STUDIES ON FLOTATION OF ALUMINA AND DEPRESSION OF SILICA FROM KASHMIR BAUXITE

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In India workable quantities of laterite type bauxites occur in the States of Bombay, Bihar, Orissa, Madhya Pradesh and Kashmir.[1] Analysis of the bauxites from different states are given by Holland[2] and Middlemiss.[3] Data regarding the annual output of Indian Bauxites, and the production and the requirements of aluminium in India are also available.[4] These figures clearly show the necessity for increasing the production of the metal in India and the scope for the exploitation of low grade bauxite ore reserves of the country.

Investigations were, therefore, carried out to establish suitable methods for enriching low-grade bauxites with high percentage of silica and iron oxides, particularly by adopting the flotation techniques. In this paper, results of studies on the flotation of alumina and the depression of silica from a sample of Kashmir bauxite are presented.

MATERIALS AND METHODS

Sample of Bauxite.—The ore was obtained from Jammu Province, Kashmir and the chemical analysis of the same is given in Table I.

TABLE I

Constituents	Percentages
Al_2O_3 (Total)	62·73
Al_2O_3 (Available) ..	58·76
SiO_2 (Total)	11·81
SiO_2 (Free)	7·13
Fe_2O_3	7·90
TiO_2	3·41
Combined H_2O	14·15
TOTAL ..	100·00

The composition of aluminium oxide and combined water in the Kaolinite and the alumina in the ore is given in Table II.

TABLE II

Silica, alumina and combined water in kaolinite			Alumina and combined water in remaining of the ore		
SiO_2	Al_2O_3	H_2O	Al_2O_3	H_2O	Ratio of H_2O to Al_2O_3
4·68	3·97	1·40	58·76	12·75	0·21

These results indicate that the aluminium oxide occurs as diaspore in this ore, in agreement with the observations of Fox[16] and Middlemiss[3] about Kashmir bauxite. The study of a thin section of the ore under a petrographic microscope confirmed this conclusion and indicated that, in the ore sample, the iron oxides occur as hematite and silica mostly as quartz. Some silica was, however, found to be present as silicate-kaolinite and some diaspore not completely liberated from hematite. Fig. 1 shows the various constituents of the ore.

The available ore was in the form of small lumps, less than ¼" in size. It was, therefore, ground in a ball mill. Sieve analysis of the ground ore was done with the standard Tyler Sieve set and the Denver Sieve Shaker. Heavy media separation and analysis of the various screen fractions were tried using acetylene tetrabromide as the heavy liquid adjusted to a specific gravity of 2·82 by dilution with benzol, the specific gravity of kaolinite and diaspore being 2·6 and 3·4 respectively.[5] Results of these analysis are given in Table III.

From these results it is evident that the percentage of alumina depressed in the sink increases with the fineness of grains indicating increasing liberation of diaspore with the fineness of the ore. The silica percentage floated is also noticed to be decreasing with the increase in the fineness of the fractions. Ore of mesh size − 100+ 250 was, therefore, selected for all the flotation studies.

Chemical Analysis.—Samples of the ore were analysed by the method suggested by Scott.[6] The decomposition of samples was done by fusion with anhydrous sodium carbonate in a platinum crucible. The colorimetric estimation of titanum dioxide was done in the "Klett-Bio" type colorimeter.

TABLE III

Mesh	Float and sink fractionations		Weight %	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	% Al_2O_3 in sink	% SiO_2 floated
−40+60	Float	..	75	11·86	7·92	62·02	..	..
	Sink ..	..	25	3·72	16·00	62·14	..	..
	Composite	..	100	9·92	9·94	62·03	31·51	89·80
−60+80	Float ..	..	51	17·51	7·30	56·99	..	..
	Sink ..	..	49	3·81	9·08	68·91	..	..
	Composite	..	100	10·82	8·17	62·84	53·73	82·30
−80+100	Float ..	..	35	26·00	6·21	49·59	..	..
	Sink ..	..	65	4·03	8·90	68·88	..	..
	Composite	..	100	11·70	7·95	62·12	72·07	77·71
−100+250	Float ..	..	30	25·12	6·14	47·54	..	..
	Sink ..	..	70	4·83	8·66	68·30	..	..
	Composite	..	100	11·84	7·92	64·07	74·61	63·63
−250	Float ..	..	28	30·35	6·02	45·40	..	..
	Sink ..	..	72	5·12	8·06	69·00	..	..
	Composite	..	100	12·11	7·58	62·39	79·62	70·17

