RADIATION WIDTHS OF INTERMEDIATE NUCLEI

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The radiation widths of a number of neutron resonances of zinc, molybdenum, niobium, and rubidium isotopes have been investigated with the JINR pulsed reactor. A maximum is observed in the dependence of the radiation widths upon the neutron number N at N = 43-44, and a minimum at N = 38-40.

MEASUREMENTS of the radiation widths of levels excited when resonance neutrons are captured by nuclei with mass numbers A from 64 to 100 have been carried out recently in the neutron physics laboratory at JINR. These measurements were performed using the time-of-flight technique with the IBR pulsed reactor as a neutron source[1].

In the work to be described measurements were made of transmission, of radiative neutron capture, and of self-indication[2,3]. By using different measuring techniques we were able to obtain a considerably greater number of radiation widths and increase the accuracy of the results by comparison with those given by the usually employed measurement of transmission only. Samples enriched in one of the isotopes, as well as a natural isotope mixture, were used for the measurements. Enriched samples of all the stable isotopes were used for the zinc measurements, and a sample enriched in Rb^{85} for rubidium. Measurements were also made using niobium and natural molybdenum. In the latter the identification of the resonances with the isotopes was taken from reference[4].

The parameters for a group of levels, obtained as a result of these measurements and from analysis of the experimental data, are shown in the table. Only those levels for which the values of the radiation width Γ_γ were determined are included in this table.

Previously unknown resonances were detected for zinc at energies of 288 eV (Zn^{64}) and 328 eV (Zn^{66}). Measurements of self-indication with Zn^{67} enabled us to refine the value of the spin and radiation width of the 226-eV resonance obtained earlier[5]. The most probable value of the spin factor for the 456-eV resonance is $g = 7/12$; however the γ-ray capture spectrum for the 456- and 226-eV resonances is quite different, indicating different spins. Accordingly, for the 456-eV resonance, the two possible values of the spin along with the associated Γ_γ are shown in the table. Also,

Nucleus-target	Isotope	E_0, eV	$g\Gamma_n$, MeV	g	Γ_γ, MeV	l
Zinc	67	226±1	520±30	7/12	370±50	0
	64	288±2	6±0.6	1	670±100	
	66	328±2	11.5±1.0	1	600±100	
	67	456±3	5400±400	7/12	490±80	0
				5/12	650±100	
	68	530±3	11000±600	1	180±30	0
Rubidium	87	378±2	450±50		145±30	0
	85	528±3	660±30		220±30	0
	85	1210±13	600±100		210±30	
Niobium	93	94.0±0.4	0.167±0.01		185±60	1
	93	119±0.6	1.90±0.08		183±10	0
	93	194±1.2	20.5±0.6		189±12	0
	93	244±2	1.08±0.06		228±80	1
	93	334±3	7.7±0.7		185±20	0
	93	379±4	48±3		214±35	0
Molybdenum	98	12.15±0.03	0.07±0.005	1	210±25	
	95	45.1±0.2	90±7		180±40	0
	97	71.6±0.4	8.5±0.6		200±30	0
	96	132.6±0.6	225±11	1	175±25	0
	95	161.0±0.7	9.0±0.6		180±30	

we must note that the radiation width of the 530-eV resonance (Zn^{68}) is considerably less than that of the levels of the other isotope. Radiation widths for rubidium, as well as for zinc, were not known previously, and their measurement was of interest, especially for the magic nucleus Rb^{87}

The measurement of the radiation widths of niobium was undertaken in conjunction with the publication of a study by Jackson [6], in which a substantial difference was observed in the radiation widths of s- and p-wave resonances: $(\bar{\Gamma}_\gamma)_s = 114$ MeV and $(\bar{\Gamma}_\gamma)_p = 230$ MeV. In view of the importance of these results, we undertook a precise verification of the magnitude of $\bar{\Gamma}_\gamma$ for niobium. The results which were obtained are shown in the table. Values of the orbital momentum l are taken from [6,7]. The values of $(\Gamma_\gamma)_s$ were found to be markedly larger than in [6,7], and agreed with $(\Gamma_\gamma)_p$ to within the limits of error. Thus the report of such a considerable difference in Γ_γ for levels of different parity was not corroborated.

