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Chemistry and History

Pasteur's Resolution of Racemic Acid: A Sesquicentennial Retrospect and a New Translation

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This classic experiment radically changed our view of the world and opened up new paths of research.

In the mind of the general public the name of Louis Pasteur (1822–1895) [1–4] (Figure 1) is inextricably linked with the science called bacteriology in his day and microbiology in ours. Yet we chemists can justifiably claim him as our own, for the discovery that first brought fame to this 25-year-old, relatively obscure *préparateur en chimie* at

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In this section we present articles by leading scientific historians that chronicle the important events, persons, and publications that make up the rich history of chemical science. The history of chemistry, of course, has taken place against the background of world history, and the articles in this section often make that very clear. Chemists and their research are always influenced by current events. These articles are intended to describe the setting in which important discoveries occurred and to humanize their discoverers.

—Clifford LeMaster, Editor in Chief

FIGURE 1. LOUIS PASTEUR (1822–1895) (CARICATURE FROM *Vanity Fair*, 1887).

Paris’s Ecole Normale Supérieure, was his famous discovery enantiomorphism among the salts of racemic acid in 1848, 150 years ago. In keeping with the popular view of Pasteur as a bacteriologist, William Dieterle in his 1936 biographical motion picture “The Story of Louis Pasteur,” nominated for an Academy Award for best picture, deals only with the French scientist’s bacteriological achievements, especially on anthrax and the pasteurization of milk. Film buffs and erudite connoisseurs of cinematic trivia, however, will recall that the movie does acknowledge that Pasteur, played by Paul Muni, who won an Oscar as best actor for his portrayal, was a chemist, but that his chemical research is referred to in a negative manner. One scene depicts an apparently fictional Dr. Charbonnet telling Emperor Napoléon III about Pasteur, who has written a pamphlet on puerperal (childbed) fever: “He isn’t even a doctor, Sire; he’s a mere chemist.” This slap at chemistry is not an isolated example, for in a second scene another fictional character, a Dr. Radisse of the French Academy of Medicine, learning

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of Pasteur's work on anthrax, sputters indignantly, "Not Louis Pasteur, that...that chemist!" No wonder the film completely ignores Pasteur's first and most famous resolution of an optically active compound, the topic of our commemorative article!

Yet Dieterle missed an opportunity to include a scene that would delight the typical Hollywood producer or filmgoer, for Pasteur's resolution was so surprising that Jean-Baptiste Biot (1774–1862), at 74 the grand old man of French science, demanded to see the evidence at first hand. The venerable physicist insisted that Pasteur repeat the experiment in Biot's laboratory at the Collège de France with Biot's reagents and under Biot's supervision. When Biot observed the strong levorotatory deviation of the solution (All previously known tartrates were dextrorotatory), the illustrious old man, visibly choked with emotion, took young Pasteur by the arm and said, *"Mon cher enfant, j'ai tant aimé les sciences dans ma vie que cela me fait battre le coeur"* (My dear child, I have loved science so much throughout my life that this makes my heart throb) [5b]. On that day there began between the two scientists, differing in age by almost half a century, one of the most touching relationships in the history of science. How could Hollywood, with its penchant for sentimentality, have improved upon this scene?

Pasteur's resolution immortalized his name in the annals of chemistry. His discovery that one of the forms of a salt of racemic acid consists of two optically active isomeric constituents laid the groundwork for the science of stereochemistry, the study of the spatial arrangement of atoms in molecules. He attributed their activity to what he called "molecular asymmetry" (*une dissymétrie dans les molécules*), a phrase selected as the title of the first volume of his collected works [6] and inscribed on his mausoleum at the Institut Pasteur in Paris.

This resolution belongs to a small group of classic experiments that radically changed our view of the world and opened up new paths of research, yet are simple enough to be duplicated by a skilled undergraduate student [7–10]. It has had a profound influence on research in stereochemistry, crystallography, biology, biochemistry, mineralogy, pharmaceutical chemistry, and organic and inorganic chemistry, to single out only a few of the fields that have benefited from Pasteur's genius. Although this resolution, in which Pasteur discovered an anomaly that had been overlooked by his predecessors, has been widely considered a classic case of serendipity (an accidental discovery of something that was unsought in the course of seeking something

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else) [11–15], especially in view of his often quoted maxim, *“Dans le champs de l’observation, l’hasard ne favorise que les esprits préparés”* (In the fields of observation, chance favors only those minds that have been prepared) [16], Mauskopf [17] and Geison [3] have argued that it “was a particularly logical and even inevitable fruition of [earlier] French scientists [Delafosse and Laurent]” [17, p 79].

