Water, the Mutable Form of Life

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By

Marcello Nicoletti

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Nature loves to hide

Eraclithus of Ephesos IV century b.C.

CONTENTS

INTRODUCTION

In the last century, innovative points of view on the interpretation of reality were depicted by Physics, well supported by Mathematics. Consolidated dogma, based on determinism and total confidence in the power of numbers, were demolished from the foundations by concepts based on probability and indeterminacy. The duality of reality was considered as inherent. The new approaches were destined to involve inexorably all Sciences, including Chemistry and Biology, with multiple interpretations as a living system works. Nowadays, questions can be more important than answers, but it is difficult to accept the complexity in a world asking for simplifications reduced to knowledge pills.

In this introduction, besides presenting the main arguments, the reader is asked to consider the architecture of this book, which is based on different levels of complexity. The same argument returns, asking for a higher effort of comprehension, obtained by the complete and organic use of previous information. Therefore, it could be necessary to read the same sentence another time, avoiding the usual current tendency to reduce the information to a few simplified essential words. Nowadays, the scientific information is reduced to indisputable declarations, often born by a personal interpretation of the author. In this case, the reader is asked to do additional work, besides just assuming the superficial content of the sentence. The first level reports how things are, or are considered to be. The second level is why things are in such a way. The third level contains the hypothesis that things could be in another way. The tentative goal is to explain the reality as clearly as possible, using the current scientific knowledge, also considering the possibility that the initial information could be wrong or partial, and finally report why this information is important in ordinary life.

Water is an ideal argument, in consideration of its importance for life, its continuous input of scientific knowledge, its multiple forms and the possibilities to influence our wellness. Water can be easily connected to many important arguments, including important decisions usually superficially taken. Water was selected as the main argument of this book for its biological relevance, but also as a selected square, like an agora, where exercises confront different points of view, and finally obtain

information useful for our health. The contradictory aspects of water are the central item of this book. Water is an inorganic compound, but we are mainly made of water and it is possible to demonstrate a total connection with organic metabolites, making possible their activity. Water is considered a homogeneous substance, but its intimate structure tells us the contrary. Water is the most known chemical structure, but its isotopic structures are neglected, though they merit consideration for their biologic properties. The different forms of water support the multiple shapes of life.

CHAPTER 1

WATER AND LIFE

No water, no life

Everybody knows that there is an intimate relation between water and life, which can be synthesized in the sentence “no water, no life”. On the basis of this paradigm, many people follow with great interest the exploration on Mars by NASA to find water and therefore support the hypothesis of Martian living organisms. However, few are aware that these are confusing simplifications. Finding water does not mean life, albeit it can be considered a pre-requisite. Ganymede, a satellite of Jupiter, has plenty of water, but without any condition to support life. Not any kind of water is useful to support life and this is in particular evident in case of human survival. It is necessary to consider that there are different kinds of water and those that are necessary to maintain our health are very rare.

Explain the concept of water as a biological agent is the aim of this written contribution. This argument is supported by the most recent investigations about the physical and energetic nature of the molecule of water. The hope is that the conscious utilization of water will be increasingly based on scientific evidence. The dogma is that only adequate water is essential to any living metabolism. On the other side, different organisms are shaped by the water available in their environments. Since from the beginning, consisting in that ancestral first movement of organic substances in a special drop of water, the complex organization of matter, in what we use to call life, evidenced the mark of the aqueous solutions. From that precise moment, when the multiple forms of water were based on the fundamental dichotomy between outer and inner water, the ancestral cellular mark is present in any living organism.

Fig. 1.1. *"Alice opened the door and found that it led into a small passage, not much larger than a rat-hole.*"

What is reality? Nothing is as it seems. This is the key to enter the water nanoworld (Fig. 1.1). Looking at a glass of water, did you ever think of what is going on inside? The water could be salty or nasty, and you will never know until the test. It could be acid or basic and the sensorial level could be not sufficient to detect the quantity of active hydrogens.

What about the deep molecular level? Liquid water seems to us very compact and homogeneous, and nothing reveals the inner untiring confusion, due to the continuous movement of its molecules. It is the difference between the conformable and predictable macroworld, as perceived by our senses, and the nanoworld, where molecules play their tireless dance under the tunes of the solute and act in accordance with the quantum mechanisms. To visualize the nanoworld, we can assume that the number of water molecules in a glass of water is much higher than the estimated number of stars in the universe. Each molecule is equal and different. Like the stars in the sky, which seem to be similar as points of light, but now we know that most of the stars are not visible and totally deprived of any light. Everything looks more reliable and well-founded when you change the perspective.

