(p, n) Reaction on Cd and Sn Isotopes

著者	Zhong G., Hosaka M., Miyamoto S., Ishimaru Y., Ishii K., Orihara H., Terakawa A., Narita A., Inomata T., Matsumoto T., Nakagawa T., Niizeki T.
journal or publication title	CYRIC annual report
volume	1992
page range	28-32
year	1992
URL	http://hdl.handle.net/10097/49686

CYRIC Annual Report 1992

I. 6. (p, n) Reaction on Cd and Sn Isotopes

Zhong G., Hosaka M., Miyamoto S., Ishimaru Y., Ishii K., Orihara H., Terakawa A., Narita A.*, Inomata T.*, Matsumoto T.* Nakagawa T.*, and Niizeki T.***

Cyclotron and Radioisotope Center, Tohoku University, Sendai 980 , Japan
** Department of Physics, Tohoku University, Sendai 980, Japan*
*** Department of Physics, Tokyo Institute of Technology, Tokyo 152, Japan*

It has been revealed that the (p, n) reaction excites quite strongly in a residual nucleus an excited state which is analog to the ground state in the target nucleus[1], and "quasi-elastic scattering" is caused by the isospin-dependent interaction proportional to $(\boldsymbol{t} \cdot \boldsymbol{T})$, first introduced by Lane[2]. Discovery of the isobaric analog state not only confirmed the conjecture that the isospin was still a good quantum number in a heavier nucleus, but also indicated that neutron-hole proton-particle (n-p) correlation played a quite significant role in collective excitation of the nucleus. The important relation between the (p, n) transitions and b-decays has been established; $\Delta J^{\pi} = 0^{+}$, IAS transition, and the $\Delta J^{\pi} = 1^{+}$ transition have close relationship to Fermi, and Gamow-Teller β-decay, respectively.

If our conjecture, that the isobaric analog state is the same one with that of the target ground except for the isospin Z-component, is valid, the Coulomb displacement energy should be same with energy difference between the IAS and target ground state; i. e.

$$\Delta E_C = E_X(IAS) + |Q\ (p, n)| \tag{1}$$

On the other hand, the Coulomb displacement energy (ΔE_C) is defined as:

$$\Delta E_C = E_C(A, Z + 1) - E_C(A, Z\,). \tag{2}$$

By taking into accounts the effect of quadrupole deformation, the Coulomb displacement energy is[3]:

$$\Delta E_C = \frac{6}{5}\frac{(Z + 1/2)e^2}{r_0 A^{1/3}}(1 - 0.76Z^{-2/3}). \tag{3}$$

Soon later the discovery of IAS, Lane et al. introduced[2] so called Lane potential as the interaction between the incident proton and nucleus:

$$V = V_0 + \frac{(\vec{t}.\vec{T})}{A}V_1. \tag{4}$$

The isospin dependent part is:

$$(\vec{t}.\vec{T}) = t_+T_- + t_-T_+ + t_zT_z \,, \tag{5}$$

where the first term corresponds to the (p, n) reaction. After algebra for vector coupling,

$$U_{p,\,n} = \frac{2\sqrt{N - Z}}{A} U_1(r, E). \tag{6}$$

Thus, the IAS cross section may roughly proportional to $(N - Z)/A^2$. Furthermore, (p, n) cross sections leading to the low-lying 1^+ states may proportional to the GT-matrix elements derived from log ft values.

The experiment was carried out using a 35 MeV proton beam from the AVF cyclotron at CYRIC, Tohoku University. We utilized a beam swinger system$^{4)}$, shown in Fig. 1, to measure angular distributions of emitted neutrons. Neutron energies were measured by the time-of-flight (TOF) technique, where neutrons were detected by a detector array, which consists of twelve detectors containing a total of 23.2 liters of NE213 scintillators, located at 44.3 m from the target. Targets used in the present study were metallic foils of Cd and Sn isotopes, the thicknesses of which were ranging 6.0 through 20 mg/cm^2. Overall time resolution of the g flash was typically 1.31 ns corresponding to 174 keV for the most energetic neutron. The detector efficiencies were obtained from Monte Carlo calculations for monoenergetic neutrons with $E_n < 34$ MeV. Absolute detector efficiencies were also measured by counting neutrons from the ^{7}Li(p, n)^{7}Be reaction and comparing its yield with the absolute neutron fluence determined by activation.

Typical neutron spectra measured for the ^{110}Cd(p, n)^{110}In reaction at 0-degree is shown in Fig. 2. The prominent peak at $E_x = 8.80$ MeV is due to the IAS in ^{110}In, while weakly populated but sharp peak near g. s. to the $0^+ \rightarrow 1^+$ GT-type transition. Typical angular distributions of emitted neutrons measured for the ^{112}Cd(p, n)^{112}In reaction are shown in Fig. 3 along with DWBA prediction for the IAS transition. The line in the figure shows comparison with calculation by the macroscopic DWBA theory with an interaction derived from eq. (6). The theory overestimates the (p, n) cross sections by 20 %, and failed to fit the empirical cross sections in angles lager than 20°.

