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Modified Hallimond Tube for Flotation Kinetics Measurements

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NOTE

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Flotation is an important method for separating particles of different chemical and physical natures from pulverized minerals. Flotation depends basically on the formation of a gas/liquid/solid interface where the solid particle becomes attached to a gas bubble as a result of its hydrophobic surface characteristics (1).

Although the kinetic characterization of flotation is an important aspect of the process, there is no precise method that allows one to calculate the rate constant for flotation of pure particles. The Hallimond tube is a laboratory flotation cell used to measure the recovery as a result of the relative flotation rates (2–5). In this note we propose a modification of the Hallimond tube that permits one to study the kinetics of flotation of particles under carefully controlled conditions, such as bubble size, gas flow, and agitation. The system has been tested with pure pyrite particles.

Flotation System

Figure 1 presents a scheme of the complete flotation system. The gas flow from the cylinder (A) passes through the column of KOH pellets B and its rate is controlled by a rotameter C. The gas temperature is maintained constant by a thermostat D. The hydrostatic height of the equalizing

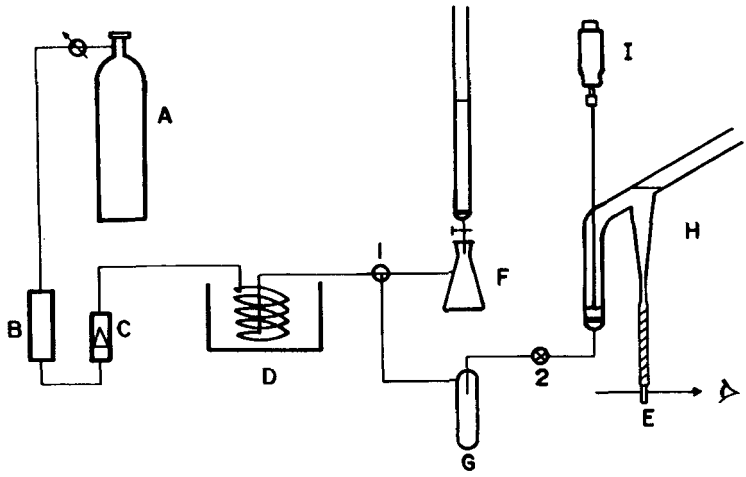

FIG. 1 Scheme of the flotation system: (A) gas cylinder, (B) KOH column, (C) rotameter, (D) thermostat, (E) collecting cuvette, (F) equalizing pressure column, (G) trap, (H) Hallimond tube, (I) stirrer, (1) and (2) stopcocks for flow control.

column F, containing an aqueous glycerine solution, is equal to the back-pressure exerted by the fritted glass disk of the Hallimond tube H (see below). This arrangement assures that, at zero time of the kinetics, opening stopcock 2 will not change the gas flow rate.

Modified Flotation Cell

A detailed description of the modified flotation cell is provided by Fig. 2. The agitation of particles in the flotation cell is obtained by a mechanical stirrer with controlled rotation. The fritted glass disks can be easily replaced in order to change the size of the gas bubbles. The floated particles are collected in a glass cuvette similar to that used in spectrophotometry, coupled to the flotation cell by a short piece of rubber tubing.

The Optical System

The increase in the volume of the collected particles can be followed by an optical system (Fig. 3). The support of the glass cuvette is connected to an ultravibrator to facilitate uniform packing and settling of the particles. The light source is a 12-V tungsten lamp, and a set of lenses is used to collect, collimate, and focus the transmitted light into the photoelectric