Quantum theory tells us that, with such numbers the macroresult is the statistical homogeneity to which we are accustomed, but each molecule of water maintains its individuality and in a certain range is different from the other molecules. This is because of continuous movements and a different affinity between water sister molecules and solutes, forming ephemeral associations, named clusters. Nanotechnology works on these differences obtaining results so far unexpected, influencing the behaviour of part of the molecules or inducing reactions on selected targets. Nowadays, the real applications are mainly hypothetic, but the expectations are enormous. Meanwhile, other aspects of water nature can be interpreted and consequences deduced.

The consequence is that we should consider not water as the molecule written in the books, but evaluate the presence of different types of water, depending on the environment. The molecules of each water type are different in many aspects, like form, conformational state and the quantity of inner energy, meaning interaction with other molecules. All these factors influence the reactivity of the molecules of water inside a biological system and they result in the metabolism of the organism. Typical manifestations of life include the functional activity, adaptations and capacity to react to environmental challenges. These aspects must be carefully considered in case of water, including that the pure water does not exist. On the other side, there is the macroscopic water, which is the common partner of so many moments of our life, when we are confident on the thirst signals or see the signs of dehydration. Is it sufficient to drink a sufficient quantity of water to maintain our health in the best condition? Can we totally ignore the water intimate organization, and simply trust on everyday experience?

It is now time to reconsider the fundamental link between water and life, avoiding any utilitarian and obvious meaning. There are several reasons to reconsider the significance of water for any form of life and evaluate the impact of new scientific information about the intimate structure of water. We end up finding arguments about water in many writings, but it is not always considered a matter of real interest. We are usually concentrated on the consequences of the endless macroscopic forms of water, i.e. a drop of rain and a crystal of snow, or the quiet surface of a lake and the confusion of a glowing waterfall, or a tear rolling down cheek and the relief of drinking. Also in scientific literature, water does not find its proper place, and it is usually treated as an obvious solvent, while all the attention is focused on the solute. Let's try to propose some useful arguments that assign to water its dutiful role, not only as a determining factor for the survival in all habitats of our planet, but exploring mechanisms beside its presence.

Every part of the book is entirely dedicated to the importance of water almost seriously, in case someone not convinced or distracted could be induced to say: "Well, after all, it's just about water". Water, as an inorganic, transparent, tasteless, odorless, nearly colorless fluid, is not the only possible definition. We are going to assign the role of living form. To obtain this aim, we must consider the change of water in its intimate molecular state, when it is in deep connection with other elements in its nanoworld environment. Water as a never alone complex dynamic system of molecules. The influence of other molecules around and inside the water system generates a continuous state, called solution.

Life needs a complex and rapid chemistry, called biochemistry, influencing the cell working and finally allowing the organic life. This acceleration and possibility to perform an enormous quantity of reaction in a minimum time is possible only in an aqueous solution. In the inorganic systems, like mountains or rocks, the reactions are possible, but more limited, casual and slow. When water takes the central place and dominates, the inorganic and organic substances can react as part of the same system and play together with the co-occurrence of water molecules, in the continuum known as metabolism.

Most of the argumentations of this book will be dedicated to the reversal of common paradigms. Let's start by eliminating some clichés on the fundamental and general information about the molecule of water. It is often described as an extraordinary molecule. However, there is nothing in water that does not perfectly agree with what is present in the Periodic Table and logically derives from a chemical point of view, once the two constituent elements, i.e. hydrogen and oxygen, are combined in the right way. It is also evident that, in the condition of our environment, H and O become special elements. The surface of our planet is made up of free oxygen, which is practically absent in the atmospheres of the other planets, whereas free hydrogen is totally absent, although it is by far the most common element in the universe. The reason is that these elements react very easily together and the difference in electronegativity is a source of a special chemistry, mainly based on unusual interactions. We are going to find that the traditional formula H_2O is not the only way to express the water elemental molecular constitution and why the other isotopic formulas, usually totally ignored, are very important for our homeostasis. The consequence is that it is more correct to refer to waters, than to water.

Water must be considered the ideal solvent that allows the solutes to operate in conditions suitable for life. This sentence ends up being a misleading

view of the reactions that take place in solution, going so far as to separate what should be considered as unitary. The water itself plays a fundamental role, on both sides, i.e. the network of water molecules and the interface with solutes. In the aqueous metabolic solution of the cellular system, solvent and solute are present and identifiable only at the starting point, i.e. before the mixing process. The idea of a continuum, including matter and energy, explains the interconnected roles of solute and solvent. This is possible thanks to the quantity of intra and extramolecular H bonds that the water molecules, acting as a system, are able to perform.

