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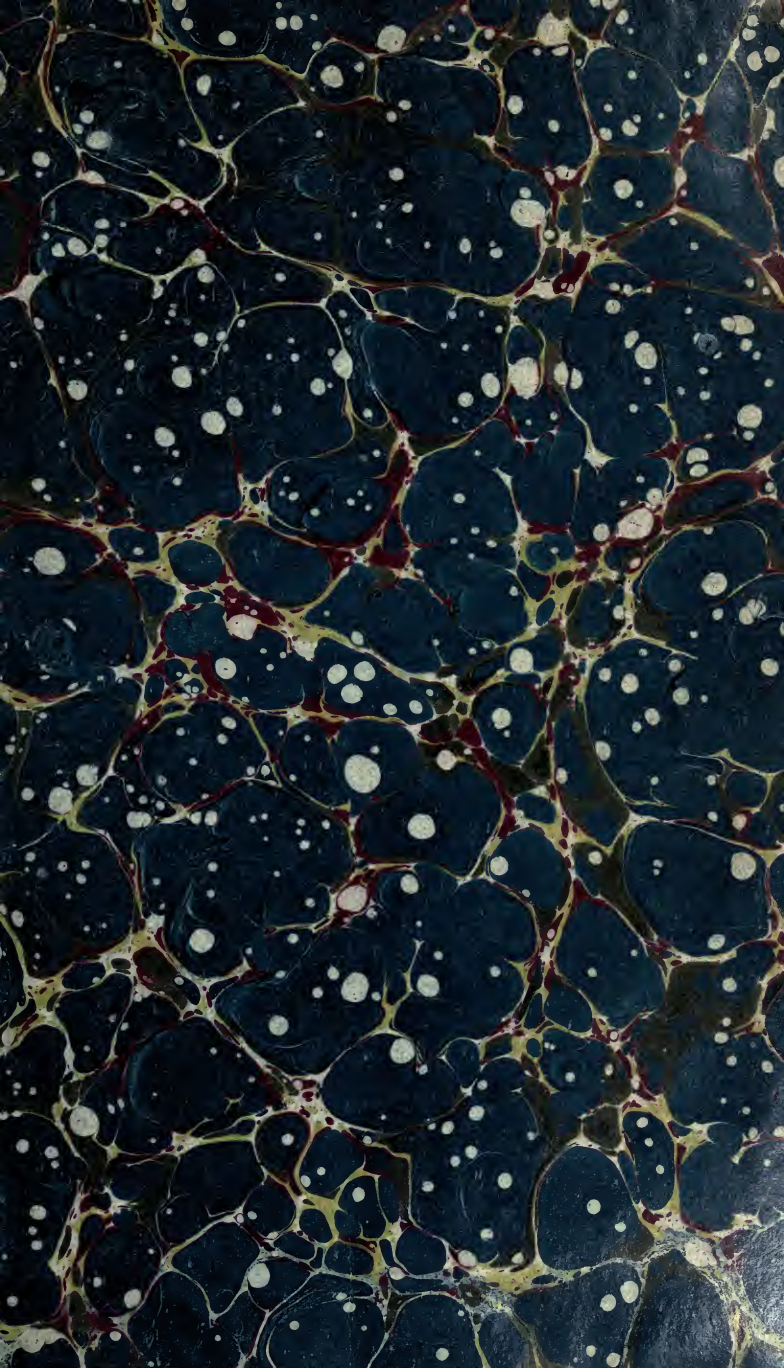
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A CONTRIBUTION

TO THE THEORY OF

CHEMICAL AFFINITY.

A PAPER

READ AT THE FIRST ANNUAL MEETING OF THE

CALIFORNIA SCIENCE ASSOCIATION,

AT SANTA CRUZ, DECEMBER 28, 1894.



