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MULTILEVEL ANALYSIS OF U^{235} SCATTERING CROSS SECTION DATA[†]

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MULTILEVEL ANALYSIS OF U^{235} SCATTERING CROSS SECTION DATA

D. B. Adler and F. T. Adler

Poortmans and Ceulemans^{1/} have reported high resolution measurements of U^{235} scattering and total cross sections, which permit to achieve a high accuracy of the resonance parameters and to deduce spin assignments, at least for the larger resonances.

The scattering data were made available⁽¹⁾ to be analyzed with the multilevel formalism.

In the preliminary investigation reported here the U^{235} total cross section data of Saclay^{2/} were chosen to be correlated with the Ceulemans' scattering data.

While multilevel parameters for scattering cross sections can be computed from the parameters obtained from the triple fit of total, capture, and fission data,^{3/} in practice they will contain the combined incertitudes of each data set, and thus be affected by large errors. A procedure more suitable for fitting high precision data with the multilevel expansion is based on the derivation of the scattering parameters from the total cross section parameters α, β ,^{4/} by

$$G_k^n + iH_k^n = i \frac{\sqrt{E}}{2g} \sum_{k'} \frac{(\alpha_k + i\beta_k)(\alpha_{k'} + i\beta_{k'})}{\mu_{k'} - \mu_k + i(\nu_{k'} + \nu_k)} \quad (1)$$

(for a given spin state). This expansion requires explicit spin assignments (not needed in the case of other cross sections) which are often uncertain, but can be deduced in some case by correlating total and scattering data.^{1/}

The multilevel expansion for the scattering cross section, in terms of the parameters of eq. (1), is given by

$$\begin{aligned} \sigma_n(E) = & 2C (1 - \cos \omega)/E \\ & + \frac{C}{\sqrt{E}} \sum_J \sum_{k(J)} \frac{v_k [\alpha_k (\cos \omega - 1) + \beta_k \sin \omega] + (\mu_k - E) [\beta_k (\cos \omega - 1) - \alpha_k \sin \omega]}{(\mu_k - E)^2 + v_k^2} \\ & + C \sum_J \sum_{k(J)} \frac{v_k G_k^n + (\mu_k - E) H_k^n}{(\mu_k - E)^2 + v_k^2} \end{aligned} \quad (2)$$

where k runs over the resonances of the spin state J , ω represents the potential scattering phase shift, and $C = 6.52 \times 10^5$ eV barns.

Eqs. (1) and (2) also include the case of non-interfering resonances when $\beta = H^n = 0$, and

$$\alpha_k \approx \Gamma_{kn}^0, \quad G_k^n \approx \frac{\Gamma_{kn}^0 \Gamma_{kn}}{\Gamma_k} \quad (3)$$

For the purpose of this work, program CODILLI ^{25/} has been generalized to include the expansion given by eq. (2) as trial function. For a given set of total cross section parameters α , β , values of G^n and H^n are also calculated independently from Eq. (1) for comparison with those obtained from the fitting. The same method thus applies to single level analysis; it can be used to compare single level and multilevel modes with the same data, as well as to determine single level parameters in absence of interferences (e.g., for non-fissile elements).

[Illustrative preliminary results of the U^{235} analysis are given] in Table I. In the fitting of the data the impurities of the sample^{1/} were taken into account using known multilevel parameters; ⁽²⁾ all other required information on the conditions of the experiment were provided by private communication. ⁽¹⁾

Table I. Preliminary Results of Multilevel Analysis of ^{235}U Scattering Data Between 7 and 17 eV.

μ (eV)	ν (eV)	$\alpha^{(1)}$	$\beta^{(1)}$	$2g^n/\alpha^{(2)}$	$\alpha/\mu / 2\nu^{(3)}$	$2g \Gamma^n/\Gamma^{(4)}$	$J^{(2)} (4)$
8.44	.390	.017	-.129	-.689			
8.77	.065	3.910	-.301	.915 10^{-2}	.892 10^{-2}	.85 10^{-2}	3
9.29	.043	.374	.033	-.910 10^{-2}			
9.42	.200	.079	.055	.307			
9.78	.090	.068	.039	.119			
10.17	.045	.165	-.031	.165 10^{-1}			
11.56	.150	.088	.042	-.863 10^{-1}			
11.66	.018	1.681	-.063	.115 10^{-1}	1.55 10^{-1}	1.48 10^{-2}	4
12.40	.023	3.791	.162	.181 10^{-1}	2.90 10^{-2}	1.95 10^{-2}	3
12.84	.085	.192	.033	-.781 10^{-2}			
13.22	.098	.079	-.039	.263 10^{-1}			
13.69	.095	.088	-.130	.573 10^{-2}			
14.07	.280	1.308	.435	.132 10^{-1}			
14.55	.032	.290	.050	.120 10^{-1}			
15.41	.035	.580	.049	.160 10^{-2}			
16.10	.030	.941	.092	.320 10^{-2}			
16.65	.073	.701	-.112	-.310 10^{-2}			

(1) in units of $(\text{eV})^{\frac{1}{2}} * 10^{-4}$

(2) from this analysis

(3) first order perturbation from eq (3), for the larger resonances

(4) from reference 1

Footnotes

- (1) The authors are indebted to Dr. Ceulemans for stimulating this work and to him and others at the Mol Laboratory for the communication of the data and associated information.
- (2) For U^{233} , R-matrix parameters,^{6/} were converted to multilevel parameters; for U^{234} and U^{236} single level parameters from the Brookhaven National Laboratory compilations were adjusted to the multilevel format.

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