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# The Chemical Basis of Medical Climatology

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*Chapter II*

# STRUCTURE OF WATER

## THE PROPERTIES OF WATER

WATER IS A LIQUID which displays properties differing greatly from those of other liquids that chemically should resemble it. Its behaviour is anomalous. In recent years, scholars have concentrated their attention on the properties of water and have found that the deeper they go and the more theory progresses and the finer the properties brought to light, the greater the anomalies. Strictly speaking, one may say that it is only recently that water has become recognised as a truly abnormal liquid. In order to realize the exceptional uniqueness of the most common of liquids we need only compare certain physical data which concern water with those of the hydrids of the elements which are close to water in the periodic system or else we can consider the same data in the homologous series: O, S, Se, Te (Table I).

TABLE I

| | $B_2H_6$ | $CH_4$ | $NH_3$ | $OH_2$ | FH |
|---|---|---|---|---|---|
| Melting point | —169 | —185 | —77 | 0 | —92 |
| Boiling point | — 87 | —161 | —31 | +100 | +19 |

| | $OH_2$ | $SH_2$ | $SeH_2$ | $TeH_2$ |
|---|---|---|---|---|
| Melting point | 0 | —82 | —64 | —48 |
| Boiling point | +100 | —60 | —41 | — 1 |

In melting, water contracts so that its density at 0° C is greater than that of ice, which is also at 0° C. As the temperature rises, water continues to contract until it reaches 4° C, at which temperature it is at its maximum density. Above 4° C, water expands at the temperature rises, The "physical scandal" of a body whose density rises with the temperature has provoked a great deal of thought among scholars since the years 1667, when the increase of density was noted by Florentine academicians of Cimento.

At 0° C, the density of ice is 0.9168 and that of water is 0.9999.

Water contracts by 8.3% as it melts and, on reaching 4° C, it further contracts by 0.12%.

The dielectric constant of water at 25° C is 78.30, a very high value which is greater than that of the dielectric constant of the common liquids with the exception of four; hydrogen cyanide (106.8 at 25°C), formamide (108.5 at 25°C), sulphuric acid (101 at 25°C) and hydrogen fluoride (83.6 at 0°C).

All other liquids present smaller dielectric constants of unity 10, 20 or even 50, if they are polar, and above unity 70 if they are non-polar. In general, the value of the dielectric constant of non-polar liquids is around 2.

The surface tension of water is remarkably higher than that of the other common liquids. Melted salts and melted metals are not included among the common liquids, because in these cases the surface tension values change their order of size. Only the surface tension of hydrogen peroxide has a value slightly greater than that of water (Table II).

TABLE II

| | Surface tension dynes/c |
|---|---|
| Common liquids | 0 — 65 |
| Melted salts | 90 — 230 |
| Melted metals | 360 — 1000 |
| Water | 73 |
| Hydrogen peroxide | 78 |

The latent heat of ice fusion is the greatest known, save for that of ammonia. And the latent heat of water vaporization is certainly the greatest known.

The specific heat of water is abnormally high. For example:

| water | mercury | alcohol | benzene | carbondisulphide |
|---|---|---|---|---|
| 1.000 | 0.033 | 0.547 | 0.397 | 0.235 |

and the difference between specific heat in the liquid state and in the solid state is also abnormally large. The specific heat of ice is 0.5026 cal/gr at 0°C and that of water is 1.008 at the same temperature. The difference is 0.4982 at 0°C. The differences revealed by other substances are not as high as that of water.

The specific heat of water is at a minimum at 35°C. This minimum was determined with great exactitude by Osborne, Stimson and Ginnings in 1939. The International Committee on Weights and Measures has approved a heat capacity table for international use in calorimetry which differs from the table of Osborne, Stimson and Ginnings by less than 0,005 joule/deg. mole. The date are thus completely dependable. The preceding measurements go back to the years 1874, 1893, 1900, 1905, 1910, 1911, 1912 and 1915. Revision and clarification were necessary.