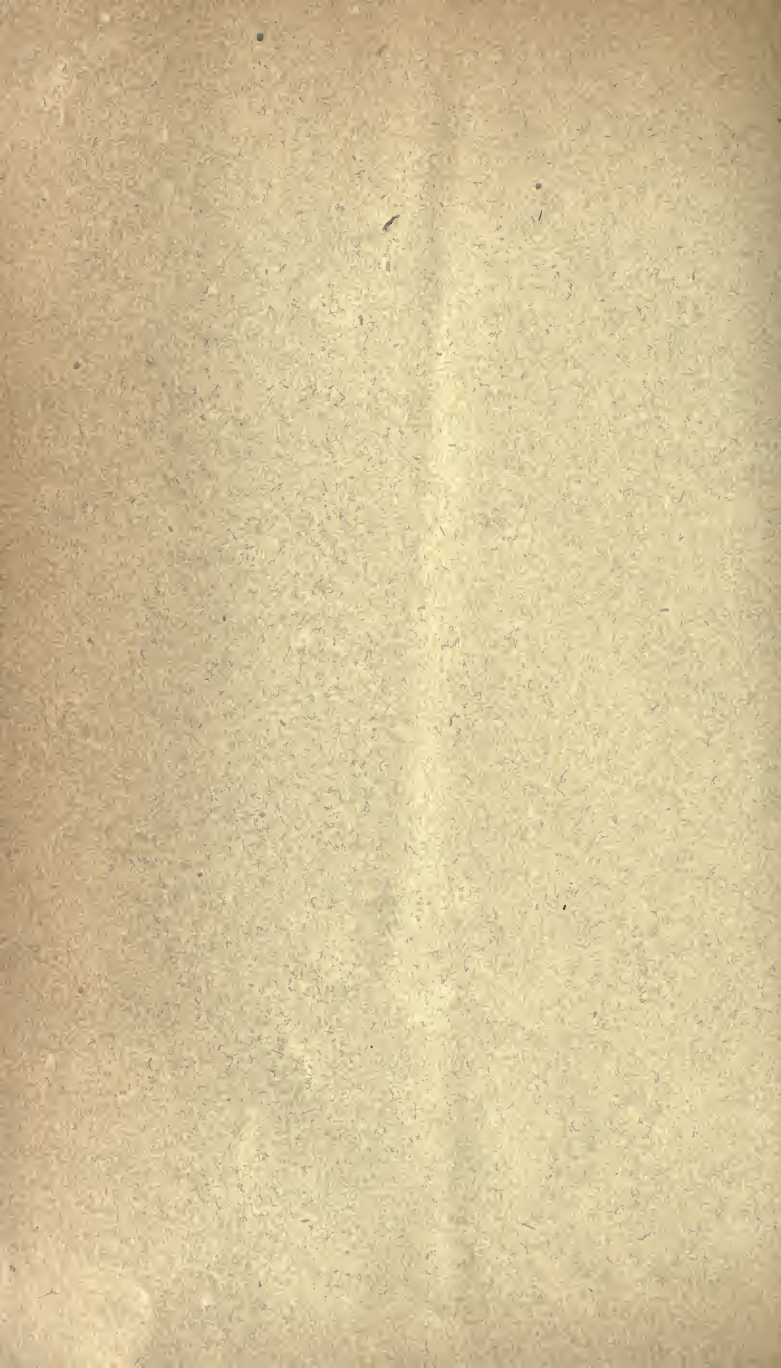
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## A CONTRIBUTION TO THE THEORY OF CHEMICAL AFFINITY.

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In this paper I propose to affirm and demonstrate the following propositions, viz. :

*First.*—That chemical affinity\* is determined by the compatibility, or accordance, of the motions proper to the respective atoms or molecules under consideration; and that affinity is directly as compatibility. By compatibility of motions, I mean such correspondence between the respective periods of oscillation, and between the respective figures of the paths in space traveled by a given point in the vibrating atoms, as renders it easy or possible for them to coalesce and oscillate together with a compound motion.

