Isoscaling studies in ^{86}Kr+^{112,124}Sn, ^{197}Au reactions at E_{lab}=30 MeV/nucleon

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Isoscaling of fragment yields from similar sources of nearly same temperature, but different isospin asymmetry (m_s), provides information about the nuclear symmetry energy [1-3]. Information about the nuclear symmetry energy would help in constraining the asymmetric part of the nuclear equation of state (EOS), which has important implications in nuclear physics and astrophysics [4-5].

In the present work, isoscaling studies have been carried out using fragment yield data from the fragmentation of projectile like source (quasiprojectile) in the reactions ^{86}Kr+^{112,124}Sn, ^{197}Au. The values of isospin asymmetry (m=(N-Z)/A) for the projectile, target and composite system for different reactions are given in the Table I.

Table I. Isospin asymmetry (*m*) for different reactions.

Reaction	*m*=(*N*-*Z*)/*A*		
	Projectile	Target	Composite system
^{86}Kr+^{112}Sn	0.163	0.107	0.131
^{86}Kr+^{124}Sn		0.194	0.181
^{86}Kr+^{197}Au		0.198	0.187

It can be seen from the table that *m* values for the composite system of ^{86}Kr+^{124}Sn and ^{86}Kr+^{197}Au reactions are close. Thus, any difference in the isospin asymmetry of the quasiprojectile in the two reactions would indicate a Coulomb effect in *N/Z* equilibration.

Experiments were carried out at the K500 superconducting cyclotron at the Cyclotron Institute, Texas A&M University. Fragments were detected using the FAUST detector array, which consists of 68 Si-CsI telescopes and covers 1.6^0 to 45^0 in the forward hemisphere. Free neutrons were not detected in these measurements. The detector thresholds and angular acceptance provide a preference for the fragments from the projectile like source or quasiprojectile by rejecting majority of slow moving target-like products. The E-ΔE spectra from FAUST array were linearized using a point to curve method and calibrated using the existing calibration data of FAUST.

The average isospin asymmetry value of fragments ($<m_f>$), calculated from the *m* values of the detected fragments, was 0.035, 0.047, 0.047 for ^{86}Kr+^{112}Sn, ^{86}Kr+^{124}Sn and ^{86}Kr+^{197}Au reactions, respectively. Similar $<m_f>$ values for the last two reactions suggest that the process of *N/Z* equilibration is mainly governed by the isospin difference between the projectile and the target nuclei and Coulomb effect is not very significant. According to the isoscaling relation, the ratio of fragment yields for a given *Z* from two different reaction systems is given as [2,3]

$$R_{21} = \ln\left(\frac{Y_2}{Y_1}\right) \propto \alpha N \qquad (1)$$

where *N* is neutron number and α is an isoscaling parameter which is equal to '$(4C_{Sym}/T)\Delta$' [2]. C_{Sym} is the symmetry energy coefficient and *T* is the temperature of the system. In the present study, Δ is taken as the difference in $<m_f>$ for the two reactions. In order to determine α values, R_{21} values were calculated by taking the ratio of fragment yields in the reactions ^{86}Kr+^{124}Sn and ^{86}Kr+^{197}Au with respect to ^{86}Kr+^{112}Sn reaction. Plots of R_{21} values calculated for ^{86}Kr+^{124}Sn/ ^{86}Kr+^{112}Sn along with the fitted lines for *Z*=4-13 are shown in Fig. 1. The behavior of fragments with Z≤3 was not consistent, possibly, due to the contribution from pre-equilibrium and neck emission.

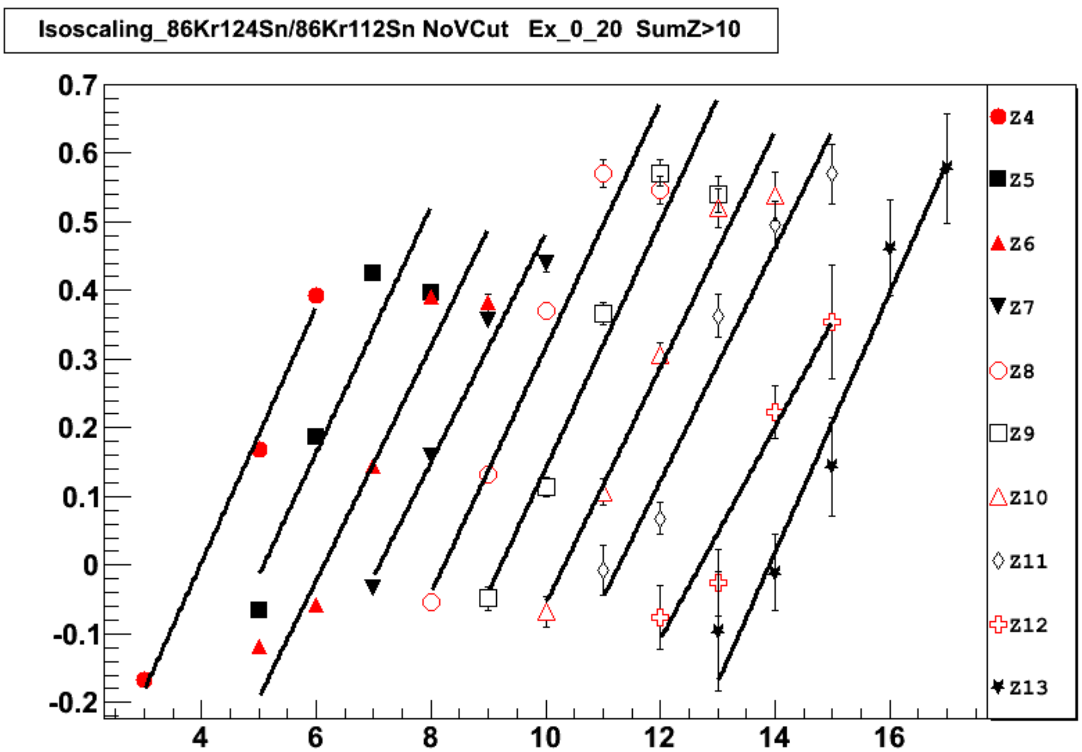

FIG. 1. Plot of R_{21} for ^{86}Kr+^{124}Sn/^{86}Kr+^{112}Sn.

