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Reevaluation of Gold Shell Transmission Data at 24 keV Neutron Energy

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Reevaluation of Gold Shell Transmission Data at 24 keV Neutron Energy*

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ABSTRACT

Quite different values of the 24 keV neutron capture cross section of gold have been extracted by various authors from the shell transmission data reported by Schmitt and Cook. The discrepancies are due to the different treatment of the rather important self-shielding and multiple-scattering corrections. A new attempt to calculate them was based on the best available total cross section data and level statistics. Monte Carlo methods were used to generate resonance cross sections. The result is σ_γ (24 keV) = (650 $\pm$ 35) mb Implications for the present gold standard situation are discussed.

ZUSAMMENFASSUNG

Stark differierende Werte des Einfangquerschnitts von Gold für 24-keV-Neutronen wurden von verschiedenen Autoren aus den Schalentransmissionsdaten von Schmitt und Cook abgeleitet. Die Diskrepanzen rühren her von der unterschiedlichen Behandlung der beträchtlichen Selbstabschirmungs- und Vielfachstreu-Korrektionen. Eine Neuberechnung dieser Korrektionen mit den besten zur Zeit verfügbaren Daten über Gesamtquerschnitt und Niveaustatistik wurde durchgeführt. Monte-Carlo-Methoden wurden zur Erzeugung von Resonanzquerschnitten benutzt. Das Ergebnis ist σ_γ (24 keV) = (650 $\pm$ 35) mb . Die Konsequenzen für die gegenwärtige Situation des Gold-Standardquerschnitts werden diskutiert.

REEVALUATION OF GOLD SHELL TRANSMISSION DATA AT 24 keV NEUTRON ENERGY

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1. INTRODUCTION

Gold is a convenient reference nuclide in fast neutron capture work. Consequently, the shape of the capture cross section of gold in the keV region was repeatedly measured (see e.g. refs. [1, 2, 3, 4]). One of the possible methods to get an absolute value is the shell transmission method [5], which was used by Schmitt and Cook [6, 7] and by Belanova [8] to find the absolute capture cross section of gold at 24 keV with neutrons from an Sb-Be source. The published shell transmissions are quite accurate. However, the extraction of absolute cross sections is seriously complicated by multiple scattering and by the (nonobserved) resonance structure of the cross section (self-shielding). The only practical way to account for these effects is the use of Monte Carlo methods in conjunction with level statistics to generate representative resonance cross sections [9].

The first Monte Carlo interpretation of the data of Schmitt and Cook [6, 7] was based on relatively sparse resonance information. The two relevant s-wave strength functions S_{01} and S_{02} (for compound spins 1 and 2, respectively) were taken as equal. However, subsequent extensive resonance parameter determinations from transmission data between 0 and 1 keV yielded vastly differing values: $S_{01} = (1.17 \pm 0.3) \cdot 10^{-4}$, $S_{02} = (2.46 \pm 0.53) \cdot 10^{-4}$ [11]. Reevaluation of the data seemed to be necessary. Two significantly differing average capture cross sections for 24 keV neutrons were reported: $\langle \sigma_\gamma \rangle = (645 \pm 35)$ mb [12] and $\langle \sigma_\gamma \rangle = (725 \pm 25)$ mb [13]. A somewhat crude histogram representation of the Wigner and Porter-Thomas distributions in ref. [13] may have introduced some error there. In the meantime the resonance analysis has been extended to 2 keV, and the s-wave strength functions calculated for the whole range 0 - 2 keV are not significantly different [14]. Hence it seems that the difference between S_{01} and S_{02} in the range 0 - 1 keV [11] is fortuituous, resulting from too small resonance samples. In the present paper we present a reevaluation of the data of Schmitt and Cook [6, 7] with level-statistical parameters derived from the improved resonance data of ref. [14].

2. CALCULATION

The theoretical background of the calculations was reported previously [12]. In the present work we assumed spin-independent strength functions. The calculations were performed in three steps.

First the resonance data of ref. [14] were used in a least-squares analysis similar to that described in [15]. The following level-statistical parameters were obtained:

$S_0 = (2.05 \pm ^{.24}_{.21}) \cdot 10^{-4}$ (s-wave strength function),

$D_0 = (18 \pm 1)$ eV (average s-wave level spacing),

$\Gamma_{\gamma 0} = (128 \pm 6)$ meV (average s-wave radiation width).

