Conference Proceedings Vol. 59
«Nuclear Data for Science and Technology»
G. Reffo, A. Ventura and C. Grandi (Eds.)
SIF, Bologna, 1997

STUDY OF THE $^{27}Al(n,2n)^{26}Al$ REACTION

A. WALLNER[1], S.V. CHUVAEV[2], A.A. FILATENKOV[2], W. KUTSCHERA[1], G. MERTENS[3], A. PRILLER[1], W. ROCHOW[3], P. STEIER[1], H. VONACH[1]

[1]Institut für Radiumforschung und Kernphysik, Universität Wien, Währinger Straße 17, A-1090 Wien, Austria.
[2]V.G. Khlopin Radium Institute, 2nd Murinski ave. 28, 194021 St. Peterburg, Russia.
[3]Physikalisches Institut, Univ. Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany.

ABSTRACT
The cross section for the $^{27}Al(n,2n)^{26}Al$ reaction leading to the long-lived ($t_{1/2}$=7.2*10^5 years) isomer of ^{26}Al was measured for neutron energies from 13.5 to 19.0 MeV. Samples of Al-metal were irradiated with neutrons at the Radium-Instituts both in Vienna (IRK) and St. Peterburg (KRI) and at the Physikalisches Institut of the University of Tübingen. The amount of ^{26}Al formed in the irradiations was determined from the $^{26}Al/^{27}Al$ isotopic ratio with the new AMS system at the Institut für Radiumforschung und Kernphysik of the University of Vienna.

1. INTRODUCTION
It has been pointed out by Smither and Greenwood [1] that the $^{27}Al(n,2n)^{26}Al$ reaction can be used as a monitor to determine the ion temperature in a deuterium tritium (DT) fusion plasma if the total neutron fluence is obtained by other dosimetry reactions, e.g. $^{27}Al(n,p)^{27}Mg$. The threshold of the (n,2n) reaction lies at 13.54 MeV and falls therefore in the neutron energy range produced in a DT-plasma. The cross section in the near threshold region is expected to be a strongly non-linear (approximately quadratic) function of E_n-E_{th}, the difference between incident neutron energy and the threshold energy. Therefore the average cross section for neutron energy distributions with the same centroid and different widths (corresponding to the DT-plasma of different temperatures) will be different and will in principle allow the measurement of the plasma temperature. Thus, the main aim of this study is to accurately determine the shape of the $^{27}Al(n,2n)^{26}Al$ cross section near threshold in order to allow a quantitative prediction of the suitability of this reaction for the discussed purpose. In addition it was also intended to get accurate absolute cross sections over the whole energy range needed in fusion technology for the purpose of activation calculations.

No clear trend for the shape of the (n,2n) excitation function near threshold can be decuced from previous results [1-5], since the individual measurements show considerable scattering (see Fig. 3). For energies lower than 14.1 MeV only upper limits (lower than 5 mb) are given. The neutron spectral distribution with the centroid around 14 MeV has a width of a few hundred keV depending on the plasma temperature, therefore it is essential that the cross section in this energy region is well known.

2. EXPERIMENTAL PROCEDURE

For this study samples of pure Al metal (99.999 %) with a thickness of 1 mm have been used. Irradiations with a special low-mass target construction with neutrons in the 14 MeV region have been performed in Vienna and St. Peterburg. Different geometries were chosen to have a check for possible systematic errors. In Vienna two Al-foils bent to cylinders of 26 and 27 mm radius (total area each 48 cm^2) were mounted around the neutron-producing target. This consisted of tritiated titanium bombarded with 220 keV deuterons from the IRK neutron generator. A thin niobium foil sandwiched between the two Al cylinders was used as fluence monitor based on the accurately known [6] $^{93}Nb(n,2n)^{92m}Nb$ cross section. For an additional energy check several Zr-Nb-Zr sandwiches were pasted on the back of this arrangement utilizing the steep energy dependence of the ratio of the (n,2n) cross sections [7]. A 300 keV d^+ beam was used in St. Peterburg. 8 Al foils with a diameter of 14 mm were distributed around the target at 2.5 cm distance. Nb foils were used for the fluence measurement too. For both irradiations neutrons with an energy between 13.4 and 14.83 MeV were used. In Tübingen a 3-MV Van de Graaff accelerator was used to generate 1.2 and 2.6 MeV d^+ beams producing 17 and 19 MeV neutrons, respectively, also by means of the DT reaction. The Al samples had a diameter of 1 cm and were positioned in forward direction 14 mm away from the target. Ni foils were used choosing the $^{58}Ni(n,np+pn+d)^{57}Co$ reaction as monitor reaction because of its well-known cross section [8] and insensitivity to low-energy neutrons. For the two irradiations in the 14-MeV region a neutron fluence of about $1.5*10^{14}$ n/cm^2 was obtained, whereas for the Tübingen irradiation $1.2*10^{12}$ n/cm^2 were striking the Al samples.

