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## WHY IS SEA-WATER SALT?

BY W. MATTIEU WILLIAMS, F.R.A.S., F.C.S., LONDON, ENGLAND.

THIS question has been regarded as a mystery and has given rise to some curious speculations, but a little consideration of the subject must, I think, satisfy us all that it would be very wonderful, quite incomprehensible, if the waters of the ocean were otherwise than salt as they are.

The following explanation was first suggested to myself many years ago when receiving my first lessons in practical chemical analysis. The problem then to be solved was the separation of the bases dissolved in water by precipitating them, one by one, in a solid condition; filtering away the water from the first, then from this filtrate precipitating the second, and so on, until all were separated or accounted for.

But in doing this there was one base that was always left to the last, on account of the difficulty of combining it with any acid that would form a solid compound, a difficulty so great that its presence was determined by a different method. This base is soda, the predominating base of sea-salt, where it is combined with hydrochloric acid. Not only is soda the most soluble of all the mineral bases, but the mineral acid with which it is combined forms a remarkably soluble series of salts, the chlorides. Thus the primary fact concerning the salinity of sea-water is that it has selected from among the stable chemical elements the two which form the most soluble compounds. Among the earthy bases is one which is exceptionally soluble,—that is, magnesia,—and this stands next to soda in its abundance in sea-water.

Modern research has shown that the ocean contains in solution nearly every element that exists upon the earth, and that these elements exist in the water in proportions nearly corresponding to the mean solubility of their various compounds. Thus gold and silver and most of the other heavy metals are found to exist there. Sonnenstadt found about 14 grains of gold to the ton of sea-water, or a dollar's worth in less than two tons.

As the ocean covers all the lower valleys of the earth, it receives all the drainage from the whole of the exposed land. This drainage is the rain-water that has fallen upon this exposed surface, has flowed down its superficial slopes, or has sunk into porous land, and descended under-ground. In either case the water must dissolve and carry with it any soluble matter that it meets, the quantity of solid matter which is thus appropriated being proportionate to its solubility and the extent of its exposure to the solvent. Rain when it falls upon the earth is distilled water nearly pure (its small impurities being what it obtains from the air), but river-water when it reaches the ocean contains measura-

ble quantities of dissolved mineral and vegetable matter. These small contributions are ever pouring in and ever accumulating. This continual addition of dissolved mineral salts without any corresponding abstraction by evaporation has been going on ever since the surface of the earth has consisted of land and water.

An examination of the composition of other bodies of water, which, like the ocean, receive rivers or rivulets and have no other outlet than that afforded by evaporation, confirms this view. All of these are more or less saline, many of them more so than the ocean itself. On the great Table Land of Asia, "the roof of the world," there is a multitude of small lakes which receive the waters of the rivers and rivulets of that region and have no outlet to the ocean. On a map they appear like bags with a string attached, the bag being the lake and the string the river. All these lakes are saline, many of them excessively so, simply because they are ever receiving river-water of slight salinity and ever giving off vapor which has no salinity at all. There is no wash through these lakes as in the great American lakes or those of Constance, Geneva, etc.

The Sea of Aral and the Caspian are lakes without any other outlet than evaporation, and they are saline accordingly. The Dead Sea, which receives the Jordan at one end and a multitude of minor rivers and rivulets at its other end and sides, is a noted example of extreme salinity. It is, as everybody knows, a sea or lake of brine. The total area of land draining into the great ocean does not exceed one-fourth of its own area, while the Dead Sea receives the drainage and soluble matter of an area above twenty times greater than its own, and thus it fulfils the demand of the above-stated theory by having far greater salinity than has the great ocean.

According to this view the salinity of the ocean must be steadily though very slowly increasing, and there must be slowly proceeding a corresponding adaptation or evolution among its inhabitants, both animal and vegetable. The study of this subject and the effect which the increasing salinity of the past must have had upon the progressive modifications of organic life displayed by fossils is, I think, worthy of more attention than it has hitherto received from palæontologists.

## THE ENERGY-FUNCTION OF THE MAGNETIC CIRCUIT.

BY CHAS. P. STEINMETZ.

