

is biconcave; the ninth being invariably biconvex." The same statement appears in the "Amphibia and Reptile" volume of the Cambridge Natural History, published some four years later (1901).

So far as I am aware, exception has never been taken to this statement. When, therefore, last year, I had occasion to examine the vertebral column of an Indian toad, *Bufo melanostictus*, I was surprised to find that the eighth and ninth vertebræ were not as described, but that, on the contrary, both were proœlous, resembling in this the seven preceding vertebræ.

At first I supposed that this was merely an abnormality resembling the condition found by Lloyd Morgan in *Rana temporaria* in 1886, and recorded by him in these columns (vol. xxxv., p. 53). I examined, however, five other specimens of *B. melanostictus* and also two of *B. andersonii*, and discovered that, in every case, all the vertebræ were proœlous, exactly as in my first specimen.

I could only come to the conclusion that, in these two species at least, we had exceptions to the rule laid down in the works quoted. On my return to England, therefore, I took an early opportunity of consulting Mr. Boulenger upon this point, who very kindly permitted me to examine a large collection of skeletons of *Bufo*.

Including my own specimens, more than fifty vertebral columns were examined, these belonging to some forty different species of *Bufo*, and it then became apparent that what I had been disposed to regard as an exceptional state of affairs, obtaining in a couple of Indian toads, was actually an invariable condition, and, moreover, one apparently diagnostic of the genus *Bufo*, for not a single specimen showed either an amphicœlous eighth or a biconvex ninth vertebra. In every case the centrum of the ninth vertebra, although hollow in front, has, of course, the usual double convexity behind.

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A Lunar Halo.

A REMARKABLE coloured halo forming a complete circle about the moon was witnessed by me on Wednesday evening, December 2, at 7.15, my position being in North Shields. I am seventy-nine years of age, and never saw anything similar—that is, encircling the moon. It only lasted about seven or eight minutes. I am wondering if anyone else took much notice of it.

An entire ring and colours were distinctly visible. The inner part—that is, to the commencement of the halo or rain-circle—had a remarkably globular appearance, with the moon as an apex, and was the most prominent part of the phenomenon.

The moon at the time was very bright, but shining through light fleecy clouds at a great height; then the yellow appearance commenced as shown, terminating with a dark orange rim.

The altitude of the moon would be about 60°, direction S.E., wind W.

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26 Percy Square, Tynemouth, December 5.

COLLOIDAL CHEMISTRY IN RELATION TO INDUSTRIES.

I.

WHEN the development of some branch of science reaches the stage at which a separate literature with its own terminology

begins to grow up, the question of its practical utility or its value to the arts begins to be asked. Whether research has to justify itself by such directly or indirectly useful results is at least arguable, but it must be admitted that the question is particularly natural when raised in connection with a discipline like colloidal chemistry which is concerned, *inter alia*, with substances such as form the raw materials or the products of important arts, many of which, like ceramics, dyeing, tanning, the making of bread and of fermented liquors, are as old as history.

Where industries have empirically reached a high degree of perfection, the chief function of science is to provide the explanation of processes which are the outcome of experience, generally with the result that improvements become possible which experience alone cannot suggest. In judging a new branch of chemistry it is too often overlooked that even inorganic chemistry has largely played this part and has not yet quite succeeded in it in some respects: thus the theory of a process as important and familiar as the lead chamber process of making sulphuric acid is still highly controversial. On the other hand, organic chemistry provides many instances of the opposite way in which science may assist industry: by producing new bodies the properties of which are anticipated on theoretical grounds.

While, therefore, too much must not be expected of a science as young as colloidal chemistry, there is no doubt that it is destined to be of considerable value to a great number of industries in both the directions indicated above. Probably the most convenient method of showing this will be to state, without undue technicalities, a number of fundamental propositions which have now been firmly established and to illustrate their bearing on industrial processes and problems.

There is an immense amount of material to prove that the physical properties of a body may be varied continuously between wide limits by simply altering the size of its particles present or—as it is technically called, "dispersed"—in another medium, below a certain maximum limit. This is strikingly the case with the most obvious property, colour: thus, colloidal gold can be obtained red, purple, blue, or green in solutions containing the same amount of metal, and silver solutions of the same concentration may range from colourless through yellow, red, and purple to blue. Colourless or slightly coloured substances, *e.g.* sulphur, may form brilliant blue solutions. Solid colloidal solutions are also known to exist, examples of which are ruby glass, coloured by gold or copper, and the blue rock salt occurring at Stassfurt, which is coloured by metallic sodium.