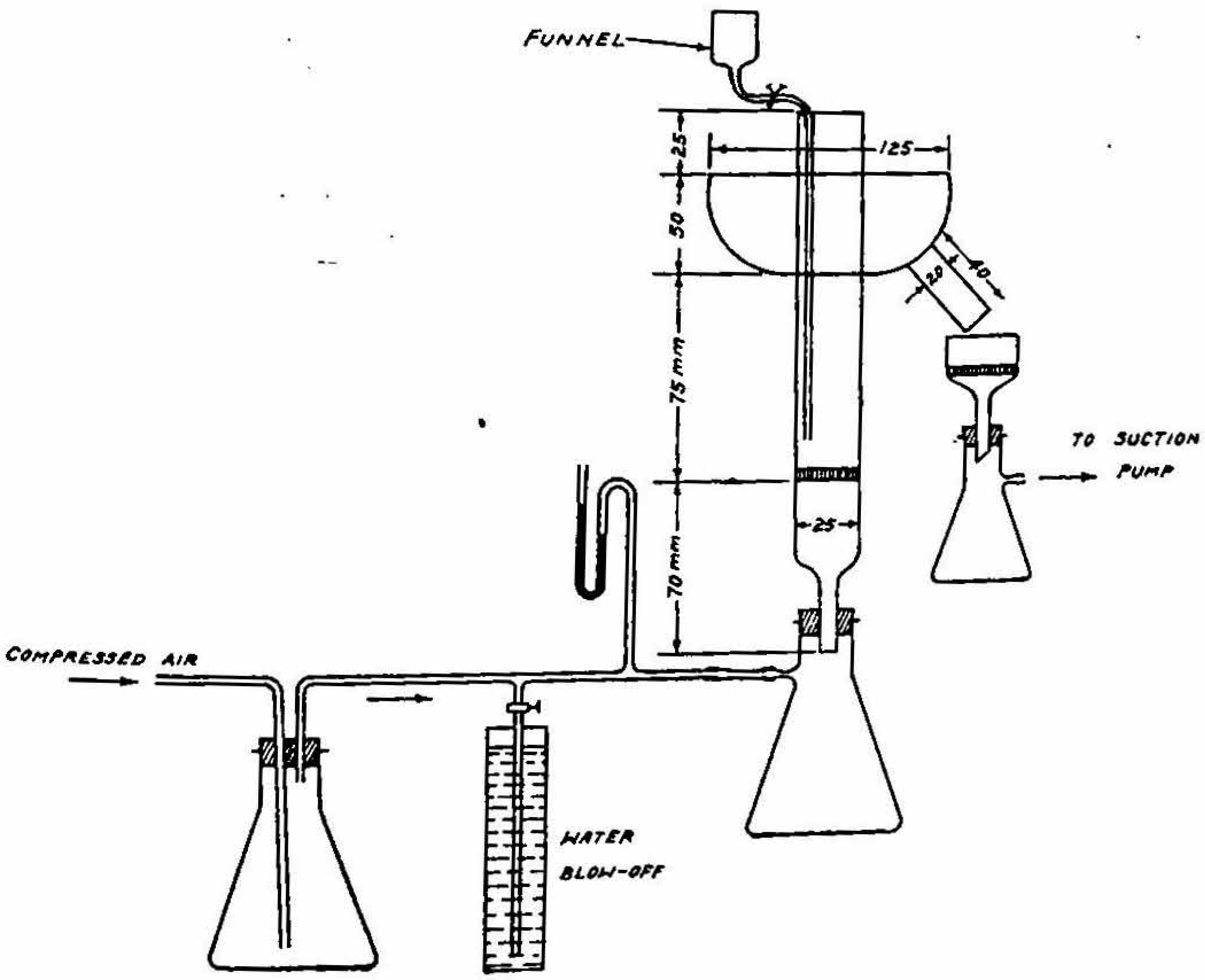

FIG. 2. Apparatus for Small-Scale Flotation Experiment.

Flotation Studies.—The Leef and Knoll[7] cell was used for the flotation tests. Details of equipment assembly are given in Fig. 2. Results tabulated in Table IV show a favourable comparison of results obtained with this cell and those from Denver 'Sub A' Flotation Machine No. 5 which is claimed[8] to give results capable of being duplicated in actual plant practice.

TABLE IV

No.	Cell	(Assay of Float) Al_2O_3 %	SiO_2 %	Fe_2O_3 %	% Recovery of Al_2O_3 in the Float
1	Leef and Knoll ..	69·88	6·71	5·44	78·23
		68·92	6·74	5·40	79·20
	Average ..	69·40	6·72	5·42	78·71
2	Denver 'Sub A' ..	69·65	6·91	5·43	82·10
		67·12	6·88	5·48	81·23
	Average ..	68·38	6·89	5·45	81·66

Effects of conditioning with sodium sulphide, of variation in the concentration of collectors, depressants, promoters, the influence of pH and pulp density on the grade of concentrate and the percentage recovery of alumina were studied. Results given in Table V relate to the effect of conditioning and the rest of the results are graphically represented in Figs. 3 to 9. Experimental details of flotation procedure followed are given along with the respective results.

RESULTS AND DISCUSSION

Results given in Table V show that conditioning of the ore with sodium sulphide prior to subjecting the same to flotation, is essential. The conditioning agent, however, does not seem to be acting as a sulphidising agent, since aluminium sulphide is easily hydrolysable and as such cannot form a coating on the alumina. This observation is confirmed by the fact that collectors like Xanthates and Aerofloats usually used with sulphide ores do not act effectively on bauxite conditioned with sodium sulphide. Significant recoveries have also been reported by pre-treatment with sodium carbonate.[9] Also, since silica activated by ferric, cupric, lead and zinc salts, is floated by

TABLE V

	Ignition loss %	SiO_2 %	Fe_2O_3 %	TiO_2 %	Al_2O_3 %
	Mesh − 100+250				
Before flotation ..	14·15	11·81	7·90	3·41	62·73
After flotation with conditioning and with kerosene:					
Float	14·35	8·41	8·10	3·14	66·00
Sink	13·92	14·12	7·55	3·43	60·98
	Mesh − 150+200				
Before flotation ..	13·67	11·95	8·07	3·47	62·84
After flotation without conditioning and without kerosene:					
Float	14·62	14·65	8·66	3·05	59·02
Sink	13·86	6·74	7·93	3·54	67·93
After flotation with conditioning and without-kerosene:					
Float	13·86	10·82	7·80	3·38	64·14
Sink	13·81	13·35	8·14	3·41	61·29
After flotation with conditioning and with kerosene:					
Float	14·25	8·21	8·82	3·14	65·58
Sink	13·84	14·50	7·12	3·34	61·20

Flotation Conditions

Oleic acid	2·5 lb./ton.
Pine oil	1·0 ,,
Kerosene	1·0 ,,
Sodium sulphide	1% of the weight of the ore.
Pulp density	15%
pH	10·0

fatty acids, the sodium sulphide in this case can be considered to inactivate the silica likely to have been activated by the hematite present in the ore.

Oleic acid is found to be a better collector than palmitic acid (Figs. 3 and 4). This is likely to be due to the fact that oleic acid molecule occupies more space than palmitic acid molecule on the mineral particle,[10] and that it may have two centres of adsorption on the solid (palmitic acid having only one such centre).[11] It is also observed that the percentage recovery of alumina increases with increasing amount of the collector, reaches a maximum

