Capture Cross Sections for Cr, Fe and Ni

F. Corvi
Commission of the European Communities
Joint Research Centre
Central Bureau for Nuclear Measurements
B - 2440 Geel, Belgium

Significance

Since stainless steel represents about 25% of the volume of a fast power reactor, its constituent elements strongly influence its two main neutronic parameters: critical enrichment and breeding gain. Also, capture in the narrow p and d-wave resonances of Cr, Fe and Ni contributes as much as 10 to 15% of the Doppler coefficient of reactivity. Following sensitivity calculations, typical accuracy requirements[1] in the energy range 0.1-100 keV are 5-10% for capture in Fe and 10-20% for capture in Ni and Cr.

The findings of the 1.15 keV ^{56}Fe task force

Since a number of years, a systematic difference of about 20% was noticed[2,3] between the results of capture and those of transmission for the neutron width of the important 1.15 keV resonance of ^{56}Fe. Such a discrepancy has become the object of a task force set up by NEANDC after the Antwerp Conference. Although this task force has not yet completed his works, a major progress has been obtained recently and will be summarized in the following.

The origin of the discrepancy lies in the fact that the neutron capture measurement techniques used in the past and based on the pulse height weighting method were unable to deal correctly with such large differences in spectrum shape as those met when comparing capture in ^{56}Fe to capture in the elements used for normalization such as Ag and Au. Basically, the method failed because the weighting function was calculated with ad hoc Monte Carlo codes which were entirely inadequate since they lacked an accurate description of the electron transport and of the influence of the environment. On the contrary, improved weighting functions have been obtained recently both with an original experimental method[4] and with a state-of-the-art electron-gamma transport code[5]: although some differences still persist between these two approaches, the use of such functions allows to obtain parameters of the 1.15 keV resonance in agreement with the transmission results, therefore eliminating the discrepancy.

Impact on structural materials

The results reported in the previous section are not limited to ^{56}Fe alone but put in question all past measurements performed with the pulse height weighting method, every time different capture spectrum shapes were compared. This applies to structural materials in general as it may be seen in Table 1 : here the sums of the intensities of thermal neutron capture γ-rays with energies higher than 6 MeV are listed for the three main isotopes of Cr, Fe and Ni and compared to similar values for the normalizing nuclides ^{109}Ag and ^{197}Au. One may notice that, for all structural isotopes, this quantity is comparable to ^{56}Fe capture while being definitely larger than in Ag or Au. The same picture should hold also for p-wave capture since, in this mass region, E1 and M1 average strengths are comparable[6].

The systematic error due to a wrong weighting and associated to a given resonance can be seen as made up of too parts : the first is related to the difference between the γ-spectrum of the normalizing element (Ag or Au) and the average spectrum of the given isotope. The second is due to variations in the spectrum shape amongst the resonances of this isotope, due to Porter-Thomas fluctuations of the intensities of primary transitions. The first error, which is very likely the predominant one, was avoided when capture data were normalized to a low energy resonance belonging to the same isotope, whose parameters were obtained from transmission [2,7,8]. In fact, besides the 1.15 keV resonance, there are other cases, listed in Table 2, in which the capture area can be determined from transmission data. As far as the second effect is concerned it certainly plays an important role [2,10] particularly in ^{54}Fe and ^{56}Fe.

Recommandations and plans for the future

Although it is clear that the whole field of structural material capture should be revisited, this does not necessarily lead to the repetition of all measurements. First of all, it is possible to re-analyse past experiments with the correct weighting as long as the amplitude information has been preserved : this is for example the case for the Geel ^{56}Fe data[2]. Secondly, there are cases (the E_o = 1.63 keV resonances of ^{52}Cr and ^{57}Fe) in which no capture-to-transmission discrepancy has been detected within the limits of the experimental uncertainties [7,8]. To check the data for these isotopes it is suggested to repeat the measurements with the corrrect weighting only for a few outstanding low energy resonances. In parallel, some transmission measurements of the resonances

of Table 2 should be performed in order to check and possibly improve the precision of the parameters. Only after comparison of the new with the old results one should decide whether it is worthwhile to repeat the whole measurements.

Finally, as far as Ni is concerned, a complete programme of capture measurements of the three main even isotopes is due to start afresh in Geel in the following months.

Table 1 : Thermal neutron capture data

Target	Abund. %	ΣI_γ [a] ($E_\gamma > 6$ MeV)	Target	Abund. %	ΣI_γ [a] ($E_\gamma > 6$ MeV)
^{50}Cr	4.35	71	^{58}Ni	68.27	62
^{52}Cr	83.79	70	^{60}Ni	26.10	62
^{53}Cr	9.50	83	^{62}Ni	3.59	92
^{54}Fe	5.8	88	^{109}Ag	48.17	5.4
^{56}Fe	91.72	72	^{197}Au	100	18.9
^{57}Fe	2.15	52			

a) Intensities in photons per 100 captures from Nuclear Data Sheets

Table 2 : Resonances suitable for normalization to transmission data

Target	E_o (keV)	J	l	g Γ_n (eV)	Γ_γ (eV)	Ref.
^{52}Cr	1.63	3/2	1	0.0624 ± 0.0020	0.67 ± 0.14	8
^{56}Fe	1.15	1/2	1	0.0617 ± 0.0009	0.574 ± 0.040	9
^{57}Fe	1.63	2	1	0.0533 ± 0.0022	1.00 ± 0.24	7
^{60}Ni	2.25		1	0.053 ± 0.001	1.20 ± 0.08	11

References

1. J.L. Rowlands, NEACRP-A-568/NEANDC-A-180 (1983)
2. F. Corvi, A. Brusegan, R. Buyl, G. Rohr, R. Shelley and T. van der Veen, Nuclear Data for Science and Technology, p. 131, Reidel Publishing Company (1983)
3. R.L. Macklin, Nucl. Sci. Eng. 83 309 (1983)
4. F. Corvi, A. Prevignano, H. Liskien and P.B. Smith : Nucl. Instr. Meth. Phys. Res. A265, 475 (1988)

5. F.G. Perey, J.O. Johnson, T.A. Gabriel, R.L. Macklin and R.R. Winters, Proc. Int. Conf. on Nucl. Data for Science and Technology, Mito, Japan, May 30-June 3, 1988, Paper AC 07
6. C.M. Mc.Cullagh, M.L. Stelts and R.E. Chrien, Phys. Rev. C23, 1394 (1981)
7. G. Rohr, A. Brusegan, F. Corvi, R. Shelley, T. van der Veen, C. Van der Vorst, Nuclear Data for Science and Technology, p. 139, Reidel Publishing Company (1983)
8. A. Brusegan et al., Nuclear Data for Basic and Applied Science, Vol. 1, p. 633, Gordon and Breach, New York (1986)
9. F. Perey, Ibid., p. 1523
10. A. Brusegan, F. Corvi, G. Rohr, T. van der Veen, C. Van der Vorst, Nuclear Data for Science and Technology, p. 127, Reidel Publishing Company (1983)
11. C.M. Perey, J.A. Harvey, R.L. Macklin, R.R. Winters and F.G. Perey, ORNL-5893 (1982)