Nuclear reaction in muon atomic collision

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Synopsis Muon screening effect enhances nuclear reaction rates in a muon atomic collision. We carefully investigate three-body intermediate states in the collision and calculate the reaction cross sections.

Low energy nuclear reactions take place via quantum tunneling of Coulomb barrier between the two nuclei. The penetration probability significantly decreases with a decrease of collision energy. In the case of an atomic target, the probability would be enhanced because of existence of orbital electrons. It is known as an electron screening effect. This effect is valid mainly outside the electron orbital radius. Inside the radius, the screened Coulomb potential is almost the same as the bare Coulomb potential. According to the Bohr model for hydrogen like atom, the radius of the electron is inversely proportional to the reduced mass of the electron and nucleus mass. If the electron is replaced by a heavier particle than electron, the radius of the atom which is so-called an exotic atom becomes smaller and the width of the Coulomb barrier becomes thin. Since the penetration probability strongly depends on the width. In the case of a muon whose mass is 207 times heavier than electron mass, the screening effect strongly enhanced. Though the muon is an unstable particle having a lifetime of 2.2 μs, the enhancement makes the nuclear fusion between two hydrogen isotopes possible for more than 100 times within the short lifetime. This phenomenon is known to be a muon catalyzed fusion (μCF) where the nuclear fusion reaction takes place inside a tiny muonic molecule [1,2]. The μCF had been expected to be an energy source of the future and had studied actively, but the studies almost disappeared because of high cost of muon production. The muonic molecular formation and muon transfer reaction are bottleneck processes in the μCF. In order to increase the number of nuclear reaction in μCF, we propose a new μCF process in which the bottleneck processes are skipped and the nuclear reaction takes place after the muonic atom formation. For this purpose, we introduce high temperature plasma. The nuclear reactions in muonic atom collision process had been calculated by Froelich et al.[3], but the result contained numerical errors caused by strong dumping of scattering wavefunction inside the Coulomb barrier. To remove the difficulty, we investigate the screening effect from negatively charged massive particle as a function of mass systematically. In the interaction region of the collision, three-body intermediate states play an important role. To reproduce the intermediate states accurately, we adopt a Gaussian expansion method [4] and combine muon atomic collision [5] and screened nuclear reaction [6,7] calculations.

References

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