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ORIGINAL ARTICLE

Art and chemistry: the topochemical principle and *Las Meninas* of Velázquez

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Abstract The present paper is intended to expose an example of similarity in chemistry and in painting not based on shape or common origin but rather on the concepts they involve. I partly wrote this text in the 1980s. I was then learning solid state chemistry at the Weizmann Institute in Israel. At that time, it became evident to me that there was a possible link between a reaction in the crystalline state and one of the many interpretations of *Las Meninas* of Velázquez. More precisely, I asked myself if a relation might be found between an organic reaction in a crystal governed by the topochemical principle and the interpretation given by the French philosopher, Michel Foucauld, in his book *The Order of Things*, of *Las Meninas* in terms of the topology the gazes of the depicted figures.

Keywords Chemistry · Art · Topochemistry · *Las Meninas*

From the world of chemistry we can ask ourselves: do we really make efforts to establish connections between our profession and the art forms that bear some relationship to it? Do those of us who teach chemistry in high schools or universities try to stimulate our students to realize that a chemical element, a compound or a reaction can also belong to the world of art? Will a day arrive in which a search for a given compound in chemical databases will provide us with information on paintings, films, and musical or literary works connected in one or another way with that compound?
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Science and art naturally overlap. Both are a means of investigation. Both involve objects, ideas, theories, and assumptions that are tested in places where mind and hand come together—the laboratory and studio. Artists, like scientists, study materials, people, culture, history, religion, mythology, and learn to transform information into something different. In ancient Greece, the word for art was *techne*, from which *technique* and *technology* are derived—terms that are aptly applied to both scientific and artistic practices. Exploring the similarities in their respective early work, Arthur I. Miller published an article [1] entitled: '*Einstein, Picasso*' in which he proposed that the Spanish painter, Pablo Picasso, and, the German physicist, Albert Einstein, were both influenced at the beginning of the twentieth Century by the book, *La Science et l'Hypothèse*, published in 1902, by the French mathematician Henri Poincaré. In his book, Poincaré speculated that geometries different from the Euclidian classical geometry could be developed and represented in curved spaces and higher dimensions. Picasso exhibited *Les Demoiselles d'Avignon* in 1907, opening the way to Cubism, while Einstein published his *Theory on Relativity* in 1905. This is a rare example showing the birth of an idea in science and art from the same original problem: the nature of time and simultaneity resolved by realizing a new aesthetic. At the birth of creativity, boundaries dissolve between disciplines.

Ideas come from objects and their representation, and one can assume that the same idea may come separately in science and art. This is often found when simply comparing images coming from science and art. For instance, the work of the Deutsch artist Maurits Cornelis Escher has been referred to many times by crystallographers and mathematicians because of his ability to use and draw objects with original and uncommon symmetries. The same was done with the geometrical paintings of the Hungarian painter Victor Vasarely. With the development of computers, many scientific images in biology or physics have been compared

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with artistic digital paintings because they are similar in colour, shape and appearance. Many examples can be found in contemporary popular literature.

The present paper is intended to expose an example of similarity in chemistry and in painting not based on shape or common origin but rather on the concepts they involve.

I partly wrote this text in the 1980s. I was then learning solid state chemistry in the laboratory of Professors Meir Lahav and Leslie Leiserowitz at the Weizman Institute in Israel. At that time, it became evident to me that there was a possible link between a reaction in the crystalline state and one of the many interpretations of *Las Meninas* of Velázquez. More precisely, I asked myself if a relation might be found between an organic reaction in a crystal governed by the topochemical principle [2] and the interpretation given by the French philosopher, Michel Foucauld, in his book *The Order of Things*, [3] of *Las Meninas* in terms of the topology the gazes of the depicted figures. I decided to publish this text now after reading a text entitled: '*Eloge paradoxal de Michel Foucauld à travers "Les Ménines"*'in which, the author, Daniel Arasse, a French critique of art declares that '*Foucauld has launched such a theoretical engine that anyone willing to write a theory on painting will be obliged, at a moment or another, to be interested in Las Meninas*' [4]. This was exactly what I felt at the moment when I started to write this paper.

