SCREENING FACTORS IN LATE STELLAR EVOLUTION*

(Abstract)

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Recent studies (DeWitt *et al.*, 1973; Graboske *et al.*, 1973) have modified the screening factors for nuclear reactions. The theory develops a general statistical mechanical framework within which the various analytical models of Salpeter are combined with Monte Carlo and perturbation calculations for specific mixtures. The result is a general effective screening function in terms of the reacting charges Z_1, Z_2 and the plasma properties ϱ, T and $\bar{z}$. This screening function greatly enhances the screening effects for presupernova models (Couch and Arnett, 1973; Bruenn, 1973) reducing carbon ignition densities in the 4–8 $M_\odot$ range by a factor of two, and even more for degenerate O and Si burning.

Current studies of screening have verified the accuracy of the general screening function relation for a wider range of physical conditions. Extensive Monte Carlo calculations by Hansen (1973) and by DeWitt and Graboske at Livermore have considerably extended and improved the accuracy of the numerical data used to determine the screening function. These new numerical results produce very slight changes in the screening function, of the order of one percent in the range $0.8 \leqslant \xi_{12} \leqslant \infty$, where $\xi_{12} = Z_1 Z_2 / \bar{z}^2$. Only for $\xi_{12} \ll 1$ are changes as large as 5% in the screening function (corresponding to a factor of 50 in the screening factor at carbon ignition densities). For late evolution reactions, however, ξ_{12} is of order unity for all cases of interest (e.g. C^{12}, C^{12} in a C–O mixture), and the modifications required for $\xi_{12} \to 0$ are not relevant. The original screening function should continue to be sufficient. A second area investigated is the effect on the screening on nonuniform electron distributions. All previous strong screening studies assume that a uniform electron distribution always exists, an assumption strictly valid only at very high density. Using Hubbard's Monte Carlo method incorporating the Linhard plasma dielectric function, calculations were made to determine the effect on screening of electron clumping around the reacting nuclei. The results show significant enhancement of the screening function over the uniform distribution result; in certain lower density regions, as much as twenty percent increase in the screening function. But, again, for reactions in late evolutionary stages in the region of degenerate ignition, the density is sufficiently high that electron uniformity is a reasonable approximation. The region where electron nonuniformity is significant is more closely related to the case of intermediate screening, and it is quite likely that this area will be relevant to weakly degenerate carbon and oxygen ignition, for example, in the 8–15 $M_\odot$ range

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where ignition occurs at lower densities and higher temperatures, before neutrino effects can radically cool and condense the interiors.

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