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# Cross Sections for Polarization Relaxation of Excited Neon Atoms by Helium Atom Collisions: Disalignment and Disorientation

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## Abstract

Disorientation and disalignment of neon excited atoms in the fine-structure $2p_2$ (Paschen notation) level of the $2p^5 3p$ configuration have been investigated in a helium-neon glow discharge at temperatures between 17 and 300 K. The determined rate coefficients for disorientation, $R_{do}$, and disalignment, $R_{da}$, due to helium atom collisions show similar temperature dependences of $T^{1.6}$ below 77 K with the ratio about $R_{do} : R_{da} = 2 : 1$. This fact indicates that both the excitation transfer cross sections between the $m_J = 1$ and $m_J = -1$ states, $\sigma_{1-1}$, and between the $m_J = \pm 1$ and $m_J = 0$ states, $\sigma_{10}$, have similar energy dependences of $E^{1.1}$ with the ratio about $\sigma_{1-1} : \sigma_{10} = 2.5 : 1$ below 10 meV.



## Keywords:

alignment, orientation, neon, helium, collision, disalignment, disorientation, radiation trapping


Atomic polarization is expressed in terms of the irreducible tensor components of the atomic density matrix $\rho_q{}^k$. Recently, the group of the present authors reported the rate coefficients for disalignment, which is defined as the relaxation of the alignment $\rho_0{}^2/\rho_0{}^0$, of excited neon atoms in the $2p_2$ and $2p_7$ (Paschen notation) states of the $2p^5 3p$ configuration due to helium atom collisions using a discharge cell at temperatures between 15 and 650 K [1,2]. The experimental results were compared with the full quantum calculations of the disalignment cross sections [3] based on the model potentials [4]. Above 77 K, the theory and experiment were in excellent agreement, while the experimental rate coefficients showed a more rapid decrease with the decrease in temperature from 40 to 15 K than the theoretical results: the experimental temperature dependence was $\propto T^{1.6}$ for $2p_2$ and $\propto T^{0.9}$ for $2p_7$.

In the present note, we report our determination of the rate coefficient for relaxation of another polarization, the orientation, $\rho_0{}^1/\rho_0{}^0$.

The experimental set up is shown in Fig. 1. The pulsed laser light of 616.4 nm $(1s_3(J = 0) - 2p_2(J = 1))$ illuminates the discharge plasma. The temperature of the discharge cell is controlled by making the evaporated helium gas from liquid helium flow through the temperature control layer surrounding the discharge channel. The Helmholtz coils produce a magnetic field of 36.4 Gauss in the direction perpendicular to the paper. The partial pressure of the neon gas is 0.05 torr and helium is added to change the helium atom density. The excitation laser light is linearly or left-circularly polarized, so that in the former case only the $m_J = 0$ magnetic sublevel is excited and alignment is produced, and in the latter case, $m_J = 1$ is excited and orientation is produced. The fluorescence of the 659.9 nm $(1s_2(J = 1)-2p_2(J = 1))$ transition line is observed with its polarized components resolved. In the former case, a liner polarizer resolves the $\pi$ and $\sigma$ components, and in the latter case the combination of the polarizer and the quarter-wave plate resolves the $\sigma_+$ and $\sigma_-$ components. Figure 2 shows examples of the results; (a) is for the former case and (b) for the latter. In the former, the $\sigma$ component is strong, but the $\pi$ component appears. In the latter, the right- and left-circularly polarized components show the oscillatory decays; the oscillations are due to the Larmor precession of the orientation and the decay is due to disorientation.

From Fig. 2 we deduce the temporal developments of the longitudinal alignment $A_L = (I_\pi - I_\sigma)/(I_\pi + 2I_\sigma)$, which is proportional to the alignment $\rho_0{}^2/\rho_0{}^0$, as shown in Fig. 3 (a), and the orientation signal $(I_R - I_L)/(I_\pi + 2I_\sigma)$, which is proportional to the orientation $\rho_0{}^1/\rho_0{}^0$, Fig. 3 (b). From the fitted line or decaying sine curve, we deduce the decay rate. Figure 4 shows the results; in this figure, the observed rates have been subtracted by the relaxation rates due to radiation reabsorption [5]. Similar measurements are done for varying helium atom density, and the results are summarized in

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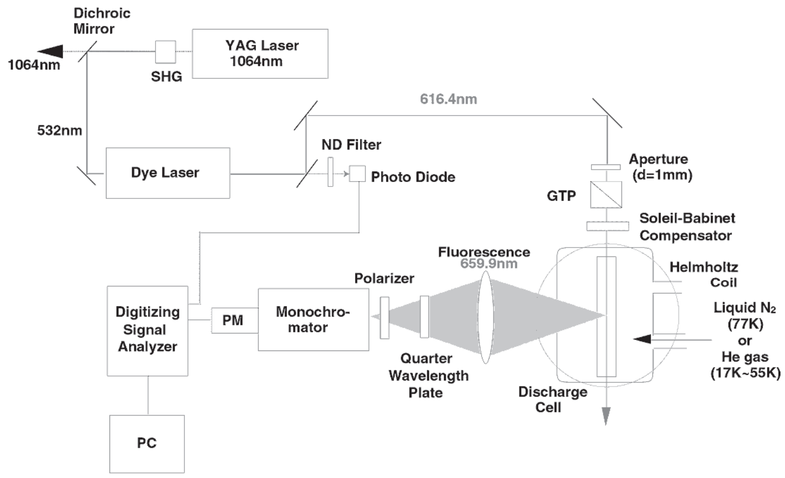