In the present text, I will try to show how objects representative of an ensemble—the organic molecules for the crystal and the figures painted in *Las Meninas*—have relations that allow the elimination of their respective identities to lead to a common representation unique in the relations. This unique relational representation for the two ensembles allows the elimination of the objects forming these ensembles to give *a purely topological interpretation or description*.

An organic solid state reaction

Organic chemistry deals with the elaboration of novel molecules and materials by new syntheses, with studies of reaction mechanisms, and focuses its effort on *the study of the reactivity of organic molecules in fluid media*. When they are in more structured or more rigid phases, as for instance crystals or biological and/or supramolecular systems, molecules are submitted to constraints due to intermolecular interactions and reactions usually occur under *topochemical control* [2]. This means that the functional groups and the reacting atoms, involved in the reaction process, are disposed such as to direct the reaction and make it as specific as possible [2]. In relation to this article, the study of *the reactivity of organic molecules in the crystal state* shows that there is a correlation between the crystalline structure and the observed reactivity.

The *topochemical principle* proposed by Cohen and Schmidt [2] implies that a reaction taking place in the solid state occurs with a minimum of atomic movements. An extension of this principle, concerning $(2\pi + 2\pi)$ topochemical reactions, holds that the phenomena observed (highly selective reactions, reactions more rapid in the solid state than in solution, absolute asymmetric syntheses, etc.) for a reaction in the solid state are often explained by the geometrical arrangement of atoms and reactive groups in the bulk of the crystal.

One of the best examples of the influence of the chemical topology in a crystal phase is the rearrangement of *p*-dimethylaminobenzene methyl sulfonate **I** into *p*-trimethylaminobenzene sulfonate **II** [5] (see Fig. 1, left). This thermal rearrangement **I** → **II** is *favoured in the crystalline phase and slowed down in solution* [5]. This behaviour is unexpected for chemical reactions that are known to necessitate the collision of molecules. In the crystal packing, neighbouring molecules **I** are disposed head to tail, probably by electrostatic attraction, with the two benzene rings making an angle of 76°. Thus, each nitrogen atom is aligned with one SO_3–CH_3 group at a distance ~3.54 Å from the carbon atom of the methyl group. The angle O (1)–C (9)···N is 147°, close to that required for a transition state of the S_N2 type. In these circumstances, the methyl group can be easily transferred from the SO_3–CH_3 group onto the neighbouring nitrogen atom (see Fig. 1, right) [3].

Of fundamental significance is the fact that such a reaction need not be analysed by means of traditional *kinetic or thermodynamic methods* but rather simply by study of the geometrical disposition of molecules in the crystal. The transition state is no longer an abstraction

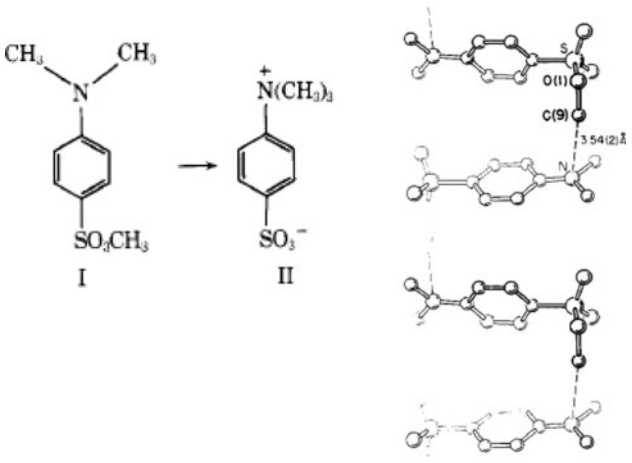

Fig. 1 Thermal rearrangement of *p*-dimethylaminobenzene methyl sulfonate **I** into *p*-trimethylaminobenzene sulfonate **II** (*left*) and molecular packing of **I** (*right*). [5]

associated with an energy diagram but a *geometrical reality* in which a portion of the pathway of atoms from the starting compound to the product can be drawn.

A related important observation is that the organic molecules are not only the elements which are *going to react* but they are also the elements *organising themselves* to allow the reaction. They are *interacting* through their functionalities to induce an arrangement suited to reaction within the crystal. The crystal is *self-built* to react. In a sense, we can assume that the functional groups are both the reacting centres and the tools for constructing the crystal. The whole combination of the structural properties of the crystal and of the molecules is self-ordered to give rise to an assembly of *cooperative* elements.

