Molecular Polarisability. The Electro-optical Polarisability Tensor Ellipsoids of Naphthalene, and the α- and β-Fluoro-, -Chloro-, -Bromo-, and -Iodo-naphthalenes.

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The molar Kerr constants for the substances named in the title have been measured at infinite dilution in carbon tetrachloride, and the half-axes of the polarisability ellipsoids estimated. While the substitution of an α- or β-hydrogen atom of naphthalene by halogen does not cause the observed value for the *average* polarisability of the resulting halogenonaphthalene to deviate markedly from that expected, yet analysis into b_1, b_2, and b_3 suggests that exaltations and depressions are in fact to be found for the directions collinear with and normal to the C–X bond. The molar Kerr constants of β-halogenonaphthalenes are 2—3 times as large as those of the related α-isomers.

The object of this investigation was, *via* the determination of the electro-optical polarisability ellipsoids of naphthalene and its eight α- and β-halogenated derivatives, to compare the half axes, so found, with those calculated from b_1, b_2, and b_3 for naphthalene in combination with the b_L, b_V, and b_T values for each carbon–halogen bond previously reported by us (*J.*, 1954, 1577).

In order to ascertain the tensor components b_1, b_2, and b_3 for naphthalene, three expressions from different experimental sources are necessary (cf. *J.*, 1953, 4041). For polar molecules in which the orientation of $\mu_{\text{resultant}}$ with reference to the axis of maximum polarisability is known, b_1, b_2, and b_3 may be extracted from the following equations :

$$\frac{3M}{4\pi Nd}\cdot\frac{n_\infty{}^2-1}{n_\infty{}^2+2}=\alpha=\frac{b_1+b_2+b_3}{3}\ \text{(from the electronic polarisation)}\quad .\quad (a)$$

$$\begin{aligned}{}_\infty({}_mK_2) &= (4\pi N/9)(\theta_1+\theta_2)\\ &= \frac{4\pi N}{9}\left\{\frac{1}{45kT}\,\frac{{}_\mathrm{D}P}{{}_\mathrm{E}P}\,[(b_1-b_2)^2+(b_2-b_3)^2+(b_3-b_1)^2]+\right.\\ &\left.\frac{1}{45k^2T^2}\,[(b_1-b_2)(\mu_1{}^2-\mu_2{}^2)+(b_2-b_3)(\mu_2{}^2-\mu_3{}^2)+(b_3-b_1)(\mu_3{}^2-\mu_1{}^2)]\right\}\end{aligned}$$

$$\text{(from the molar Kerr constant)}\quad .\ .\ .\ .\ .\ .\ .\ .\quad (b)$$

$$\frac{10\Delta}{6-7\Delta}=\frac{(b_1-b_2)^2+(b_2-b_3)^2+(b_3-b_1)^2}{(b_1+b_2+b_3)^2}$$

$$\text{(from the depolarisation of scattered light)}\quad .\ .\quad (c)$$

If, however, the molecule is non-polar, then $\theta_2 = 0$ and equations (*a*) and (*c*) can be combined to give (*b*). Accordingly, for naphthalene, even if a satisfactory figure for the depolarisation factor of scattered light were available, it would be of no help towards elucidating b_1, b_2, and b_3.

The evaluation of the three components for naphthalene by Briegleb (*Z. physikal. Chem.*, 1936, **16**, *B*, 249) by computing expression (*c*) from (*a*) and (*b*) and using the three equations so obtained to solve for b_1, b_2, and b_3 is mathematically unsound, and should therefore be disregarded.

Krishnan (*Indian J. Physics*, 1938, **8**, 431) has estimated b_1, b_2, and b_3 as 26·8, 14·1, and 11·5 × 10^{-24} respectively. He uses (1) $b_1 + b_2 + b_3 = 52{\cdot}42 \times 10^{-24}$ obtained by adopting 44·37 c.c. as the molecular refractivity;

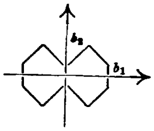
$$(2)\ [(b_1-b_2)^2+(b_2-b_3)^2+(b_3-b_1)^2]/(b_1+b_2+b_3)^2=0{\cdot}145,$$

from the depolarisation factor $\Delta = 0{\cdot}079$ found by Ramakrishna Rao (*ibid.*, 1927, **2**, 84) for naphthalene vapour; and

$$(3)\ (a_1 - a_2)(b_1 - b_2) + (a_2 - a_3)(b_2 - b_3) + (a_3 - a_1)(b_3 - b_1) = 4{\cdot}40 \times 10^{-51}$$