The final consideration is that water calls us to reconsider the fundamental difference between inorganic and organic matter. Everything living depends on the continuous transformation of water reacting with carbon, a peculiar capacity of the green creatures.

The relation between life and water

The origin of life is marked by the organization of organic substances from and in water, to first obtain the necessary separation from the environment and avoid the dilution effects. Born in an extremely diluted world, the metabolism was able to find in the cell the compromise to obtain an inner water with the organic chemistry alternative to the outside mother water, still inorganic. The collection of selected matter in an anomalous aqueous solution is the material evidence of an exceptional accumulation of negative entropy, necessary to fuel the living organic engine. This is possible only with the presence of water, with a dual role of stability and turnover of the negative entropy, allowing continuous exchanges with the habitat. In case of death, thanks to the water, the negative entropy, before encapsulated in the organic matter, rapidly returns to the environment and allows the energy turnover.

As far we know, life is the result of a series of special situations, wherein water plays a special role On our planet, the presence of water is taken for granted, but this is an exception when one considers the water presence on other planets. Its influence on the evolution of more complex living forms are often limited, resulting in only those pertaining to the relation between environment and morphology. The partial release from mother water is a fundamental step of the recent evolutionary pathways. In our planet, water can be present in three different physical states, often co-occurring in the habitat. This is very important for metabolic chemical reaction and acts as a stressor for the evolution of living organisms.

Water must be assumed as the necessary and irreplaceable bridge between living and the non-living systems. The transformation of inorganic matter in organic living substances is the key step. It always has been. From the beginning, in that unique episode, when, inside a tiny drop of the primordial ocean, something began to pulse producing extraordinary molecules never seen before. From that diluted and dispersed world rising from the primordial soup, the modified water began to concentrate the organic matter and change the environmental molecules. For this reason, living beings can be considered an advanced and complex expression of an aqueous solution, essentially like a form of modified water, based on a series of momentary dynamic equilibria. That primordial step at the sunrise of life opened the doors of a mechanism simply repeated with few changes.

Nothing is impossible and everything is possible in the molecular continuum of biochemical systems. It is interesting that the same process, in photosynthesis, is still working inside the plant cells, as producing the necessary molecules to fuel all the living machines, which are mainly constituted by water inside organic substances, like in carbohydrates as evident in their general formula $C_n(H_2O)_n$.

The correlation between the properties and structural condition of water and that of organic matter does not always appear clear. The risk is to fall once again into the forced sharp separation between the inorganic and organic worlds, which loses its meaning when inorganic substances become part of a living organism. This is possible in the nanoworld, where only molecules dominate and everything is different from our usual environment. In the nanoworld, the same laws of thermodynamics and chemistry continue to apply, but the relationships and interactions between molecules find a different dimension in the ultramicroscopic scale, one hundred million times lower than the dimension of our world. The chemistry of the nanoworld of living beings is intimately different from the domesticated one of the test tube, in which we have confined molecular chemistry, in order to be able to observe and dominate materials in their limited expression named Organic Chemistry.

The living nanoworlds

The mechanism of the molecular continuum of living substances is made possible by the omnipresence of water. Water influences in particular the thermodynamic equilibria, as well the device of the interaction enzyme/ substrate. Without water, even the most powerful and wonderful of the

living creatures is reduced to a miserable pile of ash. Thus, the negative entropy rapidly returns to the environment, from which it had been laboriously but temporarily removed.

The chemistry of the molecule of water, so small and simple, is the key to everything. Beside the multiple and co-occurring physical states, depending on the solution environment, the same molecule of inert liquid water can change in two active forms with opposite reactivity, acid or alkaline, or alter its form using all its conformational states, or associate in infinite ways with its sisters, or be responsible of the destiny of the solute breaking and forming bonds, or allow the transport of matter, or envelope the metabolites into a protective cloud, or drive and be transferred, raise and lower energy. The duality of the molecule of water is the evidence of something hybrid, that must be located into an in-between, which is difficult to realize with ordinary approaches, based on the precarious coexistence of opposite sides. Although it is very difficult to realize in our ordinary way of thinking, the in-between is the real intimate condition of the water molecule. Like the Cheshire cat in Alice in Wonderland, the intimate form of water appears and disappears (Fig. 1.2).

