Detailed Distribution of Gamow-Teller Strengths in ^{54}Co

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At the end of the star evolution, a massive star ($>$ 10 solar masses) consists of concentric shells of various nuclei. Iron is the final stage of nuclear fusion, because extra energy is needed for the synthesis of any heavier elements. If the iron core in the center of the star exceeds about 1.44 solar mass, the star starts to collapse. This is the beginning of a Type II supernova. In the early stage of the collapse, electron capture processes by nuclei play an essential role. Since they reduce the number of leptons per baryons Y_e, electron degeneracy pressure cannot support the core any longer. In addition the neutrinos produced by the electron capture can leave the star with some energy and cool the core. The cooperative effects accelerate the core collapse of presupernova [1]. The electron captures are dominated by Gamow-Teller (GT) transitions. Measurements of GT transition strengths, B(GT) values, for iron isotopes are important.

In the electron captures, iron nuclei change to manganese nuclei mainly by GT transitions. These transition strengths can be measured by (n,p) type charge exchange (CE) reactions. In general, CE reactions at intermediate energies and at 0° have been used to measure B(GT) strengths to highly excited states, because there is a proportionality between cross sections and B(GT) values [2]. This proportionality is due to the fact that $q=0$ $\sigma\tau$ part of the effective nucleon-nuclear interaction causing the GT transition is dominant, and a simple reaction mechanism of one step process is expected. The resolutions of (n,p) reactions [3, 4] in the past, however, were insufficient to resolve each GT state.

We report here the result of ^{54}Fe(^{3}He$,t$)^{54}Co high resolution experiment. The ^{54}Fe is one of the most important nuclei involved in presuprenova processes. The ^{54}Fe has $T_z=+1$, where T_z is the z component of isospin quantum number T. The ^{54}Fe ground state has $T_0=1$. Allowed T values of GT states in ^{54}Co are 0, 1 and 2, because T_z of ^{54}Co is 0. The $T=2$ GT states observed in ^{54}Co are analog states in ^{54}Mn which has $T_z=2$, if isospin symmetry structure is assumed in isobars. If the B(GT) values to $T=2$ states in ^{54}Co are determined by (^{3}He$,t$) reaction, we can predict B(GT) values to the GT states in ^{54}Mn. However, $T=0$ and 1 states also exist in ^{54}Co. The identification of T of GT states in ^{54}Co is needed. The comparison with ^{54}Fe(p,p') spectrum performed at 0° enables to identify T values.

The states which are analogous to GT states and observed in inelastic scatterings are called $M1$ states. Since the ^{54}Fe ground state has $T_0=1$, allowed T values of $M1$ states in ^{54}Fe are 1 and 2. By studying the correspondence of GT states in ^{54}Co and $M1$ states in ^{54}Fe, the analogous structure of 1^+ states in these nuclei can be studied. At intermediate incident energies and at 0°, the transition strengths to GT and $M1$ states are proportional to the squared values of matrix elements and isospin Clebsh-Gordan (CG) coefficients. The

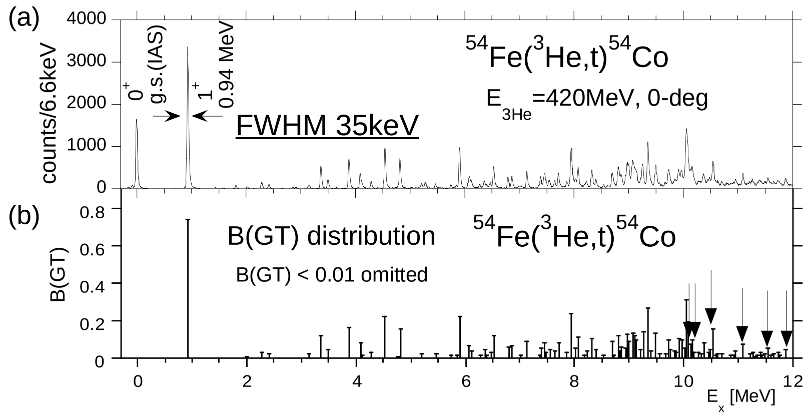

Figure 1: (a) The high resolution spectrum of ^{54}Fe(^{3}He,t) performed at RCNP. (b) The tentative B(GT) distribution of ^{54}Co. The allowed states are identified $T=2$ states from the comparison with ^{54}Fe(p,p') spectrum.

matrix elements are common for the transitions to the analog GT and $M1$ states. The CG coefficients are different depending on the T values of the final states. The squared CG coefficients are $\frac{3}{6}$ and $\frac{1}{6}$, respectively, for the transitions to $T=1$ and 2 GT states. In the transitions to $M1$ states, they are both $\frac{1}{2}$. For analog GT and $M1$ states, the ratio of CG coefficients is 1:1 if the transitions are to $T=1$ states, while it is 1:3 if the transitions are to $T=2$ states. If we normalize the strengths to analog GT and $M1$ states by $T=1$ states, the strengths to $T=2$ $M1$ states should be enhanced compared to the analogous GT transitions.

In order to make a level-by-level comparison, improvement of resolution is essential. For the improvement *dispersion matching techniques* [7, 8] were applied for the experimental system consisting of a spectrometer “Grand Raiden” [5] and a beam line “WS course” [6]. A high resolution ^{54}Fe(^{3}He,t) spectrum is shown in Fig. 1(a). We achieved an energy resolution of $\Delta E=35$ keV. The GT strengths were observed up to $E_x=12$ MeV. From Fig. 1(a) we can see the GT strengths are fragmented over many states.

The relative B(GT) values for GT transitions can be determined from the observed counts of GT states. In order to determine the absolute values, a normalization factor is needed. We tentatively normalized B(GT) values by using the result from ^{54}Fe(p,n)^{54}Co measurement [9] claiming that the B(GT) value to the $E_x=0.94$ MeV GT state is 0.736 ± 0.049. The B(GT) distribution in ^{54}Co after this normalization is shown in Fig. 1(b).

Through the transition-by-transition comparison of the strengths to the GT states in ^{54}Co and those to the analog $M1$ states in ^{54}Fe, $T=2$ states could be identified. We suggest there are six candidates of $T=2$ states in the region of $E_x=10\sim12$ MeV. They are indicated by arrows in Fig. 1(b).

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