I have insisted on the determination of the specific heat of water and on the precise establishment of the minimum point because the existence of this minimum is of greatest importance, as we will see later.

A study carried out by Bridgman concerning the viscosity of water at various pressures and various temperatures must be considered as being of fundamental importance. With a rise in temperature, the isotherm at 0°C reveals a minimum in correspondence with a pressure of 1000 $kg/cm^2$; the isotherm at 10°C reveals this minimum less markedly and the isotherm at 30°C no longer reveals a minimum. This means that below 30°C the viscosity presents an anomaly in correspondence with a pressure of 1000 $kg/cm^2$, as if something voluminous were "crushed" that the temperature destroys when it rises above 30°C.

On the other hand, it is best to note before going further that between 30 and 40°C many of water's properties reveal certain oddities, a sign that at that temperature something very important occurs with respect to the structure of water.

Magat, observing the disappearance of the intermolecular bands of the Raman spectrum of water at temperatures above 37°C, decided to determine whether the other properties of water presented anomalies at the same temperature.

He found that all the known properties reveal irregularities in the temperature interval between 30 and 40°C:

- *Compressibility of water* in function of the temperature (on the basis of data furnished by Magat, Tamman and Ruenenbeck).

- *Index of the refraction* of water for the line D in function of the temperature (on the basis of data furnished by Hall & Payne).
- *Second derivative of the viscosity* in function of the temperature (based on the average of all known values).
- *Molecular heat of water at constant pressure* in function of the temperature (based on the measurements of Dieterici). At that time there were as yet no Bureau of Standards measurements and divergences were noted between one author and another on the position of the minimum. Magat localized it between 35 and 45°C.
- *Molecular heat of water at constant volume* of the temperature, calculated by Magat on the basis of constant pressure data.
- *Derivative of the dilatation coefficient* in function of the temperature, based on the excellent measurements of Chappuis integrated with the measurements of the Phys. Techn. Reichsanstalt.
- *Solubility of water in benzene* (based on the data of Hill).
- *Solubility of water in a non-polar substance* (bromine).
- *Solubility of water in a polar substance,* but not strongly associated in the liquid state (ether).
- *Second maximum in the X diffraction spectrum.* This maximum begins to wane at 20°C and at 40°C it remains nothing but a point of inflection, according to the observation of Stewart, 1931.

It was evident that something very important was taking place in the structure of water around 35°C. Magat advanced a working hypothesis which held that the anomalies in question were linked to the transformation of a vibration in a rotation.

He immediately saw the *biological importance* of this general fact and affirmed: "Signalons enfin, qu'une variation des propriétés associatives de l'eau peut être d'une grande importance pour les processus biologiques, la région de temperatures correspondant à la transformation étant celle de l'organisme des animaux à sang chaud."

After some years Morgan and Warren studied x-ray diffraction patterns of water at five temperatures: 1,5, 13, 30, 62 and 83°C. "Radial distribution curves for water at the five temperatures were obtained by a Fourier analysis of the x-ray intensity curves. The results can be interpreted in terms of a structure. The change in the diffraction pattern of water with rise in temperature is evident. At 1.5°C exist a first peak and a second peak. With rising temperature the second peak becomes less sharply resolved from the first peak. At 83°C the two peaks have practically merged into a single peak. About the only conclusion that can be drawn from the intensity curves is that there is a change in the structure of water with rise in temperature."

In order to explain the unique properties of water which make it so different from all other liquids, Roentgen supposed that water is a mixture of two different types of molecule, which he called *ice molecules* and *water molecules.* The ice molecules form a mass which is less dense than that of the water molecules. As the temperature rises, the number of ice molecules diminishes and the number of water molecules increases. This hypothesis made possible the explanation of some of the anomalous properties of water; for example, the maximum of density at 4°C. It is important to note that until that time scholars had occupied themselves with the effect of melted substances on the lowering of temperature to the point where the maximum of density was observable, that is, in the destruction of the ice molecules.