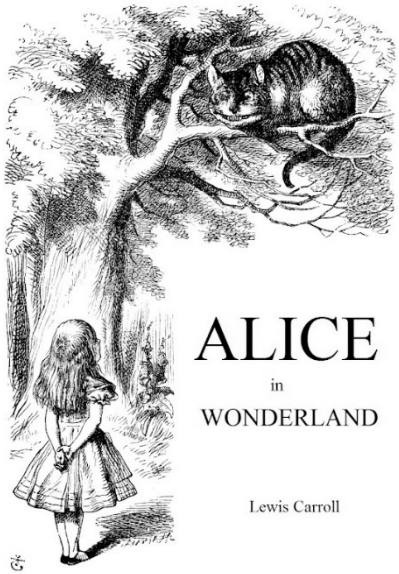

Fig. 1.2. "*What road should I take? Where do you want to go? I don't know. Then, it doesn't matter"*

For us, who have been always accustomed to gigantism and trained to take into account what is perceived and filtered by the senses, the living nanoworld is something very difficult to accept and interpret, even to imagine. For most ordinary people, the quantic lesson is a mess and in practice a method to complicate everything. The difficulty is about the possibility to accept the different levels of reality and discover how our senses trick. It is the same old story. It was necessary a lot of the time to accept that the earth is not flat and the stars are not arranged as in the night sky. However, many people still believe in astrology and every day consult the horoscope.

We finally have a recent mass of data that can help us, like a key to allow our entrance. It is important to enter into the living nanoworld, because our health and that of the other living beings, which are necessary for our survival, depends on it. Nanotechnology is opening the way, showing the characteristics of the nanoworld, and how we can interfere with it. If you ask someone working in Nanotechnology about the future, you will find them very confident: "It is only a matter of time. As for microbes and galaxies, we can find the right tools to explore the nanoworld and everything will be easier. The race for the discovery of the new dimension is open. Be ready."

Meanwhile, there are important current challenges and the enthusiasm is not sufficient, like the consequences of the utilization of nanoparticles.

Clean and modified water

Apparently, water is abundant and available, but we need a very special kind of water, because it must be easily integrated and modified. Once again, general concern is focused on purity, meaning clean water, not considering several fundamental characters necessary to the useful water. On Earth, the blue planet where liquid water dominates the surface, thanks to its thousand variable shapes, this molecule, today as never before, is indispensable for any form of living being. Living organisms utilize modified water, derived from the adaptation of the environmental water. The water present in the environment, once inside the body, is modified and converted into living elements. During this process, the starting form of water is deeply changed and adapted to the metabolism needs, until the final step which consists of a solution reaching catabolic waste.

It is noteworthy that to maintain the current forms of the modified metabolic water only a minimum part of the available water is adequate. This gives

rise to a crucial emergency and the correct use of the available water scattered in the habitats becomes increasingly important and necessary. The quality of water is crucial for human beings, whose metabolism is adapted to utilize only ultraclean water. Nature and the utility of modified water must be deeply considered, but it needs a pathway of knowledge, including recent studies and discoveries, to obtain a novel point of view about the role of the dihydrogen monoxide.

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CHAPTER 2

THE CHEMISTRY OF WATER AND ITS NETWORK

A molecule of water is never alone

The first mandatory step consists in the examination of the chemo-physical properties of water, including the dynamic structure of the network resulting from molecules association. It is fundamental to enunciate the main properties of the molecule of water, part derived from the two consisting elements and part from their unity. This step is necessary to explore the system derived from the association of water molecules as variable complex units, consisting in dynamic clusters. Life is the result of molecular organizations. Elements joined to generate organic molecules, molecules associated in temporary clusters, selected clusters as components of reliable structures, specialized structures organized in organisms able to manipulate energy and matter by systems of related reactions. On the basis of the effects of solutes in the water continuum and the reciprocal interactions, it is possible to depict a picture of living systems as molecular dynamic unity, starting from the single molecule until the whole organism.

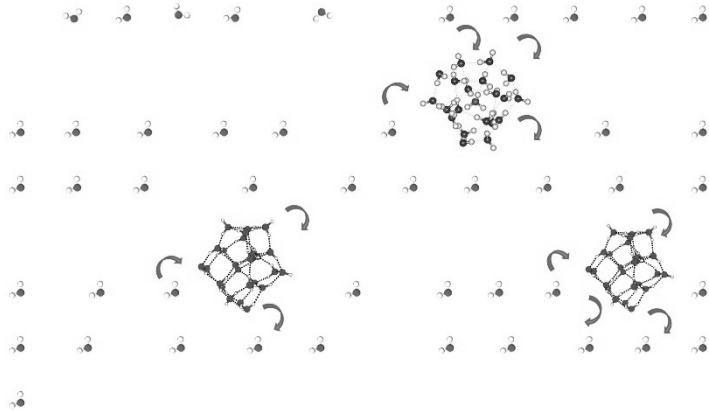

Fig. 2.1. The dynamic representation of the clusters in the water network.

