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PARAMETRIC FIT OF THE TOTAL CROSS SECTION OF ^{46}Sc*

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A parametric fit to the total cross section of Sc-45 based on the Breit-Wigner multilevel formalism was carried out. To reproduce the minimum in the total cross section at 2.0 keV and to get an acceptable fit for the low energy resonances, the spins of the bound level, the 3.24, and 4.27 keV resonances are 4,3,4 respectively. At higher energies the spins adopted for the resonances at 6.5, 7.9, 8.9, and 11.7 keV were 3,4,3,4. The parameters of the bound level are E_0 = -270 eV, Γ_n^o = 2.05 eV (J = 4) and Γ_γ = 0.38 eV.

(Bound level parameters; thermal cross sections; spin assignments)

Introduction

Because of the importance of Sc-45 in dosimetry applications and its use as a filter to produce a "monoenergetic" neutron beam at 2.0 keV an accurate knowledge of the neutron cross sections of Sc-45 is required. In this study we present the analysis and evaluation of the total cross section in the thermal and resonance regions. The total neutron cross section of Sc-45 was measured by Pattenden[1] in the energy range 0.0015 eV to 5.0 keV using a crystal spectrometer and slow and fast choppers. The data was parametrically fitted[1] in the low energy region with the aid of a negative energy resonance. However, above neutron energy region of about 300 eV, and around the famous minimum at 2.0 keV the calculated total cross section departed significantly from the measurements. Subsequent measurements carried out at the MTR showed[2,3] that the minimum at 2.0 keV is deeper than was previously measured.

The capture cross section of Sc-45 was measured by Romanov and Shapiro[4] in the energy range 1 eV to 40 keV. Alternative parameters of the bound level, and in particular a radiative width, were derived. In the resonance region, only one total cross section measurement[5] (3.0 - 35 keV) is available. The high resolution total cross section data of Cho et al[6] in the energy range 10 - 110 keV was not available during the evaluation.

Fitting Procedure

A multilevel Breit-Wigner total cross section was calculated using the code RESEND.[7] As a starting point, the resonance parameters recommended in BNL-325 (1973) were adopted. Since the spin and parity of the ground state of the target nucleus are $7/2^-$, s-wave neutron capture by Sc-45 forms compound states with spins and parities 3^- and 4^-. The spins of the resonances below 10 keV were not determined. In addition, thermal capture γ ray spectra measurements of Bolotin[8] and Delang et al[9] give some, but inconclusive, indication that the spin of the bound level is possibly 3. This is based on the observation of a primary transition to a low lying state at 142 keV with spin and parity 1^- and the lack of transitions to several low lying states with possible spin and parity of 5^+. It must be pointed out that at the start of the evaluation, thermal neutron polarization data which is important in shedding light on the coherent and incoherent cross sections and the spin of the bound level, were not available.

The total cross section in the energy range 3-10 keV was calculated and compared with the experimental data. The spin of the resonances at 3.24, 4.27, 6.59, 7.92, 8.90, 11.7 keV were found to be 3,4,3,4,3,4 respectively. With such a choice for the spins, several attempts were made to reproduce the minimum at 2.0 keV on the assumption that the spin of the bound level is 3. However, the best fit in the region of the minimum in the total cross section was achieved by adopting a spin 4 for the bound level. Table I presents the resonance parameters used in the present evaluation in the energy range up to 11.7 keV. The resonance parameters in the higher neutron energy 19.17 - 105.7 keV are the same as those quoted[10] in BNL-325 (1973). Figure 1, shows the calculated total cross section, represented by a solid smooth curve, in the energy range 10^{-5} eV to 3 keV. At low neutron energies, the solid curve passes through the data points of both Pattenden[1] and Wilson.[2] However, in the energy range 100 eV to ~ 1 keV, there is a significant discrepancy between the calculations and the data of Wilson.[2] Above the minimum, the calculations are in good agreement with the experimental data.[2] The calculated minimum of the total cross section at 1.9 keV is 85 mb. This is in good agreement with the experimental value $\sigma_t = 50^{+100}_{-50}$ mb within the stated error.