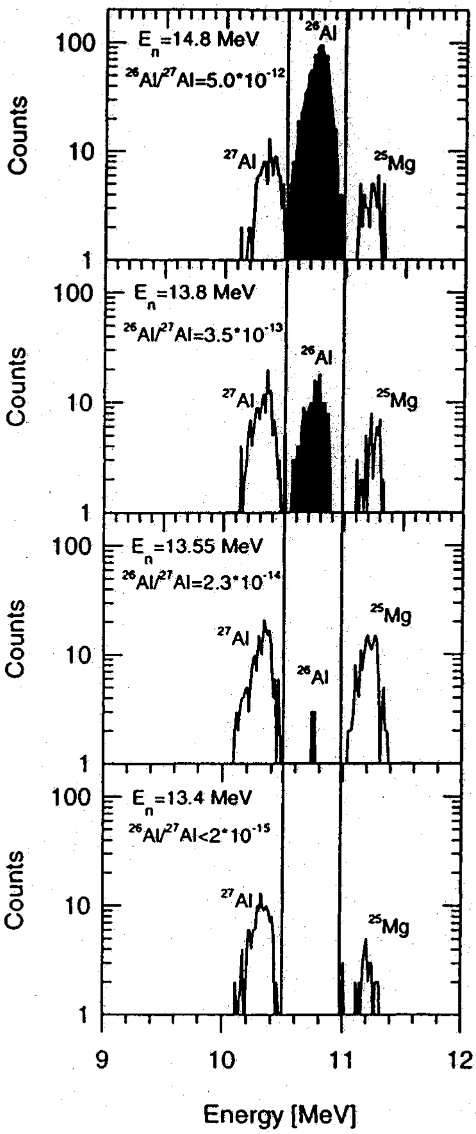

Fig. 1: Energy spectra for ^{26}Al detection measured in the rare isotope detector for different neutron energies.

The ^{26}Al formed in the irradiations was determined from the isotope ratio $^{26}Al/^{27}Al$ measured with the AMS facility VERA at the IRK [9]. A surface barrier detector is used as rare isotope detector for counting the long-lived radioisotope. The stable isotope ^{27}Al is measured via the ion current in an off-set Faraday cup after the bending magnets. Fig. 1 shows typical spectra obtained with the Si-detector covering a range in the isotope ratio from $5*10^{-12}$ to less than $2*10^{-15}$. They correspond to samples irradiated in Vienna at angles between 0° and 155°

with respect to the deuteron beam. The spectrum with no ^{26}Al count registered was obtained from an Al sample irradiated with neutrons of an energy below the threshold. The duration of a typical run is about 1000 s. Depending on the ^{26}Al/^{27}Al ratio, 3 to 6 runs on an individual sample have been performed. The setup conditions for the measurements are checked with Al standards of well-known isotope ratios. Additionally, Al blanks are used to check for the background level. With our system, a background as low as a few times 10^{-15} for the ^{26}Al/^{27}Al ratio was obtained.

3. RESULTS

The excitation function obtained with the samples irradiated in Vienna and St. Peterburg is shown in Fig. 2. The neutron energies were calculated from the deuteron energies and the

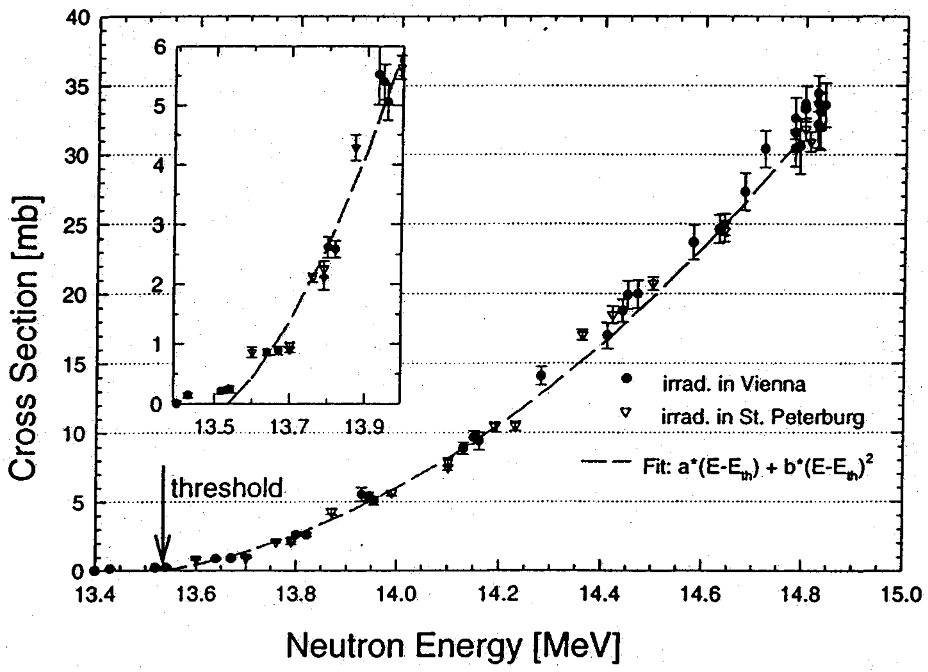

Fig. 2: ^{27}Al(n,2n)^{26}Al excitation function at the threshold region from samples irradiated with 14 MeV neutrons.

