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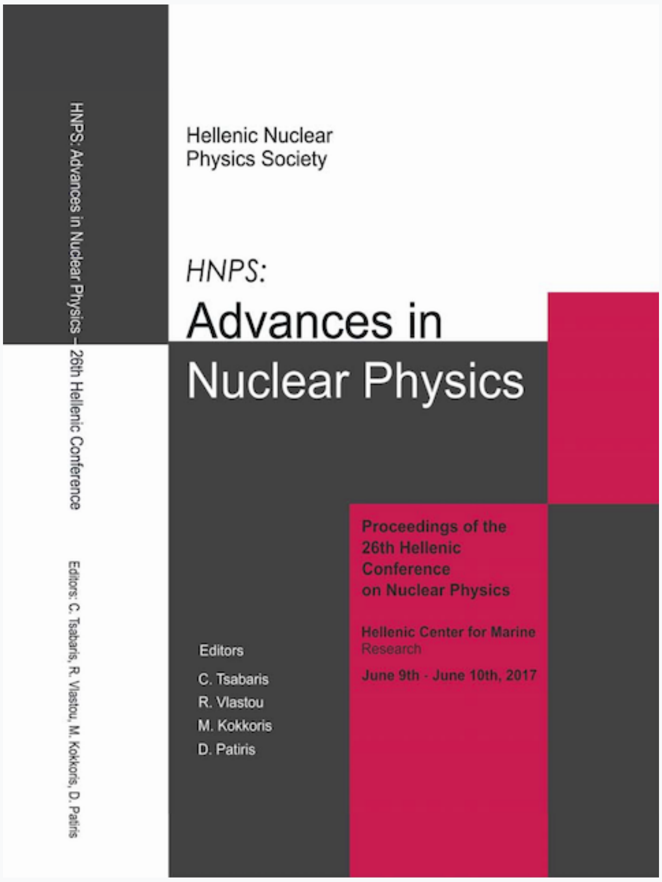

Activation cross section measurement of the (n,2n) reactions on natural Ir isotopes

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Activation Cross Section Measurement of the (n,2n) Reactions on ^{191}Ir

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Abstract Cross section of the ^{191}Ir(n,2n)^{190}Ir reaction has been experimentally measured, relative to the ^{27}Al(n,α)^{24}Na reaction by means of the activation technique. The characteristic gamma-rays 518.5, 558.0 and 569.3 keV from the decay of the residual nucleus ^{190}Ir in its ground state, have been used for the determination of the cross section of the population of ground g ($J^\pi=4^-$) and first metastable state m1 ($J^\pi=1^-$). The cross section for the population of the second metastable state m2 ($J^\pi=11^-$) of ^{190}Ir has also been deduced independently, by analyzing both 502.5 and 616.5 keV gamma-ray transitions, which acted as a fingerprint for the decay of ^{190m2}Ir. The neutron beams at 17.9 and 18.9 MeV were produced at the 5.5 MV Tandem Van de Graaff accelerator of NCSR "Demokritos", via the ^{3}H(d,n)^{4}He reaction. A BF_3 detector was used for the monitoring of the neutron flux which was of the order of 10^5 n/cm^{2}s. After the irradiation process, the γ-rays produced by the activated Aluminum and Iridium foils, were measured by HPGe detectors, calibrated with ^{152}Eu sources.

Keywords iridium, cross section, (n,2n) reactions

INTRODUCTION

The aim of this work was to experimentally determine the cross section of the reactions ^{191}Ir(n,2n)$^{190g+m1}$Ir and ^{191}Ir(n,2n)^{190m2}Ir at two neutron energies (E_n=17.9 MeV and E_n=18.9 MeV) to complete the high energy measurements carried out recently by our group at 17.1 and 20.9 MeV [1]. This energy region is very important in order to validate different model calculations and investigate reaction mechanisms, since at energies above 15 MeV the pre-equilibrium emission becomes important and more reaction channels are open. Furthermore, the formation of a high spin isomeric state in the residual nucleus of a reaction is of considerable importance for testing nuclear models, as it is governed by the spin distribution of the level densities and the level scheme of the nuclei involved [2-4]. The ^{191}Ir(n,2n) reaction presents an interesting case since the high spin value 11^- of the second isomeric state (m2) of ^{190}Ir relative to the corresponding value 4^- of the ground state (g), offers great sensitivity for such studies. However, few data sets exist in literature for these reactions with many discrepancies among them, which can reach up to 50% at some energies. The low energy part, close to the threshold of this reaction, has also been investigated by our group in the past [5]. In all experimental investigations the determination of the cross section was based on the activation technique.