Fig. 1 A schematic diagram of the experimental setup. SHG: second harmonic generator, GTP: Glan-Thompson prism, ND Filter: neutral density filter, PM: photomultiplier and PC: personal computer.

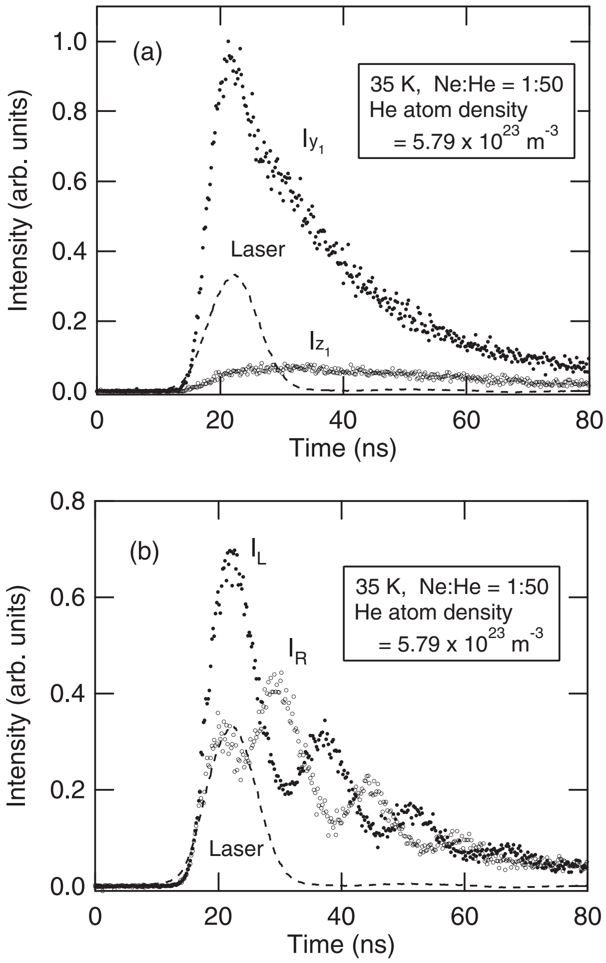


Fig. 2 Examples of the observed fluorescence line ($1s_2$ - $2p_2$) intensities with the polarized components resolved (a) subsequent to $\pi$ light excitation of the $1s_2$ - $2p_2$ transition, and (b) subsequent to the left-circularly polarized light excitation. The temperature is 35 K and the ratio of the partial pressures between neon and helium is 1: 50 with the neon partial pressure of 0.05 torr measured at room temperature. The time origin is arbitrary.

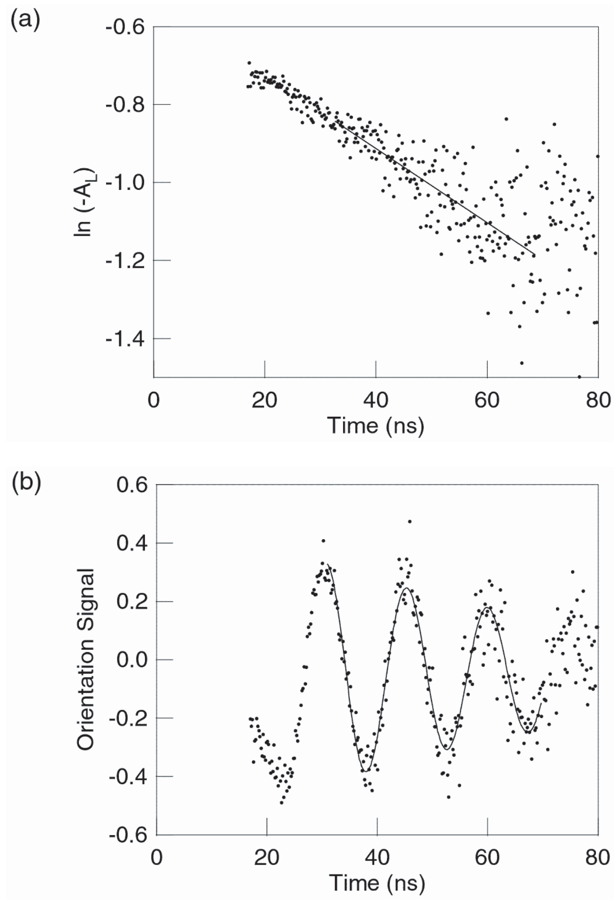


Fig. 3 The temporal development of (a) the longitudinal alignment and (b) the orientation signal.

