Isotopic distribution of fragments from the binary fission of ^{56}Ni

C. Karthikraj, P. Karthika, and M. Balasubramaniam*
Department of Physics, Bharathiar University, Coimbatore - 641046, Tamilnadu.

Introduction

Since nickel is an important structural material in fission and fusion reactor technologies, precise knowledge of the fission of nickel is very important. Basically, ^{56}Ni is the negative Q-value system and hence it is naturally stable against fission. However, if it is produced in heavy-ion/neutron induced fission reactions, depending on the incident energies and angular momentum, the formed excited nucleus could undergo fission. In order to investigate this, several experiments and theoretical models have been performed.

In Ref, [1], we have studied the decay of ^{56}Ni with the use of dynamical cluster-decay model (DCM), where the charge minimized potential is considered to obtain the favourable fission fragment combinations. On the basis of the statistical theory of fission, Rajasekaran and Devanathan [2] studied the mass distribution of the fission fragments from the binary fission of ^{236}U, ^{240}Pu and ^{258}Fm nuclei, where the charge to mass ratio is considered to generate the fragment combinations. However, in the present work we have considered the all possible ($16{\leq}A_{ff}{\leq}40$ and $8{\leq}Z_{ff}{\leq}20$) fission fragment combinations for the binary fission of ^{56}Ni. Here, we have presented for the first time, the isotopic distribution of fragments from the binary fission of ^{56}Ni at T=1 MeV.

The model

According to Fong's [3] statistical theory of fission, the fission probability is proportional to the product of nuclear level densities and is,

$$P(A_i, Z_i) \propto \rho_1(A_1, Z_1)\rho_2(A_2, Z_2). \quad (1)$$

*Electronic address: `m.balou@gmail.com`

with the use of Bethe's form [4] the nuclear level density ρ is calculated as,

$$\rho = \frac{1}{12}(\pi^2/a)^{1/4}E^{-5/4}\exp(\sqrt{2aE}), \quad (2)$$

where a is the level density parameter, $a{=}E/T^2$ and E is the excitation energy, $E{=}E_{tot} - E_0$. The total energy of the system is given by,

$$E_{tot} = \sum_k n_k^Z \epsilon_k^Z + \sum_k n_k^N \epsilon_k^N, \quad (3)$$

where n_k^Z and n_k^N are the occupation probabilities of Z protons and N neutrons of a particular fragment and ϵ_k^Z and ϵ_k^N are the single particle energies (SPEs) of Z protons and N neutrons respectively. For this calculation, the SPEs are retrieved from the Reference Input Parameter Library (RIPL-3) database [5]. The particle number equations are,

$$Z = \sum_k n_k^Z = \frac{1}{1+\exp(-\alpha^Z + \beta\epsilon_k^Z)}, \quad (4)$$

$$N = \sum_k n_k^N = \frac{1}{1+\exp(-\alpha^N + \beta\epsilon_k^N)}. \quad (5)$$

The ground state energy is,

$$E_0 = \sum_{k=1}^{Z} \epsilon_k^Z + \sum_{k=1}^{N} \epsilon_k^N. \quad (6)$$

The yield is calculated as,

$$Y(A_i, Z_i) = \frac{P(A_i, Z_i)}{\Sigma P(A_i, Z_i)}. \quad (7)$$

Results and discussion

In this study, we have not done any minimization to generate fragment combinations

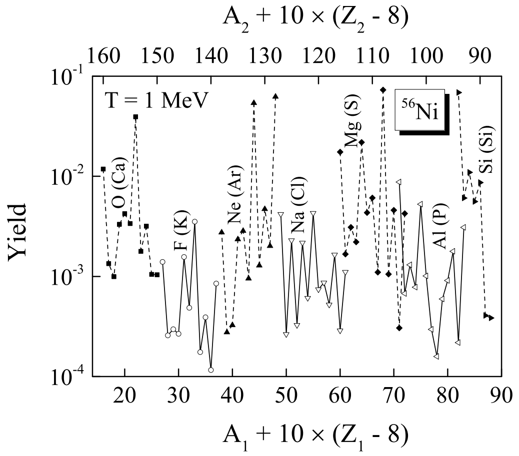

FIG. 1: Isotopic ($16 \leq A_{ff} \leq 40$) distribution of fragments from the binary fission of ^{56}Ni at T = 1 MeV.

TABLE I: Mass, charge and neutron numbers of the fission fragments having the largest yield.

A_1	Z_1	N_1	A_2	Z_2	N_2
22	8	14	34	20	14
23	9	14	33	19	14
28	10	18	28	18	10
25	11	14	31	17	14
28	12	16	28	16	12
21	13	8	35	15	20
22	14	8	34	14	20

however, we have considered the possible fragment combinations from the theoretical mass table of Ref. [6]. For these fragment combinations, we have retrieved the SPEs from the RIPL-3 database, which is based on the finite range droplet model (FRDM). With the use of statistical theory of fission, the fission probabilities are calculated for the possible fragment combinations. Further, the yield is calculated between the ratio of particular fragment combination's probability and the sum of probabilities of all fragment combinations. Fig. 1 represents the isotopic distribution of fission fragments ($16 \leq A_{ff} \leq 40$ and $8 \leq Z_{ff} \leq 20$) from the binary fission of ^{56}Ni at $T = 1$ MeV. The horizontal axis were chosen to spread the data out in such a way that the different elements do not overlap. The light (A_1) and heaviest (A_2, in brackets) elements are labelled in the figure. From this figure, the even-Z fragments having the largest yield than the odd-Z fragments. Further, the results exhibit that the largest yields for the fragment combinations having the closed shell and/or sub shell structure in any one of the associated fragments or both of the fission fragments. The most favoured fragments mass (A), charge (Z) and neutron (N) numbers are listed in Table 1, to make a clear understanding of the closed shell and/or sub shell structure of the fission fragments.

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