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Zeernan Effect in NO,

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Abstract We measured the gyromagnetic factors of the molecule NO_2, in the Zeeman Effect, under high resolution spectroscopy. We gotthevalues 0.103±0.007; 0.060±0.005 and 0.045±0.004 for the components a, β and γ respectively, by applying a magnetic field of 40 Gauss. For fields greater than 1 kilogauss we observed decouplIng of the electronic spin to the rotational angular momentum of the molecule. Under this condition we obtained for the gyromagnetic factor the value 1.86±0.25.

1. INTRODUCTION

Polyatomic molecules have in general smaller magnetic dipole moments than simpler molecules or even atoms. This is a result of the coupling of the several angular momenta of the atoms constituentsofthe molecule.

This coupling, nevertheless, can be changed in the presence of strong magnetic fields, because all the momenta align along the $\vec{B}$ direction. In particular, the electronic spin no longer couples to the rotational angular momentum of the molecule as in the case of the NO. Using the technique of high resolution spectroscopy, free from Doppler Effect and Zeeman Effect, we determined several gyromagnetic factors of the NO_2 molecule for weak and strong magnetic fields.

2. EXPERIMENTAL ARRANGEMENT

In order to prevent the Doppler Effect from the absorption spectra, we excited a molecular beam of NO_2 with the line 514.5 nm of an ion Ar laser perpendicularto the molecular beam velocity. The observation direction of the absorption spectra had the same direction as the molecular velocity. The whole apparatus was described by R. Schmiedl[1]

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et *al*. An etalon was inserted inside the resonance cavity of the laser in such a way that by tilting it we could change the output laser frequency in a range of 7 Gigahertz around the fundamental line 514.5 nm.

3. RESULTS AMD DISCUSSIONS

With the elimination of the Doppler Effect, the absorption linewidths were reduced to some MHz, and several absorption peaks were clearly seen in the total scanned range of 7 GHz, as can be seen in figure 1.

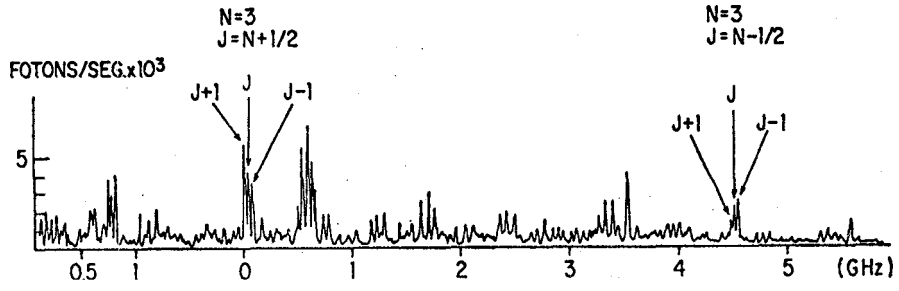

Fig.1 - High resolution absorption spectra of NO in a frequency range of 7 GHertz around the 514.5 nm ernission line of an Argon ion laser. Two sets of absorption lines in the transition N' = 3→4 (rotational quantum number of the molecule) between states having parallel and anti-parallel spins are indicated. The a, β and γ components refer to $J+1$, J and J-1 respectively.

This absorption spectra corresponds to a transition between the fundamental $^2A_1$ and the excited electronic $^2B_2$ states of the NO, molecule. According to the measurements of F. Paech[2] et *al*, this absorption also shows small contributions from the $^2B_1$ (it has a decay half-life of 30 μs which is shorter than 105 μs of the $^2B_2$ state). Some of the absorption peaks shown in Figure 1 belong to transitions between levels of known rotational quantum number N. For example, the transition N = 3→4 between levels of parallel and antiparallel spins shows six peaks corresponding to $J+1$, J and $J-1$. The components of $J = N \pm 1/2$ have an energy difference of approximately 4.5 GHz. These quantum numbers

have been determined by R. Schmiedl[1] et al. Figure 1 shows in addition several absorption peaks corresponding to transition between higher rotational angular momenta. By adiabatic cooling of the molecular beam it is possible to eliminate the majority of these high rotational angular momentum absorption peaks between the components mentioned above. The cooling process was described by Bonilla and Demtröder[3]. The simplified absorption spectra after cooling is shown in Figure 2. It is observed that between the two mentioned sets, only four components corresponding to the transitions $8_{44} \rightarrow 9_{4K}$ and $5_{14} \rightarrow 6_{K-K+}$ renain. (Only four components are distinguished because the a and β lines of the transition $8_{44} \rightarrow 9_{4K}$ are superposed to the β and γ of the transition $5_{14} \rightarrow 6_{K-K+}$. See R. Schmiedl[1] et al.).

