NUCLEAR RESONANT SCATTERING OF CAPTURE GAMMA RAYS ON Sb

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ABSTRACT

Monochromatic photons obtained from thermal neutron capture in titanium were used for exciting nuclear levels in antimony. Angular distribution of the elastic scattered radiation was carried out for the determination of the spins of the resonance levels. Total and ground state radiation widths of resonance levels were measured using self absorption and temperature variation measurements

Introduction

The scattering of photons by nuclei is an interesting and promising research field in nuclear physics of stable nuclei. The development of new experimental arrangements[2] where the intensity of the monochromatic beam is increased has permitted the analysis of elements with smaller cross-sections

In this paper it is observed the elastic scattering of two lines from a titanium source on an antimony target. For one of these lines it was possible to identify the resonant isotope as well as to determine the spins of the resonant level, the partial width of the decay to the ground state and the total width for the resonant level. By means of these data it was evaluated the excitation cross section $\sigma_{\gamma\gamma}$ at the resonance energy

The energy levels of $^{1\ \ 1}$Sb were studied earlier by other methods including Coulomb excitation[3], (d, d'), (He^2, d)[1] reactions and also by beta decay of Te[6]. In this paper we give some extra information concerning this nucleus

Experimental Method

Thermal neutrons were provided by the IEAR 1 reactor of S. Paulo and the gamma source was produced by neutron capture in five separated plates of titanium placed in the reactor core adding up to 4630 g. Details of the experimental set up were published previously[2] and they are shown in figure 1. The gamma beam was collimated, neutron filtered and allowed to hit a metalic antimony scatter. The scattered gamma radiation was measured by using a 42 5 cc Ge(Li) detector fitted into a graduated rotating arm pivoted around a perpendicular axis passing through the scatterer. The gamma ray spectrum was recorded with a 4096 multichannel analyser coupled to a digital peak stabilizer. All the electronic equipment was in a thermostatized room whose temperature was kept constant in within one degree (± 1°C)

The energy resolution of the Ge(Li) detector was then about 10 keV for the 6761 keV line. The intensity of the incident gamma rays were monitered by detecting the neutron flux just above the gamma source using a self powered neutron detector of cobalt from the firm Reuter Stokes (Model RSW 20-2M1) with a sensitivity of 2 4 x 10^{-20} Amp/nv. This procedure was necessary in long runs as in self absorption and angular distributions experiments. The energy calibration and the variable energy response of the Ge(Li) detector were measured using the well known gamma line energies and intensities of the direct Ti(n, gamma) beam.

Experimental Results

A small part of the high energy resonant spectrum scattered by the antimony target is shown in figure 2 About 2 cm of iron was placed in front of the detector for filtering out the large number of low energy gamma rays obtained from atomic interactions of the direct gamma beam with the scatterer The scattered spectrum shows two elastic components at 6417 keV and 6761 keV. In the scattered spectrum we observe also an inelastic line of 6598 keV which was identified to belong to ^{121}Sb by using the knowledge of the low energy levels of it. The 6417 keV line in the scattered spectrum was not related to either isotope of antimony

