MICROSCOPIC INVESTIGATION OF THE $^{12}C + ^{12}C$ INTERACTION

D. Baye and N. Pecher
Physique Théorique et Mathématique, CP 229, Université Libre de Bruxelles,
B 1050 Brussels, Belgium.

The generator coordinate method (GCM) applied to the scattering of heavy ions provides a framework in which the antisymmetrization and the conservation of good quantum numbers can be treated exactly. The scattering wave function is approximated by a linear combination of angular momentum projected Slater determinants representing two ^{12}C nuclei located respectively at $+\frac{1}{2}\underset{\sim}{R}$ and $-\frac{1}{2}\underset{\sim}{R}$. Each ^{12}C ground state is described by a closed p3/2 subshell in the harmonic oscillator model. The distance $\underset{\sim}{R}$ between the centres is considered as a generator coordinate.

We have performed an exact GCM calculation of elastic $^{12}C + ^{12}C$ scattering with a microscopic Hamiltonian involving central and spin-orbit two-body forces and the exact Coulomb interaction [1]. The phase shifts exhibit three bands of resonances which can be interpreted as shape or potential resonances in the $^{12}C + ^{12}C$ effective well. For $J = 0$ to 6, the barrier resonances belong to the second excited band. The $J = 8$ barrier resonance belongs to the first excited band. Beyond $J = 8$, the resonances correspond to the ground-state band.

The GCM has the drawback that its results are not interpreted in terms of a local potential. The main difficulty in obtaining an equivalent local potential is due to a difference in the Levinson theorem between a local and a GCM equation [2]. Besides k^J bound states, the GCM possesses for partial wave J a number m^J of forbidden states, i.e. energy-independent solutions for which the GCM scattering wave function vanishes identically. The usual zero-energy value of the phase shift becomes $(m^J + k^J)\pi$ in place of $k^J\pi$ [2]. We have applied to the $^{12}C + ^{12}C$ system the suggestion of Buck et al [3] to use a local potential having $m^J + k^J$ bound states. These authors obtain excellent results for $\alpha + \alpha$ scattering with a potential of the form

$$V(r) = - V_o \exp (-r^2/r_o^2)$$

We have used this gaussian form for the $^{12}C + ^{12}C$ system together with a sphere-sphere Coulomb potential [4]. With the values r_o = 3.31 fm and V_o = 181.8 MeV, the GCM phase shifts can be reproduced with an accuracy better than one degree up to 25 MeV. Six additional bound states simulate the forbidden states. The scattering wave function being orthogonal to these bound states has the same number of nodes as the GCM wave function. The quality of the fit is due to the fact that the low bound states of the gaussian plus Coulomb potential have an harmonic oscillator shape nearly identical to the forbidden states. This potential does not give correctly the resonances of the other partial waves if one does not allow the depth parameter V_o to vary with J. Table 1 summarizes the values of k^J, m^J and V_o as a function of J. Except for the low partial waves ($J \leqq 6$), the "local" phase shifts are not as good an approximation of the GCM ones as for J = 0 but the locations of the resonances are well reproduced. Up to J = 6, the depths follow an approximate rotational law with the rotational constant 0.22 MeV. The first strong irregularity in the depths arises at J = 8 when the level of excitation of the barrier resonance changes.

As a conclusion, antisymmetrization effects are well simulated for the low partial waves ($J \leqq 6$) of $^{12}C + ^{12}C$ elastic scattering by a deep local potential possessing $6 - \frac{1}{2}J$ additional bound states. Another type of approximation is necessary to describe the partial waves beyond J = 8.

References

1) D. Baye and N. Pecher, to be published
2) P. Swan, Proc. Roy. Soc. A228 (1955) 10
3) B. Buck, H. Friedrich and C. Wheatley, Nucl. Phys. A275 (1977) 246
4) D. Baye, Nucl. Phys. A272 (1976) 445

Table 1

J	k^J	m^J	V_o (MeV)
0	2	6	181.8
2	1	5	180.6
4	1	4	177.6
6	1	3	171.5
8	0	2	152.
10	0	2	158.5
12	0	1	150.