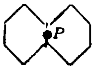
from the Cotton–Mouton effect measurements on molten naphthalene (Salceanu, *Compt. rend.*, 1930, **191**, 486). He calculates $a_1 = -6{\cdot}50$, $a_2 = -7{\cdot}09$, and $a_3 = -30{\cdot}88 \times 10^{-29}$ from the principal susceptibilities of the naphthalene crystal on the basis of the orientations of the two molecules per unit cell described by Banerjee (cf. *Phil. Trans.*, 1933, **231**, 253). We think that, in view of the well-substantiated dimensions of naphthalene (Abrahams, Robertson, and White, *Acta Cryst.*, 1949, **2**, 233, 238; Mathieson, Robertson, and Sinclair, *ibid.*, 1950, **3**, 245, 251), a greater similarity in value is to be expected between b_1 and b_2 than between b_2 and b_3; noting also the difficulties of securing accurate depolarisation factors for gases (cf. $\Delta = 0{\cdot}079$ by Ramakrishna Rao or 0·10 by Cabannes, *Compt. rend.*, 1926, **182**, 885), and the variations often to be found among published values for the principal susceptibilities of molecules, it is possible that the b's calculated by Krishnan may not be founded on reliable experimental data.

The b$_1$ *of Naphthalene.*—*X*-Ray analysis (Robertson, *Proc. Roy. Soc.*, 1933, *A*, **142**, 674) shows that our b_1 for naphthalene always lies in the single crystal along the c direction, the refractive index of which is 1·932. Because we have no other information available to us which will give a third equation containing b_1, b_2, and b_3, *faut de mieux* we propose to use Robertson's results to produce an estimate of b_1. The unit cell of naphthalene contains two molecules; its dimensions are $a = 8{\cdot}29$, $b = 5{\cdot}97$, $c = 8{\cdot}68$ Å, and $\beta = 122{\cdot}7°$ (Robertson, *loc. cit.*). The apparent average molecular polarisability in the c direction corresponding to $n = 1{\cdot}932$, obtained by means of equation (a) and the observed density (1·152 g./c.c.), is $2{\cdot}090 \times 10^{-23}$ c.c. This is not the desired polarisability b_1 since in a crystal lattice subjected to an electric field, each molecular induced dipole induces others in its neighbours. It is necessary for our purpose, therefore, to correct for this secondary induction, and also to convert to a basis of electronic polarisability alone. We shall consider a crystal lattice consisting of eight unit cells, to each of which the naphthalene nucleus O under consideration contributes one eighth of itself; let application of unit field along the c direction induce in O a dipole $b_1 \times 10^{-23}$ in the c direction; the effect of this dipole on its neighbours in the 8-celled lattice will, by mutual induction, be the effect of the b_1's of the surrounding naphthalene molecules on O. If $+\Sigma d\bar{\mu}$ be the total moments induced in its neighbours by O, then



$$b_1 = \frac{2{\cdot}090 \times 10^{-23}}{(1 - \Sigma d\bar{\mu})} \cdot {}_{\mathrm{E}}P/{}_{\mathrm{D}}P$$

An 8-celled lattice element adequately includes induced moments of significance to O. We realise that properly the mutual effects of the atoms should be considered, as in the manner of Silberstein (*Phil. Mag.*, 1917, **33**, 92, 215, 521), but the calculation of the mutual atomic inductions of sixteen 18-atomed molecules seems to be an almost insurmountable task. We therefore regard each naphthalene molecule as "an atom group" (cf. Silberstein, *loc. cit.*) with its dipole situated at the mid-point P (see annexed formula) and it is the effect of this point dipole on its neighbours in the lattice (Figure) along the c direction that constituted the datum of Table 1. The expression used is $\mu_{\text{ind.}} = b_1 \times 10^{-23}\ (3 \sin^2 \alpha - 1)$ (cf. Le Fèvre, "Dipole Moments," Methuen, 3rd edn., 1953, p. 92), where r is the distance between the inducing and the induced dipoles, and α is (90° minus the angle between r and the c direction in the crystal). The net induction in the c direction at P in O by its neighbours in the eight cells considered is therefore $-0{\cdot}1044 \times 10^{-23} b_1$; b_1 accordingly emerges as $2{\cdot}15 \times 10^{-23}$ c.c.



