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New Teaching Tools for a Modern 3D Representation of Some Molecules Involved in the Course of Food Sciences

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***Abstract* – In the Italian IPSSEOAs, the course of Food Science is a fundamental branch of study through which students start to see food as a mixture of substances, that all living organisms use to carry out their metabolism, characte--rized not only by a chemical composition but also by a specific chemical structure that make them suitable to be used as food. Despite the formulation of Schrodinger's equations, based on Bohr's Complementarity Principle and Heisenberg's Uncertainty Principle, dating back to 1927, the most widespread coursebooks used by students referred to Bohr's Atomic Model that is unsuitabl to make it easly understandable by students the reasons why some nutritive principles have a specific form, a specific geometric structure. Furthermore, often these students still do not have suitable knowledge in mathematics and in analytical geometry to understand this new Orbital Atomic Model, but thanks to these new teaching tools presented in this paper this difficulty seems to be no more a problem. Geomagword S.A. is a Swiss Company producing a large number of toys for children pointed to stimulate their fantasy and their handling ability. One of these toys, GEOMAG™, is constituted by a series of steel spheres and a series of steel magnetic bars coated by coloured plastic materials, with which children, aged between 6-10 years, can build complicated buildings of fantasy, but that in this case they can use to simulate the position of *p* orbitals of second level of Mendeleev's table of elements such Boron, Carbonium, Nitrogen, Oxygen, Fluoride and Neon. Furthermore, by connecting these GEOMAG™ elements in an opportune way it is possible to simulate also the position of hybrid orbitals sp_3, sp_2 and *sp* hollowing the building of a tridimensional model of water molecule putting in evidence the bond's angles between the orbitals and giving the opportunity to the teacher to offer his considerations to his students. It is also possible, by comparing different structure referred as Boron Hydride (BH_3), Metane (CH_4), Ammonia (NH_3), Water (H_2O) and Hydrofluoric acid (HF), putting in evidence their different chemical properties.**

***Keywords* – Atom, Orbital, Water, GEOMAG™ .**

I. Introduction

The course of Food Science in the Italian Professional Institutes for the Services in Enogastronomy and Hotel Management (IPSSEOA) in one of the most important topics supplied to students.

In facts by means this matter, the students receive not only correct information, maybe also in a tidier way, about what they do and observe in the daily food handling, but also, through the study of foods chemical composition and their content of nutritive principles.

Furthermore, during the lesson the students receive information they need to transform foods at best to respo- -nd to wishes, to diet or to traditions of customers.

A great relevance is given, finally, to the study of all ways of food qualitative decay and of all techniques to preserve it, the hygiene maintenance and the salubrity assessment.

The knowledge, therefore, of the most modern and fundamental principles of chemistry becomes necessary not only for the centrality that this subject has in the field of the matter sciences, but also and above all to explain how our diet can influence the "functioning" or the "non-functioning" of the human body through the chemical and enzymatic reactions that represent its metabolism.

These fundamental principles of chemistry, furthermore, on base of understanding the action of toxic substances that we could find in food or that in food could have origin under several condition of production, storage or environmental exposition.

Unfortunately many Authors [1], [2], [3], conducted in their reflections in areas related to quantum mechanics, do not contribute to familiarize the concept of atomic orbital nor, even less, that one of molecular orbital that would help to make modern the learning of chemistry applied to foods.

The aim of this work is to highlight how the use of the GEOMAG™, a toy produced by the Swiss Company GEOMAGWORD S.A. and meant for children between the age of 6 and 10, is particularly suitable for the comprehension of the concept of the shape and the function of the molecules through the materialization of the basic concepts of chemistry like atom, molecule, chemical bond, bond distance, bond angle, bond energy.

Furthermore it is possible make friendly, with a little imagination effort and some forays into mathematics, also the representation of the orbitals in their fundamental configuration and in the sp_3, sp_2 and *sp* hybrid, even if we remain within the game and reserving the use of chemical modeling products and the studies in quantistic mechanics to other occasions that we hope not late in coming.

