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Abstract

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A NEW DETERMINATION OF THE LIGHT-SCATTERING CONSTANT OF BENZENE

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After Peyrot ([1]), and then Vaucouleurs ([2]), determined the constant of light scattering by benzene, papers appeared with new results that differed greatly from the previous ones. In recent years this constant has been measured many times by various authors ([3]-[13]). A comparison of all the values obtained shows that the large observed scatter of the numbers cannot be called accidental. Here we are dealing with two series of numbers— "low" and "high" values, the latter exceeding the former by approximately one and a half times.

Zimm and Carr, who were among the first to obtain a "high" value, attempted to explain the discrepancy that had appeared by the fact that the authors of the "low" values had not taken into account corrections connected with the refraction of the scattered rays upon emerging from the liquid. However, Rousset and Lochet ([14]) showed the groundlessness of such objections.

Taking into account the importance of the question, we set ourselves the goal of carrying out a new measurement of the light-scattering constant of benzene. From the very beginning we set ourselves the task of choosing a method that would not require any corrections for refraction and, thus, would completely exclude any discussion of corrections of this kind.

The method adopted by us is as follows. A suitable liquid medium is selected with the same refractive index as that of benzene, but whose light scattering exceeds the light scattering of benzene by approximately a factor of 10. The second condition that this liquid must satisfy is that, like benzene, it have a strictly symmetric scattering indicatrix. In addition, it must, of course, be as colorless as benzene. As such a similar liquid it is best to choose a dilute solution of a suitable polymer in benzene.

With the two selected liquids—benzene and the solution—the following two measurements were carried out:

1. The intensities of light scattering by benzene and by the solution at an angle of 90° were compared.

2. The attenuation of a parallel beam of light upon passing through tubes with benzene and with the solution was compared.

Let $I_\mathrm{b}, \Delta_\mathrm{b}, R_\mathrm{b}, \tau_\mathrm{b}$ denote, respectively, the intensity of light scattering at an angle of 90°, the depolarization coefficient, the scattering constant, and the turbidity coefficient of benzene, and let $I_\mathrm{p}, \Delta_\mathrm{p}, R_\mathrm{p}, \tau_\mathrm{p}$ denote the same quantities for the solution.

From the first experiment we obtain:

$$\frac{R_\mathrm{p}}{R_\mathrm{b}} = \frac{I_\mathrm{p}}{I_\mathrm{b}} = a'. \tag{1}$$

Since the refractive indices of benzene and of the solution are the same, relation (1) is obtained directly from the experiment without any corrections for refraction.

···scattering. Having measured the ratio of the scattering constants and the depolarization coefficients, it is not difficult to calculate the ratio of the turbidity coefficients

$$\frac{\tau_\mathrm{p}}{\tau_\mathrm{b}} = a' \frac{1 + 0.5\Delta_\mathrm{p}}{1 + 0.5\Delta_\mathrm{b}} \frac{1 + \Delta_\mathrm{b}}{1 + \Delta_\mathrm{p}} = a. \tag{2}$$

For the second experiment we took a tube with two plane-parallel windows of length l, which was filled first with benzene and then with the solution. A parallel beam of monochromatic light was passed through the tube. Denoting the incident luminous flux by B, we obtain for the transmitted luminous flux:

$$B_\mathrm{b} = Be^{-\tau_\mathrm{b} l},$$

$$B_\mathrm{p} = Be^{-\tau_\mathrm{p} l}. \tag{3}$$

Dividing the first by the second, we obtain

$$\frac{B_\mathrm{b}}{B_\mathrm{p}} = e^{(\tau_\mathrm{p} - \tau_\mathrm{b})\, l}, \tag{4}$$

whence we find

$$\tau_\mathrm{p} - \tau_\mathrm{b} = \frac{2.30}{l} \lg \frac{B_\mathrm{b}}{B_\mathrm{p}} = b. \tag{5}$$

Thus, in order to determine the two quantities τ_{b} and τ_{p}, we have two equations, (2) and (5). Eliminating τ_{p}, we find the turbidity coefficient of benzene

$$\tau_{\text{b}} = \frac{b}{a-1}, \tag{6}$$

and then the scattering constant

$$R_{\text{b}} = \tau_{\text{b}} \frac{3}{16\pi} \frac{1+\Delta_{\text{b}}}{1+0.5\Delta_{\text{b}}}. \tag{7}$$

Let us emphasize once again that the main advantage of the proposed method is that it entirely removes the problem of corrections for refraction. Secondly, here luminous fluxes that differ relatively little in intensity are compared, which is a reliable safeguard against possible systematic errors.

