Effect of nuclear deformation parameters in heavy-ion fusion reactions involving spherical-spherical systems

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Introduction

It is well known that heavy-ion collisions at energies near the Coulomb barrier are strongly affected by the internal structure of the colliding nuclei [1]. The coupling between the relative motion and the internal degrees of freedom such as static deformation, vibration of nuclear surface, zero point motion, rotations of nuclei during collision, etc. results in the splitting of the uncoupled Coulomb barrier into distribution of barriers of varying heights.

The role of complex quadrupole and octupole surface vibrations is of particular interest [2] and the calculations within the coupled channels model may become challenging in most nuclei.

In order to study the role of important degrees of freedom of spherical nuclei in the fusion mechanism, we have calculated fusion cross section and barrier distribution (BD) for ^{16}O + ^{120}Sn and ^{16}O + ^{208}Pb systems using the code CCFULL [3].

Calculational details

In the present work, the effects of coupling of low lying vibrational states of target nuclei and their mutual excitation for ^{16}O + ^{120}Sn and ^{16}O + ^{208}Pb systems is investigated. In particular, the effects of couplings of low lying 2^+ and 3^- vibrational states of ^{120}Sn and 3^- and 5^- vibrational states of ^{208}Pb target nuclei and their mutual excitation is studied. The values of the parameters (β_λ, E_λ) for ^{16}O: $\lambda = 3^-$ are (0.728, 6.13 MeV) and for ^{120}Sn: $\lambda = 2^+$ are (0.107, 1.17 MeV), $\lambda = 3^-$ are (0.15, 2.40 MeV) and for ^{208}Pb: $\lambda = 3^-$ are (0.106, 2.61 MeV), $\lambda = 5^-$ are (0.05, 3.197 MeV) [4]. The expt. data for ^{16}O + ^{120}Sn and ^{16}O + ^{208}Pb are taken from the refs. [5] and [6] respectively.

The parameters of the Woods-Saxon form of the nuclear potential for ^{16}O + ^{120}Sn (V_0 = 167.0 MeV, r_0 = 1.10 fm, a_0 = 0.648 fm) are taken from the ref. [5] and for ^{16}O + ^{208}Pb (V_0 = 200.0 MeV, r_0 = 1.05 fm, a_0 = 0.82 fm) are chosen in such a way that the calculated cross sections fit well with the expt. data at the highest energies.

Results and Discussion

Fig. (1) and (2) show the calculated and expt. fusion cross sections and the BD for ^{16}O + ^{120}Sn and ^{16}O + ^{208}Pb systems, respectively. In both the systems, we consider the projectile nucleus ^{16}O to be inert.

As seen in fig. (1), for ^{16}O +^{120}Sn, the dotted line is the result when the projectile (^{16}O) and the target (^{120}Sn) are assumed to be inert, i.e. no excitation level. The result of coupled channel calculations taking into account the coupling to single quadrupole and octupole phonon excitation (2^+, 3^-) in ^{120}Sn with $\beta_2^N = \beta_2^C = 0.107$ is denoted by the dashed line. It fails to reproduce the expt. data of the fusion cross section as well as BD.

We then repeat this calculation by varying the values of β_2^N in order to achieve the best fit with the expt. data. The agreement between the calculations and the expt. data are improved in this way and we find the optimum value for $\beta_2^N = 0.165$. The calculated fusion cross section and the BD are denoted by a solid line in fig. (1). As seen in figs. 1 & 2, these calculations well reproduce the expt. data for the fusion cross section as well as BD. Thus, it is evident that the coupling to the quadrupole and octupole phonon states in the spherical nucleus with $\beta_2^N > \beta_2^C$ is needed to explain the expt. fusion data of ^{16}O + ^{120}Sn reaction.

