ON THE ANOMALOUS DISPERSION AND ABSORPTION OF ELECTRIC WAVES. PART IV. ANOMALOUS DISPERSION AND DEBYE'S DIPOLE THEORY.

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Received May 28, 1926. Published July 28, 1926.

A short discussion of the results obtained in the previous experiments(1) will be given in the present paper. According to Debye,(2) abnormally large values of the dielectric polarization observed in the static field as well as for long electric waves are to be ascribed to the orientation of a molecule which has a permanent dipole in it. The polarization being practically constant for a considerably wide range of frequency, the molecule must adapt itself to the change of the external field and manifest fully its dipole moment when the frequency is not very great. To the rotation of a molecule, however, there must exist a resistance which depends upon the internal friction and the dimension of the molecule. Therefore when the frequency of the external field attains a certain value, the molecule will not have time enough to arrange itself in order to exhibit fully its static moment. This must be the cause of the decrease of dielectric constants observed in the previous experiments. When the frequency is still increased, the molecule can hardly adapt itself to the external frequency and the effect of dipole to the dielectric polarization will almost disappear. This is the case for the value of dielectric constants of glycerine, amyl and isobutyl alcohols observed at lower temperatures.

Debye(3) treated this phenomenon theoretically and derived the following equation.

$$\varepsilon=\left\{\frac{\left(\frac{\varepsilon_0}{\varepsilon_0+2}\right)^2+\frac{\omega^2\rho^2}{k^2T^2}\left(\frac{\varepsilon_\infty}{\varepsilon_\infty+2}\right)^2}{\left(\frac{1}{\varepsilon_0+2}\right)^2+\frac{\omega^2\rho^2}{k^2T^2}\left(\frac{1}{\varepsilon_\infty+2}\right)^2}\right\}^{\frac{1}{2}}\cos^2\frac{\varphi}{2}$$

where

$$\tan\varphi=\frac{\omega\rho}{kT}\,\frac{\varepsilon_0+2}{\varepsilon_\infty+2}\,\frac{1-\frac{\varepsilon_\infty}{\varepsilon_0}}{1+\frac{\omega^2\rho^2}{k^2T^2}\left(\frac{\varepsilon_0+2}{\varepsilon_\infty+2}\right)^2\frac{\varepsilon_\infty}{\varepsilon_0}},\quad \rho=8\pi\eta a^3.$$

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(1) This journal, 1 (1926), 47 83 & 115.

(2) Debye, *Physik. Z.*, 13 (1912), 97.

(3) Debye, *Verh. Deut. physik. Ges.*, 15 (1913), 770.

ε is the dielectric constant observed in the alternating field, the frequency of which is $\frac{\omega}{2\pi}$; ε_0 the static dielectric constant; ε_∞ the dielectric constant at the frequency at which the effect of dipole disappears; η the viscosity; a the radius of molecule; T the absolute temperature and k Boltzmann's constant. Among the data necessary for the calculation of ε of monovalent alcohols, ε_0 is known from the study of Abegg and Seitz⁽¹⁾ and ε_∞ from the refractive indices for visible light.⁽²⁾ The most rational value of a can be obtained by the kinetic theory from the viscosities in the gaseous state. But this method is available only for ethyl alcohol.⁽³⁾ For homologous series of alcohols a^3 can be assumed to be proportional to b in van der Waals' equation. The values of a for other alcohols can, therefore, be calculated from a for ethyl alcohol and b given in Landolt-Börnstein's Tables.⁽⁴⁾ The viscosities of alcohols at low temperatures were recently measured by Mr. Yoshizaki in our institute. Thus we have all data necessary for the calculation of ε. The calculated values of ε ($\varepsilon_{\text{cal.}}$) and those observed at the wave length of 9.5 metres ($\varepsilon_{\text{obs.}}$) are shown in the following tables.

	Ethyl Alcohol $a=1.8\times10^{-8}$ cm.					Propyl Alcohol $a=2.0\times10^{-8}$ cm.				
Temp.	ε_0	ε_∞	η	ε_{cal}	ε_{obs}	ε_0	ε_∞	η	ε_{cal}	ε_{obs}
20	25.8	1.85	0.0119	26	25	22.2	1.92	0.0226	22	22
10	27.0	1.86	0.0145	27	27	23.5	1.94	0.0292	23	23
0	28.4	1.88	0.0177	28	28	24.8	1.95	0.0388	24	25
−10	30.3	1.90	0.0218	30	30	26.2	1.97	0.0513	24	25
−20	32.0	1.91	0.0276	31	31	27.5	1.98	0.0716	22	24
−30	33.7	1.92	0.0358	32	33	29.0	2.00	0.103	19	20
−40	35.3	1.94	0.0490	31	33	30.5	2.02	0.154	14	15
−50	37.6	1.96	0.0684	29	29	32.0	2.03	0.236	9	10
−60	39.7	1.98	0.0959	25	24	33.7	2.05	0.386	6	7

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(1) Abegg and Seitz, *Z. physik. Chem.*, **29** (1899), 242.

(2) The square of the refractive index for D line were taken as ε_∞, disregarding the inversion of spectrum in the infra-red region.

(3) Landolt-Börnstein "Tabellen" (1923).

(4) b for amyl alcohol can be extrapolated on the assumption that b is additive for homologous series.

	Isobutyl Alcohol $a=2.0\times10^{-8}$ cm.					Amyl Alcohol $a=2.1\times10^{-8}$ cm.				
Temp.	ε_0	ε_∞	η	ε_{cal}	ε_{obs}	ε_0	ε_∞	η	ε_{cal}	ε_{obs}
20	20.0	1.95	0.0391	19	19	16.0	1.98	0.0437	16	16
10	21.0	1.97	0.0555	20	20	16.8	2.00	0.061	16	18
0	21.8	1.99	0.0804	19	20	17.5	2.02	0.0876	15	17
−10	23.2	2.00	0.116	17	17	18.6	2.03	0.130	13	15
−20	24.5	2.02	0.182	13	11	19.7	2.05	0.207	9	10
—30	25.7	2.03	0.30	8	7	20.8	2.07	0.33	6	7
—40	27.0	2.05	0.56	4	5	21.8	2.08	0.58	4	5
−50	29.0	2.07	1.14	3	4	23.0	2.10	1.01	3	4

It can now be admitted that Debye's theory holds in the first approximation for monovalent alcohols. The discussion on glycerine will be given in the following papers which will also contain the results measured at different wave lengths.

The author wishes to express his best thanks to Prof. M. Katayama for his kind guidance.

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