FIZIKA, 2 (1970) 41-43

DEEXCITATION VIA UNBOUND STATES IN THE RADIATIVE CAPTURE OF 14 MEV NEUTRONS

F. CVELBAR, A. HUDOKLIN, M. V. MIHAILOVIĆ and M. POTOKAR

Institute »Jožef Stefan«, Ljubljana and University of Ljubljana

Received 30 October 1969; revised manuscript received 17 November 1969

Comparing the cross section for the 14 MeV neutron capture measured by the activation technique (σ_{act}) with the integrated cross sections (σ_{int}) obtained from our measurements of prompt γ-ray spectra, we found that in light and medium weight nuclei (aluminium, phosphorus, vanadium and manganese) the compound states deexcite in the first step almost completely to the bound states of final nuclei. For three cases of heavier nuclei (cooper, indium and iodine) this comparison showed that the deexcitation via unbound states is several times more intense than the deexcitation leading directly to the bound states.

The activation cross section includes the deexcitation of compound system via bound states as well as via unbound ones, while the integrated cross section covers the events leading in the first transition directly to the bound states. The integrated cross section is obtained by the integration of prompt γ-ray spectra in the energy interval from E_n to $E_n + B_n$ where E_n is the neutron energy and B_n is the binding energy of the last neutron in the ground state of the final nuclei. Thus σ_{act} is expected to exceed σ_{int}, but the difference should be small as the probability for (dipole) γ-deexcitation is proportional to the E^3_γ and the cascade deexcitation of unbound states is reduced due to the open channels for particle emission.

Until recently the activation cross sections were reported only and the contribution of the deexcitation of the compound system via unbound states has not been known. Theoretical calculations tried to explain the 14 MeV neutron capture process by taking into account only the deexcitation leading in the first step to the bound states. Results were compared either with the experimental γ-ray spectra (few recent cases)[1] or with the available data on σ_{act}[2].

In order to estimate the contribution of the deexcitation via unbound states to the activation cross-section, we measured σ_{int} for seven elements with known σ_{act} by the experimental technique described elsewhere[3]. Gamma-rays from spherical samples, placed around the neutron source were registered by a scintillation telescope pair spectrometer. Due to the nearly spherical geometry spectra obtained were already integrated over solid angle 4 π.

TABLE

Ratio $\frac{\sigma_{act}}{\sigma_{int}}$ for 14 MeV neutron capture

Element	σ_{int} μb	σ_{act} μb			$\sigma_{act}/\sigma_{int}$ Average
		Perkin[5]	Csikai[6]	Menlove[7]	
^{27}Al	410 ± 80 ref.[4]	530 ± 130	560 ± 100		1.3 ± 0.3
^{31}P	360 ± 55*		340 ± 100		0.9 ± 0.3
^{51}V	730 ± 150 ref.[4]		370 ± 60		0.5 ± 0.1
^{55}Mn	780 ± 160 ref.[4]	760 ± 76	1200 ± 200	890 ± 80	1.2 ± 0.2
$^{63+65}$Cu	780 ± 120*	3720 ± 640			4.8 ± 1.1
^{115}In	1240 ± 190*			5970 ± 810	4.8 ± 1.0
^{127}I	1130 ± 170*	2500 ± 500			2.2 ± 0.5
^{27}Al	690 ± 50 ref.[8]	530 ± 130	560 ± 130		0.8 ± 0.1
^{127}I	1090 ± 80 ref.[8]	2500 ± 500			2.3 ± 0.5

Data for σ_{int} marked with an asterisk are presented for the first time. The value of σ_{act} for Cu is a weighted average of the ^{63}Cu and ^{65}Cu values given in ref.[5].

Data on σ_{act} and σ_{int} for all nuclei for which both measurements exist are listed in the Table together with the ratios $\sigma_{act}/\sigma_{int}$. The conclusion can be done that for nuclei up to manganese σ_{act} equals σ_{int} while for heavier nuclei σ_{act} is appreciably higher than σ_{int}. This is a rather unexpected fact. As the accuracy of the measured values is not satisfactory further study is required. The case of vanadium, where σ_{act} is appreciably smaller than σ_{int} was not considered reliable due to the possible error in one of the two cross section values.

The value of the activation cross section for copper presented in the Table results from the separate values for ^{63}Cu and ^{65}Cu weighted according to the isotopic composition of natural copper.

Reported σ_{act} for indium refers to only one isomer state of ^{116}In and represents the lower limit for the total σ_{act}.

The experimental values of σ_{int} for ^{27}Al and ^{127}I reported recently by Dinter[8] are presented in the Table for comparison with our results. Dinter's measurements of γ-ray spectra were performed at an angle of 90° relative to the direction of neutrons. Because the angular distribution of γ-rays cannot be assumed isotropic, corrections have to be applied to the values of σ_{int} obtained.

The angular distribution of the 14 MeV radiative neutron capture γ-rays can be taken in the form found at (p, γ) reactions in the region of the dipole giant resonance[9] which is: $1 + 0{,}1\,P_1(\vartheta) - 0{,}6\,P_2(\vartheta)$, where $P_i(\vartheta)$ mean Legendre polynomails. The resulting correction which has to be applied for the measurement at 90° reduces the value of the integrated cross section by 30%, which lies within the interval of the experimental error of our results.

Further measurements of integrated cross sections are in progress. In order to obtain a better insight into the mass dependence of the ratio $\sigma_{act}/\sigma_{int}$ new precise measurements of activation cross sections are needed in addition.

References

1) F. Cvelbar, A. Hudoklin, M. V. Mihailović, M. Najžer and M. Petrišič, Nucl. Phys. **A130** (1969) 413;
2) G. Longo and F. Saporeti, Nucl. Phys. **A127** (1969) 503;
3) F. Cvelbar, A. Hudoklin, M. V. Mihailović, M. Najžer and V. Ramšak, Nucl. Instr. Meth. **44** (1966) 292;
4) F. Cvelbar, A. Hudoklin, M. V. Mihailović, M. Najžer and V. Ramšak, Nucl. Phys. **A130** (1969) 401;
5) J. L. Perkin, L. P. O'Connor and R. F. Colleman, Proc. Phys. Soc. **72** (1958) 505;
6) J. Csikai, G. Peto, M. Buczko, Z. Miligy and N. A. Neissa, Nucl. Phys. **A95** (1967) 229;
7) H. O. Menlove, K. L. Coop and H. A. Grench, Phys. Rev. **163** (1967) 1299;
8) H. Dinter. Nucl. Phys. **A111** (1968) 360;
9) N. W. Tanner. Nucl. Phys. **63** (1965) 383.