group or phase delay data respectively. The first analysis of the group delay data was done by neglecting the effects of the earth's magnetic field (Lien, *et al.*[1]). An improvement in the analysis was tried by using the Appleton-Hartree formula and taking a constant angle of the direction of propagation against the magnetic field. This corresponds about to the analysis used by Seddon in the phase velocity experiment. This, however, did not change the character of the bifurcation.

With the deviation from vertical transmission as encountered in both types of experiment, we feel that it is necessary to do a much more accurate analysis. This means finding the ray paths for each point on the trajectory and integrating along these paths to obtain the measured values of group or phase delay. This procedure, of course, is very laborious and complex.

The analysis we did so far along this line shows that the magnetic field properly taken into account has a definite effect on the resulting electron distribution. Therefore, the original analysis was inadequate. Nevertheless, it is doubtful that the bifurcation is due only to this. On the other hand we have to look at the results of the phase delay experiment with the same criticism. The approximation used in the analysis of the experimental data might well cause the high value of ion density obtained by Seddon,[2] which is in disagreement with the theory of Bates and Massey.[3]

If the magnetic field has an important effect on the course of the ray paths, it is obvious that the geometry of the experimental set-up with respect to the magnetic field will influence the results of an inadequate analysis. Now all the group delay data so far analyzed have been obtained from ray paths to the south of the rocket trajectory with aspect angles deviating about 17–19 degrees from the vertical. In the phase delay experiment, the corresponding angles are 14 degrees or less and the ray paths are in a northerly direction so far as available data from the height range below 100 km are concerned. This might account for the consistency of the curve within themselves of the two experiments, while compared to each other, the sets of curves are principally different. In view of the angles of aspect involved, the phase delay experiment should be less subject to error. However, an accuracy of better than 5 percent in the electron density data as claimed by Seddon and Jackson does not seem justified for heights of 100 km or lower.

A more detailed report of the instrumentation of the experiment, the quality of the obtained data, and the analysis with respect to electron density will be published in due time.

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Evidence for an Independent Particle State of C^{12} at High Excitation*†

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We wish in this note to show that the present evidence concerning the reaction $C^{12}(\gamma,p)B^{11}$ indicates rather forcibly that the "giant resonance" state at about 22-Mev excitation[1] is of an independent-particle character and is simply related by its shell model description to the ground state of C^{12} and to the low-lying levels of B^{11}.

Since the ground state of C^{12} is $0+$, the giant resonance state formed by electric dipole absorption is $1-$. If this state were a compound nucleus state (in the sense that its mode of decay is determined only by statistical factors, energy, total angular momentum, parity, and isotopic spin) it would decay to the ground state of B^{11}, which is $\frac{3}{2}-$ and to the first excited state at 2.14 Mev, which is presumed to be $\frac{1}{2}-$, chiefly by *s*-wave emission,[2] because the barrier for *d*-wave protons is so formidable. (The penetrabilities for *s*-wave protons are roughly 5 times those for *d*-waves.) Hence the angular distribution of photoprotons relative to the incident γ-ray beam would be expected to be almost isotropic. The experimental angular distribution[3] is $1+1.5\sin^2\theta$, which indicates a very considerable emission of protons of nonzero angular momentum.

The possibility that nuclear photodisintegration in the "giant resonance" region might proceed through independent-particle states has been explored by several authors.[4–8] In general, such an assumption leads to an angular distribution of the form $a+b\sin^2\theta$. For *d*-wave proton emission, those models which involve only the transitions $l\rightarrow l+1$ require[8] that the initial state of the proton be a *p*-state such as is available in C^{12}, and this leads to the predicted angular distributions $1+\sin^2\theta$ (in *jj* coupling) and $1+\frac{3}{2}\sin^2\theta$ (in *LS* coupling). It is interesting to note that *LS* coupling is in better agreement with experiment since it appears that this extreme coupling is a more realistic approximation for light nuclei than is the *jj* coupling extreme.[9]

Further, in *jj* coupling, transitions would take place only to the $(1p_{\frac{3}{2}})^{-1}$ ground state of B^{11} since, in that scheme, this state is the unique parent[10] of the ground state of C^{12}; in *LS* coupling, the ground state of C^{12} has as parents the ${}^{22}P$ doublet consisting of the two lowest states of B^{11}, but the theoretical reduced width for emission to the ground state is twice that for emission to the first excited state, and the phase-space and penetrability factors further combine to give a final theoretical favoring of the ground state by a factor of about 5. This value is consistent with the measured 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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(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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