Metastable Helium Atoms in Dense Helium Gas ◊

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Spinpolarized ^{3}He has become of great interest for NMR imaging of the lungs [1] and as a spin filter in neutron physics [2]. Samples of dense gas with at least atmospheric pressure are required for both applications. The most effective way for producing polarized ^3He, so far, is via optical pumping of Helium gas on the $2\,^3S_1 - 2\,^3P_1$ ($\lambda = 1083nm$) transition in a low pressure ($\simeq 1mbar$) discharge and subsequent compression of the gas. The discharge is used for collisional excitation of ground state $1\,^1S_0$ Helium atoms to the metastable $2\,^3S_1$ state.

In this report we describe a way which may avoid the complicated compressing of the gas by producing significant densities of metastable $2\,^3S_1$ Helium atoms for optical pumping directly at atmospheric pressure. Up to now experiments were performed using ^{4}He. Densities of Helium metastables on the order of $5\times10^{10}cm^{-3}$ could be observed using absorption spectroscopy on the 1083nm line [3]. A low energy (10keV) electron beam is sent through a thin (300nm) SiN$_x$ ceramic foil for collisional excitation of the dense Helium gas [4].

Excimer formation and collisional deexcitation by impurities have to be considered as loss processes at high gas densities. A schematic level diagram is shown in Fig.1. The formation rate of excimer molecules out of the $2\,^3S_1$ level has been studied by Köymen [5] and is e.g. $1.3 \times 10^{-33}cm^6/s$ at 500^{o}C. An estimate based on the maximum electron flux of $10^{17}/cm^2s$ which is possible with the entrance foils used, and extrapolating cross section data results in a metastable production rate on the order of $10^{18}/cm^3s$. This leads to a metastable density of more than $10^{11}/cm^3$ at atmospheric pressure.

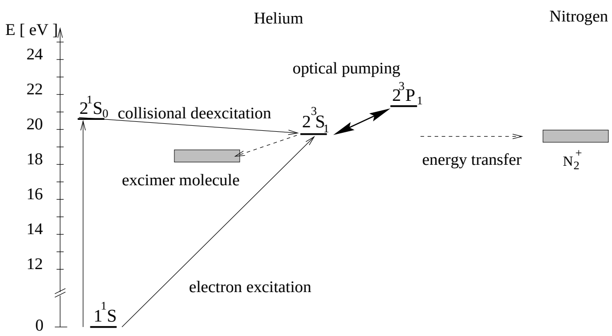

Fig. 1: Schematic level diagram

Deexcitation of metastable Helium atoms by impurities is dominated by Nitrogen due to an energy resonance of the He $2\,^3S_1$ state with the third vibrational level of the N_2^+ $B^2\Sigma_u^+$ molecular Nitrogen ion. This deexcitation process can be easily monitored by the B (v=0) to X (v=0,1) bands in N$_2^+$ around 390 and 430nm, respectively. The Helium gas was purified using an electrically heated Titanium wire which getters Nitrogen and Oxigen at about 800^{o}C. Using this purification technique, we were finally able to reduce the Nitrogen concentration to a level at which its molecular emission was negligible.

For a direct measurement of the metastable densities in the dense gas a 10keV, $200\mu A$ electron beam was sent through a rectangular $0.7\times 40mm^2$ SiN$_x$ entrance window into Helium gas (e-beam flux $\simeq 4.5\times10^{15}/cm^2s$). The Helium gas was contained in a stainless steel cell with optical windows for performing absorption experiments along the 40mm long region excited by the electron beam. Light from a low pressure Helium discharge lamp was sent through an optical chopper and the electron beam excited gas. The 1083nm line was selected using an interference filter in front of a Germanium photo diode detector. Absorption was measured using a lock-in technique thus suppressing 1083nm-light produced in the e-beam excited Helium gas.

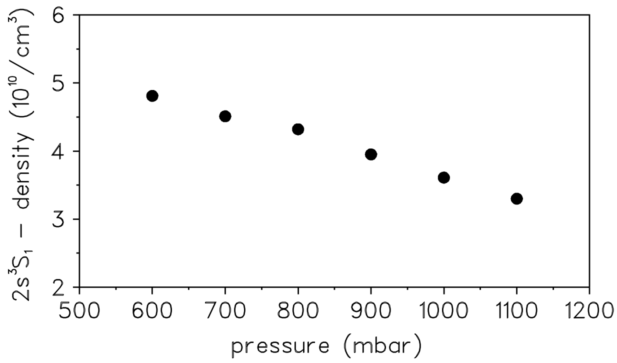

Fig. 2: Pressure dependence of Helium metastable densities. Absolute values are uncertain within a factor of 2 due to systematic error.

Typically 25% absorption was observed in the experiments. Data can be interpreted using Lambert Beer's law for calculating metastable densities. The photo-absorption cross section was estimated to $2.7 \times 10^{-12}cm^2$ with an error of 50% due to limited knowledge of the linewidths of the 1083nm line in the discharge lamp and the dense gas, respectively, both being $\simeq$ 2GHz due to Doppler broadening in the first case and pressure broadening in the latter. Note that this linewidth is small compared with the 10GHz spectral separation of the hyperfine components used for optical pumping [6]. Metastable densities obtained for various Helium gas densities are shown in Fig. 2.

References

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