Figure 2 shows the calculated cross section in the energy range 1 - 10 keV and is compared with the low resolution data.[5] The calculated cross section shows another minimum of 189 mb at a neutron energy of 7.35 keV, which is not visible in the old measured cross section. A corroborative evidence for this minimum can be found in filtered beam experiments.[3]

Discussion

With the aid of resonance parameters determined from σ_t in the present evaluation, the partial cross sections can be calculated. Of particular interest is a comparison of the calculated cross sections at neutron energies of 0.0253 and 18.8 eV. Such a comparison is shown in Table II. The calculated thermal capture and scattering cross sections are found to be 26.9b and 23.7b respectively. These are in excellent agreement with the values recommended[10] in BNL-325 (1973).

Recent measurements carried out at neutron energy of 18.8 eV by Dilg[11] reported that σ_t = 22.03 ± 0.25b. This is in excellent agreement within the stated error with a calculated value of 21.7b. In addition, the coherent free scattering amplitudes (a+ and a-) associated with spins 4 and 3 can be calculated with the aid of the relation:

$$a_\pm = \left| R' + \sum_j \frac{\lambda_j \Gamma_{nj}}{2(E-E_j) + i\Gamma_j} \right|$$

where the summation is carried out separately over j = 3 and j = 4 resonances. The nuclear scattering

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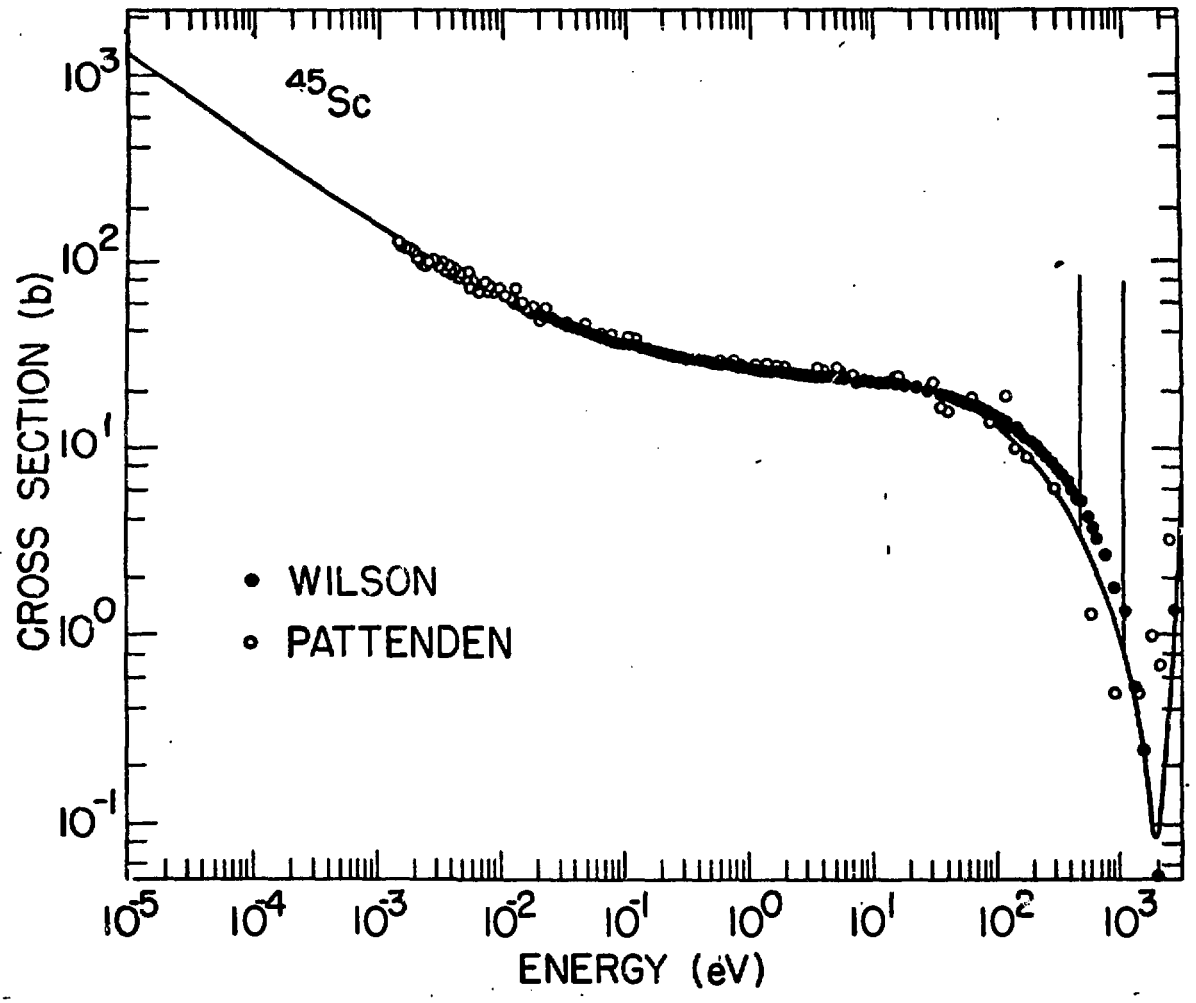