A cluster is a dynamic temporary association of water molecules, with a geometric but variable form (Fig. 2.1). In the water network, part of the water molecules are free and part are organized in the clusters. Each molecule is free to enter and leave the cluster in accordance with its energetic state. The situation is considered as a continuous complex dynamical molecular system and it is common to many similar temporary associations of components, as well known in economics and in social studies.

The form of the water cluster is clearly ordinated and resembles a crystalline structure. The difference with the ice crystals is that the movements of the molecules in the ice crystal are very limited and do not allow exchange with outside water molecules.

The presence of a solute interferes with the water network, modifying but not cancelling the cluster structure and its network. It is important to notice that solute is incorporated inside the ordered structure of the cluster, which must be considered the active constituent of the water solution. This is the reason why the salts, like the sodium chloride, which are solid and very stable, when in contact with water dissolve totally and leave no visible trace of their presence. The same argument concerns many contaminants in apparently clear water, creating the problems we will see later.

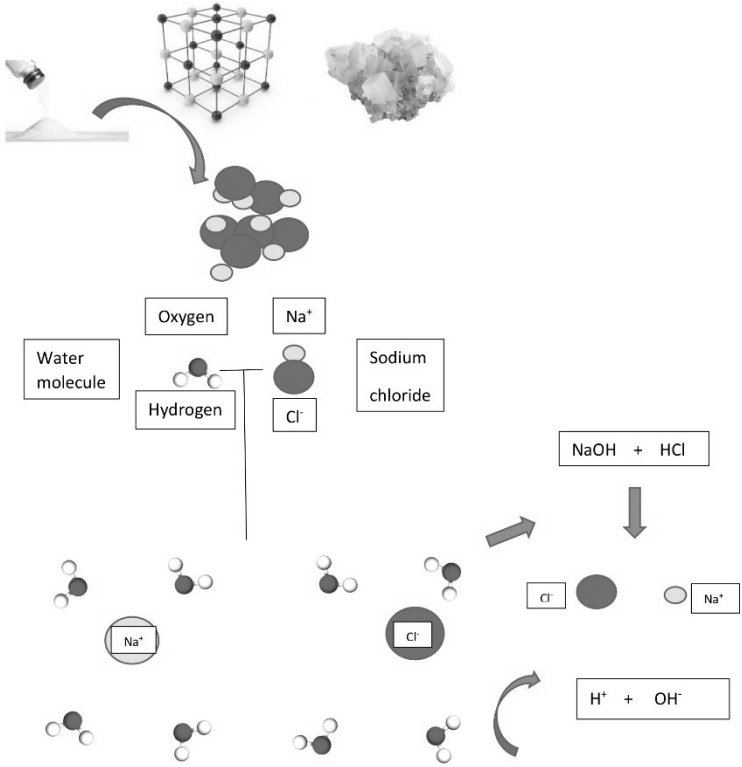

Fig. 2.2. The molecules of water are able to break the ionic bond of salts, which otherwise are very stable.

After breaking the ionic bonds of the salt, the molecules of water surround the ions, oriented in accordance with the charge. This process is the solution of the salt, wherein the water molecules remain intact. In a second step, there is the hydrolysis of water, where the formed ion reacts with water forming OH^- or H^+. The figure 2.2 evidences the complex mechanism with multiple equilibria.

For a long time, chemistry was considered a matter of reactions, where reaction is an event, wherein two molecules chock together and something happens. Reagents giving rise to products. Practically, a matter of breaking and forming bonds, as evidenced in the classic general formula: A + B → C

+ D. In this representation, there are several misleading simplifications. Another arrow in the opposite direction should be always present, as well known by everyone working in chemical synthesis and spending time in optimizing a reaction. The possibility that the reaction goes in the other direction must be always considered and every product can go further or back. This is the result of the energies involved in the reaction, meaning the difference between the starting and final energetic states and the reaction necessary to reach the transition state. In most of the organic reactions of cell biochemistry, all problems may be solved with the help of enzymes working in the aqueous solution.

