CHAPTER 3

THE NOTION OF A MIXT IN THE EIGHTEENTH CENTURY UP TO THE CHEMICAL REVOLUTION: THE NEWTONIAN SCHOOL

Physics [29] underwent a profound transformation in the eighteenth century. No longer content to consider division, shape and movement in matter, attractive and repulsive action between the various particles of bodies was countenanced. It had been Cartesian or Epicurean; now it was Newtonian.

What Newton accomplished in the domain of natural philosophy is one of the most profound revolutions known to the history of the human mind.

Newton succeeded, in his book entitled *Philosophiæ naturalis principia mathematica,* in deducing from a single law the movements of heavy bodies on the surface of the earth, the displacements, relative to the earth, of the moon, the sun, the planets, the satellites and the comets, and finally the ebb and flow of the sea. The statement of this law of universal gravitation is remembered by everyone.

When this work had been accomplished, Newton applied himself to the study of the effects of light. By means of devices which are always quoted as models of the experimental method, he had obtained results regarding the colours of the prism or thin films which have remained classics. In his *Opticks* he described these results and the experimental procedures which furnished them. He avoided dabbling with any hypotheses concerning the nature of light, or the influence [30] exerted on it by bodies it encounters or traverses. But the conjectures that he carefully eliminated from the body of the work crop up in the *Questions* with which it finishes.

In Question XXIX, Newton asks himself "Are not the rays of light very small bodies emitted from shining substances? For such bodies will pass through uniform mediums in right lines without bending into the shadow, which is the nature of rays of light. They will also be capable of several properties, and be able to conserve their properties unchanged in passing through several mediums, which is another condition of the rays of light. Pellucid substances act upon the rays of light at a distance in refracting, reflecting, and inflecting them, and the rays mutually agitate the parts of those substances at a distance for heating them; and this action and reaction at a distance very much resembles an attractive force between bodies."[1]

Pursuing these considerations, Newton shows how the principal optical phenomena might be explained by a mutual attraction exerted at insensible, but non-zero, distances, between the smaller parts of bodies and the small projectiles which constitute rays of light.

Having reached this point, the genius of Newton embraced a vaster field. Considering the collection of phenomena studied by physicists and chemists, he asked himself whether all these phenomena might not be reduced to mutual attractions and repulsions. Among these actions, one will be sensible at large distances: the attraction which produces universal gravitation. The others are insensible, unless the corpuscles between which it is exerted are extremely close together, as with the actions of material particles on the light particles. The XXXIst and last question [31] of *Opticks* is devoted to the exposition of this vast hypothesis, the sketch of an immense work which took physicists more than a century to realise.

"Have not the small particles of bodies certain powers, virtues, or forces, by which they act at a distance, not only upon the rays of light for reflecting, refracting, and inflecting them, but also upon one another for producing a great part of the phenomena of nature? For it is well known, that bodies act one upon another by the attractions of gravity, magnetism, and electricity; and these instances shew the tenor and course of nature, and make it not improbable but that there may be more attractive powers than these. For nature is very consonant and conformable to her self. ... The attractions of gravity, magnetism, and electricity, reach to very sensible distances, and so have been observed by vulgar eyes, and there may be others which reach to so small distances as hitherto escape observation."[2]

It was to attractions of this kind that he was obliged to attribute the cohesion of solids, the rising of liquids in capillary tubes and the round shape of drops of mercury. Analogously, repulsive forces explained the elasticity of gas.

"And thus[3] nature will be very conformable to her self and very simple, performing all the great motions of the heavenly bodies by the attraction of gravity which intercedes those bodies, and almost all the small ones of their particles by some other attractive and repelling powers which intercede the particles."[4]

The great physical theory would not be complete if it were to neglect the traits of chemical phenomena. And far from omitting such effects, Newton devoted the greater part of the [32] XXXIst question to them. According to the hypotheses he

