THE STUDY OF INTEGRATED CROSS-SECTION EXCITATION OF ISOMERIC STATES OF NUCLEI IN (γ,γ') REACTIONS

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By using microtron bremstrahlung beam the yield curves of ^{77m}Se, ^{111m}Cd, ^{179m}Hf isomeric states were measured in the energy range of 5-8 MeV and with step of 0.1-0.2 MeV. Using these yield curves, the corresponding isomer integrated cross-sections in the (γ,γ')-reaction were calculated.

1. Introduction

In [1] A(γ,γ')^{m}A reaction integrated cross-sections for ^{167}Er, ^{79}Br, ^{191}Ir, ^{183}W, ^{197}Au, ^{77}Se, ^{89}Y and ^{137}Ba nuclei were obtained in the energy range from 1,5 MeV to 6 MeV with a step of 0,25 MeV. Practically for the most of isotopes in the energy dependence of the cross-sections there are maxima and minima showing the existence of activative levels near these energies.

The authors of [2] reported the investigation of 19 isomers in A(γ,γ')^{m}A reactions on ^{167}Er, ^{79}Br, ^{191}Ir, ^{197}Au, ^{77}Se, ^{89}Y, ^{137}Ba, ^{179}Hf, ^{199}Hg, ^{111}Cd, ^{113}In, ^{87}Sr, ^{176}Lu, ^{115}In, ^{180}Ta, ^{135}Ba, ^{195}Pt, ^{117}Sn, ^{123}Tc nuclei. As a bremstrahlung source four different electron accelerators were used that allowed to have the maximal energy of bremstrahlung from 0,5 MeV to 11 MeV.. More than in fifty per cent of cases the accelerated channels of resonance excitation were observed with the integrated cross sections by 3–4 orders of magnitude greater than that for (γ,γ')-reaction. An explanation was proposed that for these reaction the corresponding activative levels located 3-4 MeV above the ground state were populated via the observed isomers.

In [4,5] the data on measured yields and calculated cross-sections of (γ,γ')-reactions for ^{167}Er, ^{179}Hf, ^{183}W, ^{197}Au isotopes are reported.

In the paper [6] the (γ,γ') cross-sections together with excitation of isomeric states of ^{77}Se, ^{78}Br, ^{111}Cd, ^{115}In, ^{137}Ba nuclei in the energy range 4-15 MeV with 0,5 MeV step were obtained as well as the data on absolute integrated cross-sections for A(γ,γ')^{m}A reactions for 12 isotopes with isomeric states, particularly, for ^{179}Hf, ^{199}Mg, ^{111}Cd and ^{77}Se.

The goal of the present paper is the investigation of the A(γ,γ')^{m}A-reaction excitation functions for ^{77}Se, ^{111}Cd and ^{179}Hf nuclei in the energy range 7–9,5 MeV and checking the presence of activative levels in this energy range.

2. Experimental apparatus and measuring method

The measurements were carried out using the activative method with a bremsstrahlung beam of γ-emission from M-10 microtron at the Nuclear Physics Department of Uzhgorod State University. The maximal bremsstrahlung energy was varied with a step of 0.1–0.2 MeV during the period of the samples irradiation.

For bremsstrahlung monitoring an ionization chamber was used the current from which passed to an RC-circuit.

The resulting activity in the samples was detected by a scintillation γ-spectrometer, based on the 60×60 mm NaI(Tl) crystal.

The activative method for registration of beam yield curves in nuclear reactions regarding to the sample irradiation by bremsstrahlung and neutrons is described in [7, 8].

The integrated cross-section was obtained according to the expression [9]

$$\sigma_{\text{int}} = \int_{E_p}^{E_m} \sigma(E_\gamma)\cdot dE_\gamma = \frac{Y(E_m)\cdot(E_m - E_\gamma)}{\int_{E_p}^{E_m} W(E_m, E_\gamma)\cdot dE_\gamma}, \quad (1)$$

where $Y(E_m)$ is the yield, $W(E_m, E_\gamma)$ –the bremstrahlung spectrum with the maximal energy E_m, E_t – the energy of the first activation level for the corresponding isomer.

