2.1 Electron screening in d(d,p)t for deuterated metals: a systematic study

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We continued our systematic study [1] on the anomalous enhancement of electron screening potential ($U_e$) for the d(d,p)t reaction in deuterated metals.

The 100 kV accelerator of the Dynamitron-Tandem-Laboratorium at the Bochum University provided the deuteron beam with a 54 µA current on target. A liquid-nitrogen-cooled Cu tube extended to within 5 cm of the target. Four Si detectors were installed at an angle $\theta = 130^\circ$ relative to the beam axis at a 5 cm distance from the target and covered with a Ni foil to stop the intense flux of elastically scattered particles. The target together with the chamber and the detector holders (including the Ni foils) formed a Faraday cup for beam integration. A negative voltage of 200 V was applied to the Cu tube for suppression of secondary electrons.

Each deuterated target was produced in the following way: a fresh material "M" (with a purity of better than 99%) was in situ cleaned by Kr sputtering at 35 keV removing about 200 monolayers. Then, the target was bombarded with 10 keV deuterons, whereby the proton yield of d(d,p)t was recorded as a function of implantation charge: the yield reached a saturation level usually after a charge of about 1 C, i.e. a stoichiometry M$_x$D has been produced near the surface of the target. The procedure was repeated at $E_d = 30$ keV. The deuteron distribution was investigated subsequently via Elastic-Recoil-Detection-Analysis (ERDA) and Rutherford-Back-Scattering-Analysis (RBS). For most of the materials the distribution was uniform within 10% from the surface down to a depth consistent with the range of the implanted deuterons.

The observed enhanced cross section is most likely due to electron effects of the environment of the target deuterons. In one experiment, we also used a deuterated Pt target and a $^3$He ion beam in the reaction d($^3$He,p)$^4$He to study the associated electron screening effect. The result is $U_e = 730 \pm 60$ eV showing that such high $U_e$ values do not depend on the kind of ion species but are a feature of the deuterated metals.

The results in relation to the periodic table [2,3] indicate a common feature: where more than one element of a given group of the periodic table has been studied so far, the corresponding $U_e$ values are either low ("gaseous") as for Ti, Zr, and Hf (group 4), Cu, Ag, and Au (group 11), and B and Al (group 13), or high such as for V, Nb, and Ta (group 5), Cr, Mo, and W (group 6), Mn and Re (group 7), Fe and Ru (group 8), Co, Rh, and Ir (group 9), Ni, Pd, and Pt (group 10), and Zn and Cd (group 12). Group 14 is an apparent exception to this feature: the metals Sn and Pb have a high $U_e$ value, while the semiconductors C, Si, and Ge have a low $U_e$ value indicating that high $U_e$ values are a feature of metals.

The indication is supported by other insulators (B, BeO, Al$_2$O$_3$) as well as by deuterated metals M having an observed small stoichiometric $x$ value (M$_x$D) of the order of one or smaller and thus representing also insulators (e.g. group 4 of the periodic table and the lanthanides). In summary, a large screening effect is observed in all metals except in the noble metals Cu, Ag, and Au.