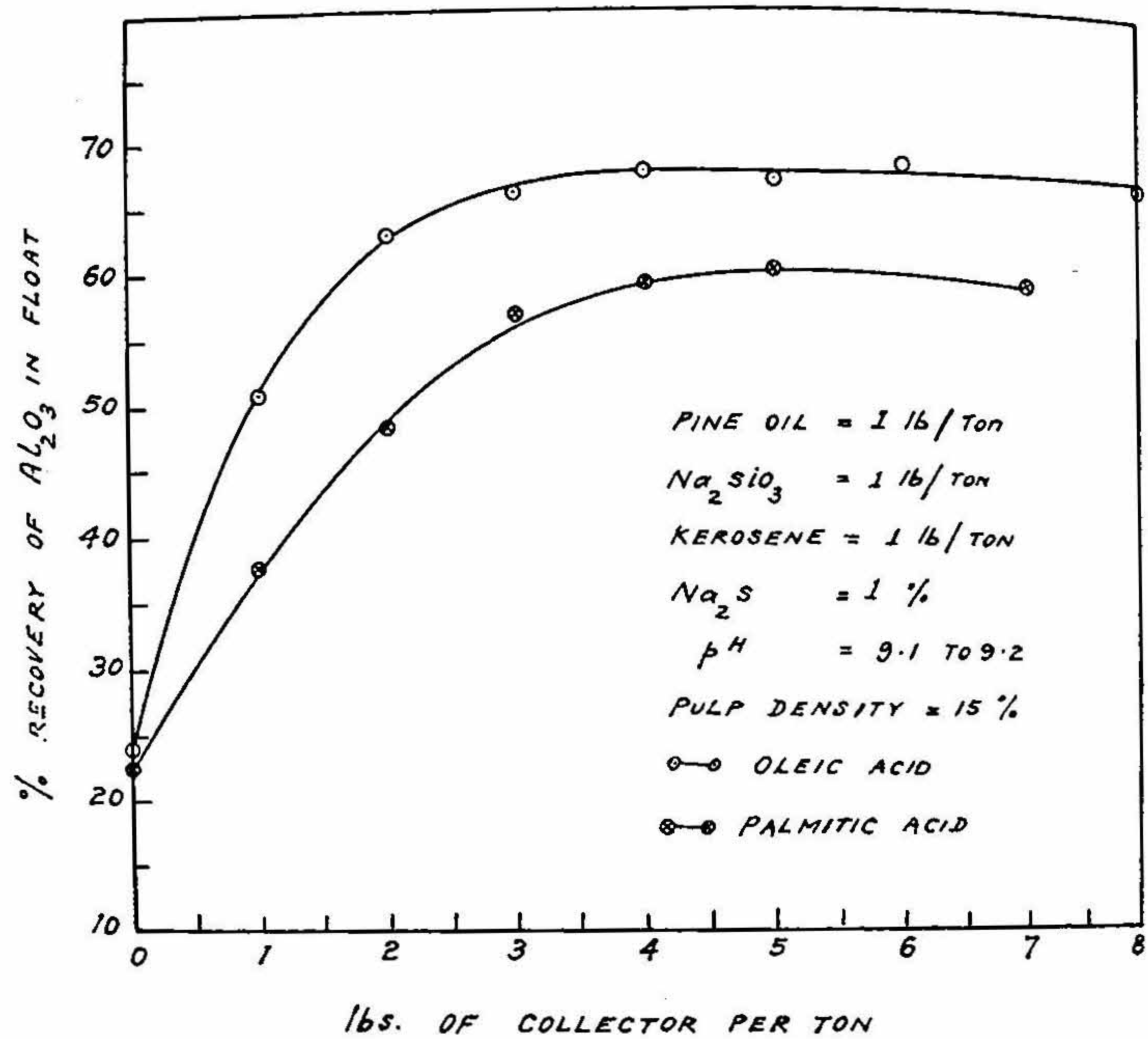

FIG. 3. Effect of Collector on the Recovery of of Bauxite.

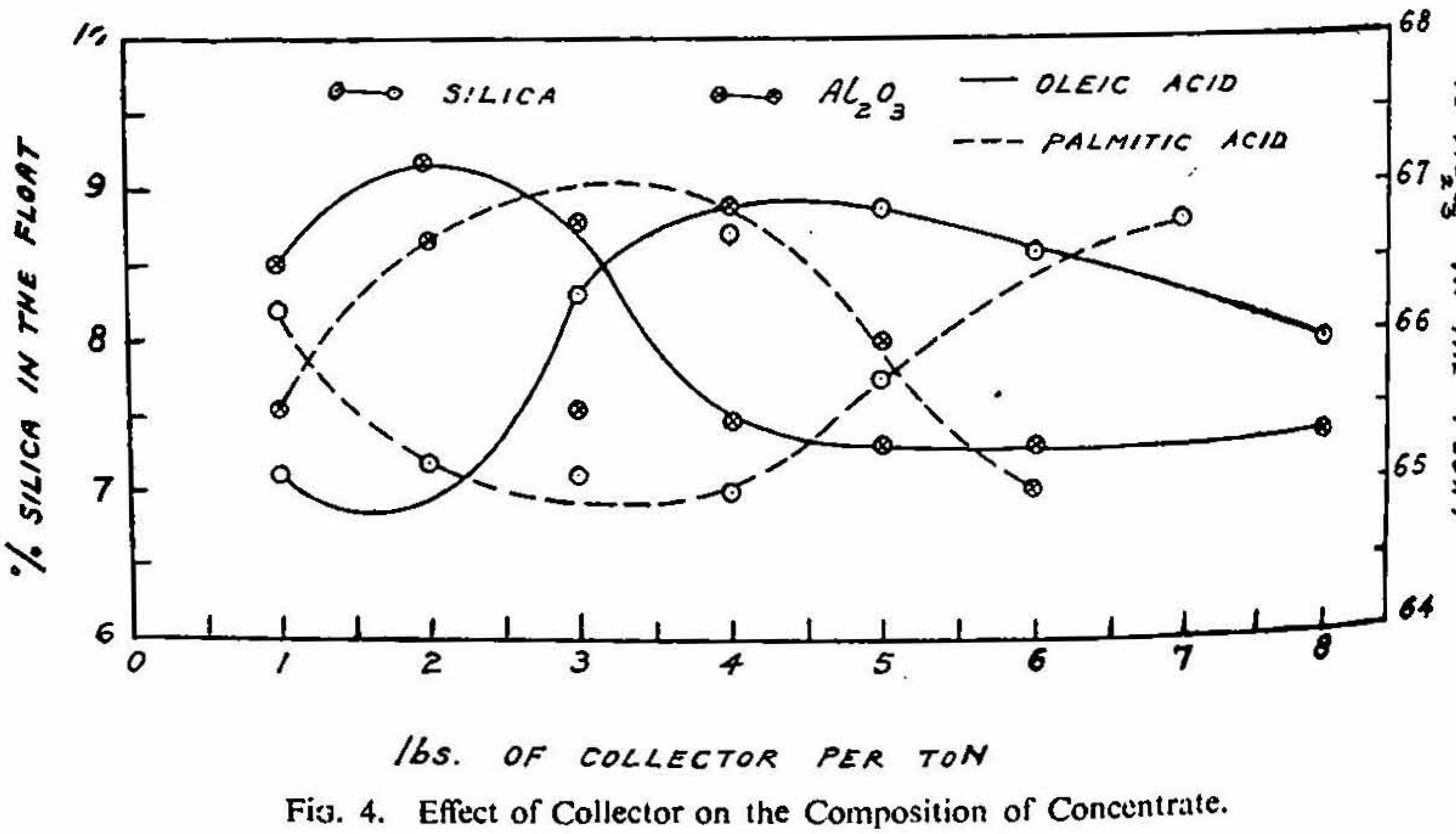

FIG. 4. Effect of Collector on the Composition of Concentrate.