The identity of the crystal is no longer defined solely by its structural and regular 3D-arrangement characterised by the crystal parameters or the crystal close packing in the sense of Kitaigorodskii [6] or interactions-directed engineering of the crystal in the sense or Dunitz and Gavezzotti [7]. Its new identity is its intrinsic reactivity and all the events involved in leading to this reactivity.

The topology of regards in *Las Meninas* of Velázquez

Figure 2 reproduces *Las Meninas* of Velázquez. *Las Meninas* (also known as *The Maids of Honour*) painted in 1656, is a work of the Spanish painter Diego Velázquez. Velázquez died in 1660 and *Las Meninas* is a work of the end of his life. For this reason, one can believe that it is a work of intellectual maturity. The individuals depicted in the painting are all known and were described by Antonio Palomino, who arrived in Madrid in 1678 to be appointed official painter to King Charles II [8]. He knew all of Velázquez' subjects.

One of the most important challenges in XVIIth century painting—namely the *representation of the space*—finds a brilliant resolution in *Las Meninas.* Although it is large, the room is in proportion with the personages [3]. The depth is created by the perspective of the wall and the pictures hanging on it and by the size, which gradually decreases, of the human figures, as well as the open door in the background [3]. In addition, the reflection in the mirror of the king and the queen, otherwise invisible to the viewer, provides an extended dimension to the main scene [3]. Considering the whole space and the identity of the figures, the French philosopher Michel Foucauld provided an interpretation of the painting, based on the play of gazes of the personages, in the introduction of his book, *The Order of Things* [3]. He argues that the first impression is that: *'In appearance, the situation is simple; a matter of pure reciprocity: we are looking at a picture in which the painter is in turn looking out at us'*. This is also true for the figures

Fig. 2 *Las Meninas* of Velasquez

whose exact identity is known. After a precise and detailed description of the part located behind the painter and the figures, Michel Foucauld explains the *'apparent reciprocity'*. The gazes of the painter and the figures are focussed on two other personages, *'Philippe IV and his wife Marianna',* whose faces we see in the mirror hanging on the wall behind the painter.

In this preliminary step, the painting seems to be understood as a topology of the gazes directed toward the royal couple, who are standing to regard the painter. However, a deeper analysis shows that the centre of *'convergence of the glances'*, which is occupied by the king Philippe and his wife, is in fact the point from which the present scene is seen.

> In the realm of the anecdote, this centre is symbolically sovereign since it is occupied by King Philip IV and his wife. But it is so above all because of the triple function it fulfils in relation to the picture. For in it there occurs an exact superimposition of the model's gaze as it is being painted, of the spectator's as he contemplates the painting, and of the painter's as he is composing his picture (not the one represented but the one in front of us which are discussing). These three 'observing' functions come together in a point exterior to the picture: that is, an ideal point in relation to what is represented, but a perfectly real one too, since it is also the starting-point that makes the representation possible. Within that reality itself, it cannot be invisible. And yet, that reality is projected within the picture – projected and diffracted in three forms which correspond to the three functions

of that ideal and real point. They are: on the left, the painter with his palette in his hand (a self-portrait of Velázquez); to the right, the visitor, one foot on the step, ready to enter the room; he is taking the scene from the back, but he can see the royal couple, who are the spectacle itself, from the front; and lastly, in the centre, the reflection of the king and the queen, richly dressed, motionless, in the attitude of patient models [3].

In this *va-et-vient* (toing-and-froing) of the observation of *Las Meninas*, one has first to reflect on the trajectory described by the gaze of each element of the '*frieze that occupies the foreground and the middle ground of the picture*', namely eight characters (including the painter) and then upon its connection to the regard of the characters at the background (the couple reflected in the mirror and the visitor). Foucault defined the problem as follows: '*What is the spectacle, what are these faces that are reflected first of all in the depths of the Infanta's eyes, then in the courtiers' and the painter's, and finally in the distant gleaming glow of the mirror ?'*. It is possible to find here a *recursive* phenomenon where each gaze shows a 'reflection' or a feed-back: *'the face reflected in the mirror is also the face that is contemplating it; what all the figures in the picture are looking at are the two figures whose eyes they too present a scene to be observed.'*. Indeed, *'The entire picture is looking out at a scene for which it is itself a scene.'*