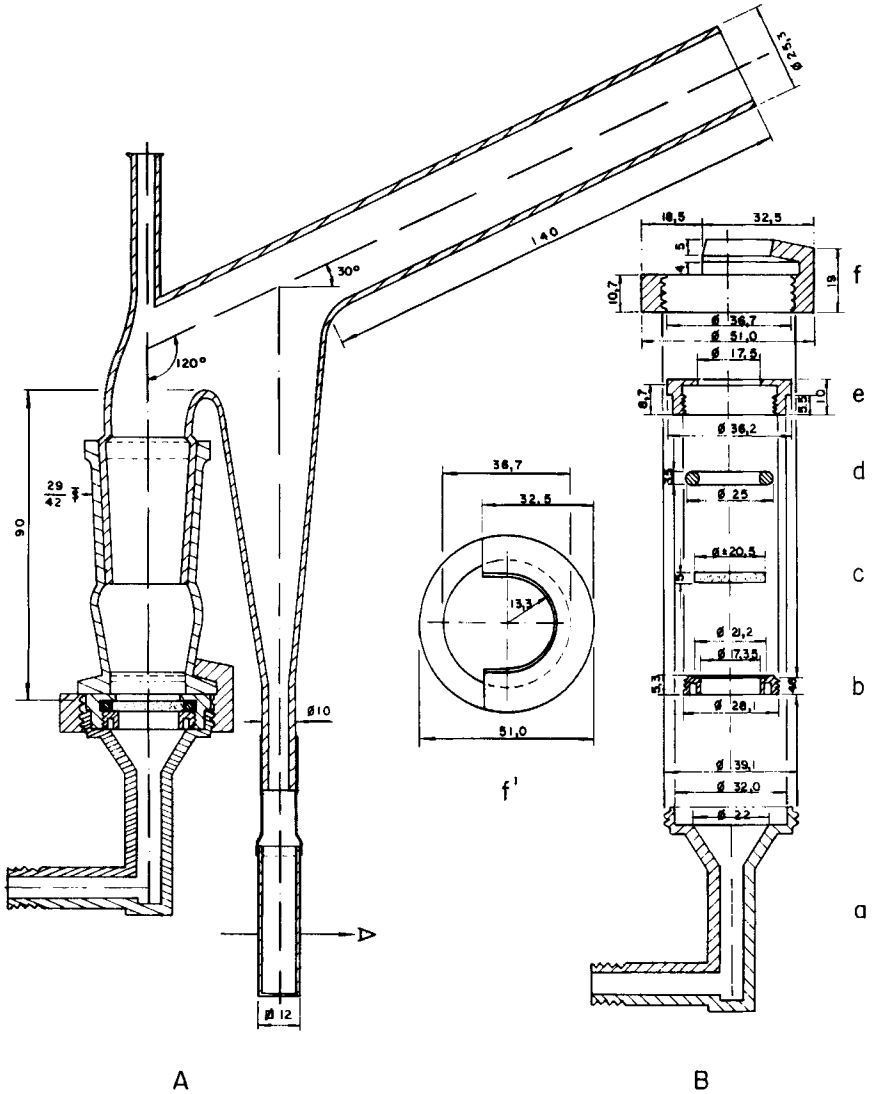

FIG. 2 (A) Modified laboratory flotation cell. (B) Detail of the fritted disk assembly: support *a* is made of brass and receives the fritted disk *c* mounted between *b* and *e*; *d* is a rubber O-ring. The whole assembly *a* through *e* is fixed to the flotation cell with *f*; *f'* is the top view of *f*; *b*, *e*, and *f* are made of high-density nylon.

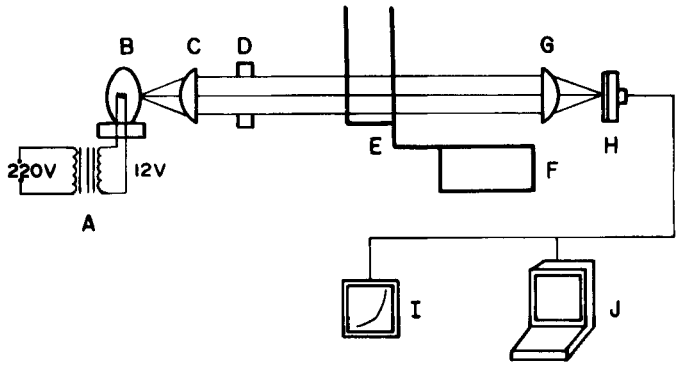

FIG. 3 Optical system: (A) 220–12 V transformer, (B) 12 V lamp, (C) lens, (D) slit, (E) cuvette support, (F) ultravibrator, (G) lens, (H) photoelectric cell, (I) recorder, (J) microcomputer.

