Kerr Effect in Liquid State

By Hideo OKABAYASHI

(Received December 23, 1960)

In the calculation of a physical property of liquid on the basis of a molecular theory, a form of local (or internal)[1] field may play an important role.

A theoretical formula for the dielctric constant of liquid has been derived, in which the local field is assumed to have the following expression[2].

$$F_i=\left(1-\frac{\varphi_i\alpha_i}{v}\right)^{-1}\left(E_i+\frac{\varphi_i\mu_{0i}}{v}\right)=\gamma_i\left(E_i+\frac{\varphi_i\mu_{0i}}{v}\right)$$

$$\varphi_i=2\pi a_1a_2a_3\int_0^{\infty}\frac{\mathrm{d}u}{(a_i{}^2+u)\sqrt{(a_1{}^2+u)(a_2{}^2+u)(a_3{}^2+u)}} \tag{1}$$

The liquid is considered as consisting of molecules, each of which has a permanent dipole and an anisotropic polarizability. Each component of the dipole moment is denoted as μ_{01}, μ_{02} and μ_{03}. The component of the polarizability tensor along the principal axis is represented as α_1, α_2 and α_3, respectively. The molecular shape is assumed to be ellipsoid. $2a_1$, $2a_2$ and $2a_3$ are the lengths of the principal axes. The molecular volume is v. Further it is assumed that the direction of each principal axis is coincident with that of each principal axis of the polarizability.

In the present paper, Eq. 1 is applied to the derivation of a theoretical formula of Kerr constant in liquid state. The numerical calculation of the Kerr constant is also made and compared with the experimental value.

The Formula of the Kerr Constant in Liquid State.—Generally, a liquid may be birefringent

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1) M. Born used the term "das wirkende Feld"; M. Born, "Optik", Verlag von J. Springer. (1933); P. Debye used the term "das (wirksame) innere Feld"; P. Debye, "Polare Molekeln", Verlag von S. Hirzel, Leipzig (1929). J. H. Van Vleck used the term "local field", and used the term "internal field" instead of the term "self-field" in the previous paper[2]; J. H. Van Vleck, "The Theory of Electric and Magnetic Susceptibilities", Oxford Press (1932). The terminology "local field" or "internal field" is according to H. Fröhlich; H. Fröhlich, "Theory of Dielectrics", Oxford Press (1950).

2) M. Yasumi, H. Okabayashi and H. Komooka, This Bulletin, 31, 402, 673 (1958).

when an electric field is applied. The magnitude of the artificial birefringence is represented quantitatively by Kerr constant B[3].

$$B=\frac{n_{\parallel}-n_{\perp}}{\lambda E^2}$$

where $n_{\parallel}$ and $n_{\perp}$ denote the refractive indices of the liquid parallel to and perpendicular to the applied field, respectively. λ is the wavelength of light in vacuo. E is the magnitude of the applied static electric field.

The theory of the Kerr effect was derived by Born[4]. According to his theory, the Kerr constant has the following expression.

$$B=\frac{\pi N_c}{3n\lambda}(n^2+2)^2\left(\frac{\varepsilon+2}{3}\right)^2(\Theta_1+\Theta_2)$$

$$\Theta_1=\frac{1}{45kT}\sum_{1,2,3}\{\alpha_i(\omega)-\alpha_j(\omega)\}\{\alpha_i(0)-\alpha_j(0)\}$$

$$\Theta_2=\frac{1}{45k^2T^2}\sum_{1,2,3}\{\alpha_i(\omega)-\alpha_j(\omega)\}\{\mu_{0i}{}^2-\mu_{0j}{}^2\} \quad (2)$$

ε is the static dielectric constant of the liquid and n is the ordinary refractive index. N_c is the number of molecules in a unit volume. $\alpha_i(\omega)$ is the polarizability at the angular frequency of ω. This formula has been successfully applied to the case of gases. A molecule of the gas may either be polar or nonpolar. However, as yet no theory of Kerr effect in liquid state could explain experimental facts sufficiently[5]. The discrepancy between theory and experiment may lie in the inappropriate assumption of the local field. In the following, on the basis of the formula 1 for the local field, the Kerr constant of liquid is calculated.