So far, the considered bonds are strong bonds, meaning some electrons in common between two elements. Thus, the first act of the reaction is always destructive, and therefore it needs energy, usually a lot of energy, to start. In a sequence of reactions, products are obtained using the ashes of products. This is the reason why the reality among us does not change rapidly and we can trust that all the objects collected in our house will stay unchanged for all our lives. With one exception, the living ones. The molecular turnover in the living organisms is different and it is mainly based on a special kind of chemistry. The key feature is the equilibrium between necessary changes and the maintenance of the structural stability. It is easy to verify that the presence of water is fundamental in the stability of matter around us, as well in the turnover.

There are other types of chemical bonds and they are called weak bonds, whose energy is much lower. The living chemistry is mainly based on bonds of low energy. In these bonds, the communion of electrons is absent, and the molecules interact by electrostatic forces, meaning negative charge attracts positive charge, or the contrary. It is sufficient a partial little inequality of the distribution of the charges on the surface of the molecule to trigger these kinds of bonds. In this case, the involved energy is low and these bonds can be easily formed and broken, leaving the basic structure of the molecules untouched, but influencing the reactivity and the form. The influence of these weak bonds is momentary, partial, limited, but very important in the organization of the molecules in the aqueous solution. They can influence the form of the molecules, when intramolecular and intermolecular, or play a role in the interaction with the environment, when extramolecular. The result is the formation of molecular ultrastructures. The organic molecule, thanks to the help of water, can change, move, adapt, follow and participate, in accordance with their sisters and other participants in the solution. All these situations, where strong and low energy bonds are

acting together, are very important to understand the role of water in the metabolisms of living organisms.

The difference is that in classic chemistry, based on reagents and products, the involved molecules are alone, whereas in ultrastructural chemistry the molecules are part of a system and their reactivity is the result of an environmental process. To explain the process, let us imagine an opera, where the tenor is playing an important Aria and the same actor singing together with the chorus and in accordance with the music of the orchestra.

Not only the living habitat is mainly determined by the prevalent presence of water, but any environment. The first condition necessary to determine the key role of water is its availability, which is not easy to obtain. Many chemical-physical characteristics of water determine its importance from a biological point of view. As far as we know, they are possible on our planet and not possible in other celestial bodies. Due to its size, water should be a gas (such as, for example, carbon dioxide and methane), especially as it derives from the reaction between two gaseous elements.

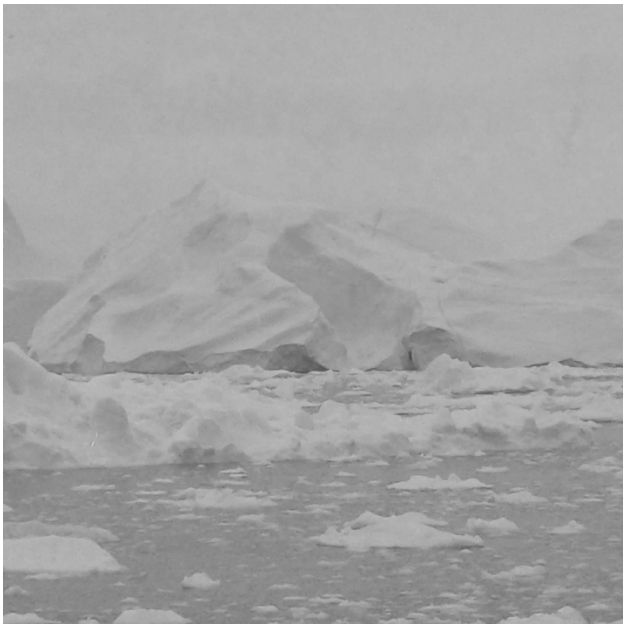

Fig. 2.3. The coexistence of the three physical states of water is a typical situation of our planet.

Instead, in most of the planet water can be found simultaneously in the three physical states, i.e. either gaseous, liquid or solid (Fig. 2.3). This is possible by the position of our planet and its characteristics. Something very special, given what happens on the two nearest planets, Mars and Venus, and the other bodies in the solar system. All three states have been and remain important for the presence of life on Earth and the evolution of living organisms. Again, the different forms of water are the key for understanding its linkage with Life. Among the three states of water the liquid one is the most favorable for life.

The chemistry of liquid water

The structural formula of the water molecule is perhaps the best known in Chemistry, if only for its simplicity, composed by two atoms of hydrogen and one of oxygen.

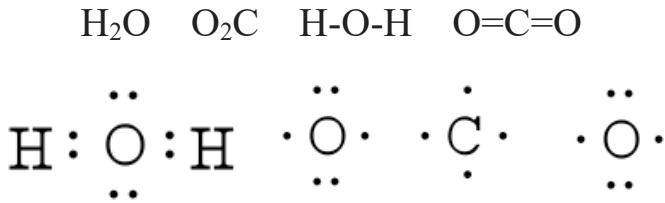

Fig. 2.4. A comparison between the formulas of water and carbon dioxide, evidencing the electrons of the most external level.