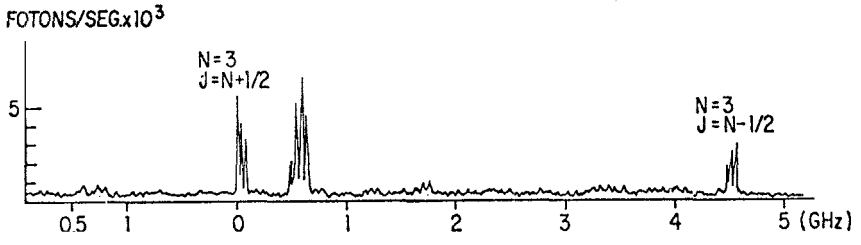

Fig. 2 - The absorption spectra of NO_2 in the same frequency range of Fig.1, after adiabatic cooling of the molecular beam. Only levels with low rotational quantum numbers remain.

In figure 3 the three hyperfine components a, β and γ of the absorption $3_{13} \rightarrow 4_{14}$ ($J = N+1/2$) are shown in detail after adiabatiç cooling. We obtained the value of 8.12 MHz for the measured linewidth of the transitions. The linewidth is experimentally limited by the residual component of the velocity perpendicular to the molecular beam, since the solid angle of the collected light was 0.02 sterorad. ($f/6$). These three components result from the hyperfine interaction of the nuclear momentum $I = 1$ of the nitrogen nucleus. It is a strong interaction, since for magnetic fields up to 2.25 kGauss we did not observe any deccupling.

By applying a magnetic field, these hyperfine lines first showed a broadening for each of the components. At a field of 40 Gauss

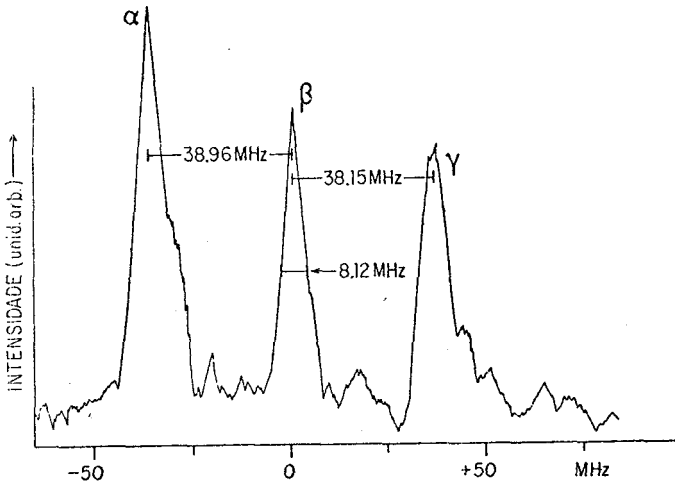

Fig. 3 - The three hyperfine components a, β and γ of the transition $3_{13} \rightarrow 4_{14}$. This results from the coupling of the rotational quantum number of the molecule, to the nuclear spin $I = 1$ of the nitrogen nucleus. The linewidth free from Doppler effect and adiabatically cooled .is about 8.12 MHz, due to the saall perpendicular component of the molecular beam velocity.

there is an overlap of the 24 components, as can be seen from Figure 4. From this data, and from the values of Figure 3, we calculated the difference between the gyromagnetic factors of the excited and fundamental states to be

$$0.103 \pm 0.007; \quad 0.060 \pm 0.005 \quad \text{and} \quad 0.045 \pm 0.004$$

for a, β and y, respectively.

For magnetic fields higher than 1 KGauss weobserveddecoupling between electronic spin and rotational angular momentum. The momentum of the NO, molecule becomes the electronic spin 1/2.

From the splitting of these two components ($J = \pm 1/2$), by increasing the magnetic field (Fig. 5), we measured thegyromagneticfactor g = 1.8620.25. The splitting of the other lines were omitted for the sake of clarity.

