0.049	0.074	0.078	0.060	0.108

Preliminary measurements of (γ,p) yields on Mg^{24}, Si^{28}, S, and Ca were made by Johansson[6] and the results show good qualitative agreement, but with rather lower yields. The difference may be due to oversimplification in the above arguments or to contributions from direct photoelectric processes. Measurements of r_{pn} using alpha particles are now under way here which might shed more light on this problem.

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