

## The Electro-Optical Kerr Effect in Methane, Ethylene and Ethane

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(Received February 21, 1936)

The Kerr effect has been measured in methane, ethylene, and ethane. The measurements were made at a wave-length of 6500A, pressures from 30 to 100 atmospheres and temperatures from 15 to 55°C. With the aid of the Langevin-Born theory absolute values for the Kerr constant at

N.P.T. and 6500A have been deduced from these measurements. The values are: for methane  $3.66 \times 10^{-12}$ , for ethylene  $16.3 \times 10^{-12}$ , and for ethane  $10.4 \times 10^{-12}$ . These are in fair agreement with theoretical values computed from the Langevin-Born theory.

### INTRODUCTION

IN continuation of the work previously reported by the author<sup>1</sup> the Kerr effect has been measured in three hydrocarbons.

As is well known a dielectric under electric stress acquires the double refracting properties of a uniaxial crystal with the optic axis parallel to the lines of force. The phase difference between the two components of a light beam traversing this dielectric is proportional to the length of path, and to the square of the electric field strength. The constant of proportionality is the so-called Kerr constant.

A theoretical examination of this effect by Langevin and by Born<sup>2</sup> resulted in the following relation between the Kerr constant  $B$ , the index of refraction  $n$ , the dielectric constant  $\epsilon$ , the wave-length  $\lambda$  and the absolute temperature  $T$ ,

$$B = \frac{(n^2 - 1)(n^2 + 2)(\epsilon + 2)^2 C}{n\lambda T}. \quad (1)$$

Here  $C$  is a constant independent of temperature, density and wave-length.

The theory further gives a relation for calculating a theoretical value for the Kerr constant if the light scattering coefficient  $\Delta$  is known. It is,

$$B = \frac{3}{4\pi N\lambda kT} (\epsilon - 1)(n - 1) \frac{\Delta}{6 - 7\Delta}, \quad (2)$$

where  $N$  is the number of molecules per cc and  $k$  is Boltzmann's constant.

### METHOD

The method used in making measurements has previously been described in detail.<sup>3, 4, 5</sup> Briefly it consists in measuring the ratio of intensities of the ordinary and extraordinary beams with a photoelectric cell and amplifier. From this the Kerr constant under the conditions of measurement can be determined. High gas densities are used to increase the magnitude of the effect.

The gases used were obtained from commercial cylinders. The manufacturer's analysis was taken in each case.

The methane contained about 5 percent nitrogen and less than 1 percent each of oxygen, carbon dioxide, and ethane. The latter two gases were removed by passing the methane under pressure through copper coils immersed in a mixture of alcohol and solid carbon dioxide. Corrections were made for the nitrogen and oxygen as described in a previous paper.<sup>1</sup>

The ethane contained about 2 percent propane and a trace of methane. The propane was removed by passing the ethane under pressure through the copper coils immersed this time in a salt and ice mixture. Correction was made for the methane.

The ethylene contained small quantities of ethane, acetylene and methane. The ethane was removed in the same manner as when purifying the methane. Corrections were made for the other impurities.

### RESULTS

Since it has been well established that the Kerr effect follows the Langevin-Born theory<sup>3-6</sup> effort

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<sup>1</sup> W. M. Breazeale, *Phys. Rev.* **48**, 3, 237 (1935).

<sup>2</sup> Langevin, *Le radium* **7**, 249 (1910); Born, *Ann. d. Physik* **55**, 177 (1918).

<sup>3</sup> Stevenson and Beams, *Phys. Rev.* **38**, 133 (1931).

<sup>4</sup> Bruce, *Phys. Rev.* **44**, 689 (1933).

<sup>5</sup> Quarles, *Phys. Rev.* **46**, 692 (1934).

<sup>6</sup> Szivessy, *Zeits. f. Physik* **26**, 323 (1924).

was concentrated on obtaining a quantitative measurement of the absolute value of the Kerr constant. To this end measurements were made under only a few different conditions but a large number of readings were taken at each point.