3. Results

3.1. The ^{111}Cd(γ,γ')^{111m}Cd-*reaction*

For the yield measurements the samples prepared of metallic cadmium with natural mixture of isotopes were used. The irradiation of the sample was carried out with the period of 30 min, cooling time duration 180 s, and the measuring period 1800 s. The measurements were performed for two lines: 151 keV and 246 keV [10], ejected by ^{111m}Cd. From the obtained yields the integrated cross-sections were found in correspondence to Eq. (1).

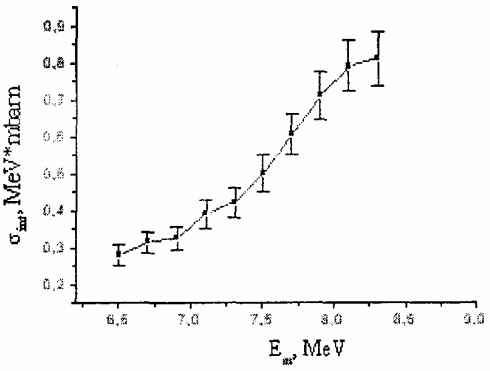

Fig.1. Integrated cross-section σ_{int} for the ^{111}Cd(γ,γ')^{111m}Cd-reaction.

In Fig.1 the dependence of the integrated cross-section σ_{int} as the function of the maximal bremsstrahlung energy is shown. It is clear from Fig.1 that the σ_{int} plot is monotonous, without sharp breaks which could indicate the existence of separate activative levels with large cross-section in this energy range.

3.2. The ^{77}Se(γ,γ')^{77m}Se-*reaction*

The sample for the yield measurements was prepared of metallic selenium. The irradiation of the sample was carried out with a period of 40 seconds, cooling time duration 5 s, the measuring period 40 s.

The yield of ^{77m}Se isomeric nuclei was obtained for the line with the energy of 160 keV [10].

In Fig.2 the results of the integrated cross-section σ_{int} calculation are shown. From these data it is obvious that there is no evidence of the yield dependence curve and no essential breaks of the integrated cross-section are observed which could indicate the presence of activative levels with a large cross-sections in this energy range.

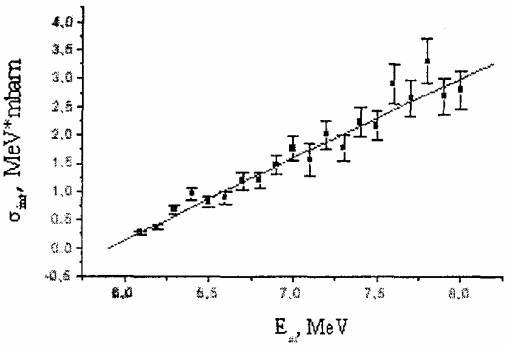

Fig.2. Integrated cross-section σ_{int} for the ^{77}Se(γ,γ')^{77m}Se-reaction.

3.3. The ^{179}Hf(γ,γ')^{179m}Hf-*reaction*

The sample for the yield measurements was prepared of HfB_2 compound. In the case of natural hafnium after bremsstrahlung irradiation 4 isomers with half-life periods of 1 s, 4.3 s, 18.6 s and 5.5 h, ejecting γ-quanta of different energies, can be formed. Hauwever, the differences in the spectra from different isotopes are negligible. In order to eliminate the influence of emission of ^{177m}Hf, ^{178m}Hf, ^{180m}Hf in our measurements, the following procedure was performed: the sample was irradiated during 100 seconds with the cooling period of 20 seconds and the registration period of 100 seconds. Thus the activity of the objectionable isotopes at the beginning of the measurement decreased to the value of 0.5% in comparison with the activity of ^{179m}Hf. The yield measurement was carried out for the most intense line with the energy 0.215 MeV (82% intensity) [10].

The calculation of the integrated cross-section was carried out according to (1).

In Fig.3 the calculated values of the integrated cross-section are shown. The energy dependence of the integrated cross-section reveals two breaks at the energies

6.2 MeV and 7.2 MeV that indicate the presence of the activative level with the large cross-section at the energy of 6.2 MeV. The break at the energy of 7.2 MeV is related to the $^{180}Hf(\gamma,n)^{179m}Hf$-reaction threshold.