II. Materials and Methods

A. *Materials*

Fig. 1. The GEOMAG™'s bars.

The GEOMAG™, in their classical configuration, are made up of two types of elements: the metallic magnetic bars and the metallic spheres.

The bars, 27mm long, are constituted by two permanent magnets made in an neodymium alloy, connected by a

metal pin, in order to reduce weight, and covered by a layer of polypropylene of a different color (Figure 1).

The spheres, instead, having a diameter of 13mm and weight of 8, 3g (Figure 2), are made in a tin/ copper alloy of to reduce the quantity of Nickel that can be toxic for children.

Fig. 2. The GEOMAG™'s spheres.

Fig. 3. The GEOMAG™'s elements jointed bar-to-bar.

Thanks to the force of attraction, of about 4, 5 g/ mm2, between the magnetic ends of the bars with opposed polarity it is possible to connect them in a linear disposition (Figure 3) or, interposing a metal sphere between the two bars, it is possible to connect them with angles which are also different from a straight angle (Figure 4).

Fig. 4. The GEOMAG™'s elements jointed bar-to-sphere

In the GEOMAG™'s packages putted on the market there is an instruction booklet attached, where there are plans to build fantastic constructions having different complexity (Figure 5).

B. *Methods*

In an attempt to describe the molecular structure of the substances which make up the nutrients, the teaching tradition, unfortunately, still refers to the Bohr's atomic models (Figure 6) and it describes the chemical bond in terms of "octet rule" [4], [5], [6], [7], [8], [9], [10], [11], [12].

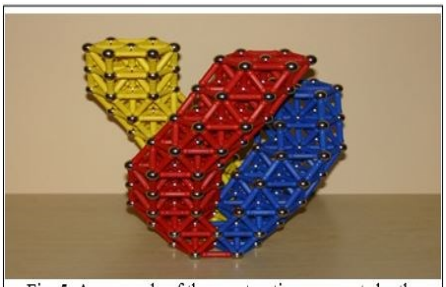

Fig. 5. An example of the constructions suggests by the producer.

Such references, although they have represented the scientific basis of crowds of students, can explain neither the real geometry of the molecules nor, least of all, the relationship which exists between molecular geometry and the substances reactivity.

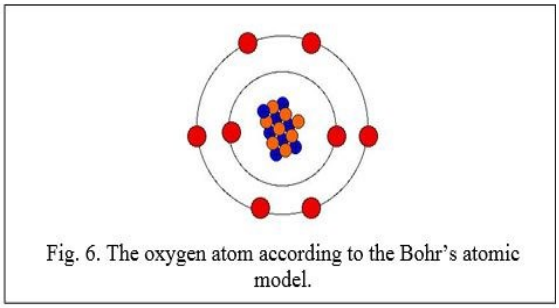

Fig. 6. The oxygen atom according to the Bohr's atomic model.

If we consider, for example, the water molecule with atoms corresponding to the Bohr model (Figure 7), we cannot imagine how it is possible to form an angle of 104, 45° between the oxygen bonds with the two hydrogen atoms, which is measured experimentally. (Figure 8).

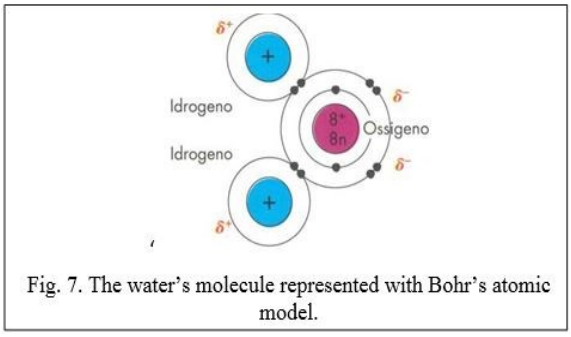

Fig. 7. The water's molecule represented with Bohr's atomic model.

