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OPTICAL PUMPING OF NEON METASTABLE ($^3P_2$) ATOMS

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Optical pumping of neon metastable atoms in a helium-neon discharge has been accomplished in a manner similar to that for helium. Metastable neon has a P configuration and was expected to have a large spin-disorientation cross section; however, the depolarization cross section is less than 5.4×10^{-17} cm^2. The measured g factor is $g_J = 1.501\,52 \pm 0.000\,64$.

The lifetimes of metastable atoms of the noble gases are known to be on the order of milliseconds. However, with the exception of helium metastable atoms[1,2] no one has reported the polarization and detection of magnetic resonance by optical pumping of the metastable atoms in any of the other noble gases. The major difficulty that is assumed in these cases arises from the P configuration of the metastable atoms. Several authors have pointed out that the spin-disorientation cross sections are very large when the atom possesses orbital angular momentum.[3,4] For example, in the similar case of optically pumped metastable mercury (6^3P_2) atoms the spin-disorientation cross section is 2.1×10^{-14} cm^2 for collisions with ground-state Hg (6^1S_0) atoms.[5]

It is the purpose of this Letter to describe the optical pumping of neon metastable ($^3P_2$) atoms in a buffer gas of helium and the measurement of an anomalously small spin-disorientation cross section. From the magnetic resonance linewidth of the $^3P_2$ level, the disorientation cross section with ground-state helium atoms (1^1S_0) is measured as $\sigma \leq 5.4 \times 10^{-17}$ cm^2. This is some 100 times smaller than the collision cross section for neon metastable atoms in helium obtained from gas-kinetic measurements[6] and implies that a P-state atom can retain its spin orientation after many collisions.

The experimental arrangement is similar to that used in earlier work on helium.[7] The radiation from a neon capillary lamp between 6400 and 7500 Å is circularly polarized and passed through an absorption cell containg 0.01 Torr neon and helium at pressures between 0.01 and 1.0 Torr. A weak electric field maintains a discharge in the cell and populates the $^3P_2$ neon metastable level. Band-pass filters are used to isolate selectively the transmitted radiation at either 640.2 nm (1 ($1s_5$-$2p_9$) or 703.2 nm ($1s_5$-$2p_{10}$) which is detected with a silicon photocell. An rf magnetic field at several megahertz is applied to the absorption cell and changes in the transmitted intensity at resonance are observed.

Figure 1 shows the change in the optical absorption of the 640.2-nm radiation at the resonance condition obtained when the magnetic field is modulated slightly at 400 Hz and synchronously detected. Observation of the transmitted light at 703.2 nm yields a magnetic resonance signal of comparable strength but opposite phase. Consequently, the magnetic resonance signal is considerably weaker when the resonance radiation is viewed directly. The fractional change in the transmitted intensity is 10^{-3}.

The neon $^3P_2$ magnetic resonance linewidth is pressure dependent and ranged from 30 kHz at

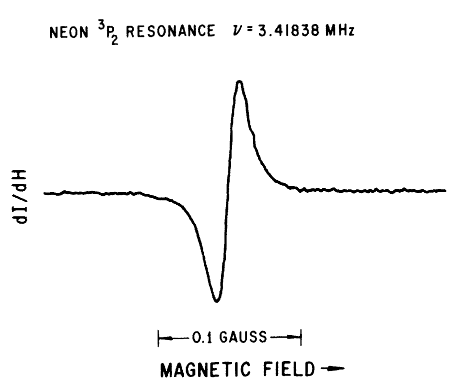

FIG. 1. Derivative of transmitted light intensity at 604.2 nm, with respect to magnetic field, versus field intensity. The lock-in time constant is 1 sec. Cell contains 0.01 Torr neon and 0.2 Torr helium.

a helium buffer gas pressure of 0.2 Torr to 85 kHz at 1.0 Torr at reduced rf field strengths. If we assume that the primary contribution to the linewidth at the higher pressure occurs as a result of collisions with the $^1S_0$ helium atoms, the disorientation cross section can be calculated from the relationship

$$\Delta\nu = 1/\pi\tau = \sigma v N/\pi,$$

where $\Delta\nu$ is the width of the resonance absorption signal at the half-maximum points in frequency units, τ is the mean time between depolarizing collisions, v is the relative velocity between the colliding neon and helium atoms, and N is the helium ground-state density. At room temperature we find $\sigma(\mathrm{Ne}^m\text{-He}) \leq 5.4\times10^{-17}$ cm^2. This must be regarded as an upper limit on the depolarization cross section since the effects of field gradients, Ne^m-Ne collisions, and the rf field were not taken into account.

The g factor can be determined from the magnetic resonance frequency and the magnetic field intensity. Sicne the cell used in this experiment contained helium, it is a simple matter to permit a small amount of helium resonance radiation at 1.083μ to align the metastable helium atoms. The location of the helium 2^3S_1 and $^3P_2$ resonances can then be observed in the same cell. From the ratio of the resonance frequencies at constant field and the measured g factor for metastable helium[8] we obtain $g_J = 1.501\,52 \pm 0.000\,64$ for the 2^3P_2 levels of neon, in good agreement with the value obtained by Lurio et al. using an atomic-beam resonance method.[9]

The results of this experiment suggest the possibility of optically pumping the other noble gas metastable atoms such as argon, xenon, and krypton. The use of isotopes having a nuclear spin would also permit the measurement of metastability-exchange cross section as well as a variety of other collisional effects and g factors.

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COLLISION-INDUCED LIGHT SCATTERING IN GASEOUS Ar AND Kr

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Light scattering attributable to a change in polarizability produced in colliding pairs of atoms is observed in gaseous Ar and Kr. The experimental results are qualitatively accounted for by relations between the integrated intensity and the collision-induced polarizability.

In a recent Letter, Levine and Birnbaum[1] discussed the scattering of light arising from the change in polarizability produced in a pair of atoms or spherical molecules by the distortion of the electronic structure during collision. This transient polarizability should scatter light into a broad frequency band whose width is related to the duration of collision and whose intensity should vary at low densities as the square of the density. Because the polarizability increment is anisotropic, it should depolarize the incident light although the isolated scatterers are spherically symmetric. In this Letter we report the observation of such scattering in gaseous Ar and Kr, and qualitatively account for the experimental results by relations between the integrated intensity and the spherical and anisotropic polarizabilities of the interacting pair.

Right-angle scattering was observed with the experimental geometry defined by a coordinate