Role of shell corrections in the temperature dependent binding energies applied to the decay of $^{56}Ni^*$

C. Karthikraj, N. S. Rajeswari,* and M. Balasubramaniam†
Deptartment of Physics, Bharathiar University, Coimbatore - 641 046, INDIA

Introduction

The decay of light to heavy mass excited nuclei into light particles (A $\leq$ 4, Z $\leq$ 2) and intermediate mass fragments (4 $<$ A $<$ 20, Z $>$ 2) has been studied extensively using the Dynamical Cluster Model(DCM) of Gupta and collaborators [1]. In DCM, the decay mechanism is considered as the dynamical collective mass motion of the preformed clusters (including LPs and IMFs) through the interaction barrier. For calculating the temperature dependent fragmentation potentials, the important ingredient is the temperature dependent binding energies.

In literature, different temperature dependent binding energy expressions are available. In DCM, it has been shown by one of us [2] that the use of Krappe's temperature dependent binding energy formula [3] over Davidson's formula exactly reproduces, the four nucleon transfer mechanism in the observed decay cross-section of ^{56}Ni*, whereas the Davidson's formula gives simply an odd-even structure in the calculated potentials as well as in the cross-sections. For the use of any temperature dependent liquid drop part of binding energy formula, it needs to be first re-fitted by varying the volume and surface energy coefficients to give g.s. experimental binding energies. While re-fitting, for shell corrections, the analytical expression of Myers-Swiatecki is used. [4].

In the mass formula of Myers-Swiatecki it has been proposed that, for calculating shell functions the magic number sequence can be considered by taking either 14 or 20 as magic numbers separately and accordingly we refer this as MS14 and MS20 parametrization and for the use of 14 and 20, as MS1420. While re-fitting the temperature dependent binding energies (at T=0) to reproduce experimental g.s. binding energies, the sequence of considering magic number also plays an important role. We present in this work, the role of different shell parametrizations (MS14, MS20 and MS1420) in the temperature dependent binding energies of Krappe applied to the decay of compound system ^{56}Ni* formed in low energy heavy ion collision $^{32}S+^{24}Mg$ for a particular incident energy ($E_{c.m}$=51.6 MeV).

Model

The temperature dependent fragmentation potential in DCM is given as

$$V(R,\eta,T) = \sum_{i=1}^{2}[V_{LDM}(A_i,Z_i,T)] + \sum_{i=1}^{2}[\delta U_i] \times exp\left(-\frac{T^2}{T_0}\right) + V_c(T) + V_p(T) + V_\ell(T) \quad (1)$$

The liquid drop part is calculated using Krappe's [3] temperature dependent mass formula. $V_c(T), V_p(T), V_\ell(T)$ are the temperature dependent Coulomb, proximity and centrifugal potentials. For the use of these potentials, the decay cross section is defined as,

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)P_0P; k = \sqrt{\frac{2\mu E_{c.m}}{\hbar^2}} \quad (2)$$

where P_0 and P, are the probability of preformation of fragments referring to η motion and the penetrability referring to R motion.

Results and discussion

Figure 1 gives the calculated temperature dependent fragmentation potentials for ℓ=0 $\hbar$

*Permanent Address: Department of Physics, Avinashilingam Inst. for Home Science and High. Edu. for Women, University,Coimbatore-43.
†Electronic address: m.balou@gmail.com

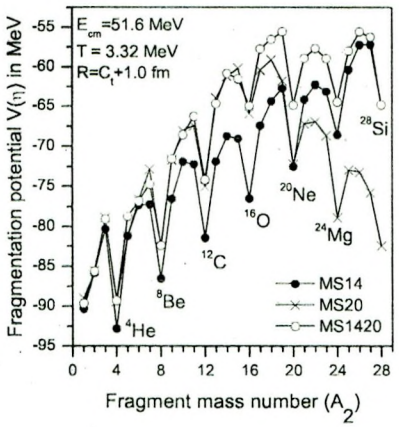

FIG. 1: The T-dependent fragmentation potentials of ^{56}Ni* for the use of MS14,MS20 and MS1420 parametrizations in fitting the B.E.'s.

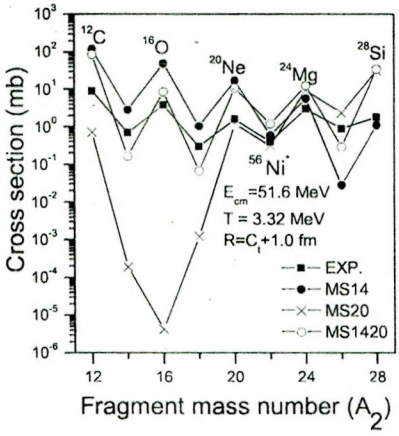

FIG. 2: Calculated decay cross section of ^{56}Ni* for the three parametrization compared with experimental data.

at fixed T=3.3272 MeV and for an arbitrary value of R chosen as R=C_t+1.0 fm for the three parametrizations considered. Though the shell corrections δU will vanish at temperature we consider, it has pronounced effect, when different parametrization is used in refitting the binding energies. We notice that all the three parametrizations gives a strong minima corresponding to the α-structured nuclei, indicating a favourable four nucleon transfer mechanism, which is mainly a liquid drop effect. However, the magnitude of the potential changes considerably between the three parametrizations. For example, with MS20 parametrization, the potential starts to decrease after fragment mass number 16, showing much preference for fragments 24 and 28 over fragments 16 and 20, whereas in the other two parametrizations, the potential increases (except at α-structured nuclei) with increase in mass number. The potential energy itself reveals important information that, the choice of magic number sequence is also important while re-fitting any temperature dependent binding energy expression to experimental values. However, the actual results can be seen only from the cross section calculations (a combined effect of preformation and penetration probability) as presented in Fig.2 for the three different parametrization along with the experimental data[5]. The variation of the cross section for MS14 and MS1420 parametrization is similar showing explicit preference for α-structured nuclei, however, the MS20 parametrization completely presents a different result atleast for lighter fragments upto 20. No attempt is made to fit the experimental data. The obtained results suggests that, the MS14 and MS1420 parametrization, would give better results than the MS20 parametrization.

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