SUPER-MULTI-NUCLEON TRANSFER OBSERVED IN ^{60}Ni + ^{124}Sn REACTION SLIGHTLY ABOVE THE BARRIER*

E. Tomasi†, M.S. Pravikoff, E. Nolte and H. Morinaga
Fachbereich Physik, Technische Universität München, Garching, Federal Republic of Germany

In order to investigate the behaviour of nucleon transfer near the Coulomb barrier through the produced radioactivities, we have studied several systems with targets in the tin region and the projectiles ^{58}Ni and ^{64}Ni. Especially in the ^{60}Ni + ^{124}Sn system, the residual activity measurements were done at three lab energies of 237, 247 and 258 MeV ($B_{C_{lab}}$ = 234 MeV). For the highest energy we measured also the angular distribution. In addition to activities corresponding to a few nucleon transfers and evaporation residues, a large number of radioactive nuclei was found, which could be attributed to another class of reaction mechanism. Here, we report on this new phenomenon, which might be due to a super-multi-nucleon transfer, on the basis of the measured angular and mass distributions and also on other recent findings[1-3].

The experiment was performed with a ^{60}Ni beam from the heavy ion postaccelerator at the tandem laboratory of Munich. The beam intensity was ≈ 40 nA. The target was 210 μg/cm^2 thick and the isotope enrichment of ^{124}Sn was 95.8 %. The energy was changed by putting gold absorbers just before the target.

The products were stopped in 0.02 mm thick gold foils, one of 2 cm diameter put in front of the target which caught fusion products and a second foil covering the inner surface of a hollow cylinder of 18 mm diameter and 55 mm length mounted in the forward direction. Very little reaction products are expected in the backward direction because of the kinematics. Irradiation times were 90 min to 170 min, the time from the end of the bombardment to the start of the counting was 4.5 min. The catcher foils were put in front of two Ge-Li gamma detectors. It was possible to measure activities with half-lives from 3 min. to 35 h. The angular distribution was obtained by cutting the side foil in three pieces corresponding to equal angular ranges in the laboratory system : 9°-31°, 31°-53°, 53°-75°.

*Supported by the "Bundesministerium für Forschung und Technologie".

†Present address : DPh-N/MF, CEN Saclay, 91191 Gif-sur-Yvette Cedex, France

Three classes of activities were identified : 1) fusion products ; 2) a few nucleon transfer, 3) and fission-like products. The fusion products were seen for all energies and showed typical characteristics expected from evaporation of 2 to 8 nucleons from the excited $^{184}_{79}Pt$ compound nucleus.

The most interesting group was the fission-like products. They were found between A ≈ 82 to A ≈ 102 scattering around $^{92}_{39}Y$ (the half of the compound nucleus). The highest measured yields of this activity were estimated to be of the order of 1mb and do not particularly peak at A=184/2. The phenomenon was seen at 247 MeV and 258 MeV incident energies.

The angular distributions (fig. 1) show remarkable tendencies. ^{123}Sn, $^{56}_{25}Mn$($^{56}_{24}Cr$) show the expected distribution of a few nucleon transfer (fig. 2). Many nucleon transfer products like ^{118}In, which is due to 5n, 1p transfer, show, however, some deviation. The symmetric "fission"-like products $^{92}_{39}Y$ show symmetry around 90° in c.m. system as expected anyway. The angular distributions of the asymmetric fission-like products $^{82}_{35}Br$, $^{84}_{37}Rb$, $^{87}_{38}Sr$, $^{90}_{39}Y$, $^{91}_{39}Y$, $^{97}_{41}Nb$, $^{101}_{43}Tc$, however, show a clear deviation from 90° symmetry : the lighter side prefers backward angle and the heavier $^{97}_{41}Nb$, $^{101}_{43}Tc$ prefers the forward distribution. This is the right tendence expected for transfers near the Coulomb barrier.

The mass distribution also seems to suggest that this fission-like process may be a very fast transfer reaction, whose cross section is conditioned by the amount of positive Q-values. In fig. 3, the Q_{eff} values are plotted as a function of the observed masses around the line connecting ^{60}Ni - ^{124}Sn. The approximately flat mass distribution observed between A ≈ 80 to A ≈ 100 may be explained as due to the cancellation of the large Q value in the middle by the larger number of transferred particles, which reduces the transfer probability.

The occurrence of such super-multi-transfer is not so surprising in view of a series of previous findings like large 4p transfer [1]) and 6n transfer[2]) at the barrier and also flow of very many neutrons slightly above the barrier[3]). These processes have been interpreted as transfer, where the identity of both the participants is still preserved, on the contrary to the fusion or the deep inelastic reactions, namely those dissipative processes in which the nuclear boundary disappears[4]).

REFERENCES

1) H. Wegmann et al., Phys. Lett. 49B (1974) 437.

2) W. Dünnweber et al., Phys. Lett. 106B (1981) 47.

3) H. Essel et al., Phys. Lett. 81B (1977) 161.

4) H. Morinaga, Macroscopic features of heavy-ion collisions and pre-equilibrium process, IPCR Cyclotron Progress Report, supplement 6 (1977) 52.