In the determination of the proton energy, measurements for the ground transition were used. In Table 1, the excitation energies thus obtained for the (p, n) reactions on ^{110,112,114,116}Cd and ^{116,118,120}Sn. reactions and Coulomb displacement energies are listed, together with previous results by Murakami et al.$^{5)}$ In Fig. 4, Coulomb displacement energies are plotted against $Z/A^{1/3}$ for nuclei ranging ^{42}Sc though ^{208}Bi, for which the (p, n) reactions on ^{42}Ca though ^{208}Pb have been systematically studied at CYRIC. The line in the figure denotes a theoretical prediction by eq. (3).

The (p, n) cross section for the $0^+ \rightarrow 1^+$ GT-type transition may give a direct measure for GT-matrix element (log ft - value). As for Cd-In nuclei, the log ft values are ~4.8, while it is ~4.5 for Sn-Sb nuclei. In the present experiment, the unknown log ft for ^{110}Cd-^{110}In, ^{116}Cd-^{116}In, and ^{116}Sn-^{116}Sb pairs have been obtained to be ~4.8 and ~4.5 for Cd-In and Sn-Sb, respectively.

References:

1) Anderson J. D. and Wong C., Phys. Rev. Lett. 7(1961) 250; ibid 8(1962)411
2) Lane A. M., Nucl. Phys. 35(1962)676.
3) Bohr A. and Mottelson B., Nuclear Structure Vol. 1, (Benjamin Inc. New York, (1969) p. 142
4) Orihara H. et al., Nucl. Instrum. Methods A257(1987)189
5) Murakami T. et al., Nucl. Phys. A377. (1982)163

Table 1. Relationship between B(GT) values derived from experimental log *ft* and (p,n) cross sections. Lower part of Table lists estimated B(GT) and log *ft*.

	log ft	*B(GT)*	*σ(p,n)* *0°(mb/sr)*	$\frac{B\,(GT)}{\sigma\,(p,\,n)}$
^{112}Cd-^{112}In	4.76	0.069	0.185	0.37
^{114}Cd-^{114}In	4.78	0.065	0.233	0.29
^{118}Sn-^{118}Sb	4.52	0.118	0.450	0.26
^{120}Sn-^{120}Sb	4.52	0.118	0.540	0.22
$\frac{B\,(GT)}{\sigma\,(p,\,n)}$(average)				0.29±0.06

	$\frac{B\,(GT)}{\sigma\,(p,\,n)}$(average)	*σ(p,n)* *0°(mb/sr)*	*B(GT)*	*log ft*
^{110}Cd-^{110}In	0.29±0.06	0.256	0.074	4.7
^{116}Cd-^{116}In	0.29±0.06	0.182	0.053	4.8
^{116}Sn-^{116}Sb	0.29±0.06	0.470	0.136	4.5

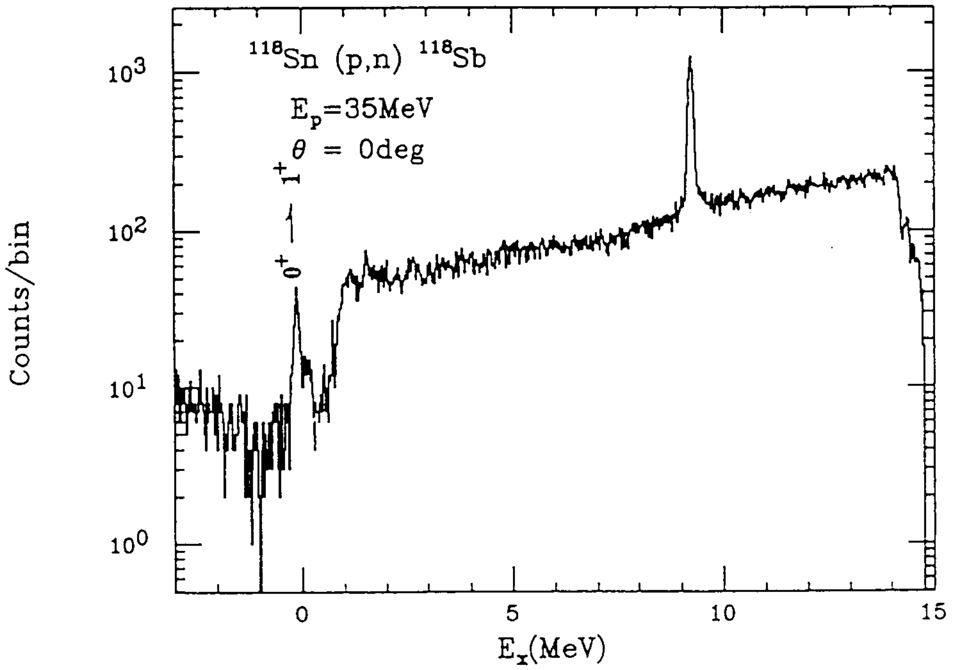

Fig. 1. Sample energy spectra for the ^{118}Sn(p, n)^{118}Sb reaction taken at laboratoryangles 0° with a flight path of 44.3 m. Energy per bin is 25 keV. The prominent peak in a medium high excitation energy is due to neutrons leading to the isobaric analog state. A weakly populated but sharp peak near the ground state is due to neutrons from the 0$^+$ → 1$^+$ transition.

