Thermal Neutron Resonance of Sm

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The total neutron cross section of Sm has been measured over the energy range 0.005 to 0.18 ev using a crystal spectrometer. Agreement with a Breit-Wigner one-level resonance formula is very good except that higher cross sections below 0.04 ev suggest an additional lower energy resonance.

SAMARIUM has been found to have a neutron resonance at 0.096 ev, near the maximum of flux from reactors. Both previous measurements of cross section near resonance, by Sturm[1] and by Borst, Ulrich, Osborne, and Hasbrouck,[2] used crystal spectrometers as velocity selectors and covered energies greater than 0.04 ev. At lower energies second and third order diffraction from the crystal invalidated measurements by introducing an unknown fraction of higher energy neutrons into the otherwise monochromatic beam.[3] In the present measurements, a crystal spectrometer has also been used to make cross-section measurements of somewhat increased accuracy in the range 0.04 to 0.180 ev and to extend the energy range of measurements from 0.04 down to 0.005 ev (1.4 to 4A). Higher-order crystal reflections in this latter range were eliminated by the use of crystalline filters.

For uniform distribution of the thin Sm absorber, four samples were used:

No. 1, $Sm(NO_3)_3$ dissolved in D_2O;
No. 2, $Sm(NO_3)_3$, 39.2 mg/cm^2 dissolved in H_2O $+HNO_3$;
No. 3, Sm_2O_3 powder, 33.3 mg/cm^2;
No. 4, Sm_2O_3 powder, 15.61 mg/cm^2 dispersed uniformly in 210.0 mg/cm^2 MgO.

For Samples 1 and 2, the Sm_2O_3 powder (spectroscopic purity, Johnson, Matthey and Company) was dissolved in nitric acid to form $Sm(NO_3)_3$ and the solutions placed in quartz photometer cells 5.00 mm and 2.00 mm thick respectively. For Sample 1, the H_2O was first evaporated and replaced by D_2O. Samples 3 and 4 were packed as uniformly as possible in accurately machined aluminum containers 0.5 and 5.00 mm thick respectively. In all cases transmission was measured by comparison with a duplicate dummy cell identical except for absence of the Sm_2O_3. In the measurements the relative cross section *vs* energy curve was determined from data primarily on Sample 1, but confirmed by repeating the measurements with Sample 3 to insure that possible H_2O contamination of the D_2O did not distort low-energy data. The resonance energy and half-width were thus determined on Samples 1 and 3. To determine the absolute cross sections, Samples 2 and 4, for which Sm weights were more accurate, were used for measurements near the resonance energy. A neutron beam of 0.15 or 0.3 degree half-width from the JENER reactor was diffracted in transmission from the (200) planes of a 1.2-cm thick Pb crystal. For neutron wavelengths 0.7 to 1.4A no filter was required since second order contamination of the beam was measured to be from 1 to 1.5 percent. For longer wavelengths a 15-cm block of large-grained lead was placed in the beam. Although the nuclear scattering cross section is constant, diffraction effects depending both on lattice structure and grain size cause the effective cross section to decrease, somewhat irregularly, as wavelength increases from 1 to 5A. Thus shorter wavelength, higher-order components of the beam are partly filtered out. Small corrections, derived from crystal spectrometer measurements of the spectrum transmitted through the lead, were applied and ranged from 1.0 to 4 percent in the

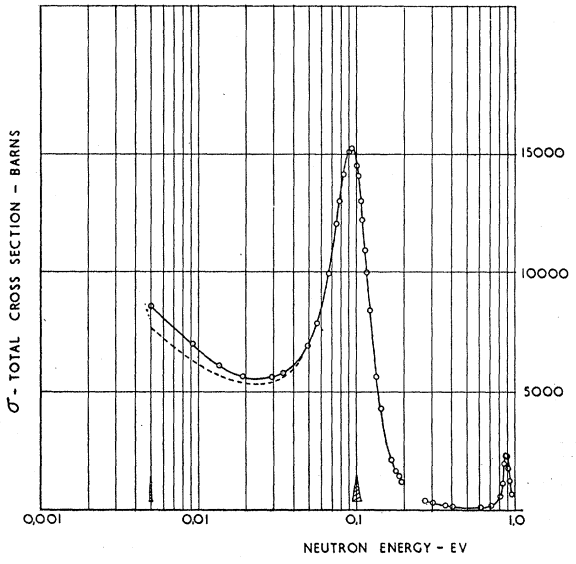

FIG. 1. Thermal neutron cross section of samarium as measured with Pb crystal spectrometer. Dotted curve is of Breit-Wigner one-level resonance form, fit to points for $E>0.04$ ev. Points above 0.2 ev are those of Sailor (reference 3).

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[1] W. S. Sturm, Phys. Rev. **71**, 757 (1947).

[2] Borst, Ulrich, Osborne, and Hasbrouck, Phys. Rev. **70**, 557 (1946).

