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Historical-philosophical foundations of chemistry

Fundamentos histórico-filosóficos de la química

*Dolores Vélez-Jiménez**
Universidad Iberoamericana/Asunción, Paraguay
dolores.velez@unibe.edu.py
http://orcid.org/0000-0003-1103-7856

*Celso Obdulio Mora-Rojas***
Universidad Del Norte/Asunción, Paraguay
celso.mora.458@docentes.uninorte.edu.py
http://orcid.org/0000-0001-9735-2683

Abstract

There is relevance in the integration of the knowledge of a natural science, mainly material such as chemistry, with the world of ideas such as philosophy, and more specifically with epistemology. The aim of this article is to contribute on the epistemology of chemistry using philosophy within the thought of diversity and its educational importance. The methodology focused on a non-experimental type of exploratory level, with a qualitative method and a historical-interpretative approach through document analysis. The theoretical development allows to glimpse the participation of chemistry in multidisciplinary, interdisciplinary and transdisciplinary dimensions; to be used in secondary and higher education institutions, avoiding continuous and dogmatic monodisciplinary learning. As research finding, it was established that history and chemistry have a fundamental and convergent dimension, the epistemological dimension. The historical evolution of chemistry accounts for the ways of accessing knowledge and categorizing it as valid knowledge. Therefore, it is concluded that the epistemology of chemistry has a causal relationship with the corresponding paradigm, and at the present, chemistry is part of the logical positivist paradigm by complying with its epistemological and epistemological characteristics and the prevalence of the empirical contrast.

Keywords

Science, Chemistry, Philosophy, Epistemology, History, Knowledge.

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* International professor and researcher of the Postgraduate Course at Universidad Iberoamericana UNIBE Paraguay. Professor, researcher, trainer and lecturer in Latin American universities.

** Holds a PhD in Education at Universidad Iberoamericana UNIBE Paraguay. Professor and researcher at Universidad del Norte UNINORTE Paraguay.

Resumen

Existe pertinencia en la integración de los conocimientos de una ciencia natural, predominantemente material como es la química, con el mundo de las ideas de la filosofía y más concretamente con la epistemología. El objetivo central del presente artículo es hacer un aporte acerca de la epistemología de la química, en la consideración de la filosofía, dentro del pensamiento de la diversidad y su importancia educativa. La metodología se enfocó en un tipo no experimental de nivel exploratorio, de método cualitativo y enfoque histórico-interpretativo mediante análisis documentológico. El desarrollo teórico permite vislumbrar la participación de la química en las dimensiones multidisciplinares, interdisciplinares y transdisciplinares; para ser utilizada en las instituciones de enseñanza media y superior, evitando el continuo y dogmático aprendizaje monodisciplinario. Como hallazgo de la investigación, se estableció que la historia y la química tienen una dimensión fundamental y convergente: la dimensión epistemológica. El devenir histórico de la química da cuenta de las formas de acceder al conocimiento, categorizándola como conocimiento válido. Se concluye que, la epistemología de la química tiene relación causal con el paradigma correspondiente. En la época actual, la química se enmarca en el paradigma positivista lógico –al cumplir con las características gnoseológicas y epistemológicas del mismo– y en la prevalencia de la contrastación empírica.

Palabras clave

Ciencia, Química, Filosofía, Epistemología, Historia, Conocimiento.

Introduction

Chemistry is a term that refers both to a discipline of knowledge, as well as to a profession or career. Because the term is polysemic, it is necessary to review the concept from the vision and position of different authors.

The main objectives of this research consist on analyzing the relationship between chemistry, philosophy and epistemology, focusing on the ways of accessing knowledge and the possibility of a representative approach in each stage in which the results are presented, so as to decrease the elusive relationship between these disciplines -in addition to describing the multidisciplinary, interdisciplinary and transdisciplinary relationships of chemistry- emphasizing the status granted by Chang et al. (2004) that considers it-: central science, with the purpose of the transmission and appropriate transfer of chemistry to students, and it represents a theoretical-methodological basis for researchers. This study is part of the line of research referred to Epistemology, understood as the Philosophy of Science and its normative-fundamentalist condition of all scientific processes.

Chang et al. (2004) consider chemistry as a central science, given its very nature that allows an important understanding of the world and its functioning from a molecular perspective, forcing us to consider the different disciplinary relationships of chemistry, either in multi, inter or transdisciplinary dimensions.

