

Nuclear reaction rate in Debye-Hückel electrolytic plasma in stellar interiors

H L DUORAH and A E MD KHAIROZZAMAN*

Department of Physics, Gauhati University, Gauhati 781 014, India

*Permanent Address: Department of Physics, B. N. College, Dhubri, India

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Abstract. The transmission probability of charged particle reactions in a stellar plasma is examined by considering the effective potential between the interacting charges as having an exponential factor in the Coulomb term arising out of the spherical distribution of electrons with its uniform background of positive charges (Debye-Hückel electrolyte). The expression for the ratio of this transmission probability to that due to pure Coulomb field, called the enhancement factor, is then obtained. Thermonuclear reactions of astrophysical interest such as $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ and $^{18}\text{O}(\alpha, \gamma)^{22}\text{Ne}$ are then considered. Our enhancement factor in the $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ reaction rate is found to agree reasonably well with those calculated from the expression given by Alastuey and Jancovici.

Keywords. Thermonuclear reactions; enhancement factor; stellar interiors; nuclear reaction rate; Debye-Hückel electrolyte.

1. Introduction

Charged particle reaction rate in vacuum depends on the penetrability of the Coulomb barrier. The situation is different in the case of stellar interiors. The Coulomb barrier is modified by the presence of polarising cloud of electrons surrounding the positive ions. The potential seen by a reacting particle (positive ion) is generally found to be smaller than the Coulomb potential and quantum-mechanical tunnelling of the barrier becomes easier. As a result, the reaction rate is augmented in stellar interiors. Salpeter (1954) calculated the accelerating factor in nuclear reaction rates and found that it was not satisfactory for both low and high density regimes at the same time. Attempts were made later by a number of workers to improve upon his work. Recently Mitler (1977) considered a two-fluid approximation which was an improvement over the Salpeter model. Ito *et al* (1977), on the other hand, calculated the enhancement factor in thermonuclear reaction rate due to strong screening effect through explicit consideration of correlations between ions. Alastuey and Jancovici (1978) considered the short-range behaviour of the pair correlation function in a dense one-component plasma. The result was an expression to be solved numerically and was an improvement over earlier studies. We wish to investigate here the enhancement factor in charged particle reaction rate in a plasma, likened to a Debye-Hückel electrolyte.

Most of the atoms are found in ionised states in the stellar interiors. Electrons and ions in stellar interiors form a plasma. Electronic plasma is a collection of electrons