Direct Photoreactions on ^{13}C and ^{13}N

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Photodisintegration of nuclei with a dominating structure of one nucleon loosely coupled to a core, has recently found some attention [1,2]. In some nuclei of this type e.g. ^{9}Be and ^{13}C, a Pygmy-resonance is occuring below the Giant dipole resonance for photonenergies $E\gamma \approx 13$ MeV. Experimental information is lacking for heavier nuclei with an assumed analogous structure.

It is the purpose of this letter to report on some tentative calculations of electric dipole cross sections in the frame of the direct interaction model. The work is limited to the reactions $^{13}C(\gamma, n)^{12}C$ and $^{13}N(\gamma, p)^{12}C$ with photonenergies varied from threshold through the Pygmy-resonance.

The differential cross sections are given by the following formula[3,4].

$$\sigma(\theta, \varphi) = K\,|\langle\psi_f|\sum_{j=1}^{A}\varepsilon_j r_j\, Y_1^1(\theta_j, \varphi_j)|\,\psi_i\rangle|^2.$$

Here ε_j is the effective nucleon charge, the other symbols having their usual significance. The quantity K is proportional to the wavenumber of the relative motion in the continuum states[3,4].

The target nucleus is assumed to be in a single particle state whose spin, parity and binding energy are the same as for the actual nucleus. The wave functions are expanded in the LS coupling scheme, and their radial dependence in both initial as well as final states are found by assuming Saxon-Woods potential wells.

The cross sections calculated with these wavefunctions are compared with corresponding cross sections calculated with harmonic oscillator or Saxon-Woods wave functions, respectively, in the initial states, but with plane waves as final states.

The cross sections for the reaction $^{13}N(\gamma, p)^{12}C$ are further corrected approximately for final state Coulomb-interaction by multiplication with a term depending on the appropriate Gamow factors[5].

Since ^{13}C and ^{13}N are mirror nuclei, they are supposed to be described by approximately the same potential parameters.

In the calculation of cross sections with Saxon-Woods wave functions in initial as well as final states, there are two sets of potential parameters which can be varied within physically given limits. It is assumed that the bound state valence nucleon is interacting more strongly with the core than the corresponding one in the unbound state. Hence, the two sets of potential parameters might be varied independent of each other. In the present calculations th final states are described by a slightly deeper and less diffuse potential well than the initial states.

The final state potential parameters are further constrained to give the elastic scattering phase shifts of the final system. These phase shifts, which are strongly dependent on the parameters, are fitted to phase shifts calculated from the optical model [6]. The cross sections are depending most sensitively on a relative variation of the two parameters sets.

Initial state	Final state
V_i = calculated	V_f = 40 MeV
r_0 = 1.25 fm	r_0 = 1.25 fm
a_0 = 0.70 fm	a_0 = 0.60 fm

Table 1. Potential parameters for ^{13}C and ^{13}N. V = potential depth. r_0 = Potential radius parameter. a_0 = diffuseness parameters.

The calculated cross sections for the reaction $^{13}C(\gamma, n)^{12}C$ as a function of the photonenergy are given in Fig. 1. For comparison, cross sections calculated with plane waves as final states are also reproduced.

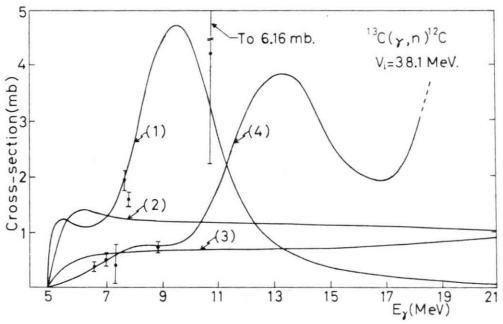

Fig. 1. Calculated electric-dipole cross sections for the reactions $^{12}C(\gamma, n)^{12}C$ as a function of the photonenergy. (1): Saxon-Woods wave functions in initial as well as final states. (2): Saxon-Woods wave functions in initial states and plane waves as final states. (3): Harmonic oscillator wave functions in initial states and plane waves as final states. (4): Experimental data after B. C. Cook[1]. • The points are experimental values after L. Green and D. J. Donahue[2], with flags indicating the uncertainties.

In Fig. 2 is shown the appropriate Coulomb corrected cross sections for the reaction $^{13}N(\gamma, p)^{12}C$.

It is seen from a comparison with existing experimental data[1,2] that the calculations are giving cross section curves with the right shape and magnitude. However, the maxi-

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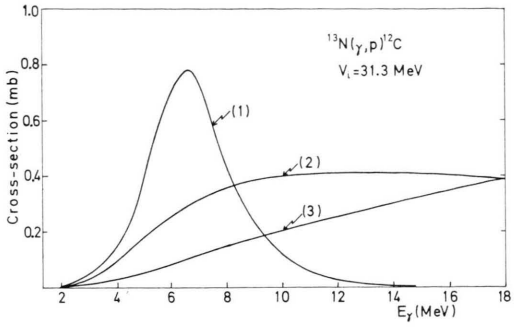

Fig. 2. Calculated electric-dipolecross sections for the reaction $^{13}N(\gamma, p)^{12}C$. The cross section curves are numerated in the same way as in Fig. 1. Experimental data are lacking.

mum of the theoretical curve is shifted to slightly lower energies as compared with observed values. Although there exists a difference between the experimental and theoretical curves, this difference seems to be not serious enough to disprove the accepted model. The inclusion of a spin-orbit term, with suitable strength, in the Hamiltonian, will probably shift the maximum sufficiently towards higher energies.

Similar direct interaction calculations of nuclear photodisintegration cross sections have been reported in the literature [7–11]. Some of these are accomplished with square well or similar potentials[8,10]. More realistic potentials, e.g. Saxon-Woods, are also used[7] in connection with distorted plane wave final states, an approximation that is valid if the contributions from the internal part of the nucleus are negligible.

It is a fact that the calculated photonuclear cross section depends sensitively on the surface behaviour of the continuum potential well. The square well- and harmonic oscillator approximations are therefore generally not to be trusted. From Fig. 1 it can also be seen that the plane wave final state approximation is not a good one.

Calculations of cross sections based on wave functions with an incorrect asymptotic behaviour, may therefore not give the correct contribution from the exitation of the valence nucleon.

The conclusion drawn from the present results is therefore that exact calculations with a realistic potential combined with the simple model, are suggesting increased contributions from the exitation of the valence nucleon.

The calculations are also indicating that contributions from the internal part of the nucleus are of some importance.

It is another point to be further investigated if this method with different potential wells in the initial and final states, in an implicit way incorporates in the calculations certain effects from the core.

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