IN designing alternate-current electric motors, in October, 1890, I was confronted by the problem, to calculate the loss of energy caused by the reversals of magnetism in the iron of the motor-field. At that time very little was known on this phenomenon besides a few experimental data of Ewing. From these data mathematical analysis yielded the result that the loss of energy (by conversion into heat) during a complete cycle of magnetization is proportional to the 1.6 power of the intensity of magnetization, or magnetic induction,  $B$ ; that is, can be expressed by the formula:—

$$H = \eta B^{1.6}$$

where  $H$  is the loss of energy per magnetic cycle, and  $\eta$  a "co-efficient of hysteresis." This result was published in the *Electrical Engineer*, New York, December, 1890.

But it was not quite satisfactory, in so far as Ewing's determinations were made by the magnetometer method, with very slow cyclic variations of magnetism, and it was doubtful whether for very quick cycles, as they take place under the influence of an alternate-current of 100 or more complete periods per second, the same law holds, and especially the co-efficient of hysteresis,  $\eta$ , is the same.

A great number of tests, made during the year 1891, partly by the three-electrodynamometer method, partly by the use of the Eickemeyer differential magnetometer, and published in a paper read before the American Institute of Electrical Engineers, January, 1892, proved that up to over 200 complete magnetic cycles per second the loss of energy per cycle—by conversion into heat—is constant and independent of the number of cycles per second, following the law of the 1.6 power; while, when under the influence of the alternating magnetism, Foucault—or eddy—cur-

rents are induced in the iron, the energy-function of the magnetic circuit follows the more general law:—

$$H = \eta B^{1.6} + \epsilon NB^2,$$

where  $H$  gives the loss of energy per cycle and  $cm^3$ , in absolute units,  $N$  is the frequency, or number of cycles per second,  $\eta$  the co-efficient of molecular friction or hysteresis, and  $\epsilon$  a co-efficient of eddy currents.

Herefrom the loss of power per  $cm^3$  of iron, in Watts, is derived, as

$$W = NH \times 10^{-7} = \left( \eta NB^{1.6} + \epsilon N^2 B^2 \right) \times 10^{-7}$$

The next problem was now, to determine the energy-function of the magnetic circuit for cyclic variations of magnetism between any two limits,  $B_1$  and  $B_2$ , and to derive numerical values of the co-efficient of molecular friction,  $\eta$ , for different magnetic materials.

In the meantime, it had been found by Kennelly (Transactions of American Institute of Electrical Engineers, October, 1891) that Fröhlich's formula of magnetic induction —

$$B = \frac{H}{a + bH}$$

(where  $H$  is the magnetomotive force or field-intensity,  $a$  and  $b$  constants), which had been abandoned already as inexact, holds rigidly by a slight modification. Using not the whole magnetic induction,  $B$ , but the "metallic-magnetic induction,"  $L = B - H$ , where  $H$  is the field-intensity, we find, that for infinitely large field-intensities  $H$ , the metallic induction  $L$  approaches a finite limiting value  $L_\infty$ , and follows Fröhlich's formula:—

$$L = \frac{H}{a + \sigma H},$$

or, if we assume Ohm's Law for the magnetic circuit,

$$L = \frac{H}{\rho},$$

where  $\rho$  is the magnetic resistance, or reluctance, it is

$$\rho = a + \sigma H;$$

that is, the magnetic resistance is a linear function of the field-intensity.

On the hand of a large number of experimental determinations, made by the electro dynamometer and by the magnetometer method, comprising several thousands of readings, I was enabled to communicate to the American Institute of Electrical Engineers at the meeting of September, 1892, the results:—

1. The loss of energy by molecular-magnetic friction, per cycle and  $cm^3$ , for a cyclic variation of the magnetic induction between the limiting values  $L_1$  and  $L_2$ , is expressed by the function —

$$H = \eta \left( \frac{L_1 - L_2}{2} \right)^{1.6}$$

where  $L_1$  and  $L_2$  most likely have to represent the metallic induction  $L = B - H$ .

When Foucault — or eddy — currents are present in the iron, the energy-function of the magnetic circuit takes the more general form —

$$H = \eta \left( \frac{L_1 - L_2}{2} \right)^{1.6} + \epsilon N \left( \frac{B_1 - B_2}{2} \right)^2$$

where the first term gives the energy converted into heat per cycle and  $cm^3$  by true molecular friction, the last term the energy converted into heat by Foucault currents.