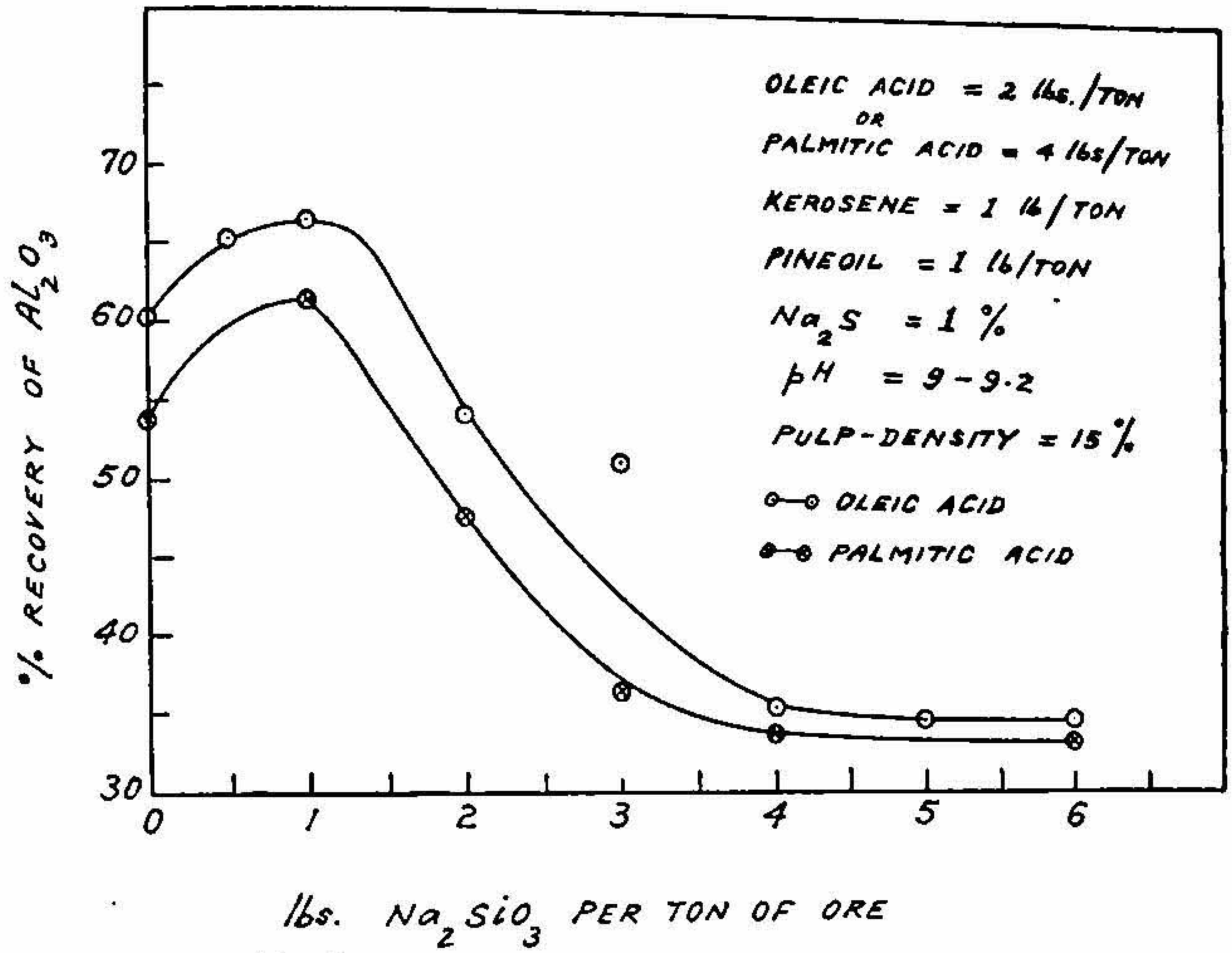

FIG. 5. Effect of Sodium Silicate on the Recovery of Bauxite.

