

TECHNICAL NOTE

Method for Evaluating Flotation Kinetics Parameters

by P. Somasundaran and I. J. Lin

There are several methods described in the literature¹ for the determination of the order and the rate constant for the flotation of minerals. These often involve some type of computational or graphical procedures. A relatively simpler method developed on the basis of a technique used by Chang^{2,3} in chemical kinetics is described in this paper. Chang's technique, like most others in chemical kinetics,⁴⁻⁶ is based on the law of mass action which states that the rate of a chemical reaction is proportional to the active masses of the reacting substances at any given time. Application of this law to the flotation of minerals would involve the adaptation of the terms "flotation" for "chemical reaction" and "floatable amount of the minerals" for "the active masses of the chemical reactants."

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There are indeed a large number of physical processes controlling the actual flotation rate. The most inefficient one of these could be considered equivalent to the slowest reaction in a series of chemical reactions. If variables such as aeration rate and agitation are kept at constant levels, the rate of flotation under free flotation conditions (i.e., conditions under which the suspension is dilute) will be given by the following equation:

$$\frac{dC}{dt} = -KC^n \quad (1)$$

where C is the concentration of the floatable minerals in the pulp at any given time t , K is the rate constant, and n is the order of the reaction. If we represent the floated fraction of the floatable mineral at time t as m ($0 \leq m \leq 1$) and C at $t = 0$ as C_0 , integration of Eq. 1 yields

$$\ln \frac{1}{1-m} = Kt_0 \quad \text{for } n = 1 \quad (2)$$

and

Table 1. Values Obtained for t_m/t_m and n With The Use of Fig. 1 and for K With The Use of Fig. 2 for Data Shown in Figs. 3-6*

Case	$t_{1/2}/t_{2/3}$	$t_{1/2}/t_{3/4}$	$t_{1/4}/t_{1/2}$	$t_{1/3}/t_{1/2}$	$t_{1/3}/t_{2/3}$	$t_{1/3}/t_{1/4}$	t_0 , Sec.	R_∞	\bar{n}	K , Sec ⁻¹	Flotation Rate Equation
1	0.500	0.360	0.337	0.500	0.250	0.440	2	1.00	2	0.12	$\frac{R}{1-R} = 0.12 t$
		0.384	0.333	0.500	0.258	0.430	4	0.80	2	0.10	$\frac{R}{0.8-R} = 0.10 t$
2	0.625	0.500	0.428	0.580	0.363	0.453	1.00	1	0.020	$\ln\left(\frac{1}{1-R}\right) = 0.020 t$	
3	0.587	0.330	0.336	0.500	0.252	0.435	0	0.90	2	0.023	$\frac{R}{0.9-R} = 0.021 t$
	b.	0.500	0.336	0.333	0.507	0.253	0.434	0	0.88	2	0.020
4	0.500	0.384	0.340	0.499	0.249	0.431	5	0.92	2	0.014	$\frac{R}{0.92-R} = 0.013 (t - t_0)$
	b.	0.610	0.444	0.407	0.582	0.354	5	0.96	1	0.008	$\ln\left(\frac{0.96}{0.96-R}\right) = 0.008 (t - t_0)$

* Fig. 3 (Case 1a: 10^{-4} mole per l; Case 1b: 5×10^{-5} mole per l dodecylammonium acetate); Fig. 4 (Case 2); Fig. 5 (Case 3a: $-0.20 + 0.15$ mm; Case 3b: $-0.15 + 0.10$ mm size fractions); Fig. 6 (Case 4a: apatite; Case 4b: hematite).

Case 2—Data obtained by Agar and coworkers⁹ for the flotation of quartz with dodecylammonium hydrochloride during four different experiments in a chambered flotation cell similar to that used by Tomlinson¹⁰ was treated in the same manner as described previously. Results obtained using the best least-square curve for flotation recovery as a function of time are given in Fig. 4 and Table 1. It might be noted at this stage that the value obtained for rate constant using the relatively

simple technique described here is identical to the value 0.020 obtained by Agar and coworkers using the conventional procedure.

Case 3—Data reported by Panu¹¹ for the flotation of $-0.15/+0.10$ mm and $-0.20/+0.15$ mm pyrite ore shown in Fig. 5 as a function of time is also treated in a similar manner and the results obtained are given in Table 1. Values for the order is found to be two in this case for both fractions, but the $-0.15/+0.10$ mm fraction is found to have a higher rate constant than the $-0.20/+0.15$ mm size fraction in line with the trend of Panu's calculated rate constants for various size fractions.