[3] The same limitation seems to apply to the unpublished data shown in U. S. Atomic Energy Commission Report AECU-2040, Supplement 1 (Office of Technical Services, Department of Commerce, Washington, D. C., 1953), attributed to L. Borst and V. L. Sailor.

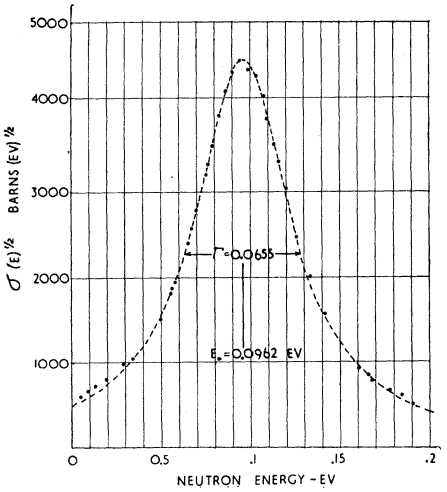

FIG. 2. Resonance curve for Sm. Data are same as Fig. 1 but plotted to indicate extent of agreement with Breit-Wigner curve shown.

Sm cross section. For still longer wavelengths, 4A or greater (0.005 ev), complete filtering could be accomplished by an additional 10 cm of Be, with a Bragg cutoff at 3.94A.

In Fig. 1 the measured cross sections are shown as a function of energy with higher-energy points as given by Sailor.[3] It is seen that over most of the energy range the points are fit well by a curve of the Breit-Wigner one level form:

$$\sigma=\frac{\sigma_0}{1+4(E-E_0)^2/\Gamma^2}\left(\frac{E_0}{E}\right)^{\frac{1}{2}}.$$

The curve shown is chosen for best fit to points from 0.04 to 0.18 ev, but data at lower energies lie about 10 percent above it. Although these points could be fit by assuming, instead of resonance width 0.066, a value of 0.070 ev, in better agreement with previous workers, the latter value lies well outside the limits of error derived from internal consistency of data. This is illustrated more clearly in Fig. 2, in which the same data are plotted as $\sigma(E)^{\frac{1}{2}}$ *vs* E for evaluation of the resonance constants E_0 and Γ. In Table I the values of these constants, as determined by analytical curve fitting, are compared with the results of references 1, 2, and 3. For each constant, independent measurements E_0 and Γ on Samples 1 and 3, and σ_0 on Samples 2 and 4, agreed within the experimental error. The constants listed under U. S. Atomic Energy Commission Report AECU-2040 are as estimated by us from the points shown there. Although this value for Γ is in agreement with ours, agreement for E_0 and σ_0 is better between our values and the earlier results of Sturm and Borst *et al.* Brockhouse[4] found that the higher value of σ_0 = 16 800 was required to fit his resonance scattering data but used Sturm's value of Γ = 0.074.

As an explanation of the deviation of low-energy points from a Breit-Wigner curve, higher order crystal reflections seem to be ruled out by several considerations. Measurement of this higher-order component showed that its effect was nowhere greater than 3 percent and at some energies lowered rather than raised the apparent cross section. Correction for this effect was made and the corrections further confirmed by measurements on the approximately $1/v$ indium cross section with the same neutron beams. The possibility of water contamination of the D_2O seems eliminated by the fact that measurements on the D_2O solution (Sample 1) and Sm_2O_3 powder (Sample 3) agree in their deviation of low-energy points from the Breit-Wigner curve. Impurities in the sample also seem improbable since an impurity of one percent Gd in the spectroscopically pure sample would be required to explain the observed effect.

The most probable explanation of the low-energy deviation seems to be a lower-energy resonance in another isotope of Sm. The 0.096-ev resonance was assigned to Sm^{149} by Lapp, Van Horn, and Dempster,[5] but there are six other isotopes of appreciable abundance. A resonance either near 0 or anywhere in the negative region roughly 0 to −0.5 ev could approximately account for the observations. Since Seren, Friedlander, and Turkel[6] report a 138-barn thermal cross section for Sm^{152} from activation measurements, a resonance near zero energy in that isotope seems plausible. Further conclusions would probably require measurements on separated isotopes to eliminate the Sm^{149} resonance.

TABLE I. Resonance constants for Sm.

	Present measurements	Sturm	Borst *et al.*	AECU-2040
E_0 (ev)	0.0962±0.0001	0.096	0.096	(0.098)
Γ (ev)	0.0655±0.0005	0.074	0.070	(0.065)
σ_0 (barns)	15 300±300	15 500	15 000	16 800

The authors are indebted to Mr. J. Garwick of the Forsvarets Forskningsinstitutt for analytical curve fitting to derive the resonance constants.

[4] B. N. Brockhouse, Can. J. Phys. **31**, 432 (1953).
[5] Lapp, Van Horn, and Dempster, Phys. Rev. **71**, 745 (1947).
[6] Seren, Friedlander, and Turkel, Phys. Rev. **72**, 888 (1947).