Optical Activity [7, 8, 10]

In the late seventeenth century Dutch physicist Christiaan Huygens (1629–1695) had observed that visible light passing through a crystal of Iceland spar (a transparent variety of calcite, $CaCO_3$) vibrates in only one plane, i.e., it is plane polarized. In 1812 the above-mentioned Biot found that when plane-polarized light is rotated through a quartz plate cut perpendicular to its crystal axis, the plane of polarization is rotated through an angle proportional to the thickness of the plate, sometimes to the left, sometimes to the right. In 1815 Biot discovered that such rotation also occurs when plane-polarized light passes through certain naturally occurring organic liquids, e.g., oils of lemon, laurel, or turpentine; sugar; or camphor. Such substances, which can deviate the plane of polarized light in this way, are said to be optically active.

Biot recognized that quartz’s optical activity is a property of the crystal while that of the above organic substances is a property of the individual molecules because it is observed even in solution. Furthermore, the Abbé René Just Haüy (1743–1822), a French mineralogist, found that quartz crystals are hemihedral, i.e., they possess only half the number of faces required by the symmetry of the crystal system to which they belong. Some crystals show hemihedral faces oriented to the left and some to the right; they are nonsuperimposable mirror images (enantiomorphs) of each other. The degree of rotation can be observed and measured by a polarimeter. In 1820 astronomer and physicist Sir John (William Frederick) Herschel (1792–1871) discovered an important relationship between the optical rotatory power of quartz and its crystalline form; he correlated the direction of its optical rotation with the sense of the hemihedrism of its crystals.

The Tartrates and Paratartrates [7, 8, 10, 18]

Pasteur began his study of optical activity as a property of molecules with two isomeric compounds and their salts. One, an optically active organic compound,

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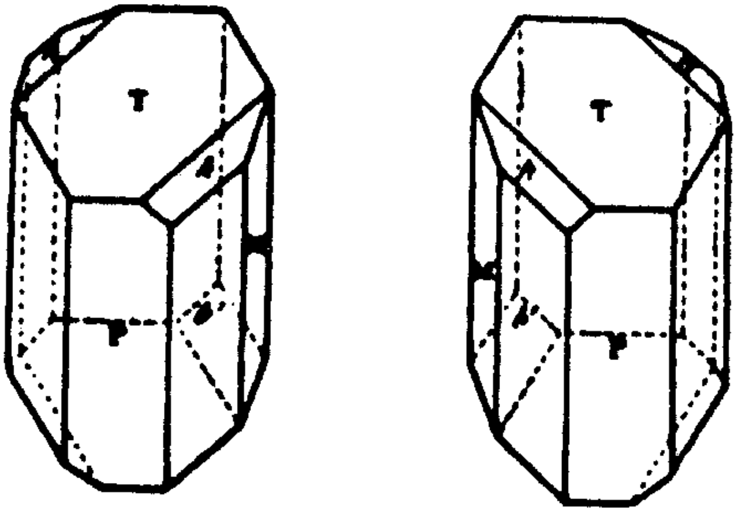
tartaric acid (2,3-dihydroxybutanedioic acid, $H_2C_4H_4O_6$ or $(CHOH.COOH)_2$), a constituent of many plants, was known to the early Greeks and Romans in the form of its potassium acid salt (tartar, $KHC_4H_4O_6$), obtained as a deposit from fermented grape juice (hence, the acid is known in German as *Weinsäure*). It was Swedish chemist and apothecary Carl Wilhelm Scheele (1742–1786) who first isolated the free acid [19]. Its optical activity in solution was discovered by Biot, who showed it to be dextrorotatory (rotating the plane of polarized light to the right) [20].

A second form of this acid, known as paratartaric acid by Pasteur, was obtained from crude tartar around 1819 by Paul Kestner, a French manufacturer of tartaric acid, who mistook it for oxalic acid ($H_2C_2O_4$ or HOOC.COOH). J. F. John recognized it as a distinct compound, and in 1828 French chemist Joseph Louis Gay-Lussac (1778–1850) gave it the name by which it is now known, racemic acid (*acide racémique*, from the Latin *racemus*, for a bunch of grapes), and showed that it has the same chemical composition as tartaric acid. In 1830 Jöns Jacob Berzelius (1779–1848), the leading chemist of the day, called it “acid of grapes” (*drufsyra* in his native Swedish; *Traubensäure* in German) and referred to it and tartaric acid as *isomeriska kroppar* (isomeric bodies) [21]. In 1831 he again cited these acids as examples of compounds having the same chemical composition but different properties, a phenomenon that he called *isomeri* (isomerism from the Greek, *ισομερης*, composed of equal parts) [22].