The b$_1$, b$_2$, *and* b$_3$ *of Naphthalene.*—By means of equations (a) and (b) we can now analyse the ${}_{\infty}({}_{m}K_2)$ of naphthalene; this, in carbon tetrachloride, is found to be $48{\cdot}1 \times 10^{-12}$. Inserting $b_1 = 2{\cdot}15 \times 10^{-23}$, in conjunction with ${}_{\mathrm{D}}P = 45{\cdot}4$ c.c. and ${}_{\mathrm{E}}P = 41{\cdot}8$ c.c. (Le Fèvre and Rao, *Austral. J. Chem.*, 1955, **8**, 39) we derive the following tensor components: $b_1 = 2{\cdot}15 \times 10^{-23}$, $b_2 = 1{\cdot}76 \times 10^{-23}$, and $b_3 = 1{\cdot}03 \times 10^{-23}$.

TABLE 1. *Calculation of net induction at P in* O.

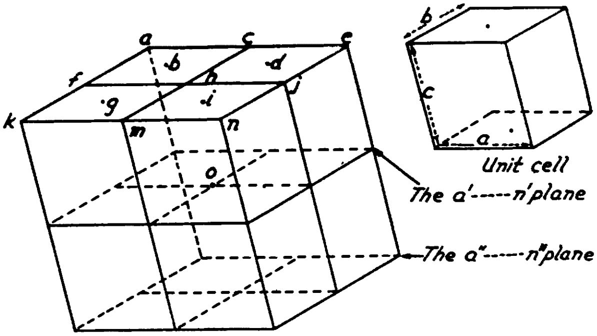
r = Distances		O–P (in Å)	Angle between r and c direction in crystal	$\mu_{\text{ind.}}$ at nuclear centre by O
O*a*	O*k*	15·805	33° 38′	+0·00273b_1
O*b*	O*g*	11·765	21° 51′	+0·00972b_1
O*c*	O*m*	10·160	31° 21′	+0·01133b_1
O*d*	O*i*	7·788	34° 12′	−0·02227b_1
O*e*	O*n*	9·711	64° 22′	−0·00479b_1
O*f*		14·894	27° 56′	+0·00406b_1
O*h*		8·680	0°	+0·03058b_1
O*j*		8·143	58° 58′	−0·00373b_1

Values in the a'' . . . . j'' plane are the counterpart of those in the a . . . . j plane, therefore

$\Sigma\mu_{\text{ind.}}$ in a . . . . j plane = $\Sigma\mu_{\text{ind.}}$ in a'' . . . . j'' plane.

O*a*′	O*e*′	$9{\cdot}833_5$	90°	−0·01052b_1
O*k*′	O*n*′			
O*b*′	O*d*′	6·953	90°	−0·02975b_1
O*g*′	O*i*′			
O*c*′	O*m*′	5·29	90°	−0·06755b_1
O*f*′	O*j*′	8·29	90°	−0·01755b_1

It is relevant to mention that ${}_{\infty}({}_mK_2)_{\text{naphthalene}}$ has hitherto been recorded in carbon tetrachloride only once: Otterbein (*Physikal. Z.*, 1934, **35**, 264) quoted it as 42 × 10^{-12} but presented no supporting details of his actual measurements. Grodde's value for molten naphthalene at 80° (33·9 × 10^{-12}; *ibid.*, 1938, **39**, 772) corresponds to 40·2 × 10^{-12} at 25°.



Briegleb (*Z. physikal. Chem.*, 1936, **16**, *B*, 249), using heptane as solvent, deduced ${}_mK_2$ as 110 × 10^{-12}—a figure of the order to be expected from available data for the Δ of naphthalene vapour (cf. Cabannes, "La Diffusion Moléculaire de la Lumière," Les Presses Universitaires de France, 1929, p. 254). We have previously commented (*J.*, 1954, 1577) on the uncertainty attending extant depolarisation factors. Briegleb does not show the B_1, n_1, ε_1, or d_1 for his heptane; when these are taken respectively as 0·071 × 10^{-7}, 1·388, 1·924, and 0·684 (*i.e.*, for 20°), and his observations extrapolated by our method (*J.*, 1953, 4041), an ${}_{\infty}({}_mK_2)$ of about 40 × 10^{-12} is derived. (As both Grodde and Briegleb computed their ${}_mK$'s by a formula lacking a 6 used by us, their measurements have been multiplied accordingly for quotation in the preceding text.)