The measurements with molybdenum were carried out with the intention of obtaining radiation widths for those isotopes for which the widths Γ_γ were not known. In addition, the radiation widths for the isotopes Mo^{95} and Mo^{97} were known only with poor precision, and further verification seemed desirable. All the values of Γ_γ obtained by us for the different molybdenum isotopes lie close to one another (175—210 MeV). In particular, for the 71-eV Mo^{97} resonance, the value of Γ_γ obtained earlier [8] turned out to be considerably oversized.

By measuring these radiation widths for a number of nuclei, we were able to trace the dependence of Γ_γ upon the neutron number rather precisely in the interval near the magic nucleus with N = 50. The figure shows the experimental points obtained by us (solid circles), along with the results in the literature. From an examination of these points we may draw several conclusions. First, the widespread opinion concerning the maximum of the radiation widths for magic nuclei [9] is not confirmed. Those nuclei lying in the immediate vicinity of N = 50 do not show a maximum in Γ_γ, whereas for the magic nucleus Rb^{87} the magnitude of Γ_γ is even less than for the neighboring nuclei. The maximum Γ_γ is observed at N = 43-44, and the minimum at N = 38-40.

From the experimental results presented it is clear that the significant variations in the radiation widths from nucleus to nucleus in this region are associated with the neutron number, i.e., with the state of the neutron shell. This is corroborated by the magnitudes of Γ_γ for zinc or selenium isotopes, whose radiation widths for various isotopes are quite different. A similar picture, though considerably less clear, occurs in the case of the proton shell. For nuclei with proton numbers 43 (Tc) and 44 (Ru), we see a maximum in the values of Γ_γ in this region. In this case the influence of the proton cloud can be seen by the fact that nuclei with the same number of neutrons in this region have different Γ_γ, whereas the radiation widths are identical for all the isotopes of ruthenium [10]. However, the precision of the Γ_γ measurements is inadequate for a rigorous verification of this relationship. It will be necessary to conduct a more precise study of radiation widths in this region, as well as in the region of proton numbers 38-40, where we might expect a minimum in Γ_γ if the behavior of the radiation widths is the same for the Z dependence as it is for the N dependence.

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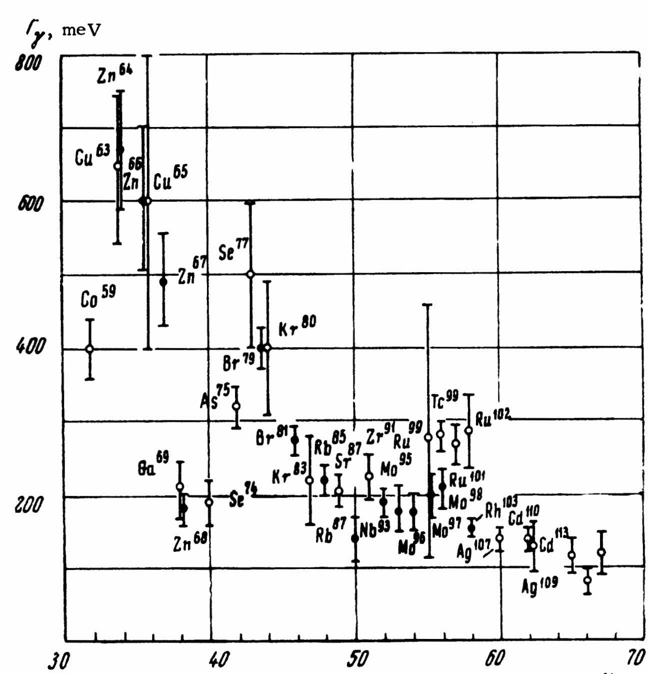

Experimental results for the radiation widths of intermediate nuclei (N — neutron number). Solid circles indicate points obtained in this investigation.

Note added in Proof (July 6, 1965). Measurements of the radiation widths of ruthenium levels carried out by us recently have shown that Γ_γ is about 170 MeV for all resonances, i.e., Γ_γ has no maximum in this region.

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