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ON NUCLEAR DATA ACTIVITIES

IN THE NDS SERVICE AREA

(Addendum)

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IAEA NUCLEAR DATA SECTION, KÄRNTNER RING 11, A-1010 VIENNA

PROGRES REPORT FOR 1973 ON NEUTRON AND NON-NEUTRON NUCLEAR DATA ACTIVITIES IN J. STEFAN INSTITUTE, LJUBLJANA, YUGOSLAVIA*

Compiled by F.Cvelbar, J. Stefan Institute and Faculty for Natural Sciences and Technology, University of Ljubljana.

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I. NEUTRON DATA

PROMPT γ-RAY SPECTRA FROM THE RADIATIVE CAPTURE OF 14.1 MeV NEUTRONS IN Cu, Se, Br, In, AND I

M.Budnar, F.Cvelbar, V.Ivković, A.Perdan and M.Potokar

Spectra of primary γ-transitions to bound states from the 14.1 MeV neutron radiative capture process in natural targets of Cu, Se, Br, In and I are presented together with the corresponding integrated cross sections. Because of the spherical geometry of the experiment, spectra are integrated over a solid angle of 4π for Cu, Se, Br, and I and over 2π for In. The energy spread of the initial neutrons is 1.35 MeV. The integrated cross section values for Cu, Se, Br, In and I are $(770 \pm 110)\mu b$, $(860 \pm 130)\mu b$, $(1100 \pm 160)\mu b$, $(1200 \pm 200)\mu b$ and $(1100 \pm 160)\mu b$ respectively.

Fizika 5, 37 (1973)

SEMIDIRECT CAPTURE MODEL AND THE ANGULAR DISTRIBUTION OF γ-RAYS FROM THE RADIATIVE CAPTURE OF FAST NEUTRONS

A.Likar, M.Potokar, F.Cvelbar

Angular distribution of γ-rays from the radiative capture of neutrons in the region of giant dipole resonance has not yet been measured. For the moment being it can be only roughly guessed from the comparison of spectra measured at 90^{o} relative to the neutron beam to that integrated over solid angle of 4π for light nuclei and over 2π for heavier ones.

A considerable difference between the two spectra in $^{88}Sr(n,\gamma)^{89}Sr$ reaction, indicating rather strong anisotropy, stimulated us to refine the semidirect capture model and cal-

culate the angular distribution of capture γ-rays. In the angular distribution of the shape $A_0(1 + A_2P_2(\cos\vartheta))$ the values of the coeficients A_2, calculated within the limits of the Clement, Lane and Rook aproach to the semidirect capture model are: -0.88, -1.0, -0.83 -0.36 and -0.19 for transitions to the $d_{5/2}$, $s_{1/2}$, $d_{3/2}$, $g_{7/2}$ and $h_{11/2}$ respectively. Calculations for proton capture process are in progress.

Reported at Annual Meeting of Yugoslav Nuclear Physicists, Zlatibor 1973.

THE RADIATIVE CAPTURE OF 14.1 MeV NEUTRONS IN ^{138}Ba, W, Pb AND ^{209}Bi

M.Potokar, A.Likar, F.Cvelbar, M.Budnar and E.R.Hodgson

Spectra of prompt γ-rays due to radiative capture of 14.1 MeV neutrons to bound nuclear states in natural Ba, W, Pb, and Bi, and the corresponding integrated cross sections are presented. The integrated cross sections for ^{138}Ba, W, Pb, and ^{209}Bi are 1600 $\pm$ 300 μb, 930 $\pm$ 170 μb, 1100 $\pm$ 180 μb and 950 $\pm$ 180 μb, respectively. The values agree with previous observations that the cross sections depend smoothly on mass number. The high energy parts of the experimental spectra and recently published fast neutron capture excitation functions are compared with those calculated according to the two approaches of the direct-semidirect theory, namely, the surface peaked particle-nucleus interaction and the volume type interaction. It is concluded that purely on the grounds of presently known experimental data one cannot judge which form of the coupling interaction is more appropriate for the description of the fast nucleon capture process.

Nucl. Phys. A213, 525 (1973)

THE COMPLEX COUPLING INTERACTION IN THE RADIATIVE CAPTURE OF FAST NUCLEONS

M.Potokar

The direct-semi-direct (DSD) theory of nucleon radiative capture in the region of giant dipole resonance (C.F.Clement et al. Nucl. Phys. 66 (1965) 273) reproduces only the general features of experimental results pretty well, but it fails in the details. For example, the experimental excitation functions for the radiative capture of the nucleon into a definite single particle state of the final nucleus are in most cases symmetric, while the predicted curves are as a rule asymmetric (due to the destructive interference between the direct and the semi-direct reaction amplitude on the low energy side). This fact can be interpreted as evidence that the reaction mechanism in considerably more complicated than that suggested by the DSD theory.