Halogenonaphthalenes.—The molar Kerr constants, at infinite dilution in carbon tetrachloride at 20° for light of λ = 5893 Å, of the eight monohalogenonaphthalenes are listed in Table 2. Otterbein (*loc. cit.*) cites ${}_mK$ values for two of these substances in carbon tetrachloride: α-$C_{10}H_7Cl$, 165 × 10^{-12}; β-$C_{10}H_7Cl$, 427 × 10^{-12}; his results resemble ours in order, but since he gives no experimental data we cannot decide whether the differences

TABLE 2. *Molar Kerr constants at infinite dilution.*

Solute	${}_{\infty}({}_mK_2) \times 10^{12}$	Solute	${}_{\infty}({}_mK_2) \times 10^{12}$
α-$C_{10}H_7F$	72·6	α-$C_{10}H_7Br$	213
β-$C_{10}H_7F$	233	β-$C_{10}H_7Br$	469
α-$C_{10}H_7Cl$	190	α-$C_{10}H_7I$	244
β-$C_{10}H_7Cl$	406	β-$C_{10}H_7I$	490

lie in the observations or merely in the extrapolation procedure used. Otterbein thought the constant for β-chloronaphthalene to be extraordinarily high; it is now clear that generally throughout the four pairs of isomeric halogenonaphthalenes $({}_mK_2)_{\beta\text{-isomer}}$ is notably greater (2—3 times) than $({}_mK_2)_{\alpha\text{-isomer}}$.

Polarisability Ellipsoids of Halogenonaphthalenes.—No depolarisation factors for halogenonaphthalenes in the vapour state exist. Lacking equation (*c*), therefore, we have compounded b_3 in each case as follows :

$$b_3{}^{\mathrm{C_{10}H_7X}} = b_3{}^{\mathrm{C_{10}H_8}} - b_{\mathrm{T}}{}^{(\mathrm{C-H})_{\mathrm{aryl}}} + b_{\mathrm{T}}{}^{(\mathrm{C-X})_{\mathrm{aryl}}}$$

and used it in conjunction with our ${}_{\infty}({}_mK_2)$ and the average polarisability, the values $b_{\mathrm{T}}{}^{(\mathrm{C-X})_{\mathrm{aryl}}}$ being those quoted in *J.*, 1954, 1577. Further, in view of the absence of polarisation–temperature data for these compounds as gases, we have assumed, in equation (*b*), that ${}_{\mathrm{D}}P/{}_{\mathrm{E}}P = 1{\cdot}1$, and in equation (*a*) that ${}_{\mathrm{E}}P = 0{\cdot}95R_{\mathrm{D}}$. We have taken b_3 to be the same for each pair of isomers, and have located b_1 along (or parallel to) the direction of action of $\mu_{\mathrm{C_{10}H_7X}}$. Results are shown in the first parts of Tables 3 and 4.

TABLE 3. *Principal axes * for the α-halogenonaphthalenes.*

	From experiment			Calculation A		Calculation B	
	b_1	b_2	b_3	b_1	b_2	b_1	b_2
α-$C_{10}H_7F$	1·71	2·19	1·01	1·78	2·15	1·74	2·13
α-$C_{10}H_7Cl$	2·31$_5$	2·09	1·19	2·12	2·28	2·06	2·43
α-$C_{10}H_7Br$	2·39	2·14$_5$	1·28	2·33	2·25	2·17	2·40
α-$C_{10}H_7I$	2·77	2·13	1·44	2·63	2·45	2·38	2·56

TABLE 4. *Principal axes * for the β-halogenonaphthalenes.*

	From experiment			Calculation A		Calculation B	
	b_1	b_2	b_3	b_1	b_2	b_1	b_2
β-$C_{10}H_7F$	2·14	1·76	1·01	2·07	1·86	2·12	1·84
β-$C_{10}H_7Cl$	2·61	1·79$_5$	1·19	2·41	1·99	2·31	2·02
β-$C_{10}H_7Br$	2·85	1·71	1·28	2·62	1·96	2·46	2·11
β-$C_{10}H_7I$	3·23	1·83	1·44	2·92	2·16	2·67	2·27

* In units : 10^{-23} c.c.

