ELEMENTS

OF

MODERN CHEMISTRY.

BY ADOLPHE WURTZ,

(SENATOR,)

MEMBER OF THE INSTITUTE, HONORARY DEAN AND PROFESSOR OF CHEMISTRY OF THE FACULTY OF MEDICINE OF PARIS, MEMBER OF THE ACADEMY OF MEDICINE, ETC.

SECOND AMERICAN EDITION.

TRANSLATED AND EDITED, WITH THE APPROBATION OF THE AUTHOR, FROM THE FIFTH FRENCH EDITION,

BY WM. H. GREENE, M.D.,

PROFESSOR OF CHEMISTRY IN THE CENTRAL HIGH SCHOOL, PHILADELPHIA, MEMBER OF THE AMERICAN PHILOSOPHICAL SOCIETY, OF THE CHEMICAL SOCIETIES OF PARIS AND BERLIN, ETC.

WITH ONE HUNDRED AND THIRTY-TWO ILLUSTRATIONS.

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AUTHOR'S PREFACE.

THIS book is translated from the fourth French edition by my pupil and friend, M. Greene, whose perfect familiarity with the French language and thorough competence, at the same time, in chemistry I have had occasion to appreciate. The translation is, then, a faithful, or even improved, representation of the original work, in which he will certainly have detected and corrected some faults.

The French editions succeed each other rapidly, showing that this little book responds to an educational need.

It has been the endeavor to keep it up with the current of the latest discoveries, and in it to condense a considerable number of exact and well-selected facts, without banishing the theory which binds them together. Thus, the origin and foundation of the atomic theory have been given, as far as possible, in historical order. The notions concerning atomicity, so important for the appreciation of the structure of combinations and for the interpretation of chemical reactions, are presented in an elementary form.

The reader will remark that the history of the metalloids is relatively more developed than the remainder of the book. Indeed, this is the fundamental part of chemistry, and a familiar knowledge of it is indispensable to the fruitful study of the metals and of organic chemistry. It is also the most attractive portion for beginners, for it is the most easily understood.

Immediately on entering the immense domain of organic chemistry, we find the facts overwhelmingly numerous and complicated. Among all these facts a severe and careful choice has been made, the historical importance and the theoretical and practical interest of the compounds described being borne in mind. In this respect many additions have been made to the third French edition. Thus, the question of isomerism, upon which the theory of atomicity has thrown so much light, has been treated in a more thorough manner. The chapter on the aromatic compounds has been considerably augmented.

The author hopes that these "Elementary Lessons" will be well received by the new public to whom they are presented, and that they will contribute to render attractive and diffuse the knowledge of the science to which he has devoted his life.

ADOLPHE WURTZ.

PARIS, November 20, 1878.

The progress of the science has made necessary many changes in the fifth edition of this little book, which has so far retained about the form and scope given to it fifteen years ago. It has been deemed advisable to complete the organic portion, and a large number of additions and corrections have been made. Whole chapters have been added to the history of the cyanogen compounds, the hydrocarbons, the acids, and the aromatic compounds. Among these will be particularly noticed the articles on isomerism, the azoic and diazoic compounds, and the pyridic bases, subjects which have acquired great importance during the last few years.

PARIS, 15th September, 1883.

TRANSLATOR'S PREFACE.

It is a privilege to be able to bring before the English-reading public a work by one who has justly won the reputation of being the most able thinker and perspicuous teacher of France. M. Wurtz is the acknowledged leader of modern chemical philosophy, and his labors have firmly established many of the views which long remained unaccepted by the majority of chemists, but which are now regarded as essential to the science.

This book is therefore a brief but accurate embodiment of modern chemical ideas, arranged in such a form that the most difficult principles are acquired gradually in the course of the descriptions.

Only such changes and additions have been made as would necessarily accompany the change of scene in which the book appears; among these are the few American mineral waters mentioned, and other mineral resources of the United States, naturally interesting and important to the American public.

WM. H. GREENE.

1st June, 1879.

THE exhaustion of a large edition of this translation, and the appearance of a new edition of the original, have called for a complete revision of the text. M. Wurtz having kindly authorized all changes likely to render the book still more acceptable in its new home, the editor has deemed it advisable to re-classify the metals in accordance with the generally-accepted theory of atomicity. He believes, however, that in an elementary text-book convenience of method is of more importance than a rigid classification, unless the basis of that classification be established beyond all doubt. For that reason the arrangement is somewhat different from that which could be adopted in an extensive treatise, in which more ample space would allow a systematic development of the classification, and a discussion of doubtful positions.

A short chapter on chemical energy, and a brief history of Mendelejeff's periodic law, have been added.

All of the elements of which the existence is unquestionable have found at least separate mention.