irradiation geometry as the centroids of the corresponding energy distributions. These mean energies are believed to be accurate to about 50 keV in the 14 MeV experiments and about 150 keV at the higher energies. Both irradiations in Vienna and St. Peterburg allow the measurement of the cross section down to the threshold region, which is shown more closely by the insert. The upper background level corresponds to 0.07 mb. The dashed line indicates a least square fit to the data with a linear and a quadratic dependence on the energy. The errors shown are mostly due to the random error of the mean value of the AMS measurements and the uncertainty of the fluence. Fig. 3 shows the excitation function for the whole energy range investigated in comparison to the existing data. The solid symbols give the results for this investigation whereas the different open symbols show the results of former measurements. There is a very good agreement with the results of Sasao et al. [5], whereas the other measurements in the 14 MeV region indicate a more steeply rising excitation function. The solid line shows the most recent evaluation

(FENDL/A-2.0) [10]. For the 17 and 19 MeV data our uncertainties are larger because only a few samples have been measured till now and the isotope ratio is lower as well as the fluence determination is not as accurate as for the 14 MeV region. The present results are still preliminary as they have not yet been corrected for the effect of the finite width of the neutron energy distributions at the various irradiation positions. This will probably result in some small corrections near threshold.

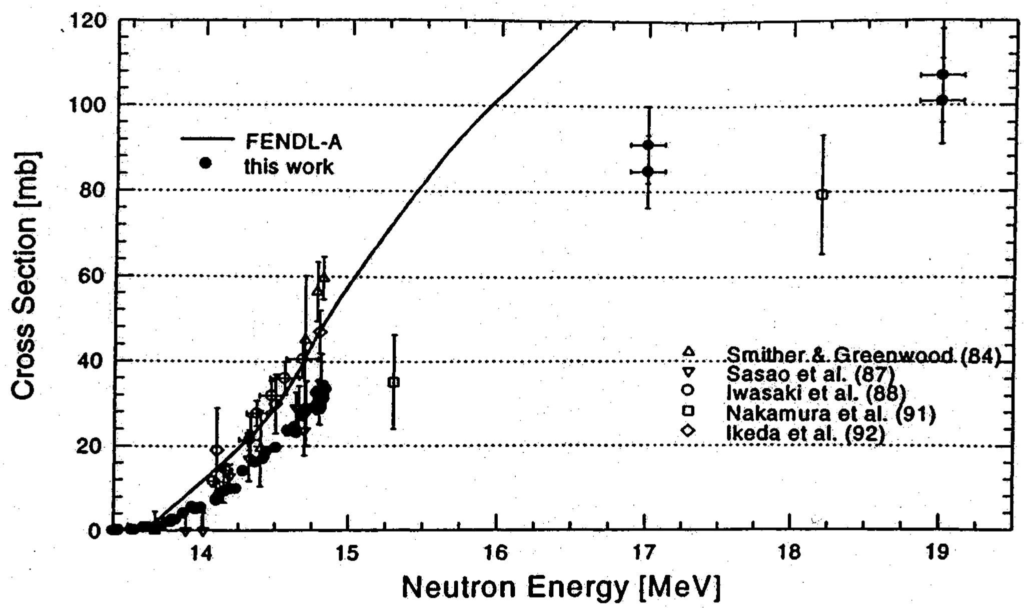

Fig. 3: Excitation function for the whole energy range investigated in comparison to existing data.

4. CONCLUSION

Our results confirm the data of Sasao et al. [5] and indicate the $^{27}Al(n,2n)^{26}Al$ cross section is smaller than assumed in recent evaluations. Some further measurements are planned to reduce the uncertainty for the samples irradiated in Tübingen and also for the region around 14 MeV where the uncertainty of the neutron energy becomes significant. The sensitivity of this reaction for changes in the temperature in a fusion plasma will then be investigated in detail.

REFERENCES

[1] R.K. Smither and L.R. Greenwood, J. Nucl. Mater. **122** & **123** (1984) 1071.

[2] Y. Ikeda, A. Kumar and C. Konno, Proc. Intern. Conf. Nucl. Data for Science and Technology, Jülich, 13-17 May 1991, Springer Verlag Berlin, Heidelberg 1992, p. 364.

[3] S. Iwasaki, J.R. Dumais and K. Sugiyama, Proc. Internat. Conf. Nucl. Data for Science and Technology, Mito May 30 - June 3 (1988) p. 295.

[4] T. Nakamura et al., Phys. Rev. C**43**, 4 (1991) 1831.

[5] M. Sasao et al., Phys. Rev. C**35**, 6 (1987) 2327.

[6] M. Wagner et al., Report INDC(AUS)-014, IAEA, Vienna, Oct. 1991.

[7] V.E. Lewis and K.J. Zieba, Nucl. Instr. and Meth. **174** (1980) 141.

[8] A. Pavlik et al., Nucl. Sci. Eng. **90** (1985) 186.

[9] W. Kutschera et al., Nucl. Instr. and Meth. B**123** (1997) 47.

[10] A.B. Pashchenko et al., „FENDL/A-2.0 neutron activation cross section data library for fusion applications", report IAEA(NDS)-173, March 1997.