Remarkable developments are obtained if we consider the orbital atomic model, which is undoubtedly more modern, which takes into account, according to the Heisenberg's Indetermination Principle, the impossibility and uselessness of determining at the same time the exact position and the kinetic characters of the electron motion around the nucleus.

In fact, if we abandon the deterministic way of thinking which sees the electron running across well-defined orbits around the nucleus, but we adopt the probabilistic conception which defines the orbits as "the regions of space

in which it is more probable to find the electrons 'in navigation' around the nucleus", we reveal that such regions of space can be calculated by means of the Schrödinger's equations.

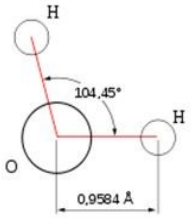

Fig. 8. The dimensions of the water molecule determined experimentally.

The tridimensional graphic representations of such equations have, in the monoelectronic atomic model, the appearance of "shells" which have characteristic shapes - spherical, with lobes which are oriented in the space in a different way - called "orbitals".

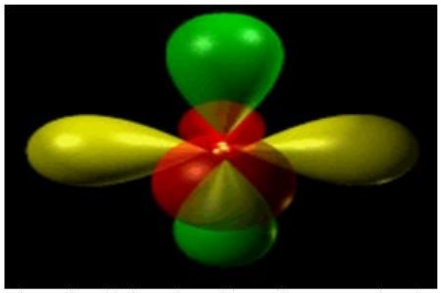

Fig. 9. The orbital atomic model: graphic representation of *p* orbitals

The orbital atomic model (figure 9) which is so originated, in its fundamental state, has, in this way, a completely different shape from that described by Bohr and it is so easily represented with the GEOMAG™ elements (figure 10) and thanks to the attractive and repulsive effects that are established among the magnetic ends.

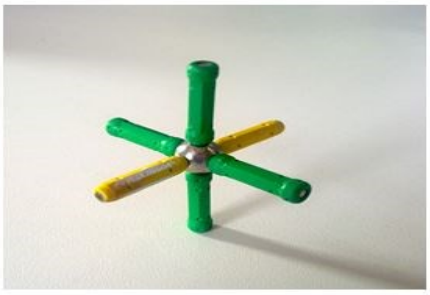

Fig. 10. The orbital atomic model: representation of *p* orbitals with the GEOMAG™.

It is soon clear how the orbital atomic model, which is merely abstract, is replaced, in the student's' opinion, by a real object, concrete as it really should be considered the atom in the light of the more recent studies and that, now, date back several decades.

The fundamental electronic configuration represented by Figures 9 and 10, however, cannot justify the shape and the dimensions, experimentally determined, of the water molecule, which is taken as an example and summarized in Figure 8.

Nevertheless the statistical-mathematical nature of the orbitals allows them to be combined, giving origin to the *sp*, sp_2 and sp_3 hybrid orbitals (Figures 11, 12 and 13) depending on whether with the spherical orbital equation s are combined the equations of one, two or all the three *p* orbitals.

So, while for well-known subjects, like that shown in figure 14, the perspective representation on a flat surface can be nearly heightened in the mind of the student and well understood by him, the same representation can be interpreted with great difficulties – especially if the student is disabled - when new and unusual shapes are represented and, maybe, even stylized like that shown in figure 15.

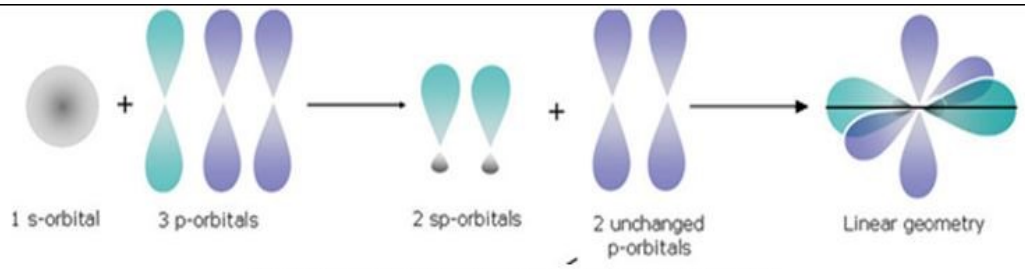

Fig. 11. The *sp* hybridization of an orbital atomic model.