It is hoped that these changes, and the extensive additions to the organic chemistry, most of which appear also in the fifth French edition, will increase the value of the book to the large class of readers by whom it has been so well received in the past.

1st January, 1884.

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ELEMENTS OF MODERN CHEMISTRY.

INTRODUCTION.

THE material objects surrounding us present striking and infinite differences. Sulphur is readily distinguished from charcoal, rock-crystal from flint, iron from copper, water from spirit of wine, and wood from ivory. It is known to all that these bodies differ not only in form, density, and structure, but also in their proper substance. They differ, too, in the changes through which they pass under the same conditions. When subjected to the action of heat they receive very differently the impression of that force. They become heated more or less quickly, and transmit the heat with greater or less rapidity throughout their own substance. A short bar of iron cannot be grasped in the hand by one extremity if the other be heated to redness; under the same conditions a cylinder of charcoal may be handled with impunity. Communicate sufficient heat to water and it is converted into steam; remove heat from it, and if the cooling be sufficient, it is frozen into ice. Spirit of wine cannot be congealed by the most intense cold known. If a magnet be placed among iron filings they attach themselves in tufts around the two poles; on the contrary, copper filings are indifferent to the magnetic attraction.

Rock-crystal is transparent to light; flint is opaque. These two bodies are unalterable by fire. They may be heated to redness in a furnace, but after the temperature has abated they will be found with their original characters unchanged. It is very different with the coal which we burn in our grates. This body disappears during the combustion, and leaves only a quantity of ashes. But it has not been destroyed, and its substance is found in entirety in a certain gas produced by the combustion. Like charcoal, sulphur is combustible, and is converted by burning into a gas, the suffocating odor of which is well known.

Neither sulphur nor charcoal undergo any alteration when exposed to damp air; it is not the same with iron. In a moist atmosphere this metal experiences a striking and lasting change. Its surface becomes covered with rust and is no longer iron.

In the forests, the leaves which fall and remain upon the moist soil are slowly consumed and disappear in the course of seasons.

All of these changes, these phenomena, take place daily before our eyes, and are familiar to all of us. On comparison, striking differences are discovered between them: some are but passing, and do not affect the proper nature of the body. They are the results of forces which act at sensible distances, and which leave the body in its primitive state as soon as their action has ceased. A piece of soft iron is attracted by the magnet before contact is established, and when under the magnetic influence, is capable of attracting other soft iron in its turn: the action of the magnet has made the iron itself magnetic, but it immediately loses this property when the magnet is withdrawn; and further, this momentary change in property has brought about no alteration in the intimate nature of the iron. It is found after the experiment in precisely the same condition as before.

In the same manner, rock-crystal undergoes no change in its specific identity by the passage of a ray of light. Withdraw from the vapor of water the heat which has been communicated to it, and the liquid water is recovered with all its properties. Restore to the ice the heat which was abstracted in its formation, and water is regenerated as before. This is characteristic of the changes produced by *physical forces*. Under the influence of such forces, bodies experience modifications more or less profound, more or less lasting, but which never affect their specific nature.

But the iron which rusts undergoes a complete and lasting change in its properties and in its substance. The rust is no longer iron, and vainly would it be sought to isolate the metal by mechanical means, or to discover its presence by the aid of the most powerful micrŏscopes. The metal has disappeared as such; it has undergone a complete transformation; it has become another body. It has attracted one of the elements of the air, oxygen, and has, moreover, fixed to itself the moisture of the atmosphere. These latter bodies, which differ from iron in substance, have intimately united with the metal itself, and the result of this union, of this *combination* as it is called, is a new body, rust or hydrated oxide of iron. In this case the alteration is profound, the change is lasting; the specific nature of the body is affected. This is characteristic of *chemical action.*

In the same manner, when the charcoal and the sulphur are burned in the air, they attract oxygen and combine with it, forming two new bodies that are called carbonic and sulphurous acids.

These phenomena may be rendered more clear by simple and well-known experiments.

Experiment 1.—A globe (Fig. 1) is filled with oxygen, a gas which constitutes one of the elements of the atmosphere, and which is eminently fitted to support combustion; into it is plunged a morsel of charcoal lighted at one end; immediately the coal glows with a brilliant light, the combination takes place actively, and the charcoal is rapidly consumed. But presently the light becomes paler, the combustion ceases, and the charcoal is extinguished. The oxygen is now nearly or quite con-

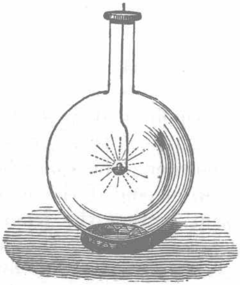


FIG. 1.

