

excess gas is driven out; (2) heating to increase the volume and drive some out; and (3) reduction of pressure.

The same cause that tends to supersaturate a liquid with gas, will evidently tend to supersaturate a solid with this same gas if this solid be within the liquid. The dissolved gas will evidently be expelled from both the liquid and a solid within it by the same force—one of the above. Due to adhesion, the gas, as it is expelled, tends to condense on the solid or increase the amount of adsorbed gas. Lest confusion arise, it may be stated that adsorb is here used in the sense of being one of the three ways that solids hold gases. With sufficient condensation, a bubble will form on the surface of the solid from these molecules as they collect.

As a logical sequence from the above reasoning, **solids with high occlusive power for gases should have a greater tendency to float.** Hezekiah Bradford was the first to recognize this fact.³ "The floating particles appear to possess some peculiar qualities which repel water from their surfaces, especially when the particles are exposed, even momentarily, to atmospheric air." It is only necessary to look into the subject of ore deposition to learn the reason why metallic particles occlude gas more readily than other minerals. Chemical affinity assists in this occlusion of air and carbon dioxide, which eventually change the sulphides and like ores into sulphates, carbonates, oxides, etc. This greater power of occlusion is a cause of selective flotation.

Selective flotation is here used as a general term in contradistinction to preferential flotation, an accepted term to designate the separation of minerals that ordinarily float together. Horwood accomplishes this by a roast that oxidizes some sulphides and not others. The same effect is accomplished by others by coating the sulphides not desired in the concentrate. Leslie Bradford uses a reducing gas to accomplish this result.

By the aid of the microscope, Hebron, an associate of Carrie J. Everson, discovered that the desirable minerals, to be saved by concentration, have larger pores and surfaces than equal sized gangue particles. This gives greater chance for gas occlusion. Oil and like substances are usually but slightly soluble in water. The reverse is also true.

There is little adhesion between water and a surface wetted with oil, or oil and a surface wetted with water. Oil, due to its property of capillary attraction can readily enter the pores of solids not filled with water. Therefore, most metals, sulphides and the like containing occluded air are capable of absorbing more oil due to their larger pores and surfaces. With sufficient oil thus attached, agglomeration or bulk oil flotation takes place.

By this process of elimination, the same conclusion is reached as that demonstrated by Mickle's experiments. **Gas is the necessary substance** for Surface Tension, Bulk Oil and Froth Flotation methods and this must be occluded gas. Nascent gas and an electrolyte are also essential elements for Froth Flotation.

What is the function of the electrolyte? As has been shown, an acid or an alkali creates the selective action in froth flotation. How? By its ability to vary the contact angle between the surface of the mineral particle and the liquid film on either a bubble of measurable radius or a horizontal liquid surface of infinite

radius. Dr. Young showed the constancy of contact angles. H. Livingston Sulman, investigating figures for contact angles found "discrepant readings" due to "existence of a variable range of the contact angle." C. G. Lamb termed this angular difference "the angle of hysteresis." Speaking of this, Mr. Sulman says:⁴ "Whereas the angular hysteresis of silica in plain water may exceed 30 degrees, thus indicating the substance to have a definite power to occlude gas and to float, it drops from 4 degrees to nil in water acidulated with sulphuric acid."

The occluded gas can be driven out from a solid in the same way that it can be driven from a liquid. This gas of the solid particles will cause them to become nuclei for the formation of bubbles from the gas "coming into being" from the liquid and, as the bubbles grow, the particles are lifted or floated. Since there is more occluded gas in the metallic particles, all that is necessary to create the selective action of flotation is to drive out a considerable portion of the occluded gas from all particles. There then will be insufficient gas remaining with the gangue particles to cause them to act as nuclei upon which to grow bubbles. The metallic particles still having occluded gas are then floated while the gangue particles sink.

As shown above, this selective effect is produced in extremely dilute solutions. An electrolyte produces it, but how? It was also shown that some force is required to expel occluded gas. No outside force such as pressure or heat is the cause. Therefore it is an internal one that drives this occluded gas from the mineral particles. The ions of the electrolyte displace the equilibrium and the force that causes the gas occlusion is, at least partially, neutralized so that the tendency of the gas is then to diffuse throughout the liquid instead of remaining in the solid.

A parallel case in physics is osmosis. **The function of the electrolyte, therefore, is to create osmotic pressure.** The septum is the surface of the mineral particle. Ions of the electrolyte enter the solid while those of the gas leave. This action continues to the eutectic point and bubbles form on the metallic particles, as described above. Greater delicacy of manipulation is obtained with an alkali. Further advancement along this line means that selective action can be created between sulphates, carbonates, etc., and gangue minerals. Also that, by means of a variation of the electrolyte, preferential flotation can be effected and different metals can be separated.

Increased strength of the electrolyte will sometimes "kill" the float; or, in other words, increased osmotic pressure drives the air from the metallic particles, leaving them in the same condition as those of the gangue. This effect is not to be confused with an entirely different phenomenon which produces the same effect. Colloidal impurities like tannin, saponin, etc., or volatile oils and the like destroy bubbles by reducing the surface tension to the extent that the gas pressure from within bursts them. This weakening of the surface tension by a colloid is thus seen to be entirely different from the strengthening of osmotic pressure by a crystalloid, although the result is practically the same—no froth.

In studying this selective action, it is difficult to explain the motive power of osmosis, as present authorities do not agree. According to the Van't Hoff school it is the kinetic energy of the dissolved molecules obey-

³U. S. Pat. No. 345,951. 1885.

⁴Presidential address of H. Livingston Sulman. Institution of Mining and Metallurgy Transactions, 1912.