Also included in Tables 3 and 4 are calculations of the respective b_1's and b_2's, made by the additivity equations (*d*) and (*e*) for the α-, and (*f*) and (*g*) for the β-, isomers :

$$b_1{}^{\mathrm{C_{10}H_7X}} = b_2{}^{\mathrm{C_{10}H_8}} - b_{\mathrm{L}}{}^{\mathrm{C-H}} + b_{\mathrm{L}}{}^{\mathrm{C-X}} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (d)$$

$$b_2{}^{\mathrm{C_{10}H_7X}} = b_1{}^{\mathrm{C_{10}H_8}} - b_{\mathrm{V}}{}^{\mathrm{C-H}} + b_{\mathrm{V}}{}^{\mathrm{C-X}} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (e)$$

$$b_1{}^{\mathrm{C_{10}H_7X}} = b_1{}^{\mathrm{C_{10}H_8}} . \cos^2 30° + b_2{}^{\mathrm{C_{10}H_8}} . \sin^2 30° - b_{\mathrm{L}}{}^{\mathrm{C-H}} + b_{\mathrm{L}}{}^{\mathrm{C-X}} \quad . \; . \quad (f)$$

$$b_2{}^{\mathrm{C_{10}H_7X}} = b_1{}^{\mathrm{C_{10}H_8}} . \sin^2 30° + b_2{}^{\mathrm{C_{10}H_8}} . \cos^2 30° - b_{\mathrm{V}}{}^{\mathrm{C-H}} + b_{\mathrm{V}}{}^{\mathrm{C-X}} \quad . \; . \quad (g)$$

The b_{L}'s and b_{V}'s are those listed in *J.*, 1954, 1577; the calculations denoted by A and B differ in that A utilises bond polarisabilities previously deduced from aromatic structures whilst B uses those derived from aliphatic molecules.

By subtracting the *b*'s from " calculation B " from those " from experiment " we obtain estimates of exaltations (Δb_1 and Δb_2). These are listed as Table 5. Except where fluorine is concerned, positive exaltations are seen in the C–Halogen bond directions—the situation is thus qualitatively analogous to that reported for the halogenobenzenes (*J.*, 1954, 1577 †). Table 5 suggests that the *average* polarisabilities for these molecules should not show marked exaltations; that this is so may be seen from Table 6, referring to R_{D} values; the column under $(R_{\mathrm{D}})_{\text{calc.}}$ is composed from the following: $R_{\text{naphthalene}} = 44{\cdot}37$ c.c., $R_{\mathrm{C-H}} = 1{\cdot}68$, $R_{\mathrm{C-F}} = 1{\cdot}44$, $R_{\mathrm{C-Cl}} = 6{\cdot}51$, $R_{\mathrm{C-Br}} = 9{\cdot}39$, and $R_{\mathrm{C-I}} = 14{\cdot}61$ (Vogel, Cresswell, Jeffery, and Leicester, *J.*, 1952, 530).

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† " Table 4," 4 lines from the bottom of p. 1582 of this reference, should read " Table 5."

TABLE 5. *Exaltations in the* b$_1$ *and* b$_2$ *directions.*

	Δb_1	Δb_2		Δb_1	Δb_2
α-$C_{10}H_7F$	−0·03	+0·06	β-$C_{10}H_7F$	+0·02	−0·08
α-$C_{10}H_7Cl$	+0·25$_5$	−0·34	β-$C_{10}H_7Cl$	+0·30	−0·22$_5$
α-$C_{10}H_7Br$	+0·22	−0·25$_5$	β-$C_{10}H_7Br$	+0·39	−0·40
α-$C_{10}H_7I$	+0·39	−0·43	β-$C_{10}H_7I$	+0·56	−0·44

TABLE 6. *Calculated and observed molecular refractions* (*in c.c.*) (*D-line*).

