CONFIGURATIONAL ASSIGNMENTS OF GIANT PHOTONUCLEAR RESONANCES*

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The electric dipole giant resonances of nuclear photodisintegration occur at an excitation of 15-20 Mev throughout the periodic table. They are associated, according to the independent-particle model (IPM) of the phenomenon,[1] with the "one-quantum" excitations of the equivalent harmonic oscillator classification: $1\,l\to 1\,l{+}1$, $2\,l\to 2\,l{+}1$, etc; $1\,l\to 2\,l{-}1$, etc. A difficulty always met by the simple IPM, which uses only the central optical model potential, is that the theoretical energy of the giant resonance tends to be too low. Very recently experiments by Schiffer et al.[2] and by Cohen et al.[3] on the location of optical model states by the gross structure of (d,p) reactions have yielded apparent spacings for typical "one-quantum" excitations that are indeed considerably less (a factor of 2 or 3) than the energy of the giant resonance. Cohen et al.[3] have called the IPM of the photoeffect in question on the basis of these results.

It is the purpose of this note to point out that the configurational assignments made by the IPM for the giant resonance rest on rather general grounds and that the conclusion to be drawn from (d,p) gross structure results is not simple. The essential correctness of the IPM configurational assignments depends only on (*i*) the approximate validity of the IPM description of the ground state, and (*ii*) the fact that the giant resonance approximately exhausts the electric dipole sum.[4] These points demand that the giant dipole state or states expanded into IPM wave functions appropriate to the potential within which those making up the ground state are defined should be linked to the ground state by single-particle transitions having large $E1$ matrix elements. It is at once clear that if the ground-state IPM wave functions were harmonic oscillator wave functions the IPM configurational assignments based on "one-quantum" excitations must be correct. Even for ground-state IPM wave functions as different from oscillator wave functions as is reasonably possible, viz., those of an infinite square well, the harmonic oscillator $E1$ selection rules persist to a very high degree and only the "one-quantum" transitions can be appreciably excited. This is illustrated in Table I where the "three-quantum" excitations $1\,l\to 2\,l{+}1$ are seen to be very small. In fact ground-state IPM wave functions evaluated for a "realistic" potential are remarkably close to oscillator wave functions even for quite heavy elements and so we can be sure that the contributions to the giant resonance from transitions other than those of the "one-quantum" type will be even smaller than suggested by the square-well results of Table I. This is illustrated in Fig. 1 which compares oscillator and "realistic" wave functions for $1h$ and $3s$ states in Ce^{140}. The "realistic" wave functions are appropriate to a velocity-dependent Saxon-Woods potential as specified by Ross, Lawson, and Mark.[5] The only adjustment made is between the $\langle r^2\rangle$ values of the

Table I. Squares of the radial overlap integrals compared for harmonic oscillator and infinite square well wave functions. Within each oscillator level the strengths of the $1\,l\to 1\,l{+}1$ transitions have been set equal to unity and the others normalized to them. The values for the square well are in parenthesis.

Oscillator level	I	II	III	IV	V	VI
$1\,l\to 1\,l{+}1$	1	1	1	1	1	1
$2\,l\to 2\,l{+}1$			0.71(0.52)	0.78(0.57)	0.82(0.62)	0.85(0.66)
$3\,l\to 3\,l{+}1$					0.64(0.42)	0.69(0.45)
$1\,l\to 2\,l{-}1$		0.40(0.24)	0.29(0.15)	0.22(0.10)	0.18(0.07)	0.15(0.06)
$1\,l\to 2\,l{+}1$	0(0.004)	0(0.005)	0(0.005)	0(0.006)		
$2\,l\to 3\,l{-}1$				0.44(0.25)	0.36(0.17)	

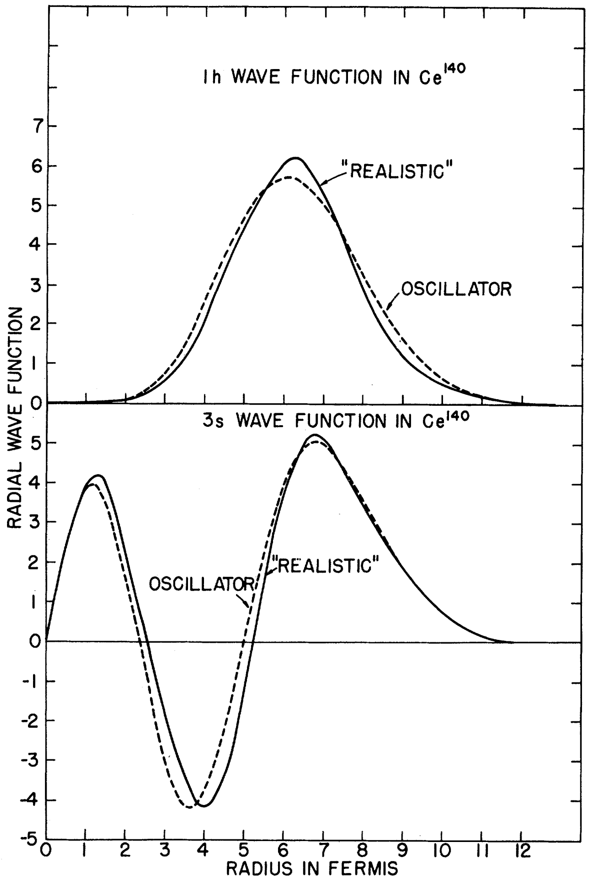

FIG. 1. Comparison between harmonic oscillator and "realistic" wave functions (velocity-dependent Saxon-Woods) for Ce^{140}. The ordinate is the radial wave function (multiplied by the radius). The only adjustment made is of the $\langle r^2\rangle$ values for the two $1h$ wave functions.

two $1h$ wave functions—the $3s$ oscillator wave function uses the same spring constant as the $1h$.

We have not, in making this argument, committed ourselves to a detailed model for the giant resonance nor are these remarks intended in any way to bear on that issue. We merely make the point that the configurational assignments that the simple IPM proposes as responsible for the absorption process must in fact make up the dipole resonance whether by incoherent or by coherent superposition. The possibility is left open that the interaction between the simple IPM excitations plays an essential role in building up the dipole state[1] and in this connection we may recall the observation of Brink[6] of the identity between the IPM account of the giant resonance for an oscillator potential and one of the forms of the collective model for that phenomenon.[7] Such interaction might result in a considerable displacement of the state so formed from the primitive positions of the simple IPM states that are mixed together to form it.[8] The apparent discrepancy between the evidence of the (d,p) gross structure states and the giant resonance may be resolved in this way. Alternatively the simple final-state IPM configurations $(lj)^{-1}(l'j')$ may each be split by parent-state excitations associated with the creation of a hole, and by the range of symmetries offered by alternative particle-hole couplings. In this case it is likely that the (d,p) mechanism and photon absorption would preferentially select different regions of the resulting split configuration. (Note that, ceteris paribus, the contribution of a transition to the dipole sum is proportional to its energy.)

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