

ROLE OF THE BREAK-UP REACTION FOLLOWED BY FUSION (BURFF) MECHANISM IN  
NONEQUILIBRIUM EFFECTS IN ALPHA INDUCED REACTIONS

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The sizeable cross-sections for  $(\alpha, xn)$  reaction channels at bombarding energies well above the evaporation maxima for any given  $x$  are usually interpreted in terms of the preequilibrium model (see e.g. <sup>1</sup>). There is, however, a mounting evidence on the important contribution to these cross-sections due to a break-up of the  $\alpha$  particle in the field of the nucleus, with subsequent fusion of one fragment with the target nucleus, while the remaining fragment - a neutron in  $(\alpha, xn)$  reactions - continues its flight on only slightly altered trajectory (cf. recent review <sup>2</sup>).

According to <sup>3</sup>) the inclusive cross-section for the  $\alpha \rightarrow t + p$  break-up process varies from  $\sim 10\%$  of the total reaction cross-section at  $E_\alpha = 80$  MeV to  $\sim 25\%$  at  $E_\alpha = 160$  MeV. The following fusion of the heavier fragment with the target nucleus can be estimated (see <sup>2</sup>) and refs. therein) to take place in  $(80 \pm 10)\%$  of the cases. Similar or even larger cross-sections can be expected for BURFF of the  $\alpha \rightarrow {}^3\text{He} + n$  type. This would correspond e.g. in the case of  ${}^{158}\text{Gd} + 70$  MeV  $\alpha$  (the present work) to about 200 mb BURFF cross-section in the  $(\alpha, xn)$  channels. This value can be compared with the measured <sup>4</sup>) value of the  $(\alpha, 4n)$  cross-section of  $(210 \pm 40)$  mb and an extrapolated one for the  $(\alpha, 3n)$  channel of about 110 mb.

In a simple model of the BURFF process <sup>5,2</sup>) the energy of the captured  ${}^3\text{He}$  should be approximately centered at  $\frac{1}{2}(E_\alpha - E_{\text{Coul}})$  with quite a wide distribution. The corresponding excitation energy of the "compound nucleus"  ${}^{161}\text{Dy}^*$  produced in bombardment of  ${}^{158}\text{Gd}$  with 70 MeV  $\alpha$  particles varies between about 6 MeV and 48 MeV. Because of the peripheral character of the  $\alpha$  break-up process <sup>3</sup>), there is a unique relation between the energy and the angular momentum brought in by the captured fragment. The cross-sections for  $({}^3\text{He}, 2n)$  and  $({}^3\text{He}, 3n)$  reactions peak at about 12 MeV above the respective threshold energies. For the  ${}^{158}\text{Gd}$  target this corresponds to 15 MeV and 22 MeV  ${}^3\text{He}$  energy for the 2n and 3n channels respectively. With  $r = 1.2 \text{ A}^{1/3}$  this leads to  $l = 11.5 \hbar$  and  $16 \hbar$ , which implies multiplicity  $M = 10$  and  $12$  for these two channels. Both agree well with the values measured at higher beam energies. It is important to notice that the BURFF model predicts the angular momentum left in a

energy,  $E_Y^{stat}$ , and multiplicity,  $M_Y^{stat}$ , are  $E_Y^{stat} = 1.32, 1.35$  and  $1.86$  MeV and  $M_Y^{stat} = 2.9, 4.9$  and  $5.4$ , respectively. Similar increase in  $E_Y^{stat}$  and  $M_Y^{stat}$  is found for  $(\alpha, 4n)$  reactions in the saturation region. In should be noted that the calculated mean entry points (GROGI, fig. 1) correspond to the predicted cross-sections which at high energies are by a factor of 20 to 100 too small. Clearly other physical effects than those included in the statistical code contribute there. It is tempting to relate the observed raise in high energy  $\gamma$ -ray yield to the coupling of GDR to high spin states. This coupling was recently found <sup>2)</sup> to result in non-negligible  $\gamma$ -neutron competition in the decay of hot, high spin nuclei. Quantitatively, however, the effect observed in our work seems to be too strong for this explanation.

1. J. Żukasiak et al., contribution to this conference.

2. J.O. Newton et al., LBL Report 12261(1981).

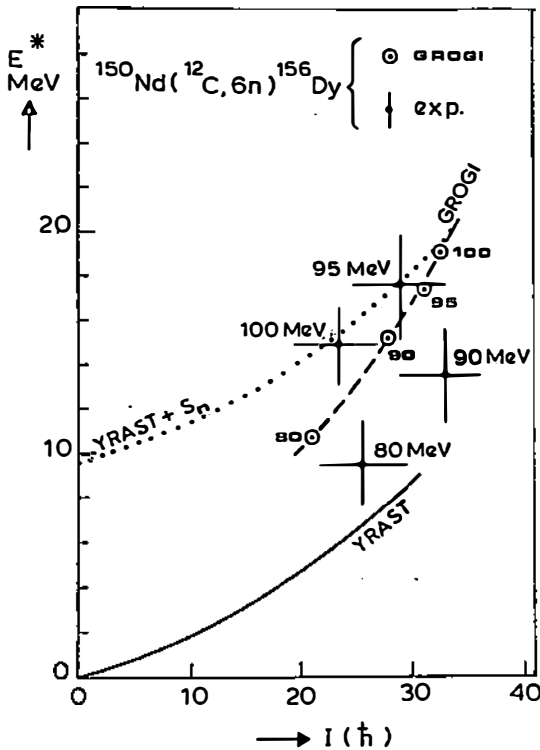


Fig.1. Experimental and calculated (statistical code GROGI) centroids of entry regions.

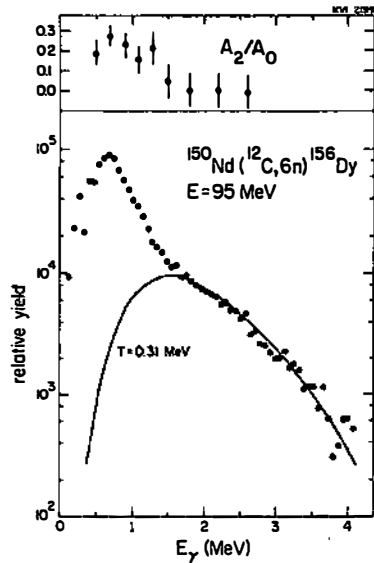


Fig.2. Example of  $\gamma$ -ray spectrum with statistical component fitted above  $E_\gamma=1.5$  MeV. Note the isotropy of high energy "tail".