Discussion

The example of *cooperativity* in a reaction within a crystal is similar to that observed for a crystal which has piezoelectric properties described by Gaston Bachelard in *Rationalisme Appliqué* [9]. The author notes: *'The crystal obtained by techniques so carefully designed is not only matter endowed with a geometrical character. It is an apparatus where an operation is performed.'* Further, he states: *'The physics eliminates the* quantity *which was used to establish relations to focus upon the concept of the relations themselves.*

Similarly, the organic crystal where the reaction takes place need no longer be defined by the molecules or the parameters usually used to describe crystals. It can be defined by a set of relations to be specified by chemist with *a new intuition* and who eschews the traditional representation of a crystal. Recently, Desiraju in a text entitled: '*Chemistry – The middle kingdom*' [10], reported that crystallization and more generally chemistry involving crystals provides a convenient introduction to chemists of the notion of *complexity*. Closely allied to the notion of complexity is the idea of *emergence*. Emergent phenomena are structures, behaviours, events or patterns that arise only when a large number of individual agents (in our case packed molecules) somehow aggregate. Similar to the painting of Velázquez, this emergence comes from the play of molecular interactions, overriding the intrinsic behaviour of molecules and which gives rise to a new field which is more than chemistry itself, based on what we have termed before a new *intuition*.

To sum up, this new intuition is based on the setting up of an emergent order of interactions. Recently, an interview [11] given by two French biochemists, Pierre Sonigo et Jean-Jacques Kupiec, concerned a similar elision of the central subject of a study. Speaking about genetics, they propose a new intuition about genes: *'Cells are self-developing for themselves'* and are not guided by rules expressed in a specific scientific idea. *'Genetics places the fundamental explicative level in the genes, we propose to place it higher in the hierarchy of structures, in the cell, the basic unit of living systems… In fact we do not replace genetics; we go beyond it and we deny a central role to the gene'* [11].

Similarly also, in *Las Meninas* of Velázquez *'it is not possible for the pure felicity of the image ever to present in the full light both the artist who is representing and the sovereign who is being represented'*. There is in both cases—the one of the crystal and the one of the painting—a topological operation which implies that their representation is *'freed finally from the relation that was impeding it'*. The subject which is shown—the molecules or the painted figures—is abstracted to leave just a set and a pattern of relationships that '*can offer itself (the representation) as a representation in its pure form'* without the need for their simple description by geometry or painting. For the crystal, this abstraction is made possible by the play of intermolecular forces and the topology of the reacting functions while for Velázquez's painting, it depends upon the play of glances and the topology of this play.

Velázquez clearly wished that this topological play should operate upon him, too. From a topological point of view, one can observe that Velázquez did not follow the « rules » of the self-portrait to represent himself, but rather he preferred to be one of the figures in full-view (that is the painter). Otherwise, the brush would be in his left hand and not in the right one and, in accord with the reciprocity principle, the painting would be the view in the mirror. Velázquez is really one constitutive element of the '*frieze*', a link in the chain *regardant-regardé (watching-watched).* Recent events (subsequent to the publication of Michel Foucauld's book) have complicated analysis of the painting, since Velázquez painted his work after the birth of a son, Prospero, from the king and queen, and radiography has shown that in the original painting, now

invisible, a servant was giving a royal sceptre to the Infanta as she was to be the Queen. The birth of a Royal Son removed her right to be sovereign [4].

However the question remains: was Velázquez left-handed? This new interrogation is reminiscent of the problem to determine if a chiral crystal is left- or right-handed without any external reference.

This text was mainly written at the beginning of the 1980s. Another more general conclusion can be given due to the evolution of research in chemistry and other field of knowledge. I have shown how objects representative of an ensemble—the organic molecules for the crystal and the figures painted in *Las Meninas*—have relations that allow the elimination of their respective identities to lead to a common representation unique in the relations. This unique relational representation for the two ensembles allows the elimination of the objects forming these ensembles to give *a purely topological interpretation or description*. Considering new findings in chemistry and other fields of thought, the elimination of objects under consideration maybe compared to the *general principle of emergence*. Emergence is often described as '*the whole is more than the sum of its parts*' and has been applied to supramolecular chemistry [12, 13].

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