CHAPTER 2

THE NOTION OF A MIXT IN THE SEVENTEENTH CENTURY

We [17] follow the fortunes of these two opinions through the course of the history of chemistry.

Throughout the middle ages, the peripatetic doctrine regarding the generation and corruption of mixed bodies was taught in the schools. Was it accepted by the alchemists? It would be difficult to fathom, under the obscure language which concealed their true thoughts; less capable of abstraction, more imaginative than the scholastics, they were undoubtedly inclined towards the views of the Epicureans. But without investigating this question, we are content to take up chemistry at the time of the scientific renaissance.

At this time, we see philosophers of nature coming back into vogue, on account of their faithfully upholding, during the course of several centuries, the Epicurean idea that apparently continuous mass is an assemblage of small bodies of various forms, and that the various arrangements of these small bodies must explain the properties of the various mixts which the chemist studies.

We find this idea clearly expressed by Bacon[1], who indicates within these limits the aim of the new physics:

"It is necessary to illuminate the texture and true constitution of bodies, from which all the peculiar properties and occult powers in things derive, and, as one [18] says, their specificity, and from which the laws of all power of alteration and transformation derive.

"For example, it is necessary to investigate, in all kinds of bodies, what the volatile part is, and what the tangible essence is: and whether the volatile part is considerable and swollen, or meagre and reduced ...; and in the same way, to study the tangible essence, which contains no less variety than the volatile part, its hairs, and its fibres and its equally variable texture; and again the disposition of the volatile part in the mass of the body, the pores, pipes veins and cells and the rudiments of organic bodies."

1. Bacon, *Novum organum,* pars ædificans.

These ideas gained more force with Gassendi's attempt to oppose scholastic physics with atomic physics; they triumphed with Descartes.

Descartes defined with admirable clarity the characteristics which he attributed to material in order to make intelligible all the phenomena that our experiences reveal. Let us quote, in particular, this passage[2]:

"Now since we are taking the liberty of fashioning this matter as we fancy, let us attribute to it, if we may, a nature in which there is absolutely nothing that everyone cannot know as perfectly as possible. To this end, let us expressly suppose that it does not have the form of earth, fire, or air, or any other more specific form, like that of wood, stone, or metal. Let us also suppose that it lacks the qualities of being hot or cold, dry or moist, light or heavy, and of having any taste, smell, sound, colour, light, or any other such quality in the nature of which there might be said to be something which is not known clearly by everyone. But on the other hand, let us not also think that this matter is the 'prime matter' of the philosophers, which they have stripped so thoroughly of all its forms and qualities that nothing remains in it which can be clearly understood. Let us rather conceive it as a real, perfectly solid body which uniformly fills [19] the entire length, breadth and depth of this huge space in the midst of which we have brought our mind to rest. Thus, each of its parts always occupies a part of that space which it fits so exactly that it could neither fill a larger one nor squeeze into a smaller; nor could it, while remaining there, allow another body to find a place there. Let us add that this matter may be divided into as many parts having as many shapes as we can imagine, and that each of its parts is capable of taking on as many motions as we can conceive. Let us suppose, moreover, that God really divides it into many such parts, some larger and some smaller, some of one shape and some of another, however we care to imagine them. It is not that God separates these parts from one another so that there is some void between them: rather, let us regard the differences he creates within this matter as consisting wholly in the diversity of the motions he gives to its parts. From the first instant of their creation, he causes some to start moving in one direction and others in another, some faster and others slower (or even, if you wish, not at all); and he causes them to continue moving thereafter in accordance with the ordinary laws of nature."

Furthermore, Descartes says in another place[3]:

"The only principles which I accept, or require, in physics are those of geometry and pure mathematics. [...] I recognise no matter in corporeal things apart from that

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2. Descartes, *Le Monde ou le Traité de la Lumière*, chap. VI. [*The World or Treatise on Light*, extracts translated by John Cottingham, Robert Stoothoff and Dugald Murdoch, *The Philosophical Writings of Descartes*, Vol. I, Cambridge University Press, 1985; pp. 90-1. Reproduced by permission of Cambridge University Press.]
3. Descartes, *Principia Philosophiæ*, pars secunda, art. LXIV. [*Principles of Philosophy*, part two, art. 64, in *The Philosophical Writings of Descartes*, Vol. I (note 2), p. 247. Reproduced by permission of Cambridge University Press.]

which the geometers call quantity, and take as the object of demonstrations, i.e. that to which every kind of division, shape and motion is applicable. Moreover, my consideration of such matter involves absolutely nothing apart from these divisions, shapes and motions."

