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DISCRETE GAMMA-RAY PRODUCTION CROSS SECTIONS AND ANGULAR DISTRIBUTIONS IN $^{52}Cr(n,x\gamma)$ AT 14.6 MeV

S. Hlaváč and P. Obložinský
Institute of Physics
Electrophysical Research Centre of the
Slovak Academy of Sciences
842 28 Bratislava, Czechoslovakia

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Discrete γ ray production cross sections and angular distributions in $^{52}Cr(n,x\gamma)$ at 14.6 MeV

S. Hlaváč and P. Obložinský
Institute of Physics, Electro-Physical Research Centre of the Slovak Academy of Sciences, 842 28 Bratislava, Czechoslovakia

Highly enriched sample of ^{52}Cr was irradiated by 14.6 MeV neutrons and γ rays production spectra were measured by the Ge(Li) spectrometer at several angles. Differential cross sections of 15 discrete γ ray transitions in $(n,n'\gamma)$, $(n,2n\gamma)$ and $(n,np\gamma)$ channels were observed. Angular distributions and angle-integrated production cross sections were determined for 10 transitions in the $(n,n'\gamma)$ channel as well as for 2 transitions in the $(n,2n\gamma)$ channel.

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1. Introduction

As a part of our research program we observed γ rays emitted in $^{52}Cr(n,x\gamma)$ reactions. Earlier we reported on the coincident data such as the average γ ray multiplicities [1], here we concentrate on discrete γ ray production cross sections.

2. Experimental procedure

Measurements were performed using the multidetector system described in detail elsewhere[2]. The system employs the associated α particle method. Part of the system used in the present study is sketched in fig. 1. Neutrons of energy 14.6 MeV are col-

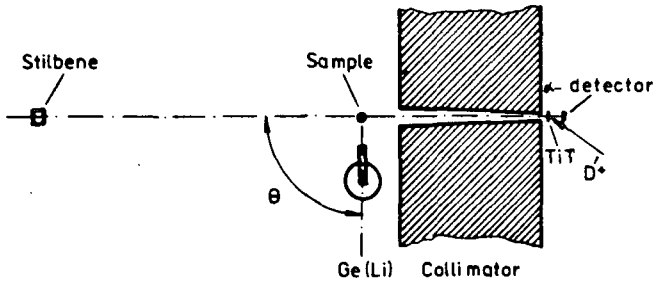

Fig. 1. Simplified drawing of the experimental arrangement

limated electronically by the associated particle detector and pass through a mechanical collimator.

We used 119.8 g of highly enriched (99.8 %) ^{52}Cr sample in metallic powder form delivered by TECHSNABEXPORT, Moscow. Its average thickness during the experiment was 0.071 at/barn.

We observed differential cross sections at 6 angles, ranging from 42° to 156° toward the neutron beam, by a 70 cm^3 Ge(Li) detector. Detector distance from sample was 20 cm (15 cm at 90°). Absolute efficiency of the Ge(Li) detector was measured and in-situ checked for all angles. Part of the γ ray spectrum observed with ^{52}Cr sample at 90° is given in fig. 2.

Absolute neutron fluence was determined from the associated α particle counts corrected for coincident neutron fraction as