In Fig. 2, α values, obtained as slopes of linear fits to R_{21} values for '^{86}Kr+^{124}Sn/^{86}Kr+^{112}Sn', '^{86}Kr+^{197}Au/^{86}Kr+^{112}Sn' and '^{86}Kr+^{197}Au /^{86}Kr+^{124}Sn' are shown. The error weighted average values of α for these reaction pairs were 0.177±0.008, 0.175±0.024 and -0.002±0.024 respectively. The close agreement between the α values for the first two reaction pairs further suggests similar isospin asymmetry of the fragmenting sources in ^{86}Kr+^{124}Sn and ^{86}Kr+^{197}Au reactions, which is also the reason

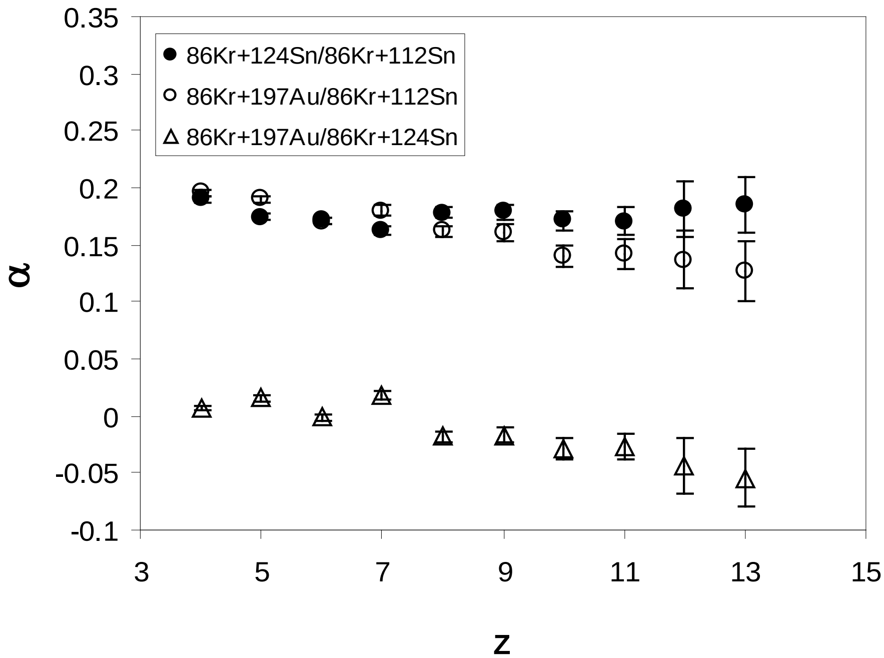

FIG. 2. Plot of α values vs. Z for different pairs of reactions.

for negligibly small α values for the third pair. For Z>9, a systematic difference between the α values for ^{86}Kr+^{124}Sn/^{86}Kr+^{112}Sn and ^{86}Kr+^{124}Sn/^{86}Kr+^{112}Sn pairs needs further investigation. In Fig. 3, C_{Sym}/T values calculated using average α values are shown as a function of apparent excitation energy [1] of the fragmenting source. As seen in Fig. 3, decrease in C_{Sym}/T with increasing excitation energy has also been reported in recent isoscaling studies [1,6,7]. Further work is going on to determine the temperature of the system, in order to extract information about C_{Sym}.

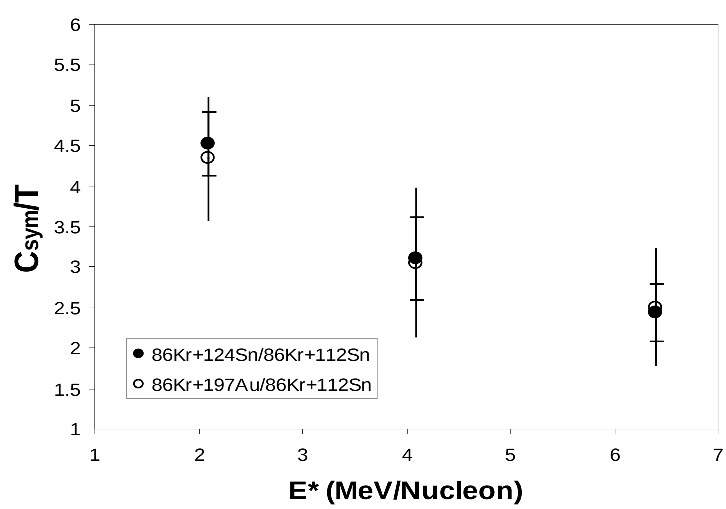

FIG. 3. Plot of C_{Sym}/T vs. excitation energy of the source.

In summary, isoscaling studies showed formation of projectile-like fragmenting sources with similar isospin asymmetry in ^{86}Kr+^{124}Sn and ^{86}Kr+^{197}Au reactions which have significantly different Coulomb repulsion in the entrance channel. C_{Sym}/T values determined from the isoscaling parameter α showed a systematic decrease with increasing excitation energy of the fragmenting source.

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