The natural way to bring the theory into closer agreement with experiment is to include in the reaction mechanism more complicated nuclear excitations which have been so far neglected. To make a step in this direction, we have refined the DSD theory by replacing the original real nucleon-nucleus coupling interaction by a complex one, having a real part of volume form and an imaginary surface peaked part. The form factor has been derived following the original approach of Clement et al. (but calculating the nuclear matrix element more exactly) and applying the semiphenomenological model of Satchler (Phys. Letters 35 B (1971) 279) to introduce an imaginary component into the effective nucleon-nucleon interaction.

Results of the calculation were compared with the $^{208}Pb(n,\gamma)^{209}Pb$ experimental excitation functions and some 14 MeV neutron capture γ-ray spectra. The agreement between the two data is considerably improved.

Phys. Lett. 46B, 346 (1973).

FAST NEUTRON SPECTRA IN STANDARD SEED IRRADIATION FACILITIES FOR TRIGA REACTORS

J.Krajnik, M.Najžer, M.Pauko and J.Rant

Two facilities have been tested at TRIGA Mark II reactor in Ljubljana. One facility has been located in the reactor pool, the other in the thermal column. The outstanding characteristic of such a facility is its relatively high fast neutron to gamma dose ratio. They are made of depleted uranium acting as a converter of thermal to fast neutron and simultaneously as an excellent gamma and thermal neutron shield. The user is principally interested for fast neutron and gamma dose rates and fast neutron spectrum in the facilities. Dose rates were previously determined by ionization chambers while the measurement of the fast neutron spectrum.is described in the present article. A set of nine threshold detectors $^{103}Rh(n,n')$, $^{115}In(n,n')$, $^{64}Zn(n,p)$, $^{32}S(n,p)^{32}P$, $^{27}Al(n,p)$, $^{56}Fe(n,p)$, $^{24}Mg(n,p)$, $^{27}Al(n,alpha)$, $^{18}F(n,2n)$ was used. The effective thresholds of the above set range from 0,7 MeV to 12 MeV. Induced activities were detected by a calibrated NaI(Tl) scintillation spectrometer. Activation data were unfolded by the code ITER to obtain fast neutron spectrum. Different input approximation were studied to obtain a reasonable estimate of uncertainities in the energy region below 1,5 MeV which is the most sensitive to experimental errors. The spectrum was converted to fast neutron dose rates and results compared with dose rates obtained by ionization chambers.

Symp. on the Effects of Neutron Irradiation Upon Cell Function, Neuherberg, 22. - 26. Oct. 1973

FAST NEUTRON AND GAMMA SEED IRRADIATION FACILITIES AT THE TRIGA MARK II REACTOR IN LJUBLJANA

M.Najžer, M.Pavko

Two fast neutron and one gamma-irradiation facilities have been installed and calibrated. The fast neutron facilities were designed to obtain the maximum ratio of fast neutron to gamma and thermal neutron intensity. They were made of depleted uranium, which provided an excellent gamma and thermal neutron shield acting at the same time as a converter of thermal to fast neutrons. One fast neutron facility was located in the reactor pool between the core reflector and pool wall, while the other was installed in the central hole of the thermal column. Both facilities provided a net irradiation space of 100 cm^3 (40 mm diam. x 80 mm height) where irradiations uniform to within $\pm$ 5 % could be obtained. Three standard irradiation containers (16 mm diam. x 60 mm height) could be irradiated simultaneously. The gamma irradiation facility was made of cadmium, which converted thermal neutrons to gamma rays, and was located in the thermal column hole.

The performance of the facilities was determined by measuring the profiles of fast neutron and gamma doses, fast and thermal neutron fluxes and temperature at the different positions of the facilities. Radiation doses were measured by a pair of ionization chambers, one gamma, the other gamma and fast neutron sensitive. Fast and thermal neutrons were detected by activation of indium and gold foils respectively. It was established that the requirements for seed irradiation were fulfilled over the whole operating range of all three facilities, and far exceeded over most of the operating range. On comparison the TIF was found to be superior with regard to irradiation conditions while the advantages of TCIF were its simple installation and manipulation of samples and lower price. For both facilities rather a strong influence of sample quantity on the fast neutron dose rate was established.

Irradiation Facilities for Ressearch Reactor IAEA 1973, p.423.

II. NON-NEUTRON DATA

HALF-LIFE OF ^{88}Zr

A.Stanovnik, B.Pucelj

The half-life of ^{88}Zr has been measured directly by following the decay of the 0.394 MeV gamma ray activity. A value of 83.4 ± 0.3 days has been obtained.

Radiochem. Radioanal. Letters 14/4/ 273-275 (1973).

