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FAR INFRARED LASER MAGNETIC RESONANCE OF METASTABLE (^3P) Mg

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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[1], carbon[2], and silicon[3] 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[3], 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.[4] 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 $M_J=0 \to M_J=+1$ and $M_J=0 \to M_J=-1$ components were tuned into resonance with the 602383.9 MHz and 598893.7 MHz lines of CD_2F_2 respectively. The $^3P_1$-$^3P_2$ ($\Delta M_J = \pm 1$) transitions were observed using the 1208313.9 MHz line of CD_2F_2 and the 1236396.8 MHz line of CH_3OH. 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_2F_2 is shown in Fig. 2.

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

$$W(J,M_J) = W_0(J) + \mu_B g_J M_J B + C(J,M_J)B^2$$

where μ_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[2]. Since the zero field value for the $^3P_0$ - $^3P_1$ separation is very well known[5], its value was constrained, and the data were used to obtain g_1, g_2, and $\nu_{12} = W_0(2)-W_0(1)$. The resulting preliminary values are $g_1 = 1.50117(27)$, $g_2 = 1.50115(41)$ and $\nu_{12} = 1220575 \pm 2.6$ MHz = 40714.00(8) cm^{-1}. It is seen that to within the estimated experimental uncertainty, $g_1 = g_2$. The value of ν_{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

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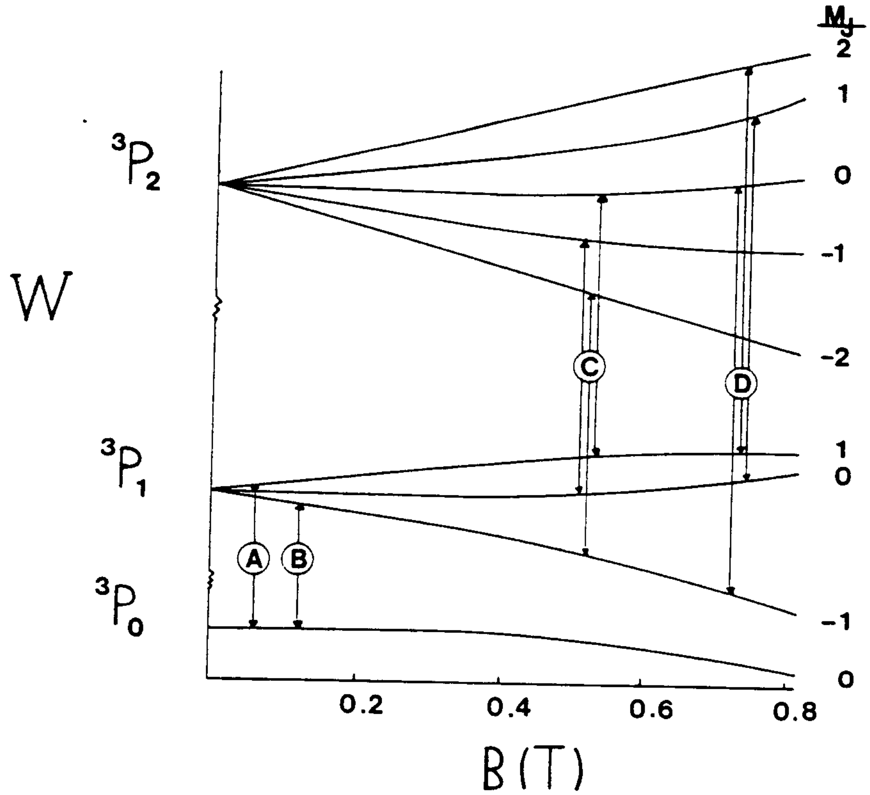

Fig. 1 Observed transitions of ^3P Mg; a) 602383.9 MHz CD_2F_2; b) 598893.7 MHz CD_2F_2; c) 1208313.9 MHz CD_2F_2; d) 1236396.8 MHz CH_3OH; curvature due to 2nd order Zeeman effect has been exaggerated for clarity.

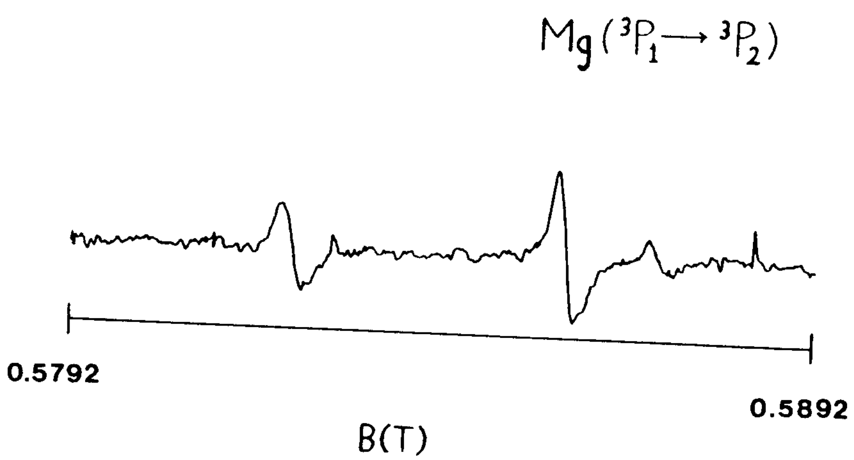

Fig. 2 The $^3P_1 \rightarrow {}^3P_2$ transition of magnesium observed using the 1208313.9 MHz lasing line of CD_2F_2.