Isospin conservation in neutron-rich fission fragments from thermal neutron induced fission

A.K. Jain and Deepika Choudhury
Department of Physics, Indian Institute of Technology Roorkee, Roorkee-247667, INDIA

Neutron rich nuclei are unique examples of large isospin systems where observation of new phenomena are expected. Fission fragments from fission of heavy nuclei are a good source of such neutron rich nuclei. We have recently shown that [1] in the HI fusion-fission reactions [2, 3], for each fission partition dominated by a particular neutron emission channel, the observed relative intensities of the correlated pairs of fission fragment masses can be explained in a strikingly precise manner by isospin conservation. We further show that the same arguments lead to a very precise prediction of partition-wise fission fragment mass distribution in thermal-n induced fission.

We adopt the convention where nucleons carry an isospin $\vec{t} = 1/2$ with projections $t_3 = +1/2$ and $t_3 = -1/2$ (in units of $\hbar$) corresponding to a neutron and a proton, respectively. The projection of the total isospin of the nucleus is given by $T_3 = \sum t_3 = (N-Z)/2$ and is known precisely. However, the total isospin T of a nuclear state can have any value between a maximum of $(A/2)$ to a minimum of $(N-Z)/2$.

We, now, consider a compound nucleus (CN) formed in a neutron induced fission reaction (neutron + target T) where the compound nucleus (CN) formed, fissions into two fragments F_1 and F_2 along with the emission of q neutrons,

$$n \;+\; T(Z_T, N_T) \rightarrow CN(Z, N)^* \\ \rightarrow\; F_1(Z_1, N_1) + F_2(Z_2, N_2) + q\,{}^1_0n\ .$$

For a given T_3 value, the lowest T value that can be assigned to a nucleus is $T = T_3$. Hence, the minimum value of the total isospin T of the projectile (neutron in this case) and target denoted by $T_n (= 1/2)$ and T_T respectively is equal to the respective T_3 component. The incident beam can excite compound nuclear systems which have minimum isospin values $T_{CN} = T_T$ and $T_T \pm 1/2$. When the excited and unstable CN fissions into a pair of daughter fragments and q neutrons, the total isospin of the fission fragments, emerging from the residual compound nucleus (RCN), must lie in the range

$$|T_{CN} - (q/2)| \leq T_1 + T_2 \leq (T_{CN} + (q/2))\ .$$

Here, T_1, T_2 represent the total isospins of the fission fragment pairs and T_{3_1}, T_{3_2} are their respective T_3 components. We have introduced an auxiliary concept of RCN (remaining after the emission of fission neutrons), having $T_{RCN} = T_1 + T_2$, to facilitate the discussions. After excluding the T and T_3 of the emitted neutrons, the isospin wavefunction of the RCN can be related to the isospins of the two correlated fission fragments in a given partition as

$$|T, T_3\rangle_{RCN} = \sum_{T_{3_1}, T_{3_2}} \langle T_1, T_2, T_{3_1}, T_{3_2} | T, T_3\rangle \\ |T_1, T_{3_1}\rangle |T_2, T_{3_2}\rangle\ .$$

All the isospin components T_3 of the correlated pairs of fragments in a given partition (defined by Z_1, Z_2) should form a multiplet of the total isospin T of the fragments. The intensity or relative yield of each member of a correlated pair of fission fragments in a given partition can, therefore, be obtained from the square of the corresponding C.G. coefficients.

We have analysed the fission fragment mass distribution from the reaction ${}^{245}Cm(n^{th}, f)$ [4]. The authors [4] have measured the isotopic yields from mass A=85 to A=115 corresponding to nuclear charges Z=33(As) to Z=47(Ag). The corresponding correlated pairs of fragments for these nuclei having nuclear charges Z=49 (In) for Ag to

Z=63 (Eu) for As could not be observed as the experimental technique was not sensitive enough beyond Z=47. Here, we discuss the relative yield of correlated pairs of fragments for two of the fission partitions:
(1) Ru-Te correlated pair of fragments: Only Ru isotopes observed experimentally.
(2) Kr-Nd correlated pair of fragments: Only Kr isotopes observed experimentally.

In thermal neutron induced reactions, 0-7 neutrons are emitted with the respective weight factors which we have considered in our interpretation/calculations. Table I shows T values of the emitted neutrons and the RCN along with the weight factors for the various neutron emission channels. The weight factors quoted in Table I have been taken from the LLNL report [5]. The chosen T values do not violate the triangle identity of isospin conservation during the entire reaction/process.

TABLE I:

neutron emission	weight factor	T of emitted neutrons	T of RCN
0	0.004373	0	27
1	0.008011	0.5	27.5
2	0.100233	1	27
3	0.277928	1.5	28.5
4	0.334261	2	28
5	0.196610	2.5	29.5
6	0.065010	3	29
7	0.017510	3.5	28.5

It was found that, for a particular neutron emission channel, the more asymmetric correlated pairs of fission fragments are related to more asymmetric combinations of the individual T values. Also, the T assignment to the fragments depends on the T value taken away by the neutron emission and follows a particular pattern. Fig. 1 shows the results of our calculations for the observed even-A isotopes of Ru and Kr. An excellent agreement between theory and experiment is observed.

The concept of isospin conservation in neutron induced fission reactions is able to explain very precisely the relative yields of the observed member of the correlated pairs of fission fragments in each pair partition. This

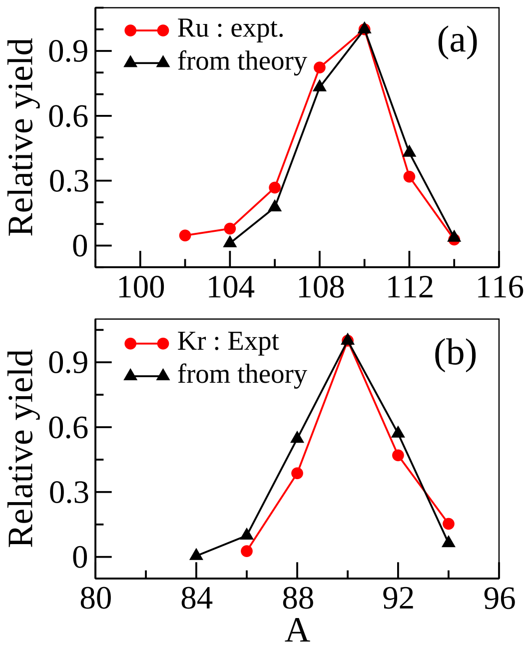

FIG. 1: Comparison of the measured and calculated relative yields of the observed even-A isotopes of (a) Ru and (b) Kr.

supports our earlier claims in HI fusion-fission reactions.

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