The possibility of obtaining colour by dispersing a colourless substance in a colourless medium has been suggested as an explanation of the striking tint of a very puzzling class of bodies, the artificial ultramarines. Their chemical composition is very uncertain, but none of the compounds of which they are a mixture are at all likely to be

blue. Moreover, the ingredients used can, on one hand, be varied considerably without affecting the colour, and, on the other, batches of exactly the same composition may vary in colour from the desired blue to a greenish-white owing to variations in the process of fusion. The suggestion has been made, and supported by a good deal of evidence, that these variations may be due simply to differences in the "degree of dispersity," *i.e.*, in the size of the particles of one constituent disseminated through another. The same explanation has been tentatively put forward by Wo. Ostwald to account for the peculiarities of a very interesting group of dyes, the sulphide dyes—peculiarities which are not easily accounted for by their constitution alone.

It is, of course, well known that certain inorganic pigments, obtained by precipitation, vary in colour according to the concentrations and temperatures of the reacting solutions: thus, cadmium sulphide may be any shade from salmon pink to golden yellow. The reason is again to be found in the different size of the particles of precipitate which—up to certain limits—tends to increase with decreasing concentrations. There is a possibility of still further reducing this size with resulting changes in tint and incidentally with an increase in covering power, by adding to the solutions extremely small amounts of some organic colloids like glue or casein—a procedure which deserves extensive investigation by those interested.

Among the most important and most exhaustively investigated properties of colloids are their electrical characteristics. To describe these as briefly as possible, we may say that finely divided substances in contact with water and a few other liquids become electrically charged. In the majority of cases the charge is negative, but the oxides and hydroxides of a number of metals and a few dyestuffs are positive. The amount and eventually the sign of these charges can be modified by the addition of acid or alkali: thus, negatively charged particles become more so in alkaline media, while acid in increasing amounts diminishes and finally neutralises negative charges. Both these effects find technical application: thus, very fine precipitates or slimes which obstinately refuse to settle in neutral or alkaline liquids come down rapidly if the latter are made acid. The effect of acidity is to neutralise the negative charges on the particles, and their mutual electric repulsion, which helps largely to keep them in suspension. On the other hand, the addition of alkali to clay slip (the particles of which are also negative) has the opposite effect of suspending or "dispersing" the particles, so that the slip loses its plasticity and can be cast in moulds, a procedure which is employed on a large scale.

Owing to the charge on particles in contact with a liquid—which, as need scarcely be said, assumes the opposite charge—a relative movement of the two phases takes place in an electric field, that is, when electrodes connected to a source of

current are immersed in the liquid. If the particles are freely suspended, they move towards the electrode having the opposite sign; if, as is sometimes the case, the solid is aggregated into a porous diaphragm, the liquid flows through the diaphragm towards the other pole. To take a concrete example: particles of carbon are negative and therefore travel towards the positive pole or anode; if they are formed into a fixed diaphragm, for instance, a plate of porous carbon, the water—which is positively charged—flows through this diaphragm to the negative pole or cathode. The movement of particles in the electric field is called cataphoresis; the flow of liquid through a diaphragm electro-osmosis. Both phenomena have been applied industrially by Count Schwerin. Thus, clays can be freed from iron oxide by being suspended in water in an electric field, since clay particles are negative while iron oxide is positive, so that the two substances travel to opposite electrodes. Spongy substances having a cellular structure, like peat, can be freed from water by being placed between a perforated plate acting as cathode while a second plate resting on the peat serves as anode. The solid being negative, the water is positive and flows to the cathode, escaping through the perforations in the latter. Both processes are capable of varied and extensive applications, many of which are being developed.

It is highly probable that electric factors play a considerable, although by no means clear, part in the various processes for separating sulphide ores from gangue with the aid of oil, particularly in the Minerals Separation process, which consists in adding to a slightly acid pulp made from the ore, part of which must be exceedingly fine, a minute quantity of oil and agitating in such a manner that a considerable quantity of air becomes mixed with the liquid. As soon as agitation ceases the air rises in the form of bubbles which carry the sulphide to the top, while the gangue sinks to the bottom. The necessity for acid reaction, in conjunction with known differences in the electrical properties of oil, quartz and air surfaces in contact with acid water, is strong evidence that the electrical properties of suspended particles play an essential part in the process, and its future investigation will have to take them into account to a much greater extent than has been the case up to the present.

Our knowledge of the effects of the two factors discussed so far—size and electric state of particles—has been gained through the study of colloidal solutions, chiefly of metals and sulphides, *i.e.*, of suspensions in which the diameter of the particles lies below the limit of microscopic visibility, roughly speaking, below 200 $\mu\mu$ (1 $\mu\mu$ = one-millionth millimetre). While the preparation of such solutions is of the greatest theoretical interest, and some are used therapeutically, they have found only a few technical applications worth mentioning.

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