Chemical analysis designated the composition of water as $H_2O$. But the density of steam was slightly greater than should have been the case if it were completely made up of $H_2O$ molecules, and less than should have been the case if water were made up of $H_4O_2$ or $(H_2O)_2$ molecules. Thus steam is to be considered as a mixture of two molecular types. At 0°C the molecular ratio of $H_4O_2$ or $(H_2O)_2$ would be 2.6% (Bose).

But in order to explain the behaviour of water in a gaseous state at various temperatures, more complex hypotheses were necessary. There is nothing to be gained now by reviving those old hypotheses. It will suffice to point out that until the early years of this century the behaviour of water in a gaseous state made it necessary to assume the simultaneous presence of several types of molecule and, in addition, the possibility that one of these behaved in a special manner.

The properties of liquid water have to be explained by even more complex hypotheses.

Sutherland put forth the hypothesis that water was composed of *three molecular types: hydrol,* $H_2O$; *dihydrol,* $(H_2O)_2$ or $H_4O_2$; *trihydrol,* $(H_2O)_3$ or $H_6O_3$. Hydrol would exist only in water vapour, dihydrol and trihydrol would be the normal components of liquid water, together with a small percentage of hydrol.

According to Sutherland, liquid water at 0°C would be composed of 62.5% dihydrol and 37.5% trihydrol. Dihydrol would possess a greater density, 1.089 at 0°C, and trihydrol a lesser density, 0.88 at 0°C. High pressure would then reduce the quantity of trihydrol present.

This hypothesis made it possible to explain partially the unusual properties of liquid water, and between 1900 and 1933 there was no substantial change of thought. But in the meantime, general progress in spectroscopy and molecular physics led to some very precise notions regarding the isolated $H_2O$ molecule in a gaseous state.

Even when thoroughly purified, water retains a slight electrical conductivity. Highly purified water, equilibrated with the surrounding air (equilibrated water) has a conductivity of $0{,}75.10^{-6}ohm^{-1}cm^{-1}$ at 18°C, attributable to a slight dissociation of the water in the hydrogen and hydroxil ions:

$$H_2O \rightleftarrows H^+ + OH^- \quad \text{or:} \quad 2.H_2O \rightleftarrows H_3O^+ + OH^-$$

The concentration of hydrogen and hydroxil ions is $0{,}8.10^{-7}$ equivalent per litre at 25°C.

Water is an ionizing liquid, and if one imagines it to be a homogeneous fluid with a given dielectric constant and a given viscosity, with the ions of the solute as little charged spheres subjected to resistance proportional to their velocity, modern theories of solutions substantiate the mobilities of the ions in a quite satisfactory manner. But until now no theory has been able to account for the mobility of the $H^+$ and $OH^-$ ions water, a mobility that is unusually great compared with that of the other ions.

Here are some data, at 18°C (Kohlrausch):

$$H^+\ \underline{315}, \qquad OH^-\ \underline{174}$$

$$Na^+ 33,\ K^+ 65,\ NH_4^+ 64,\ Cl^- 65,\ Br^- 67,\ \tfrac{1}{2}SO_4^-\ 68$$

The great anomaly displayed by the ions of water has led to modern theory's first general assault on the nature of liquid water.

## THE SUBTLE PROPERTIES OF WATER

Establishing that water possesses exceptional properties compared with other liquids and that its behaviour is completely anomalous, has not yet solved the problem of the properties of water. What we have shown are the general, characteristic and easily-definable properties that determine the behaviour of water in a wide sense.

But beyond the easily-definable properties, water displays a quantity of other properties not so easily-defined and hardly predictable that evade all attempts at documentation or thorough study. Chemists and, to an even lesser degree, physicists never consider the possibility that water could display such subtle and evasive properties. But biologists, hydrologists, hydrobiologists and balneologists are quite aware of the existence of these properties and know that they are highly important despite the difficulty of coming to grips with them.

