# SCATTERING OF POLARISED LIGHT IN COLLOIDS

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When a horizontal beam of polarised light is passed through a colloidal solution the light scattered in the transverse horizontal direction is found to be depolarised. The magnitude of the depolarisation depends not only on the optical properties of the colloidal solution but also on the inclination of the plane of polarisation of the incident beam to the vertical. In the two extreme cases, *i.e.*, when the direction of the incident electric vector is vertical and horizontal respectively, the corresponding depolarisation factors are given by

$$\rho_v = H_v/V_v$$
$$\rho_h = V_h/H_h, \tag{1}[1]$$

where $H_v = V_h$. If, on the other hand, the plane of polarisation of the incident beam is inclined at an angle $\theta$ to the vertical the depolarisation of the light scattered in the transverse horizontal direction can be calculated under certain assumptions. The incident electric vector can be split up into two components, one vertical and the other horizontal, the intensity being proportional to $\cos^2\theta$ and $\sin^2\theta$ respectively. The light scattered in the transverse horizontal direction is made up of four components of intensities, $V_v \cos^2\theta$, $V_h \sin^2\theta$, $H_v \cos^2\theta$ and $H_h \sin^2\theta$ respectively, of which the first two are with vibrations vertical and the last two are with vibrations horizontal. *If these four components are entirely unrelated* the resultant effect is obtained by the addition of intensities. The depolarisation factor $\rho_\theta$ is therefore given by

$$\rho_\theta = \frac{\text{Horizontal Comp.}}{\text{Vertical Comp.}} = \frac{H_v \cos^2\theta + H_h \sin^2\theta}{V_v \cos^2\theta + V_h \sin^2\theta} = \frac{1 + \tan^2\theta/\rho_h}{\tan^2\theta + 1/\rho_v} \tag{2}$$

and hence $\rho_{45°} = \rho_u$.

Thus, from a knowledge of $\rho_v$ and $\rho_h$, $\rho_\theta$ can be calculated for any value of $\theta$. Let us now consider some special cases.

*Case I : Small anisotropic particles.—*

According to the theory of Rayleigh and Gans, if a beam of light with electric vector along the $z$-axis be incident on a colloidal solution

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[1] The symbols used in this equation have the same significance as those given in *Proc. Ind. Acad. Sci.*, (A), 1938, **7**, 22.

containing in suspension small anisotropic particles, along the $x$-axis of a system of co-ordinates $x, y, z$, the components of the intensity of the scattered radiation polarised parallel to $x$, $y$ and $z$ directions are given by X, Y and Z such that X = Y and X/Z $= \rho_v$. If we suppose that the $z$-axis is inclined at an angle $\theta$ to the vertical and $x$-axis lies along the horizontal plane, the depolarisation of the light scattered in the transverse horizontal direction, i.e., in a direction in the $xy$-plane inclined at an angle $\theta$ to the $y$-axis is given by

$$\rho_\theta = \frac{X}{Z \cos^2\theta + Y \sin^2\theta} = \frac{\sec^2\theta}{\tan^2\theta + 1/\rho_v}. \tag{3}$$

Equation (3) is identical with equation (2) if we put $\rho_h = 1$ for small anisotropic particles.

*Case II* : *Large isotropic particles.*—

According to Mie's theory[2] if the incident light is plane polarised, the light scattered by large isotropic particles in any direction except directions parallel and perpendicular to the incident electric vector, is elliptically polarised. If the plane of polarisation of the incident beam is inclined at an angle $\theta$ to the vertical the vertical and hotizontal components of the light scattered in the transverse horizontal direction are $V_\theta$ and $H_\theta$ where

$$V_\theta = k \left| \sum_0^\infty n \left\{ A_n \Pi_n - P_n \Pi'_n \right\} \right|^2 \cdot \cos^2\theta.$$

$$H_\theta = k \left| \sum_0^\infty n \left\{ A_n \Pi_n' - P_n \Pi_n \right\} \right|^2 \cdot \sin^2\theta \tag{4}[3]$$