The strength of the total electric field in the medium is denoted by $\vec{E}_t$, and

$$\vec{E}_t=\vec{E}+\vec{e}\cdot\exp(-i\omega t) \quad (3)$$

$\vec{E}$ is the static part and $\vec{e}\cdot\exp(-i\omega t)$ is the oscillating part. The static part of the local field is expressed as before:

$$F_i=\left\{1-\frac{\varphi_i\alpha_i(0)}{v}\right\}^{-1}\left(E_i+\frac{\varphi_i\mu_{0i}}{v}\right)$$
$$=\gamma_i(0)\left(E_i+\frac{\varphi_i\mu_{0i}}{v}\right) \quad (1)'$$

$\alpha_i(0)$ is used instead of α_i, in order to indicate that it concerns the static field.

The oscillating part of the local filed $\vec{f}\cdot\exp(-i\omega t)$ is represented as,

$$f_i e^{-i\omega t}=\left\{1-\frac{\varphi_i\alpha_i(\omega)}{v}\right\}^{-1}e_i e^{-i\omega t}=\gamma_i(\omega)e_i e^{-i\omega t} \quad (4)$$

The expression 4 is obtained from the assumption that the liquid molecule can not follow the oscillating field.

To obtain the formula of the Kerr constant, the value of the electric moment due to the oscillating field must be known.

It is denoted by $\vec{\mu}_e\cdot\exp(-i\omega t)$, and

$$\mu_e=\frac{\vec{\mu}_e\cdot\vec{e}}{e}=\frac{\sum\alpha_i(\omega)f_ie_i}{e} \quad (5)$$

The refractive index n_e along the $\vec{e}$ is related to the mean value of μ_e as follows;

$$(n_e{}^2-1)e=4\pi N_c\langle\mu_e\rangle \quad (6)$$

$\langle\mu_e\rangle$ is obtained according to the Boltzmann statistics.

$$\langle\mu_e\rangle=\frac{\int\mu_e\exp(-U/kT)\mathrm{d}\Omega}{\int\exp(-U/kT)\mathrm{d}\Omega} \quad (7)$$

$\mathrm{d}\Omega$ represents elementary solid angle. U is the potential energy under the influence of the field.

$$U=-\left\{\frac{1}{2}\sum\alpha_i(0)F_i{}^2+\sum\mu_{0i}F_i\right\} \quad (8)$$

Here an assumption is made that,

$$E_1,\ E_2,\ E_3\gg e_1,\ e_2,\ e_3 \quad (9)$$

In the calculation of $\langle\mu_e\rangle$, $\exp(-U/kT)$ is expressed in the power series of E, and only the terms proportional to E and E^2 are retained. Two distinct cases must be considered.

(1) If the direction of the electric vector of the incident light is coincident with that of the static electric field, and $\langle\mu_e\rangle$ is denoted as $\langle\mu_{\parallel}\rangle$, then

$$\begin{aligned}\langle\mu_{\parallel}\rangle=e\Bigg[&\frac{1}{3}\sum\alpha_i(\omega)\gamma_i(\omega)\\&+\frac{E^2}{45kT}\sum_{1,2,3}\{\alpha_i(\omega)\gamma_i(\omega)-\alpha_j(\omega)\gamma_j(\omega)\}\\&\times\{\alpha_i(0)\gamma_i{}^2(0)-\alpha_j(0)\gamma_j{}^2(0)\}\\&+\frac{E^2}{45k^2T^2}\sum_{1,2,3}\{\alpha_i(\omega)\gamma_i(\omega)-\alpha_j(\omega)\gamma_j(\omega)\}\\&\times\{\mu_{0i}{}^2\gamma_i{}^4(0)-\mu_{0j}{}^2\gamma_j{}^4(0)\}\Bigg] \quad (10)\end{aligned}$$

