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Electron Screening in nuclear reactions at low energies

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In nuclear reactions induced by low-energy charged particles, atomic electrons can participate in the process by screening the nuclear charge and so, effectively reduce the repulsive Coulomb barrier. Consequently, the measured cross section is enhanced by an effect called electron screening. In numerous experiments, different research groups [1-4] obtained extremely high values of electron screening, that are in several cases (depending on target-nuclei environment) more than an order of magnitude above the prediction based on available theoretical model in adiabatic limit [5].
Nevertheless, even as a considerable amount of experimental data was collected over the past twenty years, a suitable theory, which can give an explanation of this effect, has not yet been found. However, electron screening is very important in nuclear astrophysics. For nucleosynthesis calculations, precise reaction rates should be known at very low energies. At these energies charged-particle-induced reaction cross sections become difficult to measure due to their sharp drop with decreasing energy. Nowadays, the energies of astrophysical interest can only be reached in underground laboratories with high-current low energy accelerators [6]. In spite of that, even when the lowest energies are reached, the measurements do not give the nuclear cross section, since the reaction rate in the laboratory is always influenced by the atomic electrons that surround the reacting nuclei.
Trying to understand this process, the effect of electron screening has been investigated by our group [7-9]. We measured the highest value of electron screening in a graphite target. The measured value is about a factor of 50 above the adiabatic limit prediction and much higher than any potential measured so far. Further, our results pointed out that the Z dependence of the screening is even higher than Z^2 instead of expected linear dependence. This rules out the theory based on static electron densities. In order to explain our data, we proposed a new model assuming that an electron is caught in the attractive potential of the two approaching nuclei, similar to the potential of the hydrogen molecular ion [8].
At the moment, our group is focusing on studying the electron screening effect in deuterium implanted titanium targets using the ^{19}F(d,p)^{20}F reaction. Titanium is particularly suitable because it can absorb deuterium up to the stoichiometric ratio of 1:2. It is also very interesting for our investigations due to particular dependence of the electron screening potential on the concentration of deuterium in titanium [3]. Deuterium depth profiles of Ti targets were analysed by nuclear reaction analysis. In order to get a better insight into the condition of the titanium lattice itself, targets were additionally analysed by X-ray diffraction, thermal desorption and Raman spectroscopy. Our goal is to find a different value of the screening potential in two titanium targets and then to understand which parameters of those targets differ and cause high electron screening. An overview of our work will be given and our latest results will be presented.

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