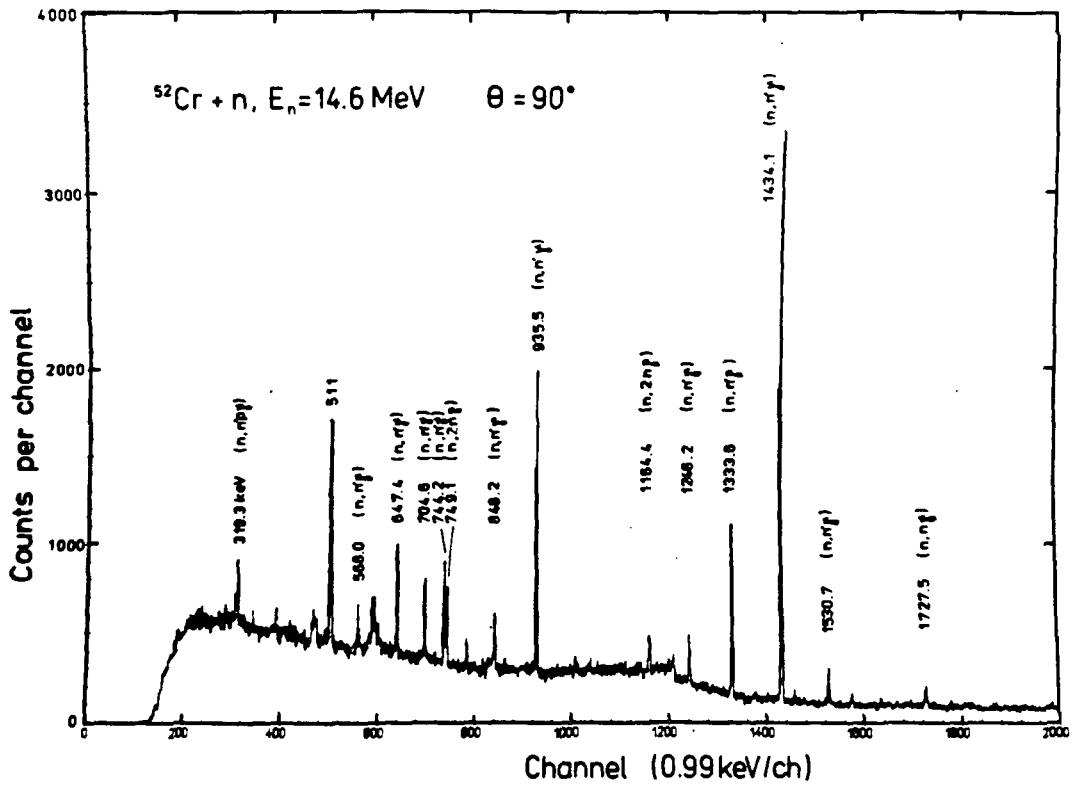

Fig. 2. γ ray spectrum from ^{52}Cr(n,xγ) reactions observed at 90°.

measured by the stilbene monitor.

The γ ray spectra were analysed using the nonlinear least squares code GWENN[3]. Corrections for neutron and γ ray absorption as well as for voluminous sample, but not multiple scattering, were applied.

3. Results and discussion

Observed differential cross sections for 15 discrete transitions are given in Tab. 1 and fig. 3. Uncertainties were obtained assuming independent contribution form the Ge(Li) absolute efficiency (typical value 8 %), peak area (1 - 15 %) and the neutron fluence (3 %).

γ ray angular distribution can be described by the expression

$$\frac{d\sigma}{d\omega} = \frac{\sigma_{4\pi}}{4\pi}\left(1 + a_2 P_2(\cos\vartheta) + a_4 P_4(\cos\vartheta)\right).$$

The angle-integrated cross sections $\sigma_{4\pi}$ as well as the Legendre coefficients a_2, a_4 were extracted from the observed angular distributions using weighted linear least squares method. Uncertainties were obtained by normal matrix inversion. The angle-integrated cross sections and Legendre coefficients are given in Tab. 2.

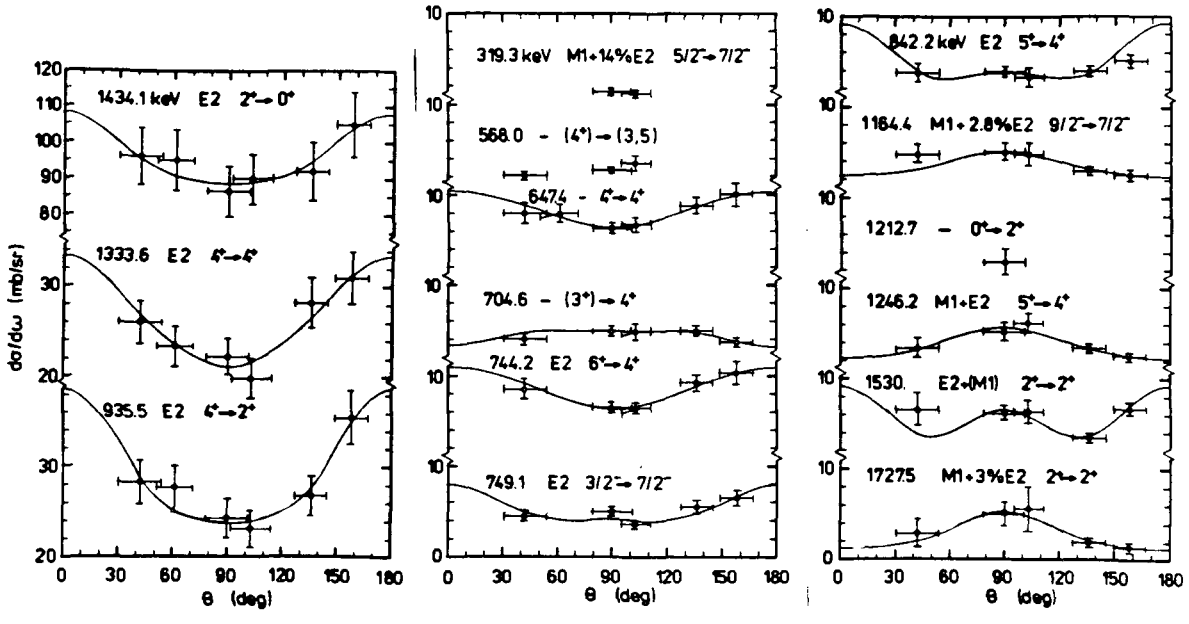

Fig. 3. Differential cross sections of observed transitions. Curves are fits to the experimental data.

