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SWISS ACTIVITIES IN THE FIELD OF TRANSMUTATION

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1. General Background

In Switzerland, transmutation is currently not considered as a method for simplifying the country's radioactive waste management problems. Because of the institution of a 10-year nuclear moratorium, decisions for replacing existing or launching new nuclear power plants have to be deferred at least until the turn of the century. From a short– to medium-term point of view, the radioactive waste management problem is therefore limited for the 5 existing reactors, the National Cooperative for the Storage of Radioactive Waste assumes a 120 GWe–year scenario and has a firm policy to establish low–level and to plan medium– and high–level waste repositories in suitable geological formations. The associated risk for the population is considered to be negligible.

However, in view of the long-term potential of nuclear fission energy, and since the Swiss Government has explicitly declared its will to keep the nuclear option open, there exists an incentive for investigating advanced reprocessing technologies also in Switzerland. With its experience in reactor and accelerator-based physics, the development of the SINQ spallation neutron source and the fabrication of advanced fuels, the Paul Scherrer Institute (PSI) is in a good position to perform physics studies relating to accelerator-based transmutation systems and fuel and target development for any type of transmutation system. Recently completed and ongoing analytical studies and planned experimental activities are summarised below.

2. Transmutation Effectiveness of Systems with Actinides in the Target

There are two principal types of accelerator-based transmutation systems: "thermal" systems similar to spallation neutron sources, and driven subcritical systems with a fast neutron spectrum. In the latter case, one can distinguish between systems with and without actinides in the target. Advantages of utilising the high-energy reactions in the target themselves for transmuting actinides are the high fission probability and the tendency of the high-energy reactions to directly reduce' the mass of the bombarded nuclei and thus to mitigate the build-up of undesirable heavier reaction products. To assess quantitatively the transmutation effectiveness of the high-energy reactions, the toxicity of the remaining waste following transmutation of typical minor actinide mixtures was calculated for an idealised pure actinide target and different recycling schemes [1]. The calculations showed that the above-mentioned advantages of the high-energy reactions are partly compensated by the generation of toxic spallation products, and that interesting toxicity reduction factors can only be achieved, if the spallation products are recycled together with the actinides.

The transmutation effectiveness of a "fast" system, measured in terms of the fission–to-capture ratio of the fissionable nuclides, increases with the mean energy of the neutron spectrum. It is therefore interesting to study the effect of the high-energy source neutrons on the spectrum in an actinide target. To this end, a parameter study has been initiated using the PHOENIX system as a reference case. First results indicate that, at a k_{eff} of 0.9, the high–energy source neutrons give rise to a 20-25 % increase in the fission–to–capture ratio of all fissionable nuclides. Modifications to improve the transmutation efficiency of this system (e.g. substitution of the oxide fuel by metal fuel, reduction of the steel volume fraction, etc.) are also being investigated.

3. Data and Methods Problems Related to Accelerator-Based Transmutation

With the aim of solving some specific nuclear data and calculational methods problems related to accelerator-based transmutation systems, a programme of differential and integral measurements at the PSI ring accelerator has been initiated [2]. In a first phase of this programme, thin samples of actinides will be irradiated with 590 MeV protons using an existing irradiation facility. The generated spallation and fission products will be analysed using different experimental techniques and the results will be compared with theoretical predictions based on high-energy nucleon-meson transport calculations. The principal motivation for these experiments is to resolve discrepancies observed between calculations based on different high–energy fission models. In a second phase of the programme, it is proposed to study the neutronic behaviour of multiplying target-blanket assemblies with the help of zero-power experiments set up at a separate, dedicated beam line of the accelerator. These experiments are intended to provide integral checks on the nuclear data (models) and calculational methods for specific target-blanket configurations.

4. Preparation of Fuel and Target Materials

Here, the idea is to apply the wet chemistry processes developed at PSI for the fabrication of fuel and target materials needed for different transmutation concepts [3]. More specifically, the aim is to prepare uranium-plutonium-neptunium nitride and uranium–plutonium nitride microsphere and to compare the behaviour of sphere–pac and hybrid sphere-pellet fuel with that of dry route pellet fuel in a fast flux reactor.

The wet chemistry preparation of potential matrix materials for actinide fuels without uranium (e.g. zirconium–cerium oxide and zirconium-uranium nitride) has also been initiated. The coprecipitation of the actinides together with the inert matrix material has the advantage of providing solid solutions or a very intimate mixture of the components and therefore a good behaviour under irradiation.

5. References

[1] H.U. Wenger, P. Wydler, F. Atchison, "The influence of different recycling schemes on toxicity reduction for transmutation systems using high-energy spallation reactions", Proc. of the OECD-NEA Specialists' Meeting on Accelerator-Based Transmutation, PSI Villigen (Switzerland), 24-26 March 1992

[2] P. Wydler, "Research activities related to accelerator-based transmutation at PSI", Proc. of the OECD-NEA Specialists' Meeting on Accelerator-Based Transmutation, PSI Villigen (Switzerland), 24-26 March 1992

[3] C. Prunier, D. Warin, R.W. Stratton, G. Ledergerber, "Flow sheet, fabrication and properties comparison of nitride fuel obtained by powder-metallurgy and gelation processes", Trans. Amer. Nucl. Sot., Vol. 66, p. 187-188 (1992)