ON THE RELATIONS WHICH EXIST BETWEEN THE ATOMIC FORMULAS OF ORGANIC COMPOUNDS AND THE ROTATORY POWER OF THEIR SOLUTIONS.

Joseph Achille LeBel
Bull. soc. chim. (November 1874)
volume 22, pages 337-347

Up to the present time we do not possess any certain rule which enables us to foresee whether or not the solution of a substance has rotatory power. We know only that the derivatives of an active substance are in general also active; nevertheless we often see the rotatory power suddenly disappear in the most immediate derivatives, while in other cases, it persists in very remote derivatives. By considerations, purely geometrical, I have been able to formulate a rule of a quite general character.

Before giving the reasoning which has led me to this law I shall give the facts upon which it rests, and then shall conclude with a discussion of the confirmation of the law offered by the present state of our chemical knowledge.

The labors of Pasteur and others have completely established the correlation which exists between molecular asymmetry and rotatory power. If the asymmetry exists only in the crystalline molecule, the crystal alone will be active; if, on the contrary, it belongs to the chemical molecule, the solution will show rotatory power, and often the crystal also if the structure of the crystal allows us to perceive it, as in the case of the sulphate of strychnine and the alum of amyl amine.

There are, moreover, mathematical demonstrations of the necessary existence of this correlation, which we may consider a perfectly ascertained fact.

In the reasoning which follows, we shall ignore the asymmetries which might arise from the arrangement in space possessed by the atoms and univalent radicals; but shall consider them as spheres or material points, which will be equal if the atoms or radicals are equal, and different if they are different. This restriction is justified by the fact that, up to the present time, it has been possible to account for all the cases of isomerism observed without recourse to such arrangement and the discussion at the end of the paper will show that the appearance of the rotatory power can be equally well foreseen without the aid of the hypothesis of which we have just spoken.

First general principle. Let us consider a molecule of a chemical compound having the formula MA_4; M being a simple or complex radical combined with four univalent atoms A, capable of being replaced by substitution. Let us replace three of them by simple or complex univalent radicals differing from one another and from M; the body obtained will be asymmetric.

Indeed, the group of radicals R, R', R", A when considered as material points differing among themselves form a structure which is enantimorphous with its reflected image, and the residue, M, cannot re-establish the symmetry. In general then, it may be stated that if a body is derived from the original type MA_4 by the substitution of three different atoms or radicals for A, its molecules will be asymmetric, and it will have rotatory power.

But there are two exceptional cases, distinct in character.

(1) If the molecular type has a plane of symmetry containing the four atoms A, the substitution of these by radicals (which we must consider as not capable of changing their position) can in no way alter the symmetry with respect to this plane, and in such cases the whole series of substitution products will be inactive.

(2) The last radical substituted for A may be composed of the same atoms that compose all the rest of the group into which it enters, and these two equal groups may have a neutralizing effect upon polarized light, or they may increase the activity; when the former is the case the body will be inactive. Now this arrangement may present

itself in a derivative of an active asymmetric body where there is but slight difference in constitution, and later we shall see a remarkable instance of this.

Second general principle. If, in our fundamental type we substitute but two radicals, R, R', it is possible to have symmetry or asymmetry according to the constitution of the original type MA_4. If this molecule originally had a plane of symmetry passing through the two atoms A which have been replaced by R and R', this plane will remain a plane of symmetry after the substitution; the body obtained will then be inactive . Our knowledge of the constitution of certain simple types will enable us to assert that certain bodies derived from them by two substitutions will be inactive.

Again, if it happens not only that a single substitution furnished but one derivative, but also that two and even three substitutions give only one and the same chemical isomer, we are obliged to admit that the four atoms A occupy the angles of a regular tetrahedron, whose planes of symmetry are identical with those of the whole molecule MA_4; in this case also no bisubstitution product can have rotatory power . . . .

Theorem. When an asymmetric body is formed in a reaction where there are present originally only unsymmetric bodies, the two isomers of inverse symmetry will be formed in equal quantities.

We know that the general principle of the calculation of probabilities consists in this:

When any phenomenon whatever can take place in two ways only, and there is no reason why it should take place in one of the ways in preference to the other, if the phenomenon has taken place m times in one manner and m' times in the other manner, the ratio m/m' approaches unity as the sum m + m' approaches infinity.

When an asymmetric body has been formed by substitution from a symmetric one, the asymmetry has been introduced by one of the substitutions which has taken place; let us consider this point carefully. The radical or the atom, the substitution of which introduced the asymmetry had formerly a homolog which was symmetrical to it by its connection with a point or a plane of symmetry; these radicals being in similar dynamic and geometrical considerations, if m and m' represent the number of times that each one of them is substituted, m'/m ought to approach unity as the number of these substitutions grows beyond a measurable unit.

Now if the substitution of these similar radicals produces a dextro-body, then the other will produce the laevo-body, both will in consequence be formed in equal proportions.

It is the same for asymmetric bodies formed by addition; indeed the body which destroys the symmetry of a symmetrical molecule by adding itself to it, would be able to occupy an identical place situated on the other side of the point or plane of symmetry; the preceding reasoning therefore can be applied equally well to this case.

This is not necessarily true of asymmetric bodies formed in the presence of other active bodies, or traversed by circularly polarized light, or, in short, when submitted to any cause whatever which favors the formation of one of the asymmetric isomers. Such conditions are exceptional; and generally in the case of bodies prepared synthetically those which are active will escape the observation of the chemist unless he endeavors to separate the mixed isomeric products, the combined action of which upon polarized light is neutral.

We have a striking example of this in tartaric acid, for neither the dextro- nor the laevo-tartaric acid has ever been obtained directly by synthesis, but the inactive racemic acid which is a combination of equal parts of the dextro and laevo acids, is always obtained.