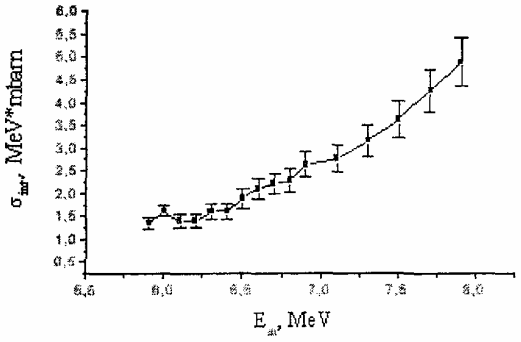

Fig.3. Integrated cross-section σ_{int} for the $^{179}Hf((\gamma,\gamma')^{179m}Hf$-reaction.

4. Conclusions

The comparison of the measured integrated cross-section for $^{111}Cd(\gamma,\gamma')^{111m}Cd$-reaction in the present work with the results of [6] shows that the difference of these results does not exceed + 15 % at the energy of 8 MeV.

The value of the integrated cross-section of the $^{77}Se((\gamma,\gamma')^{77m}Se$-reaction in the present paper is by 20 % less than that in [6] .

The results of the $^{179}Hf(\gamma,\gamma')^{179m}Hf$-reaction studies (Fig.3) show two breaks at the energy of 6.2 and 7.2 MeV. Although the first break can be interpreted as corresponding to the activative level at this energy, the second one corresponds to the threshold energy of the $^{179}Hf(\ ,n)^{179m}Hf$ reaction (7.3 MeV), resulting in the yield increase. The natural mixture of hafnium isotopes contains 35.4 % ^{180}Hf and only 13.7 % ^{179}Hf. Thus, the observed break can be used for calibration of the energy scale of electron accelerators, e. g. microtrons or linear accelerators. Note, that the obtained integrated cross-section at the energy of 8 MeV is by 20 % less than that in [6].

References

1. J.A.Anderson, *Nucl. Instr. and Method in Phys. B* **40/41**, 452 (1989).
2. J.J.Carrol, M.J.Byrd, D.G.Richmond *et al., Phys. Rev. C.* **43**, 1238 (1991).
3. C.B.Collins, J.J.Carrol *et al., Phys.Rev. C*, **46**, 952 (1992).
4. V.M.Mazur, A.A.Teke, Preprint No 81-40 (Institute of Nuclear Research, Kiev, 1981) [In Russian].
5. Z.M.Bigan, I.V.Sokolyuk, Preprint No 84-13 (Institute of Nuclear Research, Kiev, 1984) [In Russian].
6. V.M.Mazur, I.V.Sokolyuk *et al., Zh. Yadern. Fiz.* **56**, 20 (1993) [In Russian].
7. J.Perdijon, *L'analys par activation* (Masson et c'editeurs, Paris, 1967) p.256.
8. B.S.Ishkhanov, I.M.Kapitonov, *Interaction of electromagnetic radiation with atomic nuclei* (Moscow University edition, Moscow, 1979).
9. Antonov A.D. *et al. Zh. Yadern. Fiz.* **53**, 14 (1993) [In Russian].
10. *Table of Isotopes*, Ed. by C.M.Lederer, V.S.Shirley (Wiley, New York, 1978).

ДОСЛІДЖЕННЯ ІНТЕГРАЛЬНИХ ПЕРЕРІЗІВ РЕАКЦІЙ ЗБУДЖЕННЯ ІЗОМЕРНИХ СТАНІВ ЯДЕР У (γ,γ') - РЕАКЦІЯХ

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На пучку гальмівного випромінювання мікротрона виміряно криві виходу ізомерних станів ядер ^{77m}Se, ^{111m}Cd, ^{179m}Hf в інтервалі енергій 5-8 МеВ з кроком 0,1-0,2 МеВ. Використовуючи ці криві виходу, розраховано інтегральні перерізи реакцій (γ,γ') для відповідних ізомерів.