selected atoms was found by moving the filament across the beam (*a*) when the transition field current was set at the value for which the peak intensity was a maximum and (*b*) when this current was set to minimize the peak intensity. The results when the state $m=-\delta$ with negative strong field moments was selected is shown in Fig. 6*a*. The circles are the experimental points for procedure (*a*); the crosses are those for procedure (*b*). The peak in the solid line curve at the position of the dotted line is due to atoms which have made observable transitions, in consequence of which they have received smaller deflections in the *B* field. The other peak in this curve is due to atoms which have not made observable transitions. Since this state shows observable transitions, it must have $F=2$. Fig. 6*b* shows the corresponding situation when atoms of the state $m=-\delta$ with positive strong field atomic moments were selected. Atoms making observable transitions would give rise to a peak at the position of the dotted line. In this case procedures (*a*) and (*b*) are equivalent, since it was found impossible to alter the intensity of the observed peak by varying the transition field currents. It was also impossible to produce a displaced peak in this manner. The absence of observable transitions identifies this state as $F=1$. These results determine the sign of the magnetic moment of the K^{39} nucleus to be positive in agreement with the results of the first experiment.

In conclusion the author wishes to express his gratitude to the members of the molecular beam laboratory for generously contributed assistance and especially to Professor I. I. Rabi who suggested the problem and whose advice and resourcefulness insured its successful solution.

MARCH 15, 1937 PHYSICAL REVIEW VOLUME 51

Effect of CCl_4 Vapor on the Dielectric Strength of Air

M. T. Rodine and R. G. Herb
Department of Physics, University of Wisconsin, Madison, Wisconsin
(Received January 14, 1937)

The effect of CCl_4 vapor on the dielectric strength of air has been studied at a number of different air pressures up to a maximum of 75 lb./in.^{2}. With air at 25°C and 15 lb. pressure the dielectric strengths of the mixtures relative to pure air ranged from a value of 1.25 for a CCl_4 vapor pressure of 5 percent of saturation to a value of 1.80 for a saturated vapor pressure. At higher air pressures the addition of CCl_4 vapor gives a greater increase in the absolute value of the dielectric strength, but the percentage increase, relative to the pure air, is less than at 15 lb. pressure.

Introduction

The effect of CCl_4 vapor on the dielectric strength of air was first noticed three years ago by one of the authors (R.G.H.) while working with an electrostatic generator of the Van de Graaff type which operates in a steel tank under an air pressure up to 45 lb. With air at atmospheric pressure containing a high concentration of CCl_4 vapor the maximum generator potential was found to be about 1.7 times the maximum potential obtainable with pure air.

Qualitative measurements were then made on the breakdown potential of the generator as a function of CCl_4 vapor pressure, with air at atmospheric pressure and also at higher pressures. The electrostatic generator proved to be unsatisfactory, however, for a thorough study of the CCl_4 effect because of sparking along a textolite support which determined an upper voltage limit that could not be improved by higher air pressure or higher concentrations of CCl_4 vapor. A small pressure chamber, equipped with an adjustable sphere gap was therefore constructed and with this apparatus sparking potentials were determined as a function of CCl_4 vapor pressure at a number of different air pressures. Publication of these results was de-

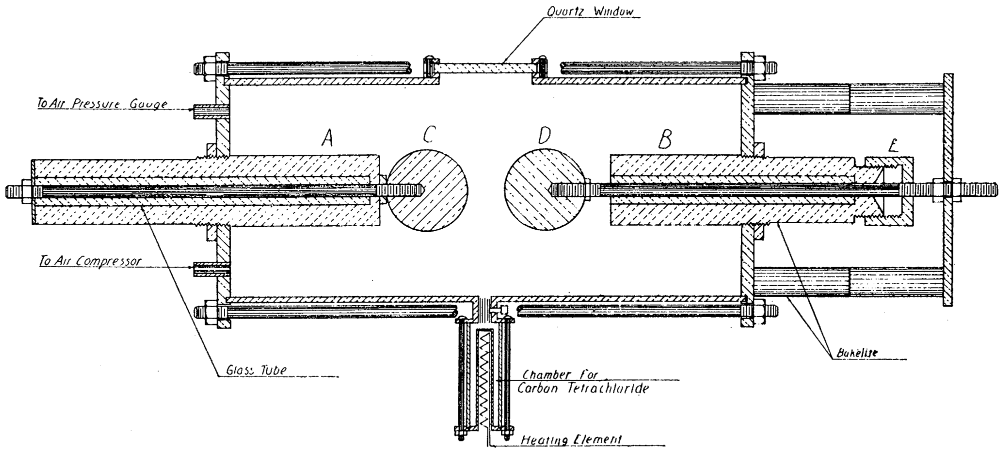

FIG. 1. Pressure chamber for study of sparking potentials.

layed because it was intended to look for similar effects caused by other vapors, but because of a shortage of personnel and equipment the research has been discontinued and the investigation, as reported in this paper, therefore covers only the effect of CCl_4 vapor on the breakdown strength of air.

