SPECIAL ARTICLES

THE FORMS OF GAS AND LIQUID CAVITIES IN GELS, AND THEIR INTERPRETATION BY SURFACE COMPRESSION

IT has been observed by both chemists and biologists that gas bubbles arising in gels exhibit lenticular forms. The most complete investigation of the phenomenon has been made by Hatschek who, after making measurement on many bubbles, endeavored by a statistical study of their orientations to explain the observed facts, including the divergence from sphericity, by postulating definitely oriented directions of cleavage within the gel, corresponding presumably to a honeycomb microstructure of its water-poor phase. Neither Hatschek himself nor later workers have been convinced that this explanation was the true one. Working with gelatine, but more especially with silica gels, the writers have produced, from air-saturated media, controllable air-bubbles both by rise of temperature and by reduction of air pressure, and have observed additional facts that lead to an altogether different, albeit simple and complete, interpretation of everything observed.

Concomitantly as the gas content of a bubble is caused progressively to diminish, the space formerly occupied by the gas becomes filled by infiltration with liquid from the liquid phase of the gel, giving rise finally to liquid-filled, phantomlike, cavities, whose very existence has heretofore escaped observation. The forms of these cavities thus arising spontaneously in an isotropic medium on alteration of a single external condition are exceedingly symmetrical and beautiful. As demonstrated by photomicrographs, they exhibit two main types:

(1) If derived from gas cavities of oblate spheroidal form, the liquid-filled phantoms are of forms that may be likened to bivalve molluscs whose shells are either (a) segments of spheres, or bowl-shaped; or (b) of inflected curvature, like a circular basin with a flaring edge; or (c) like the last, but with a central apical spike like that of a helmet. Each one of these forms is immediately explicable if it be considered that, while forming, the original airbubble thrust aside the elastic water-poor phase of the gel, which was thus obliged to collect in an elastic layer or membrane under compression round the periphery of the bubble. The bubble cavity is thus contained and enveloped by a membrane which may appropriately be considered in surface *compression*, as contrasted with the customary surface tension, because adjacent portions of this enveloping membrane tend to move apart from instead of toward each other, in a direction tangential to the surface of curvature. The sphere is the stable form that must be enveloped by a membrane in surface tension, but is no longer stable if its bounding membrane is in surface compression; and this instability is, therefore, in such a case, relieved first by an exhibition of oblateness and later by an out-thrusting of the membrane in the region of smallest radius of curvature, giving rise to the forms observed in a manner entirely predicable by purely geometrical reasoning.

(2) If derived from gas cavities of prolate spheroidal form, the liquid cavities are of forms somewhat like that of those walnuts, occasionally met with, that have three instead of two lunes or boat-like portions composing their shells. This spontaneously formed solid, trilunar, figure has one axis of triad symmetry perpendicular to one plane of symmetry, and is usually of sharpened angle both along its three edge-ribs and especially at the ends of its chief axis, by reason of the outward thrust of its enclosing membrane, precisely as would be predicted by the reasoning noted above. An example of this form is shown in Fig. 2;

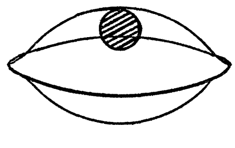

FIG. 1

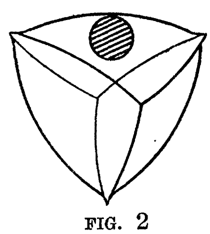

FIG. 2

while Fig. 1 shows the form referred to under (b) above. These figures are from photomicrographs of cavities not more than one millimeter in diameter; and each cavity contains, besides liquid, a small spherical bubble of air, which appears dark.

It is believed that the forms here described and interpreted are unique in inorganic nature.

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UNLIKE INTERPRETATIONS OF FULLER'S SCALE IN DETERMINING DEGREE OF ACIDITY

In following directions for making up bacteriological culture media the writer has been impressed by the marked differences in acidity as recommended by different bacteriologists. For example, "The Standard Methods of Water Analysis," adopted by the American Public Health Association, 1917, and commonly used by bacteriologists, recommends the use of culture media of a + 1.0 acidty.[1] Smith (4, p. 69), however, apparently recommends a + 15.0 agar and a + 10.0 gelatin, and these figures are frequently used by plant pathologists in designating the acidity of culture media.

The question which naturally arises is, do bacterial pathogens of plants require in general a much higher degree of acidity than bacteria of milk, sewage, water, animal pathogens, etc., or is it possible to explain this difference by assuming unlike interpretations of Fuller's scale. The writer with the hope of clarifying the situation has compared the descriptions of Fuller's method as given by Smith, whose texts are universally used by plant pathologists, with the description usually presented by bacteriologists, particularly animal pathologists, and also with the description originally presented by Fuller. He finds that Fuller's scale is interpreted differently.

Smith's (l. c.) description follows: "The plus and minus on Fuller's scale denotes, respectively, acid and alkaline media. The + 10, for example, means that exactly 10 cubic centimeters of normal alkali must be added to a *liter* (writer's italics) of the culture medium to render it exactly neutral to phenolphthalein, and, correspondingly — 10 means that the fluid is alkaline to phenolphthalein and that 10 cc. of normal acid would need to be added to bring 1 *liter* back to the neutral point." He follows this interpretation of Fuller's scale, as amount per liter, in his very recent work (5, p. 106): "Our standard agar is + 15 and our standard gelatin + 10 on Fuller's scale, or 1.5 per cent. and 1 per cent. respectively, if reckoned on 100 c. c. portions. It is best to keep to Fuller's scale since we make up media in liters, not in 100 c. c. portions."

The following description of Fuller's scale, taken from Park and Williams' (3, p. 102), is typical of the interpretations placed upon this scale by various texts on animal pathogens: "Calculation—Five c. c. of medium require 2.4 c. c. of N/20 NaOH, therefore *100 c. c.* (writer's italics)—would require 2.4 c. c. of N/1 NaOH—; in other words, the medium is 2.4 per cent. acid to phenolphthalein or + 2.4 if expressed according to *Fuller's method* or *scale.*" It will be noted that in this interpretation Fuller's scale is used as degree of acidity in *100 c. c.* of medium in contrast to those interpretations in which the scale denotes degree of acidity in *1,000 c. c.* of medium.

Fuller's (1, p. 388) own description reads as follows: "For accuracy and convenience, the expression of acidity or alkalinity of culture media in numbers of cubic centimeters of a normal solution *per liter* (writer's italics) is by far the best, and I recommend its universal adoption as a standard method." Concerning degree of acidity with reference to optimum growth, he says (p. 391): "Speaking in general terms the available data appear to warrant the placement of the optimum degree of reaction within narrower limits, between 10 and 20 of our scale," and (p. 394) he adds, "As it is very urgent that some fixed point be adopted I venture to suggest that for quantitative water analysis . . . . 18 on our scale be taken as a standard. This means, of course, that such a solution would require 18 cubic centimeters per liter of normal alkali to render it neutral to phenolphthalein." This usage, as amount per liter, has been generally adopted by plant pathologists, while the animal pathologists, in general, use the scale as denoting amount per 100 c. c.

It should be pointed out that Fuller does not

[1] Since Fuller's scheme has several decided disadvantages it is being supplanted by more accurate methods. (See Report of the Committee on the Descriptive Chart for 1919. *Jour. Bact.*, 5: 127-143. 1920).