Fig. 4. A line is fitted to the experimental points, where the intercept is assumed zero. This is because the relaxation rates due to residual neon atom collisions are known to be negligibly small. We obtain the rate coefficients for this particular temperature. By changing the atom temperature, we followed a similar procedure.

The rate coefficients against atom temperature are plotted in Fig. 5. It is seen that the rate coefficients for

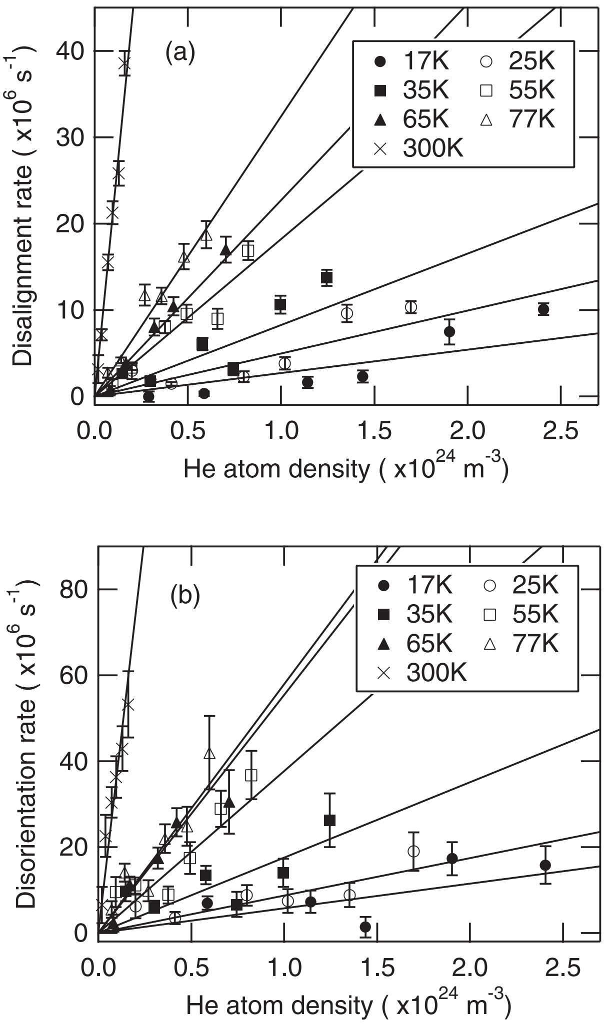


Fig. 4 Experimental values for (a) the disalignment rate, and (b) the disorientation rate of the $2p_2$ state of neon as a function of the helium atom density. The effect of the radiation reabsorption has been separated [5]. The solid lines show the results of the linear fit within the least-squares method with the null intercept for each temperature.

disorientation, $R_{do}$, and disalignment, $R_{da}$, show similar temperature dependences of $T^{1.6}$ below 77 K with the ratio about $R_{do} : R_{da} = 2 : 1$. This fact indicates that both the excitation transfer cross sections between the $m_J = 1$ and $m_J = -1$ states, $\sigma_{1-1}$, and between the $m_J = \pm 1$ and $m_J = 0$ states, $\sigma_{10}$, have similar energy dependences of $E^{1.1}$ with the ratio about $\sigma_{1-1} : \sigma_{10} = 2.5 : 1$ below 10 meV. Intuitively speaking, the $m_J = 1 \to 0$ transition is a rotation of the atomic angular momentum by 90°, and the $m_J = 1 \to -1$ transition is that by 180°. Thus, the relative magnitudes of these cross sections pose a puzzle.

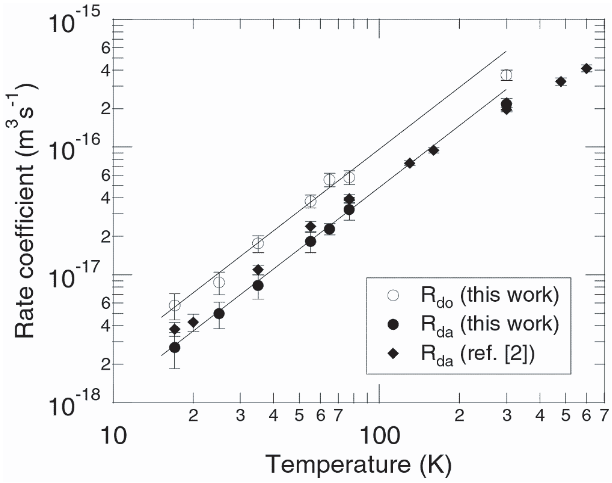


Fig. 5 The disorientation rate coefficient (open circles) and the disalignment rate coefficient (close circles) from the experiment for $Ne^*(2p_2)$+He collisions as a function of temperature. The experimental disalignment in the previous work [2] are also plotted. The two solid lines show the $T^{1.6}$ dependence of the rate coefficient with the ratio 2:1 for the guide for the eye.

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