Recently Joliot, Feldenkrais and Lazard reported[1] the discovery of the CCl_4 effect. They find that an electrostatic generator operated in air containing a high concentration of CCl_4 vapor gives a maximum potential twice as high as when operated in ordinary air. As our results differ considerably from these and since our investigation covers a wide range of air pressures and CCl_4 vapor pressures we believe that this belated report of our work may be of interest.

Apparatus

Fig. 1 shows the pressure chamber with its adjustable sphere gap. The walls of the chamber are formed of a brass cylinder $4\frac{1}{2}$ inches in diameter, 11 inches long, and $\frac{1}{8}$ inch thick, equipped with brass end plates $\frac{5}{16}$ inches thick. One end plate is soldered to the cylinder and the other, which is removable, is held in place by 6 steel stay rods and is sealed by a rubber gasket. C and D are brass spheres 5 cm in diameter which are threaded onto brass rods that pass through insulating bushings. Sphere C is fixed in position while sphere D can be adjusted for different separations by sliding its supporting rod through bushing B and stuffing box E. The displacement of the supporting rod and consequent displacement of the sphere is measured by means of a traveling microscope mounted on the pressure chamber. A small chamber for vaporization of CCl_4 is located on the bottom part of the main cylinder. The walls of this vaporizer are made up of an outer glass cylinder and a reentrant brass cylinder containing a heating coil. Liquid CCl_4 is injected into the vaporizing chamber through a small hole near the top which is then closed by a threaded plug. The pressure chamber is provided with two windows, one made of glass, to permit observation of the spark discharge, and the other made of quartz so that the spark gap can be illuminated with ultraviolet light.

The apparatus is provided with a calibrated gauge of the dial type for measurement of pressure.

Method and Results

For the necessary high voltage the sphere gap was connected across the terminals of a 125 kv transformer with a 175,000 ohm water resistance in series with each terminal to prevent large surges of current and oscillations. The secondary voltage of the transformer was determined in the following way. The primary voltage was measured by means of a voltmeter and for different sphere separations the value of the

[1] Joliot, Feldenkrais and Lazard, Comptes rendus **202**, 291 (1936).

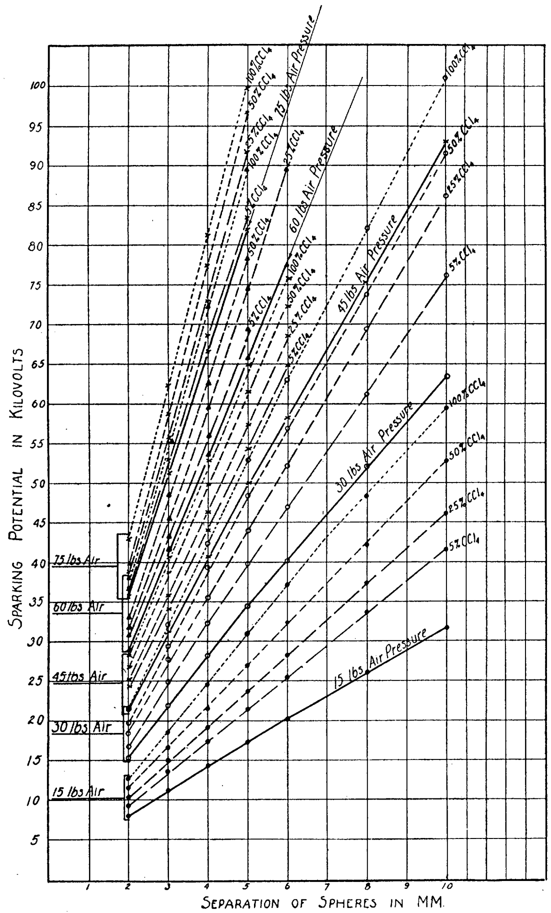

FIG. 2. Curves showing sparking potential as a function of sphere separation. Full lines are for pure air and broken lines for air to which CCl_4 vapor has been added.

primary voltage was recorded as the breakdown occurred at the sphere gap. Using these data and Peek's data on sparking potentials for sphere gaps, with corrections for temperature and barometric pressure, the peak secondary voltage of the transformer was plotted as a function of primary voltage and the resulting calibration curve was used in all subsequent measurements. During these measurements and for all subsequent work the spheres were illuminated with ultraviolet light from a quartz mercury arc lamp to avoid possible trouble from spark lag.