Why is it that natural water drunk at a spring is more effective from a medical point of view than the same water bottled and aged? Why is natural water so different from a medical point of view in spite of the fact that the difference in chemical composition reveals nothing in particular? It is certainly not the small variations in common salts content that justify the efficacy of this or that water. Even the existence of small traces of radioactivity does not justify the differences in properties at all. Today we are beginning to speak of changes in the biological properties of water due to the heating and subsequent cooling of the water, which does not return to its previous state from a biological standpoint, even if we replace the gases it had lost during the heating and return it to exactly the same conditions in which it was found previously. This is what is known as *fervourisation* of water (Vale Vouk); an operation that bestows different characteristics upon water in spite of the fact that nothing different has definitely taken place from a chemical or physical standpoint.

The biological effects of fervourisation seem to be evident.

Then there are other facts to keep in mind, in spite of the fact that the majority of physicists and chemists have refused to consider them: the so-called phenomena of "*activation,*" which I mentioned in the introduction.

Water which is subjected to physical treatment, that puts minute quantities of energy in play, acquires some properties which last for quite some time, even for several days. Nothing has changed from a chemical standpoint. The properties that activated water acquires have been employed in the *physical descaling* of boilers and have been the subject of patents. Many of these patents have not served their purpose at all, but others have come into wide use and their results in industry are controllable. The effects of activation are changeable in the course of time and may only be evaluated statistically. But the effects do exist. The results can be good, and then suddenly turn bad. Why is this? In spite of the aleatoriability of its function, it has appeared convenient in many cases to attempt the use of physical descaling, which does not tie down specialized personnel, or consume chemical products and does not involve delicate chemical operations.

This is a subtle property of water that may be observed in the field of inorganic chemistry and in industry. It is a marvel that such a tiny quantity of energy is capable of such remarkable results, to say nothing of the economical aspects.

I will return to the subject of the activation of water in a subsequent chapter.

There are facts then which were considered a few years ago impossible to apprehend scientifically.

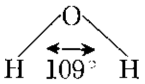
The study of natural phenomena may only be carried out when conditions are favorable. But to deny facts that are beginning to appear before our very eyes merely because they do not fall within the range of our standard knowledge is highly unscientific.

That these facts exist, at least with highly interesting frequency, is proved by industry which has spent and is still spending millions to make use of the very facts that many scientific scholars choose to ignore.

## THE STRUCTURE OF WATER

In the midst of studies of the properties of water based on theoretical concepts and on previously established facts, atomic physics, molecular physics and spectroscopy we are able to proceed from well-defined ideas regarding the isolated $H_2O$ molecule; that is, the molecule in a gaseous state. It would not have been possible to define these ideas earlier because the general theory would not have been sufficiently advanced.

The isolated $H_2O$ molecule has the following form:



The bond angle is 105°, the tetrahedral angle almost 109°. The internuclear distance O—H is 0.97 A. The electrical dipole moment is $1,87.10^{--18}$c.s.u. The vector of dipole moment acts upon the bisector of the angle H-O-H.
The negative end is that nearest the oxygen.

The mechanical wave theory gives some information on electronic distribution. The water molecule has 10 electron wave functions which can, according to Mulliken, be designated thus:

$$(1s)^2[2s_1]^2[2p_z]^2[2p_y]^2[2p_x]^2$$

Z is oriented along the bisector of the angle H-O-H, Y lies in the plane H-O-H perpendicular to Z, and X is perpendicular to the plane H-O-H.

Z, Y and X pass through the nucleus of the atom O. The radius of the water molecule is about 1.4 A. This means that if water were made up of spherical molecules in disorderly arrangement and touching one another, the density of water should be 1.84. If we wish to ascribe to water its true density, imagining it to be composed of spherical molecules arranged as we have suggested, its radius should be 1.72 A. The water molecule would then have to undergo a remarkable change of dimension during the process of fusion, because in ice, as we know from roentgenographic studies, its radius is 1.4 A. The extreme dissymmetry between the water molecule and its electropolarity does not permit such a conclusion. Apart from this, the study of X-ray diffraction on liquid water provides us with an independent and conclusive argument. X diffraction indicates that the radius of the $H_2O$ molecule in liquid water is 1.38 A.