Pasteur’s Classic Resolution [7, 8, 10, 23, 24]

In 1838 Biot found that racemic acid, unlike its isomer, tartaric acid, was optically inactive [25]. Frédéric Hervé de la Provostaye (1812–1863) [26], Carl Remigius Fresenius (1818–1897) [27], and one of the most distinguished crystallographers of the day, Eilhard Mitscherlich (1794–1863) [28] of isomorphism fame prepared, analyzed, and characterized the acids or their salts. To gain practice in research on crystals Pasteur repeated de la Provostaye’s work and discovered something that de la Provostaye had overlooked: crystals of tartaric acid and its salts, which had previously been shown by Biot to be optically active in solution [20], are hemihedral, whereas crystals of paratartaric (racemic) acid, its optically inactive isomer, and its salts—with one important exception—were not. In repeating the work of Mitscherlich, who had examined the sodium ammonium salts of tartaric and racemic acids and found them to be identical in crystalline form except that the former was optically active and the latter was not, Pasteur noticed an unusual anomaly that the older and more experienced



(a) Dextrorotatory (b) Lævorotatory

FIGURE 2. HEMIHEDRAL CRYSTALS OF SODIUM AMMONIUM TARTRATES (PASTEUR).

Mitscherlich had overlooked. A dozen years after this revolutionary discovery Pasteur recalled it as follows [5b, p 19]:

> I found...that the tartrate was hemihedral..., but strange to say the paratartrate was hemihedral also. Only the hemihedral faces which in the tartrate were all turned the same way, were, in the paratartrates inclined sometimes to the right and sometimes to the left.... I carefully separated the crystals that were hemihedral to the right from those hemihedral to the left, and examined their solutions separately in the polarizing apparatus. I then saw with no less surprise than pleasure that the crystals hemihedral to the right deviated the plane of polarization to the right, and that those hemihedral to the left deviated it to the left; and when I took an equal weight of each of the two kinds of crystals, the mixed solution was indifferent towards the light in consequence of the neutralization of the two equal and opposite individual deviations.

Pasteur had mechanically separated the two types of sodium ammonium paratartrate (racemate) crystals from an equimolar mixture of dextrorotatory (+) and previously unknown levorotatory (–) tartrates (Figures 2 and 3); however, there were two elements of sheer luck in his discovery. First, with the possible exception of the sodium potassium salt (Rochelle salt, $NaKC_4H_4O_6.4H_2O$), the sodium ammonium salt

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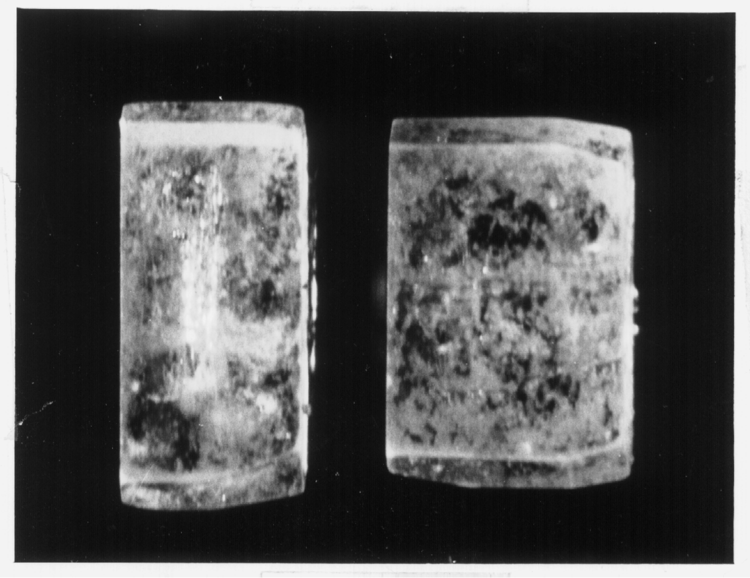

FIGURE 3. ACTUAL CRYSTALS OF SODIUM AMMONIUM TARTRATE: *d* OR (+) FORM (ON LEFT); *l* OR (–) FORM (ON RIGHT) [7].

