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Systematics of asymmetry in fission based on order-disorder model

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Abstract. According to Order-Disorder Model (ODM), in the early stages of fission, the charges in a fissioning nucleus gets polarised into two impending parts along with corresponding most stable neutrons which are calculated from the minimum in isobaric mass parabola. This polarisation into two most stable configuration leaves a small number of neutrons as balance neutrons i.e. $N_{\rm bal}$. The distribution of these $N_{\rm bal}$ for various polarisation modes, shows a very profound correlation with the yield distribution. Judging from this striking correlation between these two distributions, it can be predicted that the asymmetry in fission decreases gradually and ultimately disappear for nuclei having $Z \simeq 102$ but reappears again for the nuclei in super heavy region.

Keywords. Order-disorder model; asymmetry; fission; polarisation; balance neutrons.

1. Introduction

In the Order-Disorder Model (ODM) (Iyer and Ganguly *et al* 1971) it was visualised that in the early stages of fission process a fissioning nucleus undergoes polarisation into two impending fragment clusters having a number of protons and neutrons corresponding to the most stable species of nuclei at their ground states. As a result of this polarisation a few neutrons are left out as balance neutrons, called as $N_{\rm bal}$.

2. Balance neutrons

The number of balance neutrons are given by

$$N_{\rm bal} = N_F - N_L^S - N_H^S$$

where N_F is the to*t*al number of neutrons of the original nucleus and N_L^S and N_H^S are the stable neutron numbers for the corresponding polarised charges Z_L and Z_H for the stability condition for the clusters.

The stable neutron number for a nuclear charge has been obtained from the stable proton number for a given mass, using an experimental mass table (Wapstra and Gove 1971). Stable charges for a mass have been arrived at by fitting the isobaric mass values in a parabola. The minimum in the parabola gives the most stable charge for a mass and by intrapolation stable neutron number for the charges are obtained.

3. Systematics of N_{bal}

The parameter N_{bal} has been found to have a significant correlation with yield distribution, namely higher value of N_{bal} for symmetric low yield region and lower value for the higher asymmetric yield region. The parameter $1/N_{bal}$ as a function of Z for a number of fissioning nuclei are shown in figure 1. These distributions show all characteristic features of low energy fission, namely asymmetry in actinide region, decrease of asymmetry with increasing mass/charge of the fissile nuclei and bunching of the higher Z-peak. For higher mass nuclei whose symmetric charge falls in the region of $Z=52$, the asymmetry is found to disappear to a large extent as in case of ^{260}Ku. Empirically it is also observed that the yield value of the fragment distribution can be approximately related as yield $(Z) \simeq (1/N_{bal})^P$, where $P \gg 1$.

4. Conclusions

In figure 2 the stable neutron numbers as a function of nuclear charge are shown. Distribution of these stable neutron numbers shows departure from straight line at shell-edges. The $1/N_{bal}$ distributions in three typical cases in different shell regions are shown in the insets. The stable neutron numbers for the charges without taking