$\langle\mu_{\parallel}\rangle$ is related to $n_{\parallel}$ as follows.

$$(n_{\parallel}{}^2-1)e=4\pi N_c\langle\mu_{\parallel}\rangle \quad (11)$$

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[3] This definition is based on the experimental method. From the theoretical standpoint, it is more convenient to define $K=B\lambda$ as the Kerr constant than B. However, in the present paper the quantity of B is dealt with according to the traditional custom.

[4] M. Born, *Ann. Physik*, **55**, 177 (1918).

[5] c. g. A. Peterlin and H. A. Stuart, *Z. Physik*, **113**, 663 (1937); H. A. Stuart, "Die Physik der Hochpolymeren", Bd. I., Springer-Verlag, Berlin (1952), p. 426.

(2) If the electric vector of the light is perpendicular to the direction of the static electric field and $\langle\mu_e\rangle$ is denoted as $\langle\mu_\perp\rangle$, then

$$\begin{aligned}\langle\mu_\perp\rangle=e\Big[&\frac{1}{3}\sum\alpha_i(\omega)\gamma_i(\omega)\\ &-\frac{E^2}{90kT}\sum_{1,2,3}\{\alpha_i(\omega)\gamma_i(\omega)-\alpha_j(\omega)\gamma_j(\omega)\}\\ &\times\{\alpha_i(0)\gamma_i^2(0)-\alpha_j(0)\gamma_j^2(0)\}\\ &-\frac{E^2}{90k^2T^2}\sum_{1,2,3}\{\alpha_i(\omega)\gamma_i(\omega)-\alpha_j(\omega)\gamma_j(\omega)\}\\ &\times\{\mu_{0i}^2\gamma_i^4(0)-\mu_{0j}^2\gamma_j^4(0)\}\Big]\end{aligned}\tag{12}$$

and

$$(n_\perp^2-1)e=4\pi N_c\langle\mu_\perp\rangle\tag{13}$$

The Kerr constant B is expressed as:

$$\begin{aligned}B=\frac{\pi N_c}{n\lambda}\Big[&\frac{1}{15kT}\sum_{1,2,3}\{\alpha_i(\omega)\gamma_i(\omega)-\alpha_j(\omega)\gamma_j(\omega)\}\\ &\times\{\alpha_i(0)\gamma_i^2(0)-\alpha_j(0)\gamma_j^2(0)\}\\ &+\frac{1}{15k^2T^2}\sum_{1,2,3}\{\alpha_i(\omega)\gamma_i(\omega)-\alpha_j(\omega)\gamma_j(\omega)\\ &\times\{\mu_{0i}^2\gamma_i^4(0)-\mu_{0j}^2\gamma_j^4(0)\}\Big]\end{aligned}\tag{14}$$

Because of small magnitude of $(n_\parallel-n_\perp)$, $(n_\parallel+n_\perp)$ is replaced by $2n$.

In the case when the direction of the permanent dipole moment is coincident with the direction of one of the principal axes of the molecular ellipsoid (i. e. a_1 axis), Eq. 14 is simplified as,

$$\begin{aligned}B=\frac{\pi N_c}{n\lambda}\Big[&\frac{1}{15kT}\sum_{1,2,3}\{\alpha_i(\omega)\gamma_i(\omega)-\alpha_j(\omega)\gamma_j(\omega)\}\\ &\times\{\alpha_i(0)\gamma_i^2(0)-\alpha_j(0)\gamma_j^2(0)\}\\ &+\frac{1}{15k^2T^2}\{3\alpha_1(\omega)\gamma_1(\omega)-\sum\alpha_i(\omega)\gamma_i(\omega)\}\\ &\times\mu_0^2\gamma_1^4(0)\Big]\end{aligned}\tag{15}$$