	$(R_D)_{calc.}$	$(R)_{obs.}$ for α-isomers	$(R)_{obs.}$ for β-isomers
$C_{10}H_7F$	44·13	43·7	43·7
$C_{10}H_7Cl$	49·20	49·2	49·4
$C_{10}H_7Br$	52·08	51·6	51·8
$C_{10}H_7I$	57·30	56·5	57·9

EXPERIMENTAL

Materials.—The naphthalene and halogenated naphthalenes were spectroscopically pure specimens kindly lent by Mr. A. Ferguson, to whom we express our gratitude. The carbon tetrachloride (sulphur-free) was a gift of a " middle cut " of the fractionation plant of Imperial Chemical Industries (Australia and New Zealand Ltd.) whom we also thank.

Measurements.—These were made by our method previously described (*J.*, 1953, 4041), where the symbols used here are defined and the extrapolation procedure is explained. The observations recorded in Table 6 are for either 20° or 25°, at which temperatures the following data for the solvents are taken.

Temp.	10^7B_D	n_D^t	d_4^t	ε_1	H	J	$10^{14}.K_1$
20°	0·072	1·4604	1·5940	2·2360	2·064	0·4721	0·761
25°	0·070	1·4575	1·5845	2·2270	2·060	0·4731	0·749

TABLE 7. *Weight fractions, Kerr constants, refractive indexes, densities, and dielectric constants of solutions.*

Naphthalene in carbon tetrachloride at 25°

10^5w_2	10^7B_{12}	$(n_D^t)_{12}$	$(d_4^t)_{12}$	$(\varepsilon_t)_{12}$	10^5w_2	10^7B_{12}	$(n_D^t)_{12}$	$(d_4^t)_{12}$	$(\varepsilon_t)_{12}$
309	0·085	—	—	2·2288	3514	0·179	—	—	—
840	0·101	1·4597	1·57774	2·2322	4265	0·267	1·4689	1·55005	2·2545
1319	0·116	—	1·57363	—	4389	0·213	—	1·54759	—
2098	0·139	—	1·56728	—	4537	0·220	—	—	—
2356	0·150	1·4637	1·56528	2·2416					

whence $\Delta B = 3{\cdot}43_2w_2 - 4{\cdot}5w_2^2$

α-Fluoronaphthalene in carbon tetrachloride at 20°

152	0·082	—	1·5928$_5$	2·2404	1278	0·133	1·4629	1·5863	2·2730
166	0·083	—	1·5927	2·2410	1641	0·153	1·4635	1·5835	2·2836
561	0·102	1·4614	1·5903	2·2503	2300	0·184	1·4650	1·5795	2·3042

whence $\Sigma(\Delta B\ .\ w_2)/\Sigma w_2^2 = 4{\cdot}81$

β-Fluoronaphthalene in carbon tetrachloride at 20°

334	0·121	1·4610	1·5922	2·2464	855	0·199	1·4621	1·5889	2·2647
374	0·131	1·4611	1·5918	2·2486	1413	0·283	1·4632	1·5853	2·2846
747	0·182	1·4619	1·5895	2·2607					

whence $\Sigma(\Delta B\ .\ w_2)/\Sigma w_2^2 = 14{\cdot}91$

α-Chloronaphthalene in carbon tetrachloride at 20°

871	0·163	1·4625	1·5897	2·2624	2265	0·317	—	—	—
1532	0·240	—	1·5867	2·2868	2765	0·375	1·4675	1·5805	2·3238
1634$_5$	0·248	1·4640	—	—	4040	0·517	—	—	—
1640	0·250	—	1·5863	2·2876					

whence $\Sigma(\Delta B\ .\ w_2)/\Sigma w_2^2 = 10{\cdot}93$

β-Chloronaphthalene in carbon tetrachloride at 20°

322	0·148	—	—	—	1088	0·322	1·4662	1·5884	2·2787
634	0·221	1·4651	1·5908	2·2605	1245	0·361	—	—	—
680	0·232	—	—	—	1408	0·406	1·4671	1·5867	2·2906

whence $\Sigma(\Delta B\ .\ w_2)/\Sigma w_2^2 = 23{\cdot}39$

TABLE 7. *Continued.*

α-Bromonaphthalene in carbon tetrachloride at 20°

10^5w_2	10^7B_{12}	$(n_D^t)_{12}$	$(d_4^t)_{12}$	$(\varepsilon_t)_{12}$	10^5w_2	10^7B_{12}	$(n_D^t)_{12}$	$(d_4^t)_{12}$	$(\varepsilon_t)_{12}$
737	0·150	1·4621	1·5933	2·2530	1706	0·240	—	—	—
981	0·168	1·4625	1·5930	2·2612	2255	0·280	1·4652	1·5921	2·2947
1522	0·221	—	—	—	2589$_5$	0·326	—	—	—