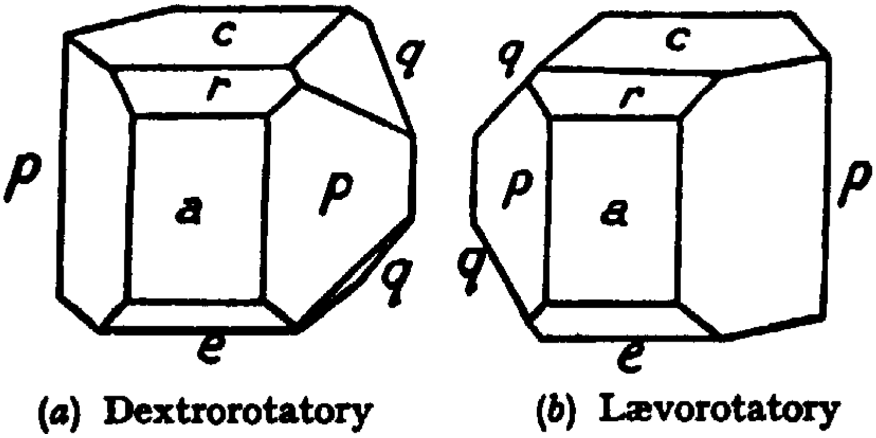

FIGURE 4. HEMIHEDRAL CRYSTALS OF TARTARIC ACID (PASTEUR).

is the only inactive tartrate that undergoes conglomerate crystallization and can be mechanically resolved in this manner because the two forms of tartaric acid (Figure 4) and the two forms of all its other salts combine to form crystalline racemic acids (Figure 5) and racemates, respectively, which show no hemihedrism or optical activity. Second, Pasteur carried out his experiments in the cool Parisian climate rather than in a Mediterranean or tropical one, say in the French Riviera. In the latter case he would

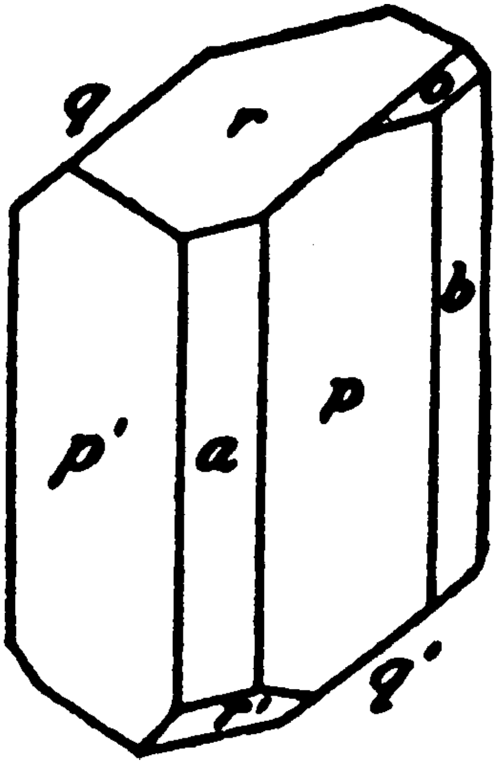

FIGURE 5. HOLOHEDRAL CRYSTAL OF RACEMIC ACID (PASTEUR).

not have made his revolutionary discovery, for it was later found that the two sodium ammonium tartrates unite to form a single inactive, holohedral racemate at temperatures above 26° C. (78.8° F). See Figure 6.

The Translation

To commemorate the sesquicentennial of Pasteur's resolution we offer below our translation of the first public announcement of this momentous discovery [24] reported to the Parisian Académie des Sciences on May 15, 1848 and published on May 22, 1848. In order to preserve the flavor of the original we have retained Pasteur's nomenclature. We have chosen it for three reasons: (1) It is short (4 pages) and relatively nontechnical. (2) It is a preliminary report intended to establish priority; it possesses a freshness and immediacy, uncontaminated by material added later by Pasteur to improve his public image and foster the myth that he was a genius and scientific hero above reproach, a practice to which he was particularly prone, as Gerald Geison has demonstrated in his recent critical biography [3, 29]. (3) To the best

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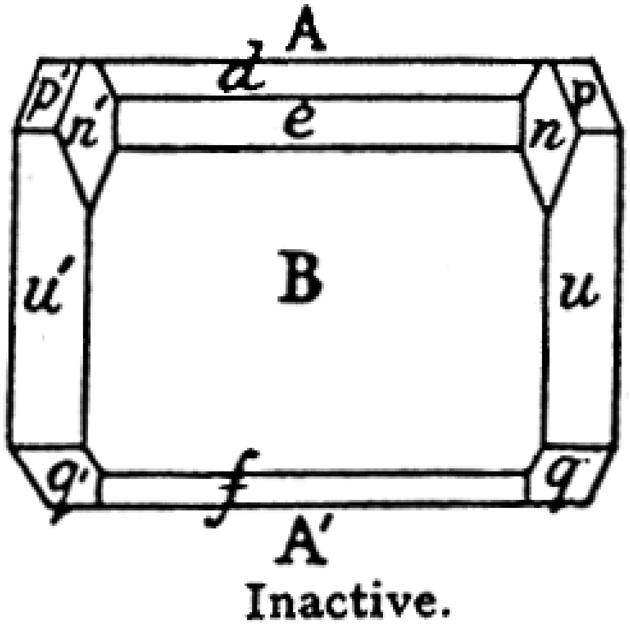