The procedure followed in studying the carbon tetrachloride effect was as follows: With pure dry air in the chamber several runs were taken on sparking potential as a function of sphere separation in order to check the consistency of the results. Sufficient CCl_4 was then introduced, by means of a calibrated glass pipette, to give a vapor pressure of 5 percent of the value for saturation for a temperature of 25°C, and again the sparking potential was determined at a number of sphere separations. The chamber was then flushed out with clean dry air and a check run was taken on pure air before the introduction of a higher concentration of CCl_4. Following this procedure sparking potentials were determined as a function of CCl_4 vapor pressure using air at a number of different pressures up to a maximum of 75 lb./in.^{2}.

Fig. 2 shows the results obtained. The sparking potentials determined by the curves of Fig. 2 for a sphere separation of 5 mm are replotted in Fig. 3 to give the curves showing sparking potential as a function of vapor pressure of CCl_4.

Because of the limited time available for this research sufficient check runs could not be made

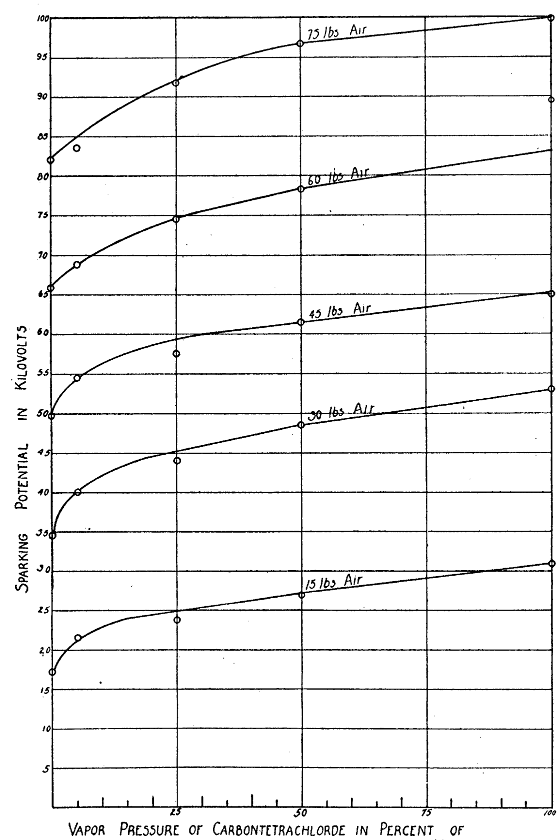

FIG. 3. Curves showing sparking potential as a function of vapor pressure of CCl_4 for several different air pressures.

and therefore no great precision can be claimed for the data. When saturated vapor pressures of CCl_4 were used the values obtained for sparking potentials were found to be very inconsistent and the values plotted are the highest obtained out of several trials. After each spark a light fog due to condensed vapor could be seen in the region of the sphere gap and a second spark would then pass at a very low voltage. At lower concentrations of CCl_4 vapor the sparking potential was found to be independent of the number of sparks which had previously passed, thus showing that any decomposition of the vapor due to spark discharges was not noticeably influencing the results.

Natterer[2] and Wright[3] have measured the dielectric strength of pure CCl_4 vapor. Wright found that its dielectric strength is 20 times as great as that of pure air with the same temperature and pressure. If the dielectric strength of CCl_4 vapor measured by Wright simply added to that of the air with which it is mixed the dielectric strength of the mixture would show a linear increase with vapor pressure of CCl_4, and for a mixture consisting of 15 lb. of air and a 100 percent concentration of CCl_4 vapor at 25°C the dielectric strength would be 3.9 times the value for pure air. The curves of Fig. 3 show, however, that the dielectric strengths of the two components of the mixture do not add together in this simple way and that the actual behavior is more complex. All of the curves rise more rapidly in the region of low concentration of CCl_4 than at high concentrations, although this characteristic behavior is less pronounced at high air pressure.

The lowest curve of Fig. 3 shows that the breakdown potential of air at 15 lb. pressure is increased by the addition of a 50 percent concentration of CCl_4 vapor to a value of about 1.56 times the value for pure air. This increase corresponds to that obtained by the addition of 8.5 lb. of pure air. At high air pressures the increase in sparking potential due to the addition of CCl_4 vapor is somewhat greater than at 15 lb. but the percentage increase becomes much less. These results indicate that carbon tetrachloride vapor would not be of great value for increasing the breakdown strength of air at high pressures. It may be of interest to note that while working with the small electrostatic generator previously referred to, certain results indicated that CCl_4 vapor may be more efficient for suppression of corona discharge than for suppression of sparking.

We wish to express our indebtedness to the late Professor C. E. Mendenhall for advice and support and to D. B. Parkinson and D. W. Kerst for valuable help in part of this work.

[2] K. Natterer, Ann. Phys. Chem. **38**, 663 (1889).
[3] R. Wright, J. Chem. Soc. **111**, 643 (1917).