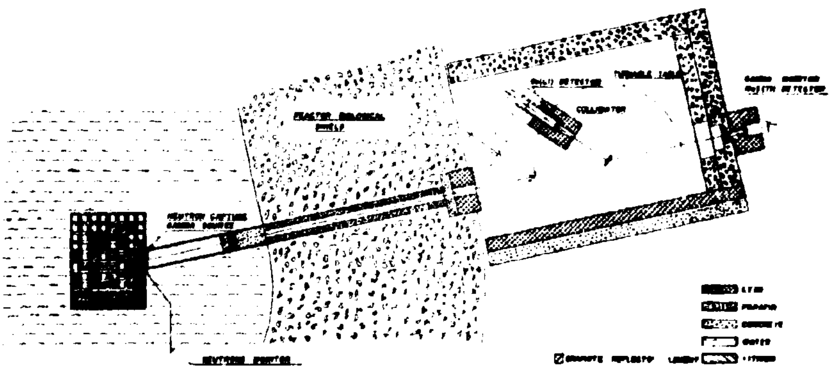

Figure 1

Experimental arrangement

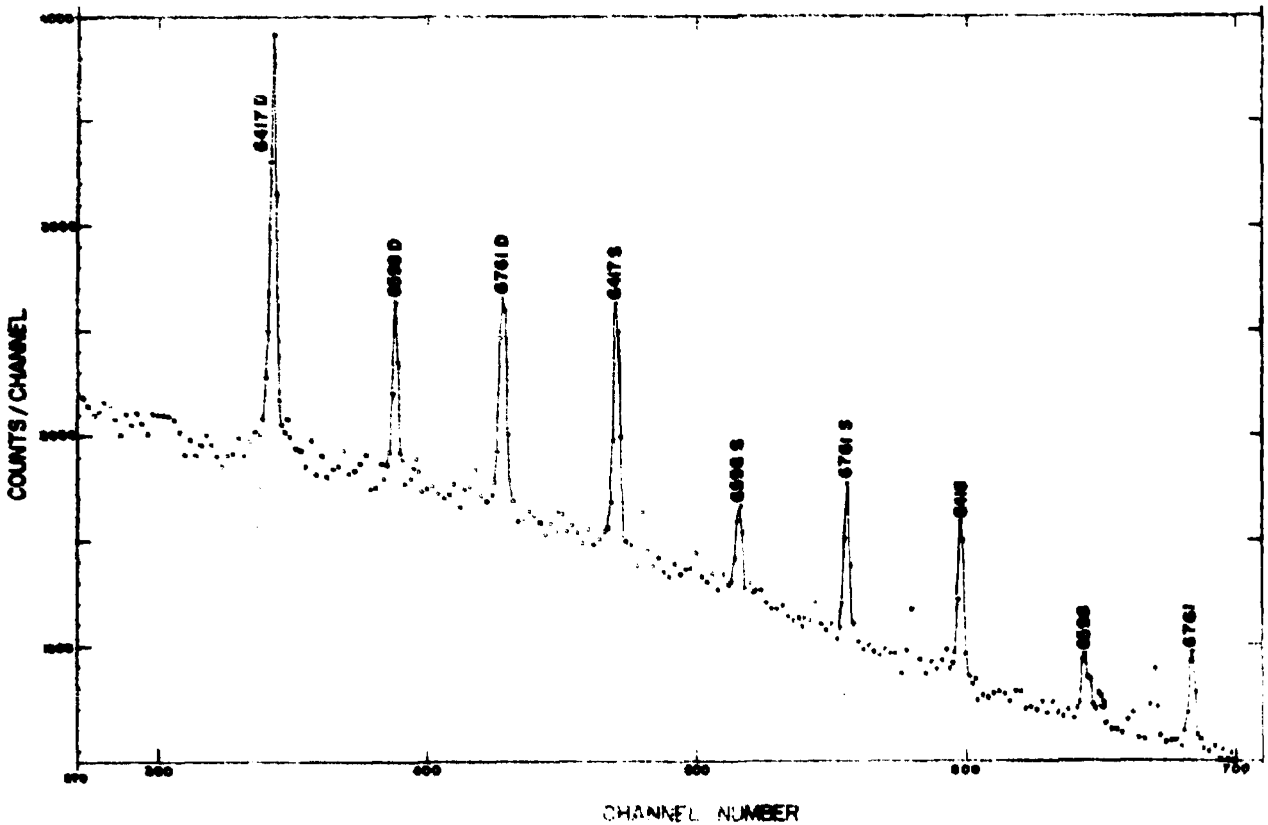

Figure 2

Scattered spectrum

The angular distribution measurements were carried out by using the Ge(Li) spectrometer mounted on an arm pivoted around a pependicular axis passing through the scatterer. In order to determine the spins of the levels involved, the experimental angular distribution was fitted by the expansion

$$C(\theta) = a_0 + a_2 \cos^2\theta + a_4 \cos^4\theta + \ldots + a_n \cos^n\theta$$

wich corresponds to the general expansion in even Legendre polynomials of the form.

$$W(\theta) = A_0 + A_2 P_2(\cos\theta) + A_4 P_4(\cos\theta) + \ldots + A_{max} P_{\gamma max}(\cos\theta)$$

From the values obtained for the parameters A_i and from informations of the spins of the low energy levels it was possible to establish the spin of the resonant level (see figures 3 and 4). From the angular distribution of the 6417 KeV resonant line however it was not possible to establish the spin (figure 5) because it was not possible to know in which isotope it scatter resonantly.