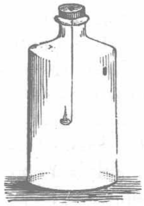


FIG. 2.

sumed, and the globe is filled with another gas which is no longer oxygen, although it contains that oxygen. It contains also the matter of the charcoal which has disappeared, and these two bodies have combined to form a new body, which is carbonic acid. This latter will not support combustion, and further, it extinguishes burning bodies. It is then a body having entirely new properties, and is formed by a chemical action.

Experiment 2.—Into another jar filled with oxygen (Fig. 2) is plunged a spoon containing ignited sulphur. The combustion takes place with a beautiful blue flame, and in burning in the oxygen with so much energy, the sulphur unites with the gas and forms with it a new body, which is called anhydrous sulphurous acid. It is a suffocating gas, which extinguishes flame. It reddens, and afterwards bleaches, a solution of blue litmus poured into the jar. These are special properties which do not belong to the oxygen at first contained in the jar. They characterize a new body, the result of the combination of the sulphur with the oxygen, and formed by chemical action.

Carbon, sulphur, and oxygen are *simple bodies* or *elements.* They are so called because from neither of them can more than one kind of matter be obtained. But when the charcoal in burning unites with the oxygen, the carbonic acid which results from the union contains two kinds of matter,—carbon and oxygen; and these two elements are united in such an intimate manner that the body which contains both does not resemble either carbon or oxygen: it is endowed with new properties which do not in any manner recall those of the elements which constitute it. In fact, it is a new substance, a *compound body* formed by the combination of the matter of the charcoal with the matter of the oxygen.

Considering the preceding facts, we may give to chemistry the following definition: chemistry studies those intimate actions of bodies upon each other which modify their natures and cause a complete and lasting change in their properties.

Iron may be reduced to a fine powder. This may be mixed with sulphur itself reduced to powder, and if the mixture be sufficiently intimate, it will present neither the lemon-yellow color of sulphur nor the gray-black of finely-divided iron. Nevertheless, a homogeneous substance cannot be formed in this manner. If the powder be examined under the microscope, the particles of iron may be recognized disseminated among those of the sulphur, but not confounded with them. By the aid of a magnet the iron may be separated. On the other hand, if the mass be thrown into water, the particles of iron will sink first to the bottom, while the lighter particles of sulphur remain in suspension. Thus, after having triturated the sulphur and iron together, not only can each substance be recognized in the mass, but they can be again separated by mechanical means. Here there has been no chemical action, but simply a *mixture.* If, however, this mixture be heated, the sulphur will first be seen to melt, and afterwards the whole mass will blacken and enter into fusion if the temperature be sufficiently elevated. After cooling, it is perfectly homogeneous, and neither iron nor sulphur can be recognized. Both have disappeared as such, and in their place is found a substance having new properties; it is the sulphide of iron.

They have disappeared, but their substance is not lost; and it may be proved by experiment that the weight of the sulphide of iron produced is exactly equal to the sum of the weights of the iron and the sulphur. The ponderable matter of the iron is then added to the ponderable matter of the sulphur, and has formed with it a union so intimate that there results a new body, the smallest particles of which are perfectly similar to each other and to the entire mass. This example and a thousand others that might be given prove that when bodies combine there is neither loss nor creation of matter. The result of the combination, that is, the compound body, contains the whole of the substance and nothing more than the substance of the combining bodies. This is an essential characteristic of chemical combination.

The force which presides over chemical combination is called *affinity*. It is important that this force be distinguished from another which is often opposed to it, and which is *cohesion*.

In order to reduce to powder a solid substance, such as pyrites or sulphide of iron, it is necessary to overcome the resistance opposed by the particles of the mass to their separation. This resistance is due to a special force, which brings and maintains in relation to each other the homogeneous particles of the sulphide of iron, as indeed of all solid bodies. This is cohesion. The particles which are bound together by this force are not only those minute particles which are visible to the naked eye or under the microscope, and of which the most impalpable powder of a solid body is composed. Such particles still present a magnitude that can be measured; they must be considered as little masses, so to speak, indivisible by the mechanical means at our command, but formed in reality of particles still smaller. These smallest particles of a solid body which are bound by cohesion are called *molecules*. They are not in immediate contact with each other. In a perfectly compact and homogeneous mass, such as sulphide of iron, the molecules do not touch each other. Between them exist spaces of considerable magnitude, compared to the real volume of the molecule. This idea must not be confounded with porosity, which is caused by those accidental spaces which form visible pores in solid bodies. These intermolecular spaces are those which separate the molecules of a homogeneous and compact solid body, and physicists have further been led to believe that even in solid bodies the molecules are not perfectly immobile, but that they execute vibratory movements in the spaces which separate them, at the same time maintaining their own relative positions.