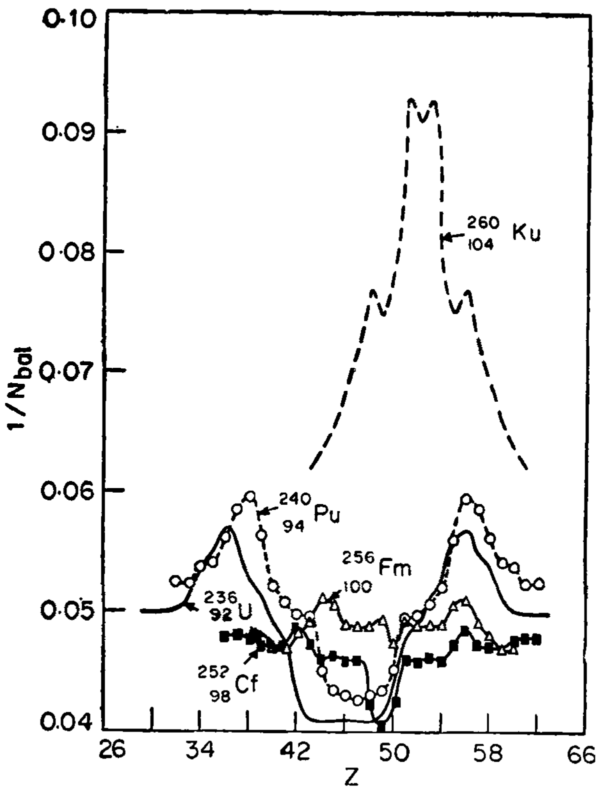

Figure 1. Distribution of $1/N_{bal}$ vs Z for the charge polarisation in ^{236}U, ^{240}Pu, ^{252}Cf, ^{256}Fm and ^{260}Ku.

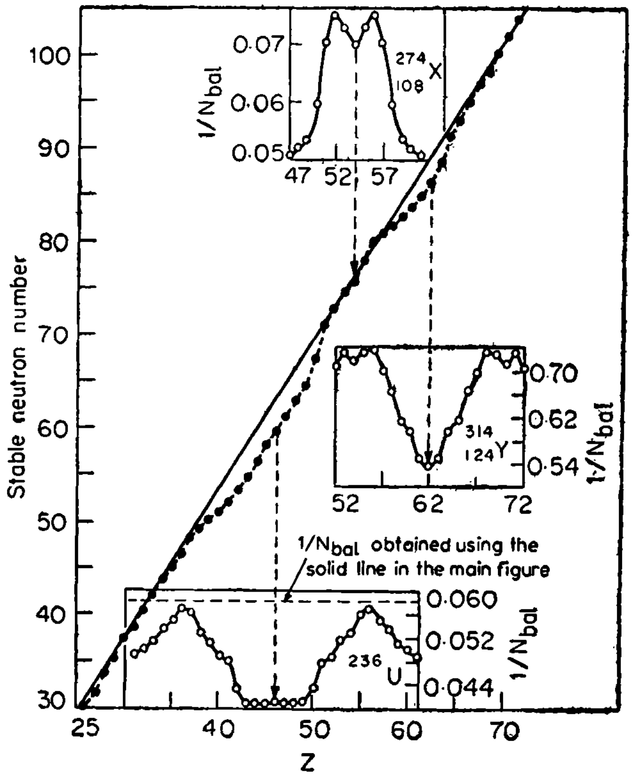

Figure 2. Stable neutron number vs Z derived from Wapstra's mass table. The solid line in the main figure represents the stable neutron number vs Z without any shell effects. $1/N_{bal}$ distribution for ^{236}U, $^{274}_{108}X$ and $^{314}_{124}Y$ are given in the insets. The dashed line in the inset for ^{236}U represents the $1/N_{bal}$ values obtained using the solid line in the main figure.

into account the shell effects would have been as indicated by the straight line. N_{bal} obtained from this line always gives a constant value (see in the inset for ^{236}U) and thus observed asymmetry in the $1/N_{bal}$ distribution disappears. The asymmetry in fission being due to shell effects can also be reconciled in the ODM approach, without making any explicit assumption for preferential formation of closed shell species. The possible shell effects in ODM approach are reflected in a natural manner through the stable neutron numbers for the charges.

The concept of charge polarisation with stable neutron number seems to point to some profound consequences. In figure 2, $1/N_{bal}$ distribution for ^{236}U and two other hypothetical nuclei $^{274}_{108}X$ and $^{314}_{124}Y$ are given and their symmetric charges lie near the mid points of the three neutron and proton shell regions. When one moves from the symmetric charge at the first shell region to the second ($Z > 50$) the asymmetry in $1/N_{bal}$ distribution almost disappears as shown for $^{274}_{108}X$. With further increase of symmetric charge which lie in the 3rd mid-shell region ($Z > 56$), the asymmetry in $1/N_{bal}$ distribution reappears as shown in the inset for $^{314}_{124}Y$. Judging from this systematics one can expect reappearance of prominance of asymmetric mode of division for super heavy nuclei.

References

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