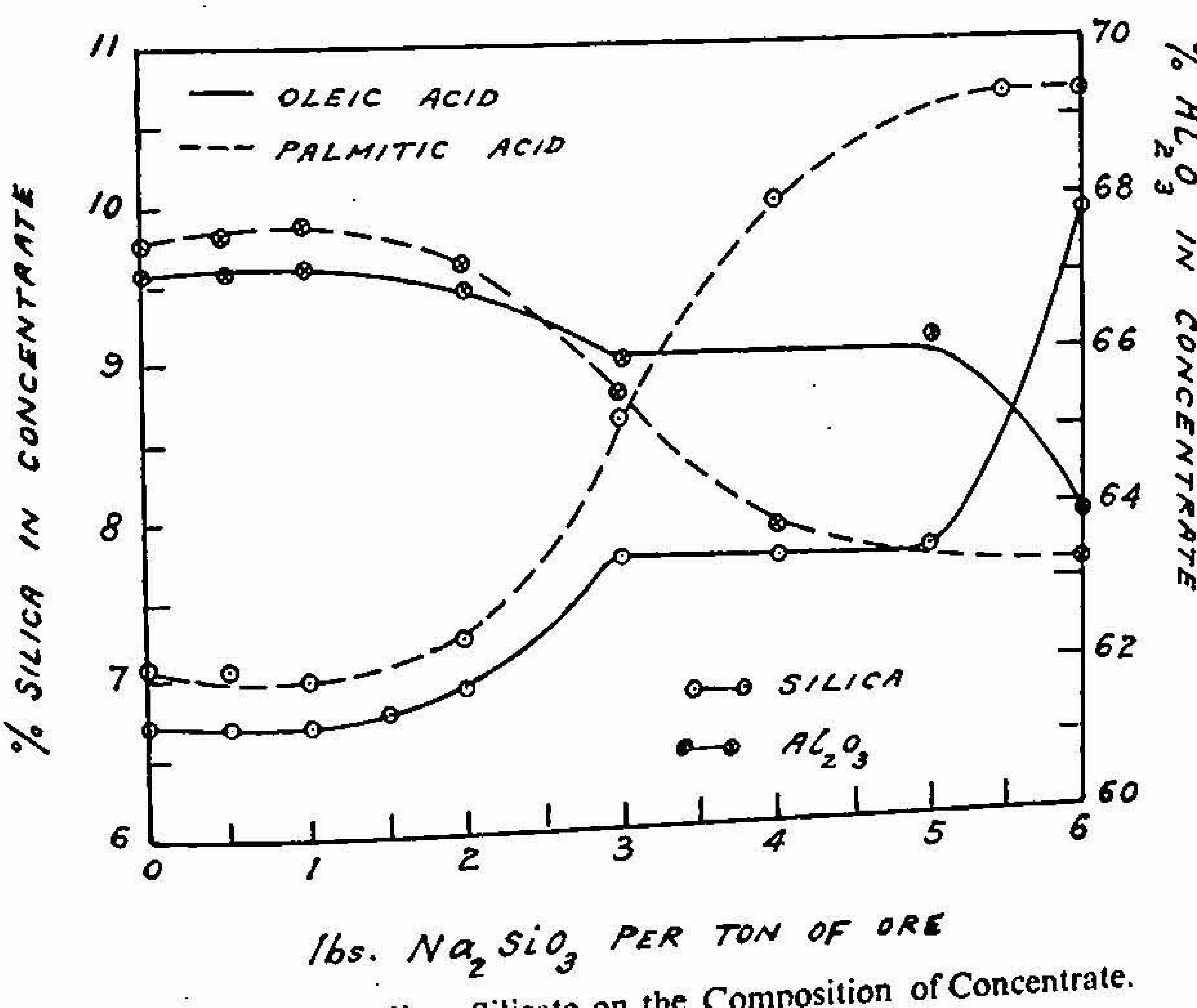

FIG. 6. Effect of Sodium Silicate on the Composition of Concentrate.

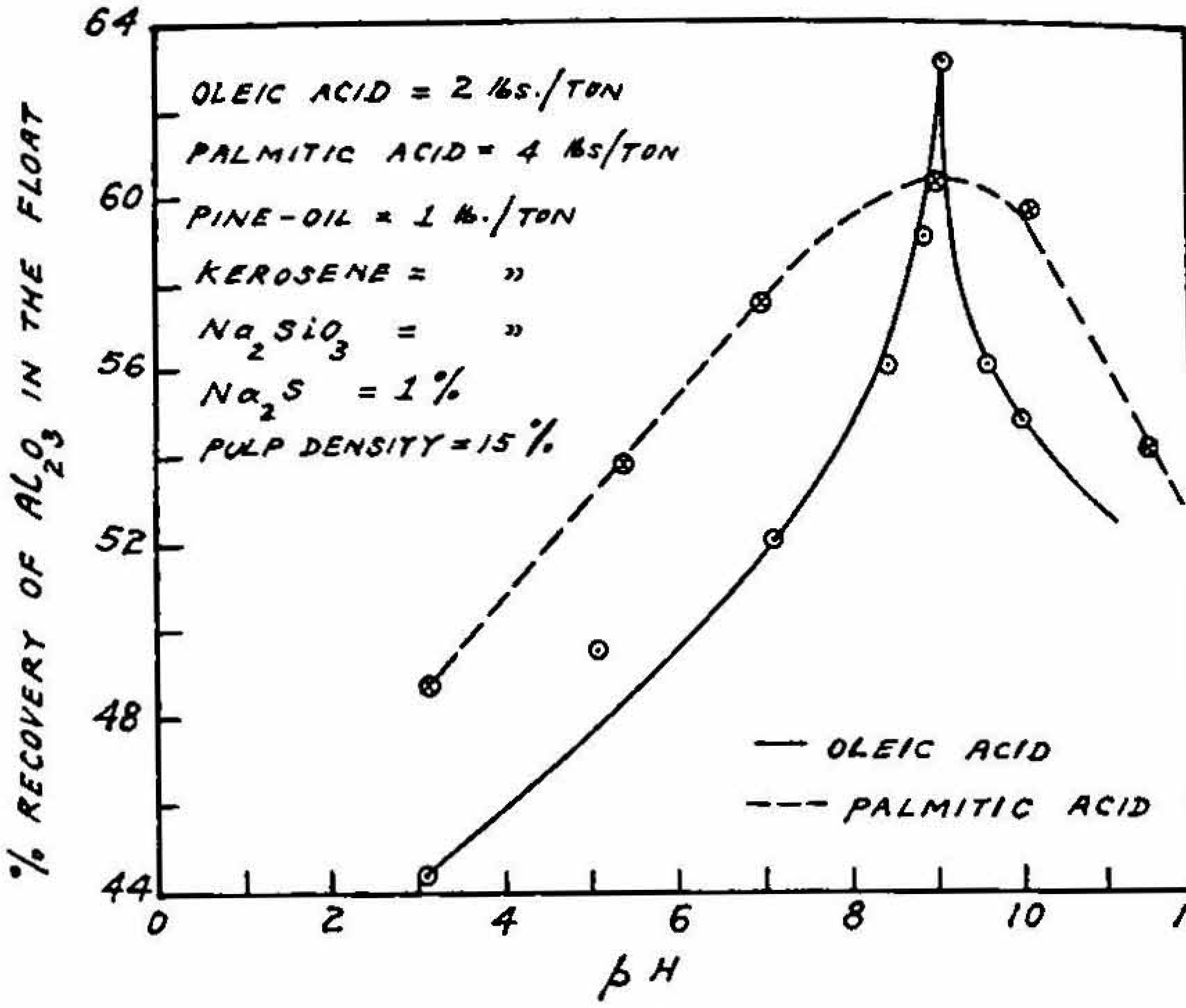

FIG. 7. Effect of pH on the Recovery of Bauxite.