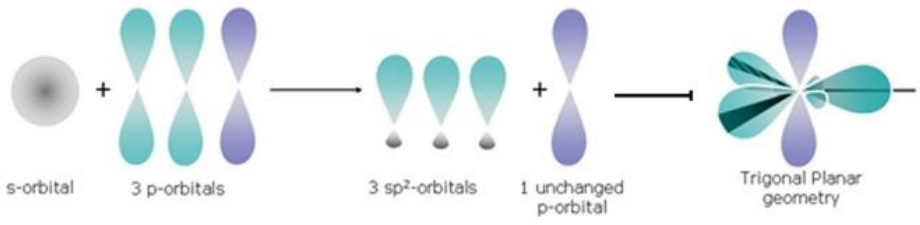

Fig 12. The sp_2 hybridization of an orbital atomic model.

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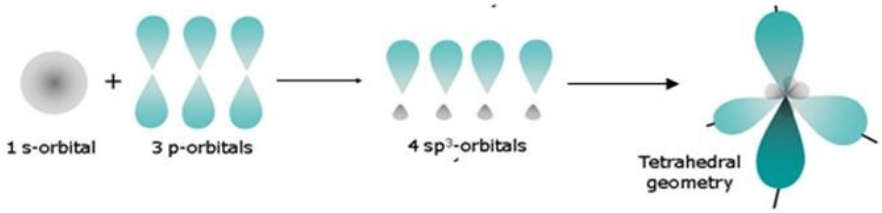

Fig. 13. The *sp*₃ hybridization of an orbital atomic model.

Fig. 14. La città ideale. Unknown (1480-1490). National Gallery, Urbino.

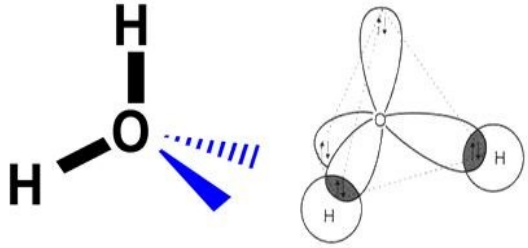

Fig. 15. Schematic representations of the water molecule.

The use of GEOMAG™ comes out to be, at this point, a precious help to represent in a tridimensional and absolutely concrete way not only the sp, sp_2 and sp_3 hybrid orbitals (figures 16, 17 and 18), but also the shape of simple molecules such as methane (CH_4) (figure 19), ammonia (NH_3) (figure 20), hydrofluoric acid (HF) (figure 21) and, above all, water (H_2O) (figure 22).

The possibilities offered by GEOMAG™, besides, do not confine themselves to the simple reproduction of simple molecular structures like the ones above, but they can also clarify concepts like the one of secondary bond.

In fact, by means of plastic elements which are magnetically neutral, in this case represented by segments of straws, it is possible to represent the hydrogen bond which is very important in the field of the biological chemistry (figure 23).

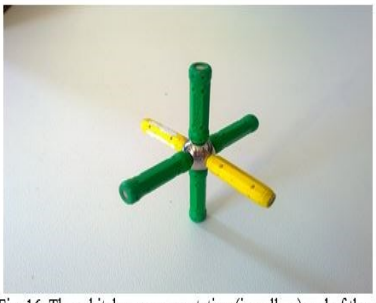

Fig. 16. The orbitals *sp* representation (in yellow) and of the *p* orbitals (in green).

Exploiting such plastic elements as simple spacers among the spheres which represent the hydrogen atoms and the bars which represent the sp_3 orbitals occupied by the lone pairs, the solitary electron pairs, it is possible to reduce the attraction between a magnetic element and another.