Comparison of Eq. 15 with Experiments.—In the calculation of the Kerr constant with Eq. 15, the value of permanent dipole moment, that of the component of polarizability and that of the molecular dimension must be known. Values of these quantities are taken

TABLE I. THE VALUES OF μ_0, $\alpha_i(\omega)$, (P_E+P_A) AND THE AXIAL RATIO OF THE MOLECULAR ELLIPSOID[a]

Substance	$\mu_0\times10^{18}$	$\alpha_1\times10^{25}$	$\alpha_2\times10^{25}$	$\alpha_3\times10^{25}$	(P_E+P_A)	Axial ratio
Carbon disulfide	0	151.4	55.4	55.4	22.7[4]	1 : 0.54 : 0.54
Chloroform	1.05	66.8	90.1	90.1	25.3[4]	1 : 1.54 : 1.54
Methylene dichloride	1.62	59.6	84.7	50.2	20.0[4]	1 : 1.50 : 0.91
Methyl iodide	1.65	87.2	65.7	65.7	21.9[5]	1 : 0.64 : 0.64
Nitromethane	3.46	51.8	71.7	18.3	18.3[5]	1 : 0.94 : 0.73
Diethyl ether	1.17	78.7	112.6	70.7	23.2[4]	1 : 1.80 : 0.82
Benzene	0	123.1	123.1	63.5	27[4]	1 : 1 : 0.52
Toluene	0.37	156.4	136.6	74.8	32.3[4]	1 : 0.76 : 0.47
m-Xylene	0.34[1]	161.6[1]	178.3[1]	83.5		1 : 1.30 : 0.57
Fluorobenzene	1.57	112.6	110.6	71.1	31.3[5]	1 : 0.85 : 0.49
Chlorobenzene	1.70	155.1	138.2	74.2	34.9[4]	1 : 0.76 : 0.44
Bromobenzene	1.64	168.4	121.3	95.6	35.6[5]	1 : 0.74 : 0.44
Iodobenzene	1.70	198.4	140.7	113.6	41.4[5]	1 : 0.71 : 0.47
p-Dichlorobenzene	0	212.9	124.8	88.3	37.9[4]	1 : 0.66 : 0.38
m-Dichlorobenzene	1.72	158.2	178.4	90.4	39.0[4]	1 : 1.28 : 0.52
o-Dichlorobenzene	2.50	176.8	158.5	89.7	40.2[4]	1 : 0.92 : 0.55
α-Bromonaphthalene	1.45[2]	239[3]	214.5[3]	128[3]		1 : 1.01 : 0.44
Nitrobenzene	4.19	171.6	141.9	74.1	36.2[4]	1 : 0.76 : 0.44
Acetone	2.87	69.6	72.2	48.2	16.7[4]	1 : 1.24 : 0.47
Ethyl-methyl ketone	2.87	85.5	98.3	60.2		1 : 1.50 : 0.74
Pyridine	2.15	108.4	118.8	57.8		1 : 0.98 : 0.56

a) The values of μ_0, $\alpha_i(\omega)$ and the axial ratio of the molecular ellipsoid are the same as values in the previous paper except for *m*-xylene and α-bromonaphthalene (This Bulletin, **31**, 402, 673 (1958)).

1) H. A. Stuart and H. Volkmann, *Z. Physik*, **80**, 107 (1933).

2) C. G. Le Fèvre and R. J. W. Le Fèvre, *J. Chem. Soc.*, **1955**, 1641.

3) C. G. Le Fèvre and R. J. W. Le Fèvre, *Rev. Pure Appl. Chem.*, 5, 26 (1955). They have assumed that $(P_E+P_A)=1.1\ P_E$.