FIGURE 6. HOLOHEDRAL CRYSTAL OF SODIUM AMMONIUM RACEMATE (SCACCHI, A. *REND. ACCAD. SCI. FIS. MAT., NAPOLI* **1865**, *4*, 250).

of our knowledge, it has never appeared in an English translation. However, the report was apparently transcribed by a nonscientist, perhaps a secretary, attending Pasteur's talk who did not give Pasteur the opportunity of editing or correcting the transcript. The language is informal and in spots obscure and difficult to understand, which leads one to surmise that Pasteur may have been speaking from, at most, meager notes. With the help of several knowledgeable colleagues who critically examined our effort, we have tried to render the report into reasonably comprehensible English without violating the spirit of the original. The reader can decide how well we have succeeded by comparing the translation with the French report which is reproduced below it.

Comptes rendus hebdomadaires de l'Académie des Sciences, Paris, **Seance of May 15, 1848**, *26* (21), 535–538 (Published on May 22, 1848).

Memoirs Read.

CHEMISTRY—*Memoir on the relation that can exist between crystalline form and chemical composition, and on the cause of rotatory polarization*; by Monsieur **L. Pasteur**. (Extract.)

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(Commission members, Mssrs. [Jean-Baptiste] Biot [1774–1862], [Henri Victor] Regnault [1810–1878], [Jacques] Babinet [1794–1872], [Antoine Jérôme] Balard [1802–1876])

If the crystalline forms of all the tartrates, whatever they may be, including the emetics [$K[(SbO)C_4H_4O_6]\cdot 1/2H_2O$], are compared, it will be readily noticed that in all these forms some facets among them have similar interfacial angles. On placing these forms in order, one will have a series of prisms diversely modified at the extremities and on the edges of the faces. But these latter modifications, relative to the edges of the faces, will be repeated in all the prisms, with the same angles or nearly so. The forms could belong to different systems, and together with a rhombohedral prism one could find a right or oblique rectangular prism or even an entirely oblique prism of the latter crystalline system; but, nevertheless, the facial angles or those of the modified facets will differ very little, one from another. When two forms are not of the same system, one will be a limiting form of the other. Here I disregard the extremities of the prisms, and, indeed, it is only by the extremities of the prisms that the crystalline forms of all the tartrates differ. No matter how the chemical composition varies, these relations do not change, and one recognizes them in the neutral salts compared with each other, as well as with the acid salts, with the double salts, and, finally, with the emetics.

I therefore think that it is impossible to doubt that a certain molecular group remains constant in all of these salts; that the water of crystallization, the bases, relegated to the extremities of this group, modify it only at these extremities, hardly affecting the central molecular group and then corresponding to the difference of the angles observed between the facets. Certainly here I only confirm what all chemists would say, namely, that among all the salts of the same acid, there is something in common. However, these facts show us, furthermore, the close relationship that exists between crystalline form and molecular constitution, and what crystallographic studies can reveal about the arrangement of the atoms [These conclusions show the strong influence of August Laurent (1807–1853), which Pasteur initially acknowledged but later ignored [3; 17, pp 68–79]].

Let us leave aside the tartrates for a moment and compare in the same manner the crystalline forms of all the paratartrates [modern, racemates]. One will find that they show among themselves something in common, and, what will be surprising at first sight, because of the well-known isomerism of these salts, their relation is absolutely

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the same as in the tartrates. All the forms differ only by the extremities of the corresponding prisms; but furthermore, the angles of the faces and of their modifications are nearly the same as in the tartrates. In such a way there exists a molecular group common to all the paratartrates, and this group is the same as in the tartrates.

