Chemistry and its transformations

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INTRODUCTION

When the ontologically pluralist perspective is applied to the relationship between chemistry and physics, a picture completely different from the traditional one appears. Once the epistemological irreducibility of chemistry to physics is admitted, the ontological priority of the physical world turns out to be a mere metaphysical prejudice. From the pluralist view point, concepts like bonding, molecular shape and orbital, refer to entities belonging to the chemical ontology, which only depends on the theory that constitutes it. Chemical entities do not owe their existence to an ontologically more fundamental level of reality, but to the fact that they are described by theories whose immense predictive and creative power cannot be ignored

O. Lombardi (2015, p. 23)

As we know it today, chemistry is the result of a thousand- year-old multitude of inheritances that, embodied in trades, influenced the daily life of all cultures, helping to build, in all of them, a material culture (Tilley, 2006). It is still surprising that practices as different as that of the blacksmith and metallurgy, the healer and pharmacy, the potter and ceramics, the baker and biotechnology have come together to end up merging, barely three centuries ago, in a common field: chemistry. It should be noted that there is no disciplinary knowledge absent from a social context of transmission and from a social group (the current chemical community, both academic and industrial) that reproduces itself. For this reason, what we currently call chemistry, as is the case with the other sciences, can only be understood through their historical changes.

Chemistry is thus a pluralistic relatively young discipline that has integrated a multitude of millenary trades, today transformed into technosciences (Chamizo, 2013) a place where it is studied, practiced and transmitted how to manufacture and transform substances in small and very large quantities. Chemistry is mainly about chemical reactions.

In the scientific practices of chemistry, the laboratory is the central place, where the chemical experiment is carried out. Chemical practices (analysis and synthesis) are different from other scientific practices, particularly those from physics (Kim, 2014). By participating in a practice, one knows what to do and what to say, although part of the knowledge about it is tacit knowledge (Polanyi, 1966). Chemical practices are related to Kuhn's 'exemplars', that is, the collection of problems, theoretical and experimental, shared and solved by a specific community at a particular historical moment that are generally found in professional publications, and especially in their own discipline textbooks. It is apprenticeship in the regimented discipline of the chemical community that allows transmission of purposes. Chemical practices do not try to discover what matter is like, what they mainly seek is to build new substances (Tobin, 2016).

The value of instruments in the development of science and technology is already out of the question: *Scientific instruments are fundamental to the practice of science* (Bud, 1998, p. ix). This is noted because chemistry, or rather its predecessor alchemy, was the first practice that dedicated an isolated space in which it gathered the instruments necessary to carry out their activities (Holmes, 2000). From the beginning, the analysis of substances, permanently associated with the concept of purity, has been an obsession for chemists (Bensaude-Vincent and Simon, 2008). Since "natural" substances are not pure, the separation of the parts that constitute them, the isolation of what is wanted, has been a constant in chemical practices, even since they were alchemical. There is no such thing as pure substances. What we have direct access is to a "predominant" substance mixed in minor or very minor amounts with different substances. The purity depends on our technical ability to identify impurities. Different techniques indicate different levels of purity. For this reason, generally, when the purity is indicated, the analysis technique through which it has been recognized is mentioned.

Through the operation of technical-chemical systems, human beings as willing agents obtain objects that were not in the world, such as Dynamite, Aspirin, Nylon, freons and the millions of artificial substances that constitute a supernature, and which are philosophically called artifacts. There are no new substances - or artifacts - without action and without design. They are not only the result of an intentional human action, they also have a meaning embedded in a specific historical context. Since its millennial origin, through the trades, the main way in which chemists today 'know' is 'doing' and this chemical practice characterized by action increases and has increased the complexity of the world. For chemists, besides their substances, reality is found in the hidden accumulated entities (Arabatzis 2008) that explain chemical practices, such as chemical atoms, chemical electrons, ions, spin or molecular orbitals (Mulder, 2011), not in the underlying physical theories, like quantum mechanics. As Morrison indicated (2004, p.446): *Too often philosophical debates about the reality of particular entities focus on specific conditions that are taken as defining what counts as "real". By focussing less on definitional aspects and more on the evolution of properties and ideas within a conceptual/ physical framework, our philosophical arguments will gain historical accuracy and hence greater credibility as an explanation of scientific practice.*