4) Landolt-Börnstein Tabellen, 6. Aufl., Bd. I., Teil 3 (1951). p. 514. The value of $\alpha_i(0)$ is obtained on the assumption that $R_\lambda=(4\pi/3)N_A\{\sum\alpha_i(\omega)/3\}$ and $\alpha_i(0)/\alpha_i(\omega)=(P_E+P_A)/R_\lambda$. N_A is Avogadro's number.

5) C. G. Le Fèvre and R. J. W. Le Fèvre, *J. Chem. Soc.*, **1954**, 1577. The value of $\alpha_i(0)$ is obtained on the assumption that $P_E=(4\pi/3)N_A\{\sum\alpha_i(\omega)/3\}$ and $\alpha_i(0)/\alpha_i(\omega)=(P_E+P_A)/P_E$.

TABLE II. THE CALCULATED AND OBSERVED VALUES OF THE KERR CONSTANT[a]

Substance	Temp. °C	Wavelength mμ	$B_{\text{calcd}}\times 10^7$ [b,c] (Eq. 15)	$B_{\text{calcd}}\times 10^7$ (Eq. 15)	$B_{\text{calcd}}\times 10^7$ [c] (Eq. 2)	$B_{\text{obs}}\times 10^7$	ε
Carbron disulfide	20	589.3	4.44 (1 : 0.54 : 0.54) 3.64 (1 : 0.50 : 0.50) 3.14 (1 : 0.48 : 0.48)	4.74 3.87 3.34	8.56	3.226[1]	2.632[2]
Chloroform	25	589.3	−2.13 (1 : 1.54 : 1.54) −1.80 (1 : 1.82 : 1.82)	−3.08 −2.58	−4.74	−2.56[3]	4.724[3]
	20	546	−2.41 (1 : 1.54 : 1.54) −2.04 (1 : 1.82 : 1.82)	−3.49 −3.14	−5.46	−3.08[1]	4.81[2a]
Methylene dichloride	18	white	−1.51 (1 : 1.50 : 0.91)	−2.09	−12.4	−1.16[1]	9.14[2a]
Methyl iodide	—	red	4.26 (1 : 0.64 : 0.64) 5.29 (1 : 0.68 : 0.68)	5.32 6.83	31.1	6.74[1]	7.00[2a]
Nitromethane	—	white	4.60 (1 : 0.94 : 0.73)	11.7	846	10.65[1]	38.57[2a]
Diethyl ether	25	589.3	−0.69 (1 : 1.80 : 0.82)	−0.74	−1.42	−0.614[3]	4.265[3]
Benzene	25	589.3	0.59 (1 : 1 : 0.52) 0.40 (1 : 1 : 0.44)	0.62 0.42	1.12	0.41[4]	2.2725[4]
Toluene	20	546	1.22 (1 : 0.78 : 0.47)	1.27	6.24	0.835[1]	2.379[2a]
m-Xylene	20	546	1.22 (1 : 1.30 : 0.57)		2.16	0.809[1]	2.386[5]
Fluorobenzene	16.5	red	2.36 (1 : 0.86 : 0.50)	3.04	14.3	6.16[1]	5.54[6]
Chlorobenzene	23.5	589.3	6.95 (1 : 0.77 : 0.43)	8.11	39.1	11.4[3]	5.634[3]
	20	546	7.78 (1 : 0.77 : 0.43)	9.08	40.6	10.5[1]	5.612[2b]
Bromobenzene	24.9	560	9.15 (1 : 0.75 : 0.45)	10.2	38.1	9.9[1]	5.39[2b]
Iodobenzene	17.1	red	11.2 (1 : 0.69 : 0.45)	12.1	39.3	9.29[1]	4.625[2a]
p-Dichlorobenzene	75	546	1.11 (1 : 0.65 : 0.37)	1.20	2.77	2.63[1]	
m-Dichlorobenzene	19	546	6.45 (1 : 1.28 : 0.52)	7.31	18.6	8.9_8[1]	5.039[2b]
o-Dichlorobenzene	21	546	29.6 (1 : 0.93 : 0.55)	36.2	201	ca. 44.0[1]	9.930[2b]
α-Bromonaphthalene	21.5	580	8.43 (1 : 1.01 : 0.44)	9.85	27.4	10.5[1]	4.83[7]
Nitrobenzene	23	546	68.7 (1 : 0.77 : 0.43)	78.5	6407	354[8]	34.5[3]
Acetone	20	589.3	11.0 (1 : 1.24 : 0.74)	11.6	178	16.3[3]	19.6[3]
Ethyl methyl ketone	—	white	7.86 (1 : 1.53 : 0.74)		93.8	13.6[1]	18.51[2a]
Pyridine	—	red	8.50 (1 : 1 : 0.57)		112	20.4[1]	13.55[2a]

