LIGHT SCATTERING IN SILVER SOLS

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Abstract

The intensity of the transversely scattered light has been measured at different wave-lengths for six typical silver sols using a photomultiplier. Applying Gans' theory for small ellipsoidal particles in metallic sols, the intensities of scattering have been calculated for different axial ratios B/A of a small prolate ellipsoid of silver and compared with the experimental data. The relative sizes as well as the degree of departure from spherical shape for the particles present in the different sols have been estimated. A comparison has also been made between the absorption and intensities of scattering at different wave-lengths.

1. Introduction

So far the experimental work on silver sols has been confined mainly to measurements of the absorption and depolarisation (Krishnan, 1937; Guinand and Tonnelat, 1947; Wiegel, 1954) and the refractive index dispersion (Jausseran, 1937). No detailed investigation has been made in the case of silver sols on the variation with wave-length of the intensity of scattering in the horizontal transverse direction and the results compared with the theoretical conclusions of Gans (1912, 1915, 1920) for metallic sols containing small ellipsoidal particles. In a previous paper (Sivarajan, 1953) the author made a study of the intensity of light scattered by gold sols in a horizontal transverse direction and at different wave-lengths and interpreted the results in terms of Gans' theory. This work has been extended to the case of six silver sols and the results are reported in this paper.

2. Experimental Details and Results

Six silver sols identical with those used by Krishnan (1937) were prepared. Details of preparation are given in his paper. Suitable precautions were taken to render the sols dust free. The sols were kept in thoroughly cleaned resistance glass bottles and were numbered as done by Krishnan.

The intensity measurements were made as in the case of the gold sols using the photomultiplier set-up described therein and the corrections applied (Sivarajan, 1953). The absorption measurements were carried out using a Beckman photoelectric spectrophotometer. The intensity of scattering was measured at several wave-lengths, namely, λ 3650, λ 4047, λ 4358 and λ 5461 of

mercury, λ 5893 of sodium and narrow bands of mean wave-length λ 4700, λ 5100 and λ 6200, these being obtained from the continuous radiation of a 500 C.P. pointolite lamp by the use of suitable filters.

Using the method of calculating the theoretical values of the intensity of scattering as given in the paper on gold sols (Sivarajan, *loc. cit.*), the intensities of scattering for silver sols containing prolate spheroids of axial ratios B/A=0·85, 0·8, 0·75 and 0·7 were calculated and plotted graphically as a function of wave-length. The theoretical intensity ratios given in Table I were obtained

TABLE I

Theoretical Values of Intensity Ratios λ 3650/λ 4358, λ 4047/ λ 4358, λ 6200/ λ 4358 *for Different Axial Ratios B/A*

B/A		$I_{\lambda 3650}/I_{\lambda 4358}$	$I_{\lambda 4047}/I_{\lambda 4358}$	$I_{\lambda 6200}/I_{\lambda 4358}$
0·7	U	·5	1·134	·024
	V	·66	1·00	·028
	H	·27	1·21	·0042
0·75	U	·31	1·125	·018
	V	·38	·93	·017
	H	·125	1·45	·003
0·8	U	·8	2·54	·032
	V	·68	1·94	·032
	H	·35	8·0	·0045
0·85	U	1·55	4·8	·053
	V	1·45	4·1	·053
	H	1·70	21·9	·003

U, V, H refer to incident unpolarised, vertically polarised and horizontally polarised light respectively.

from these graphs. In Table II the corresponding experimental intensity ratios for the six silver sols have been tabulated. Table III contains the experimental values of the extinction coefficients for these sols at the different wave-lengths at which the intensity measurements were made.

3. DISCUSSION

From the theoretical values of the intensity ratios for prolate spheroids as given in Table I and the corresponding experimental values given in Table II, it can be concluded that nuclear silver sol II contains particles which are more spherical than in the other sols, the axial ratio B/A being about 0·85. The particles in sols III and V behave more like prolate spheroids of axial ratio 0·75,

TABLE II

Experimental Values of Intensity Ratios for Silver Sols I-VI

Sol		$I_{\lambda 3650}/I_{\lambda 4358}$	$I_{\lambda 4047}/I_{\lambda 4358}$	$I/_{\lambda 6200}/I_{\lambda 4358}$
I	U	·46	·52	·19
	V	·50	·582	·20
	H	·36	·41	·20
II	U	1·6	4·17	·06
	V	1·6	3·83	·06
	H	1·5	3·00	·0045
III	U	·26	1·03	·024
	V	·30	·90	·021
	H	·104	1·4	·0025
IV	U	·08	·43	·0105
	V	·1	·52	·011
	H	·025	·17	·009
V	U	·32	1·26	·012
	V	·34	·97	·011
	H	·20	1·47	·008
VI	U	·14	·53	·02
	V	·20	·644	·027
	H	·11	·52	·017

U, V, H refer to incident unpolarised, vertically polarised and horizontally polarised light respectively.

TABLE III

Silver Sols

Extinction coefficient log 1/T. T = Transmission

Sol / λ	I	II	III	IV	V	VI
3650	·095	·097	·68	·48	·23	·77
4047	·115	·18	1·05	1·2	·34	1·2
4358	·12	·097	·96	1·00	·3	1·37
4700	·11	·05	·495	·53	·19	1·275
5100	·097	·03	·32	·32	·13	1·00
5461	·085	·027	·34	·21	·11	·74
5893	·076	·03	·24	·125	·11	·48
6200	·06	·02	·23	·08	·097	·37

i.e., they show greater departure from spherical shape. Also, since the experimental intensity of scattering values for these sols are about the same the particles in both are more or less of the same size. Depolarisation measurements show that sols IV and VI contain particles which are not small compared with the wave-length of light and as such it is not justifiable to interpret the measured intensities of scattering on the basis of Gans' theory.

An examination of the absorption data given in Table III when compared with the theoretical data for silver sols (Gans, 1915) confirms the fact that silver sol II as well as sols III and V contain nearly spherical particles small in comparison with the wave-length of light. As the size of the particle as well as the anisotropy increase the absorption maximum is seen to shift to longer wave-lengths. In Bredig's sol there is no sharp maximum in the absorption and this is probably due to the presence of polydispersivity in this sol.

When the experimental intensity values were plotted as a function of wave-length it was seen that in sols I, IV and VI the intensities were a maximum between λ 4200 and λ 4800 whereas for sols II, III and V which contained smaller and more spherical particles the maxima shifted to the shorter wave-length side. This could also be seen from the theoretical plot of intensity *versus* wave-length for different axial ratios. Furthermore the relative intensities of scattering were found to increase in the order sol II, III, V, IV and VI, which was also the order of increasing particle size and were found to be in agreement with depolarisation data for these sols. Finally the interesting feature noticed in the case of gold sols (Sivarajan, *loc. cit.*) was also seen in the case of these silver sols, *viz.*, the correspondence between the intensity of scattering at different wave-lengths and the absorption.

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References

R. Gans .. *Ann. d. Physik.*, 1912, **37**, 883.

——— .. *Ibid.*, 1915, **47**, 270.

——— .. *Ibid.*, 1920, **62**, 331.

S. Guinand and J. Tonnelat .. *Comptes Rendus*, 1947, **224**, 1529.

——— .. *Ibid.*, 1947, **225**, 1029.

C. Jausseran .. *Ibid.*, 1937, **204**, 1646.

R. S. Krishnan .. *Proc. Ind. Acad. Sci.*, 1937, **5A**, 94.

S. R. Sivarajan .. *Ibid*, 1953, **37A**, 418.

E. Wiegel .. *Z. Phys.*, 1954 **136**, 642.