This conclusion, deduced from crystallographic studies, is in disagreement with chemical observations. The isomerism of these two kinds of salts is well known, that is, the molecular arrangement of paratartaric acid differs from the molecular arrangement of tartaric acid; [and] it is the same with their salts. If the extremities of the molecular group common to the tartrates and to the paratartrates were not modified in the same manner by the introduction of new elements in the tartrates and paratartrates, one would still understand the isomerism of these salts. In fact, this is what occurs in general, that is, if one compares all the tartrates, as I have said, only the extremities of the forms will be different. But let one compare a particular tartrate, and one will see immediately, without a shadow of a doubt in this regard, that in this tartrate the two extremities of the prism are dissymmetric. The law of the renowned [René-Just] Haüy [1743–1822], which requires that identical parts be modified in the same manner, is violated. [Haüy’s law states that for a given crystal there is a set of ratios such that the ratios of the intercepts of any crystal plane on the crystal axes are rational fractions of these ratios.] In short, all the tartrates are hemihedral. Thus this molecular group common to all these salts, which is modified in the extremities by the introduction of water of crystallization and of oxides, does not receive the same elements in these two extremities, or at least, they are distributed in a dissymmetric manner. On the contrary, in most of the paratartrates that I have examined, I have never observed anything indicating the hemihedrism of these salts.

I have just said that in most but not in all the paratartrates I have not found any hemihedral crystals. In fact, one of these salts is hemihedral, and it is here that we are approaching the true cause of rotatory polarization. It is known, in fact, since Monsieur Biot’s beautiful and extensive researches, that many organic substances possess the peculiar property of deviating the plane of polarization of light rays in solution. It is also known that one of the main differences between the tartrates and the paratartrates is the fact that tartaric acid and the tartrates deviate the plane of polarization, whereas paratartaric acid and its salts do not deviate it. There even exists a quite curious observation of Monsieur [Eilhard] Mitscherlich [1794–1863] concerning this

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difference between the two types of salts. As the note where this observation is recorded is very short, I am going to reproduce it here just as he addressed it to the Académie [des Sciences] through Monsieur Biot's intermediacy [*Compt. rend.* **Oct. 14, 1844,** *19*(16)**,** 720]:

> The (double) paratartrate and tartrate of sodium and ammonium have the same chemical composition, the same crystalline form with the same angles, the same specific gravity, same double refraction, and consequently, the same angles between the optical axes. Dissolved in water, their refraction is the same; but the dissolved tartrate rotates the plane of polarized light, and the paratartrate is indifferent, as Monsieur Biot found for all the series of these two kinds of salts; but here the nature and the number of the atoms, their arrangement, and their distances are the same in the two substances compared.

Such is Monsieur Mitscherlich's observation. Concerning the inactivity of the paratartrate on polarized light, Monsieur Biot has repeated the experiment of the learned chemist of Berlin on a sample of the paratartrate that Monsieur Mitscherlich had sent to him. Well, by the greatest of chances Monsieur Mitscherlich was led into an error as was Monsieur Biot in turn. The paratartrate of sodium and ammonium deviates the plane of polarization: but, among crystals coming from the same sample, there are some which deviate the plane of polarization to the left, [and] others to the right; and when there are as many of one kind as of the other, the solution is inactive; the two opposite deviations neutralize each other. Now here is the crystallographic difference between these two kinds of crystals. They are all hemihedral, but there are some that are hemihedral to the right, others to the left, and the direction of this deviation depends on this disymmetry. When I want a deviation to the right, I choose crystals hemihedral to the left; when I want a deviation to the left, I choose crystals hemihedral to the right [This is the exact opposite of Pasteur's later statement quoted above [5b, p 19]]. I also happened not to have any deviation when I had taken some mixed crystals without making any choice. Now is it not obvious that the property of deviating the plane of polarization, which certain molecules possess, has for an immediate cause, or at least is linked in the most intimate manner to, the dissymmetry of these molecules? for here are, in brief, the principal facts: Tartaric acid and the tartrates deviate the plane of polarization; they are all hemihedral. They deviate [the plane of polarized light] always to the right and are also hemihedral in the same direction. The paratartrates do not deviate; they are not hemihedral. One of them [the sodium ammonium paratartrate] does deviate and is thus hemihedral. It deviates sometimes to the right, sometimes to the left; this is because it is hemihedral, sometimes in one direction, sometimes in the other.

One will correctly say: All organic substances that deviate the plane of polarization when they are dissolved thus possess hemihedrism. I would have preferred to present this work to the Académie only after having examined organic bases, camphor, and other substances. But here one encounters great difficulties in research on hemihedrism. The beauty of the tartrate crystals [and] their large size has helped me considerably. However, I have been able to study easily sugar candy, and I can report, according to my own researches, that this substance is hemihedral and possesses a high degree of polar pyroelectricity. Indeed, it is by the study of this last very same property that I have been assured of the hemihedrism which I afterward ascertained by careful observation of the crystalline form. Subsequently, I found that this determination had already been made long ago by Dr. Hankel [Wilhelm Gottlieb Hankel (1814–1899) had shown a connection between the presence of hemihedral facets in potassium tartrate and its pyroelectricity (the property of certain crystals to produce a state of electrical polarity by a change of temperature) and had used the presence of pyroelectricity to identify hemihedrism in this compound].