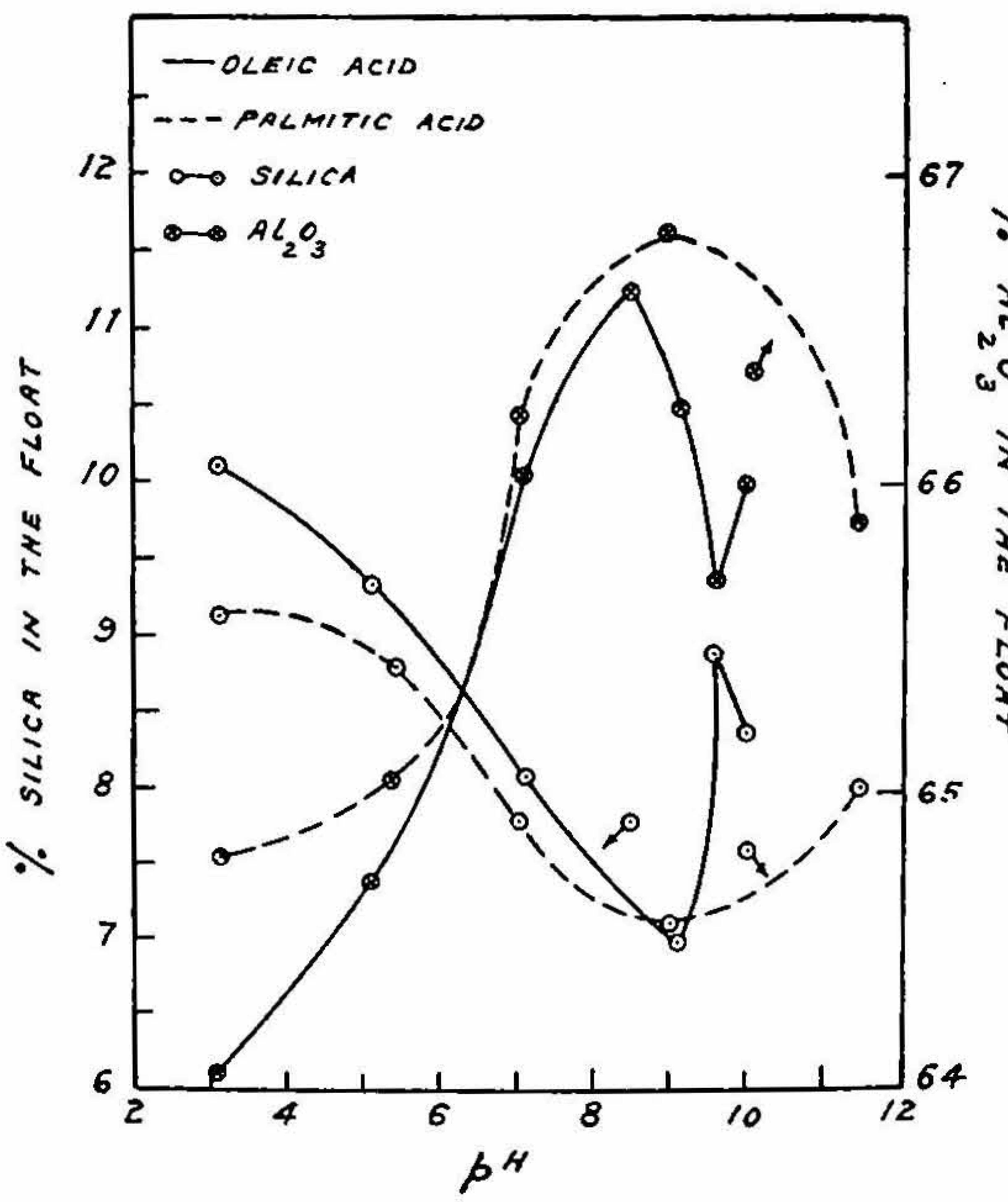

FIG. 8. Effect of pH on the Composition of the Concentrate.

