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IRMM

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Activities of the Neutron Physics Unit of IRMM

Since January 2003, the neutron physics unit has its activities organized in two so-called Actions "H4241 Neutron data for nuclear waste and innovative options" and "H4242 Neutron data for standards and basic science". Further changes include an increased emphasis on training – PHDs and postdocs - and maintenance of competence in the field – Scientific Visitors and Seconded National Experts - and opening of the neutron facilities for use by interested parties. We are seeking financial support to enhance our training activities and facilitate the access to the linear accelerator (GELINA) and the Van de Graaff accelerator. Information concerning open posts can be obtained either from www.jrc.org or from www.irmm.jrc.be.

Neutron data for waste transmutation and innovative options

The action consists of four main tasks: waste transmutation, accelerator driven systems, thorium fuel cycle and high temperature reactor technology.

Waste transmutation.

- Recently completed are the studies for capture and total cross sections of ^{237}Np in the resonance region. This is a long-lived minor actinide, and the most abundant transuranic actinide following plutonium, which makes it an important candidate for transmutation. This work was conducted as a collaboration between IRMM and CEA-Saclay.
- Ongoing is the data-analysis of capture and total cross section of ^{129}I. The work is a joint effort between IRMM and CEA-Cadarache, and is currently being carried out at Cadarache by a PHD student that is in the final year of his thesis work. ^{129}I is the second major long-lived fission product, after ^{99}Tc, that is studied at IRMM in collaboration with CEA. Although long-lived fission products do not present the major radiological hazard in spent fuel, they have the largest migration probability from storage in geological disposal sites. Therefore they present the larger risk for contamination of surface water over the time-spans of their half lives.
- Fission product yields of Cm-244, Cm-248, Cf-252, U-235 and Pu-239 are being studied in the frame of ISTC contracts with PNPI Gatchina and KRI in St. Petersburg. Studies concentrate on data to understand the fission process and data that are relevant to understand the production of precursors to delayed neutron emission in minor actinides.
- Tritium production in ternary fission on minor actinides is being studied at IRMM. Often this concerns spontaneous fission.
- Finally, a feasibility study is ongoing to measure the N-14(n,p)C-14 cross section at energies between 16 and 19 MeV in the interest of nitride fuels in combination with accelerator driven systems. Activity of irradiated AlN samples will have to be established by accelerator mass spectrometry using carbon dating separation techniques. The work is a collaboration between IRMM, FZ-Jülich and U. of Vienna.

Accelerator driven systems

- ^{206}Pb capture and total cross sections in the resonance region are being studied at the 60 m flight path using C_6D_6 detectors, to guarantee low neutron sensitivity. Excellent low background in the energy region above 1 keV allows IRMM to study this isotope to about 500 keV. The data are relevant to transparancy of lead to fast reactor neutrons and the change of isotopic vector with fluence.
- The study of ^{209}Bi inelastic scattering is being started. Measurements will determine gamma-ray production cross sections for characteristic gamma-rays using two HPGe detectors at a 200 m flight path at the GELINA facility. Gamma-ray production cross sections will allow the construction of the total inelastic cross section up to an excitation energy where a) the level scheme is reliable and b) at least one gamma-transition is observed experimentally. The same setup was used succesfully for ^{58}Ni, where gamma-ray production data were obtained up to 18 MeV at Gelina, which were found to be consistent with available data even at 14.2 and 14.8 MeV. Data were taken and are still being analyzed for ^{52}Cr.

- A large program of activation cross section measurements is ongoing at IRMM. The most recent results concern the measurement of reactions on various isotopes of Zr, using enriched samples on loan from JAERI. In 2002 a large measurement program was carried out for Ni isotopes, Co and Cu. Present concerns are for more exotic channels such as (n,t) and (n,αp).
- On request of CEA and rather in the interest of LWRs, the precise capture and total cross sections of fission products are being investigated. A pilot case was the study of ^{103}Rh from thermal to several eVs. Further fp studies may follow and in particular lanthanides are considered important as they may turnup in minor actinide fuels as left-over carrier from pyro-processing.