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For Whitten (1998) chemistry studies matter in terms of description, physical and chemical properties, chemical or physical transformations and energy changes that may accompany them.

As for Domínguez Reboiras (2006) Chemistry is a basic science. In the field of the production of knowledge, concepts, theories, models and postulates - this premise is totally correct; however, Whitten et al. (2008) indicate that chemistry is almost always present in the various aspects of life, such as culture, health, environment, economy, etc., studying practical situations, so it is also an applied science.

Among the studies mentioned, it has been found that chemistry studies matter-concept as mentioned by Oilia et al. (2018), who also consider that the transformations of matter occur by the action of energy and that chemistry is divided into several branches, among which there are some exceptions, indirectly raising the intersection between the branches or divisions of this science.

Chang et al. (2017) say that chemistry is a science with ancient roots, but modern and constantly evolving, that studies matter and the changes that occur in it, and whose purpose in the 21st century is to maintain a determinant function in all areas of science and technology.

According to Atkins et al. (2005) chemistry levels are the macroscopic, the microscopic and the symbolic. They also indicate that chemical science focuses on everything material, stating that there is nothing material outside chemistry, whether living, dead, inert or mineral.

The research problem focuses on the apparent and limited integration of the knowledge of a natural science, predominantly material as chemistry, with the world of ideas as is philosophy, and more specifically, with epistemology. Therefore, from the research this question is planned-teamed: What is the epistemological foundation of chemistry? The findings are approached descriptively with the philosophy and epistemology of chemistry, in the light of the documents analyzed, from a historical-interpretative approach. As Chamizo (2009) states: despite the long and rich history of chemistry, his philosophy is practically a nascent intellectual activity.

From the phenomenological point of view, the objects of study of chemistry are matter and energy. Regarding an integrative vision, Martínez (2009) establishes that physical, biological, social, political and environmental phenomena have interdependencies. Chemistry is not isolated - to paraphrase Monroy et al. (2016)- the search for knowledge in a simple way produces a disfigured reality, and referring to Morín (1983: 29) there is evidence that life is based on the paradigm of the rapid acquisi-

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tion of knowledge, without giving importance to the fact that knowledge is reduced and fragmented.

On the other hand, Martínez (2009), quoted by Monroy et al. (2016), states that there are interconnections, interdependencies, reciprocities; therefore, it is necessary and valuable to consider the integral, systemic and ecological coherence of the physical, biological, social, environmental and political phenomena, otherwise the results of learning or scientific knowledge would be simple, isolated and decontextualized.

As for Monroy et al. (2016), chemistry as a discipline because it has scientific foundations conceived under paradigms accepted in each era. However, considering its relationship with other sciences, it can be identified from the multidiscipline conception, in which several areas converge from their methods to a specific subject, or in the interdisciplinary, in which methods converge and generate a new discipline as occurs in biochemistry or robotics. Also, Martínez-Miguélez (2009), makes readings from the transdiscipline or meta-discipline, and emphasizes in the influx of knowledge, in their interaction and reciprocal integration and in their transformation and overcoming, in a much broader context and with a greater sense: a systemic paradigm.

As in all sciences, it is essential to reflect between the gnoseological aspects of epistemologies to understand the implications that lead to focus knowledge and its generation forms. Velez and Calderon (2018) emphasize that philosophy is considered the mother of all sciences, gnoseology is a derivation of it and deals with the problems of knowledge, subject-object relations, as well as the theory of knowledge itself, for which, it is limited to large-scale philosophical issues. Instead, epistemology deals with the sciences -in particular- and their interdisciplinary fields.

From the point of view of theory, there is an elusive relationship between chemistry and epistemology described by Villaveces Cardoso (2000), who also states that chemists constitute the largest group of scientists whose results have great economic impact in the world today. Guzón (2020) mentions that “philosophy and science often carry parallel or even convergent discourses, although both are critical in nature” (p. 100). In this way, the relationship is likely to exist; however, it has not been addressed deeply.

The second industrial revolution was essentially a chemical process, as was the green revolution achieved by the application of chemicals to agriculture with great influence on the environment, health, agriculture, molecular biology, heavy industry, cosmology, the production and synthesis of new materials, nanotechnology. These are presented, related

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and classified in this document, from a relevant theoretical foundation, through a non-experimental methodology, exploratory level, qualitative method and historical-interpretative approach through documentary analysis. The results, classified in historical stages, support the importance of the history of chemistry and its relations with philosophy, particularly epistemology, confirming its disciplinary character.

