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Measurement of the ^{189}Os(n,n')^{189}Os reaction cross section and the Re-Os chronometer

Abstract

The age of the universe is one of the most interesting themes in astrophysics. It is known that the Re-Os chronometer is one of the good chronometers to estimate the age of the universe, since it has following unique features. First, the parent nucleus ^{187}Re is formed only by rapid (r-) process and its half-life is 42.3 ± 1.3 Gyr, longer than the age of the universe estimated using the Hubble constant. Second, the geochemical property of Re is similar to that of Os is similar, therefore the Re and Os were not fractionated from each other. However there remain non-trivial problems in the Re-Os chronometer. First, ^{187}Os is produced not only by β decay of ^{187}Re, but also by the slow (s-) process of ^{186}Os. Second, ^{187}Os is depleted by the neutron capture process not only by the ground state of ^{187}Os but also through the 1st excited state at 9.75 keV in ^{187}Os, which could be significantly populated at a stellar temperature (~ 30keV). Therefore, the neutron capture cross section of ^{186,187}Os through the ground state and that of ^{187}Os through the 1st excited state are very important in order to precisely determine the age of the universe by using the Re-Os chronometer. Since one can hardly measure the neutron capture cross section for the 1st excited state of ^{187}Os, the cross section should be estimated by a theoretical calculation. For constructing the reliable theoretical model to calculate the cross section, measurements of the inelastic scattering cross section σ_{inela}(^{187}Os) off the ground state ($J^{\pi} = 1/2^{-}$) of ^{187}Os to its excited 9.75 keV state ($J^{\pi} = 3/2^{-}$), and the neutron capture cross section of the ground state ($J^{\pi} = 3/2^{-}$) for ^{189}Os and neutron inelastic scattering cross section σ_{inela}(^{189}Os) off the ground state ($J^{\pi} = 3/2^{-}$) of ^{189}Os to its excited 36.20 keV state ($J^{\pi} = 1/2^{-}$) were suggested.

In the present study, we have measured the σ_{inela}(^{189}Os) as well as σ_{ela}(^{189}Os) with use of two different experimental methods. We measured the σ_{inela}(^{189}Os) for the first time at 59 ≤ En ≤ 90 keV using four ^{6}Li-glass scintillation detectors, and also at 36 ≤ En ≤ 90 keV by detecting the 36.20 keV γ-ray from the 2nd excited state of ^{189}Os to the ground state with a newly developed system with Si(Li) detectors. The obtained results are quite important to constrain parameters in a theoretical model.