The arrangement of the molecule cannot then be disordered as mentioned above, but must be of an entirely different order.

In 1933, Bernal and Fowler put forth a completely new idea, based on spectroscopic data, concerning the $H_2O$ molecule in a gaseous state, its electric moment and its dimension even bearing in mind certain similarities to order chemical compounds. Their idea revolutionized concepts of the constitution of water.

"$[2p_z]^2$ gives a concentration of negative electricity in two regions at right angles to the plane H-O-H. The net distribution of electronic density will therefore resemble a *tetrahedron* with two corners of positive and two corners of negative charge. Also it is possible to find that water molecules arrange themselves in a tetrahedral co-ordination.

Each molecule is surrounded by four others, the binding being between the positive regions on one molecule to the negative regions on the next."

Barnes found tetrahedral co-ordination in ice.

Bernal and Fowler pointed out that in the case of solid silica $(SiO)_2$ there exists a similar fourfold co-ordination. The variations of the polymorphous forms of silica showed that tetrahedral co-ordination alone is however not sufficient to determine the structure completely. The forms are: cristobalite, tridymite and quartz. *Ice is isomorphous with tridymite.*

It seems likely that when ice melts the water molecules tend to join together, as ice in a *tridymite-like pseudo crystalline structure,* which is less dense, and that with rise in temperature the tridymite-like pseudo-structure tends to transform itself into a *quartz-like pseudo-structure,* which is denser.

The maximum of density at 4°C would thus be easily explained theoretically. Bernal and Fowler acknowledge three types of structure, corresponding to three types of water.

*Water I:* Ice and tridymite-like, light, viscous;
*Water II:* Quartz-like, heavy, semi-viscous;
*Water III:* Liquid ammonia-like, light, non viscous.

"The nature of the water is determined by different geometrical arrangements of the same molecules in small regions of the liquid, due to a different amount of molecular movement, imposed by the temperature. In each small region the arrangement is *pseudo-crystalline.* These regions have an appreciable electric moment, and are needed to account for the large dielectric constant of water which is practically identical with that of crystalline ice for low frequences."

These arguments were used quantitavely *to calculate the internal energy of ice and water from the water molecule model derived from spectra and dipole moment* ". . . It is possible to go further on the basis of the theory to find the real nature of the hydrogen ion in solution and provide a theory for the *abnormal mobilities of the hydrogen and hydroxil ions.*"

These are characteristic problems of water.

Thus Bernal and Fowler successfully confronted the most central problem of water.

It serves no purpose to probe deeply into the work of Bernal and Fowler, the two pioneers of the modern theory of the structure of water. A great deal has changed since then.

The revolutionary idea of the two authors was met by a lively reaction. The supporters of the theory which held that water had to be considered as a *mixture of aggregates,* according to traditional ideas, attacked the concepts of Bernal and Fowler. New ideas cannot be perfect at their birth and attacks are inevitable, both for their imperfections and for the uneasiness provoked by their appearance.

Eucken found that the properties of water can be satisfactorily explained by supposing that around a temperature of 0° there exist, in roughly equal quantities: simple, dimer, tetramer and octomer molecules.

The *octomers* occupy a large volume and for this reason behave like *ice molecules (Eisartig)* and to a certain degree substitute Bernal and Fowler's tridymitic structure. Eucken supposes that the hydrogen bonds are the forces which bind the $H_2O$ water molecules in larger aggregates.

Gierer and Virtz found, however, that two conceptions, that of Eucken and that of Bernal and Fowler, although they differed, were capable of a certain mutual relationship. Eucken's mixture of aggregates may be interpreted as a quantitative representation of the equilibria among three forms of arrangement whose coexistence in a quasi-crystalline liquid reticule constitutes the starting point of Bernal and Fowler's theory. Gierer and Virtz considered the number of hydrogen bonds that the various molecular species were able to produce, and on this basis and on the basis of the effect of temperature on the rupture of hydrogen bonds, they sought to explain the properties of water.