Theoretical foundation

To understand the relationships between chemistry, philosophy and epistemology, precepts and theoretical considerations are established, so that this research has been contextualized and interpreted within the frameworks set out in the following paragraphs.

As for the establishment of sciences, Gadea et al. (2019) express that science seeks the knowledge of reality, and each discipline aims to understand the part of reality to which it has circumscribed as its object of study. Sciences are divided into two main groups: empirical sciences and non-empirical sciences. Empirical theories seek to pronounce themselves on the world, so the statements they make must have a solid foundation on the portion of reality they take for object, known as empirical basis, i.e., they must confront their statements with facts or their hypotheses with demonstrations and explanations.

On the other hand, formal or non-empirical sciences do not present this relationship of dependence on the empirical basis, such as logic and pure mathematics, whose propositions are shown without essential reference to empirical data. Empirical sciences require non-empirical sciences as instruments. This classification of science is equivalent to the distinction between the natural and social sciences. Natural sciences include physics, biology, chemistry and astronomy.

It is generally accepted that chemistry is a natural science, and the general perception of this science also identifies it as one of the hard sciences. On this regard, Borjas Gil et al. (2009) state that the division between hard sciences and soft sciences is false, and that it is wrong to consider the former as scientific and the latter as speculative.

The most used definition of chemistry is that of science that studies matter, energy and its changes - as can be seen in the preceding paragraphs - so that its main object of study is matter and energy. However, Sosa (2015) states that, although the definition is true, it is extremely imprecise, since chemistry does not study everything about matter and energy; it is

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rather physics that studies most of the phenomena related to these two objects of study. Chemistry only studies a small portion of that universe.

Sosa (2015), who cites Sosa and Méndez (2011), conceptualizes chemistry as the science that studies what is related to processes, in which some substances are obtained from others. Chemistry is the science of substances, and its object of study is substances and their interactions.

Chamizo (2009) argues that chemistry is the discipline where one studies, practices and transmits how to transform matter, an activity that could be considered as its teleology or purpose through its own linguistics and specific logic. This knowledge has not yet soaked the academic community that still considers chemistry with a logical-positivist vision, as a science reduced to physics. It also considers that the chemical properties of matter can be characterized through three axes that have constituted -over time- the chemical activity. These axes are method, measure and language.

Berthelot, quoted by Serratosa (1969) states that chemistry creates its object. This creative faculty, similar to that of art itself, distinguishes it from the natural and historical sciences. This creation of the object is valued above all, in the synthesis reactions, in which new substances are formed from others.

Chemistry is an experimental science and although its practice goes back to the very existence of the human being in the planet, Carmona (2010) clarifies that the ex-exhaustive chemical experimentation, scientific or systematic, is relatively recent with little more than two centuries. The experiment, according to Carmona, is an operation that is performed to elicit a response in the system being studied. Chemical experimentation is carried out by analysis and synthesis. It should be noted that the scientific activity of the chemical requires a thorough subsequent analysis with correct and precise interpretation of the results obtained. In science, experiments are designed to consolidate a theory; or, on the contrary, to rebuke it or in some circumstances, to distinguish between two different or opposite interpretations of the same phenomenon that constitute real dilemmas. In chemistry, experiments are mainly performed to obtain new substances, new molecules and new materials, either by synthesis or by analysis; although in Chamizo (2009), reference is made to the method of chemistry, under the consideration that science is divided into two categories: physics and philately.

Chamizo's General Chemistry (2018) states that the ancient antecedents of chemistry should not be forgotten, i.e., the transition from alchemy, passing through a period named protochemistry to modern chemistry. Considering the historical approaches of chemistry, it is evi-

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dent that different historical periods are marked by different conceptions, institutions and epistemic objects. Thus, the importance of reviewing the evolution of Chemistry (Table 1).

