MICROSCOPIC STUDY OF INELASTIC $^{12}C + ^{16}O$ SCATTERING

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Recent microscopic studies of $^{12}C + ^{16}O$ scattering [1,2] have provided an interpretation of broad resonances observed in elastic C - O scattering. These studies are made in a single-channel approximation and thus cannot explain the fact that resonances located a few Mev above their respective barrier are observed [3]. Investigations on inelastic scattering and reactions are expected to give indications about the mechanism of absorption.

A generalization [4] of the microscopic R-matrix theory (MRM) [5] allows us now to couple a few selected channels with the elastic one. The calculation is equivalent to a coupled-channel resonating group calculation. The present communication is a preliminary report on the coupling of $^{12}C_{g.s.}(^{16}O\,,^{16}O\,)^{12}C(2^+)$ channel with the elastic one.

Let us define the basis of GCM wave functions we use. If $\mathcal{A}$ is the antisymmetrization projector, the intrinsic wave functions Ψ_{IK} are linear combinations of Slater determinants defined by [1]

$$\Psi_{IK}(\underset{\sim}{R}) = \left(\frac{28!}{16!\,12!}\right)^{\frac{1}{2}} \mathcal{A}\ \Phi^{^{12}C}_{IK}(\tfrac{4}{7}\underset{\sim}{R})\ \Phi^{^{16}O}_{00}(-\tfrac{3}{7}\underset{\sim}{R}) \qquad (1)$$

where $\Phi^{x}_{IK}(\underset{\sim}{X})$ is the combination of Slater determinants describing nucleus x located at $\underset{\sim}{X}$ with angular momentum I and projection K on the intrinsic axis $\hat{X}$. Wave functions $\Phi^{^{16}O}_{00}$ and $\Phi^{^{12}C}_{IK}$ correspond respectively to the configurations $\left[(0s)^4(0p)^{12}\ L=0\ M=0\right]$ and $\left[(0s)^4(0p)^8\ L=I\ M=K\right]$ in the harmonic oscillator basis. The GCM wave function (1) has to be projected on parity π and on total angular momentum J

$$\Psi^{JM\pi}_{IK}(R) = \frac{1}{2}(1+\pi P)\int d\Omega\ \mathcal{D}^{J\,*}_{KM}(\Omega)\,\mathcal{R}(\Omega)\ \Psi_{IK}(\underset{\sim}{R}) \qquad (2)$$

using usual projection techniques. It can be shown that wave functions differing by the sign of K only are not independent [4]. Moreover, the entran-

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ce channel (I=K=0) only populates states of "natural" parity $\pi = (-)^J$. For each value of (JMπ), we thus have a basis of four wave functions with (I|K|) equal to (00), (20), (21) and (22).

In the RGM, the total wave function describing the same system is given by

$$\Psi^{JM\pi}_{RGM} = \sum_{\ell, I} \mathcal{A}\, g^{JM\pi}_{\ell I}(\rho) \sum_{m_\ell \nu} \langle \ell I m_\ell \nu | JM \rangle Y^{m_\ell}_\ell(\Omega_\rho)\, \varphi^{12}_{I\nu}\, \varphi^{4}_{00} \qquad (3)$$

where $\underset{\sim}{\rho}$ is the relative coordinate and φ^{12}_{IK} is the internal wave function corresponding to Φ^{12}_{IK}. For the natural parity, there are four unknown functions $g^{JM\pi}_{\ell I}$ with (ℓI) equal to (J 0), (J-2 2), (J 2) and (J+2 2). Wave function (3) can also be defined in the GCM basis (2) using four generating functions [4]

$$\Psi^{JM\pi}_{RGM} = \sum_{I|K|} \int_0^\infty R^2 dR \cdot f^{JM\pi}_{I|K|}(R)\ \Psi^{JM\pi}_{I|K|}(R) \qquad (4)$$

which shows the complete equivalence of both treatments.