Only cross sections of the most prominent γ rays from $^{52}Cr(n,x\gamma)$ reactions were reported earlier. Using the associated α particle method, the NaI(Tl) spectrometer and a massive sample (Ø60 mm x 120 mm) of natural Cr, Abbondanno et al.[4] observed angular distribution of 1434.1, 1333.6 and 935.5 keV lines at 14.2 MeV. The shapes of these distributions are in accord with ours. However, the angle-integrated cross sections 757(56), 239(36) and 221(31) mb, respectively, are by about 30 % higher than our values. They did not apply correactions for neutron absorption and multiple scattering, which seem to be necessary for their 2.4 kg sample. Further, their values include also contribution from $^{53}Cr(n,2n\gamma)$ reaction (natural abundance of ^{53}Cr is 9.5 %).

Tab. 1. Differential cross sections of discrete γ-ray transitions observed in $^{52}Cr(n,x\gamma)$ at various angles. Uncertainties are given in parenthesis.

ϑ (°)	42(12)	61(10)	90(12)	103(11)	136(9)	158(9)
E_γ(keV)			$d\sigma(\vartheta)/d\omega$ (mb/sr)			
319.3	-	-	1.5(0.2)	1.3(0.2)	-	-
568.0	2.1(0.4)	-	2.8(0.3)	3.6(0.9)	-	-
647.4	8.0(1.1)	8.0(1.0)	6.4(0.6)	6.8(0.8)	8.9(0.9)	10.2(1.4)
704.6	4.0(0.6)	-	4.9(0.5)	4.9(0.9)	5.0(0.5)	3.8(0.5)
744.2	8.6(1.1)	-	6.6(0.6)	6.5(0.6)	9.3(0.9)	10.4(1.3)
749.1	4.6(0.6)	-	5.1(0.5)	3.7(0.3)	5.6(0.7)	6.5(0.8)
848.2	3.9(1.0)	-	4.0(0.6)	3.4(1.0)	4.0(0.5)	7.2(0.7)
935.5	28.3(2.3)	27.5(2.6)	24.3(2.1)	23.1(1.9)	26.8(2.2)	35.5(3.0)
1164.4	5.0(2.0)	-	5.2(0.9)	4.9(1.3)	3.1(0.4)	2.5(0.6)
1212.7	-	-	3.1(1.4)	-	-	-
1246.2	3.5(1.1)	-	5.3(1.0)	6.2(1.1)	3.4(0.5)	2.5(0.5)
1333.6	26.0(2.3)	23.3(2.2)	22.3(2.0)	19.8(2.2)	28.2(2.8)	31.0(2.9)
1434.1	95.4(8.0)	95.0(8.5)	86.5(7.0)	90.0(7.0)	92.0(8.0)	105.0(9.0)
1530.7	6.7(1.8)	-	6.3(0.8)	6.4(1.3)	3.5(0.5)	6.8(0.7)
1727.5	3.0(1.5)	-	5.1(1.3)	5.6(2.5)	2.0(0.5)	1.4(0.5)

Tab. 2. Angle integrated production cross sections and Legendre coefficients for angular distributions of discrete γ rays emitted in $^{52}Cr(n,x\gamma)$ at 14.6 MeV.

E_γ (keV)	Reaction	a_2	a_4	$\sigma_{4\pi}$ (mb)
647.4	$(n,n'\gamma)$	0.33(14)	-0.02(17)	99(5)
704.6	$(n,n'\gamma)$	-0.19(11)	-0.11(15)	59(4)
744.2	$(n,n'\gamma)$	0.39(13)	-0.01(18)	101(5)
749.1	$(n,2n\gamma)$	0.42(13)	0.26(20)	59(3)
848.2	$(n,n'\gamma)$	0.60(16)	0.60(20)	53(4)
935.5	$(n,n'\gamma)$	0.31(09)	0.12(12)	339(12)
1164.4	$(n,2n\gamma)$	-0.52(19)	0.13(20)	50(5)
1246.2	$(n,n'\gamma)$	-0.59(17)	0.10(19)	55(5)
1333.6	$(n,n'\gamma)$	0.31(09)	0.04(12)	310(12)
1434.1	$(n,n'\gamma)$	0.12(08)	0.04(11)	1171(40)
1530.7	$(n,n'\gamma)$	0.04(15)	0.74(18)	65(5)
1727.5	$(n,n'\gamma)$	-0.90(30)	0.32(28)	42(7)

Larson[5)] reports cross sections of 1434.1 and 749.1 keV transitions in (n,n'γ) and (n,2nγ) channels, respectively, observed at the ORELA white neutron source. He used the Ge(Li) detector placed at 125° toward the neutron beam and a natural sample. For 1434.1 and 749.1 keV transitions we extracted cross sections 810 and 50(12) mb, respectively, from his fig. 9. The neutron bin width around 14 MeV neutron energy was larger than 1 MeV. The data were apparently corrected for ^{53}Cr contributions. Again, Larson's cross sections for 1434.1 keV transition is lower than our value. However, his cross section of 749.1 keV transition is in accord with our value 59(3) mb.

The rest of our angular distributions and cross sections is reported for the first time. Our measurement is the only one performed so far with the enriched ^{52}Cr sample.

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