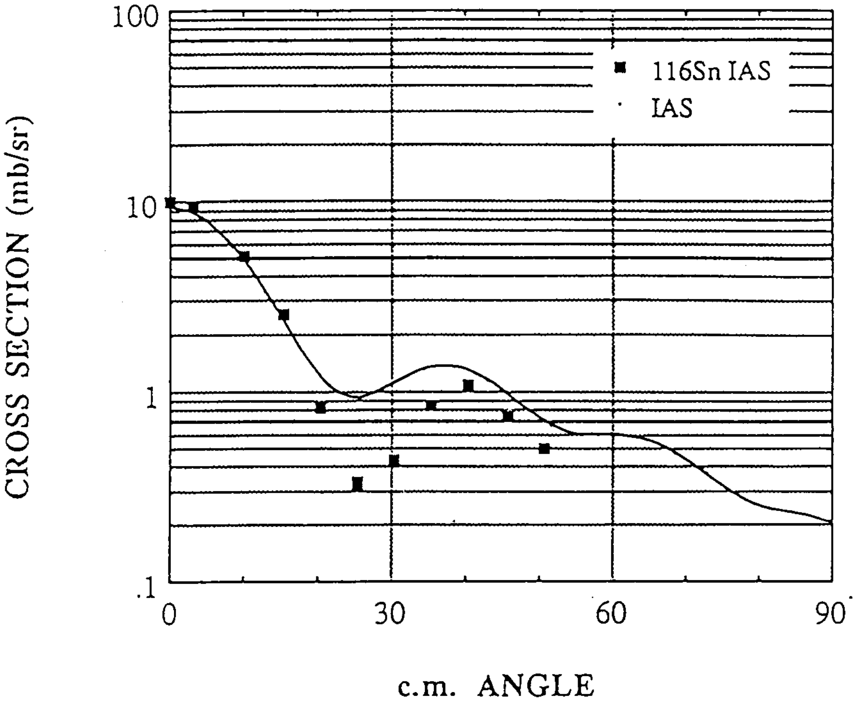

Fig. 2. Angular distribution of differential cross sections for the IAS transition in the ^{116}Sn(p, n)^{116}Sb reaction. The curve in the figure is calculated cross section by the machroscopic DWBA theory.

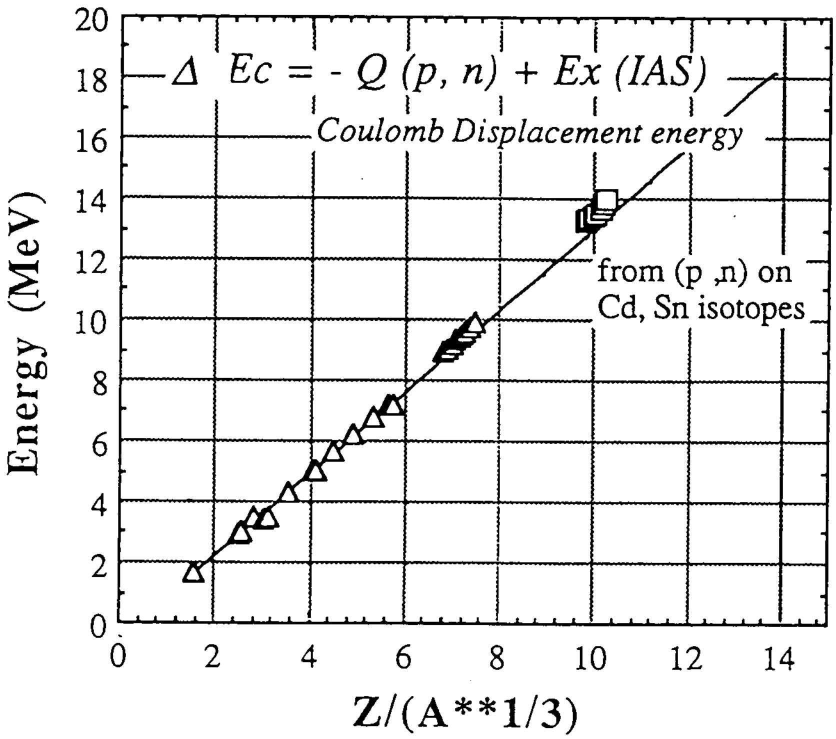

Fig. 3. A systematic plot for Coulomb displacement energy. The present result is also plotted. Line in the figure is the prediction by eq. (1-4) with $r_0 = 1.25$ fm.