Table 1
The fifth periods of the evolution of Chemistry

N° OF PERIODS	YEARS	MAIN CHARACTERS	ENTITIES
1	1754-1818	Henry Cavendish, Antoine Lavoisier, Jhon Dalton	Atom
2	1828-1874	Stanislao Cannizzaro, Louis Pasteur, Dmitri Mendeleiev	molecule
3	1897-1923	J. J. Thomsom, Gilbert N. Lewis, Marie Curie, Ernest Rutherford	Nucleus, isotope, radical
4	1945-1966	Linus Pauling, Robert S. Mulliken	Spin
5	1974-1999	James Lovelock, Richard Smalley, Ahmed Zwail	nanoparticle

Note. Taken from Chamizo, José Antonio (2018). Química General. Una Aproximación Histórica. (1st. Ed.). Universidad Nacional Autónoma de México. p. 13.

Following the methodology of chemistry, it is convenient to consider Pickstone (2000) who distinguishes, basically, 3 forms of knowledge developed during the period of his study: natural history, analysis and experimentation. These are ways to understand nature and the changes brought about by human action, in other words, the natural and the artificial. Natural history classifies objects, describes them and integrates the systems; the analysis is responsible for decomposing into constituent elements; experimentation orders the elements with the aim of producing new results and phenomena. They are three forms of knowledge that are integrated, complementary and present in chemistry.

After establishing the foundations of chemistry, the next step is philosophy that, according to Vélez and Pérez (2019), is the primary science that gives foundation to all sciences, being epistemology one of its components, which is the study of scientific knowledge, considering scientific methods in terms of objectivity and its value for man.

Because of philosophy and its relationship with chemistry, Labarca (2005) expresses that epistemology has been divided into various disci-

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plines focused on analyzing philosophical issues of the particular sciences, so there is the philosophy of biology, physics, mathematics. However, the specific philosophy of chemistry and other fundamental sciences is generally almost absent from these lists, fortunately this fact is changing. The specific philosophy of modern chemistry -still incipient- presents some of the main dilemmas that could be debated in this new research interest such as autonomy of chemistry, models, laws and chemical theories, importance of chemistry education, social perception of chemistry, chemistry-technology and society, among the most outstanding topics.

It should be borne in mind that a meaning of chemistry is that of being a discipline or subject and, it is part of the curriculum at the secondary and higher levels. According to Raviolo et al. (2011), it would be interesting to make philosophical discussions in these environments in the conceptual, historical and didactic dimensions of the concepts used in chemistry.

In this context Adúriz-Bravo et al. (2006) express that symbolic systems allow to express scientific knowledge, relating propositions with evidence. In the language of chemistry, the use of symbology occupies a very important place because the chemical formulae of substances are represented through the symbols and chemical nomenclature of the elements, thus establishing the axis of language as mentioned by Chamizo (2007).

Another axis that characterizes chemistry is measurement, giving it a positivist and quantitative meaning. This science required the establishment of measurement units according to its object of study; thus, for the atomic and molecular mass, it has defined and uses the so-called atomic mass unit - Uma - to express the amount of mass in the international system, it uses the term -mol- just to illustrate some. Thus, the term mol was previously named mole as quoted by Skoog et al. (1995), formula weight and molecular weight frequently used in the ancient literature as synonyms of molar mass, not forgetting trivial or common names of substances that in an attempt to achieve accuracy and systematicity are nomenclature following strict rules or precepts accepted by the scientific community. It has characterized chemistry as an empirical science.

Another important aspect in the language of chemistry is the use of models. According to Adúriz-Bravo (2005) the scientific model is an abstract representation of a phenomenon that resembles many other phenomena. According to Chamizo (2009), the wide use of models in chemistry is that these representations allow chemical explanations without resorting to physics.

In the previous paragraphs, relationships in chemistry and philosophy are evident; however, there are few people focused on reflecting

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on the bases of their discipline and its relationship with other areas of knowledge, leaving a brief space for the groups involved with topics of specific and general interest, resulting in a discipline widely developed in its utilitarian and pragmatic aspects, but with labile theoretical bases.

Materials and methods

From a post-positivist paradigm, the research was developed with a qualitative character and historical-interpretative approach. Mardones (2003) conceives knowledge from a methodological framework different from quantification, where the validity of statements is not technical, but through the understanding of meaning when interpreting texts. The typology refers to a basic research purpose with temporal scope, transversal order and descriptive depth, with a documental nature. The applied technique was the content analysis, with an eight-unit sample. The selection criteria are only books and scientific treatises, available in indexed or arbitrated scientific journals and on electronic publishing platforms. Originals belonging to monographic issues, revisions, editorials, letters to the editor and information notes were not considered.

