Study of the $^{193}Ir(n,2n)^{192}Ir$ Reaction Cross Section

Nikolas Patronis

Department of Physics, University of Ioannina

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Motivation

Test and improve nuclear reaction models

- Improve local/global parameters of theoretical calculations
- Understand the reaction dynamics
- Explore the role of pre-equilibrium emission

Motivation

Improve the nuclear physics information

- Almost no experimental data for En<14 MeV
- Only two points from B. P. Bayhurst et al. (1975)

Experiment

Irradiation setup

Irradiations	10 MeV	10.5 MeV
Deuterium beam energy (MeV)	7.2	7.7
Irradiation time (h)	7.07	10.13
Integrated Neutron flux (x 10^{11} cm^{-2})	1.02 ± 0.05	1.07 ± 0.06

Experiment

Activity measurements

- 50% relative efficiency HPGe detector
- Sample to Detector distance: 10.0 cm
- Calibration using point sources
- The extended geometry of the samples + self attenuation was taken into account by means of Geant4 MC calculations

Experiment

Activity measurements

- 308 keV, I = 30.0 %
- 316 keV, I = 82.8 %
- 468 keV, I = 47.8 %

Data analysis

Au189 28.7 m 1/2+ * EC,α	Au190 42.8 m 1- * EC,α	Au191 3.18 h 3/2+ * EC	Au192 4.94 h 1- * EC	Au193 17.65 h 3/2+ * EC	Au194 38.02 h 1- * EC	Au195 186.09 d 3/2+ * EC	Au196 6.183 d 2- * EC,β-	Au197 3/2+ * 100	Au198 2.6935 d 2- * β-	Au199 3.139 d 3/2+ β-
Pt188 10.2 d 0+ EC,α	Pt189 10.87 h 3/2- EC	Pt190 6.5E11 y 0+ α 0.01	Pt191 2.9 d 3/2- EC	Pt192 0+ * 0.79	Pt193 50 y 1/2- * EC	Pt194 0+ 32.9	Pt195 1/2- * 33.8	Pt196 0+ * 25.3	Pt197 18.3 h 1/2- * β-	Pt198 0+ * 7.2
Ir187 10.5 h 3/2+ * EC	Ir188 41.5 h 1- * EC	Ir189 13.2 d 3/2+ * EC	Ir190 11.78 d (4)+ EC,β-	Ir191 3/2+ * 37.3	Ir192 73.831 d 4(+) * EC,β-	Ir193 3/2+ * 62.7	Ir194 19.15 h 1- * β-	Ir195 2.5 h 3/2+ * β-	Ir196 52 s (0-) * β-	Ir197 5.8 m 3/2+ * β-
Os186 2.0E+15 y 0+ α 1.58	Os187 1/2- 1.6	Os188 0+ 13.3	Os189 3/2- * 16.1	Os190 0+ * 26.4	Os191 15.4 d 9/2- * β-	Os192 0+ * 41.0	Os193 30.5 h 3/2- β-	Os194 6.0 y 0+ β-	Os195 6.5 m [13/2+] β-	Os196 34.9 m 0+ β-

Previous work

Present work

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Activation cross section and isomeric cross-section ratio for the $(n, 2n)$ reaction on ^{191}Ir

N. Patronis,* C. T. Papadopoulos, S. Galanopoulos, M. Kokkoris, G. Perdikakis, and R. Vlastou
Department of Physics, National Technical University of Athens, Athens, Greece

A. Lagoyannis and S. Harissopulos
Institute of Nuclear Physics, NCSR "Demokritos," Athens, Greece
(Received 23 August 2006; published 16 March 2007)