*Second.*— That chemical attraction in fact, is referable to the mechanical principle: "Motion in the line of least resistance" ; and is the result of the motion of contiguous, and accordantly-vibrating atoms or molecules along paths of least resistance in the surrounding ether—paths formed by the coalescence or composition of the several ether-waves accompanying the attracting atoms.†

If we mix intimately a given quantity of sodium chloride in watery solution with an equivalent quantity of silver nitrate, likewise in watery solution, we shall obtain a solid precipitate of silver chloride in a solution of sodium nitrate.

Or, if we take a watery solution containing both silver and copper nitrates, and add to this a sufficient quantity of sodium chloride in solution, we shall find on examination that every atom of the silver has been picked out from the mixture and separated by precipitation in the form of silver chloride.

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\*By affinity is here denoted *latent attraction*, attraction *in posse*, the capability of attracting or of being attracted.

†I use the word "accompanying" rather than "caused by" the attracting atoms, for the reason that it may possibly become a question whether the initiative lies with the ether, or with the atom.

What are we to think of the so called "cause" of these reactions? What is the condition, or what the conditions of the ultimate particles—atoms or molecules—underlying and prompting this change of associates? To say that chemical affinity is the cause; that the chlorine atoms—at first associated in these experiments with those of sodium—have an inherently stronger attraction for silver than for sodium; and that the molecules of the nitric acid radical—which we found associated with silver atoms—have naturally a greater attraction for sodium than for silver, and conversely; and that in obeying these stronger attractions, which is the law of their several beings, the decompositions and reconstructions recited are accomplished; is not to explain, but to *relate* the facts of the case; it is equivalent to saying that copper is red because of its inherent quality of redness. The real question, is *why* has the chlorine atom a greater attraction for the silver atom than for that of sodium? What property, state or condition of the chlorine atom, which is appreciable by our senses or mind, determines its stronger attraction for silver, and its weaker attraction for sodium, and conversely?

This thesis has for its object to answer these questions.

We have here, *apparently*, a case where the atoms involved in the reactions are conscious entities, which know and are known by each other; a case where, in associating to build up molecular structures, they reciprocally prefer this atom to that, and choose out from a mixed aggregation of atoms or molecules those of one kind in preference to those of another. Is it that the fundamental elements and raw material, *so to speak*, of intelligence, viz.: consciousness, the power of knowing, and the power of volition, are inherent in the raw material or *stuff* of the Universe?\*

We are reminded here of Tyndall's celebrated declaration, in the nature of a confession, made in his Belfast address, twenty years ago, before the British Association for the Advancement of Science: "Believing, as I do, in the continuity of nature, I cannot stop abruptly where our microscopes cease to be of use. Here the vision of the mind authoritatively supplements the vision of the eye. By an intellectual necessity, I cross the boundary of the experimental evidence, and discern in that matter—which we in our ignorance of its latent powers, and notwithstanding our professed reverence for its creator, have hitherto covered with opprobrium—the promise and potency of all terrestrial life."

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\*Par parenthesis, it may here be affirmed that Intelligence, in its ultimate analysis is nothing more nor less than sensitiveness to, and capability of being "moved" by the motions—molar and molecular—of other bodies (the *non ego*); and the process of ratiocination consists of consciousness in series, of the ratios between the different kinds and degrees of motion affecting us.

Suppose, in illustration, that, among ourselves, men and women, we have in each of two adjoining halls, a company composed of several couples; these in one hall consisting of two men, while those in the other consist of two women; suppose the wall between the halls to be removed, and the two companies to mingle with each other: presto, the couples fall apart, and thereupon fall again into couples—this time, however, consisting each of a man and woman. What should we say—what do we say of such a happening? This, viz., that the men and women concerned were possessed of at least intelligence enough to recognize the difference between men and women; and that they choose, each the other sex as an associate in preference to their own sex. Making due allowance for the fact that, being human, we can understand and sympathize with the feelings and motives leading to the changes last recited; while we cannot definitely realize the *elementary* sources of action in the atomic changes heretofore described, the cases appear to be precisely parallel.