The results of the measurement of the Kerr constant  $B$  in methane, ethylene and ethane are shown in Table I. The first three columns give

TABLE I. Kerr constant in methane, ethylene and ethane. Wave-length = 6500A.

PRESSURE (atmos.)	TEMP. (°C)	FIELD (e.s.u.)	$B$ (Measured) $\times 10^{10}$	$B$ (Std. Den.) $\times 10^{12}$	$B$ (N. P. T.) $\times 10^{12}$
METHANE					
94.0	20.0	370	3.89	3.59	3.85
97.9	20.0	367	3.85	3.30	3.54
99.6	40.0	370	3.32	3.13	3.58
98.7	55.1	369	3.01	3.07	3.68
				Mean	3.66
ETHYLENE					
58.4	20.0	305	22.3	15.0	16.1
57.9	20.0	306	21.2	15.4	16.5
73.8	40.0	304	20.9	14.3	16.4
83.0	55.0	304	18.4	13.4	16.1
				Mean	16.3
ETHANE					
31.2	15.2	278	5.04	9.6	10.1
30.1	15.2	279	5.23	10.4	11.0
49.0	53.1	281	5.70	8.5	10.1
50.4	53.1	283	6.18	8.7	10.4
				Mean	10.4

the experimental conditions under which the measurements were made. The fourth column gives the Kerr constant at the temperature and pressure of measurement. The fifth column gives  $B$  reduced with the aid of Eq. (1) to standard density (i.e., the density at N. P. T.) but at the temperature of measurement. Indices of refraction were determined by using the Lorentz-Lorenz relation and dielectric constants using Debye's law. Values at normal pressure were taken from the *International Critical Tables*. This column then shows the variation of  $B$  with temperature. The last column gives  $B$  reduced to N. P. T., again with the use of Eq. (1). The constancy of this column is a measure of the precision of the measurements and of the reduction formulae.

The variation of  $B$  with temperature is shown

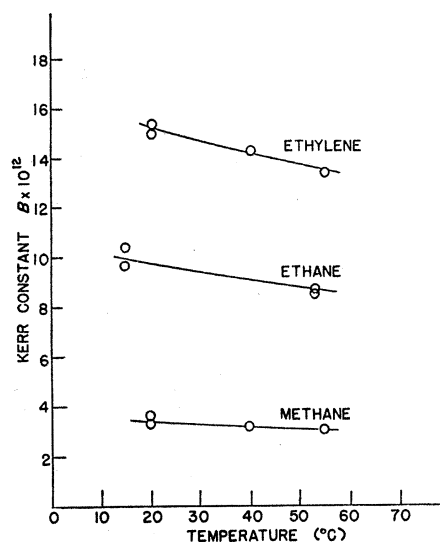


FIG. 1. Kerr constant  $B$  vs. temperature.

graphically in Fig. 1. The experimental points are shown by circles while the solid lines are theoretical curves plotted from Eq. (1).

The absolute value for the Kerr constant at N. P. T. and 6500A, deduced as explained above, for methane is  $3.66 \times 10^{-12}$  for ethylene  $16.3 \times 10^{-12}$ , and for ethane  $10.4 \times 10^{-12}$ . The limit of the experimental error is 4, 2 and 4 percent, respectively.

No published values of experimental determinations of these Kerr constants have been found. A theoretical value calculated from (2) is for methane  $2.86 \times 10^{-12}$ , for ethylene  $17.2 \times 10^{-12}$ , and for ethane  $9.0 \times 10^{-12}$ . Parthasarathy's<sup>7</sup> values for the light scattering coefficient were used. This would indicate at least a fair agreement between the values predicted by the Langevin-Born theory and the values deduced from experimental measurements.

#### ACKNOWLEDGMENTS

The author wishes to express his appreciation to Dr. J. W. Beams and to Dr. L. G. Hoxton for assistance and advice during the progress of this work, and to Dr. F. G. Slack for reading the manuscript.

<sup>7</sup> Parthasarathy, *Ind. J. Phys.* **7**, 139 (1932).