Similarly, we investigate the effect of β_2^N for ^{16}O + ^{208}Pb system. For this system, we assume $\beta_2^C = 0.106$. First we assume both ^{16}O and ^{208}Pb nuclei to be inert which is denoted by a dotted line in fig. (2). Then we take the low lying

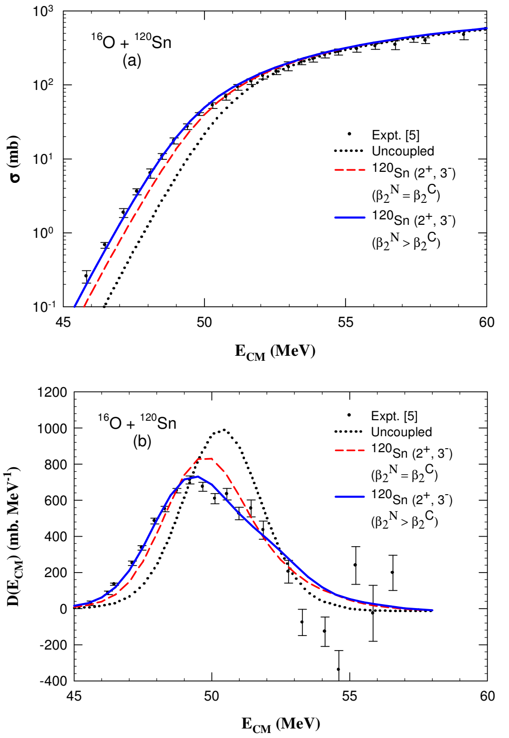

Fig. 1. Comparison of CCFULL calculations with expt. data for (a) the fusion cross section and (b) fusion barrier distribution for ^{16}O + ^{120}Sn system.

vibrational states 3^- and 5^- of ^{208}Pb target nucleus. The calculation with the same value of β_2^N and β_2^C is denoted by a dashed line in fig. (2). Here also it fails to explain the structure of barrier distribution.

Then again we vary the value of β_2^N in order to achieve the best fit with the expt. data. We find the optimum value of $\beta_2^N = 0.161$ for this system. This value matches with the value used in ref. [7]. As seen in fig. (2), these calculations denoted by the solid line, reproduce the expt. data well for the fusion cross section as well as the BD. Therefore, it is clear that the coupling to the low lying vibrational states in the spherical nucleus with $\beta_2^N > \beta_2^C$ is needed to explain the expt. fusion data of ^{16}O + ^{208}Pb reaction.

Conclusion

From the present calculations for both the systems, we concluded that the nuclear deformation parameter β_2^N plays an important role in fusion reaction near the Coulomb barrier and it may have values greater than that for the Coulomb deformation parameter β_2^C.

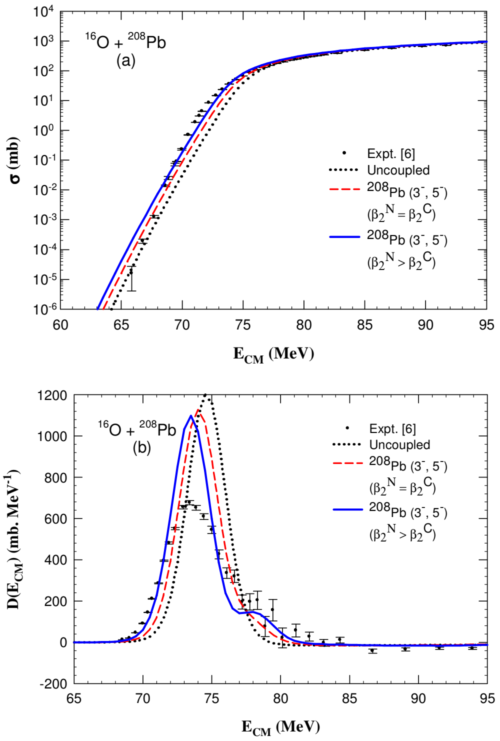

Fig. 2. Comparison of CCFULL calculations with expt. data for (a) the fusion cross section and (b) fusion barrier distribution for ^{16}O + ^{208}Pb system.

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