

Estimation of CaH density in cell

In our experiment, we observed 10% absorption of CaH in a 6K cell. We would like to know what the CaH density is.

$$I = I_0 e^{-n\sigma z}, \quad (1)$$

where I is the intensity of laser passing through the cell, I_0 is the original intensity of laser, n is the CaH density, σ is the absorption cross section, and z is the length of the cell.

Since the interaction length, z , is set by the cell size, we only need to evaluate the absorption cross section, σ , in order to estimate the density.

From eq. (29) in [2], we learn

$$\sigma(\omega) = \frac{1}{4}(g_2/g_1)\lambda^2 g(\omega)A_{21}, \quad (2)$$

where g_1 and g_2 are the degeneracy factors of the two levels, λ is the transition wavelength, $g(\omega)$ is the line shape function, and A_{21} is the Einstein A coefficient.

The nature linewidth of CaH, 2.2 MHz, is much smaller than the doppler linewidth of CaH at 6K, which is 118 MHz. We can use doppler line shape for $g(\omega)$ in (2).

$$g(\omega) = \frac{1}{\sqrt{\pi}\Gamma} e^{-\frac{(\omega-\omega_0)^2}{\Gamma^2}}, \quad (3)$$

where Γ is given by

$$\Gamma = \frac{2\pi}{\lambda} \sqrt{\frac{2k_B T}{m_{CaH}}}. \quad (4)$$

Our laser was locked to stabilized He-Ne via a Fabry Perot cavity, so we can assume our laser frequency is half of the nature linewidth away from

resonance. Now, let's calculate absorption cross sections first. For $\lambda = 695$ nm, $A_{21} = 14.3 \times 10^6$ (s⁻¹) [1], nature linewidth, $\gamma = 2\pi \times 2.3$ MHz (note: we use angular frequency here),

$$\begin{aligned}\sigma(\omega = \omega_0 + \gamma/2) &= \frac{1}{4} \lambda^2 \frac{1}{\sqrt{\pi}} \frac{\gamma}{\Gamma} e^{-\frac{1}{4} \frac{\gamma^2}{\Gamma^2}} \\ &= 2.2 \times 10^{-11} \text{cm}^2.\end{aligned}\tag{5}$$

From Eq.(1) and Eq.(5), we can compute the density of CaH.

$$\begin{aligned}\frac{I}{I_0} &= 0.9 = e^{-\sigma(\omega=\omega_0+\gamma/2)nz} \\ \Rightarrow n &= 9.5 \times 10^8 \simeq 10^9 (1/\text{cm}^3),\end{aligned}\tag{6}$$

where we use $z = 5$ cm.

References

- [1] M.D. Di Rosa. Laser cooling of molecules. 2004.
- [2] R.C. Hilborn. Einstein coefficients, cross sections, f values, dipole moments, and all that.