Taking this illustration for what it is worth, however, and returning to our atoms and molecules; it will readily be perceived that the hypothesis of conscious selection *appears* to involve the absurdity spoken of by Newton in relation to gravity, viz., *action at a distance*; for, although the distances between and separating atoms and molecules are small beyond comprehension, they are nevertheless just as real as the equally incomprehensible distances separating us from the fixed stars, or those intervening between the planets and the sun.

Observe, however, Newton's words are these: "That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance *through a vacuum*, without the mediation of anything else by and through which their action and force may be conveyed from one to another, is to me so great an absurdity," etc. Now, action at a distance *through a vacuum* without the mediation of anything else, seems to have constituted the *gravamen* of the absurdity; but at this time we postulate an all-pervading ether between one body and another, and between one atom and another, and surrounding all atoms.

In point of fact, then, whatever may be the worth or unworth of this hypothesis of conscious and intelligent atoms, it does not even by implication involve the absurdity of action at a distance; it takes into account that, between atoms as between stars, there is a medium of communication, the ether; it postulates just such action between atoms and molecules, as all bodies, and we ourselves, severally exert on each other. Do bodies of sensible dimensions ever come into actual contact? and yet they unmistakably act on each other, as we see in the example of the blacksmith's hammer shaping a piece of iron on an anvil. But

observe: according to the molecular theory and its corollaries, there is no actual contact. The surfaces of all solid bodies present, instead of an unbroken front of "stuff," only a superficial array of atoms, vibrating molecules, with spaces between; therefore two such bodies, when in so-called contact, can only be as near to each other as the repulsion between the moving molecules or their respective surfaces will permit. Observe, too, that although in discussing the kinetic theory of gases, we speak in a rough way, of collisions between the atoms or molecules constituting a gas; yet in strictness, no one with a competent faculty of thinking will contend that in such collisions the atoms come into true contact—that is, a contact which excludes an atmosphere of ether.

Here may be permitted a digression, to speak of repulsion as the opposite of attraction. The repulsion between atoms when they come into close, so-called contact, which prevents them touching, and pushes them away, can be nothing else than the elasticity of the film or atmosphere of ether surrounding each. This atmosphere being subjected by the *moment* of the approaching atoms, to pressure, is rendered so *tense* as to obstruct farther movement in that direction.

In demonstrating the initial propositions of this thesis, however, we are not greatly concerned with the acceptance or rejection of this hypothesis of consciousness and intelligence in the atom; all that is demanded at this stage of the argument is, *motion of the atom as an essential mode of its existence; and for every different kind of atom and molecule a different motion.*

So far as we have learned hitherto, all the sensible qualities (excepting, *perhaps*, gravity) of bodies seem to depend finally upon motion—the motion of *their* several constituent particles reacting on ether-waves set in motion by particles in the sun or other radiating body. Before this audience, it is unnecessary to particularize, farther, than to mention color, fluidity, solidity, sonority, transparency, diathermancy, etc. Even odors and sapidities appear to come within the generalization. In saying, however, that the sensible qualities of things depend on and are expressions of atomic and molecular motion, we shall do well to bear in mind that these motions (of solid particles) are communicated to us and to each other by means of etherial undulations or waves. These ether-waves, flowing outward from their source, impinge and break on the molecules constituting our bodies and modify thus their motions in various ways. Thus only is consciousness excited in us, and the varied and varying character of our consciousness is the expression and effect of the various and varying *rhythm and mode* of the impinging waves, which, in this way and that, modify the motions of our individual molecules.

