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Optically Pumped Atoms with Velocity- and Spin-Changing Collisions at Low Gas Pressures

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We discuss optical pumping when: (a) the collision rates of optically pumped atoms with atoms or molecules of the background gas are small enough that individual velocity groups can be preferentially excited by a monochromatic light beam, (b) the collision rates are still fast enough to partially transfer the spin polarization to other velocity groups, and (c) there are non-negligible losses of polarization due to collisional spin relaxation and Larmor precession. These conditions lead to a strong correlation between the velocity and the spin polarization of the atoms–that is, to "spin-tagging" of the different velocity groups. This regime is similar to that of optically pumped 23Na atoms of the earth's upper atmosphere, but it is seldom encountered in laboratory experiments. For cooling and trapping experiments, the collision rates with background gas are negligible. For gas-cell experiments the velocity-changing rates are normally so fast compared to spin relaxation or Larmor precession rates, that the atoms have a Maxwellian velocity distribution with negligible correlation between the spin-polarization and the velocity. We analyze the limiting cases of strong and weak collisions, which change the velocity by a large or small fraction, respectively, of the mean thermal velocity. The Keilson-Storer model (J. Keilson and A. E. Storer, Q. Appl. Math. 10, 243 (1952)) is used to discuss strong collisions, with memory parameter _ = 0, and weak collisions with _ $\to$ 1. For weak collisions, the physics can be modelled by coupled Fokker-Planck equations, identical to those for forced diffusion in a harmonic-oscillator potential well. In this limit there are solutions analogous to the quantum-mechanical coherent states of a harmonic oscillator.