Intracavity Far Infrared Laser Magnetic Resonance (LMR) spectroscopy has been shown to be a sensitive method for obtaining high resolution spectra of free radicals and metastable atoms and molecules. Using this technique direct measurements of the fine structure transitions in atomic oxygen, carbon, and silicon produced in electric discharges or flames have recently yielded accurate fine structure splittings and g-factors for the atomic levels involved. We report here a similar study of the metastable $^3P$ state of magnesium. The high resolution obtainable by LMR has permitted the determination of accurate g-factors for both the $^3P_1$ and $^3P_2$ states, as well as an improved value for the $^3P_1-^3P_2$ separation.

Accurate values for atomic g-factors have traditionally provided a critical test of the theory of atomic magnetism. Recent work has shown fairly large differences between the theoretical and experimental values for the g-factors of a number of atomic systems, the origins of which do not appear to be firmly established. Thus, additional data of this nature for a variety of systems would appear valuable.

The details of the far infrared LMR spectrometer have been given elsewhere. Briefly, it consists of a far-infrared gain cell pumped transversely by a grating tuned CO$_2$ laser, and separated from the intracavity sample region by a polypropylene beam splitter mounted at Brewster angle to the FIR laser cavity. The sample region is placed between the ring-shimmed Hyperco 38 cm pole caps of an electromagnet producing a homogeneous field region 7.5 cm in diameter.

A stable source of the $^3P$ state of magnesium consisted of a resistively heated titanium oven through which a steady flow of argon was maintained to entrain the metallic vapor. The total pressure in these experiments was held between 80 and 133 Pa (1 Torr = 133.322 Pa), and the magnesium atoms were excited to the metastable state before entering the laser cavity by a hot cathode discharge operated at about 3 mA.

Several near coincidences with known FIR lasing lines permitted two independent observations of both the $^3P_0-^3P_1$ and $^3P_1-^3P_2$ transitions, as summarized in Fig. 1.

For the first of these, the $M_J=0-M_J=+1$ and $M_J=0-M_J=-1$ components were tuned into resonance with the 602383.9 MHz and 598893.7 MHz lines of CD$_2$F$_2$ respectively. The $^3P_1-^3P_2 (AMJ = \pm 1)$ transitions were observed using the 1208313.9 MHz line of CD$_2$F$_2$ and the 1236396.8 MHz line of CH$_3$OH. In this case, the spectra appear as closely spaced (but well resolved) triplets due to the $M_J$ dependence of the quadratic Zeeman coefficients. The spectrum taken using the 1208313.9 MHz line of CD$_2$F$_2$ is shown in Fig. 2.

The data may be fit using an energy level expression of the form

$$W(J,M_J) = W_0(J) + u_B g_J M_J + C(J,M_J) S^2$$

where $u_B$ is the Bohr magneton, $W_0(J)$ is the zero-field energy of the $^3P_J$ state, $g_J$ is the g-factor for that state, and $C(J,M_J)$ are the second order Zeeman coefficients, which have been given elsewhere. Since the zero field value for the $^3P_0-^3P_1$ separation is very well known, its value was constrained, and the data were used to obtain $g_1$, $g_2$, and $v_{12} = \sqrt{W_2(2) - W_2(1)}$. The resulting preliminary values are $g_1 = 1.50117(27)$, $g_2 = 1.50115(41)$, and $v_{12} = 1220575 \pm 2.6$ MHz $= 40714.00(8)$ cm$^{-1}$. It is seen that to within the estimated experimental uncertainty, $g_1 = g_2$. The value of $v_{12}$ obtained is seen to agree well with the previously reported value of 40714 cm$^{-1}$ but is seen to be significantly more accurate.

References

Fig. 1 Observed transitions of $^3P$ Mg; a) 602383.9 MHz CD$_2$F$_2$; b) 598893.7 MHz CD$_2$F$_2$; c) 1208313.9 MHz CD$_2$F$_2$; d) 1236396.8 MHz CH$_3$OH; curvature due to 2nd order Zeeman effect has been exaggerated for clarity.

$\text{Mg}\left(^3P_1 \rightarrow ^3P_2\right)$

Fig. 2 The $^3P_1 \rightarrow ^3P_2$ transition of magnesium observed using the 1208313.9 MHz lasing line of CD$_2$F$_2$. 