

Study of the $^{60}\text{Ni} (n,2n) ^{59}\text{Ni}$ Reaction from Threshold to 20 MeV and the Half-life of ^{59}Ni

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The production of long-lived radionuclides as activation products is of concern for a thermonuclear fusion environment, e.g. for ITER, because these nuclides may lead to significant long-term waste. In addition, long-lived radionuclides can also serve as diagnostic tools for nuclear fusion for different applications [1,2]. For such nuclides production cross-sections as well as total induced activities are key parameters for safety and design analyses. Therefore, well-established data on their production rates are highly desired. One of those long-lived radionuclides is ^{59}Ni with a half-life of about 76 000 years [3]. Its main production in a fusion environment is the (n,2n) reaction on stable ^{60}Ni with some additional contributions from neutron capture on ^{58}Ni via lower energy neutrons. Experimental information for the production of ^{59}Ni via the (n,2n) reaction is strongly discordant or completely missing.

Ni metal samples have been irradiated with quasi-monoenergetic neutrons of 17 and 19 MeV energy in a dedicated low-mass geometry to minimize the production of ^{59}Ni via neutron capture by scattered neutrons [4]. No experimental data exist for the neutron energy range above 15 MeV. This energy region is of interest for activation calculations in fusion technology: Supra-thermal neutrons are produced in reactions of high-energy tritons with deuterium, where the tritons are secondary products of D-D reactions in the D-T plasma.

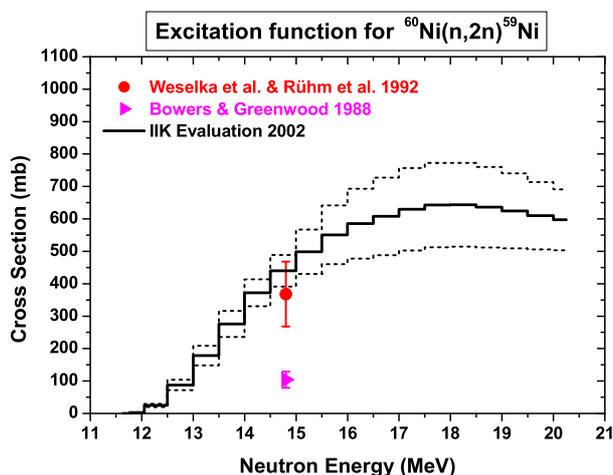


Fig. 1: Excitation function for the $^{60}\text{Ni}(n,2n)^{59}\text{Ni}$ reaction from threshold to 20 MeV. The two experimental data points are compared to a recent evaluation (IIK-evaluation: see INDC-AUS-17 [5]).

17 and 19 MeV neutrons were produced in Tübingen using a single-ended 3 MV van de Graaff accelerator. An irradiation time between 4 days (17 MeV) and 8 days (19 MeV)

was necessary to obtain a neutron fluence of about 10^{12} n cm⁻². After the irradiation the amount of produced ^{59}Ni was measured via accelerator mass spectrometry (AMS) in Munich. In combination with a dedicated particle detection system featuring a time-of-flight system, a gas-filled magnet and a multi-anode ionization chamber, a low detection limit in the range of 10^{-14} was achieved for $^{59}\text{Ni}/^{58}\text{Ni}$ isotope ratios [6,7]. Assuming a cross section value of 600 mbarn and the well-known neutron fluence we expect an isotope ratio $^{59}\text{Ni}/^{60}\text{Ni}$ of about 10^{-12} , which converts to about 3-4 · 10⁻¹³ for $^{59}\text{Ni}/^{58}\text{Ni}$. Two previous measurements for the $^{60}\text{Ni}(n,2n)^{59}\text{Ni}$ reaction exist at 14.8 MeV [1,8,9]. However, their results disagree by a factor of 4 (see fig. 1). In combination with a recent evaluation in the relevant neutron energy range from threshold to 20 MeV [5] the new results at 17 and 19 MeV neutron energy will be useful to quantify the production in the 14-MeV region as well. Both, preliminary results from our measurement and the recent evaluation favour the higher value reported by [9].

The accepted half-life of ^{59}Ni is $t_{1/2} = (76\,000 \pm 5\,000)$ years [3] which is substantially lower than the value of 108 000 years which was obtained a few years later in an independent measurement [10]. The latter half-life value is based on measurements relative to the thermal ^{54}Fe neutron capture cross section. However, the uncertainty of this cross section dominates the uncertainty of the latter half-life measurement. We are remeasuring the ^{54}Fe (n,γ) cross section at the VERA (Vienna Environmental Research Accelerator) laboratory applying AMS for the quantification of ^{55}Fe . ^{55}Fe detection benefits from the efficient background suppression at VERA, enabling us to investigate very low reaction cross-sections. Applying the fast-sequencing mode at VERA allows to generate precise AMS data for ^{55}Fe [11]. The new data will be used to produce a more precise value for the half-life of ^{59}Ni compared to the previous one.

References

- [1] D.L. Bowers and L.R. Greenwood, J.Radioanal. Nucl.Chem. **123** (1988) 461.
- [2] A. Wallner *et al.*, AIP Conf.Proc. **769** (2005) 621-624.
- [3] K. Nishiizumi, *et al.*, Radiochim.Acta **29** (1981) 113.
- [4] A. Wallner *et al.*, Europ.Phys.J. **A17** (2003) 285.
- [5] S. Tagesen *et al.*, <http://www-nds.iaea.org/reports-new/indc-reports/indc-aus/indc-aus-0017.pdf>
- [6] K. Knie *et al.*, Nucl. Instr. and Meth. **B172** (2000) 717.
- [7] G. Rugel *et al.*, Nucl. Instr. and Meth. **2007** (in press) .
- [8] D. Weselka *et al.*, Proc.Nucl.Data for Science and Techn., Jülich, 13 - 17 May 1991, Springer Verlag, Berlin, Heidelberg, New York (1992) 559.
- [9] W. Rühm *et al.*, Planet. Space Sci. **42** (1994) 227.
- [10] K. Knie *et al.*, Annual report 1992, p. 106.
- [11] A. Wallner *et al.*, Nucl. Instr. and Meth. **2007** (in press) .