cell. The intensity of the transmitted light decreases with increasing volume of the collected particles, and it can be measured by a potentiometric recorder and/or a microcomputer with an analog-to-digital converter. We employed a Microquimica MQ 8/8 AP 8 bit AD-converter specially designed for an Apple microcomputer. The photoelectric cell is connected to the AD-converter via a high impedance amplifier with programmed gain, allowing one to select the best range of operation for the output of the photoelectric cell.

Linearity of the Optical Response

Figure 4 shows the range of linear response of the optical system with respect to the volume of floated pyrite particles. Measurements with the potentiometric recorder show a linear response up to about 0.5 g pyrite, while for measurements with the interfaced computer, linearity is observed up to 0.6 g pyrite.

Precision and Limits of the Rates Constants

The analysis of data is done using special programs for first-order kinetics. Figures 5(a) and 5(b) show two runs followed through the potentiometric recorder and the microcomputer, respectively. The rate constants calculated by both methods are essentially the same. In general, the rate constants are reproducible within a standard deviation of ~10%. The speed

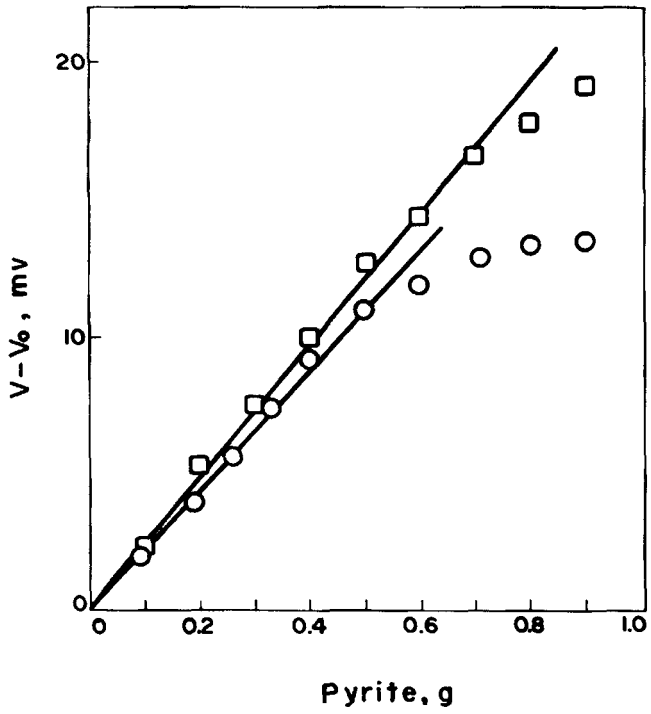

FIG. 4 Calibration curves of the optical system with respect to the volume of floated particles: (○) potentiometric response measured with the recorder, (□) potentiometric response of the interfaced microcomputer.

of data collection with the microcomputer allows one to follow kinetics with half-lives as short as 5 seconds (Fig. 5c). This limit is dictated by the rate of ascension of the particle–bubble complex and the rate of deposition of the collected particles. The system is useful for flotation of heavy particles whose deposition rate is much higher than the ascension rate of the particle–bubble complex. It can, however, be used for lighter particles if the kinetic measurements are performed discontinuously using gas-flow pulses and measuring the resulting differences of floated volume.