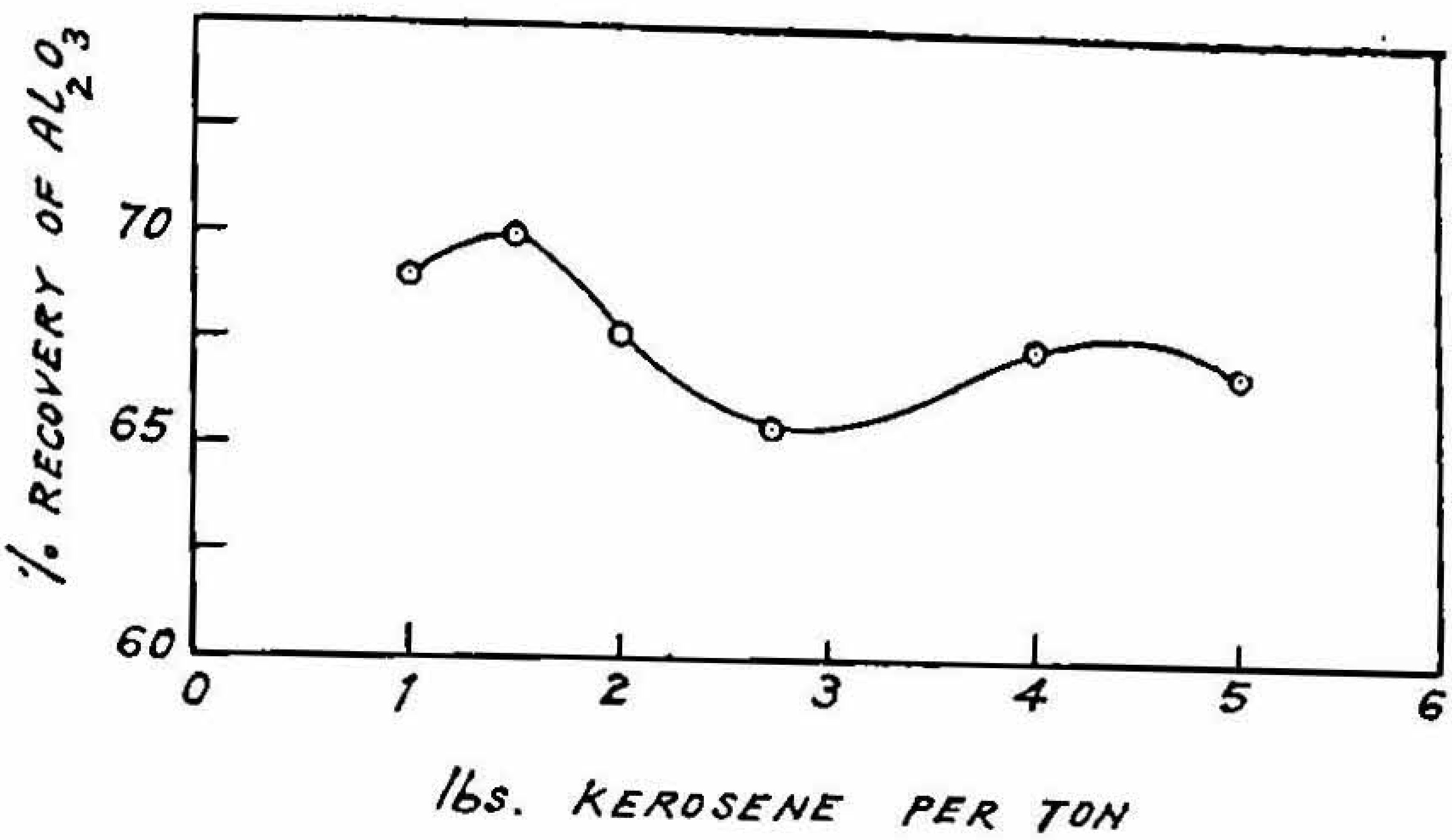

FIG. 9. Effect of Kerosene on the Recovery of Bauxite.

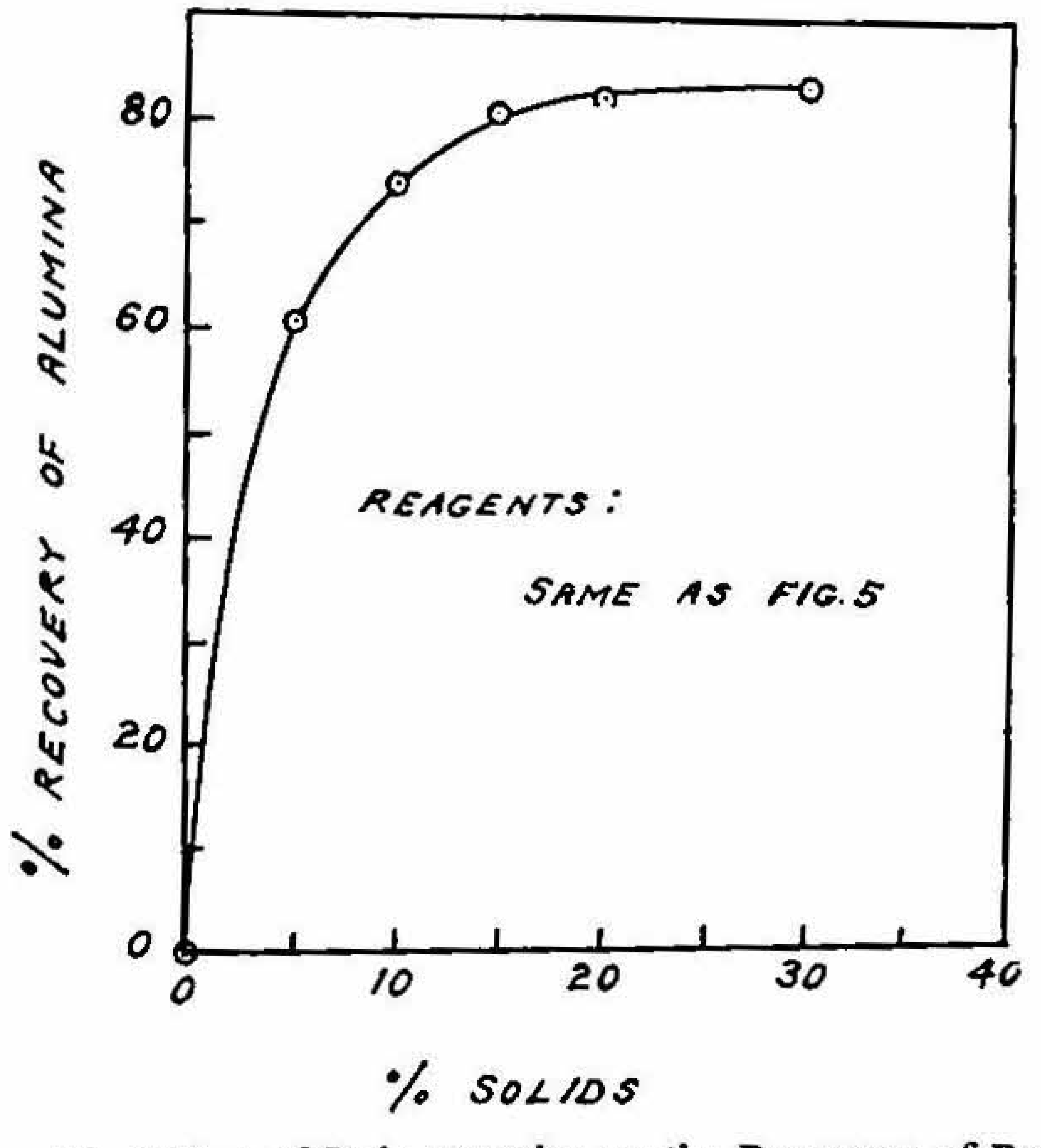

FIG. 10. Effect of Pulp-Density on the Recovery of Bauxite.

and then remains constant. Such may be due to formation of a unimolecular layer of the collector around the mineral yielding maximum recovery. Excess addition of collector will have no action on the recovery. Excess of collector forms a partial or complete second layer of adsorbed collector molecules on the mineral, oriented the wrong way for attraction between collector film and an air bubble.[12] This lowers the grade of the concentrate.

Following the " Free-acid " adsorption theory of Cook and Nixon,[13] the action of sodium sulphide and sodium silicate as depressants for silica can be attributed to the hydrolytic (free-acid) adsorption, *i.e.*, H_2S and H_2SiO_3 formed due to hydrolysis are responsible for the depressing action. It is observed that the alumina recovery decreases with the increase in depressant amount. This observation agrees with the results of "bubble-pick-up" experiments of Last and Cook[14] (Figs. 5 and 6).