a) In the case in which the temperature t or the wavelength λ of light is not specified, it is assumed that $t=20°\text{C}$ or $\lambda=589\ \text{m}\mu$.
b) Figures in parentheses are the assumed values of axial ratios.
c) Calculated on the assumption that $\alpha_1(0)=\alpha_1(\omega)$.
1) H. A. Stuart, "Hand- und Jahrbuch über Chemischen Physik," Bd. I/III, Leipzig (1939). p. 49.
2) Quoted from the table in the previous paper (This Bulletin, **31**, 673 (1958)). a) Observed value at 20°C. b) Observed value at 25°C.
3) C. G. Le Fèvre and R. J. W. Le Fèvre, *J. Chem. Soc.*, **1953**, 4041.
4) C. G. Le Fèvre and R. J. W. Le Fèvre, *Rev. Pure Appl. Chem.*, Chem., **5**, 261 (1955).
5) L. M. Heil, *Phys. Rev.*, **39**, 666 (1932).
6) R. Mecke and K. Rosswog, *Z. Elektrochem.*, **60**, 47 (1956).
7) The observed value at 25°C. W. M. Heston, E. J. Hennelly and C. P. Smith, *J. Am. Chem. Soc.*, **72**, 2071 (1950).
8) H. Friedrich, *Physik. Z.*, **38**, 318 (1937).

from the literatures by the method similar to that written in the previous paper[2].

Contrary to the case of the calculation of the static dielectric constant, in the case of the calculation of the Kerr constant, both the values of $\alpha_i(0)$ and $\alpha_i(\omega)$ are needed. However, as yet the value of $\alpha_i(0)$ is not known. Stuart[6] and Le Fèvre[7] have assumed that $\alpha_i(0)/\alpha_i(\omega)=(P_E+P_A)/R_\lambda$. P_E is electronic polarisation and P_A is atomic polarization. R_λ is molecular refraction for the wavelength of λ.

In Table I the values of the following quantities are tabulated; the value of permanent dipole moment μ_0, the value of the component of polarizability $\alpha_i(\omega)$, the value of (P_E+P_A) and the values of the ratios of axial lengths of the molecular ellipsoid.

The Kerr constant of about twenty substances is calculated with Eq. 15 and compared with the experimental value.

The value calculated with Eq. 2 is also compared with experimental one.

Generally speaking, the considerable discrepancy between the theoretical value and the experimental one is observed if we apply Eq. 2, and moreover, the greater the value of the dielectric constant of liquid, the greater becomes the discrepancy[8].

On the contrary, the calculated value with Eq. 15 is not very far from the experimental one.

When atomic polarization is taken in account, the coincidence is not unsatisfactory.

In Table II, the calculated and the experimental values of B are tabulated. In the fourth column, the calculated values with Eq. 15 are tabulated, in which $\alpha_i(0)$ is replaced by $\alpha_i(\omega)$. In the fifth, the value of $\alpha_i(0)$ is taken in account.