The selection of the academic literature was made from the relationship of the titles with the thematic category considered, especially addressing the terms history and philosophy of chemistry. The main categories of analysis -from the gnoseology and as part of the epistemic model- were established as role of the conscious subject and way of accessing knowledge. From the epistemology and as part of the epistemological model, the categories of analysis determined were importance of epistemology and paradigm. It is important to specify the distinction between models, since the epistemic deals with the problem of knowledge and the epistemological with the foundation to systematize the generation of knowledge. This article seeks to establish a disciplinary matrix that strengthens the relationship between epistemology and chemistry. It is considered that the history of science has implicit models for scientific knowledge, therefore, for rational knowledge.

The paradigm -as the main epistemological question- is that which describes the way in which a scientific community legitimizes concepts and methods used for a specific stage of history and glimpses the theoretical-methodological aspects to know a phenomenon. The history of science shows the supralunar paradigm, the phlogiston paradigm, the ether paradigm, as well as among other conceptions, indicates what is proposed for chemistry, presented in the results and discussion of this research.

Results

The relevant findings of this research are shown and ordered according to Chemistry periods based on Lockemann (1960), who defines the prehistoric or primitive period until the fourth century AC. The alchemy period from the fourth century to the sixteenth century, the period of the iatochemistry from the sixteenth to the middle of the seventeenth century; and later, chemistry itself.

Table 2
Ancient or primitive period

Role of the individual	Ways to access chemistry knowledge	Main characters	Importance of epistemology	Approach	Documents analyzed
It starts to glimpse the radicalism of atomist theory. Democritus thinks from experience of thought from the point of view of its structure, identity and difference	Philosophical practice	Democritus	Democritus was the first to conceive the idea of atom and its indivisible nature.	Atomists affirm this limit in the very concept that defines them. It could be considered a structural paradigm	Rodríguez Arriagada, 2014
Fundamental question of the conscious subject. The spirit of the man who looks the problem of the elementary matter. The idea was to find out what the world was made of.	Daily experience and productive life provided isolated chemical knowledge, but systematic studies were lacking.	Theophrastus: wrote *a* Mineralogical record, in which coal was first mentioned.	In ancient times, chemistry was unknown as it is now. Knowledge in the art of nature and ability was outstanding.	The doctrine of the elements states that there are four fundamental substances on earth: fire, water, air and earth.	Lockemann, 1960

Note. Prepared by the authors based on Rodríguez Arriagada, M. (2014) Democritus: a "new" practice of philosophy. *Byzantion Nea Hellás*, (33), P. 104. 101-118 and Lockemann, Georg (1960) History of Chemistry.

In ancient times, people had access to the basic knowledge of chemistry through philosophy, the main science. This situation places chemistry as an ancient science, which was developing with the evolution of humanity itself. The results from Table 2 indicate that the development of chemistry as a scientific discipline started within the philosophy that constitutes the relentless pursuit of wisdom.

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Table 3
The Age of Alchemy

Role of the individual	Ways to access chemistry knowledge	Main characters	Importance of epistemology	Approach	Documents analyzed
Mysticism, mixed with magic.	Alchemy was considered mystical, magical and a secret. Later it was exclusive to a few.	The preparation of caustic potash which is attributed to Saint Albert	The alchemists considered the metallic character, the volatility and combustibility.	Philosopher's Stone, Hermetic.	Babor & Ibarz, 1960.
The subject is before a cosmic art, made of mastery, prodigy and power.	The science of alchemy is never accessed as the result of man's labors, but by instruction or revelation.	Newton: it was profoundly influenced by the neoplatonic and hermetic movements.	Used methods still used nowadays to investigate nature.	Allegory, symbolism.	Brock, 1998.

Note. Elaborated by the authors from Babor, Joseph A.; Ibarz Aznárez, J., (1962) Química General Moderna Editorial Marín SA, Bilbao and Brock, William H. (1998) Historia de la Química

The age of alchemy constitutes a period of high mysticism, magic, esotericism -which implies the hidden and reserved- in addition to the exotericism that implies the common, the accessible or public. Some techniques, methodologies and equipment used to date come from this era. Among several paradigms found in the period of alchemy, the symbology is perhaps one of the most important, since the notation and nomenclature of chemistry - as formal science - is based on the use of symbols for representing elements and chemical formulas of molecules.