The shapes which Descartes attributes to the small parts of bodies often differ very little from those attributed by Epicurus, in agreement with Lucretius. In [20] one of the writings which he published following the *Discourse on Method*, by way of exemplifying this method, he describes these shapes thus[4]:

"First, I suppose that water, earth, air and all other bodies which surround us are composed of several small parts of various shapes and sizes which are never so well arranged nor so precisely joined together that there are not several intervals around them. These intervals are not empty, but filled with that very subtle matter, by the mediation of which I have shown above the action of light is communicated. And in particular, I also suppose that the small parts of which water is composed are long, smooth and slippery, like small eels, which, although they are joined and interwoven, neither become knotted nor ever fasten onto one another in such a way that they cannot easily be separated. And contrary to nearly all these, the parts, both of earth and even of air, and of most other bodies, have very irregular and uneven shapes, and are of such kind that they cannot be so little interlaced but that they fasten onto and bind with one another, as do the different branches of shrubs which grow together in a hedge. And when they bind together in this way, they compose bodies as hard as earth, wood and suchlike. Whereas if they had simply rested one on the other, being hardly intertwined and perhaps not at all, and being so small that they could be moved and separated by the agitation of the subtle matter that surrounds them, then they would occupy much space, and compose liquid bodies which are very rare and light, such as oils and the air."

These hypotheses are taken up again in the books of the *Principles*[5] and *Treatise on Light*[6].

Descartes obtained bodies by mixing together three elements which, as he conceived them, [21] bore very little resemblance to the mixts conceived by Aristotle. The Stagirite had compared them with the mixture of wheat and straw that was raked together in the air. Could Descartes, without contradicting himself, imagine the mixture of the two elements otherwise than as a juxtaposition of small shaped parts of which these elements are composed? Could he conceive of the mutual penetration of two of these particles that he regarded as identical with the extension they themselves occupied? Already in the *Treatise on Light* he had informed us that "each of its parts always occupies a part of that space which it fits so exactly that it could neither fill a larger one nor squeeze into a smaller; nor could

4. Descartes, *Les Météores*, chap. I, art. III.
5. Descartes, *Principia Philosophiæ*, pars quarta, passim.
6. Descartes, *Le Monde ou le Traité de la Lumière*, chap. III and IV.

it, while remaining there, allow another body to find a place there." In a letter to Henry More[7], he maintains yet more clearly the impenetrability of material as a necessary consequence of the essence that he attributed to it: "It is not possible to conceive that one part of an extended thing penetrates an equal part, unless one understands by that that the part of its extension which it has in common with the latter is removed or annihilated; but what is annihilated does not penetrate anything else; that demonstrates, in my opinion, that impenetrability belongs to the very essence of extension, and not to the essence of any other thing."

A solution cannot therefore be, according to this view, anything other than an interposition of particles of the dissolved body with particles of the solvent; and it is this Descartes[8] allows regarding the water of the sea. Among the elongated, smooth, flexible particles, slippery as eels, which ordinarily constitute fresh water, are found little, pointed and rigid sticks which constitute sea salt. The shape and size of these two elements which constitute sea water explain all the properties as one would wish. Descartes shows how [22] evaporation easily carries off the fresh water which leaves behind the sea salt. He shows likewise[9], following the example of Lucretius, how filtration through soil retains the larger and stiffer sticks to which the sea owes its salinity, and allows only the tenuous, fleeting particles which constitute fresh water to pass through.

This example well illustrates to what extent Descartes was inspired by the physics of the atomists. He did not, however, adopt their ideas[10]. Not only are the particles which compose bodies not, for him, indivisible *atoms*; there is also *subtle matter* filling the intervals left between the particles, so that there is no vacuum in nature.

