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Observation of the spin polarization of Cs atoms during collisions with oriented metastable helium atoms

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Synopsis We are the first to experimentally observe a magnetic resonance signal of $6^2S_{1/2}$ Cs atoms by absorption of light from a helium lamp that was used to optically orient metastable 2^3S_1 He atoms. The amplitude of the cesium signal proved to be almost three orders of magnitude lower than the amplitude of the magnetic resonance of 2^3S_1 He atoms. The theoretical explanation of the effect is presented.

Optical orientation of atoms by polarized radiation is a powerful tool for obtaining spin polarized atomic particles. Thus obtained polarized atomic particles have been used both to study various physical processes (e.g., to study atom–atom and atom–molecule collisions, to measure rate constants of collisional processes, etc.) and for practical purposes.

Upon optical orientation of atoms in a Cs–He mixture under gas discharge conditions, polarization transfer between particles can occur in the following collisions:

$$Cs(6^2S_{1/2})\uparrow + He(2^3S_1)\downarrow\downarrow \to Cs^+(2^1S_0) + He(1^1S_0) + e^-\downarrow \quad , (1)$$

$$Cs(6^2S_{1/2})\uparrow + He(2^3S_1)\downarrow\downarrow \leftrightarrow Cs(6^2S_{1/2})\downarrow \; He(2^3S_1)\uparrow\downarrow \quad , (2)$$

$$Cs(6^2S_{1/2})\uparrow + e^-\downarrow \leftrightarrow Cs(6^2S_{1/2})\downarrow + e^-\uparrow \quad , (3)$$

$$He(2^3S_1)\downarrow\downarrow + e^-\downarrow \leftrightarrow He(2^3S_1)\uparrow\downarrow + e^-\downarrow \quad . (4)$$

Here, the arrow denotes conventionally the direction of the electron spin of the particle.

As follows from (1)-(4), if the polarization transfer process between colliding particles involves the participation of metastable helium atoms, it is a result of collisional processes of two types—elastic and inelastic collisions. Thus, reactions (2)–(4) correspond to the elastic process, as a result of which the spin is transferred from one particle to the other, with the total momentum being preserved during collisions. At the same time, process (1) is an inelastic process. As a result of the collision of this type, the alkali atom is ionized (the Penning process) at the expense of the internal energy of the metastable helium atom (19.82 eV). As a result of collisions of this kind, the polarization is also transferred to an ensemble of alkali atoms.

Previously in works on optical orientation of atoms in alkali–helium plasma, indirect optical orientation of metastable helium atoms and electrons have been observed in the case in which Cs atoms were optically oriented by resonant radiation of a cesium lamp. It follows from reactions (1)–(4) that a pattern of this kind should also be observed in the case of an experiment in which metastable helium atoms are optically oriented in the 2^3S_1 state, whereas the polarizations of cesium atoms in the ground state and of electrons arise as a result of collisions with polarization transfer (by virtue of the symmetry of reactions (1)–(4) with respect to Cs and He atoms). However, experiment tally, this has not been detected. This paper describes our successful attempt to observe magnetic resonance signals of polarized Cs.

The explanation of a small value of the observed effect is the following. Since the values of the nuclear and electron spins of the cesium atom differ by seven times, upon the redistribution of the polarization between the electron and nuclear systems, the value of the electron polarization becomes considerably smaller compared to the polarization that was initially transferred upon collision. Subsequently, under the magnetic resonance conditions, the polarization of the hyperfine **F** level of the Cs atom is destroyed. In this case, a change in the electron polarization of the cesium atom that the helium atom "senses" upon collision will also be small, since, as was noted above, the electron spin of the cesium is considerably smaller than its nuclear spin. Therefore, as a result of these two processes, the change in the polarization transferred to cesium will affect helium more than an order of magnitude more weakly than in the case in which both the registration and the pumping are performed using the light from the cesium lamp.

References

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