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Rotational Magnetic Moment of OCS

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The first-order molecular Zeeman effect on the $J=0\rightarrow J=1$ and $J=1\rightarrow J=2$ rotational transitions in OCS is measured by using high-resolution microwave techniques. The g value obtained for the $J=0\rightarrow J=1$ transition gives the g value for the $J=1$ rotational state. The value is $g=-0.02851\pm0.0004$. The g value obtained for the $J=1\rightarrow J=2$ transition is an average g value for the $J=1$ and $J=2$ states. The result is $g=-0.02915\pm0.0005$. The results are in good agreement with the molecular beam work.

I. INTRODUCTION

THE rotational magnetic moment of OCS has been measured several times by microwave spectroscopy[1-4] and more recently by molecular beams.[5] The most accurate microwave value was obtained from the $J=1\rightarrow J=2$ transition in OCS by Eshbach and Strandberg.[3] Their results give $g=-0.0251\pm0.002$ which is an average g value over the $J=1$ and $J=2$ rotational states. Their number is within experimental error of all of the other microwave measurements. It is well known that molecular g values have a small dependence on the rotational angular momentum owing to centrifugal distortion as has been demonstrated experimentally in NH_3.[3] Thus, the only microwave transition which gives a g value for a single rotational state is the $J=0\rightarrow J=1$ as the $J=0$ state is not perturbed by the magnetic field. A microwave Zeeman effect experiment on the $J=0\rightarrow J=1$ transition has apparently not been performed. Cox and Gordy[4] have measured the g value in OCS for several high-J states and they were not able to obtain any J dependence in the g value. However, their experimental error was much higher than either Jen's or Eshbach and Strandberg's.

Recently Cederberg, Anderson, and Ramsey[5] have measured the g value of OCS at room temperature using molecular beam techniques. Their measured value of $g=-0.02889\pm0.00002$ is not in agreement with the value of -0.0251 ± 0.002 given by Eshbach and Strandberg.[3] As the two measurements are basically different it is important to determine whether the discrepancy is real or due to the different types of averaging. It is easy to show that at room temperature the J state in OCS having the highest population is $J=22$. Thus, the molecular beam method, while highly accurate, is a rotational average including well over 22 rotational states. The microwave method, while not so accurate, is a more specific measurement as it can measure the g value for a specific pair of states (or a single state in the case of the $0\rightarrow1$ transition).

In order to shed more light on the above questions, we have remeasured, with higher accuracy, the molecular Zeeman effect by the microwave method on the $J=1\rightarrow J=2$ transition. We have also measured the Zeeman effect of the $J=0\rightarrow J=1$ transition. The first-order correction to the rotational energy levels of a linear molecule in the presence of a magnetic field is well known. The result is

$$E=-\mu_N M H_z g_{bb}, \tag{1}$$

where μ_N is the nuclear magneton, M is the projection of the rotational angular momentum, J, on the space-fixed z axis, H_z is the external magnetic field along the z axis, and g_{bb} is the molecular g value along the b axis perpendicular to the internuclear axis.

II. EXPERIMENTAL RESULTS

Recent g-value determinations[6,7] on OCF_2 and $HC\equiv CF$ in this laboratory have shown the ability to measure g values with higher accuracy than the earlier work,[1-4] and the same apparatus is used in this work.

A Varian electromagnet Model V-4012-3B with pole diameter 11.9 in. and pole gap of 2.25 in. was used in these experiments. The maximum magnetic field obtainable was about 11 kG with the field being measured with a Perkin-Elmer Model M-2 precision gaussmeter. The ^7Li resonance was monitored directly on a frequency counter throughout the experiment giving rise to a highly accurate field measurement. The inhomogeneity of the field inside the region 1 in. from the edge of the magnet poles is less than 1%.

As $\Delta m=0$ transitions in the $J=0\rightarrow1$ transition would show no splitting [see Eq. (1)], the long dimension of the guide was placed parallel to the magnetic field leading to $\Delta m=\pm1$ transitions. As the dominant mode of transmission in the waveguide is the $TE_{1,0}$ mode, the electric field of the radiation is perpendicular to the static magnetic field giving rise to $\Delta m=\pm1$ transitions and a doublet in the $J=0\rightarrow J=1$ and $J=1\rightarrow J=2$ spectra. The microwave gear was as-

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sembled around the 8-in. microwave cell, and the transition was observed in the absence of the field with a half-width at half-height of about 15 kc/sec. The magnetic field gave rise to the expected doublet with splitting equal to $2\mu_N H_z g_{bb}$ as given in Eq. (1). All measurements were taken at dry-ice temperatures.

The results of a series of measurements on the $J=0\rightarrow J=1$ and $J=1\rightarrow J=2$ transitions gives:

$J=0\rightarrow J=1$

$$\left|\frac{\Delta\nu}{2\mu_N H_z}\right| = g_{bb} = |0.02851\pm0.0004|\,,$$

$J=1\rightarrow J=2$

$$\left|\frac{\Delta\nu}{2\mu_N H_z}\right| = g_{bb} = |0.02915\pm0.0005|\,.$$

The signs are negative as determined previously.[3] Although the value for the $J=0\rightarrow J=1$ appears less than the average in $J=1\rightarrow J=2$, the two values are identical within experimental error. Both values are also, within experimental error, identical to the value obtained by Cederberg, Anderson, and Ramsey.[5] Our value for the $J=1\rightarrow J=2$ transition also disagrees with the result of $g=0.025\pm0.002$ of Eshbach and Strandberg.

It appears that the microwave and molecular beam results are now in good agreement in the measurement of the molecular magnetic moment in OCS. It appears somewhat surprising, however, that the molecular beam measurement does not give rise to a different g value due to the average obtained over the large number of rotational states populated at room temperatures.

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Rare-Gas Collision Broadening in the Lowest $^3P_1$ Level of Cd

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Alignment depolarization collision cross sections have been measured for the lowest $^3P_1$ level of cadmium broadened by the rare gases. Cross sections obtained with the Hanle effect (zero-field level crossing) and the method of modulated-light double resonance are the same within approximately 5%. They agree with theoretical predictions except in the case of helium, for which the measured cross section is nearly twice as large as the theoretical value. Average experimental values (units of 10^{-16} cm^2) for He, Ne, Ar, Kr, and Xe, respectively, are 51, 52, 81, 118, and 165.

I. INTRODUCTION

Accurate width measurements of upper electronic levels of optical transitions can be obtained without optical frequency Doppler broadening through use of the Hanle effect[1,2] (zero-field level crossing) and the recently developed method of modulated-light double resonance.[3,4] In the present investigation the cadmium $^3P_1$-$^1S_0$ intercombination line (3261 Å) has been observed for measurement of alignment depolarization cross sections for the $^3P_1$ level broadened by collisions with the rare gases helium, neon, argon, krypton, and xenon.

Observation of this cadmium level is advantageous since the level width is small (approximately 70 kc), allowing measurement of small collision frequencies. Also, the $^3P_1$ level has low excitation energy (3.8 eV) and is well separated from other cadmium energy levels. Thus, bombardment with electrons of nominal energy spread can produce excitation to this level without excitation of other cadmium levels or of gas atom levels. This eliminates cascade effects and ensures that collisions are with ground-state rare gas atoms.

The Hanle effect has been used for these measurements with both resonance fluorescence and electron excitation. The modulated-light technique has been used only with electron excitation. It was of interest to obtain a comparison of cross sections measured with the two methods since the observed levels are degenerate for the Hanle effect and well resolved for the modulated-light technique.

II. THEORY

The Hanle effect is a variation in the polarization of emitted light as a function of magnetic field strength H,

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