In the sixth, the values of B calculated with Eq. 2 are represented. The experimental values of B are also represented in the seventh column. In addition, the values of ε are tabulated in the eighth.

For a symmetrical top molecule the calculation which is to be described in the following is also made.

A symmetrical top molecule can be approximated as a spheroid. The shape of a spheroid can be determined by only one axial ratio. In this case, the value of the axial ratio is chosen as to fit the experimental value of the Kerr constant, and is compared with the geometrical one.

In the case of a general ellipsoidal molecule, the Kerr constant is calculated with Eq. 15, in which the value of axial ratio is taken as the value of the geometrical one.

In the following, some remarks are made on special cases.

Spheroide Molecules. — a) *Carbon Disulfide* —For liquid carbon disulfide the calculated value of the Kerr constant is sensitive to the assumed axial ratio. The value of axial ratio 0.48 is fitted best to the observed value of the Kerr constant. In the case of dielectric constant the value of axial ratio 0.50 is the fittest value. The geometrical value is 0.54.

b) *Benzene.* — The obtained value of the axial ratio 0.44 is smaller than the geometrical one 0.52.

c) *Chloroform.* — The value of axial ratio 1.82 is the fittest value if atomic polarization is taken in account. The geometrical value is 1.54.

General Ellipsoid Molecules. — a) *Benzene Derivatives.*—The calculated value of the Kerr constant gives the right magnitude, but the values for fluorobenzene[10], *p*-dichlorobenzene and nitrobenzene are excepted. As the only one exceptional case, the value for *p*-dichlorobenzene obtained with Eq. 2 is better than the value obtained with Eq. 15. The calculated value of the Kerr constant of liquid fluorobenzene is lower than the experimental one. The theoretical value for nitrobenzene is much lower than the experimental one.

b) *Pyridine.*—The calculated value is lower than the experimental one.

c) *Nitromethane.*—The value of electronic polarization and that of atomic polarization are evaluated by Le Fèvre[7] as 12.0 cc. and 6.3 cc., respectively. The calculated value of the Kerr constant coincides fairly with the observed one if atomic polarization is taken in account. However, whether the coincidence is fortuitous or not is not determined as yet.

d) *Diethyl Ether.*—For diethyl ether planer zigzag form is assumed. The value of axial ratio calculated from the molecular model is fairly consistent with the value which is fittest for the value of the Kerr constant.

e) *Ethyl Methyl Ketone.*—Also the model of planer zigzag form is adopted. The calculated value is lower than the experimental one.

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[6] H. A. Stuart and H. Volkmann, *Ann. Physik*, **18**, 121 (1933).

[7] C. G. Le Fèvre and R. J. W. Le Fèvre, *J. Chem. Soc.*, **1953**, 4041. Further they have used $P_E=R_\infty$ (molecular refraction for light of infinite wavelength) instead of R_λ.

[8] However, the so-called $4\pi/3$ catastrophe[9] does not arise in the Kerr effect.

[9] J. H. Van Vleck, *Ann. N. Y. Acad. Sci.*, **40**, 295 (1940).

[10] It is interesting to note that the value of the component of the molecular polarizability of fluorobenzene is almost the same as that of benzene. Le Fèvre[7] has obtained the following values.

	$\alpha_1\times10^{25}$	$\alpha_2\times10^{25}$	$\alpha_3\times10^{25}$
Benzene	111.4	111.4	73.6
Fluorobenzene	112.6	110.6	71.1

Summary

A formula for the Kerr constant in liquid state has been derived, in which the form of the local field is assumed to be the same as that derived previously[2]. The formnla is able to explain experimental data to some extent, although there are some exceptions.

The author is grateful to Professor Masasi Yasumi for his kind guidance and encouragement throughout this work, and to Mr. Hitoshi Komooka for his advice. Thanks are also due to the Ministry of Education for a grant in aid of this research.

Aeronautical Research Institute
The University of Tokyo
Meguro-ku, Tokyo