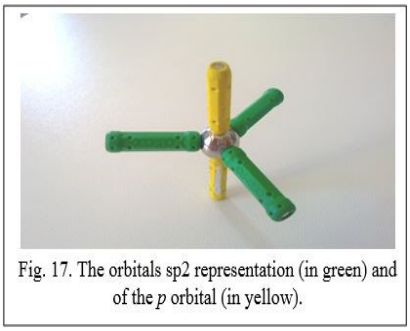

Fig. 17. The orbitals sp2 representation (in green) and of the *p* orbital (in yellow).

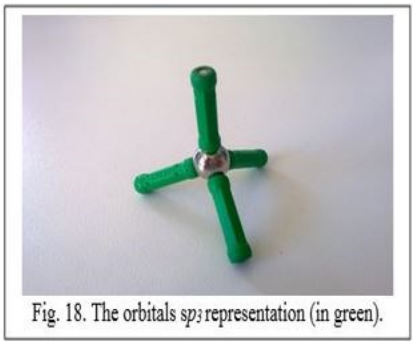

Fig. 18. The orbitals sp_3 representation (in green).

Fig. 19. The methane orbital molecular model (CH_4).

Fig. 20. The ammonia orbital molecular model (NH_3).

Fig. 21. The hydrofluoric acid orbital molecular model (HF).

Fig. 22. The water orbital molecular model (H_2O)

The smaller attractive force between the so spaced out elements can distinguish the strong or principal chemical bonds, those that the current literature indicates as the ones that have a bond's energy below -5kcal/mol from the weak or secondary bond which, having a bond's energy above that limit.

So, while first ones participate to build the structure of molecules, the second one are formed between two different molecular structures.

Fig. 23. The model molecular orbitals to water (H_2O) and the representation of the hydrogen bond.

In this way, therefore, it is possible put in evidence one of the most important characteristic of water's molecule: the hydrogen bond realized between the molecules near to the points where there are concentrations of opposite charge.

III. Results

The models obtained with the GEOMAG™ have been proposed during the lessons of Principles of Nutrition to the students in some first classes of the IPSSEOA in Margherita di Savoia as an experience done in the Food Science laboratory.

Despite the curricular course of Chemistry is planned for the second year, the early study of the atomic structure of matter is effectively assigned to one of first year Food Science.

During these lesson emerged the necessity to show substances like water, mineral salts, glucides, lipids, proteins and the vitamins not only with a nutritional approach but also from a chemical point of view, considering the digestive processes that, charged on them, occur in the human body and that will be studied in the following didactic modules according to the teacher's work plan.

The experience done with the GEOMAG™ has produced brilliant results both for having given the students a new environment, the laboratory, where the vision of the equipment, of the materials and of the reagents has contributed to create the consciousness that what they would learn wouldn't remain for so long confined to the textbook pages only, and for having discovered that what they have used, until some years before, to build fantastic shapes, without a practical application, could be used to give shape to concepts that have nothing fantastic, having practical- cognitive implications of undoubted utility.

After having built the atomic models described above and having clarified the principles on which such models are founded, each student is given the possibility of reproducing autonomously what the teacher has shown them.

After a little initial uncertainty, all the students have demonstrated of knowing how to reassemble the models shown them, giving proof of having understood the meaning of the topics dealt with during the course of the frontal lessons administered them.

IV. Conclusions

In the course of his teaching activity the teacher often finds himself to compete with more pleasant afterschool interests which distract the students' attention from the lesson, reducing the quality of education and of learning.

It is necessary, then, that the teacher begins to search the indispensable tools in order to bring back the student's interest on the topics subject of his study, to optimize the effectiveness of his intervention.

So the use of the GEOMAG™ appears to be precious both for the characteristics of the product that is very suitable to represent the structures subject of study, and for the nearness to the game world that has fascinated the student until some years before.

