THE LACK OF EFFECT OF A MAGNETIC FIELD ON THE DIELECTRIC CONSTANT OF HCl AND NO

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ABSTRACT

Using an electron tube method, experiments have been performed to test whether the dielectric constant of HCl and NO gases changes when a strong magnetic field is applied. The magnetic field strength was 4800 gauss and the apparatus was capable of definitely detecting a change in dielectric constant of one part in 100,000. The gases were tested at pressures of from about 2 to 40 cm of mercury, at room temperature, and with the magnetic field both parallel and perpendicular to the electric field. No change was detected under any conditions.

RECENT theoretical investigations by Debye,[1] Ruark and Breit, and others have made it of interest to look for a change in the dielectric constant of a gas when a strong magnetic field is applied to it. Experiments in search of this effect have been performed by Weatherby and Wolf.[3] They worked with helium, oxygen, and air and found that the dielectric constant of these gases does not change by more than one part in half a million when the gas is put into a magnetic field of 10,000 gauss. The dielectric constant was measured both parallel and perpendicular to the direction of the magnetic field with gas pressures of 20 cm for helium and 76 cm for air and oxygen. It is to be noted that none of these gases, helium, oxygen, or nitrogen, are gases of the so-called "polar" class, which means that their molecules are known to have only a very small permanent electric polarization. At the suggestion of Dr. Linus Pauling it was accordingly thought interesting to try gases having a strong permanent electric dipole. From the work of Zahn[4] HCl is definitely known to be such a gas. The strength of the electric moment of the NO molecule has not been directly measured but there is evidence that it also has a rather large electric dipole. It is of interest to try both gases since HCl is diamagnetic and NO paramagnetic.

The experimental procedure consisted in placing the gas to be investigated in a special parallel plate condenser which was placed between the pole pieces of a powerful electromagnet, and in noting whether the capacity of the condenser changed when the field was applied. To detect

[1] P. Debye, Phys. Zeits. **27**, 67 (1926).
[2] A. E. Ruark and G. Breit, Phil. Mag. **49**, 504 (1925).
[3] B. B. Weatherby and A. Wolf, Phys. Rev. **27**, 769 (1926).
[4] C. T. Zahn, Phys. Rev. **24**, 400 (1924).

a change in capacity a method was used similar to that first employed by Herweg and subsequently by several other investigators, including Weatherby and Wolf. In essence it consists in measuring the change in capacity by measuring the frequency produced in an oscillatory circuit formed by the condenser and an inductance. Continuous oscillations were maintained in this circuit by a special electron-tube oscillator circuit. To detect the change in frequency the main oscillator and another similar oscillator induced small e.m.f.'s in a detecting circuit, the difference in frequency being such that electrical beats were produced in this circuit. After rectification these became a low frequency alternating current which was then amplified and made to operate a simple oscillograph. The mirror of the oscillograph reflected light from a pinhole into a telescope and oscillated the spot up and down; the same beam of light was also reflected from a mirror attached to one of the prongs of an electrically driven tuning fork which caused the spot to oscillate horizontally. Lissajou's figures are thus produced when the two frequencies are commensurable. When they are not exactly commensurable but nearly so, the figure slowly changes from one shape to another. This arrangement gave us a sensitive method of detecting a change in the frequency of the beat note and consequently of detecting a change in the frequency of the gas-condenser-oscillator.

The gas-condenser was built up of interleaved flat copper plates, spaced about 1 mm apart and supported on a Pyrex frame. All the exposed metal parts were gold plated to prevent corrosion, the condenser was enclosed in a glass tube and attached to the gas generating and pumping apparatus. Its capacity when evacuated was measured by comparison with a standard and found to be 324×10^{-6} microfarad. The part of the capacity not influenced by the introduction of the gas was estimated to be only a few percent of the total capacity and it was therefore neglected in these experiments. To measure changes in capacity and to adjust the frequency of the oscillator to a stationary Lissajou figure a small variable condenser was connected in parallel with the gas-condenser. This was of the sliding coaxial cylinder type and was provided with a micrometer screw adjustment, the smallest division of which corresponded to a calculated change in capacity of 9.10×10^{-9} microfarad. The electron-tube driving circuit was designed so as to have as small an influence as possible on the frequency of oscillation, in order that accidental changes in frequency due to variations in battery e.m.f.'s, or other changes in the driving circuit, might be as small as possible. This circuit arrangement maintained very feeble oscillations in the condenser circuit so that the maximum electric field in the condenser was about ten volts per cm.

