The phenomenon of adsorption is considered in connection with the necessity of evaluation of methods for investigation of the process to indicate the orientation of molecules of reagents in the adsorption layer on the surface of particles. Our work is based on the results of the fundamental work by Langmuir and his collaborator Blodgett.

In 1920 Langmuir established that the layers of molecules of oleic acid compressed in a cuvette (of a balance designed by him), being transferred to the surface of clean glass plate, makes it hydrophobic. Later (1934), Blodgett continued these experiments and found that the second deposited layer makes the solid surface hydrophilic. The same takes place with all subsequent layers, which can be only paired.

Let us consider these general results as applied to flotation.

Let there be a hydrophilic solid surface of a mineral in water (Fig. 1a). As a result of the chemisorption of heteropolar molecules of the collector, the hydrophobization of the surface takes place (Fig. 1b). This is an energy-consuming process because the forming resulting interface (dashed line in a schematic diagram) between, for example, methyl groups of the collector molecules and water molecules, is similar to the hexadecane−water boundary with energy ~50 mJ/m². The energy source for hydrophobization is the chemical reaction between the atom of the functional group of the collector and the atom on the mineral surface (a bond between them is shown in schematics by vertical dashes).

With the presence of an excess of molecules of this type in the solution, the second layer is formed (see Figs. 1c, 1d) as a result of physical adsorption, which proceeds spontaneously with the loss of free energy. The surface becomes hydrophilic, and the flotability of the particles worsens. Researchers of flotation call this case “overoiling.” Then, in the presence of the excess of the collector or other similar surfactants, paired layers are immediately formed, i.e., the third and fourth ones (see Fig. 1e), fifth and sixth, etc. Blodgett showed that it is possible to deposit many hundreds of them, and all of them will hydorphilize the surface because there is no energy source for its hydrophobization.

Abstract—Methods for evaluation of the adsorption and orientation of heteropolar molecules of reagents in the adsorption layer on the surface of particles and the adsorption of reagents on the surface of bubbles are considered. Experiments of nonfrothing flotation from a turbulent medium, methods of froth flotation (FF) with a limited air consumption, measurement of detachment forces simulating the FF, determination of the adherence times of the particles to the bubbles, and measurement of the contact angles can be used to reveal the character of the orientation of adsorbed molecules or ions of reagents. To evaluate the adsorption of reagents on the surface of bubbles, only static procedures for determination of the surface tension (σ), methods of recording the relaxation curves σ(t), and methods for evaluation of froth formation and destruction can be used. This possibility is reviewed to establish the relation between the definite properties of reagents and their concrete effect under the dynamic FF.

Key words: froth flotation, nonfrothing flotation, detachment forces, angles of contact, adherence time, foam formation, foam destruction, relaxation curves, static surface tension.

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2.1. Measurement of Angles of Contact $\theta_p$ and the Source of a Systematic Error in the Obtained Results

Measurement of angles of contact $\theta_p$, which satisfy the Young law [1, p. 30; 2, pp. 40–48] is probably the most widespread (after flotation experiments) method of investigation of the effect of reagents during flotation. Let us consider the results of determination of this parameter based on the Laplace equation [1, p. 25, 3]

$$\sigma = \delta gb^2/\beta,$$  

(1)

where $\delta$ is the difference in densities of bordering phases, $g$ is the acceleration of gravity, $b$ is the radius of curvature of the form in its cupola, and $\beta$ is the coefficient unambiguously characterizing the shape of a symmetric bubble (drop) and its difference with the sphere.

It follows from Eq. (1) that a decrease in $\sigma$ should invariably, other conditions being equal, lead to an increase in $\beta$, i.e., to a flattening of the bubble, to an increase in difference of its shape with the sphere, and to an increase in the observed contact angle under the condition that the bubble perimeter is not restricted by the sizes of the substrate. In Fig. 2, two hydrogen bubbles of the same volume which isolated electrolytically on the mercury surface are depicted.

The surface of the bubble on the right is slightly contaminated and its contact angle is $30^\circ$ larger than that of the bubble on the left, which is in complete agreement with Eq. (1). It should be noted that the purity at which the bubbles were obtained is unachievable when working with minerals.

The data of Wark on the measurement of angles of contact on sulfides and their dependence on the length of the radical in the xanthate molecule coincide with conclusions of Gaudin [4, pp. 17, 18] on the flotation activity of xanthates for the same minerals. Therefore, it is evident that this activity is noticeably affected by the action of xanthates on the bubble surface. This statement may seem to be erroneous to researchers of flotation, but this is just the case.

A mechanism of multiple strengthening of the particle–bubble contact was considered in detail by the numerical example in [5] (previously in [1, p. 45]). The circumstances stated there are in complete agreement with the work of Taggart and Gaudin [6], from which it follows that the quantity $\Delta\sigma$, which equals the difference between the dynamic ($\sigma_d$) and static ($\sigma_r$) values of $\sigma$ on the bubble surface

$$\Delta\sigma = \sigma_d - \sigma_r$$  

(2)

is responsible for strengthening.

Based on their measurements and conclusions, the authors of [6] wrote the relation

$$a = K(\Delta\sigma)^m,$$  

(3)

where $a$ is the size of the floated particle and $K$ and $m$ are the empiric constants. This relation was also presented by Taggart in the first edition of his reference book in 1927 [7], but later neither he nor Gaudin referred to this relation because it is impossible to interpret it without taking into account the capillary pressure ($P_c$) in the bubble, and they had neglected it (see section 1.3 of the first part of this work). However, this is not important; Eq. (3) is correct, but it was ahead of its time. It is important that its authors correctly and, possibly, intuitively associated the strengthening of the particle–bubble contact with the surface of the last one and the value of decreasing $\sigma$ on this surface.