Table 4
Iatrochemistry Period

Role of the individual	Ways to access chemistry knowledge	Main characters	Importance of epistemology	Approach	Documents analyzed
Preparation of drugs and remedies.	Same form of alchemy, but with the objective to cure diseases.	The objective of Alchemy was to cure the disease, according to Paracelsus.	Iatrochemestry or medical chemistry	Remedies. Medical chemistry	Babor & Ibarz, 1960

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Role of the individual	Ways to access chemistry knowledge	Main characters	Importance of epistemology	Approach	Documents analyzed
The subject used chemistry as a support for medicine, with pantheistic and individualistic interpretation.	They were only transmitted exclusively by and through the magician's own inspiration.	Paracelsus	Enigmatic. They wanted to find and prepare useful remedies.	Water and ferment or active organizing principle. The Doctrine of the Trier Prima.	Brock, 1998.

Note. Authors' own elaboration based on Babor, Joseph A.; Ibarz Aznárez, J., (1962) Química General Moderna Editorial Marín SA, Bilbao and Brock, William H. (1998) Historia de la Química.

The findings presented on Table 4 show a significant historical leap in the development of chemistry, showing that the teleology of iatrochemistry was the production of remedies. This brief epoch -even ignored by several authors- constitutes the foundation of galenics and pharmaceutical chemistry.

Table 5
Present Time

Role of the individual	Ways to access chemistry knowledge	Main characters	Importance of epistemology	Approach	Documents analyzed
Pervasive chemistry.	Not only to discover, but also to invent and create.	Emil Fischer. Jean-Marie Lehn, Donald Cram y Charles Pedersen.	It meets the needs of humanity.	Molecule and molecular recognition, nanotechnology	Lehn, 2011
To be a man is to transform matter. We are all chemists	Through the systematization and mathematization of Chemistry.	Antoine Lavoisier, Joseph Priestley. Dimitri Mendeleiev	*Chemistry as a science*	Mendeleiev's chart. Quantitative science. Chemical synthesis.	Meyer, 2011
The subject questions the phlogiston theory. Experiments based on chemistry	The phlogiston theory is eradicated by knowing the true nature of the combustion.	Lavoisier	Principle of the preservation of matter.	*Chemistry as modern science*	Babor & Ibarz, 1960

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Role of the individual	Ways to access chemistry knowledge	Main characters	Importance of epistemology	Approach	Documents analyzed
Fifth chemical revolution.	*Supra-molecular chemistry*	*Researchers of nanoparticles*	Chemistry has reached the limit of what is possible, developing extremely fast chemical reactions.	The concept of an atom can now move and manipulate.	Chamizo, 2009

Note. Prepared by the authors based on Lehn, Jean-Marie, (2011) Chemistry: Science and Art of Matter. UNESCO January-March 2011; Meyer, Michal (2011). Chemistry and life. The forefathers of chemistry. Reproduced by UNESCO Mail January-March 2011; Babor, Joseph A.; Ibarz Aznárez, J., (1962) Química General Moderna Editorial Marín SA, Bilbao; Chamizo, José Antonio (2009). Philosophy of chemistry: I. About the method and models. UNAM Magazines. Chemical education. Volume 20 (1), 6-11.

As seen in Chamizo's contributions (2009): chemistry has achieved its own identity as a science and not as a chapter of physics. Table 5 shows the various paradigms of chemistry up to the present days, as shown by Sierra et al. (2014) -it is a contribution and complement of the table above- reaching to green chemistry, in which the transdisciplinarity of this science is consolidated. The current times are characterized by immediacy, so it is not surprising that chemistry acquires new paradigms more rapidly.

As for the interdisciplinarity of chemistry, it has originated other sciences such as biochemistry, which is defined as the study of molecules found in living organisms, as well as their chemical reactions -emphasizing that life involves biochemical reactions- Murray (2013) says that biochemistry has become the fundamental-mental language of the biological sciences. Another result of the interdisciplinary nature of central science is geochemistry, which can be defined according to Viladevall et al. (1996), as the function that chemical elements perform in the synthesis and decomposition of natural materials. Also, Flores-Morales et al., (2014) specify that phytochemistry is the study of the chemical structures of plants.