The struggle between the *mixture of aggregates* exponents and the *pseudo-crystalline structure* exponents was even carried to certain bands of the Raman spectrum. There exist bands in the Raman liquid water spectrum which were interpreted as being intermolecular that is, due to molecules which are bound together. The bands in question disappear with the rise in temperature, as previously observed by Magat. Rao has consistently argued in favour of the classical concept: these bands had to be attributed to the $H_2O$ molecules $(H_2O)_2$ and $(H_2O)_3$. Rao's immense authority on the subject of the Raman spectrum made itself felt. But it was later observed that the difference between the classical conception and Bernal and Fowler's theory, was more illusory than real.

In 1939, Hibben summed up the situation in the following manner:

"Rao has consistently ascribed the variation in the bands adjacent to $\Delta\nu$ 3400 as due to a change in the proportion in which the water polymers, i.e., $H_2O$, $(H_2O)_2$, $(H_2O)_3$, are present and he has ascribed to the frequency near $\Delta\nu$ 3600 the unpolymerised water. Bernal and Fowler have proposed a quasi-crystalline arrangement for water having respectively a tridymite, quartz and close-packed ideal structure as a function of increasing temperature. The difference between these concepts is more illusory than real. The essential fact is that there is a profound influence on the Raman spectrum of water as changes in the constitution of water take place . . .

". . . Rao has argued in favour of the classical concept of water and has pointed out the variation in intensity of the water bands with temperature. This concept appears to be somewhat too well defined. On the other hand it is often too easy to explain departures from the normal on the basis of hydrogen bonding or resonance. These explanations may err in the opposite extreme.

Neither concept is in contradiction to the experimental observations upon which ultimately any explication must be founded. In any case the formula $H_2O$ given water or ice is undoubtedly incorrect. Other factors, which are due to intermolecular interaction and influence both the physical and chemical properties of water intervene. Evidence as to the nature of these factors and their magnitude obtained from Raman spectra illustrates an important application of this method of attack on the structure of liquids."

Here we see that the shift from opposition to the ideas of Bernal and Fowler to a reconciliation of the opposing theses has already been accomplished.

Pople brilliantly modified Bernal and Fowler's theory, overcoming the difficulties which it had encountered. Pople's theory is based on results of the study of molecular orbitals. The external electrons of the water molecule occupy four tetrahedrally-directed orbits, two of which are associated with O-H bonds, the remaining two with lone pairs of electrons. Each molecule then tends to *form four hydrogen bonds in tetrahedral directions.*

This concept of Pople's, so very new, met with great success.

Hydrogen bonds can stretch or bend without breaking, absorbing great amounts of energy and enthropy. Water differs from ice in that the hydrogen bonds of water *can bend independently instead of cooperatively*. The necessity of an over-extensive bond-breaking to explain the high heat capacity of water is thus eliminated.

Lennard-Jones and Pople hold that in water there exists a *network of bonds extending throughout the entire liquid which is, in a sense, one large molecule.*

The theory permits us to explain the properties of water determined by the various experimental techniques, both by x-rays, calorimetry and by electric conductivity.

On the basis of the Pople theory, Harris and Alder calculated the dielectric constant of water at various temperatures. The values determined by these calculations were *identical* to the experimental values. This striking success determined the fate of the new concept, which had by this time definitely won the day.

A quasi-crystalline structure implies the existence of a *quasi-Curie point,* observable either directly in first degree transformations or in those of the second or third. Magat, as I have mentioned, had listed those properties which reveal anomalies between 30 and 40° C. Certain of those anomalies are not strictly probatory, but at least two of them doubtless are: the specific heat minimum of water at 35° C and the behavior of viscosity at high pressure. With the old experiments of Bridgman, which I referred to in the first part of this chapter, the crushing of the tridymitic structure at a temperature below 30°C may be directly observed. The crushing is no longer observable above this temperature.