Thorium fuel cycle

- Total and capture cross sections measurements in the resolved resonance region and the unresolved resonance region are being studied in collaboration with INRNE. In particular, great progress is being made in the understanding of the normalization and the multiple scattering corrections in case of the average cross section. The latter also play an important role in the analysis of resonance parameters. The problem of the Th capture cross section is a long standing one with important implications for the burnup criticality swing in thorium fueled reactors.
- The first direct measurements of the ^{233}Pa(n,f) cross section have led to a contribution to Physical Review Letters. Measurements for additional data points to map the excitation curve in more detail are ongoing. These serve to improve understanding differences with an indirect measurement that determines the fission probability of the same compound nucleus through the ^{232}Th(^{3}He,pf) measurement by CENBG Bordeaux at IPN Orsay. The inferred (n,f) cross section by this method is different in magnitude and shape from the IRMM direct result. ^{233}Pa has a significant equilibrium concentration and leads to increase of reactivity by decay to ^{233}U following reactor shutdown.
- ^{234,236}U(n,f) cross sections and ^{234}U(n,f) fission fragment properties are being studied by U. Gent and S. Oberstedt/F.J. Hambsch. Thermal values are obtained at ILL. For the former cross sections will be determined in the resolved resonance region at IRMM.

High temperature reactors

- ^{240,242}Pu resonances are being studied with the Doppler broadening setup at IRMM. The aim of the work is to study the implications of the crystal lattice model on the shape of resonances and offset this broadening mechanism against the conventional free gas model with effective temperature.

Basic nuclear physics and standards.

Standard cross sections

- The measurement of the ^{10}B(n,α) branching ratio up to 1 MeV at GELINA was completed. Results confirm ENDF/B-VI except for the energy range between 50 and 300 keV. This measurement did however highlight the great care is required with the use of this standard cross sections since forward and backward oriented deposits result in vaslty different branching ratios above 50 keV. The result is a consequence of the rise with energy of the probability that both the alpha and the lithium ion will be emitted in the forward direction. This leads to a summing-out effect dubbed “particle leaking”. In combination with a difference in angular distribution for α_0 and α_1 this affects the branching ratio as well. From 1 to 5 MeV single energy cross section measurements of the total (n,α) cross sections have been measured as well. Earlier attempts to determine the branching ratio were halted since improved equipment, a 3d time-projection chamber with segmented cathode, will be required to adequately study the effect of particle leaking.
- Fission fragment properties are being studied for 251Cf(n,f) at ILL. For 252Cf(SF), 235U(n,f) and 239Pu(n,f) neutron multiplicity and neutron spectra will be studied in the near future with the aid of DEMON detectors.

Theory

- The fission process is being studied theoretically with the U. of Bucharest making use of the FF yield data, neutron multiplicity data and the so-called saw-tooth information. The Brosa mode model is employed in order to explain and analyze energy dependent trends.
- Doppler broadening will be studied with the aid of a theoretical calculation to determine the phonon spectrum.

General interest

Neutron resonance capture analysis is being developped by the U. of Delft in collaboration with P. Schillebeeckx of IRMM. In a first project, elemental Zn concentrations were employed to determine whether or not particular bronze statues were of genuine Etruscan origin. A second project is to determine whether the method may be employed to study the uptake of Ca in bones.

Fluence measurements

IRMM has taken part in the CCRI(III)-K.10 international comparison of neutron fluence measurements in mono-energetic neutron fields. The report is available to the CCRI(III) members. IRMM intends to take part in the thermal fluence intercomparison, that is now scheduled to take place at NIST in the early spring of 2005.

Specific fluence measurements employed at IRMM concern

- the measurement of the neutron fluence with a U235 chamber (6 layers of 8 cm diameter and 400 $\mu g/cm^2$, 1% accuracy on mass) for the inelastic scattering measurements at the 200 m FP of GELINA
- the measurement of the neutron fluence with activation foils in the study of activation cross sections. The stacked foil technique is employed with monitor foils sandwiching the sample material. $^{27}Al(n,\alpha)^{24}Na$, $^{27}Al(n,p)^{27}Mg$, $^{93}Nb(n,2n)^{92m}Nb$, $^{115}In(n,n')^{115m}In$ reactions are used to determine the primary fluence and the low-energy neutron contaminants. Activation foil measurements are combined with time-of-flight based prior information to determine the low-energy contributions for each measurement session. The $^{27}Al(n,\alpha)^{24}Na$ reaction is the primary standard for this work.
- For the activation work and for activities like the ^{233}Pa fission cross section it has become very important to know the neutron spectrum at low energy for the (d,T) and (p,T) sources. This concerns the low threshold reactions in a major way, in particular at the highest energies where these sources are used. In the near future additional work will focus on this issue.