What is an ether-wave? It can only be that it consists of a differen-

tiation of the ethereal substance in a definite direction, a rhythmic disturbance of its homogeneity by the formation of volumes or spheres of *tension* in alternation with volumes or spheres of *laxity*, tension and laxity successively changing places or regularly succeeding in lines radiating from its source, in a manner analagous to sound-waves, which consist of alternate successive spheres of condensation and rarefaction in the gaseous atmosphere or other conducting medium.

Now the motions of the atoms of the several elementary substances, differing as they do one from the other, differ, it is fair to assume, in at least two respects, viz., first in their rates or periods of vibration, that is, in the frequency with which, in a given time, they change shape by the back and forward swinging of their proper substance; and second in their mode or path of vibration, that is, in the figures which a point in their respective surfaces describes in space during a complete vibration. The term vibration is here used in the most general sense to designate any and every form of recurring or cyclic movement, reciprocating motion in straight lines, rotation, revolution, and every conceivable compound of two or more of these.

We can study molecular motions under the three known conditions of matter: gaseous, liquid and solid. A rapid glance at the facts involved in chemical reactions, both synthetic and analytic under these several conditions, will discover indications which, while not conclusive on the subject, tend strongly to support the proposition that combining attractions depend on compatibility of motions as herein affirmed.

The molecules of matter in a gaseous state may be regarded as in a semi-chaotic condition with a tendency to separate, rather than to aggregate; their excursive motions in more or less straight lines are immeasurably greater in extent than any proper self-centred vibratory movements they may execute. Moreover, as the direction of their excursion lines is determined largely by impact and reflection, the element of accident or irregularity is more or less involved. These conditions cannot *a priori* be considered favorable to composition or coalescence of varying motions. And as a matter of fact, mixed gases do not combine easily nor rapidly (and sometimes they refuse to combine) under ordinary conditions. The oxygen and nitrogen of our atmosphere remain constantly and persistently distinct, except as a result of the special action of outside agents, as *e. g.* an electric discharge, etc., Chlorine and hydrogen gases, while they do slowly and gradually combine even in the dark, need the influence of the sun's rays, or those of the electric light, to produce a rapid union; so with oxygen and hydrogen; and many others might be cited. Observe that in all these cases the special agent—the critical factor—determining the union, is some

mode of motion introduced; some ethereal wave-force adding to or changing in some way the motions of one or both of the combining molecules.

In the solid state, too, the conditions favorable to molecular changes, either of combination or decomposition, are absent in still greater degree; the distances between atom and atom or between molecule and molecule being inconsiderable when compared with the line or orbit of vibration and size of particles. As a matter of fact, the solid state does not present many striking examples of chemical reaction except at the surface. In this state, inasmuch as amplitude of vibration is reduced to a low degree, the introduction of diverse elements is not easy. Even when such rough mechanical mixture as we can secure by trituration is made, the distance separating the little masses of the mixture are immeasurably larger than those necessary for atomic combination. At the surfaces where the molecules are free in some cases to make limited excursions into the vaporous or gaseous atmosphere surrounding them; and the atmosphere is perhaps condensed, combinations take place easily enough in some cases; iron rust, silver sulphuret, copper oxides and carbonates, and others will at once suggest themselves as examples.

With substances in liquid solution, or rendered fluid by heat, the conditions favoring chemical changes seem to be the best possible. The most unfettered motion in every direction throughout the mass; nothing in the way of accident (as in gases) to disturb the natural and proper rhythm of the atoms or molecules. The waves formed in the ether pervading the intermolecular spaces of a mixture in solution of compatible atoms, present to the eye of the imagination a picture of the most beautiful and regular, though intricate tracery. Along these variously curving lines, paths of least resistance, it is possible, and delightful to the philosophic mind, to picture the atoms having affinity, moving and uniting with their complimentary atoms to form molecules, which, continuing to swing with the double or multiple force and composite motion, speed along the ethereal paths in figures of still greater intricacy and beauty.