Contamination issue

- ^{191}Ir(n,γ)^{192}Ir
- ^{193}Ir(n,2n)^{192}Ir

Data analysis

Correction for the counts attributed to the n,γ channel

N(n,2n)= N(observed-NA counts) - N(n,γ counts)

$$N(n,\gamma) = N_T \cdot \sum \sigma_i \Phi_i \cdot \frac{1-e^{-\lambda t_B}}{\lambda} \cdot e^{-\lambda t_W} \cdot (1-e^{-\lambda t_m}) \cdot \epsilon \cdot I \cdot F$$

- The conditions of the irradiation (irradiation time, neutron flux fluctuations, neutron flux,…)
- The sample mass (Number of target nuclei)
- The conditions of measurement (duration, efficiency, waiting time, etc)
- The decay information (intensities, half-half life time)
- The self attenuation of γ rays within the sample material
- The **n,γ reaction channel excitation function**
- The **neutron beam energy distribution** (primary beam **+ parasitic neutrons**)

Data analysis

Correction for the counts attributed to the n,γ channel

N(n,2n)= N(observed-NA counts) - N(n,γ counts)

How safe is the n,γ reaction counts estimation?

Estimation of the ^{191}Ir(n,γ)^{192}Ir reaction rate through the recorded ^{197}Au(n,γ)^{198}Au reaction rate

Data analysis

Correction for the counts attributed to the n,γ channel

Neutron field

=

primary beam

+

parasitic neutrons

break-up
$^2H(d,pn)^2H$

scattered neutrons

“room bgr” neutrons

Data analysis

Correction for the counts attributed to the n,γ channel

Neutron field = primary beam + break-up + scattered + "room bgr"

NeuSDESk code (+break-up model A.B Kagalenko & N.V. Kornilov)

MCNP calculations (Thanks to: Andigoni Kalamara)

UNKNOWN!!!

How important is this unknown component to the n,γ reaction rate estimation ?

Data analysis

Correction for the counts attributed to the n,γ channel

Neutron field = primary beam + break-up + scattered

Data analysis

Correction for the counts attributed to the n,γ channel

Neutron field = primary beam + break-up + scattered + …

A small part (~0.5%) of the neutron flux is missing as to reproduce the observed $^{197}Au(n,\gamma)^{198}Au$ reaction rate

Data analysis

Correction for the counts attributed to the n,γ channel

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N(n,2n)= N(NA counts) - N(n,γ counts)

	10.0 MeV			10.5 MeV		
	308 keV	316 keV	468 keV	308 keV	316 keV	468 keV
Net Area	7.41E3 ± 1.2E2	2.08E4 ± 1.7E2	9.61E3 ± 1.1E2	1.96E3 ± 1.9E2	5.42E4 ± 2.8E2	2.52E4 ± 1.8E2
n,γ	3.28E2 ± 8.6E1	8.97E2 ± 2.4E2	4.20E2 ± 1.1E2	6.99E2 ± 1.6E2	1.92E3 ± 4.4E2	8.96E2 ± 2.0E2
n,2n	**7.08E3 ± 1.5E2**	**1.99E4 ± 2.9E2**	**9.19E3 ± 1.6E2**	**1.89E4 ± 2.5E2**	**5.23E4 ± 5.17E2**	**2.43E4 ± 2.7E2**
% uncertainty	**2.1**	**1.4**	**1.7**	**1.3**	**1**	**1.1**

Results

	10 MeV	10.5 MeV
σ(b)	1.39 ± 0.08	1.66 ± 0.1

Conclusions

- The $^{193}Ir(n,2n)^{192}Ir$ reaction cross section was determined for the first time at 10.0 MeV and 10.5 MeV

- The overall uncertainty of the data is less than 6%

- The contribution of the $^{191}Ir(n,\gamma)^{192}Ir$ reaction to the observed population of the product nucleus ^{192}Ir was determined according to the observed $^{197}Au(n,\gamma)^{198}Au$ reaction rate

Collaboration

N. Patronis

A. Kalamara

S. Harissopulos

M. Kokkoris

A. Lagoyannis

R. Vlastou

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stdDEV	26	26	26	23	23	23