The results obtained have demonstrated that the representation, for example, of the water molecule done with the GEOMAG™ has a particular charme that, unfortunately, the traditional representation on the board

doesn't have, both for the nature of the support and for the resistance to disappear put up by the atomic models, traditionally adopted by teachers, even if they are surpassed (figure 24).

It is a very precious help the one offered by the GEOMAG™ when, thanks to the use of appropriate spacers, it is necessary to represent the smaller energy involved in the secondary bonds between a water molecule and the other.

The use of spacers, riducing the attraction among the GEOMAG™ elements emphasizes how a light traction can break the hydrogen bonds more easily, because they are weaker than the stronger ones, which are the "core element" of the molecules represented.

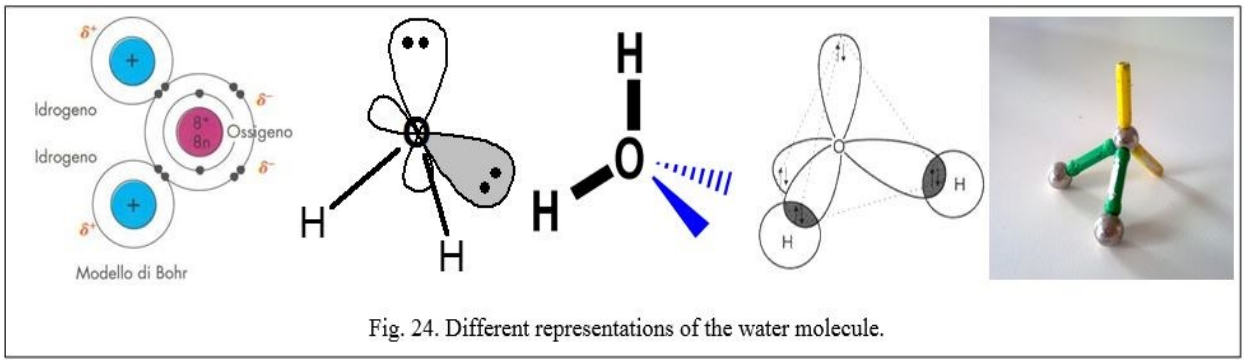

Fig. 24. Different representations of the water molecule.

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Nicola G.G. Cecca, born in Barletta, Italy, on June 18. 1963. Earned a Degree in Agricultural Sciences by Universita degli Studi di Bari, Italy, on December 21. 1989 discussing a thesis in Soil Chemistry Since march 1990 till February 1991, he served in the army.

He was awarded with the following scholarships:

I. March 1991 - February 1992 - Italian National Research Council (CNR), at the Study Center on Colloids of the Soil-Florence (Italy), "Interactions between molecules of herbicides and clay minerals";
II. June 1992 - May 1993 - AUSIMONT SpA - Bollate Research and Development Center (MI) - PCB degradation with H2O2 / HRP systems;
III. March 1995 - December 1995 - Italian National Research Council (CNR), at the Institute of Toxins and Mycotoxins from plant parasites - Bari (Italy) - "Production and biochemical characterization of phytotoxins and mycotoxins";
IV. September 1996 - July 1997 Italian Ministry of Agriculture at the Experimental Institute for the Study and Defense of Soil – Florence (Italy) - "Effects in soil of chemicals, wastewater and atmospheric depositions".
V. He worked
VI. September 1997 - August 2007 - Ministry of Education, University and Research - Different schools - Part time teacher in various scientific subjects;
VII. September 2007 - Ministry of Education, University and Research - State Professional Institute for Food and Wine and Hospitality Services of Margherita di Savoia - Professor of Food Science;
VIII. November 2017 - Ministry of Education, University and Research - University of Basilicata di Potenza (Italy) - Department of Science - PhD-student in "Applied Biology and Environmental Safeguard", subtopics: "Geo-resources and Geo-systems".
IX. Prof. Cecca participated in different Scientific Conferences publishing several articles on International Journals.
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