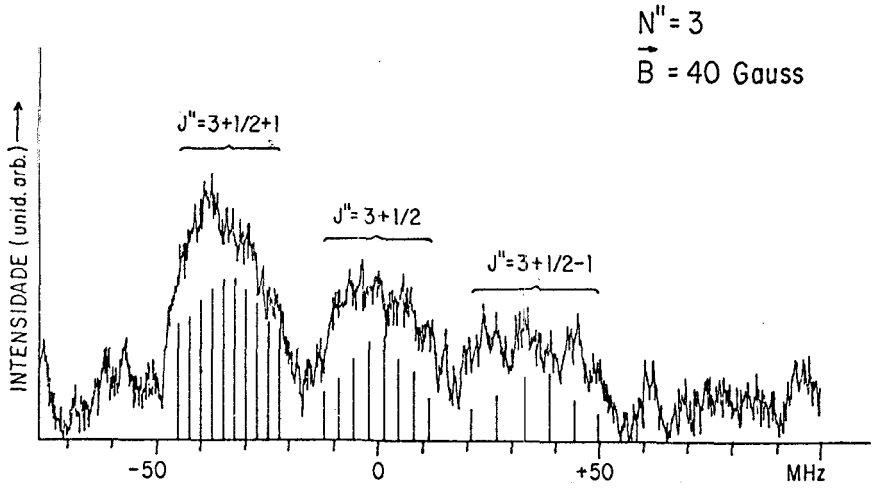

Fig.4 - Under a magnetic field of 40 Gauss, the $2J+1$ lines of the a, β and γ components completely overlap, since the natural line-width becomes greater than the line separations, for thetransition $3_{13} \rightarrow 4_{14}$.

Brown[4] and others measured this *g* factor for the same transition with higher accuracy by optic microwave double resonance and reported the value of 1.99984. The accuracy discrepancy between these measurements is because magnetic field strength of *2.25* kGauss that we worked at is not strong enough to completely decouple the spin and the rotational angular momentum. This is justified by observing that the energy difference of 4.5 GHz between parallel and antiparallel coupling at $\vec{B} = 0$ is larger than the splitting energy at 2.25 kGauss. W. Hüttner[5] made both a theoretical analysis of the Zeeman Effect in NO, and some measurements on the transition $8_{08} \rightarrow 7_{17}$ for fields up to 22 kGauss.

The measured lines are π components confirming the selection rule $\Delta M_S = \Delta M_I = 0$.

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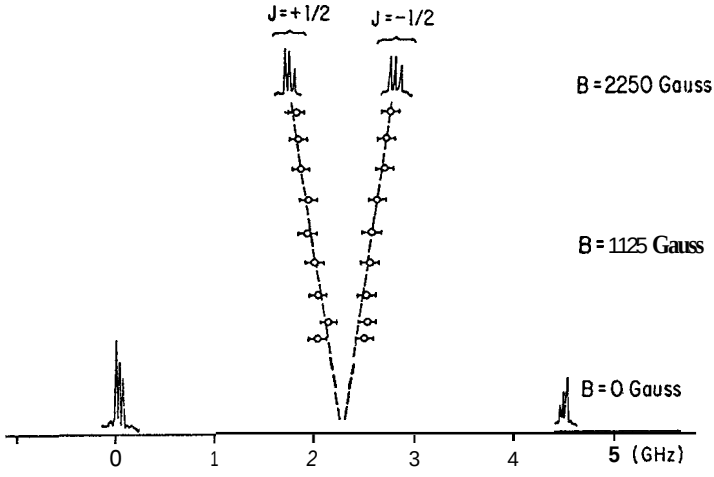

Fig.5 - Energy splitting of the two components of the molecular spin of NO_2 in the transition $3_{13} \rightarrow 4_{14}$ under higher magnetic fields. Without magnetic field (bottom of the figure), the spin couples to the rotational angular momentum of the molecule. This coupling is clearly destroyed for magnetic field strength greater than 1 kGauss. The splitted spectra for the remainder peaks located between these we have discussed, are omitted for the sake of simplicity.

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Resumo

Usando a técnica de espectroscopia de alta resolução, medimos através do Efeito Zeeman, os fatoras giromagnéticos da molécula NO_2, para campus magnéticos fracos até 40 Gauss, que mantêm o acoplamento entre o spin eletrônico e o momentum angular rotacional da molécula, encontrando os valores 0.103±0.007; 0.60±0.005 e 0.045±0.004 para os componentes α @ y respectivamente e o valor g = 1.86±0.25 para campos magnéticos fortes acima de 1 kilogauss, onde houve desacoplamento.