whence $\Sigma(\Delta B \,.\, w_2)/\Sigma w_2^2 = 9{\cdot}43$

β-Bromonaphthalene in carbon tetrachloride at 20°

10^5w_2	10^7B_{12}	$(n_D^t)_{12}$	$(d_4^t)_{12}$	$(\varepsilon_t)_{12}$	10^5w_2	10^7B_{12}	$(n_D^t)_{12}$	$(d_4^t)_{12}$	$(\varepsilon_t)_{12}$
311	0·139	1·4610	1·5935	2·2450	1210	0·330	1·4629	1·5924	2·2711
445	0·169	—	—	—	1474	0·387	—	—	—
905	0·262	—	—	—	1525	0·394	1·4638$_5$	1·5920	2·2795

whence $\Sigma(\Delta B \,.\, w_2)/\Sigma w_2^2 = 21{\cdot}25$

α-Iodonaphthalene in carbon tetrachloride at 20°

10^5w_2	10^7B_{12}	$(n_D^t)_{12}$	$(d_4^t)_{12}$	$(\varepsilon_t)_{12}$	10^5w_2	10^7B_{12}	$(n_D^t)_{12}$	$(d_4^t)_{12}$	$(\varepsilon_t)_{12}$
536	0·128	1·4615	1·5948	2·2452	2007	0·253	—	—	—
1161	0·184	1·4629	1·5959	2·2599	2338	0·274	—	1·5979	2·2840
1382	0·197	—	—	—	6067	—	1·4746	1·6037	2·3579
1595	0·228	1·4641	1·5965	2·2679					

whence $\Sigma(\Delta B \,.\, w_2)/\Sigma w_2^2 = 9{\cdot}53$

β-Iodonaphthalene in carbon tetrachloride at 20°

10^5w_2	10^7B_{12}	$(n_D^t)_{12}$	$(d_4^t)_{12}$	$(\varepsilon_t)_{12}$	10^5w_2	10^7B_{12}	$(n_D^t)_{12}$	$(d_4^t)_{12}$	$(\varepsilon_t)_{12}$
276	0·122	1·4609	1·5943	2·2417	706	0·197	1·4620	1·5950	2·2509
335	0·133	—	—	—	905	0·238	1·4625	1·5954	2·2567
462	0·150	—	1·5946	2·2455	983	0·253	1·4629	1·5955	2·2585

whence $\Sigma(\Delta B \,.\, w_2)/\Sigma w_2^2 = 18{\cdot}12$

TABLE 8. *Calculation of molar Kerr constants and dipole moments at infinite dilution in carbon tetrachloride.*

Temp.	Solute	$\alpha\varepsilon_1$	β	γ	δ	$_\infty({}_mK_2) \times 10^{12}$	$_\infty P_2$	(R_D)	μ, D
25°	Naphthalene	0·617	−0·515	0·181	49·0	48·1	44·0	—	0
20	α-Fluoronaphthalene	3·03	−0·400	0·133	66·8$_5$	72·6	83·9	43·7 [1]	1·39
20	β- ,, ,,	3·36	−0·376	0·134	207·1	233·1	88·3$_5$	,,	1·47
20	α-Chloronaphthalene	3·18	−0·302	0·166	151·8	189·8	93·0	49·2 [2]	1·45
20	β- ,, ,,	3·89	−0·323	0·166	324·9	406·2	105·7	49·4 [2]	1·65
20	α-Bromonaphthalene	2·54	−0·057	0·148	131·0	213·4	95·2	51·6 [2]	1·45
20	β- ,, ,,	2·88	−0·085	0·147	295·1	468·6	103·7	51·8 [2]	1·58
20	α-Iodonaphthalene	2·01	0·101	0·160	125·5	244·2	95·4	56·5 [3]	1·37
20	β- ,, ,,	2·20	0·090	0·151	251·4	489·9	101·0	57·9 [3]	1·44

[1] Parts (*Z. physikal. Chem.*, 1930, *B*, **10**, 264). [2] Auwers and Frühling (*Annalen*, 1921, **422**, 192).
[3] Krollpfeiffer (*Annalen*, 1923, **430**, 161).

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