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3 - 22 Study of the Urca Cooling Ability of ^{63}Fe - ^{63}Mn

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The temperature in the crust of an accreting neutron star is believed to have a significant impact on observable phenomena at the outer layer of a neutron star. This temperature is regulated by various factors, such as heating from nuclear reactions, neutrino cooling processes and heat transport from the interior^[1]. Among these, Urca process is considered to be the primary mechanism for neutrino cooling.

Urca process is a cycle consisting of electron capture and β^- decay. Nuclei participate in the Urca process are Urca pairs. The concept of Urca process was first introduced in 1941 by Gamow. In 2014, Schatz considered the Urca process in neutron stars for the first time. They calculated the cooling ability of 85 odd- A nuclei and identified ^{63}Fe - ^{63}Mn as a non-significant Urca pair. This result is supported by a recent experiment, which suggests that the ground state J^π of ^{63}Fe could be $1/2^-$ ^[2]. Such a value of J^π leads to a second-order forbidden transition between the ground states of ^{63}Fe and ^{63}Mn . However, the systematics of nuclear structure suggests that the ground state J^π of ^{63}Fe may have a possible value of $5/2^-$. The value given by β^- decay of ^{63}Mn is also $5/2^-$ ^[3]. Therefore, the transition between the ground states of ^{63}Fe and ^{63}Mn could be an allowed transition, and the cooling ability of ^{63}Fe - ^{63}Mn needs to be recalculated.

The cooling ability of an Urca pair is quantified by the neutrino luminosity, which refers to the energy loss caused by neutrinos. In the previous work, ^{33}Al - ^{33}Mg is identified to be the strongest Urca pair with neutrino luminosity $L_\nu = 0.042 \times 10^{36} \text{erg} \cdot \text{s}^{-1}$ ^[4,5]. Here we find that the neutrino luminosity of ^{63}Fe - ^{63}Mn is $L_\nu = 0.0397 \times 10^{36} \text{erg} \cdot \text{s}^{-1}$, with the ground state J^π of ^{63}Fe as $5/2^-$. Our calculation indicates that the neutrino luminosity of ^{63}Fe - ^{63}Mn is comparable to that of ^{33}Al - ^{33}Mg .

Overall, we recalculate the cooling ability of ^{63}Fe - ^{63}Mn , using a suggested ground state $J^\pi = 5/2^-$ of ^{63}Fe from the systematics of nuclear structure. Our result suggests that ^{63}Fe - ^{63}Mn is a significant Urca pair. The discrepancy between our result and previous one is primarily attributed to the uncertainty surrounding the ground state J^π of ^{63}Fe . Therefore, it is essential to determine the J^π of the ground state of ^{63}Fe or the transition strength between the ground states of ^{63}Fe and ^{63}Mn in future experiments.

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