$k$ is a constant depending on the wave-length of the incident light, $A_n$ and $P_n$ are complex functions defined by boundary conditions depending upon the wave-length, the radius of the particle and the relative refractive index, and $\Pi_n$ and $\Pi_n'$ are spherical functions. The two components $V_\theta$ and $H_\theta$ are coherent with a definite phase difference. The depolarisation is equal to $H_\theta/V_\theta$. When the incident beam is unpolarised the vertical and horizontal components of the transversely scattered light are given by

$$V_u = k \left| \sum_0^\infty n \left\{ A_n \Pi_n - P_n \Pi_n' \right\} \right|^2$$

$$H_u = k \left| \sum_0^\infty n \left\{ A_n \Pi_n' - P_n \Pi_n \right\} \right|^2. \tag{5}[3]$$

[2] G. Mie, *Ann. d. Phys.*, 1908, **25**, 377.

[3] These relations are obtained from Mie's paper by putting $\theta = 90 - \theta$ and $\phi = 0$ and applying the relations 44 and 45 in equations (78). See *ibid.*, 1908, **25**, 410.

It follows from equations (4) and (5) that

$$\rho_\theta = \frac{H_\theta}{V_\theta} = \frac{H_u}{V_u} \tan^2\theta = \rho_u \tan^2\theta. \tag{6}$$

This is identical with equation (2) since $H_v = V_h = 0$ for large isotropic particles.

Thus it is seen that the equation (2) giving the value of $\rho_\theta$ in terms of $\rho_v$ and $\rho_h$ is rigorously true for small anisotropic particles and for large isotropic particles. In the most general case of large anisotropic particles the equation (2) will be true if there is no coherence between the two vertical components $V_v \cos^2\theta$ and $V_h \sin^2\theta$ and also between the two horizontal components $H_v \cos^2\theta$ and $H_h \sin^2\theta$, *i.e.*, the *volume scattering and the anisotropic scattering are uncorrelated as in the case of small anisotropic particles.* Theoretically, however, this assumption does not seem justifiable.

### Some Experimental Observations

In order to find out how far the above assumption is valid in the case of large anisotropic particles, some preliminary measurements of the depolarisation factor $\rho_\theta$ have been made for three different colloidal solutions and for various values of $\theta$. The results are tabulated below. The values of $\rho_\theta$

| $\theta$ | Graphite sol | | $As_2S_3$ sol | | Toluene emulsion | |
|---|---|---|---|---|---|---|
| | $\rho_\theta$ observed | $\rho_\theta$ calculated | $\rho_\theta$ observed | $\rho_\theta$ calculated | $\rho_\theta$ observed | $\rho_\theta$ calculated |
| 0° | 0·049 | .. | 0·027 | .. | 0·0032 | .. |
| 10 | 0·053 | 0·057 | 0·03 | 0·034 | 0·008 | 0·008 |
| 20 | 0·071 | 0·084 | 0·052 | 0·056 | 0·021 | 0·025 |
| 30 | 0·118 | 0·133 | 0·087 | 0·1 | 0·055 | 0·057 |
| 40 | 0·188 | 0·231 | 0·17 | 0·17 | 0·105 | 0·121 |
| 45 | 0·234 | 0·29 | 0·213 | 0·244 | 0·155 | 0·164 |
| 50 | 0·306 | 0·386 | 0·297 | 0·331 | 0·203 | 0·231 |
| 60 | 0·575 | 0·719 | 0·561 | 0·644 | 0·409 | 0·48 |
| 70 | 1·172 | 1·46 | 1·16 | 1·42 | 1·03 | 1·19 |
| 80 | 2·47 | 3·24 | 2·99 | 3·86 | 4·0 | 4·70 |
| 90 | 5·21 | .. | 8·26 | .. | 50·0 | .. |
| $\rho_u$ | 0·31 | .. | 0·25 | .. | 0·17 | .. |

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calculated from the observed values of $\rho_v\ (=\rho_{0^\circ})$ and $\rho_h\ (=\rho_{90^\circ})$ applying the formula (2), are also given.

A critical survey of the figures given in the table shows that the observed values of $\rho_\theta$ are not in agreement with the calculated values showing thereby that the formula (2) is not strictly true for particles of any size and shape. Graphite sol which contains highly anisotropic particles shows a greater deviation than toluene emulsion which contains isotropic droplets in suspension. The deviations, however, are not large and may conceivably be due to a second order effect.

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