There is an apparent similarity between the chemical formulas of water and carbon dioxide. When the molecules are considered in the real tridimensional state, the formulas are completely different (Fig. 2.4). These two formulas represent the molecular basis of the starting step of the synthesis of organic molecules, as reagents of the photosynthetic process. There is a strange similarity, but this is due to our habit of representing things in a simplifying way. In reality, this geometric representation of water molecule as shown here is wrong. It yields from the temptation to put things in line, and therefore order them in the easiest way.

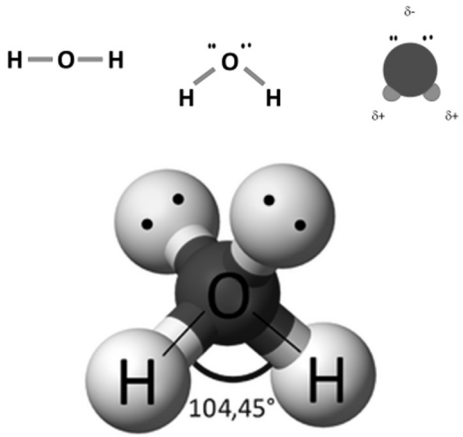

Fig. 2.5. The real spatial configuration of a molecule of water is derived from the hybridization of the electronic entities.

In fact, following the difference in electronegativity, the two partial positive charges located on the two hydrogens will tend to move away as much as possible, arranging themselves to the opposite sides of the oxygen (Fig. 2.5). This generates a linear structure, similar to that of the carbon dioxide. However, if all the electrons reported in the previous structures are now considered, we must also add the two additional lone pairs of the oxygen, and consider the space occupied by them. Then, after the hybridity of all these electronic entities, the structure of the water molecule becomes tetrahedral, and it is more difficult to be written on a paper sheet. This 3D geometry implies a series of consequences, such as the formation of a dipole and the generation of hydrogen bonds between water molecules. The covalent bond between the two elements is in favor of the O, generating a dipole. Considering the difference in electronegativity between H and O, one part of the molecule, where the oxygen is prevalent, is negatively charged, and the opposite where the H are prevalent, meaning a partial positive charge.

This passage merits further argumentation. The aim of Exact Sciences is the representation of reality through a particular and adequate language made by numbers and symbols. Arithmetic uses numbers and the symbols of few fundamental operations. Mathematics applies to numbers and a series of complicated symbols. Algebra uses angles and lines. Chemistry is based on letters, numbers and lines, meaning the elements, their numbers and bonds,

respectively. Generally, the representation of the structure of a molecule is confined in a design quite simple, but difficult to understand if you do not know the interpretation of the chemical language. Usually, the design is written on paper and therefore two dimensional. This simplification is often useful, but also misunderstood. Most molecules, certainly the organic ones, are organized in space, that means a 3D representation. In the case of a molecule of water, when we consider its form, as a consequence of the hybridization of the elements of symmetry, we obtain a tetrahedral form, which is common to other molecules also important for life, like ammonia and methane (Fig. 2.6). However, in methane the distribution of charges is homogeneous, whereas water is a dipole, with negative electronic density in the part dominated by the O and the positive in the opposite site where the hydrogens are present.

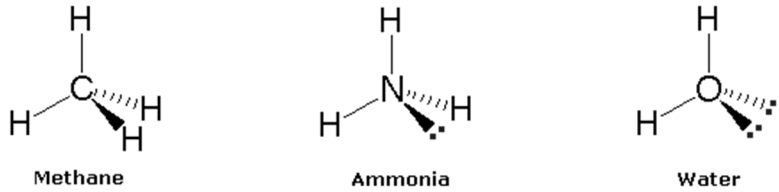

Fig. 2.6. The 3D formula of water is similar to the formulas of methane and ammonia, but different in the distribution of electronic charges.

