CONF-850507--10

CONF-850507--10

DE85 011913

CAPTURE IN THE 1.15-keV IRON RESONANCE*

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Abstract The 1.15-keV resonance in iron is important to reactors in that a major part of the iron capture integral is due to this one resonance. This resonance is also a good test case for capture gamma-ray detectors, which are meant to have an efficiency independent of gamma-ray energy spectra, because this resonance has an unusually hard spectrum and other iron resonances do not. There have been severe discrepancies among different groups who have measured the capture area and transmission of this resonance. A new measurement, employing C_6F_6 liquid scintillators and pulse-height weighting to effect total energy detection, has been made of the ratio of the capture area of the 22.8-keV resonance relative to that of the 1.15-keV resonance. The 22.8-keV resonance has a relatively soft gamma-ray spectrum and there is agreement on the capture area. The results (2.91 ± 0.17) agree well with transmission measurements and confirm the applicability of total energy detectors for use on capture resonances with very hard capture gamma-ray spectra.

INTRODUCTION

Because of the discrepancy in the resonance parameters[1-10] of the 1.15-keV resonance in iron which has continued to defy understanding, a measurement of the ratio of the area of the 22.8- to the 1.15-keV resonance was carried out at the 20-m flight path of the Oak Ridge Electron Linear Accelerator (ORELA) with equipment which has normally been used in measurements on the fissile and fertile nuclides. This was a ratio measurement in order to avoid normalization uncertainties and because the reported total and capture cross-section measurements agree on the parameters of the 22.8-keV resonance.[8] The problem has been that the resonance parameters derived from the capture cross-section measurements of Corvi *et al.*[3,4] at GEEL and Macklin[6,7] at ORELA have not been in agreement with the total cross-section measurements of Perey *et al.*[8] at ORELA, or earlier workers, for the 1.15-keV resonance.

EXPERIMENTAL TECHNIQUE

For this experiment, four liquid scintillators of C_6F_6, 10 cm in diameter and 4-cm thick, were used as the gamma-ray detectors. There was 0.32 cm of lead shielding

*Research sponsored by the U.S. Department of Energy, Office of Basic Energy Sciences, under contract DC-AC05-840R21400 with the Martin Marietta Energy Systems, Inc.

the gamma-ray detectors. The detector faces were 8.3 cm from the center of the sample. The geometry is more open than most capture detectors because of the frequent use of fission chambers in previous experiments.

The weighting factors used for the total energy detectors were derived with the computer code of Macklin[11] for the geometry of the detectors used. These weighting factors were modified to account for the 0.32 cm of lead in front of the detectors.

The sample (5.08 × 6.35 × 0.051 cm) of natural iron used in the experiment was from the same material used by Macklin.[6] ORELA was run with a repetition rate of 800 pps and a pulse width of 15 ns for the experiment. A ^{10}B overlap filter was used and NaF and S filters were permanently in the beam. The relative flux was measured with a parallel plate ^{10}B pulse ionization chamber[12] placed 26 cm in front of the iron sample. This chamber covered the complete neutron beam and contained 56 $\mu g/cm^2$ of ^{10}B.

The resonances at 1.15 and 22.8 keV were fitted for their relative capture areas with the code LSFIT[13] of Macklin. The background cross section was fitted as well as the resonance.

RESULTS

Table 1 gives a comparison of the present ratio with previously reported results. The results of Macklin[6,7] are significantly lower than the other results and this discrepancy is not understood. The results of Rohr[3] and Corvi *et al.*[4] are high relative to the transmission[8] and present results but are consistent because of their uncertainties. There has been a problem with the normalization of the 1.15-keV resonance area for the Rohr[3] and Corvi *et al.*[4] data; however, this problem does not appear in the ratio. The results of Gayther *et al.*[14] were carried out with a large liquid scintillator tank rather than total energy detectors and are in agreement with the present results.

The ratio derived for the transmission experiments of Perey *et al.*[8] are probably the least susceptible to unknown systematic uncertainties. The present results are in excellent agreement with the transmission experiments.

From the above considerations, it appears that the discrepancies in the capture area of the 1.15-keV resonance are not associated with the unusually hard gamma-ray spectrum of the 1.15-keV resonance since the 22.8-keV resonance has a relatively soft spectrum and most of the capture measurements agree with the transmission measurement on the ratio. This would indicate that it should be possible to use total energy detectors for capture cross-section measurements in the structural materials. There will, however, continue to be concern[3,8] about such measurements until the discrepancies concerning the 1.15-keV ^{56}Fe resonance are better understood.

TABLE I Ratio of area of the 22.8- to 1.15-keV ^{56}Fe resonance

Source	Measurement	Ratio of areas
Gayther *et al.*[14]	Capture	3.02 ± 0.07
Rohr[3]	Capture	3.21 ± 0.26
Corvi *et al.*[4]	Capture	3.07 ± 0.15
Macklin[6]	Capture (0.5 mm sample)	2.47 ± 0.06
Macklin[7]	Capture (0.125 mm sample)	2.54 ± 0.08
Perey *et al.*[8]	Transmission	2.83 ± 0.16
Present	Capture	2.91 ± 0.17

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