Figure 1

Total Cross Section of Sc-45 in Energy Range 10^{-5} eV to 3 keV

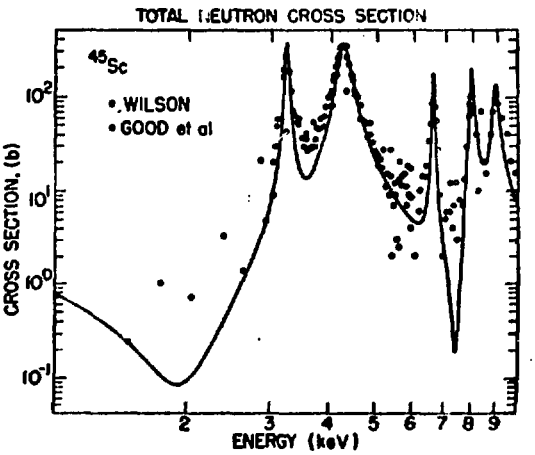

Figure 2

Total Cross Section of Sc-45 in Energy Range 1 keV to 10 keV

radius R' is found to be 5.1 fm. The total coherent free scattering amplitued is then

$$a = g_+ a_+ + g_- a_-$$

where g_+ and g_- are the statistical weight factors associated with spins I + 1/2 and I - 1/2. In this evaluation we find

$a_+ = 18.2$ fm
$a_- = 2.1$ fm
$a = 11.2$ fm

From the latter value, we calculate a coherent bound scattering amplitude of 11.4 fm. This is in good agreement with a measured value of 11.8 ± 0.5 fm.

After the completion of the evaluation, a polarization measurement, in which the incoherent scattering amplitude was accurately determined, was reported by Roubeau et al[12]. The result is:

$$b_+ - b_- = 12.0 \pm 0.3 \text{ fm}$$

which strongly supports a spin assignment of 4 for the bound level in agreement with the present conclusions. However, the present evaluation gives

$$b_+ - b_- = 16.1 \text{ fm}$$

indicating that the calculated incoherent cross section is larger than measured by Roubeau at al[12] Since the total scattering cross section is well established, this indicates that coherent scattering cross section should be larger than previously determined. A new measurement of the coherent scattering amplitude by Koester and Knopf[13] reporting a preliminary value b = 12.9 ± 0.7 fm supports this conclusion.

Table I

Resonance Parameters of
Low Energy Neutron Resonances

E_o (keV)	J	Γ_n (eV)	Γ_γ (eV)
- 0.270	4	$\Gamma_n^0 = 2.05$	0.379
3.24	3	70	0.3
4.27	4	300	0.35
6.59	3	73	(1.5)
7.92	4	160	(1.5)
8.90	3	260	(1.5)
11.7	4	140	(1.5)

Table II

Total, Scattering, and Capture Cross Sections
at 0.0253 eV and 18.8 eV

	0.0253 eV		18.8 eV	
E(eV)	BNL 325	present evaluation	Dilg	present evaluation
σ_t(b)	50.5±1.0	50.6	22.03±0.25	21.7
σ_γ(b)	26.5±1.0	26.9	(1.01)	0.9
σ_s(b)	24±2	23.7	21.9	20.8

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