学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Coulomb screening correction to the Q value of the triple-alpha process in thermal plasmas
（熱プラズマ中の３アルファ反応におけるクーロン遮蔽効果に関する研究）

One of the most important nuclear reactions in nuclear astrophysics is the triple-alpha (^{4}He) process which leads to the formation of stable carbon, the fourth most abundant element in the universe. The first excited $J^\pi = 0^+$ state of ^{12}C, the so-called Hoyle state, plays an essential role in a triple-alpha reaction. Meanwhile, this triple-alpha process may occur in weakly-coupled, thermal plasmas as encountered in normal stars. The purpose of this thesis is to investigate changes of the Hoyle state energy due to the Coulomb screening in this weakly-coupled thermal plasma environment, which may affect the triple-alpha reaction rate. We already know that if the Coulomb potential is screened off the repulsive force in this astrophysical environment would be less than that in a vacuum. In such a condition that a two-alpha state become zero energy, we expect that we would find series of the Efimov 0^+ states might appear below the Hoyle state. First, we investigate the Coulomb screening effects on the energy shifts of the Hoyle state in a weakly-coupled thermal plasma environment by precise three-body calculations within the Debye-Hueckel approximation. To reproduce the Hoyle state energy in a vacuum, we employ a three-alpha model with two kinds of three-alpha potential. To take the Debye screening in thermal plasmas into account, we use the Coulomb interaction modified in the Yukawa form. By superposing the correlated Gaussian bases, we get the precise three-body wave function of the three-alpha system. The energy shifts of the Hoyle state due to the Coulomb screening are obtained as a function of the Debye screening length. We find that our results are consistent with the conventional results based on the Coulomb correction to the chemical potentials of ions that are regarded as point charges in a weakly-coupled, thermal plasma. We have given a theoretical basis to the conventional point-charge approach to the Coulomb screening problem relevant for nuclear reactions in normal stars by providing the first evaluation of the Coulomb corrections to the Q value of the triple alpha process that produces a finite size Hoyle state. Finally, we discuss the existence of the Efimov states for the three-alpha system, which was suggested in the literature. However, we did not find these states in our calculations. The Hoyle state is still a resonant state even two-alpha state become zero energy.