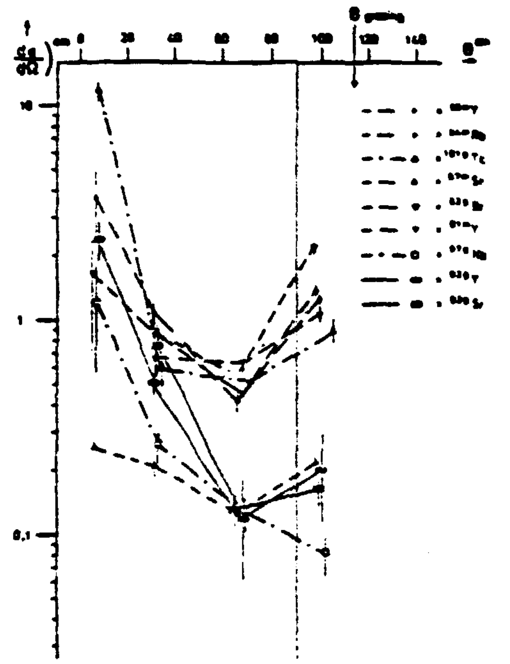

Fig. 1 - Angular distributions of some fission-like products in c.m. system.

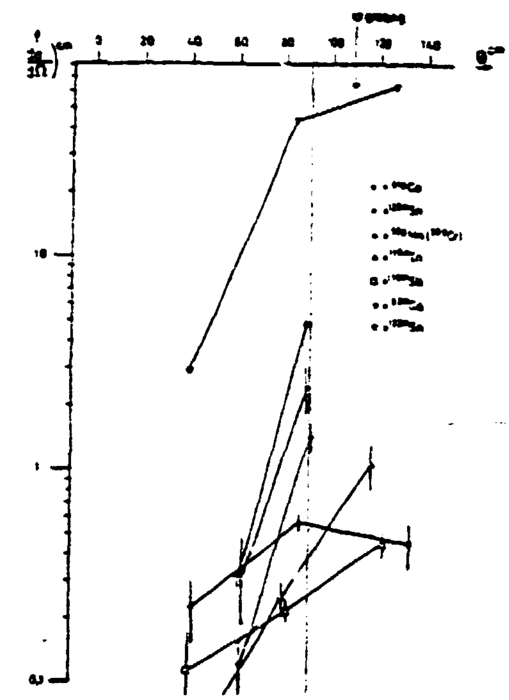

Fig. 2 - Angular distributions of some few-nucleon transfer products in c.m. system.

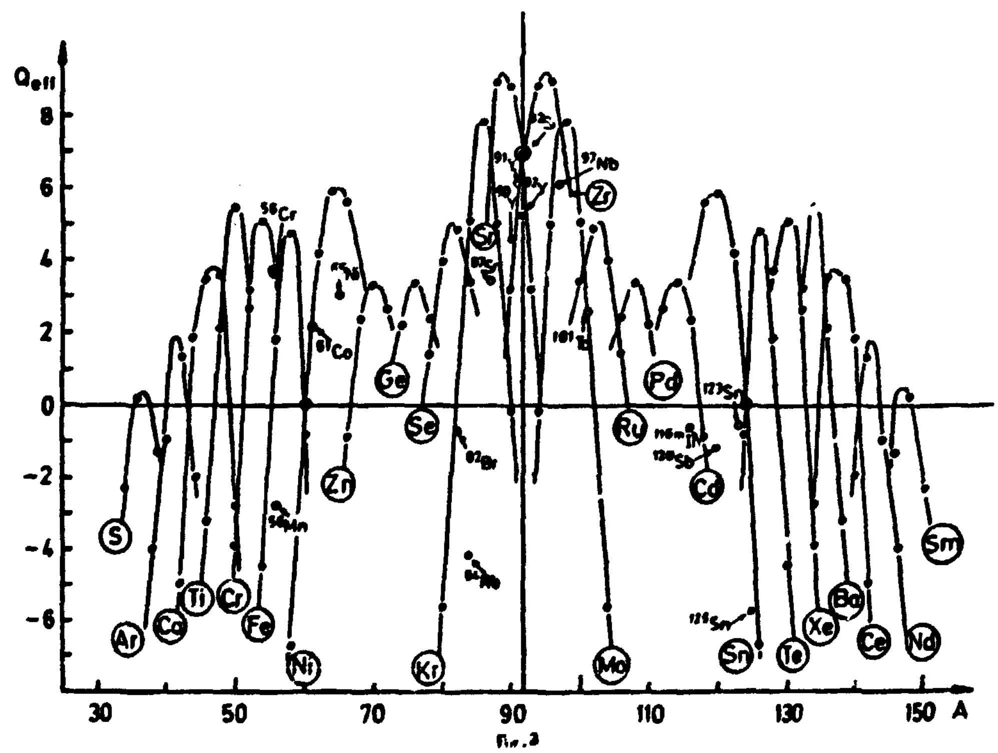

Fig. 3 - Effective Q values calculated with a formula $Q_{eff}=Q_m+B_i^C-B_f^C$, where Q_m is the Q-value calculated from measured masses and $B_i^C(B_f^C)$ is the Coulomb barrier in the entrance channel (exit channel). Calculation covers even-even pairs and the detected isotopes.