EXPERIMENTAL PROCEDURE

The measurements were carried out at the 5.5MV tandem Accelerator at NCSR "Demokritos". The two quasi-monoenergetic neutron beams were produced via the $^{3}H(d,n)^{4}He$ reaction. The production of the two different neutron energy beams at E_n=17.9 MeV and E_n=18.9 MeV was possible through deuteron incident beams corresponding to E_d=2.0 MeV and E_d=2.7 MeV, respectively. The flux of the beam Φ was obtained with respect to the reference reactions $^{27}Al(n,a)^{24}Na$ and $^{93}Nb(n,2n)^{92m1}Nb$ as shown in the following table.

E_n (MeV)	Reference reactions used	Φ (n/cm^2)
17.9	$^{27}Al(n,a)^{24}Na$	(7.52 ± 0.40) 10^9
18.9	$^{27}Al(n,a)^{24}Na$ and $^{93}Nb(n,2n)^{92m1}Nb$	(2.95 ± 0.17) 10^9

Table 1. Neutron fluxes

Beam fluctuations were monitored during the irradiations with a BF_3 detector. High purity metal targets were used for Ir as well as for Al and Nb reference foils. The first set of the irradiation, referring to incident neutron energy E_n=17.9 MeV, had a duration of ~9.7 h (corresponding to ~3 half lives of the second isomeric state ^{190m2}Ir). The second set of the irradiation (En=18.9 MeV), had a duration of ~27.8 h (corresponding to ~8.55 half lives of the ^{190m2}Ir state).

After the end of each irradiation, the activated foils were placed at a 10 cm distance from the window of three HPGe detectors so that the induced γ-rays from the deexcitation of the residual nuclei could be measured. The efficiency relative to the energy, for each detector was determined with the use of a calibrated ^{152}Eu source. The deexcitation of the ground state (g) of the residual nucleus ^{190}Ir ($t_{1/2}$=11.78 days) from the reaction $^{191}Ir(n,2n)^{190}Ir$ was studied through the 518.5 keV, 558.0 keV and 569.3 keV gamma-rays. The same isotope was also produced in a metastable state (m2) ($t_{1/2}$=3.25 h) through the reaction $^{191}Ir(n,2n)^{190m2}Ir$. The study of ^{190m2}Ir was possible through the 502.5 keV and 616.5 keV transitions. The production of these transitions can be found in the following figure, while the decay properties of all residual nuclei from the irradiation of Ir, Al and Nb foils are presented in Table 2. It is noted that for the study of the ground state, the first isomeric state m1 ($t_{1/2}$= 1.12h) should have first been fully deexcitated, so the spectra for the $^{191}Ir(n,2n)^{190g+m1}Ir$ reaction were taken 22 hours after the irradiation to ensure the full decay of the m1 isomeric state.

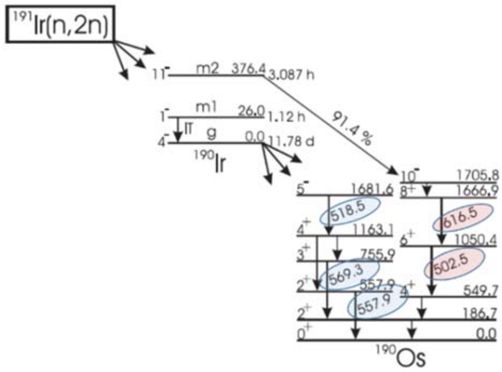

Fig. 1. Decay scheme of both the second isomeric (m2) and the ground state (g) of the residual nucleus ^{190}Ir [4]

Reaction	Daughter Nucleus	Half-life	γ-ray energy (keV)	Intensity (%)
^{191}Ir(n,2n)^{190}Ir	^{190}Ir	11.78 d	518.5	34.00
			558.0	30.10
			569.3	28.50
^{191}Ir(n,2n)^{190m2}Ir	^{190m2}Ir	3.25 h	502.5	92.31
			616.5	93.10
^{27}Al(n,a)^{24}Na	^{24}Na	14.96 h	1368.6	100.00
^{93}Nb(n,2n)^{92m1}Nb	^{92m1}Nb	10.15 d	934.5	99.00

Table *2*. Decay properties of the produced nuclei

Corrections for self-absorption in the sample, coincidence summing effects of cascading gamma rays and counting geometry were taken into account along with the decay of product nuclides over the whole time range, as well as the fluctuations of the neutron beam flux during the irradiation time.