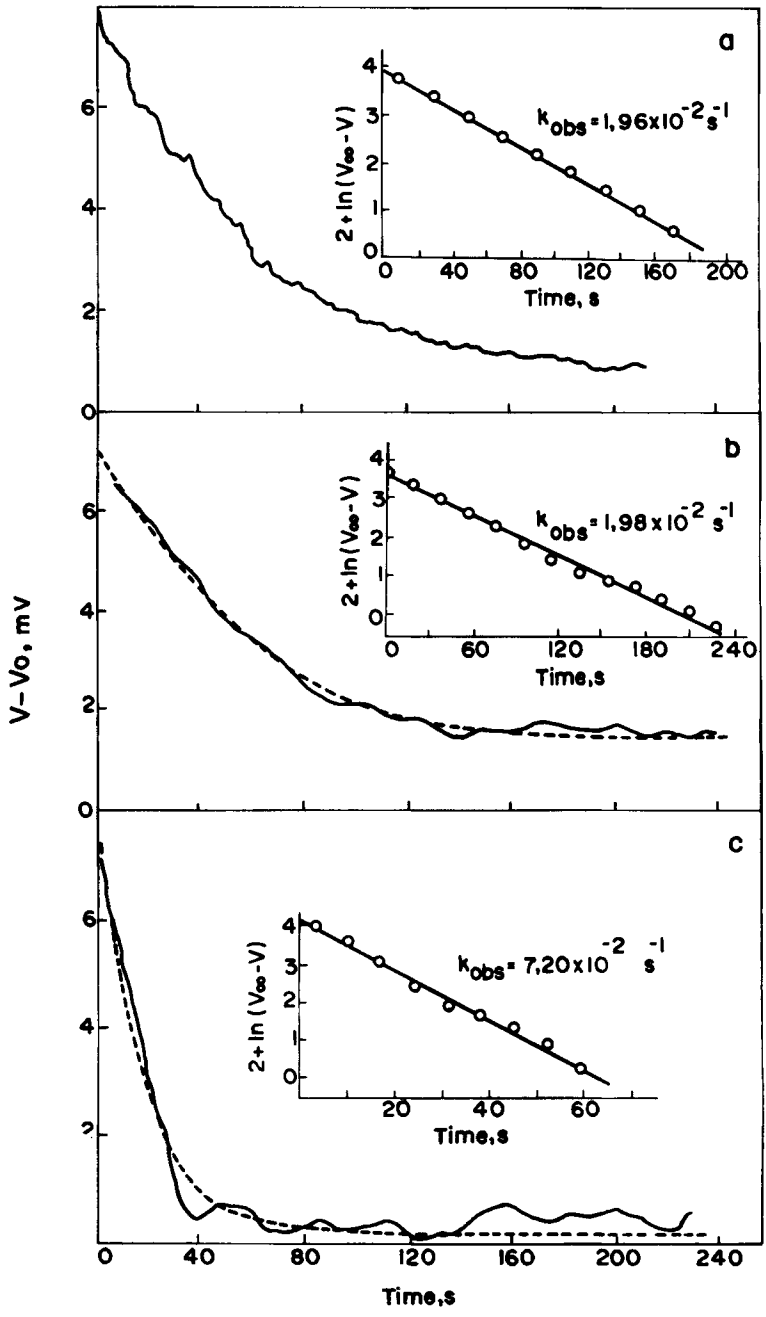

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FIG. 5 Kinetics of the flotation of pure pyrite at 25°C, particle diameter 149–210 μm, oxygen flow 492 mL/min, stirring 710 rpm, pH 5.80 (succinate 0.05 M), 0.5 g pyrite conditioned for 5 minutes. In deoxygenated water; *a*, curve of potential vs time obtained with the recorder; *b*, curve of potential vs time collected with the computer, dashed curve calculated for a first-order process; *c*, same conditions as for *a* and *b* but with an oxygen flow of 400 mL/min, 0.6 g pyrite conditioned in a 0.005 M potassium ethylxanthate solution, bubbling oxygen for 5 minutes, and then the system was allowed to stand for 10 minutes prior to flotation.