PHOTOPROTONS FROM ^{90}Zr AND THE ISOSPIN SPLITTING OF THE GIANT DIPOLE RESONANCE

D.Brajnik, D.Jamnik, G.Kernel, M.Korun, U.Miklavžič, B.Pucelj and A.Stanovnik

Photoproton spectra have been measured by irradiating a ^{90}Zr target with bremsstrahlung gamma-rays of seven different end-point energies in the range from 14.7 to 23.8 MeV. By the least squares method cross sections for reactions, leaving ^{89}Y in the ground and different excited states have been calculated.

Photoprotons emerging from a 8.05 mg/cm^2 target, enriched to 97.5 % of ^{90}Zr were detected with Si(Li) detectors at three angles (30°, 90° and 150°). Because of the large background at low energies only protons, with energy greater than 4 MeV were counted. Proton energy resolution was defined practically only by the target thickness and ranged from 230 keV at 8 MeV to 180 keV at 12 MeV.

Since the average spacing of the energy levels in ^{89}Y is narrower than the used steps of the bremsstrahlung end-point

energies (1.5 MeV) it was possible to obtain cross sections for transitions to g.s. and only a few groups of excited states.

In contrast to the (γ,p_0) reaction, the cross section for the transition to the group of residual states from 1-3 MeV excitation energy in ^{89}Y (mean energy 1.8 MeV) shows two broad resonances centred around 16 and 21 MeV. They could be interpreted as the $T_<$ (=5) and the $T_>$ (=6) of the giant resonance

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SOME NEW EVIDENCE FOR THE ISOSPIN SPLITTING OF THE PHOTONUCLEAR GIANT RESONANCE IN ^{90}Zr

D.Brajnik, D.Jamnik, G.Kernel, M.Korun, U.Miklavžič, B.Pucelj and A.Stanovnik

Several photonuclear reactions in ^{90}Zr were investigated using bremsstrahlung gamma rays from a 31 MeV betatron. Some preliminary results were obtained $^{90}Zr(\gamma,2n)^{88}Zr$, and $^{90}Zr(\gamma,np)^{88}Y$. reactions from the analysis of activation gamma lines.

The $^{90}Zr(\gamma,2n)^{88}Zr$ and $^{90}Zr(\gamma,np)^{88}Y$ cross sections were measured simultaneously by detecting the 83^d activity of the 0.394 MeV ^{88}Y state$^+$ and the 107^d activity of the 1.84 MeV ^{88}Sr state at different bremsstrahlung end-point energies. The $(\gamma,2n)$ cross section is in good agreement with the data of Berman et al. Considering $(\gamma,2n)$ and (γ,np) reactions as two-step processes, the first step being a (γ,n) reaction to continuum states of ^{89}Zr, and assuming that the decay of these states is governed solely by transmission coefficients and level densities, one finds that experimental values yield a ratio of (γ,np) to $(\gamma,2n)$ cross sections which is too large. This could be explained with a dominant $T_>$ isobaric spin of the ^{90}Zr giant resonance in the region above

22 MeV. In this case the residual ^{89}Zr states have $T = \frac{11}{2}$ for which the neutron decay is isospin forbidden; thus enhancing the decay through proton channels.

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PHOTONUCLEAR REACTIONS IN Ca

D.Brajnik, D.Jamnik, G.Kernel, U.Miklavžič, A.Stanovnik

Natural calcium targets were bombarded with gamma rays from a 31 MeV betatron at several bremsstrahlung end-point energies. Angular and energy distributions of photoprotons were measured. In addition, the gamma-ray spectra emerging from the thick target were recorded at several angles. They were used to study the gamma rays accompanying the decay of excited residual nuclei formed in the reactions $^{40}Ca(\gamma,p)$ and $^{40}Ca(\gamma,n)$. The analysis yielded the following results for the main reaction channels: the energy dependence of the cross sections, the energy dependence of photoproton angular distributions, and the bremsstrahlung weighted angular distributions of deexcitation gamma rays.

Acording to the experimental results the following amplitudes seem to dominate in the particle channels: $f_{5/2}$ waves for the (γ,p_0) reaction, $p_{3/2}$ waves for (γ,p_1), and p waves for reaction channels in which the residual nuclei are left in states above 4.93 MeV. This is consistent with the giant dipole state configuration, predicted on the basis of the shell-model bound-state calculation by Gillet and Sanderson. The agreement with continuum theories is less satisfactory. It is also found that the shapes of cross sections are more uniform and that the angular distributions are less energy dependent than expected from theory.

The (γ,p_1) cross section was separated into S = 0 and S = 1 channel spin contributions of which only the dominant S = 0 part shows a resonant structure. Negative parity hole channels bear evidence for two-step reaction processes and impurities in the ground state of ^{40}Ca. Ratios of (γ,p) and (γ,n) cross sections imply an admixture of less than 3 % of the T = 0 strength in the ^{40}Ca giant dipole resonance.

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