RESULTS

The results of this work are presented below for the reactions ^{191}Ir(n,2n)$^{190g+m1}$Ir (Fig. 2) and ^{191}Ir(n,2n)^{190m2}Ir (Fig. 3) along with existing EXFOR data, as well as evaluations (ENDF/B-VII.1) presented as a solid line in the Figs. As far as the ^{191}Ir(n,2n)$^{190g+m1}$Ir reaction is concerned (Fig. 2), the experimental points referring to the present work seem to be in better agreement with the evaluation curve, in comparison with prior measurements in the same energy region, for both neutron energies (17.9 and 18.9 MeV). In Fig.3, the new measurements, referring to the ^{191}Ir(n,2n)^{190m2}Ir reaction seem to follow the general trend of the existing data for both energies that were studied.

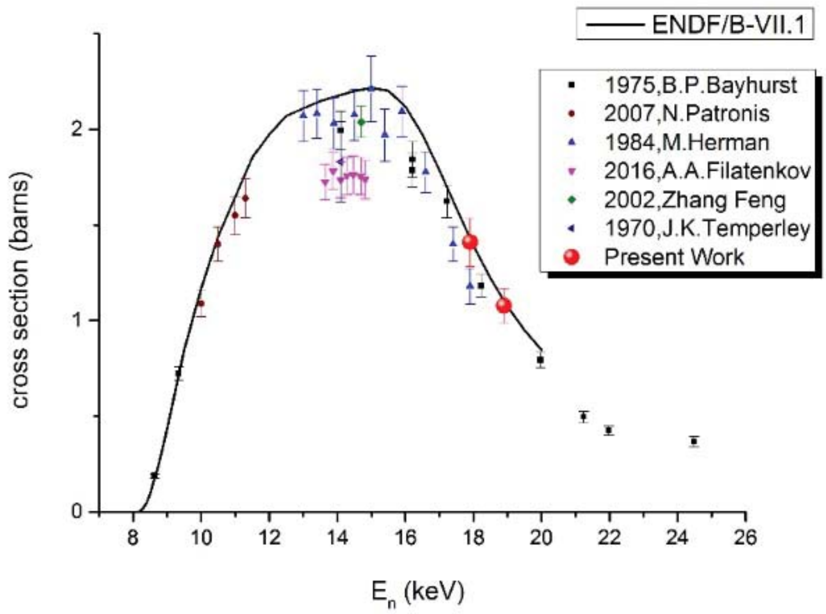

Fig. 2. Cross section results for the ^{191}Ir(n,2n)$^{190g+m1}$Ir reaction at 17.9 and 18.9 MeV along with existing data from literature

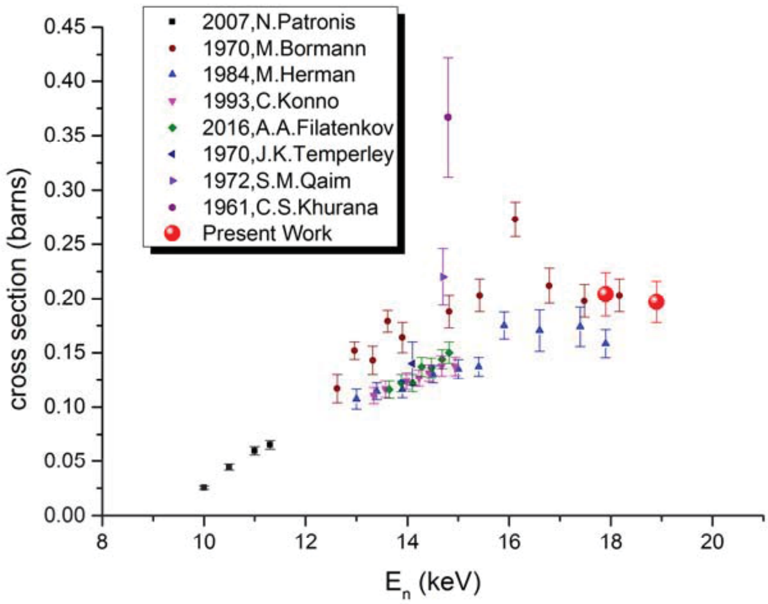

Fig. 3. Cross section results for the ^{191}Ir(n,2n)^{190m2}Ir reaction at 17.9 and 18.9 MeV along with existing data from literature

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