SECTION 6 — NUCLEAR REACTIONS AND CAPTURE PROCESSES

6.1. Prompt γ-ray spectra and integrated cross sections for the radiative capture of 14 MeV neutrons

F. CVELBAR, M. BUDNAR and M. POTOKAR, *J. Stefan Institute and Faculty for Natural Sciences and Technology, University of Ljubljana*

Introduction. The excitation energy E of the intermediate system after capture of neutrons of the energy between 5 MeV and 10 MeV is between about 12 MeV and 22 MeV i. e. in the region of the giant dipole resonance (GDR). In this region the dipole absorption of γ-rays is enhanced. On the other hand the nuclei, being excited e. g. just to the peak energy $E = E_R$ of GDR should have enhanced probability for dipole deexcitation to the ground state.

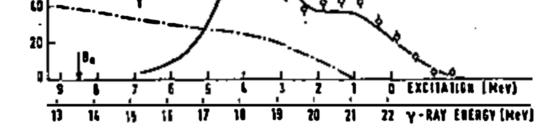

Fig. 1. Spectrum of prompt γ-rays from the radiative capture of 14,1 MeV neutrons in ^{28}Si.

According to the collective (semi-direct) model[1] this is a consequence of the fact that a part of the wave function of such an intermediate state can be written as a product of the wave function, describing the collective dipole vibrations and the ground state wave function.

If the excitation energy is higher than E_R and appears as a sum $E = R_R + E_f$, where E_f means the energy of one of the bound states, in the above product, the wave function of this state appears instead of the ground state wave function.

Correspondingly the maximum spectral intensity is not expected to be found in the ground state transition but in the transition to the excited state.

When the excitation energy cannot be divided exactly into a sum of E_R and E_f but $E = E'_R + E_f$ where E'_R is an energy not exactly equal to the peak value of the GDR but still within its width, for the transitions to the different final states the previous expectation applies, except that the intensity is reduced due to the fact that $E'_R \neq E_R$.

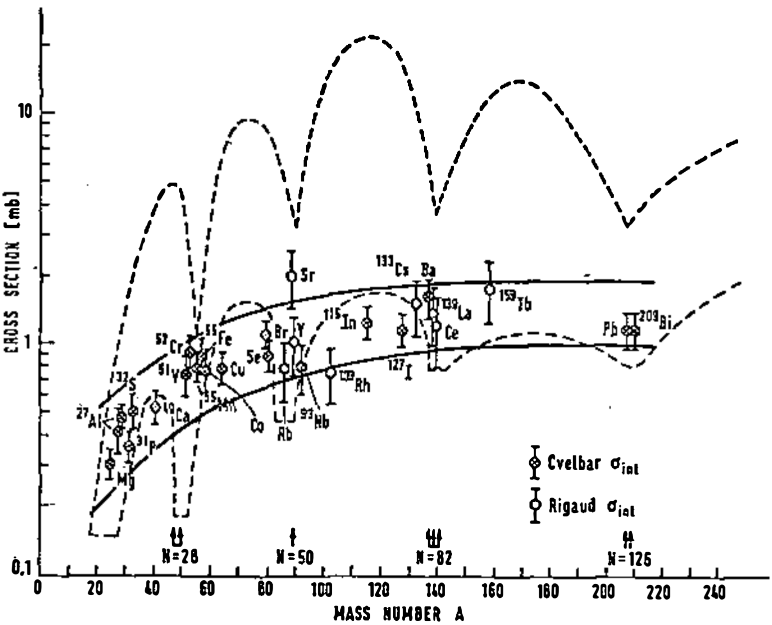

Fig. 2. Mass dependence of the integrated cross section for the radiative capture of 14 MeV neutrons. Corresponding activation cross section values are scattered within the region bounded by the broken line.

From this it follows that in the spectra from the radiative capture of 14 MeV neutrons the shape of the GDR should be in some way reproduced. This expectation was confirmed experimentally in many cases (see e. g. Refs.[2,3]).

Results. Prompt γ-ray spectra from the radiative capture of 14,1 MeV neutrons such as the one presented in Fig. 1 were measured in this laboratory with a special telescopic scintillation pair spectrometer which allows the measurement of γ-rays from a sample placed around the neutron source. Spectra obtained in this way are integrated over 4π solid angle and are therefore directly comparable with the calculated ones[2,3] without knowledge or speculation about the angular distribution of γ-rays from the capture process. In Fig. 1 the experimental γ-ray spectrum for ^{28}Si is compared with the result of the calculation according to the approach of Lushnikov and Zaretsky.

The integrals of the measured (n, γ) spectra (σ_{int}) have been compared with the values (σ_{act}) obtained by the activation technique[4]. As the values of σ_{int} cover only the transitions to the bound states of final nuclei, but the σ_{act} include also the transitions via unbound states, it was expected that $\sigma_{act} > \sigma_{int}$. The difference should be of the order of a few tens of percent. The probability of populating unbound states by radiative transitions is reduced by the factor E^3 (dipole term in multipole expansion), but the probability for further γ-ray deexcitation is additionally reduced due to the high probability of particle emission.

The experimentally observed values of σ_{act} are up to 20 times higher than the σ_{int}. In contrast with the σ_{int}, which shows a smooth mass dependence saturating in the region of medium nuclei where the cross section is about 1,2 mb, the values of σ_{act} are scattered between 0,5 mb and 20 mb. The two cross sections roughly agree only for nuclei in the vicinity of closed neutron shells. Probably the most convincing explanation for this discrepancy is that based on the suposition that the σ_{act} observations are severely contaminated by events due to the slowed down neutrons (for which the capture cross sections tend to be larger). This conjecture is supported by the similarity of the observed A dependence of σ_{act} for 1 MeV and 14 MeV neutrons, i. e. both show the same extreme dependence on shell structure.

References

1) J. Zimanyi, I. Halpern and V. A. Madsen, Phys. Lett. **33B** (1970) 205 and references citied therein;

2) F. Cvelbar, A. Hudoklin, M. V. Mihailovič, M. Najžer and M. Petrišič, Nucl. Phys. **A130** (1969);

3) F. Cvelbar and A. Hudoklin, Nucl. Phys. **A159** (1970) 555;

4) F. Cvelbar, A. Hudoklin and M. Potokar, Nucl. Phys. **A158** (1970) 251.

6.2. The radiative capture of 10 MeV neutrons in heavy nuclei

M. POTOKAR, F. CVELBAR and M. BUDNAR, *J. Stefan Institute, and Faculty for Natural Sciences and Technology, University of Ljubljana*

In an attempt to remove considerable discrepancies between the early experimental data on fast (10—30 MeV) nucleon capture and the predictions of the statistical theory and the simple direct theory of nucleon capture the so-called direct-semi direct (DSD) theory arose. The spectra of prompt gamma-rays following the radiative capture of 14 MeV neutrons have been recognized as an effective tool for testing the new theory. The agreement between the experimental spectra and the spectra calculated by using this theory has been good in the case of light and medium nuclei[1]. The integrated cross sections obtained by summing all counts in the spectrum corresponding to gamma-ray transitions to bound states have been found to exhibit smooth mass dependence, the cross sections being between 300 μb and 1200 μb, increasing with A. This observation is in contradiction with the cross section data obtained by the activation technique, but does not contradict DSD theory[2].