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Effect of Temperature and Non-electrolyte during Mutual Coagulation of Ferric Oxide and Antimony Sulphide Sols

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Barve and Jambotkar[1] and Gore[2] studied the mutual coagulation of ferric oxide and antimony sulphide sols with reference to dialysis and periodic coagulation of sols. From the electron microscopic study of mutual coagulation, Bromberg *et al.*[3] observed that particles of positive sol adhered to the threads or rods of vanadium pentoxide. Gupta[4] used dropping mercury-electrode capacity measurement in detecting the mutual coagulation. Ferric oxide sol was coagulated by negatively charged arsenic sulphide sol by Krishnamurti and Karbelkar[5] and they assumed that the instantaneous aggregation of the primary particles of the sol took place on mixing the sols. Hazel and McQueen[6] attributed the mutual coagulation of sols primarily to the mutual adsorption of oppositely charged particles with an unequal distribution of the total charges.

Prasad and Ghosh[7] found the stability ratio '*W*' to decrease in presence of acetone, ethanol, and gelatin for the same amount of coagulating electrolyte. Beg[8] made studies during coagulation of copper ferrocyanide sol by electrolyte in presence of non-electrolytes. An attempt has been made here to study the effect of temperature and non-electrolyte (formamide) on the average velocity of mutual coagulation and consequently to determine the stability of ferric oxide and antimony sulphide sols in their mutual coagulation.

Procedure.—The details of the experimental procedure adopted here are the same as reported earlier[9]. The dialysed sol of ferric oxide was used throughout the experiment. This sol (10ml) was mixed with the required volume of Sb_2S_3 sol and water, keeping the total volume always 15 ml. Changes in viscosity during mutual coagulation were measured after definite intervals of time for 1 hour. The experiment was performed at 35°, 40°, 45°, and 50°. The viscosity changes during mutual coagulation were also measured in presence of four different concentrations of formamide. The average velocity of mutual coagulation was obtained by dividing the total changes produced in viscosity by the corresponding time in minutes. The coagulation changes have been expressed in terms of viscosity (millipoise).

[1] This *Journal*, 1951, **28**, 453.
[2] *Kolloid Z.*, 1958, **160**, 27.
[3] *Doklady Akad. Nauk, S. S. S. R.*, 1951, **79**, 281.
[4] *Kolloid Z.*, 1955, **141**, 102.
[5] *Science & Culture*, 1953, **19**, 37.
[6] *J. Phys. Chem.*, 1933, **37**, 553, 571.
[7] *Kolloid Z.*, 1961, **175**, 1304.
[8] *Ibid.*, 1957, **153**, 164.
[9] Yadava and Verma, this *Journal*, 1962, **39**, 325.

TABLE I

Temperature effect.

Conc. of Fe_2O_3 sol=6.064g. litre. Conc. of Sb_2S_3 sol=0.8 g./litre.
Fe_2O_2 sol (10ml)+Sb_2S_3 sol+water. Total volume=15ml.

Sb_2S_3 sol.	Average velocity of coagulation per minute in terms of viscosity changes (millipoise) at:			
	35°.	40°.	45°.	50°.
3.0 ml	..	..	..	0.060
3.1	..	..	..	0.074
3.2	..	..	0.042	0.079
3.3	0.012	0.021	0.047	..
3.4	0.018	0.027	0.064	..
3.5	0.028	0.038	0.074	..
3.6	0.040	0.064	..	..

TABLE II

Non-electrolyte effect.

Non-electrolyte : formamide. Temp.=35°. Other conditions are same as in Table I.

Sb_2S_3 sol.	Average velocity of coagulation per minute in terms of viscosity changes (millipoise) on addition of formamide.				
	0. ml.	0.25 ml.	0.50 ml.	0.75 ml.	1.00 ml.
3.05 ml	..	..	..	..	0.0[illegible]
3.10	..	..	0.028	0.057	0.096
3.15	..	..	..	0.074	0.126
3.20	..	0.021	0.062	0.106	0.129
3.25	..	..	0.085	0.137	..
3.30	0.012	0.048	0.147	..	..
3.40	0.018	0.084	..	..	..
3.50	0.028	0.128	..	..	..
3.60	0.046	..	..	..	..

Assuming the changes produced in viscosity of a sol during slow coagulation to be proportional to the amount of sol coagulated, the average velocity of coagulation can be expressed by the changes produced in viscosity. Table I shows that the average velocity of mutual coagulation increases with the rise in temperature. At 35°, when 3.3ml of Sb_2S_3 sol is mixed with 10ml of Fe_2O_3 sol, the average velocity of coagulation increases from 0.012 to 0.047 m.poise, as the temperature is raised from 35° to 45°. Similar increase in the velocity of mutual coagulation is obtained at other concentrations of Sb_2S_3 sol on raising the temperature, provided that the concentrations of Sb_2S_3 sol remain so adjusted as to cause only slow coagulation. At higher temperatures, the coagulation concentration of Sb_2S_3 sol decreases, whereas the velocity of mutual coagulation increases.

Table II shows that the mutual coagulation proceeds with greater velocity on increasing the concentration of formamide, e.g., when 3.3 ml of Sb_2S_3 sol is added for coagulating 10 ml of Fe_2O_3 sol, the average velocity of mutual coagulation increases from 0.012 to

0.147m. poise on addition of 0.5 ml of formamide. Similar results are also found at other concentrations of Sb_2S_3 sol when the amount of formamide is increased in the coagulating mixture. It can be predicted from these observations that the velocity of mutual coagulation will further increase on increasing formamide concentration.

According to Hazel and McQueens[6], the mutual coagulation of sol is due to the mutual adsorption of oppositely charged particles with an unequal distribution of the total charges. The increased velocity of mutual coagulation at higher temperatures and concentrations of charged formamide means that the mutual adsorption of oppositely particles increases, causing a decrease in the stability of sols. Mutual coagulation can further be explained on Freundlich's assumption of kinetic theory of coagulation[10]. According to this theory only those particles are coagulated, kinetic energy of which is greater than the critical value. The increased average velocity of mutual coagulation for Fe_2O_3 and Sb_2S_3 sols shows that these two factors contribute the kinetic energy to the coagulating particles required for this purpose and as such they decrease the stability of sols considerably.

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[10] Freundlich, *Kolloid Z.*, 1918, **23**, 163.