According to Acuña and Elguero (2012), this science studies the microscopic structure of tissues, cells and cellular organelles, their morphology and function, and is also interested in describing the molecular level, getting to know the composition and chemical reactivity of the biological system. Baquerizo et al. (2020) specify that there is also the physicochemical, which studies the physical properties related to the chemical properties of matter and the laws of termodynamics.

As for multidisciplinarity, considered as disciplinary collaboration, both empirical and social sciences are involved. According to Paoli (2019) there are theories and hypotheses about the previous eras and have allowed to understand the nature and conditions of human life. It is here that disciplines such as physics, biology, linguistics, zoology, political science, sociology, economics, anthropology, archeology, genetics, to name a few, and of course, chemistry, are integrated.

Considering Doria (2009) and as an example of transdisciplinarity, green chemistry has been used; its principles have been useful in the development of a variety of products and processes to reduce risks to health, damage to the environment, and prevent pollution.

Discussion

There is no clarity and universality in the historical considerations of chemistry. The ambiguity that presents its history is mainly due to the beginning of chemistry as a science attributed to mathematization, as Meyer (2011) says, ignoring all previous events and discoveries, disagreeing with authors such as Lockemann (1960) who consider the existence of this science from remote or primitive times.

Protochemistry is considered by a few authors a stage in the history of chemistry, including Chamizo (2018). Llamas (2017) describes in the history of prehistoric man, the existence of a transition stage in the stone age -the Mesolithic- period in which succeeded the paleolithic and preceded the neolithic. Likewise, the transition to chemistry is understandable and justifiable as mature science, going through the protochemistry -stage described in this research- and considered as a period of the history of chemistry.

Regarding alchemy, some authors such as Esteva de Sagrera (1991) give a negative meaning to alchemy as a precursor or antecedent of chemistry; precisely he states that modern chemistry emerged as a contrast of the hermetic theory. However, other authors such as Las (2005) assert that alchemy can be considered the antecedent of the modern chemistry, known as scientific method.

On the other hand, iatrochemistry is considered by few authors as a stage of chemistry, which shows the need for a thorough verification by historians of science and, likewise, constitutes the basis of the state-

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ment presented above that indicates that the history of chemistry does not present a universalization in terms of its stages. This research supports Chamizo's (2018) statement about the ancient antecedents of chemistry, i.e., the transition from alchemy, passing through protochemistry to modern chemistry. Taking the historical approximations of chemistry denotes that different historical periods are marked by different people, institutions and epistemic objects.

The time elapsed between the revolutions of chemistry was about a decade in the transitions of the first and second revolutions and between the fourth and fifth revolutions, while more than two decades passed in the transitions of the second to the third revolution and from this to the fourth. As Kuhn (1962) states in the structures of scientific revolutions, the normal channels of science are interrupted, and new conceptions and methodologies are established. In chemistry, in the first revolution, the paradigm substituted was that of phlogiston, while the paradigms were not discarded in the other revolutions. The preeminence in the development of chemistry occupied other epistemic objects without detriment to the paradigms considered valid until those historical moments.

The incursion of chemists in philosophy is scarce and incipient, but progressive. The marked influence of philosophy in the ancient stage of chemistry evidences once again that primitive science is philosophy, as expressed by Vélez and Pérez (2019): philosophy is the primary science that gives foundation to all sciences, being epistemology one of its components. Although the elusive relationship between chemistry and epistemology, as described by Villaveces Cardoso (2000), it is expected that chemists, who constitute the largest group of scientists -whose results have great economic impact in the current world- also contribute greatly to the epistemology of their discipline. According to Monroy et al. (2016): "Epistemology proposes to look at the reality holistically to contemplate the data and its interdependence with the whole or with the set of properties of the system to which the data belongs" (p. 14). Therefore, it is possible to consider the pertinence of the discourse.

As for interdisciplinarity, the participation of chemistry in this form of disciplinary collaboration is undeniable. For Paoli (2019), this interdisciplinarity is not the juxtaposition of several sciences, but is the integration of the theory of more than one discipline; however, in the specific case of physicochemistry, it is found that authors like Capparelli (2013) defines it as one of the most relevant topics of chemistry, and not a new discipline resulting from the integration of the theory of physics and chemistry - and others - as a new discipline.

