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PROPOSAL FOR RADIOCHEMICAL STUDY OF HIGH-ENERGY NUCLEAR FISSION AT CERN

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INTRODUCTION

Members of the Oslo group have during the last eight years as fellows or staff members in the CERN Nuclear Chemistry group or as short-term visitors studied high-energy fission by radiochemical methods.

Since no member of the CERN Nuclear Chemistry group is at present actively involved in this field of research, we wish to propose an independent programme to continue such studies.

BACKGROUND

Analyses of experimental results from radiochemical work including the use of isotope separators and mass spectrometers have disclosed that for irradiation of uranium and thorium with proton energies above ~ 1 GeV some of the charge dispersion curves or isotopic yield distributions have two peaks[1-5]. On the other hand, thick-target thick-catcher recoil experiments have shown that the kinetic energies of the products in the neutron-deficient peak are very much lower than the kinetic energies of the neutron-rich products[6,7]. (A factor of two is involved).

These results are generally suggesting that different mechanisms are responsible for the formation of the two different groups of products.

The neutron-rich products are generally accepted to be products from fission of nuclei with masses fairly close to the target mass. Comparison of recoil properties and charge distribution as well as charge dispersion, between products formed with 400-600 MeV protons and 18-30 GeV protons shows here similarity which appears conclusive[1,2,5,7-9].

Looking closer at this high-energy fission, it is seen that the connection between cascade deposition energy and the kinetic energies shows entirely new features of the fission process which are at variance with accepted views of fission of heavy nuclei[8,10]. The liquid-drop model[11] predicts kinetic energies which are constant or slightly increasing with excitation energy of the fissioning nucleus, while recent experiments show a decrease in kinetic energy for products that are formed in fission of the most excited fissioning species[8,10]. At present one cannot conclude that there is only a direct connection between excitation energy and kinetic energies as there may also be an effect of mass split and thus of the nuclear structure of the fragments even at high excitation energies.

The neutron-deficient products observed along with the above-mentioned fission products have been called spallation products, fragmentation products and also fission products. In the following, this process will be referred to as a spallation process. Until recently a main difficulty in interpreting these products 100 or more nucleon masses from the target, as spallation products, lay in the fact that the excitation energy deposited by the nucleonic cascade has to be of the same order of magnitude as the total binding energy of the nucleus. Theoretical calculations have however recently removed that difficulty[12] showing that a nucleus can very quickly come to an equilibrium even with such a high excitation energy, and that the two-step model thus can work at these high energies.

Another difficulty is in the observed F/B-ratios and kinetic energies. The average linear momentum received by the spallation products in the direction of the incoming protons, and the average kinetic energies of the products are measured to be much smaller and much larger, respectively, than is implied by the Monte Carlo calculations of the cascade and evaporation processes[13-17]. The measured results may in this case be somewhat misleading since one may have some contamination from fission producing the same products. This can be done better by differential range measurements as have also been done for a few products from 2.2 GeV protons on uranium[18].

Proposed experiments

Investigations of fission and spallation products in the fission product mass region by irradiation of uranium and lead with 600 MeV and 18 GeV protons. Apart from cross-section measurements, the recoil properties will be studied both using the thick-target thick-catcher technique and by differential range studies with thin target and thin catchers. The aim is an increased knowledge of the high-energy fission process by the separation of the complex spallation products from the fission products and thereby get a clearer measurement of the recoil properties. This will allow proper comparisons to be made with theories for fission and with Monte Carlo calculations of the spallation process. The work will partly be performed by Hagebø as corresponding fellow at CERN (1971-1973).

Machine time requirements for 1970 and 1971

SC: 10 x 2 hours
PS: 8 x 2 hours.

Experiment performance

The irradiated targets and catcher foils will generally be transported to Oslo, so that there will be little need for laboratory space. Only for some experiments it might be desirable to perform chemical separations and measurements at CERN, in order to get information about short-lived nuclides. In this case we would only need space in the hot lab for about one day per experiment.

Personnel

The Oslo group will supply personnel, except for the inevitable administrative asistance which has to be asked from CERN staff. In addition, some technical assistance will probably be needed for an efficient use of the chemistry laboratories for those experiments that have to be finished at CERN.

References

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