Isospin Symmetry Transitions in $A = 58$ System Probed by Strong and Weak Interactions

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Under the assumption that isospin is a good quantum number, symmetry is expected for the transitions from the ground states of $T = 1, T_z = \pm 1$ nuclei to the common excited states of the $T_z = 0$ nucleus between them. The symmetry can be studied by comparing the strengths of Gamow-Teller (GT) transitions obtained form a (p, n)-type charge-exchange reaction on a target nucleus with $T_z = 1$ and those from the β decay of $T_z = -1$ nucleus.

Among the $T = 1 \rightarrow 0$ candidates, we find that analogous transitions in $A = 58$ system, i.e., ^{58}Ni($T_z = 1$) to ^{58}Cu($T_z = 0$) and ^{58}Zn($T_z = -1$) to ^{58}Cu are very much suited for the accurate study of isospin symmetry. The former can be studied in a (p, n)-type CE reaction on the ^{58}Ni target, while the latter in the β decay of ^{58}Zn. The $A = 58$ system is attractive from both β-decay as well as CE reaction sides. They are (a) the β decay of ^{58}Zn has a large Q_{EC} value of 9.37 MeV, which allows the study of B(GT) values up to highly excited region: (b) the B(GT) values in the ^{58}Ni to ^{58}Cu transitions are determined independently of the ^{58}Zn β-decay study; since the ground states of ^{58}Cu and ^{58}Ni have $J^\pi = 1^+$ and 0^+, respectively, the B(GT) value of the ground-states transition obtained in the β decay of ^{58}Cu can be used as the calibration standard of B(GT) values obtainable in the CE reaction. If both type of analogous GT transitions can be measured, and compared, the isospin symmetry structure of nuclei with the same mass number can be studied. The β decay of ^{58}Zn to a few low-lying states of ^{58}Cu has been studied [1]. In addition, a plan to measure the β-delayed proton up to high excited states by using a "Silicon Ball" is in progress at ISOLDE, CERN [2].

As a part of the study, the GT transitions from $T_z = 1$ nucleus ^{58}Ni to $T_z = 0$ ^{58}Cu have been studied by using the zero-degree $(^3\text{He}, t)$ reaction at 150 MeV/nucleon. In the study of GT transitions from ^{58}Ni to ^{58}Cu using a (p, n)-type CE reactions, important is the resolution allowing the study of strength of individual transition. It is found that $(^3\text{He}, t)$ reaction is a good tool for such purpose. The good resolution of it has changed the image of the Gamow-Teller resonance in ^{58}Cu; fine structure has been observed [3] for the broad bump structure observed in the pioneering (p, n) reaction [4].

In April, 2000, a new beam line called "WS course" commissioned at RCNP, Osaka [5, 6]. It enables an accurate realization of dispersion matching and angular dispersion matching. Using a 150 MeV/u ^{3}He beam from the $K = 400$ RCNP Ring Cyclotron, further improvement of energy resolution, a resolution of 50 keV (FWHM), has been achieved (see the spectrum shown in Fig. 1) in combination with the spectrometer Grand Raiden [7]. States have been clearly resolved up to 8 MeV excitation, approximately the maximum energy reached by the study of β decay. Owing to the energy resolution of 50 keV, the yield of each peak was accurately obtained by exerting a peak-decomposition program.

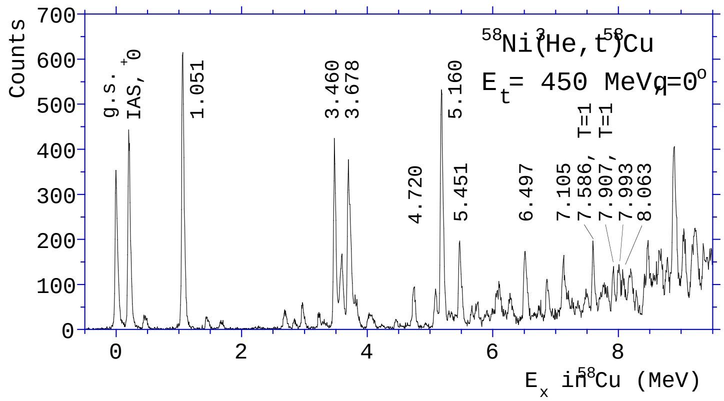

Figure 1: High-resolution ^{58}Ni(^{3}He, t)^{58}Cu spectrum measured at 0°. Major states with $L = 0$ character are indicated by their excitation energies.

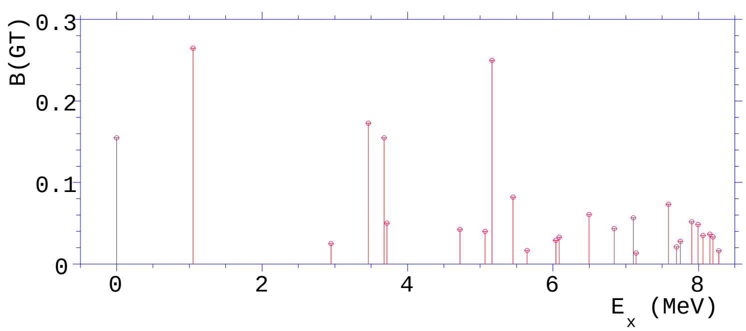

Figure 2: The B(GT) distributions obtained in the experiment.

As the calibration standard, the B(GT) value from the β-decay ^{58}Cu g.s. $\rightarrow$ ^{58}Ni g.s. was used, because the g.s. of ^{58}Cu has $J^{\pi} = 1^{+}$. Using the accurate branching ratio of 81.2(5)% to the g.s. of ^{58}Ni measured by the total absorption spectrometer at GSI Darmstadt [8], B(GT) value for the transition ^{58}Ni g.s. $\rightarrow$ ^{58}Cu g.s. is obtained to be $B(\mathrm{GT}) = 0.155 \pm 0.001$. The B(GT) values of transitions to the other GT states was obtained using the proportional relationship between the reaction cross sections at 0° and B(GT) values. For estimating the change of the factor of proportion as a function of excitation energy, a DWBA calculation was performed using the code DW81 [9]. It was found that the calculated 0° cross section decreases by about 10 % at $E_x = 8$ MeV. The B(GT) distribution obtained in the present experiment is shown in Fig. 2.

References

[1] A. Jokinen *et al.*, Eur. Phys. J. A **3** (1998) 271.
[2] Y. Fujita *et al.*, CERN/INTC/2001-008, INTC/P136.
[3] Y. Fujita *et al.*, Phys. Lett. **B365** (1996) 29.
[4] J. Rapaport *et al.*, Nucl. Phys. **A410** (1983) 371.
[5] Y. Fujita *et al.*, Nucl. Instrum. Methods Phys. Res. B **126** (1997) 274.
[6] T. Wakasa *et al.*, RCNP Annual Report 1999, RCNP, Osaka University, p. 95
[7] M. Fujiwara *et al.*, Nucl. Instrum. Methods Phys. Res. A **422** (1999) 484.
[8] Z. Janas *et al.*, GSI annual report 1999, GSI rep. 2000-1, p. 13.
[9] DW81, a DWBA computer code by J. R. Comfort (1981).