2.3 The active forms of water

The revision of the simplified formula of water has other important consequences. Beside the typical molecular formula of water, the famous H_2O, at least two other formulas always present in a water solution. A minimal part of the water is still water, but in different forms. It is present in an apparently negligible percentage, an insignificant 0.0000001%, which accounts for

less than a millionth of the whole. This alternative water is present as H^+ (or rather H_3O^+) and OH^-, and generated by an internal reaction between water molecules, called ionic dissociation. Two water molecules, that have no ionic charge, give rise to two ions of opposite charge, which must resist the temptation to get back together in the reverse reaction. Also in this case, there is a dynamic continuous exchange, although the total percentages remain stable and equalized. In fact, even if subjected to the law of dynamic equilibrium, although the minimum quantity of water molecules is in

percentage exactly constant, the molecules involved are not always the same. This is the first clue of how the macro and microstructure of water are profoundly discordant, that is, our perceived appearance of water hides profound secrets, which we have only recently managed to understand.

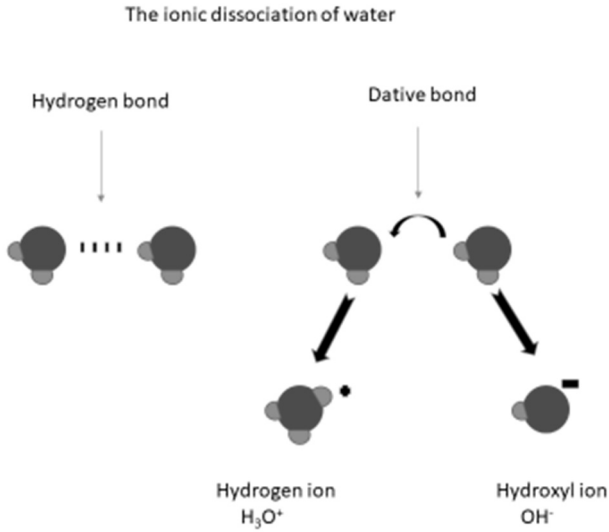

Fig. 2.7. The ionic dissociation of water, wherein two molecules of water react and give rise to two ions, the hydrogen ion (H^+) and the hydroxyl ion (OH^-), with opposite charges. The two ionic forms of water are the reactive part of water.

Among the consequences linked to the dissociation of water (Fig. 2.7), it must be considered that most of the water, understood as H_2O, is practically inert from the point of view of chemical reactivity, but it works very well as a solvent for hydrophilic substances, and force the hydrophobic ones to join together. The active water is the ionized part that determines many of the reactions inside an aqueous solution. If the hydrogen ions (H^+) prevail, the water, or an aqueous solution, is acidic. If the hydroxyl ions (OH^-) prevail, it will be basic. In other words, two opposite forms of water and two ways of the water to be reactive. In pure water, due to the hydrolysis reaction, the two quantities of hydrogen ions and hydroxyl ions are equivalent, but the nature of the solute is able to shift this balance. In fact, it does not take much to change the pH of an aqueous solution, so neutral water actually does not exist, unless specifically buffered.

However, if you ask someone about the pH of water, the usual concern is that water is neutral, but this is not true. Pure distilled water has a hypothetical pH 7.0, but the pH of pure rain (in equilibrium with atmospheric CO_2) is 6.2, whereas seawater is 8.0 and baking soda ($NaHCO_3$) solution has 8.1. These values can greatly change for environmental waters, as evidenced in Table 1.

Table 1. pH values and range of several environmental waters.

Water	pH range	Main
Rain	4-8	5.5 6.5
Soil water	3-10	5-7
Groundwater	5-9	6-6.5
Mine water	2-9	6.5-8.5
Rivers, lakes	4-10	6.5
Sediments (rivers and lakes)	4-9	6-7
Marine sediments	5-10	6-8.9
Seawater	6-10	8.1
Swamps, bogs	3-8	6.5-7.5

As evident in Table 2, the ranges are quite large and this is confirmed by the phenomenon of the acid rain. Although there are medium and common pH values for each type of water, the lesson is that any agent, material or energetic, is able to change the sensible equilibrium of the water solution. As a confirmation, the pH and mineral contents of spring and bottled mineral waters present a wide range.

Athmospheric $CO_2 <> CO_2 + H_2O <> H_2CO_3 <> H^+ + HCO_3^- <> H^+ + CO_3^{2-}$

Carbonated water value is around pH 6, because the carbon dioxide present in the air dissolves in the water, forming carbonic acid, which, producing 2 H^+ for each molecule, acidifies the aqueous solution, even if only slightly. However, this is also subjected to a slight equilibrium. As we see in carbonated water, a minimal input of energy, such as agitation, is enough to modify the saturation balance and generate the bubbles of CO_2, that leave the mother solution, changing the balance again. There are many arguments regarding the negative consequences of drinking sparkling water, instead of so-called natural water. Almost all of the depicted negative effects are so far devoid of scientific verification and there are opposite reports about the consequences.