As the auxiliary liquid we chose a solution of polychlorostyrene in benzene. We prepared two solutions: with concentrations of 6.6 and 8.2 g/l and refractive indices n_D^{20} of 1.5013 and 1.5015, respectively (the refractive index of pure benzene is $n_D^{20} = 1.5010$). The refractive indices of our solutions and of benzene differ so little from one another that there is no need to speak of any corrections for refraction.

The polychlorostyrene for the first solution was prepared from monochlorostyrene by polymerization in bulk under vacuum at a temperature of 120° for 100 hours. The second sample was prepared under analogous conditions at a temperature of 110°. Under such polymerization conditions, polychlorostyrene with a molecular weight of about 100,000 is obtained. A solution of such a polymer should not exhibit asymmetry of light scattering, the presence of which could lead to an overestimation of the scattering constants of benzene. Indeed, comparison of the light scattering of our solutions at angles of 45 and 135° showed that asymmetry is absent.

The benzene used was cryoscopic and was additionally purified by vacuum distillation. When filling the tubes, the necessary measures were taken against the entry of dust into the benzene or into the solution, since the presence of dust in the sol-

also should lead to an overestimation of the scattering constant of benzene. Before beginning the measurements, the solution and the benzene were allowed to stand for a long time.

The measurements were carried out on three monochromatic lines of a mercury lamp: $\lambda\lambda$ 4358, 5461, and 5780 Å. The scattering intensity was measured both photoelectrically and visually, the two methods giving coincident results. To measure the attenuation, the incident light beam was split into two beams: one passed through a tube with benzene or solution of length $l = 100$ cm, while the other passed outside the tube. A photometric wedge was placed in the path of the second beam. The measurements were made on a photometer with two selenium photocells having identical spectral characteristics and connected by the emf compensation method.

Table 1

Results of measuring the light-scattering constant of benzene, $t = 20^{\circ}$

λ, Å	Δ_b	Δ_p	a'	a	$\lg \frac{B_b}{B_p}$	$b \cdot 10^4$	$\tau_b \cdot 10^4$	$R_b \cdot 10^6$
Solution I	**Solution I**	**Solution I**	**Solution I**	**Solution I**	**Solution I**	**Solution I**	**Solution I**	**Solution I**
4358	0.43	0.064	8.4	9.6	0.192	44.2	5.14	36.0
5461	0.43	0.064	8.3	9.5	0.062	14.3	1.68	11.8
5780	0.43	0.064	8.3	9.5	0.052	12.0	1.41	9.9
Solution II	**Solution II**	**Solution II**	**Solution II**	**Solution II**	**Solution II**	**Solution II**	**Solution II**	**Solution II**
4358	0.43	0.055	10.4	11.9	0.238	54.8	5.03	35.3
5461	0.43	0.055	10.1	11.6	0.081	18.6	1.76	12.4
5780	0.43	0.055	10.3	11.8	0.064	14.7	1.36	9.6

Table 1 gives the results of the measurements. In the experiment, Δ_b, Δ_p, a' and $\lg(B_b/B_p)$ were measured. As the table shows, the results obtained by us serve as convincing evidence of the correctness of the so-called "low" values of the scattering constant of benzene. For the blue line we obtained a somewhat higher value than for the yellow and green lines. It is possible that for the blue line the scattering indicatrix was not quite symmetric. We tested for asymmetry of light scattering with green rays. However, the deviations for the blue rays do not exceed the limits of the measurement errors. Therefore we can average all the results for all wavelengths, using the known relation

$$\frac{R_1}{R_2} = \frac{\lambda_2^4}{\lambda_1^4} \frac{(n_1^2 - 1)^2}{(n_2^2 - 1)^2}. \tag{8}$$

After such averaging, on the basis of the data of Table 1, we obtained for $\lambda\lambda$ 4358, 5461, and 5780 Å, respectively, the following values of the scattering constant of benzene: $9.9 \cdot 10^{-6}$; $12.6 \cdot 10^{-6}$; $33.7 \cdot 10^{-6}$ cm^{-1}.

The accuracy of our measurements may be estimated at $\pm 6\%$.

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Note: Figure translations are in progress. See original paper for figures.