Only alkaline flotation circuits are found to be effective with both the collectors studied (Figs. 7 and 8). With oleic acid, however, the pH range for optimum recovery is found to be very narrow, while that for palmitic acid wider yielding almost the same recovery in the pH range 8–10.

Kerosene as a promoter improves the grade of the concentrate but over-oiling due to its excess lowers the grade (Fig. 9). The explanation given by Rogers and Sutherlands[15] seems to be plausible in this respect. The recoveries obtained with the frothers, pine-oil, eucalyptus oil and cresol are also found to be almost the same. The pulp density does not seem to have any effect on the grade of the concentrate while the recovery of alumina is found to increase with the increasing pulp density. It is always beneficial to float the mineral at as high a pulp density as possible and 30% pulp density was found to be giving optimum results (Fig. 10).

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REFERENCES

1. Fox, C. S. .. *Geol. Surv. India*, 1928, **49** (Memoirs).
2. Holland, T. .. *Rec. Geol. Surv. India*, 1905, **32**, 175.
3. Middlemiss, C. S. .. *Geol. Surv. India*, 1928, **49** (Memoirs).
4. *Indian Minerals*, Jan. 1951, **5**, No. 1.
5. Rogers, A. F. .. *Study of Minerals and Rocks*, 1921, 287, 259, 403.
6. Scott .. *Standard Methods of Chemical Analysis*, **1**, 545.
7. Leaf, C. W. and Knoll, A. .. *Ind. Eng. Chem.*, Anal. Ed, 1939, **11**, 510.
8. Denver Equipment Co. Index, 1947, **1**, 65.
9. Gandrud, B. W. and De Vaney, F. D. U.S. Dept. of Commerce, *Bur. Mines Bull.*, 1929, 312.
10. Daniel, S. O. .. *Trans. Far. Soc.*, 1951, **47**, 1345.
11. Bhrany, U. N. and Rao, M. R. A. .. *J. Sc. & Ind. Res.*, 1953, **12**, No. 12.
12. Taggart, A. F. and Arbiter, N. *Trans. A.I.M.E.*, 1943, **153**, 500.
13. Cook, M. A. and Nixon, J. C. *Jour. Phys. Chem.*, 1950, **54**, 445.
14. Last, G. A. and Cook, M. A. *Ibid.*, 1952, **56**, 637, 643.
15. Rogers and Southerlands . *A.I.M.M.E. Tech. Publ.*, 1947, 2082.
16. Fox, C. S. .. *Bauxite*, London, 1927, 312.

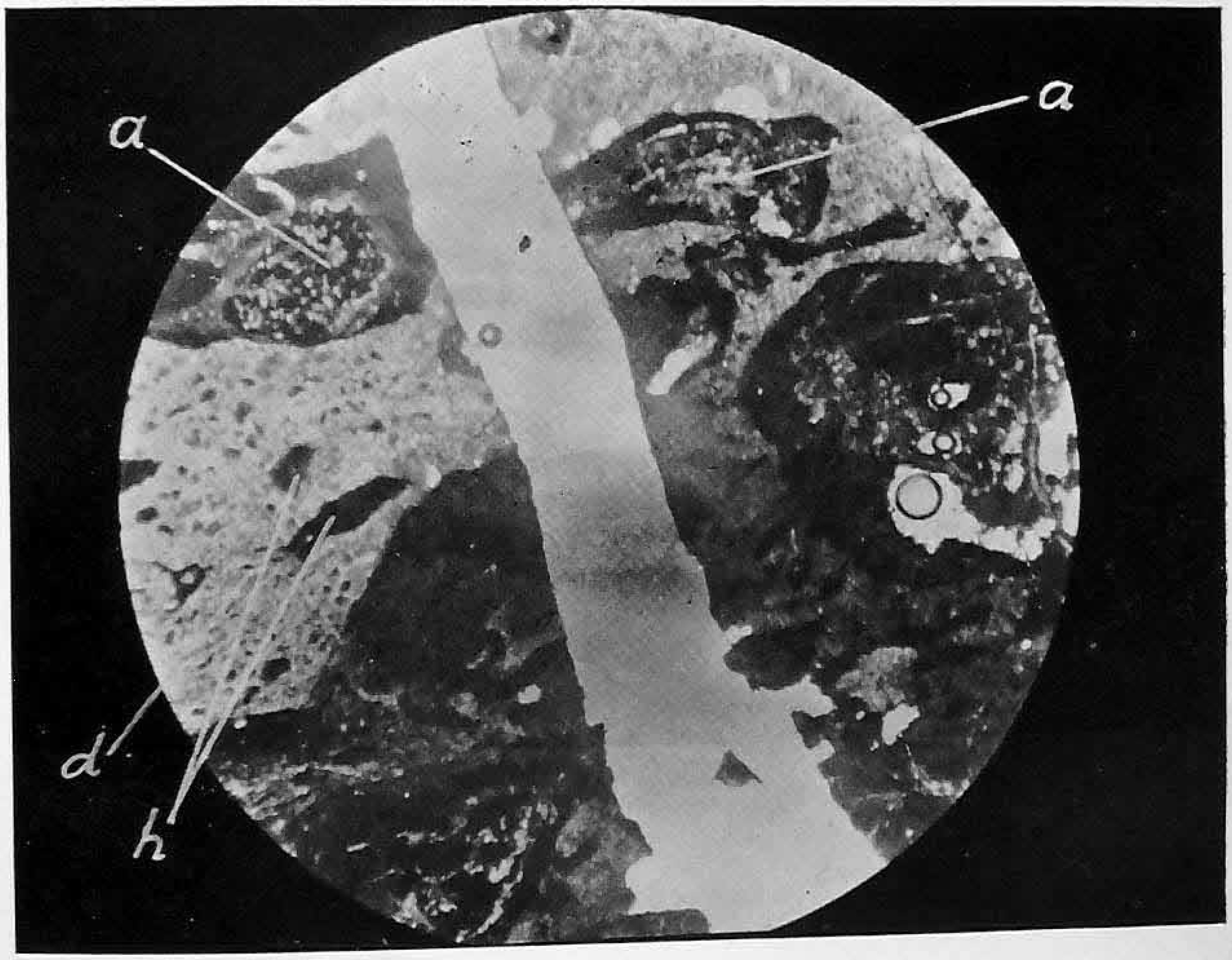

FIG. 1. Kashmir Bauxite ×12

d—Diaspore *h*—Hematite *a*— Diaspore not completely liberated from Hematite