

The Origin of Osmotic Effects. II.—Differential Septa.

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I have had the privilege of following the progress of the inquiry of which an account is given by Prof. A. J. Brown in the previous communication and of watching the development of the exquisite and invaluable method of studying the osmotic process which he has devised; I trust that I shall not be presuming if I discuss the results which he has arrived at and attempt to interpret them in the light of views already placed before the Society in my communication on "The Origin of Osmotic Effects"* and in the series of "Studies of the Processes Operative in Solutions."†

Prof. Brown's observations appear to be extraordinarily significant, as affording the means of dividing substances broadly into two classes according as they will or will not diffuse through a membrane such as that which forms the outer covering of the seed of barley (*Hordeum vulgare*) and with the aid of the classification thus secured of arriving at an explanation of the selective process.

Inasmuch as the barley grain contains but a small amount of soluble crystalloids, the absorption of water by the grain may be regarded as mainly conditioned by the extremely minute granules of starch enclosed within it; presumably these have great attraction for certain molecules in the liquid and become coated superficially therewith. From this point of view the method developed by Prof. Brown involves the study of a struggle for *hydrone* between a mass of fine particles of solid and the solution of a substance present in the liquid state in solution in water; the observations are the first of their kind, I believe.

It is clear, although the method affords only approximate results, that the conclusions to be deduced as to the relative "concentrating" efficiencies of the several solutes are in general accordance with those arrived at in other ways. The observations made in my laboratory show that chlorides are more active than nitrates in solution and that sodium salts are more active than either potassium or ammonium salts—more active, that is to say, in the sense that they exercise a greater concentrating effect; this is precisely the result arrived at by Prof. Brown.

No division of the substances into electrolytes and non-electrolytes can be made in any way corresponding to the extent to which water is absorbed

* 'Roy. Soc. Proc.,' 1906, A, vol. 78, p. 264.

† *Ibid.*, p. 272 (I); II—V, vol. 79, 1907, pp. 564—597; VI—X, vol. 81, 1908, pp. 80—140.

from the solutions by the grains—cane-sugar is nearly as active as common salt. In like manner, not only are strong acids and most salts indiffusible through the membrane covering the grain but also not a few non-electrolytes; the membrane is slowly permeated by certain weakly oxygenated organic acids, by salts such as mercuric chloride and cadmium iodide, by iodine, by ammonia and by a number of non-electrolytes of low molecular weight.

The compounds which penetrate the membrane, whether electrolytes or non-electrolytes, are all substances which attract water presumably only to a minor extent and which exist to some extent in solution in an unhydrated condition; those which cannot penetrate it, on the other hand, probably all form hydrates of considerable stability in solution.

I picture surfaces generally, colloid surfaces in particular, as not merely wetted by water but as more or less hydronated and hydrolated—using these terms in the specific sense explained in No. VIII of my “Studies on Solutions”; that is to say, they are not merely wetted by water complexes* but associated with *hydrone*, the simple fundamental molecule of which water is composed. The intramolecular passages in a colloid membrane, if thus hydrolated, would be guarded by the attached hydrone molecules; molecules in a solution bathing the membrane which attempted to effect an entry through such passages, if hydrolated, would be seized upon and held back in virtue of the attraction which the two hydrolated surfaces—that of the membrane and that of the solute—would exercise upon one another. The hydrolated passages, however, would be indifferent to molecules which were not hydrolated—consequently, a substance such as acetic acid, of which probably only a small proportion is present in solution in the hydrolated state, would gradually pass through them.

The apparently exceptional behaviour of trichloroacetic acid, which must be more fully if not more firmly hydrolated than acetic acid, is very striking and may be taken as proof that the hydrolation must extend over a certain area to secure protection against penetration; it should be noted, however, that the result is in accordance with the behaviour of the acid as a substitution derivative. Hydroxy- and amino-acetic acids (glycollic acid and glycine), which are far weaker acids, are nevertheless far less easily diffusible—presumably because not only the carboxyl group of the acid but also the adjacent hydroxyl- or amino-group is hydrolated. The behaviour of glycol, $\text{C}_2\text{H}_4(\text{OH})_2$, in comparison with that of alcohol, $\text{C}_2\text{H}_5(\text{OH})$, may be interpreted in a similar manner. The concentrating effect exercised by the sugars has already been

* Compare ‘Chemical News,’ Jan. 15 and 22, 1909, pp. 28 and 37; ‘Science Progress,’ Jan., 1909, No. XI, p. 484.

considered from this point of view in our previous "Studies" (VIII, pp. 111,⁶112; X, p. 130).

The exceptional rapidity, to which Prof. Brown directs attention, with which ethylic acetate acts in promoting the entry of water into the grain is also easily explicable from the same point of view. Entering together with water, it should render water within the grain more active and more attractive of external water (by promoting its dissociation, $(\text{H}_2\text{O})_x \rightarrow x\text{H}_2\text{O}$) than the water would be which entered alone from a solution of an indiffusible solute, as in such water (on account of its homogeneity) the osmotic stress would be at a minimum.*

It is obvious that the argument now put forward may be applied to the discussion of a great number of more or less obscure physiological phenomena. It may be desirable to consider the rise of the sap in trees from such a point of view. The argument affords an explanation of the well-known efficacy, for example, of mercury salts, of iodine and of alkaloids as drugs. It should point the way to the production of medicaments adjusted to their purpose—according as it is desired that they should penetrate this or that membrane. It may lead to the discovery of a method of using stains as the means of determining whether this or that membrane or layer in a cellular tissue is to be regarded as a mere sieve or as differentially penetrable, inasmuch as stains—which hitherto have been used all but empirically—must vary greatly in penetrative power and it should be possible to grade them, according to their diffusibility, by observations similar to those made by Prof. Brown.

* [February 15, 1909.—Attention has been specially drawn in No. VIII of our Studies (p. 108) to the behaviour of methylic acetate as a weak hydrolyte in comparison with the strong hydrolyte cane-sugar; the observations now under discussion appear to afford complete confirmation of the argument there put forward that in discussing the phenomena of hydrolysis it is necessary to take into account not only the condition of the medium but also the nature both of hydrolyte and of hydrolyst, which are reciprocally concerned in the change. The argument should be extended to colloid and other surfaces. Sir James Dewar has shown that solids differ greatly in their power of attracting and holding gases at low temperatures; hydrolytes and dissolved substances generally, we must suppose, also differ in the extent to which they undergo "hydration"; wetted surfaces generally must also differ in the extent to which they become hydrolated; consequently, it is to be supposed that more or less considerable variations will be met with when differential septa are studied comparatively. Apparently the barley septum is not penetrated even by ammonium chloride, so that it is more exclusive than that of red blood cells, which are rapidly penetrated by this salt but scarcely if at all by ammonium sulphate. The difference between ammonium chloride and ammonia is very striking, the latter resembling ethylic acetate in passing rapidly into the seed and in promoting the ingress of water; this behaviour is easily understood, as it exists in solution partly in the free state and partly, it may be supposed, as the hydrone $\text{H}_3\text{N}:\text{OH}_2$, the hydroxide being present in only very small proportion. If ammonia were contained in solution as the hydroxide, its behaviour would undoubtedly be that of caustic soda.]