If a solid body be heated, a part of the heat is employed in raising the temperature, another part serves to increase the distances which separate the molecules: the body expands in becoming heated. But, as the distances between the molecules increase by the action of the heat and the effect of the expansion, the molecular attraction necessarily becomes more feeble. Cohesion is thus somewhat diminished, and if the heat be further increased, it may be so much diminished that the molecules, which have thus far been maintained in definite relations, can move and glide freely over each other; the solid body then enters into fusion: it becomes a liquid. The liquid state is produced by a diminution of cohesion, and is characterized by a greater mobility of the molecules.

But if the liquid body be still further heated, at a certain point the additional heat may produce such a separation of the molecules that, already freed from all mutual attraction, they become completely independent of each other. This is characteristic of the gaseous state.

It may be stated, then, that cohesion is considerable in solid bodies, but slightly energetic in liquids, and null in gases, and we have just seen that heat, by causing the changes of state of a body, can overcome and even practically abolish this physical force.

Chemical force or affinity is at the same time more intimate and more powerful. It modifies the molecules themselves. It brings heterogeneous substances into intimate relations, and thus produces new molecules. A consideration of the examples already cited may indicate more clearly the meaning of this important proposition.

We have brought together sulphur and iron, and by their reciprocal action and the aid of heat there has been formed a new body,—sulphide of iron. We know that the smallest mass of sulphur we can obtain is composed of a collection of perfectly homogeneous molecules, aggregated by cohesion. In each of them but one kind of matter can be found. It is the same with iron: the particles of this metal are perfectly homogeneous. Sulphur and iron are simple bodies or elements.

Let us now consider the sulphide of iron which results from their combination. This body also is formed of a collection of molecules, bound together by cohesion and perfectly similar to each other, but not homogeneous, for in each molecule we distinguish two kinds of matter,—sulphur and iron.

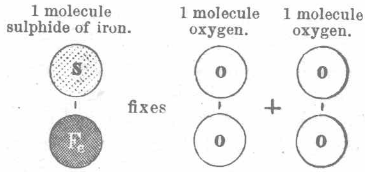
It cannot be admitted that these two substances are confounded in the molecule, or that the effect of the combination of sulphur with iron is an interpenetration of the two bodies so intimate that they both disappear in what might be called a homogeneous mixture. On the contrary, it is supposed that the combination results from the juxtaposition of two infinitely small masses, each of which possesses a real magnitude and a constant weight.

These little masses that no force, chemical or physical, can divide further, constitute the *atoms*. In each molecule of sulphide of iron there exist two of these masses,—one of sulphur and one of iron; and the atom of sulphur and the atom of iron are bound together, but not confounded, by chemical force. And when sulphur combines with iron it is because the atoms of the sulphur arrange themselves in juxtaposition with those of the iron, and it is affinity which brings about the action.

When these atoms again separate, the sulphide of iron is said to *decompose*. When it attracts the atoms of another body, it is said to combine with that body.

If sulphide of iron remain for some time exposed to moist air, its surface becomes covered with an efflorescence formed of a saline matter. In this case it has attracted one of the elements of the air, oxygen, with which it has combined to form green vitriol or sulphate of iron.

The molecules of oxygen, upon which cohesion has no hold, the body being gaseous, are each formed of two atoms, but these atoms are of the same kind; the molecules of sulphide of iron, on the contrary, are each formed of two unlike atoms,—one of sulphur and one of iron. These latter attract four atoms of oxygen, which constitute two molecules of that gas, and these group themselves around the atom of sulphur and the atom of iron, forming with them one single molecule, more complex than the primitive molecule of sulphide of iron, for it contains in addition four atoms of oxygen.



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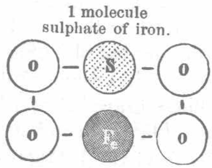

It is seen from what precedes that the words molecule and atom are far from being synonyms. The chemical molecule constitutes a whole of which the atoms form the parts, and these atoms are held together by affinity. In the preceding figure, this exchange of affinities between the atoms is indicated by lines of union.

Chemical molecules have been well compared to edifices: the atoms constitute the materials, and it is readily conceived that such molecular edifices differ from each other according to the nature, number, and arrangement of the atoms, that is, the materials composing them.

An edifice may be enlarged by the addition of new parts: it may be reduced in size or it may be entirely demolished. In the same manner a chemical molecule may be increased by the annexation of new atoms, or diminished by the separation of some of those which it already contains. In the first case there is combination, in the second, decomposition.

We may still further consider these phenomena of combination and decomposition.

Since the combination of two bodies results from the reciprocal action of their atoms, and has for effect a change in the nature of the molecules, it is evident that it can only take place when these atoms, and consequently the molecules, are brought into intimate relations; or more precisely, when the molecules of one of the bodies enter within the sphere of action of the molecules of the other body. And this sphere of action is very limited, for the affinity or elective attraction of the atoms is only exercised at infinitely small distances.