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Molecular structures and clustering effects in reactions induced by light nuclei

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A great deal of research work has been performed in the field of alpha clustering since the pioneering discovery, by Bromley and his collaborators half a century ago, of molecular resonances in the excitation functions for 12C+12C scattering [1]. Our knowledge of this field of nuclear molecular physics has increased considerably [2] and nuclear clustering remains one of the most fruitful domains of nuclear physics [3-7], facing some of the greatest challenges and opportunities in the years ahead.

The question whether quasi-molecular resonances always represent true cluster states in the compound systems, or whether they may also simply reflect scattering states in the ion-ion potential is still unresolved [1-3]. In many cases, these resonant structures have been associated with strongly-deformed shapes and with clustering phenomena, predicted from the Nilsson-Strutinsky approach, the cranked alpha-cluster model, or other mean-field calculations (see for instance last chapter of [4] and references therein). Of particular interest is the relationship between superdeformation (SD) and nuclear molecules, since nuclear shapes with major-to-minor axis ratios of 2:1 have the typical ellipsoidal elongation (with quadrupole deformation parameter beta ~0.6) for light nuclei. Furthermore, the structure of possible octupole-unstable 3:1 nuclear shapes (with beta ~1.0) - hyperdeformation (HD) - for actinide nuclei has also been widely discussed in terms of clustering phenomena. Typical examples of the possible link between quasi-molecular bands and extremely deformed (SD/HD)shapes have been widely discussed in the literature for N=Z nuclei such as 28Si [8], 32S [9], 36Ar [10-12], 40Ca [13] and 48Cr [14,15].

Large quadrupole deformations and alpha-clustering in light N = Z nuclei are known to be general phenomena at low excitation energy. For high angular momenta and higher excitation energies, very elongated shapes are expected to occur in alpha-like nuclei for A(CN)= 20-60. In fact, highly deformed shapes and SD rotational bands have been recently discovered in several such N = Z nuclei, in particular, 36Ar using gamma-ray spectroscopy techniques [16,17]. Extremely deformed rotational bands in 36Ar are observed as quasi-molecular bands in both 12C+24Mg and 16O+20Ne reactions [10-12,17], and their related ternary clusterizations are also predicted theoretically [13,17].

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