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ACCURATE FREQUENCIES BELOW 5 GHz OF THE LOWER *J* STATES OF OD

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ABSTRACT

The hyperfine Λ-doubling transitions of the low-*J* states of OD were measured, using the molecular beam electric-resonance technique. These measurements are used to calculate some other transitions of OD, which might also be of interest for radio astrophysics.

Subject headings: hyperfine structure — molecules — radio lines

In 1955 Dousmanis, Sanders, and Townes (1955) reported the first measurements of the microwave Λ-doubling transition frequencies of OD. The observed frequencies were those belonging to the $\Delta F = 0$ transitions in the $^2\Pi_{3/2}$ and $^2\Pi_{1/2}$ electronic states. The hyperfine splitting of the transition was well resolved in the latter state but not in the $^2\Pi_{3/2}$ state. Consequently these lines contain almost no information about the hyperfine structure of OD. Some of the hyperfine-structure constants of OD can be predicted, however, from the corresponding values of OH reported by Radford (1962) and the ratio of the nuclear g-factors of proton and deuteron. Because of the rather large uncertainties of the frequencies measured by Dousmanis *et al.* (1955), it is not possible to predict the transitions in the low-lying J-states of OD with an accuracy better than 2 MHz, using this approach. It is felt that more precise transition frequencies are needed to increase chance of detecting the presence of the OD radical in interstellar space.

We measured all the hyperfine Λ-doubling transitions below 5 GHz originating in the lower J states of the electronic states $^2\Pi_{1/2}$ and $^2\Pi_{3/2}$. The measurements were performed using the molecular-beam electric-resonance method. The OD radicals are produced by the reaction $D + NO_2 \rightarrow OD + NO$ (Del Greco and Kaufman 1962). The atomic deuterium was produced by a 2.45-GHz microwave discharge in D_2O. The Earth's magnetic field is reduced by careful screening and compensation to about 5 milligauss. The signal-to-noise ratio of the observed transitions varied from 5 to 25 with an RC time of 3 s. The full line width at half-height was in the order of 10 kHz for most transitions. The experimental accuracy of the frequencies varied from 0.2 to 3 kHz and was mainly determined by the signal-to-noise ratio. The observed frequencies correspond to the $\Delta J = 0$; $\Delta F = 0, \pm 1$; Λ-doubling transitions between states with different Kronig symmetries. They are tabulated in table 1.

The theory developed in the previous paper (Meerts and Dymanus 1972) for a diatomic molecule in a $^2\Pi$ state is used to explain the observed spectrum. The molecular constants defined herein are calculated using a least-squares fit of our experimental frequencies and those of Dousmanis *et al.* (1955), weighted with their experimental uncertainties. As can be seen from table 1, the agreement is quite good. The molecular constants, which are varied in this fit, are those discussed in the previous paper (Meerts and Dymanus 1972); in addition, the spin-orbit coupling constant A_π is calculated. The values obtained for the hyperfine structure constants are given in table 2. Their definitions are those of Frosh and Foley (1952) and are also given by Meerts and Dymanus (1972). By using the molecular constants, obtained from the least squares fit, we calculated frequencies of a number of transitions of OD

TABLE 1

OBSERVED AND PREDICTED HYPERFINE Λ-DOUBLING TRANSITIONS OF THE OD RADICAL

Electronic State	J	F_+*	F_-	Observed Frequency (MHz)	Observed minus Predicted Frequency (kHz)
$^2\Pi_{1/2}$	0.5	0.5	0.5	3093.6057(10)	+0.4
		1.5	1.5	3111.1414(10)	+0.5
		0.5	1.5	3090.2163(10)	−0.3
		1.5	0.5	3114.5294(10)	−0.3
$^2\Pi_{3/2}$	1.5	0.5	0.5	310.1445(5)	+0.4
		1.5	1.5	310.2147(5)	+0.7
		2.5	2.5	310.3627(10)	+0.4
		1.5	0.5	303.0320(20)	+0.3
		0.5	1.5	317.3290(40)	+2.6
		2.5	1.5	298.0970(10)	0.0
		1.5	2.5	322.4800(20)	+0.6
$^2\Pi_{3/2}$	2.5	1.5	1.5	1190.5659(2)	0.0
		2.5	2.5	1190.7741(2)	0.0
		3.5	3.5	1191.1047(2)	+0.1
		1.5	2.5	1186.9986(30)	−1.5
		2.5	1.5	1194.3390(10)	−0.9
		2.5	3.5	1185.8712(10)	0.0
		3.5	2.5	1196.0060(30)	−1.4
$^2\Pi_{3/2}$	3.5	2.5	2.5	2822.0007(20)	+1.4
		3.5	3.5	2822.3883(20)	+2.0
		3.5	2.5	2820.8514(20)	−1.6
		2.5	3.5	2823.5328(20)	+0.2
		3.5	4.5	2821.0857(20)	−0.4
		4.5	3.5	2824.2276(20)	−0.2

* The subscript + (−) refers to the even (odd) Kronig symmetry (Meerts and Dymanus 1972).

in the range 5–10 GHz which might also be of interest to radio astronomy. The results can be found in table 3. The estimated accuracy is 20 kHz or less for the lower J states increasing to 200 kHz for the higher J states.

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TABLE 2

HYPERFINE COUPLING CONSTANTS OF OD

Molecular Constant*	Value (MHz)
a	+13.297(2)
b	−17.962(6)
c	+20.234(6)
d	+8.768(1)
eQq_1	+0.143(2)
eQq_2	−0.122(6)

* For the convention of the constants see Meerts and Dymanus (1972).

TABLE 3

Predicted Frequencies (in MHz) of Some Hyperfine Λ-doubling Transitions of OD

J	F_+	F_-	$^2\Pi_{1/2}$ Level	$^2\Pi_{3/2}$ Level
1.5	0.5	0.5	5887.720	
	1.5	1.5	5894.655	
	2.5	2.5	5906.189	
	1.5	0.5	5887.241	
	0.5	1.5	5895.134	
	2.5	1.5	5894.123	
	1.5	2.5	5906.721	
2.5	1.5	1.5	8110.631	
	2.5	2.5	8117.917	
	3.5	3.5	8128.085	
	1.5	2.5	8109.867	
	2.5	1.5	8118.681	
	2.5	3.5	8117.082	
	3.5	2.5	8128.920	
3.5	2.5	2.5	9578.721	
	3.5	3.5	9586.088	
	4.5	4.5	9595.526	
	3.5	2.5	9577.391	
	2.5	3.5	9587.419	
	4.5	3.5	9584.601	
	3.5	4.5	9597.014	
4.5	3.5	3.5	10191.845	5303.986
	4.5	4.5	10199.164	5304.575
	5.5	5.5	10208.077	5305.339
	3.5	4.5	10189.893	5304.645
	4.5	3.5	10201.116	5303.916
	4.5	5.5	10196.995	5305.585
	5.5	4.5	10210.246	5304.329

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