This doctrine, according to which vacuum is impossible in nature, was harshly criticised by Pascal. Huygens followed suit, declaring that vacuum is necessary for the movement of small corpuscles. This was soon to become the general opinion of physicists, whose principles thenceforth accorded with those taught by Epicurus and Lucretius. But just as Descartes had preserved intact the notion of a mixt as conceived by the Greek atomists in his philosophy, this notion was not in any way affected by the failures of the Cartesian physics.

One Jean Rey, a doctor of medicine living in Bugue, Périgord, and contemporary of Descartes, was an expert in natural philosophy. Mr. Brun, apothecary in Bergerac, established that lead and tin increase in weight when burnt in air, and was so surprised by his discovery which he believed unknown that he wrote to the doctor in

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7. Descartes, *Epistolæ*, Amsterdam edition (1714), pars prima, epist. LIX. [Letter to More dated 15 April, 1649.]
8. Descartes, *Les Météores*, chap. I, art. VIII, and chap. III.—*Principia Philosophiæ*, pars quarta, art. XLVIII.
9. Descartes, *Les Météores*, chap. III, art. VIII, and chap. III.—*Principia Philosophiæ*, pars quarta, art. LXVI.—*Epistolæ*, pars secunda, epist. I and II.
10. Descartes, *Principia Philosophiæ*, pars quarta, art. CCII.

Bugue: "I entreat you with all my heart to engage in searching for the cause of so unusual an effect, and I would be obliged if your efforts could illuminate this marvel for me." [23] Jean Rey[11], who had already established the previously unknown fact that the air is heavy, replied in these terms: "Resting on foundations already laid down, I therefore reply to this question and triumphantly uphold that the addition of weight comes from the air in the vessel, which is dense, heavy, and not in any way made sticky by the violent and prolonged heat from the furnace. This air mixes with the lime (aided by frequent agitation) and attaches to the smallest parts in the way that sand thrown and stirred into water is made heavier by making it wet and adhering to the smaller grains."

It is clear that Jean Rey imagined, as did the atomists, that the mixt is formed from the air and the chalk of tin.

According to the reply just heard, Jean Rey is a precursor of Lavoisier. The anti-phlogiston revolution assures the glory of his name, but the friendship of Mersenne did not prevent him remaining unknown to his contemporaries and his *Essays* had no influence on the development of chemistry.

The same cannot be said of the writings of Boyle and Lémery.

When discussing the theory of mixtures, Robert Boyle does not hesitate to declare that the opinion of the ancient atomists, adopted in his time by the "chemists," if not the most probable, is at least more probable than that of the peripatetics. Still, he brings a correction to this opinion of the chemists. But this correction is conceived in the spirit of the Epicurean doctrine.

"Now in this general notion of mistion it does not appear clearly comprehended," he says[12], "that the *miscibilia* or ingredients do in their small parts so retain their nature and remain distinct in the compound, that they may thence by the fire be taken again asunder: [24] for though I deny not that in some mistions of certain permanent bodies this recovery of the same ingredients may be made; yet I am not convinced that it will hold in all or even in most, or that it is necessarily deducible from chymicall experiments, and the true notion of mistion. ... I will not peremptorily deny, but that there may be some clusters of particles, wherein the particles are so minute, and the coherence so strict, or both, that when bodies of differing denominations, and consisting of such durable clusters, happen to be mingled, though the compound body made up of them may be very differing from either of the ingredients, yet each of the little masses or clusters may so retain its own nature, as to be again separable, such as it was before. As when gold and silver being melted together in a due proportion[13] *aqua fortis* will dissolve the silver, and leave the gold untoucht; by which means, as you lately noted, both the metals may

11. *Essays de* Jean REY, *docteur en médecin, sur la recherche de la cause par laquelle l'Estain et le Plomb argmentent le poinds quand on les calcine;* Bazas, 1630; Essay XVI.
12. Robert Boyle, *The Skeptical Chymist,* part II. [Dent, 1911 reprint of the 1661 edition, pp. 86-8]
13. [Boyle's text has at this point the parenthetical comment "(for in every proportion, the refiners will tell you that the experiment will not succeed)" which Duhem does not indicate that he omits.]

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