The MRM allows one to calculate easily the elements $U^{JM\pi}_{\ell I,\ell' I'}$ of the collision matrix, knowing numerical values of matrix elements of the total microscopic hamiltonian H over the whole configuration space. The main problem is thus to compute

$$\langle \Psi^{JM\pi}_{IK}(R) | E - H | \Psi^{JM\pi}_{I'K'}(R') \rangle = \frac{4\pi^4}{2J+1} \int_0^\pi \sin\beta\, d\beta$$
$$\left\{ \langle \Psi_{IK}(R) | (E-H)\, e^{i\beta J_y} | \Psi_{I'K'}(R') \rangle\, d^J_{KK'}(\beta) \right.$$
$$\left. + \langle \Psi_{IK}(R) | (E-H)\, e^{i\beta J_y} | \Psi_{I'-K'}(R') \rangle\, d^J_{K-K'}(\beta) \right\} \qquad (5)$$

where axis y is orthogonal to the intrinsic axis, β is an Euler rotation angle and $d^J_{KK'}$ is a Wigner matrix. Matrix elements (5) are computed numerically using an improved version of the parametrization technique of ref [1]. The calculation is made for a small number of values R_n of R and R' (ten values located from 2.4 to 9.6 fm in the present case). Knowing the values of (5), the (4x4) collision matrix $\underset{\sim}{U}$ can be computed in a simple and straightforward way [4].

The coupled-channel microscopic calculation is performed using effective force B1 and the exact Coulomb interaction. The harmonic oscillator size parameter is 1.79 fm ($\hbar\omega$ = 12.94 MeV). The 2^+ state of ^{12}C is located

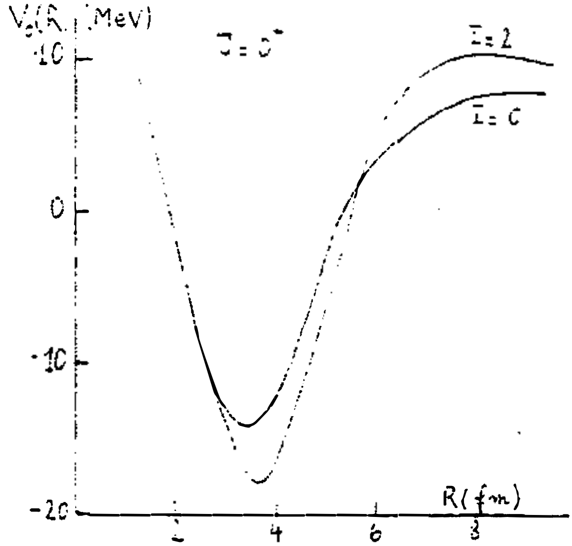

Fig 1. Energy curves for J = 0.

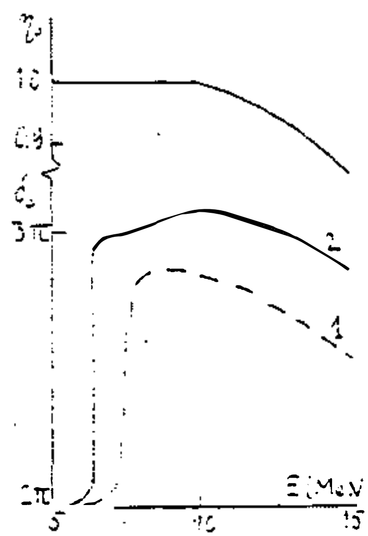

Fig 2. Absorption coefficient η_0 . Elastic scattering phase shift δ_0 in the one-channel (1) and two-channel (2) cases.

2.22 MeV above the ground state (experiment : 4.44 MeV).This underestimation is due to the use of the one-centre harmonic oscillator shell model to describe the ^{12}C nucleus. For J = 0, we present in Fig. 1, energy curves and, in Fig. 2, preliminary results for the elastic matrix element $U^{J\pi\tau}_{00,00} = \eta_0 e^{2i\delta_0}$. The phase shift δ_0 is compared in Fig. 2 to the corresponding one-channel value (dashed line). Both curves show the same qualitative shape but the resonance is lower and narrower in the multichannel case. The absorption coefficient η_0 deviates from unity beyond 10 MeV.

The differences between both phase shifts are due to two distinct causes. Below 10 MeV, the incident energy is smaller than the energy of the Coulomb barrier of the inelastic channel (see Fig. 1), there is nearly no outgoing flux in this channel. However, the GCM basis is larger than in the one-channel case. Wave function φ_{10} has an important overlap with φ_{00} for small R-values. The energies of the quasibound states are thus lowered and their width is therefore reduced. Above 10 MeV, there is a loss of flux from the entrance channel and both calculations become very different.

The analysis of results concerning the other J-values and inelastic scattering is in progress and should be available at the time of the conference.

References

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