1. [Sir Isaac Newton, *Opticks or a Treatise of the Reflections, Refractions, Inflections & Colours of Light*, based of the fourth edition, 1730, Dover, 1952, pp. 370-1. Henceforth *Opticks*.]
2. [*Opticks*, pp. 375-6.]
3. [Duhem writes "*Si toutes ces choses sont comme nous l'avons supposé*"—If everything is as we have supposed; the English edition has "And thus."]
4. [*Opticks*, p. 397.]

developed, when two substances combine, this combination is the result of attractions which are exerted at small distances between the particles of the two bodies. "For when salt of tartar runs *per deliquium*, is not this done by an attraction between the particles of the salt of tartar, and the particles of water which float in the air in the form of vapours? And why does not common salt, or salt-petre, or vitriol, run *per deliquium*, but for want of such an attraction?"[5]

This is not the place to follow the immense development of the doctrine of molecular attraction in physics. In chemistry itself, this notion only interests us in so far as it concerns the motion of a mixt.

Certainly, the doctrine of molecular attraction diverges essentially, in its fundamental principles, from the Epicurean and the Cartesian doctrines. Rather than explaining all natural phenomena by shape and movement, a third irreducible element, force, is invoked, and both Epicureans and Cartesians recoil in horror at the intervention of this *occult quality*.

Nevertheless, like the Epicureans and the Cartesians, the Newtonians supposed bodies to be composed of particles distinct from one another. In fact, the Newtonians were not obliged to formulate precise and detailed hypotheses about the shape of these particles, since they could attribute, on the basis of various laws, attractions and repulsions which their predecessors explained by the shape of particles. In this way, they avoided the naive and infantile reasoning invoked by Descartes, Boyle and Lémery, and they rejoiced in their superiority.

Why do various parts of solid bodies adhere so strongly to one another? In order to explain the durability of solid bodies, the Epicureans invoked the entanglement of small hooks and the [33] ramifications borne by the atoms "which," Newton observed, "is begging the question." The Cartesians imagined that the particles of bodies are glued together by rest. "To compose a body as hard as can be imagined," Descartes[6] said, "I think that it is enough if all its parts touch, without any space between them, and without any being in motion. For what paste or cement could be conceived beyond this, for holding the parts together better?" This cement made of rest, Newton replies, is an occult quality, or rather, pure nothing. "I had rather infer from their cohesion, that their particles attract one another by some force, which in immediate contact is exceeding strong, ... and reaches not far from the particles with any sensible effect."[7]

Descartes, we have seen, assimilated[8] gases to bundles of small twigs whose branches are placed one on top of the other. Boyle insisted on this hypothesis:

5 [*Opticks*, p. 377.]

6 Descartes, *Le Monde ou le Traité de la Lumière*, chap. III.

7 [*Opticks*, p. 389.]

8 Descartes, *Les Météores*, chap. I, art. III.

"[T]he particles of air," he said[9], "must be as well sometimes considered under the notion of little springs, which remaining bent, are in their entire bulk transported from place to place; as under the notion of springs displaying themselves, whose parts fly abroad, whilst, as to their entire bulk, they scarce change place: as the two ends of a bow, shot off, fly from one another; whereas the bow it self may be held fast in the archer's hand." Newton was repelled by the puerility of these hypotheses: "[The] vast contraction and expansion [of the air] seems unintelligible, by feigning the particles of air to be springy and ramous, or rolled up like hoops, [34] or by any other means than a repulsive power."[10]

In the same way, instead of explaining the substitution of one body by another in a chemical reaction like Lémery, as a certain proportion of points and pores, Newton attributes the displacement to the relative size of the attractions brought into play: "When salt of tartar *per deliquium*, being poured into the solution of any metal, precipitates the metal and makes it fall down to the bottom of the liquor in the form of mud: Does not this argue that the acid particles are attracted more strongly by the salt of tartar than by the metal, and by the stronger attraction go from the metal to the salt of tartar?"[11]

The study of such substitutions enables the metals to be arranged in order of the magnitude of attraction which they exert on an acid such as aqua fortis: "A solution of iron in *aqua fortis* dissolves the *lapis calaminaris* [cadmia], and lets go the iron, or a solution of copper dissolves iron immersed in it and lets go the copper, or a solution of silver dissolves copper and lets go the silver, or a solution of mercury in *aqua fortis* being poured upon iron, copper, tin, or lead, dissolves the metal and lets go the mercury; does not this argue that the acid particles of the *aqua fortis* are attracted more strongly by the *lapis calaminaris* than by iron, and more strongly by iron than by copper, and more strongly by copper than by silver, and more strongly by iron, copper, tin, and lead, than by mercury?"[12]

This passage has inspired all those chemists, from Geoffroy to Bergmann, who have constructed tables of affinities.