Case 4—Data obtained by Tomlinson and Fleming¹⁰ for the flotation of apatite and hematite in the chambered cell using 1.55×10^{-5} mole per l potassium oleate as collector at $\text{pH } 8.0 \pm 0.01$ and temperature $25 \pm 1^\circ\text{C}$ is shown in Fig. 6, and the results obtained by applying the present method to the data are given in Table 1. Tomlinson and Fleming report the overall rate for apatite flotation to correspond to a second order equation and that for hematite flotation close to a first order. It can be seen that the results obtained for the order using the present method are in agreement with the foregoing values.

Summary and Conclusions

The method presented here using the general curves presented in Figs. 1 and 2 offers a relatively simple and fast way for the evaluation of the order and the rate

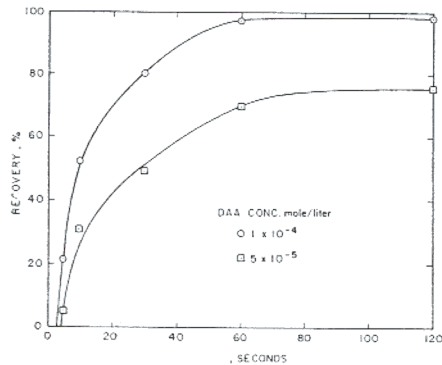


Fig. 3—Flotation of quartz in a modified Hallimond cell as a function of time at various dodecylammonium acetate concentrations (after Ref. 8).

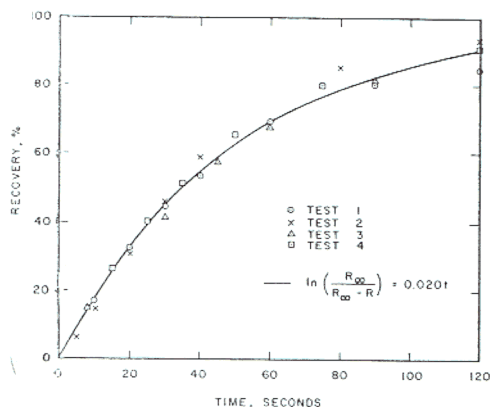


Fig. 4—Flotation of quartz in a chambered cell as a function of time during four tests with dodecylammonium hydrochloride (8×10^{-6} mole per l) as collector.

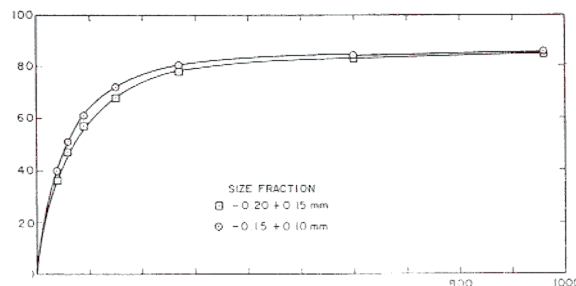
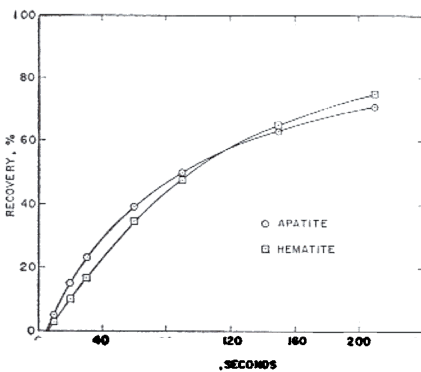


Fig. 5—Flotation of pyrite ore of $-0.20 + 0.15$ mm and $-0.15 + 0.10$ mm size fraction as a function of time (after Panu¹¹).

Fig. 6—Flotation of apatite and hematite in a chambered cell as a function of time using 1.55×10^{-4} mole per l potassium oleate at pH 8.0 ± 0.1 and temperature $25 \pm 1^\circ\text{C}$, (after Tomlinson and Fleming⁽¹⁰⁾).



constant of a flotation operation. Results obtained using this technique are identical within experimental errors, to those obtained using conventional procedures. The technique developed here, using the analogy between chemical reactions and flotation processes, is of general application with no restrictions as to the type of ores processed or the type of flotation operations used.

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