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Collisions between spin polarized alkali atoms. Complex cross sections.

Victor Kartoshkin[1]

Ioffe Institute, Politechnicheskaya 26, 194021 St-Petersburg, Russia

Synopsis This work is devoted to the calculation of complex cross sections for the spin exchange collisions between polarized alkali atoms. This is of interest for two reasons. First, knowledge of the cross sections allows one to quantitatively analyze spin-exchange collisions. Second, the obtained results can be used in practice to create quantum electronic devices with optical orientation based on the spin-exchange principle.

Collisions of alkali-metal atoms in the ground state with the electron spin $\vec{S}$ =1/2 are accompanied by the exchange of electron coordinates between the colliding particles, which leads to the polarization transfer between them, i.e., to the well-known phenomenon of spin exchange. Spin-exchange collisions between alkali atoms play an important role in quantum electronic devices, such as quantum magnetometers and time and frequency standards

The spin-exchange process can be described in terms of the complex spin-exchange cross sections

$$q^{AB} = \bar{q}^{AB} + i \cdot \bar{\bar{q}}^{AB}$$

The real part of the cross section ($\bar{q}^{AB}$) determines the transfer of orientation in a collision of particles, their relaxation, and the formation of higher polarization moments (the alignment and hyperfine polarization). The imaginary part ($\bar{\bar{q}}^{AB}$) of the cross section determines the magnetic resonance frequency shifts in the system of both Zeeman and hyperfine levels of atoms. Consequently, once the complex spin-exchange cross section is known, the processes that occur in spin-exchange collisions can be described.

In order to calculate the complex cross section one has to know potentials of the diatomic molecule, which is formed during the collision of alkali atoms in the ground state. This molecule might evolve on two terms – the singlet term V_s with the total spin $\vec{S}$ = 0 and the triplet term V_t with the total spin $\vec{S}$ = 1. Complex cross sections of spin exchange were calculated for collisions of alkali metal atoms based on the data of the singlet ($X\,^1\Sigma^+$) and triplet ($a\,^3\Sigma^+$) potentials that describe the interaction of these alkali atoms in the ground state. Calculations have been done for the following pairs of alkali atoms: K-Na [1], K-Rb [2], K-K, and Cs-Cs.

The complex spin-exchange cross section q^{AB} can be written in the form

$$q^{AB} = \frac{\pi}{k_{AB}^2} \sum_{l=0}^{\infty} (2l+1) \left[1 - T_0^{AB}(l) T_1^{AB}(l)^* \right].$$

Here $k_{AB}^2 = \mu_{AB} V_{AB} / h$ id the wave vector, μ_{AB} is the reduced mass of colliding atoms A and B, $V_{AB} = \left(8kT / \pi\mu_{AB} \right)^{1/2}$ is the average relative velocity of colliding atoms, and the sign * denotes the complex conjugate. The scattering matrix is: $T_S^{AB}(l) = \exp(2i\delta_S^{AB}(l))$.

In Fig.1 there are energy dependences of the real $\bar{q}^{AB}$ (1) and imaginary $\bar{\bar{q}}^{AB}$ (2) parts of complex cross section for Na_2 dimer.

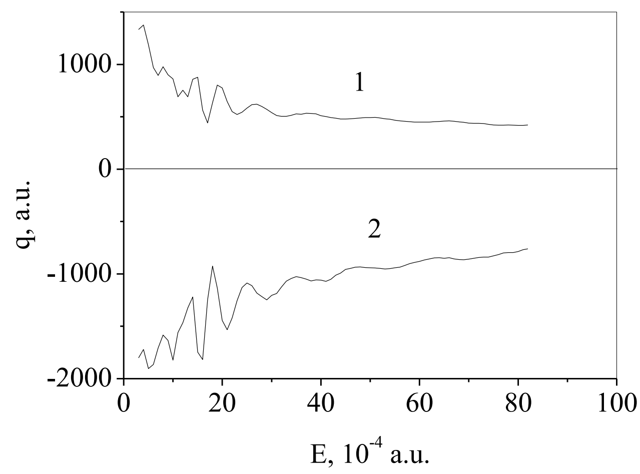

Figure 1. Real $\bar{q}^{AB}$ (1) and imaginary $\bar{\bar{q}}^{AB}$ (2) parts of complex cross section for Na_2 dimer

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References

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[1]E-mail: victor.kart@mail.ioffe.ru