Alpha-structured fragments and isospin influence

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Introduction

A compound nucleus formed in low energy heavy-ion reactions, generally have high angular momentum and excitation energy. It decays with the emission of light particles like neutron, proton, helium or gamma-rays and/or some fragments. It has been observed experimentally that the fragments with mass number $A_2 = 4n$ (n = 1, 2, 3, ...) has a relatively large cross-section, see Fig. 3 of ref. [1] and has speculated that this may be due to the presence of α-structure in 4n fragments. Theoretically, Gupta *et al.*, [2] has shown that there are deep minima in the potential energy surface and these correspond to the α-structured fragments within their preformed cluster model.

In this paper, we have adopted a similar approach, but with the binding energies calculated using the formulae of [3] and [4]. The binding energies of [3] have been calculated with new bulk and asymmetry constants refitted by two of us [5] to reproduce the recent experimental [6] and theoretical [7] mass excess. The theoretical mass excess is considered, wherever the experimental mass excess were not available. Using these binding energies we have calculated the fragmentation potential for the isotopes of nickel, molybdenum and barium nuclei, that is the isotopes from proton-drip line to neutron-drip line, of the available isotopes in [7], with a step of four neutrons for a given nucleus. Also the effect of isospin (I = N/Z ratio) on the number of α-structured fragments has been studied.

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Formalism

The fragmentation potential is defined as,

$$V_T = \sum_{i=1}^{2} V_{LDM}(A_i, Z_i) + \sum_{i=1}^{2} \delta U_i + V_C(Z_i) + V_P(A_i) \quad (1)$$

This potential is calculated by using V_{LDM} of Davidson [3] and Krappe [4]. The V_{LDM} of [3] is,

$$V_{LDM} = \alpha A + \beta A^{\frac{2}{3}} + \left(\gamma - \frac{\eta}{A^{\frac{1}{3}}}\right)\left(\frac{4t_\zeta^2 + 4|t_\zeta|}{A}\right) + \frac{Z^2}{r_0 A^{\frac{1}{3}}}\left(1 - \frac{0.7636}{Z^{\frac{2}{3}}} - \frac{2.29}{[r_0 A^{\frac{1}{3}}]^2}\right) + \delta\frac{f(Z,A)}{A^{3/4}}; \qquad t_\zeta = a_a(Z-N) \quad (2)$$

In this case, new bulk (α) and asymmetry (a_a) constants of [5] have been used. The V_{LDM} of [4] is,

$$V_{LDM} = E_{ld} + E_W + E_{pair} + f(k_f r_p)Z^2/A - c_a(N-Z) - a_{el}Z^{2.39} \quad (3)$$

The terms in Eq. (3), respectively are: liquid drop energy, Wigner term, average pairing energy, proton-form factor correction to the Coulomb energy, charge-asymmetry energy and energy of bound electrons. The shell corrections δU_i are of [8] and V_C, V_P are Coulomb potential and proximity potentials, respectively.

Calculations and results

Fig. 1 shows the fragmentation potentials calculated by using binding energy formulae of Davidson's [3] (solid line plus • symbol) and of Krappe [4] (solid line plus ∘ symbol) for the isotopes of Ba (with neutron numbers

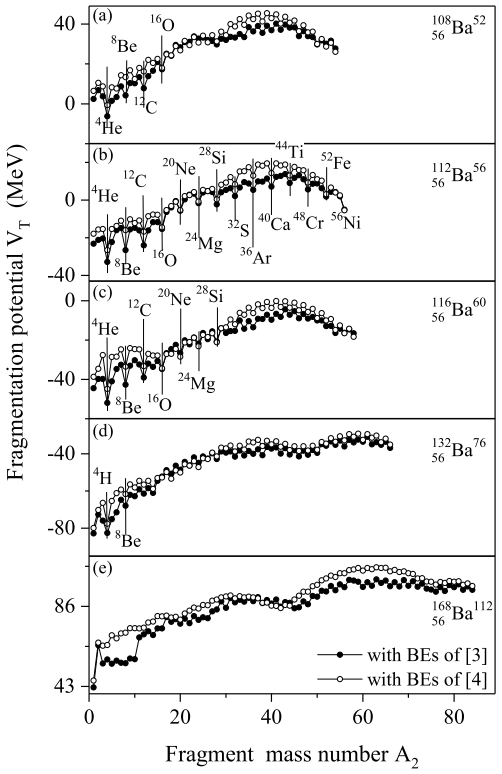

FIG. 1: The calculated fragmentation potentials for the Ba-isotopes, by using binding energies formulae (BEs) of Davidson's [3] (line plus • symbol) and of Krappe [4] (line plus ◦ symbol).

52, 56, 60, 76, 112). Fig. 1 (a) shows the α-structure for ^{8}Be, ^{12}C and ^{16}O fragments in the fragmentation of $^{108}_{56}Ba^{52}$ nucleus with I = 0.929. Similarly, Fig. 1 (b) shows ^{8}Be, ^{12}C, ^{16}O, ^{20}Ne, ^{24}Mg, ^{28}Si, ^{32}S, ^{36}Ar, ^{40}Ca, ^{44}Ti, ^{48}Cr, ^{52}Fe and ^{56}Ni as α-structured fragments for $^{112}_{56}Ba^{56}$ nucleus with I = 1, Fig. 1 (c) shows ^{8}Be, ^{12}C, ^{16}O, ^{20}Ne, ^{24}Mg and ^{28}Si as α-structured fragments for $^{116}_{56}Ba^{60}$ nucleus with I = 1.071 and Fig. 1 (d) for nucleus $^{132}_{56}Ba^{76}$ with I = 1.357 shows only one α-structured fragment ^{8}Be. While the fragmentation of the nucleus $^{168}_{56}Ba^{112}$ (Fig. 1 (e)) with I = 2.0 have no α-structured fragments.

Fig. 2 shows the variation of calculated

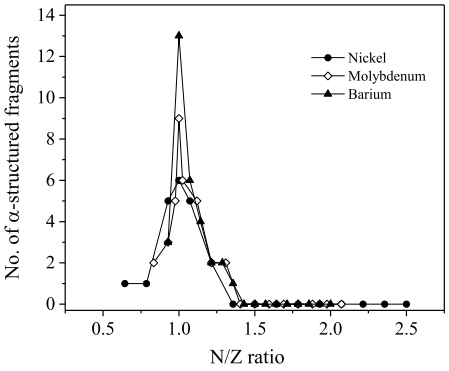

FIG. 2: The variation of calculated number of α-structured fragments as a function of neutron-proton (N/Z) ratio for the nickel (line plus • symbol), molybdenum (line plus ◇ symbol) and barium (line plus ▲ symbol) nuclei.

number of α-structured fragments for the nickel (solid line plus • symbol), molybdenum (solid line plus ◇ symbol) and barium (solid line plus ▲ symbol) nuclei as a function of N/Z ratio. It is clear from the figure that the number of α-structured fragments is maximum for N = Z nuclei in each case. Thus, we conclude that the isospin affects the number of α-structured fragments in the fragmentation of a compound nucleus.

References

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