Substances are the ontology of chemical practices (van Brakel, 2012). Through his synthetic practices, the number of substances grew from several hundred in 1800 to more than 150 million at the beginning of the 21st century, most of which are commercialized. And every day, and day after day, more than 15,000 new substances are added to the world, posing a major ethical problem (Schummer, 2001).

Chemical practices mainly use models rather than theories (Schummer, 2010). Because in chemistry, models are also mediators between the real world and us, which means that they function not only as representations, but also as means of intervention (Klein, 2003). Because different models for the same field of application can coexist and complement each other in useful ways, for example in the diverse and complex number of acid-base reactions (Jensen, 1980). Because models are also used in industrial and technological chemistry (Suckling, 1978).

CHEMISTRY AND ITS TRANSFORMATIONS

Chemical sciences
are not aimed at unveiling the underlying reality beneath the surface.
Rather they are dealing with a jungle of molecules
and striving to take advantage of their dispositions
B. Bensaude-Vincent (2008)

In 1732, in Europe, chemistry emerged as an independent science, with strong and stabilized shared practices: didactics (Powers, 2012), industrial (Clow. 1992; Aftalion, 2001), and experimental (Holmes, 1989). Since then, 1818, it has undergone four major transformations, characterized by the appropriation and accumulation of new epistemic objects or "hidden entities", the first of them chemical atoms, that continue to be used today, and by the emergence of new subdisciplines such as organic chemistry, physical chemistry, instrumental chemistry, and organometallic chemistry, among others.

Transformation incorporates novelty into persistence (Chamizo, 2022). We transform what already exists, what we have, and after doing so, something of what we had always remains, a minimal common ground that in the case of chemistry refers to its method: analysis and synthesis. Transformations are not absolute changes. After a transformation, the questions and criteria for acceptable answers are changed; its practitioners work in separate fields. After a transformation, different "exemplars" are introduced that incorporate new entities, which their practitioners share, thus changing the way chemistry is practiced. In addition, the transformations are cumulative, each one of them adds these new entities to the common ground, which allows building more detailed models of chemical reactions. In brief, transformation is continuation and modification. The most relevant characteristics of the four chemical transformations are shown in Table 1.

Table 1. Most important characteristics of chemical transformations

Trans formation	**New instruments**	**New subdisciplines**	**New entities**	**New industrial developments**	**Alternative name**
First (1828-1874)	Kaliapparat, polarimeter	Organic chemistry	Molecule	Techno-chemistry	Silent Revoliution (Rocke 1993)
Second (1887-1923)	Cathode rays tube, mass spectrometer	Physical chemistry	Electrons, Atomic nuclei, Ions, Radicals	Chemical engineering-Unit operations	Atomic number revolution (Wray, 2018)
Third (1945-1966)	Ultraviolet and infrared spectrometers, Nuclear magnetic resonance, Electron paramagnetic resonance, X-rays crystallography, chromatographs	Instrumental analysis, Quantum chemistry, Molecular biology	Spin, Orbitals	The words 'plastic' identified a valuable attitude, even though they also characterized the emerging global consumer society	Instrumental revolution (Morris, 2002)
Fourth (1973-1999)	Electron capture detector, Scanning tunneling microscope, Femtosecond spectroscopy	Organometallic, Green, Nano, Supramolecular, Femto, Chemistry	Nanoparticles	Recombinant DNA technology and combinatorial chemistry was used for the design of medicines.Ciba, Geigy and Sandoz merged in Novartis. Biotechnology.	Organo metallic historical regime (Llanos, 2019)

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