2. Beyond a minimum value of field-intensity,  $Hm$ , the metallic magnetic resistance follows the linear law:—

$$\rho = a + \sigma H.$$

3. Beyond this minimum value of field-intensity,  $Hm$ , all the essential properties of magnetic materials can be expressed by three constants:—

- $a$ , the co-efficient of magnetic hardness;
- $\sigma$ , " " " " saturation;
- $\eta$ , " " " " hysteresis;

or, instead of this, by the three constants:—

$L_\infty = \frac{1}{\sigma}$ , the value of absolute (metallic) magnetic saturation.

$H_0 = \frac{a}{\sigma}$ , the critical field-intensity, or that field intensity where

half-saturation,  $\frac{L_\infty}{2}$ , would be reached, if the linear law of magnetic resistance held already for this field-intensity  $H_0$ , and

$H_\infty = \eta L_\infty^{1.6}$ , the maximum value of hysteretic loss, by means of the formulas:—

The equations of magnetic resistance, or reluctance —

$$\rho = a + \sigma H = \frac{H_0 + H}{L_\infty}$$

(corresponding to Ohm's Law in the electric circuit), and the energy-function —

$$H = \eta \left( \frac{L_1 - L_2}{2} \right)^{1.6} = H_\infty \left( \frac{L_1 - L_2}{2 L_\infty} \right)^{1.6}$$

(corresponding to the energy-function of the electric circuit,  $W = c^2 R$ ).

4. These equations hold for all kinds of iron and steel, for nickel, cobalt, and magnetite, and most likely for the amalgams of iron, that is, for all magnetic materials.

5. In first approximation, the magnetic induction,  $B$ , and the magnetic hysteresis, or molecular friction,  $H$ , depend upon the magnetic field-intensity,  $H$ , by the law of probability of molecular distances.

6. Average values of magnetic constants are:—

For wrought-iron, soft cast-steel, and mild metal —

$$a = .38 \times 10^{-3} \quad \sigma = .055 \times 10^{-3} \quad \eta = .003 \quad (Hm = 9);$$

for cast-iron and low-permeability cast-steel —

$$a = 3 \times 10^{-3} \quad \sigma = .095 \times 10^{-3} \quad \eta = .013 \quad (Hm = 22);$$

for soft welded-steel and medium-hard cast-steel of high permeability —

$$a = 1.7 \times 10^{-3} \quad \sigma = .06 \times 10^{-3} \quad \eta = .02 \quad (Hm = 50);$$

for glass-hard steel —

$$a = 10 \times 10^{-3} \quad \sigma = .1 \times 10^{-3} \quad \eta = .07 \quad (Hm = 110).$$

October, 1892.

## THE APPARENT GROWTH OF GOLD.

BY RICHARD EAMES, JR., M.E.

OF the many myths prevalent regarding gold, the greatest one of all is its growth. Of course there are many interesting instances where ancient worked-out galleries in mines are slowly closing up by the incrustation process, so that space long ago excavated is being filled with an accumulation resulting from the percolation of water through the adjacent wall-rock. This water has in chemical combination such minerals as iron, copper, sulphur, and the precious metals, which are deposited in the open crevice, making for a second time a mineralized body which will show by analysis the above named and many more minerals. In fact, I have had this actual experience resultant on the examination of an old gold mine in Honduras, Central America, that had been worked some time prior to any history we have of that country. This circumstance gave to the natives the idea that gold grew, and they so expressed themselves; while it seemed in the case of one individual a transmutation idea had permeated his head, for he explained that the green carbonate of copper was undergoing a change into silver, while the silver in turn would develop into gold.

In India I found a caste of mining people who believed that gold grew in the bottom of the large lakes situated in that country. They expressed no practical reason other than fairy-tale superstitions. And even in this country there are converts to the idea. I was much amused and interested some years ago to hear an intelligent acquaintance maintain in strong and not altogether religious terms that "the stuff grew and he knew it." His experience was based on the fact that in a certain pile of tailings, resulting from the milling of heavy sulphuretted gold-ores, he had treated at one time several tons with no result. Again, in