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The Dipole Moment of Nitric Oxide

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The dielectric constant of nitric oxide is measured over a wide range of temperature and used to calculate the dipole moment of the molecule, which is found to be less than 0.1×10^{-18}, and so small as to be indistinguishable from zero.

Because of the importance of nitric oxide as one of the simple and frequently discussed molecules, it has seemed desirable to obtain an accurate value for its dipole moment.

Experimental Method

The dielectric constant of the gas was measured with an apparatus and method to be described elsewhere. Since, at the pressures and temperatures here used, the deviation of nitric oxide from the ideal gas laws is small in comparison with the experimental error, the determinations at each temperature were made at approximately the same pressure, the pressures used being such as would maintain the observed dielectric constant at approximately the same value and thus restrict the capacity readings to the same range on the precision condenser. The relative accuracy of the determinations of the small dielectric constant values was, in this way, increased. The vacuum capacity of the apparatus was determined after each measurement with gas in the condenser.

Preparation of Nitric Oxide

The nitric oxide was prepared by the method used by Noyes,[1] concentrated sulfuric acid being dropped upon sodium nitrite covered with two or three times its weight of water. The gas evolved was passed through concentrated sulfuric acid and dilute sodium hydroxide solution in spiral wash bottles, through calcium chloride and phosphorus pentoxide tubes, then very slowly through a coil surrounded by a mush of petroleum ether maintained at about $-130°C$ to remove less volatile impurities, in particular, any other oxides of nitrogen not previously absorbed. Finally, it was condensed in a trap surrounded by liquid air and subjected to fractionation. The liquid obtained in the trap had a faint blue color which could not be removed by repeated passage through the coil at $-130°$. The trace of higher oxides indicated by this color was too small to affect the results.

[1] W. A. Noyes, J. Am. Chem. Soc. **47**, 2170 (1925).

Experimental Results

From each measurement of the dielectric constant ϵ, the polarization was calculated as $P=[(\epsilon-1)/(\epsilon+2)]V$, where V is the molar volume. In Table I, the first column gives the absolute temperature at which each run or

Table I. *Experimental data.*

T, °K	p(mm)	P	Mean	T, °K	p(mm)	P	Mean
235.2	579.4	4.83		355.9	816.6	4.85	
(7)	576.4	4.79		(8)	857.5	4.81	
	565.4	4.84			853.1	4.79	
	579.1	4.80			849.7	4.88	
	578.4	4.78			852.7	4.78	4.82
	581.0	4.80	4.81				
				384.5	931.7	4.86	
266.5	678.8	4.87		(3)	949.9	4.85	
(6)	686.3	4.85			949.3	4.84	
	673.9	4.85			943.0	4.81	
	682.2	4.88			948.3	4.81	
	669.6	4.90	4.87		947.4	4.80	4.83
299.3	752.2	4.88		421.9	1021.0	4.84	
(1)	753.0	4.91		(4)	1028.6	4.82	
	752.5	4.89			1031.9	4.84	
	755.4,	4.85			1034.2	4.79	
	753.3	4.85			1025.4	4.80	
	751.0	4.86			1028.7	4.78	4.81
	753.5	4.86					
	750.4	4.85	4.87	477.0	1103.6	4.76	
				(5)	1118.8	4.78	
335.4	790.9	4.93			1115.1	4.79	
(2)	790.5	4.89			1149.6	4.78	
	794.4	4.89			1154.6	4.83	
	797.8	4.92			1147.5	4.82	
	817.3	4.88			1146.6	4.81	
	814.6	4.88			1155.2	4.82	4.80
	829.0	4.94	4.90				

$a=4.75$, $b=28$, $MR_\infty=4.31$,
$P_A=0.44$, $\mu=0.0_7\times10^{-18}$.

series of measurements was made and, under each temperature, the number of the run in parentheses. The second column gives in order the pressures at which the measurements were made, the third column the polarization calculated from the dielectric constant, and the fourth column the mean of the polarization values at each temperature, the order being repeated in the second half of the table. At the bottom of the table are the values of the constants of the Debye equation, $P=a+b/T$, obtained from the mean values of P by the method of least squares. The value of the atomic polarization was calculated as $P_A=a-MR_\infty$, the molar refraction for infinite wave-length, MR_∞, being obtained by extrapolation from values in *International Critical Tables*. The electric moment was calculated from b as $\mu=0.0127\times10^{-18}(b^{\frac{1}{2}})$.

Discussion of Results

The polarization values in Table I pass through a maximum which is 2 percent higher than the values found at the highest and lowest temperatures. Although this 2 percent difference is larger than the probable error as estimated for the apparatus and as evidenced by the agreement between the individual measurements at any one temperature, it is too small to have any definite significance. There is obviously no regular falling off of the polarization with rising temperature as required by the Debye equation for a substance with a dipole moment in the molecule. The value of b is too small to have real significance, which means that the value given for the moment is so small as to be indistinguishable from zero. This does not mean, however, that the moment is necessarily 0, but, rather, that it is less than 0.1×10^{-18}, distinctly smaller than the value, 0.2×10^{-18}, used by Huber[2] in the investigation of the possibility of a magneto-electric directive effect, and obtained from an unpublished dielectric constant value determined by Sänger and regarded by him as uncertain.

As the carbon monoxide molecule has a greater difference between its two nuclear charges than has nitric oxide and yet has a moment of only 0.11×10^{-18},[3] it is not surprising to find so small a moment in nitric oxide. It is also in harmony with the small or zero moment found for the seemingly unsymmetrical molecule of nitrous oxide.[3] Evidently, the odd number of electrons in the nitric oxide molecule, which gives rise to paramagnetism, causes nothing out of the way in the dipole moment.

[2] A. Huber, Phys. Zeits. **27**, 619 (1926).

[3] Smyth, *Dielectric Constant and Molecular Structure*, New York, The Chemical Catalog Company, Inc., (1931) p. 192.