The role of Fe and Ni for s-process nucleosynthesis and innovative nuclear technologies

J.L.Tain*, G.Giubrone, and n_TOF Collaboration**

*Instituto de Fisica corpuscular, Centro mixto C.S.I.C.- Univ. Valencia, Apdo Correos 22085, 46071 Valencia , Spain
Tel. +34963543499, fax +34963543488, giubrone@ific.uv.es
**CERN, Geneve, Switzerland

Fisica nuclear experimental

Elements heavier than iron in the Universe are formed mainly by the slow and rapid neutron capture process. Very old ultra metal-poor stars have been found whose elemental abundance pattern matches perfectly the solar r-process abundance for elements heavier than barium while discrepancies are observed for lighter nuclei. This has been taken as an indication for the existence of two type of r-process. However the separation of s- and r- contributions to the solar abundance requires a precise knowledge of neutron capture cross-section of the isotope involved. In this mass region the so called weak s-process happening in massive stars contributes significantly and the calculations show sensitivity to the cross-section. The uncertainty of the data in this region is larger than required and moreover there are recent activation measurements showing significant systematic deviation with previously accepted values. Fe and Ni are also an important part of the structural materials of nuclear energy systems including ADS systems.
Better cross-section are required for the design of these systems and the estimation of the activation.
At the n_TOF-CERN facility a program for systematic measurements of neutron capture cross-section with improved accuracy in this mass region has been started. In the initial phase all stable Fe and Ni isotopes will be measured using C6D6 detectors featuring low neutron sensitivity.
A campaign of measurements to determine the (n,γ) cross sections of all stable Fe and Ni isotopes in the neutron energy region between 0.1 keV and 1 MeV has been started at the n_TOF facility [1]. A large “instantaneous” number of neutrons from spallation reactions are produced by the impact of intense proton bunches from the CERN PS (7×10^{12} protons in a 7 ns wide bunch) with an energy of 20 GeV on a massive lead target. The initial neutron bursts are further moderated in a water volume at the exit towards the evacuated neutron beam pipe, which connects the target with the experimental area at a distance of about 185 m. The long flight path provides high resolution in neutron energy, which allows resolving closely spaced neutron resonances. The prompt capture γ-rays were detected with two optimized deuterated benzene (C_6D_6) liquid scintillation detectors [2]. The choice of deuterium, the utilization of a thin carbon fibre canning, and the thorough reduction of dead materials in and near the detector resulted in a reduced sensitivity to background from sample scattered neutrons. This type of background had been the cause of undetected problems in previous work, because the probability for neutron scattering may well exceed that for capture by more

than a factor of 1000 in many Fe and Ni resonances.

In order to properly account for the γ-ray energy dependence of the detection efficiency, the Pulse Height Weighting Technique (PHWT) is used. The technique can be applied because the probability for detecting more than one γ-ray of a capture γ-ray cascade in the C_6D_6 detectors is sufficiently small. The PHWT requires the precise knowledge of the detector response as a function of γ energy. The latter is obtained from very detailed Monte Carlo simulations using Geant4 [3] with a complete description of the experimental setup. From this information a counting weight as a function of deposited energy can be calculated. It has been shown that an accuracy of 2% can be achieved in this way [4]. Examples for time of flight spectra of weighted counts for ^{56}Fe samples are shown in Fig. 1.

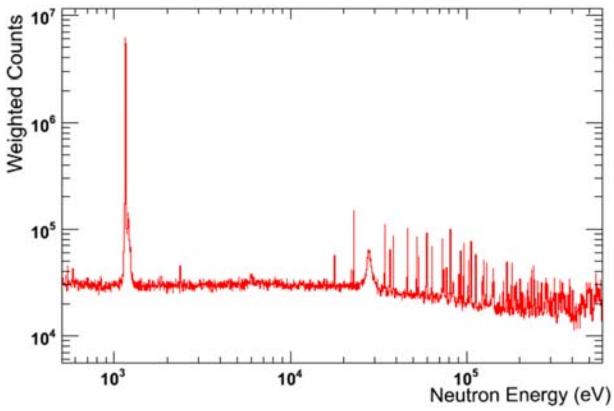

Fig. 1. **Weighted γ-spectrum obtained for ^{56}Fe**

[1] U. Abbondanno et al., “CERN n_TOF facility: performance report”, CERN-SL-2002-053 ECT, Geneva, 2003.

[2] R. Plag et al., “An optimized C_6D_6 detector for studies of resonance-dominated (n,γ) cross sections”, Nucl. Instr. Meth. A, **496**, 425 (2003).

[3] S. Agostinelli et al., “Geant4 – a simulation toolkit”, Nucl. Instr. Meth. A, **506**, 250 (2003).

[4] U. Abbondanno et al., “New experimental validation of the pulse height weighting technique for capture cross section measurements”, Nucl. Instr. Meth. A, **521**, 454(2004).