Newton therefore rejects, more often than not, the adventitious hypotheses concerning the shape of molecules which have condemned the Epicureans and the [35] Cartesians; but he did not avoid them altogether. In order to explain the colours of thin films by *fits of easy reflection* and the *easy transmission*[13], he was

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9 R. Boyle, *New experiments physico-mechanical, touching the spring of the air; and its effects made for the most part in a new pneumatical engine*, experiment I. [*The Works of the Honourable Robert Boyle in Five Volumes*, 1744. Vol. I, "New experiments ...," p. 10.]

10 [*Opticks*, p. 396.]

11 [*Opticks*, p. 380.]

12 [*Opticks*, pp. 380-1.]

13 [Question 29, *Opticks*, p. 372.]

constrained to attribute a particular shape to luminal projectiles. Buffon[14], one of the more fervent, if not more competent, admirers of Newton, upheld against Clairaut this hypothesis: The particular laws of molecular attraction are all only simple modifications of the universal law of attraction, inversely proportional to the square of the distance; they appear different only because at very small distances, the shape of the atoms which attract themselves does as much or more than the mass for the expression of this law. This view was accepted and developed by Macquer[15], by Guyton de Morveau[16], by Monge[17], and by Bergmann[18].

Based on the vast synthesis of the doctrines of Newton and Leibniz, P. Boscovich, avowed opponent of the Atomists and the Cartesians, rejected Buffon's views. For him, the elementary particles between which molecular attractions and repulsions are exerted are without extension, and consequently without shape. But under the influence of forces which strain at nearby and remote material points, they are able to form groups, kinds of structures. Newton had already countenanced the existence of these kinds of arrangements when he wrote in his *Opticks*: "Now the smallest particles of matter may cohere by the [36] strongest attractions, and compose bigger particles of weaker virtue; and many of these may cohere and compose bigger particles whose virtue is still weaker, and so on for divers successions, until the progression end in the biggest particles on which the operations in chymistry, and the colours of natural bodies depend, and which by cohering compose bodies of sensible magnitude."[19] Following this idea of Newton's, Boscovich allowed that material points, the elements of every body, are able to arrange themselves in more or less complex molecular structures. These complex molecules differ from one another by their exterior shape, the distribution of material points within this figure, and the actions exerted by the one on the other. The peculiarities of these molecules explain the various properties of solids, liquids and gases, and these explanations present considerable analogies with those proffered by the Epicureans and the Cartesians.

The three great Atomist, Cartesian and Newtonian schools were therefore led to conceive of the notion a mixt in the same way.

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14 Buffon, *Mémoires de l'Académie des Sciences pour* 1745 (parus in 1749).—Clairaut, *ibid.*—Buffon, *Histoire naturelle, générale et particulière, servant de suite à l'histoire de la Terre et d'introduction à l'histoire des minéraux. Supplément*, t. I, Paris, 1774.

15 Macquer, *Dictionnaire de chimie*, deuxième édition. Paris, 1778, art. *Affinité.*

16 Guyton de Morveau, *Digressions académiques*, Dijon, 1772.—*Encyclopédie méthodique. (Chimie, Pharmacie et Métallurgie)*, t. I. Paris 1786, art. *Affinité*; t. II. Paris, 1792, art. *Attraction.*

17 Monge, *Encyclopédie méthodique. Dictionnaire de physique*, t. I. Paris, 1793, art. *Affinité* et *Attraction.*

18 Bergman, *Opuscula*, dissertatio XXXIII, §1.—*Traité des affinités électives*, Paris 1788, p. 2.

19 [*Opticks*, p. 394.]

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