Mémoires Lus.
CHIMIE.–*Mémoire sur la relation qui peut exister entre la forme cristalline et la composition chimique, et sur la cause de la polarisation rotatoire; par* M. **L. Pasteur**. (Extratit.)

(Commissaires, MM. Biot, Regnault, Babinet, Balard.)

« Si l'on compare les formes cristallines de tous les tartrates quels qu'ils soient, y compris les émétiques, on s'apercevra sans peine que dans toutes ces formes plusieurs facettes se retrouvent inclinées entre elles de la même manière. En plaçant toutes ces formes les unes auprès des autres, on aura une série de prismes diversement modifiés aux extrémités et sur les arêtes des pans. Mais ces dernières modifications relatives aux arêtes des pans se répéteront les mêmes dans tous les prismes, inclinées respectivement de la même manière, ou à très-peu près. Les formes pourront appartenir à des systèmes différents, et à côté du prisme rhomboïdal on pourra trouver le prisme rectangulaire droit ou oblique, ou même le prisme tout à fait oblique du dernier

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système cristallin; mais néanmoins les angles des pans ou ceux des facettes de modification différeront très-peu les uns des autres. Quand deux formes ne seront pas du même système, l’une sera pour l’autre une forme limite. Je fais ici abstraction des extrémités des prismes, et, en effet, c’est par les extrémités seules des prismes que diffèrent les formes cristallines de tous les tartrates. La composition chimique a beau varier, ces relations ne cessent pas d’avoir lieu, et on les retrouve dans les sels neutres comparés entre eux, et avec les sels acides, et avec les sels doubles, et, enfin, avec les émétiques.

» Je pense dès lors qu’il est impossible de douter qu’un certain groupe moléculaire reste constant dans tous ces sels; que l’eau de cristallisation, que les bases, reléguées aux extrémités de ce groupe, le modifient à ces extrémités seulement, ne touchant qu’à peine et dans la mesure de la différence des angles observés entre les facettes, à l’arrangement moléculaire central. Assurément je ne fais que confirmer ici cette opinion que tous les chimistes énonceraient, savoir, qu’entre tous les sels d’un même acide, il y a quelque chose de commun. Ces faits cependant nous montrent, en outre, l’étroite relation qui existe entre la forme cristalline et la constitution moléculaire, et le jour que l’on peut jeter, par les études cristallographiques, sur l’arrangement des atomes.

» Laissons de côté, pour un instant, les tartrates et comparons de même les formes cristallines de tous les paratartrates. On trouvera qu’elles présentent entre elles quelque chose de commun, et, ce qui surpendra au premier abord, à cause de l’isomérie bien connue de ces sels, leur relation est absolument la même que dans les tartrates. Toutes les formes ne diffèrent que par les extrémités des prismes qui leur correspondent; mais, de plus, les angles des pans et de leurs modifications sont à très-peu près les mêmes que dans les tartrates. De telle sorte qu’il existe un groupe moléculaire commun à tous les paratartrates, et que ce groupe est le même que dans les tartrates.

» Cette conclusion, déduite d’études cristallographiques, est en désaccord avec les observations chimiques. L’isomérie de ces deux genres de sels n’est pas douteuse, c’est-à-dire que l’arrangement moléculaire de l’acide paratartrique diffère de l’arrangement moléculaire de l’acide tartrique; qu’il en est de même de leurs sels. Si les extrémités du groupe moléculaire commun aux tartrates et aux paratartrates n’étaient pas modifiées de la même manière par l’introduction de nouveaux éléments dans les tartrates et les paratartrates, on concverait encore très-bien l’isomérie de ces

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sels. Or c'est ce qui à lieu en général. Que si l'on compare tous les tartrates, ai-je dit, les extrémités seules des formes seront différentes. Mais que l'on considère un tartrate en particulier, et l'on verra bientôt, sans qu'il existe ombre de doute à cet égard, que dans ce tartrate les deux extrémités du prisme sont dissymétriques. La loi du célèbre Haüy, qui veut que les parties identiques soient modifiées de la même manière, est violée. En un mot, tous les tartrates sont hémyédriques. Ainsi ce groupe moléculaire commun à tous ces sels, et que l'introduction de l'eau de cristallisation et des oxydes vient modifier aux extrémités, ne reçoit pas à ces deux extrémités les mêmes éléments, ou du moins, ils y sont distribués d'une manière dissymétrique. Au contraire, dans la pluralité des paratartrates que j'ai examinés, je n'ai rien observé qui annonçat l'hémyédrie de ces sels.

