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Electron screening – still an open question

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Our understanding of energy generation in stars and primordial and stellar nucleosynthesis strongly depends on reliable knowledge of nuclear reaction rates at low energies. However, at low energies, barrier penetration leads to a steep energy dependence of the cross section thus making the cross section measurements extremely difficult. Also, the influence of surrounding electrons is very poorly understood in still experimentally unachievable stellar plasmas. Therefore, it is of crucial importance to measure the bare cross sections as well as possible. In recent years, the availability of high-current low energy accelerators together with improved target and detection techniques have allowed for a reaction rate measurements at very low energies. However these measurements are also complicated by the presence of atomic electrons which alter the Coulomb barrier by screening the nuclear charge and lead to enhancement of cross section at low energies compared to the case of bare nuclei. Experimental studies of various nuclear reactions in metallic environments [1-4] have shown the expected cross section enhancement at low energies. However, the enhancements in metallic targets were significantly larger than expected from the adiabatic limit, which is thought to provide the theoretical maximum for the magnitude of electron screening. Therefore, the size of electron screening has to be measured for each metallic environment and each target separately. Recently, we performed an extensive experimental campaign, with an aim to study the electron screening in the laboratory for various nuclear reactions and involving both low and high Z targets. The 1H(7Li,α)4He fusion reaction was studied for hydrogen implanted Pd, Pt, Zn and Ni targets. Large electron screening, of a few keV was observed in all targets. On the contrary, no large electron screening was observed in the following proton induced reactions: 55Mn(p,γ)56Fe, 55Mn(p,n)55Fe, 113Cd(p,n)113In, 115In(p,n)115Sn, 50V(p,n)50Cr and 51V(p,γ)52Cr. Moreover, no shift in resonance energy for metallic compared to insulator environment was observed for the studied (p,n) and (p,γ) reactions. These results are quite surprising and do not follow expected trends [4]. In order to further study the interplay between nuclei and their surroundings we further studied the 1H(7Li,α)4He reaction in W, Pd and C environments. In addition, we also focused on studies of electron screening in the 1H(19F,αγ)16O reaction in the same targets (in both normal and inverse kinematics). Preliminary results showed unexpectedly large electron screening values (of the order of 10 keV), pointing to a dependence of the electron screening potential on the position of the target nuclei in metallic lattice as well as to a non-linear scaling (instead of widely accepted linear one) of electron screening potential with the charge number of the target. In a continuation of our experimental campaign, we aim to investigate 1H(11B, γ)12C reaction in order to thoroughly investigate the stated hypotheses. If correct, these results would have a profound effect on the understanding of the "laboratory" electron screening effect and would eventually lead to the more correct bare cross sections extracted from laboratory measurements. Until plasma experiments become feasible in the laboratory, the study of electron screening in a metal - the plasma of a poor man [2], is the only means of study that will hopefully successfully point towards the correct interpretation of the electron screening and further understanding of immensely important fusion processes in stellar environments. A review of previous results, as well as newly obtained ones will be presented.

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