Neutron Capture And Neutron Total Cross Sections Measurements For ^{27}Al At The Oak Ridge Electron Linear Accelerator¹

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Abstract. We have used the Oak Ridge Electron Linear Accelerator (ORELA) to measure neutron total and capture cross sections of ^{27}Al in the energy range from 100 eV to ~400 keV. We report the resonance parameters as well as the Maxwellian average capture cross sections.

INTRODUCTION

To support the Nuclear Criticality Predictability Program, neutron cross section measurements have been initiated at the Oak Ridge Electron Linear Accelerator (ORELA). We measured the total and capture cross sections of ^{27}Al in the neutron energy range from 100 eV to several hundred keV. This will help to clarify inconsistencies in the criticality calculations for systems including Al and ^{235}U .

DESCRIPTION

The Oak Ridge Electron Linear Accelerator (ORELA) was used as the neutron source for the present experiment. We used two extremely high purity (0.01520 a/b and 0.04573 a/b) rectangular aluminum samples for the neutron capture measurements. The samples and the C_6D_6 detectors were located at a distance of 40 meters from the neutron target. This capture system¹ has been re-engineered to minimize structural material surrounding the sample and detectors in order to reduce the prompt neutron sensitivity. A 0.5-mm thick ^6Li -glass scintillator served as the neutron flux monitor. Pulse-height weighting was employed with the C_6D_6 detectors; normalization of the capture efficiency was carried out in a separate measurement using the "black resonance" technique by means of the 4.9-eV resonance from a gold sample.²

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For the transmission measurements the two extremely high purity (0.0189a/b and 0.1513 a/b) aluminum samples were mounted in the sample changer positioned at about 10 meters from the neutron target in the beam of ORELA. A pre-sample collimation limited the beam size to about 2.54 cm on the samples and allowed only neutrons from the water moderator part of the neutron source to be used. The neutron detector was a 11.1cm diameter, 1.25 cm thick ^6Li glass scintillator viewed on edge by two 12.7 cm diameter photomultipliers and positioned in the beam at 79.815 meters from the neutron source. Additional measurements were made in both experiments for the open beam, and measurements with a thick polyethylene sample were used to determine the gamma-ray background from the neutron source.

TABLE 1. Resonance parameters for ^{27}Al .

Energy (eV)	Γ_γ (meV)	Γ_n (meV)	l	$g\Gamma_n\Gamma_\gamma/\Gamma$ (meV)
5906.5	526.30	16708	1	212.59
34765.1	1980.50	3245200	0	824.71
86183.2	1065.60	10361000	0	621.54
90744.3	77.74	14586	1	32.22
91413.1	51.05	202150	1	21.27
92033.3	215.34	3542.5	1	84.58
99789.6	931.90	4392.5	1	320.33
103928.5	399.44	5367.4	1	154.91
119976.6	1258.20	2688100	1	524.00
142897.3	1655.00	18317000	0	965.33
146217.7	253.29	114570	1	105.30
158457.4	220.40	3351000	1	91.83
203459.6	1406.60	15829000	0	586.03
203884.8	843.28	361.6	1	105.45
224322.3	312.41	414130	1	130.07
257603.3	236.24	797830	1	98.40
261040.0	569.51	44885	2	328.05
268867.4	183.19	73206	2	106.59
280558.4	1512.50	14567000	0	882.20
316902.9	2950.70	8061400	2	1229.01
345458.0	432.58	20379	2	247.09
360695.4	2002.20	56494	1	805.70
368784.7	1502.50	3651300	1	876.10
366669.9	1235.10	5129200	1	720.30
376037.6	1390.30	2850300	1	579.01
386912.3	1297.30	2395600	1	756.35
415782.8	1912.00	21910000	1	796.60
420980.7	1032.30	309070	2	600.17
430293.1	1997.10	52612000	0	832.09

RESULTS

The capture and transmission data sets were analyzed with the R-matrix code SAMMY.³ Using the new determined Γ_n values SAMMY calculated the corrections for self-shielding and multiple scattering to the capture data. The preliminary resonance parameters and capture kernels are reported in table I. From our

experimental data and resonance parameters we calculated the average and Maxwellian average capture cross section which are compiled in tables II and III, together with previous experiments and evaluation. We find an overall reduction of about 25% in the capture cross section and the maxwellian average cross sections. This probably is a result of the underestimated neutron sensitivity in the older measurements and a now improved calculation of the weighting function.

TABLE 2. Average capture cross section (mb).

Energy (keV)	This work	Allen et al. (1975) ⁴
5-6	92.3	150
10-50	2.93	2.90
50-100	1.40	2.54
100-200	0.74	2.05
200-300	0.39	1.02
300-400	0.58	0.6

TABLE 3. Maxwellian average cross sections (mb).

kT (keV)	Present experiment	Beer et al. (Evaluation) ⁵	Wisshak et al (1984) ⁶	Allen et al. (1975) ⁴
2.00	9.24			
5.00	8.20			
8.00	5.89			
10.00	5.17	6.72		
15.00	4.22	5.39		
20.00	3.65	4.64	4.75	
25.00	3.24	4.14	4.24	
30.00	2.92	3.80	3.89	3.9
35.00	2.66	3.55	3.63	
40.00	2.45	3.34	3.42	
50.00	2.10			

REFERENCES

1. R. L. Macklin and B. J. Allen, Nucl. Instrum. Methods, **91**, 565 (1971).
2. R. L. Macklin, J. Halperin, and R. R. Winters, Nucl. Instrum. Methods, **164**, 213 (1979).
3. N.M. Larson, Oak Ridge National Laboratory technical report No. ORNL/TM-9179/R4, 1998
4. B.J. Allen et al., "Neutron Capture Mechanism in Light and Closed Shell Nuclide" in Nuclear Cross Sections and Technology, edited by R.A. Schrack and C.D. Bowman, Washington DC, 1975, pp 360-362.
5. H. Beer, F. Voss, and R.R. Winters, Astropys. J. Suppl. **80**, 403 (1992).
6. K. Wisshak, F. Käppeler, and G. Reffo, Nucl. Sci. and Eng. **88**, 594 (1984).