For measuring the remperature dependence of the yield of gamma rays scattered by the antimony scatterer, it was placed on an aluminium support whose temperature could be adjusted and controlled by a thermostat installed into the antimony target. The yield variation was measured at 503°C and at room temperature.

The effective temperature was calculated using the expression of Lamb[5] and using the Sb correspondent lattice Debye temperature[4]. From this experiment it was calculated the value of the separation energy between the peaks of the resonant level and the incident line.

The values of ϵ were obtained by using the expression for the ratio of the yields measurements at temperature T_1 and T_2.

$$Y(T_1)/Y(T_2) = [\Delta_0(T_2)/\Delta_0(T_1)] \exp\left|\epsilon^2[\Delta_0^{-2}(T_2) - \Delta_0^{-2}(T_1)]\right|$$

where $\Delta_0^2(T) = \Delta^2(T) + \Delta_0^2$ is the total Doppler width

The branching ratios for the decay of the 6761 keV level were evaluated from the relative intensities of the scattered gamma lines as measured at an angle of 140° after accounting for the angular distributions of the lines de exciting the resonant level. The value obtained for Γ_0/Γ was then $\Gamma_0/\Gamma = 0{,}6$ for the 6761 keV transition and $\Gamma_0/\Gamma = 1$ for the 6417 keV transition. The self absorption ratio R is defined by $R = (I_{NR} - I_R)/I_R$ where I_{NR} denotes the scattering intensity with non resonant tin absorber and I_R denotes the scattering intensity with resonant antimony absorber. The thickness of the two absorbers were chosen so as to give an equal electronic absorption. The value of Γ_0 obtained out of this experiment together with the calculated effective cross sections $\langle\sigma_r\rangle$ are displayed in table I.

Conclusion

The technique of resonant scattering of thermal neutron capture gamma rays is useful to investigate the properties of levels at relatively high excitation energy which are populated by the transitions from the well defined resonant level near the neutron binding energy. However, in some cases only few informations can be obtained from the excited nucleus due to the high branching ratio Γ_0/Γ. From the analysis of the angular distribution of the scattered gamma rays we find $J = 7/2$ for the spin 6761 keV resonant level in ^{123}Sb. The identification of the resonant isotope was possible due to the existence of a inelastic line which fits the 163 keV low energy level of the ^{123}Sb. For the 6417 keV it was not possible to establish the resonant isotope.

Table I

Transitions	6761 keV	6418 keV	
Isotope	^{123}Sb	^{121}Sb	^{123}Sb
ϵ (eV)	7.8 ± 2.3	5.8 ± 2.4	5.8 ± 2.4
Γ_0 (eV)	1.5 ± 1.1	0.030 ± 1.1	0.043 ± 1.6
Γ_0/Γ	0.60	∿ 1	∿ 1
$<\sigma_r>$ (barn)	2.2 ± 2.6 1.3	0.12 ± 0.04	0.17 ± 0.06