» Je viens de dire que dans la plupart, et non dans tous les paratartrates, je n'avais pas rencontré de cristaux hémyèdres. En effet, il est un de ces sels qui est hémyédrique, et c'est ici que nous allons toucher au doigt en quelque sorte la véritable cause de la polarisation rotatoire. Chacun sait, en effet, depuis les belles et nombreuses recherches de M. Biot, que beaucoup de substances organiques jouissent de la propriété singuliére de dévier à l'état de dissolution le plan de polarisation des rayons lumineux. Chacun sait aussi qu'une des différences capitales entre les tartrates et les paratartrates consiste en ce que l'acide tartrique et les tartrates dévient le plan de polarisation, tandis que l'acide paratartrique et ses sels ne le dévient pas. Il existe même une observation bien curieuse de M. Mitscherlich relative à cette différence des deux espèces de sels. Comme la Note où cette observation est consignée est très-courte, je vais la reproduire ici telle qu'il l'a adressée à l'Académie, en 1844, par l'intermédiaire de M. Biot:

« Le paratartrate et le tartrate (double) de soude et d'ammoniaque ont la même
» composition chimique, la même forme cristalline avec les mêmes angles, le même
» poids spécifique, la même double réfraction, et, par conséquent, les mêmes angles
» entre des axes optiques. Dissous dans l'eau, leur réfraction est la même; mais le
» tartrate dissous tourne le plan de la lumière polarisée, et le paratartrate est
» indifférent, comme M. Biot l'a trouvé pour toute la série de ces deux genres de sels;
» mais ici la nature et le nombre des atomes, leur arrangement et leurs distances sont
» les mêmes dans les deux corps compares. »

» Telle est l'observation de M. Mitscherlich. Pour ce qui concerne l'inaction du paratartrate sur la lumière polarisée, M. Biot a répété l'expérience du savant chimiste

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de Berlin sur un échantillon de ce paratartrate que lui avait remis M. Mitscherlich. Eh bien, par le plus grand des hasards, M. Mitscherlich a été induit en erreur, et M. Biot à son tour. Le paratartrate de soude et d'ammoniaque dévie le plan de polarisation: seulement, parmi les cristaux provenant d'un même échantillon, il en est qui dévient le plan de polarisation à gauche, d'autres à droite; et quand il y en a autant d'une espèce que de l'autre, la solution est inactive, les deux déviations contraires se compensent. Voici maintenant la différence cristallographique de ces deux espèces de cristaux. Ils sont tous hémyédriques; mais il y en a qui sont hémyédres à droite, d'autres à gauche, et la déviation dépend, pour le sens, de cette dissymétrie. Quand je veux une déviation à droite, je choisis les cristaux hémyèdres à gauche, quand je veux une déviation à gauche, je choisis les cristaux hémyèdres à droite. Il m'est arrivé aussi de n'avoir pas de déviation; c'est que j'avais pris des cristaux mêlés, sans faire aucun choix. N'est-il pas évident maintenant que la propriété que possèdent certaines molécules de dévier le plan de polarisation a pour cause immédiate, ou du moins est liée de la manière la plus étroite à la dissymétrie de ces molécules? car voici, en résumé, les faits principaux: L'acide tartrique et les tartrates dévient le plan de polarisation; ils sont tous hémyèdres. Ils dévient tous à droite, et sont aussi tous hémyèdres dans le même sens. Les paratartrates ne dévient pas; ils ne sont pas hémyèdres. L'un d'eux dévie, il est alors hémyèdre. Il dévie tantôt à droite, tantôt à gauche; c'est qu'il est hémyèdre, tantôt dans un sens, tantôt dans l'autre.

» On dira, et avec juste raison: Toutes les substances organiques qui dévient le plan de polarisation lorsqu'elles sont dissoutes jouiront donc de l'hémyédrie. J'aurais beaucoup désiré ne présenter ce travail à l'Académie qu'après avoir examiné les bases organiques, le camphre et d'autres substances. Mais ici on rencontre de grandes difficultés pour la recherche de l'hémyédrie. La beauté des cristaux des tartrates, leur grosseur, m'a servi considérablement. Cependant j'ai pu facilement étudier le sucre candi, et je puis annoncer, d'après mes propres recherches, que cette substance est hémyédrique, et jouit à un haut degré de la pyro-électricité polaire. C'est même par l'étude de cette dernière propriété que j'ai été assuré de l'hémyédrie, dont je me suis rendu compte ensuite par l'observation attentive de la forme cristalline. Postérieurement, j'ai trouvé que cette détermination avait été déjà faite il y a longtemps par le docteur Hankel. »

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