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The participation of chemistry in multidisciplinarity allows the understanding of the most complex phenomena mentioned by Paoli (2019), such as the functioning of the brain or climate change. In these times of COVID-19 pandemic, chemistry has contributed to numerous other sciences -both to assist in techniques and procedures of analysis- so that chemical sciences have provided solutions to fight the disease, as to ensure the supply of basic products of hygiene, prevention and detection, as well as the case of laboratory tests and their theory, in addition to technology for the creation of the vaccine.

Coinciding with Martínez-Miguélez (2012) and his conception of transdisciplinarity: as an emerging knowledge and higher rank that -part of a dialectical movement of thought feedback- helps to integrate different areas of knowledge and the approach to a reality: more complete, more integrated and truer. It has been seen that chemistry has crossed its own boundaries and its disciplinary boundaries, thus supporting the understanding of reality. In the same sense, Cernadas (2009) argues that the main idea of transdisciplinarity is that different disciplines work in an integrated way with professional experts and people involved in solving concrete problems.

Conclusiones

In response to the general research question, what is the epistemological basis of chemistry? First, after reviewing the historical periods of chemistry, theorized and subsequently integrated in a matrix for its analysis, it is concluded that the important elements considered are those concerning the role of the conscious subject, the way to access knowledge of chemistry, the main representatives, the importance of epistemology and the current paradigm. This allows us to point out that philosophy and history of science represent an inseparable goal, in this case, chemistry. The normative condition of epistemology to access knowledge is strongly influenced by the evolution of history. This is also consistent with Khun (1962) and scientific revolutions.

Secondly, it is concluded that the general objective has been achieved, when obtaining the description of the epistemology and the epistemic and epistemological model from the analysis of the elements considered outstanding in the history of chemistry. Based on Stadler (2010), in current terms, -epistemologically- chemistry is framed within the paradigm of logical positivism that arises from the Vienna Circle, founded in 1922 by Schlick. This paradigm is characterized by formal logic or

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mathematical logic, analytical depth, isolated and decontextualized reality, objectivity, rationalism -as theory of knowledge- mechanistic mode for the subject-object relationship, centered on quantity and axiological neutrality. Rudolf Carnap -an outstanding member- provides support for the above idea by pointing out that objectivity is the condition of the facts that makes them empirically verifiable. This agrees with the results obtained that evidence the empirical, analytical, objective and rationalist work in all the historical stages of chemistry.

The methodological monism in chemistry is indisputable from the hypothetical-deductive method of experimental nature, with a linear conception of the research process. Therefore, having the necessary clarity of an epistemology proper to chemistry, it contributes towards a naturalistic epistemology for each type of science; and, in consistency with Gazmuri (2022): "Reason, from the positivist model (with its idea of progress) aims to unravel the laws of the universe to achieve technical progress" (p. 200). This represents a consolidation of the essence and development of chemistry.

So far, chemistry is denoted as a science attached to the theories of knowledge such as empiricism and rationalism, the sensitive or empirical experience conceived from Protagoras, Locke and Hume -on the basis of rationalism- as a source of knowledge based on logic and mathematics, based on the ideas of Plato and Descartes, who are the main exponents. As a concrete support of these historical positions, Aguilar (2011) says "The scientism or absolute value of science is a corollary of positivism. Positive knowledge denounces the invalidity of philosophical, religious and ethical discourses" (p. 136). This shows the limitation of thought, and in contrast to the results, this article proposes another methodological vision in the study that leads to epistemological possibilities and tendencies for a better understanding of chemistry -which are set out below- as a recommendation and suggestion.

The empirical qualitative methodology was relevant, however, it is proposed and recommended to make a study that integrates other categories such as the knowledge about epistemology of today chemistry, the axiological, ontological and teleological approach of chemistry texts to advance in postpositivist studies.

Indeed, there is a philosophical, gnoseo-epistemological basis of chemistry, although this is not normally visible in the professional life and perception of the chemist always present in the ways of accessing knowledge. Finally, this research may represent an example of the interest and ap-

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proach of chemists to the philosophy of science. It is important to point out the need to conceive a broad sense of research from epistemology.

Regarding the study of disciplines, from the philosophical discourse, chemistry is a science with the capacity to encompass univocism or unique truth -to advance towards equivocism- where each human being has his own truth, until achieving plurivocism, as archetypal knowledge (perfect ideas) and intersubjective; reflection of the transdisciplinarity scope described in this research, reason for which an immersion in these scopes is suggested to continue searching for meaning in this area of knowledge with emphasis on its educational importance for present and future generations.

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