The frequency of oscillation was 168,000 cycles per second. The magnetic field was produced by a large electromagnet having flat pole faces to make the field as uniform as possible over the condenser area. The field strength was measured with a bismuth spiral and found to be 4800 gauss, and fairly uniform.

Preliminary experiments were made to see if any effect was produced by turning on the field while the condenser was evacuated, and to determine the sensitivity of the apparatus. It was found that at the instant of making or breaking the electromagnet circuit there was a slight jump in the figure but that after a few moments it again became stationary. To determine the sensitivity of our apparatus we first obtained a stationary figure, then changed the capacity of the variable condenser until the figure could definitely be seen to be changing. It was found that a change in capacity corresponding to 1/3 division produced an easily detected movement in the figure. Since 1/3 division corresponds to a change in capacity of 3.0×10^{-9} microfarads and the capacity of the gas condenser is 324×10^{-6} microfarads it is seen that our apparatus is capable of detecting a change in capacity of this condenser of about 1 part in 100,000.

The HCl gas was handled in a manner similar to that used by Zahn. It was generated by dropping concentrated H_2SO_4 on fused NaCl, passed over P_2O_5 and collected by condensation into a liquid air trap. When sufficient gas had been collected the generator was closed off, the trap and condenser pumped out over the frozen HCl and a portion of the gas allowed to evaporate into the condenser. The pressures used were about 2.5, 10, 19 and 42 cm of mercury. The magnetic field was applied both parallel and perpendicular to the electric field at each pressure. When the switch in the electromagnet circuit was closed no movement of the figure was detected at any pressure or direction of field, except the momentary jump mentioned above. This shows that to one part in 100,000 there is no change in the value of ϵ for HCl. Since the value of ϵ at room temperature and say 20 cm pressure is 1.0010 we would have been able to observe a change in $\epsilon-1$ of 1.0 percent.

The nitric oxide gas was generated by dropping H_2SO_4 into a solution of $NaNO_2$. It was passed through water to remove NO_2 and through H_2SO_4 to remove water vapor. Condensation by liquid air was found troublesome, hence the gas was collected into an evacuated chamber and thence allowed to escape into the gas-condenser. The pressures in this case were about 4, 13 and 40 cm and again tests were made with the field in both positions. No effect was detected. In order to be able to say what fractional change in $\epsilon-1$ would have been detected it was necessary to make a determination of ϵ since this quantity has not yet been measured. A rough determination was made which gave at room temperature, and reduced to 76 cm pressure, the value 1.00044. The detectable percent change in $\epsilon - 1$ can now be calculated and gives the value 8.3 percent for a pressure of 20 cm. It is interesting to note that the dielectric constant is about the same as that of air which makes it appear possible that the electric moment of the NO molecule is not as large as has been supposed.

Our work thus shows that there is no large change in the dielectric constant due to a magnetic field even for polar molecules. Other polar molecules could be tried but the interest is not great since we cannot expect any difference in behavior. These experiments together with those of Weatherby and Wolf, therefore complete the experimental side of this question until a method more sensitive than one part in 100,000 is devised.[5] Experiments in this direction are now in progress.

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[5] The authors feel that the sensitivity claimed by Weatherby and Wolf is a little too high. By using the method which Weatherby and Wolf used of counting beats for a few seconds before and after the field is applied we also obtained results for which we could claim as high sensitivity. It is believed that the sensitivity determined in the manner explained above is the true one for our apparatus and that Weatherby and Wolf's results are reliable to no greater accuracy.