Hastening to a conclusion of this attempt to sketch a theory of chemical attraction; let me say that, as we judge of the truths of hypotheses largely by their correspondence with other accepted hypotheses, and by the number of phenomena which they "explain" or bring under a broader generalization; I shall attempt to show such correspondence and such power in this. Only a few of the phenomena in the domain of chemistry, which, by this theory are shown to be regular, while formerly considered anomalous, can be indicated. And first *catalysis*, or the action of presence, *e. g.* manganese dioxide, used in the reaction for procuring oxygen from potassium chlorate. Here,

although the manganese oxide is entirely unchanged, its presence renders the liberation of oxygen easy and copious at about 200° F., where in its absence a heat sufficient to melt the chlorate would be required. Another example is found in the case of sulphuric acid, used with heat, to effect the metamorphosis of starch into glucose. These examples, it is true, are instances of decomposition, and only inversely related to attraction; but they show the power of ether-waves, complementary to the atomic motions of contiguous bodies, to affect the strength of existing attractions—they are cases of the inverse of the proposition to be demonstrated. Second, the influence or condition called the *nascent state* on chemical combination, *e. g.* the easy combination of carbon and nitrogen with hydrogen, when liberated simultaneously in the destructive distillation, or spontaneous decay of organic matter; in contrast to the fact that they do not combine when mixed in the gaseous state. The considerations adduced herein when treating of the obstacles presented by mixed gases to chemical union, on the one hand; and the fact that the atom of nitrogen, *e. g.* must have a slightly different rate *and figure* of vibration from the *molecule* of the same substance in a gaseous condition; lead us to see that, while the atom may very easily combine with carbon and hydrogen, the molecule, from its different rate and mode, and therefore different wave, may and does not.

The explanation which Liebig suggested as the cause and nature of fermentation is in point here. He imagined that when certain *ferments* (by which, however, he did not mean the same thing as Pasteur describes under that name) in the act of undergoing change (decomposition) were in contact with neutral ternary compounds of slight stability (*because built up of many atoms and therefore having a highly complex motion and wave figure*—G. P.) as sugar, the molecular disturbance of the decomposing ferment was propagated (by ether waves—G. P.) to the sugar, and wrought destruction of the equilibrium of forces (destruction of the special composite motion—G. P.) to which it owed its being.

Third, the action of light (ether-waves) on the combination of atoms, *e. g.* in plants, etc., and on the decomposition of certain salts. Fourth, going outside of chemistry and taking an example from zoology, it explains the order and the reason therefor in which birds of passage—ducks and geese—arrange themselves in flight, *viz.*, in lines oblique to the line of progress. Certain points in the air-wave caused by the movements of the leader are more fitted to sustain the succeeding bird in its flight, *e. g.* the *crest* rather than the *trough* of the wave. Doubtless the same condition of affairs, substituting ether-wave for air-wave, determines the various forms of crystallization assumed by different substances.

There are other chemical facts which will probably be illustrated and

more or less explained by this theory: some of the phenomena of thermal chemistry and some phenomena connected with contraction of bulk in combining elements. I am not sure but the matter of attraction, of gravitation will ultimately be found related to this hypothesis.

Finally, while analogies—correspondences in nature in various departments—require to be carefully handled, if we would adhere to strictly scientific methods; nevertheless the appeal to analogies may be useful in illustrating and corroborating inductions already drawn from facts in other fields. Now, what, in fact, is the foundation and “cause” of affinities and attractions among human beings and the lower animals? Compatibility and accordance of movements! That is to say, conduct on the part of two or more individuals which will harmonize and fit together. The tendency of all of us to move in lines of least resistance causes us to be attracted towards those who are in sympathy with us, and whose movements are therefore synchronous and of like form to, and harmonize with ours, instead of being obstructive. It was forbidden by a wise law giver to yoke the ox and the ass together, and why? Because their movements in walking and pulling are totally uncomformable, inconsistent, and will not combine; they are heteromorphous as well as unsynchronous, and therefore destructive to each other's efficiency.





