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Hyperfine-changing transitions in ^{3}He II and other one-electron ions by electron scattering

Klaus Bartschat*,† [1] **and H. R. Sadeghpour**† [2]

* Department of Physics and Astronomy, Drake University, Des Moines, Iowa, 50311, USA
† ITAMP, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA

Synopsis We present short-range phase shifts and spin-exchange cross sections for elastic electron scattering from selected one-electron ions from He^+ to Fe^{25+}. The results are explained in a simple physical picture based on quantum defect theory.

The hyperfine-changing transition in $^3He^+$ at 3.46 cm (8.665 GHz) is used for precise determination of the ^{3}He/H abundance in the interstellar medium [1]. In models to obtain the ^{3}He/H ratio, non-LTE effects and line broadening due to electron collisions should be included [2]. Spin-exchange effects in highly charged ions are also of interest for many storage ring experiments.

Calculations using the Coulomb-Born and static exchange approximation, both in non-relativistic and relativistic form, were carried out by Augustin *et al* [3]. They focused on the angle-integrated spin-exchange cross section [4]

$$\sigma_{\rm SE} = \frac{\pi}{k^2}\sum_{\ell=0}^{\infty}(2\ell+1)\sin^2(\delta_\ell^t-\delta_\ell^s) \qquad (1)$$

for elastic collisions, where k and ℓ denote the electron's linear and angular momenta while the superscripts on the short-range potential phase shifts, δ_ℓ^t and δ_ℓ^s, refer to triplet (t) and singlet (s) scattering with total electron spin $S=1$ or $S=0$, respectively.

In a recent paper [5], we showed how highly accurate results for this problem can be obtained using Rydberg energy levels of neutral helium or those of the respective two-electron ions. The essential idea is to write the energy levels as

$$E_{nl} = -\frac{1}{2}\frac{Z^2}{n_\ell^*}, \qquad (2)$$

with an effective quantum number $n_\ell^* = n - \bar{\mu}_\ell$, and obtain the phaseshift from the relation

$$\lim_{E\to 0}\delta_\ell(E) = \pi\bar{\mu}_\ell. \qquad (3)$$

Figure 1 exhibits some examples. Spin-exchange cross sections for H and $^3He^+$ are shown in Fig. 2. Note the entirely different energy dependence, particularly at low energies.

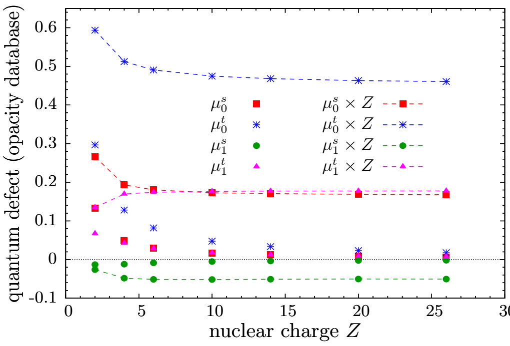

Figure 1. Quantum defects for two-electron systems as a function of the nuclear charge Z, based on data from the Opacity Project [6]. As expected, the quantum defects scale as $1/Z$.

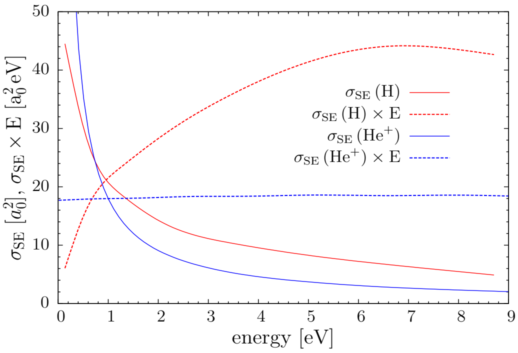

Figure 2. Spin-exchange cross sections for He^+ and atomic hydrogen [5].

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[1] E-mail: klaus.bartschat@drake.edu
[2] E-mail: hrs@cfa.harvard.edu