Then values of the p-wave strength function S_1 were calculated from the expressions (see ref. [12])

$$\langle \sigma \rangle = 2\pi^2 \lambda\!\!\!^{-}{}^2 \sum_{l=0}^{1} (2l+1)\, S_l (E/1\ \text{eV})^{1/2}\, V_l \cos 2\xi_l + \sigma_p$$

with $$\sigma_p = 4\pi \lambda\!\!\!^{-}{}^2 \sum_{l=0}^{1} (2l+1) \sin^2 \xi_l$$

$$\xi_o = -kR' , \quad \xi_1 \approx \xi_o - \arctan \xi_o ;$$

$$V_o = 1 , \quad V_1 = \xi_o^2 (1 + \xi_o^2)^{-1} .$$

S_o values between 1.8 and $2.3 \cdot 10^{-4}$ were chosen. The effective radius R' was chosen so as to reproduce the σ_p values 9.5 b and 10 b given in refs. [11, 14] and $\langle\sigma\rangle$ values between 13.5 and 13.9 were used in accordance with the values published in the literature ([6, 7, 13]) and with own measurements reported at this conference [16]. In this way self-consistent sets of the quantities $\langle\sigma\rangle$, S_o, S_1, R' were found. Eventually these sets together with $\Gamma_{\gamma o} = 128$ meV were used in Monte Carlo calculations with the code SESH. The only remaining free parameter, the p-wave radiation width $\Gamma_{\gamma 1}$, was adjusted in such a way as to reproduce the measured shell transmission as well as possible. The best fit resulted from the following values:

$$\langle\sigma\rangle = 13.7\ \text{b}, \quad S_o = 1.8 \cdot 10^{-4}, \quad D_o = 18\ \text{eV}, \quad \Gamma_{\gamma o} = 128\ \text{meV},$$

$$\sigma_p = 9.5\ \text{b}, \quad S_1 = 0.7 \cdot 10^{-4}, \quad D_1 = 9\ \text{eV}, \quad \Gamma_{\gamma 1} = 100\ \text{meV}.$$

The resulting sphere transmissions were

$T_s = .80 \pm .01$ for a shell thickness corresponding to 0.149 nuclei/b,

$T_s = .88 \pm .01$ for a shell thickness corresponding to 0.099 nuclei/b,

in agreement with the measured values $.800 \pm .004$ and $.876 \pm .005$ given in refs. [6, 7]. The average capture cross section found with these input numbers is $\langle\sigma_\gamma\rangle = (660 \pm 20)$ mb. The uncertainties given here for $\langle\sigma_\gamma\rangle$ and T_s are due to the limited number of Monte Carlo histories. Similar calculations with slightly different input numbers yield as final result

$$\langle\sigma_\gamma\rangle = (650 \pm 35)\ \text{mb}.$$

where the uncertainty reflects also the uncertainty of the input numbers, $\langle\sigma\rangle$, σ_p, S_o, D_o, $\Gamma_{\gamma o}$. This result is not much different from that found for $S_{01} \neq S_{02}$ [12], (645 ± 25) mb.

3. CONCLUSION

Level statistics with spin-independent strength functions derived from the new Saclay resonance parameters [14] were used to reanalyze the shell transmission data of Schmitt and Cook [6, 7]. The result, $\langle\sigma_\gamma\rangle = (650 \pm 35)$ mb at 24 keV, is not much different from the numbers of refs. [12] which were obtained with spin-dependent strength functions derived from older Saclay data [11]. It also agrees with Semler's result for spin-independent strength function [13]. Discrepancies exist with Semler's value (725 ± 25) mb for spin-dependent strength functions, which however can no longer be considered correct in view of the new Saclay results. Furthermore, our result does not agree with the high gold capture cross section reported in ref. [4]. These cross sections, however, were revised recently and are now in agreement with our result [18]. Thus the standard capture cross section of gold used in our capture work, with a normalization value of 596 mb at 30 keV [2, 3], which was somewhat in doubt after publication of the high values of refs. [13] and [4], is reasonably confirmed by this reevaluation.

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