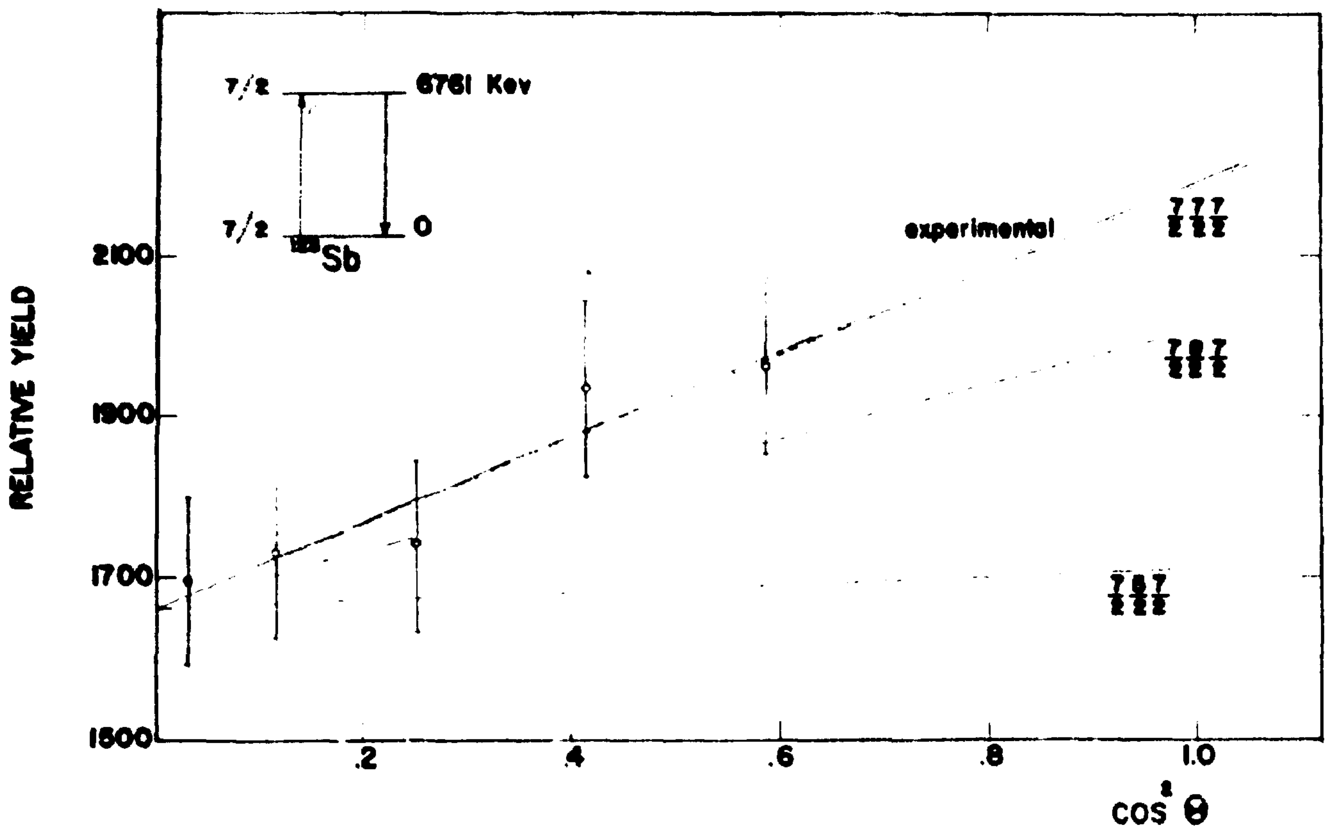

Figure 3

Angular distribution of the 6761 KeV line

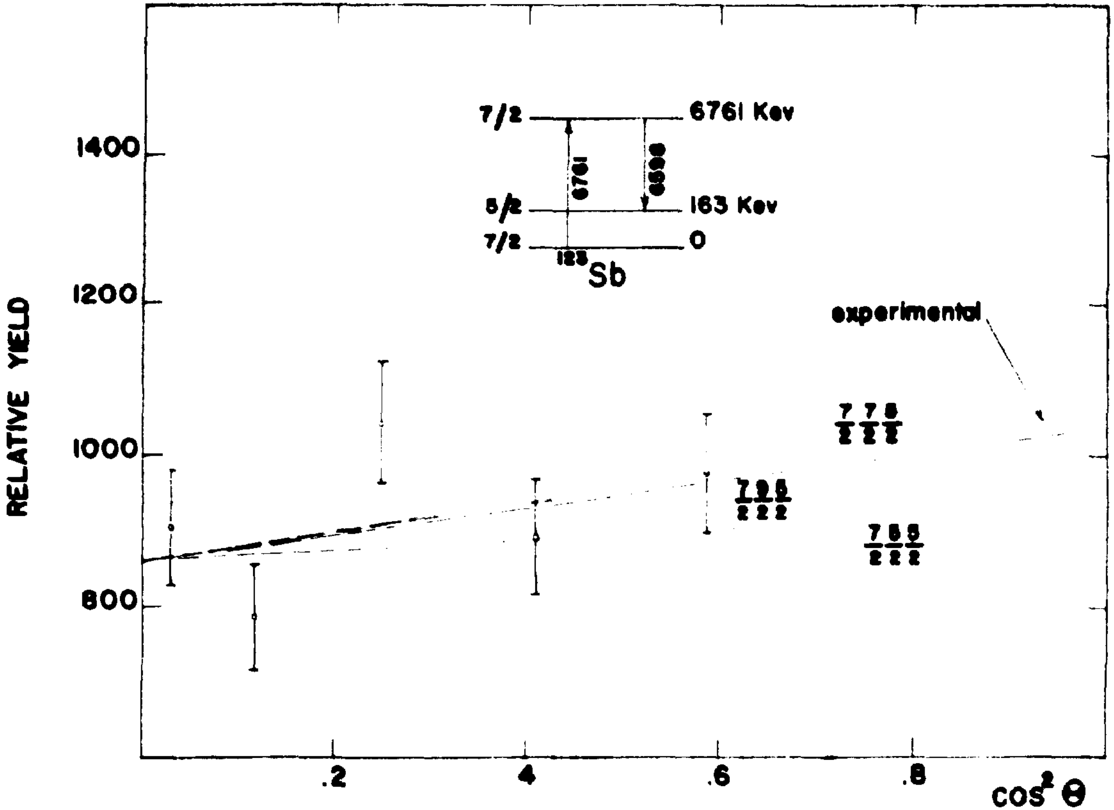

Figure 4

Angular distribution of the inelastic 6598 KeV line

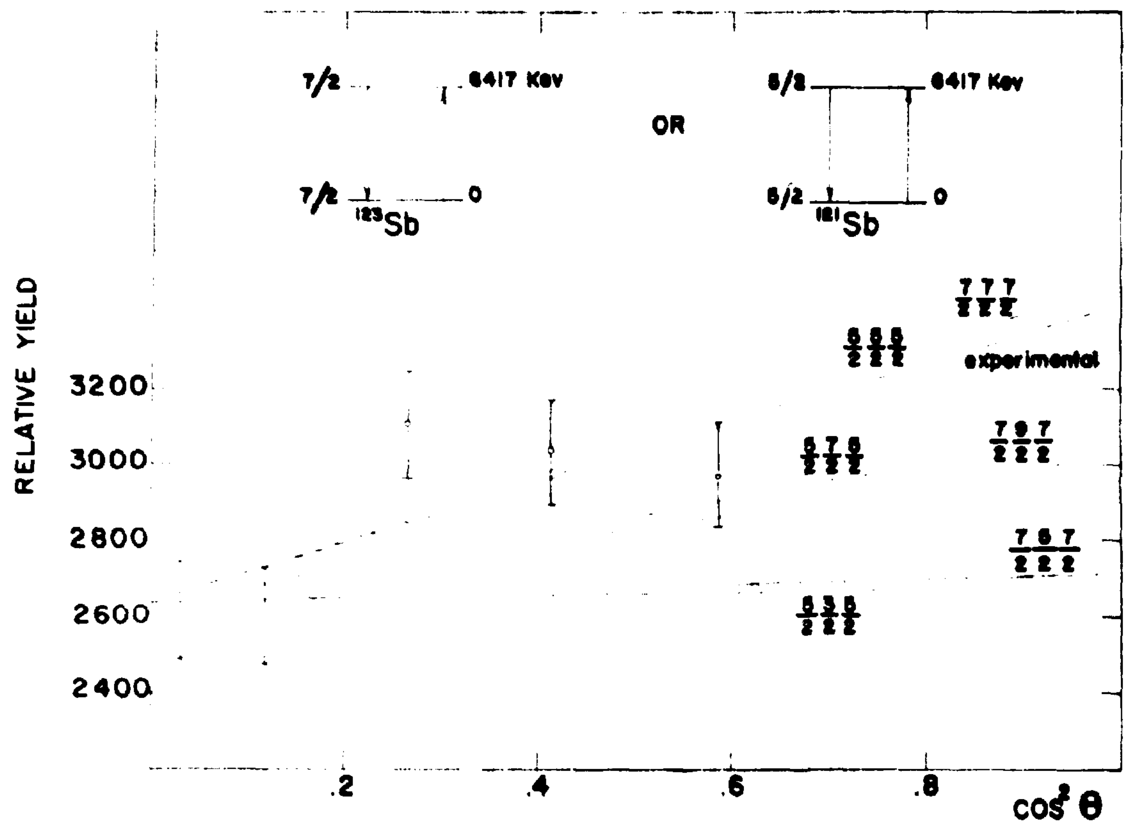

Figure 5

Angular distribution of the 6417 KeV line

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RESUMO

Foram utilizados fotons monocromaticos obtidos na captura radioativa de neutrons termicos em titânio para a excitação de níveis nucleares no antimonio. Foi medida tambem a distribuição angular da radiação espalhada para a determinação dos spins dos níveis ressonantes. As larguras radioativas total e para o estado fundamental foram medidas em experiências de auto absorção e variação de temperatura.

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