For this reason it is held that the *structure* of *water* melts at 35°C.

Thus *there exists in water below 35°C a tridimensional self-perpetuating structure.*

Now that our ideas have changed so greatly from those of times past, how are we to look upon the phenomenon of dissolution and how are we to deal with the problem of the solutions?

Frank, Frank and Evans studied the problem from a thermodynamic standpoint, which is the most general one, on the basis of new criteria. When a non-polar gas is released in a non-polar liquid, there is a diminution of enthropy. When a non-polar gas is released in water, the diminution of enthropy is more than double. The loss of enthropy in the first instance diminishes but little with the rise in temperature, while the loss of enthropy in the second instance diminishes rapidly with the variation in temperature. In other words, the enthropy that the dissolution of the non-polar substance *in a non-polar liquid* had caused to diminish slightly, increases slightly with the rise in temperature; but the enthropy that the dissolution of the non-polar substance *in water* had caused to diminish greatly, increases rapidly with the rise in temperature.

Since the diminution of enthropy is related to the establishment of a highly-ordered state, it must be concluded that the dissolution of a non-polar substance in water creates a greater order than in a non-polar solvent. The order has been conceived as the geometrically well-defined *fixation of the water molecules around the non-polar molecule of the solute.* Thus we have the formation of *ice particles,* or icebergs as they are now called. The rise in temperature brings about the fusion of the icebergs and thence a more rapid increase in the disarrangement and, thus, of enthropy.

This point of view is completely new, but it must be regarded as being dependable since it is in perfect harmony with the principles of thermodynamics.

The case of the dissolution of a substance which generates ions is presented in a highly complex manner. Even in the case of the interactions between ions and water the formation of the icebergs is taken into account; but here we must remember many other factors, such as the polarization of the molecules due to the electric fields of ions, the variation of the entire dielectric constant that goes with variation in concentration, and the variation of the microscopic dielectric constant that goes with the variation in the distance from an ion. New problems rise, and a new field is opened to study the solutions.

Molecules and ions, at least when they are in sufficient concentration, break down the structure of water to generate ice-like structural entities: icebergs. Since the high value of the thermic capacity of water is due to its structure, the breakdown of the structure, either by heating or by introduction of a soluble substance without heating produces a diminution of its thermic capacity.

The manner in which the various ions create their own icebergs and bind them in relation to the remainder of the water which does not adhere to them, is extremely interesting. But this is a special chapter, now under study.

This brief and summary review of the evolution of ideas on the structure of water was indispensable in order to demonstrate how the most common of liquids, the giver of life, is the most complex and has the richest properties of all liquids known. Water is an exceptional substance. Its visible and ascertainable properties have occupied the efforts of scholars for years; but these, as I said, do not complete our knowledge of water. There is much more. And it is upon this *much more* that, with all probability, the phenomena which interest us work.

Even aqueous systems must possess, at least within certain limits, similar possibilities of change and adaptation.

The existence of a structure so delicate and sensitive permits the assumption that appropriate actions are capable of modifying the structure itself in an infinite number of ways, and thus we may assume that water is sensitive to extremely delicate influences and is capable of adapting itself to the most varying circumstances to a degree attained by no other liquid. It may be that it is this infinity of possibilities that makes the existence of life possible.

*Perhaps it is even by means of water and the aqueous system that external forces are able to react on living organisms.*

It is opportune, at this point, to note how recently it was shown that water presents beyond the absorption bands in the far red and infra-red already known, absorption bands in the field of very low frequencies (VLF).

Freymann found in fact that *water in the solid state (ice)*, the *hydratation water* and the *water chemically absorbed by solids* presents wide absorption bands at the frequencies of 10kHz, that is for electromagnetic waves of 30 km length.

That demonstrates that electromagnetic fields of low frequency and therefore of very little energy are capable of acting upon water. That is extremely important from our point of view. Unfortunately the spectroscopy of VLF is still left to be done. An immense lacuna is before us and makes it difficult to follow our work.

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