# CHEMISTRY TO-DAY AND ITS PROBLEMS.

If we compare the chemistry of the present day with that existing in the earlier half of the century, we certainly see no epoch-making, far-reaching discovery such as that which has marked the sister science, biology. There is nothing which warrants us in speaking of the "new" or of the "old" chemistry. Nevertheless we have witnessed a most important advance. Our science is gaining a more complete organic and internal cohesion, and is entering into closer federal relations with the other sciences, giving and receiving fresh light. Chemistry, in conjunction with physics, furnishes astronomy with a new and most powerful method of research, and with a new body of facts and generalizations. But to these results we have no occasion to refer, as they have been ably explained by Professor C. A. Young.*

At the same time, chemistry is deriving new light from the very opposite direction. Not many years ago few persons, if any, surmised that certain microscopic living beings—microbia, or micro-organisms—could be powerful agents of combination and decomposition, not merely in living plants and animals, and not alone in dead organic matter, but even in the mineral kingdom. Some time ago the researches of Schloesing and Muntz, of Marcagno, of P. F. Frankland, and of others showed that the decomposition of dead organisms into their components depends mainly on the action of microbia which break up blood, flesh, leaves, and even wood, into carbonic acid and ammonia. Living organisms further convert the ammonia into nitric acid, which, if potash is present, forms saltpetre. By a due selection of different ferments—all of them living organisms—we can produce, in a solution of sugar or a decoction of malt, alcoholic liquors having the actual aroma and flavor of the choicest wines. More remarkable still, it is now proved that the green rust on antique bronzes is a product of microscopic plant life.

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The interfusion—not confusion—of chemistry and physics is being rapidly developed, and is constantly proving more and more fruitful. Just as the miner is apt to find the amplest booty where different rock formations meet; just as the flora and the fauna are richest where land and water adjoin each other; so also the border land of chemistry and physics forms the happy hunting ground of the experimentalist—a truth which I would strongly urge upon every student.

We were told formerly that bodies cannot act upon each other chemically except after they have been dissolved. Yet even gravitation, the least versatile form of energy, can, when it acts as pressure, compel certain solid bodies to enter into mutual combination even at ordinary temperatures. W. Spring, a Belgian chemist, by submitting sulphur and copper, in the form of fine powder, to an enormous pressure, has been able to combine the two chemically, forming a copper sulphide; and, in an analogous manner, it is possible to form the sulphides of other metals which have a powerful affinity for sulphur. This experiment has a most important bearing upon the formation of minerals in that part of nature's laboratory which we call the interior of the earth. Of the processes in play in that laboratory we know very little, as our main evidences are merely rocks raised by upheavals and matter ejected by volcanoes.

An important result of the joint action of low temperature and intense pressure is the liquefaction, and even the solidification, of gases. Faraday formerly experimented in this direction with no little success, but certain gases bade defiance to the resources at his disposal and remained in the gaseous condition. Consequently in old text books we used to read of "condensible" and of "permanent" gases. But of late the question has been re-opened with improved methods and more powerful appliances. Pictet, Cailletet, and Wroblewski have been so successful that the class of "permanent gases" has disappeared. It has been asked what would be the condition of any substance, or of matter in general, if it could be exposed to the temperature of absolute zero supposed to exist in the depths of space. Such a body, so far as we can judge from approximate experiments, need retain none of the properties of matter save inertia and impenetrability. We even hesitate to say how far it might be entitled to be called matter at all.

Chemical compositions and decompositions may be effected, in a variety of cases, by a shock or a vibration. The slightest touch may cause certain bodies to assume a crystalline structure or to change color. In other cases a blow may lead to a complete decomposition attended with combustion and explosion. The effects of prolonged vibration upon chemical compounds have not been thoroughly studied. It is found impracticable to preserve wines in a cellar situated near a powerful tilt hammer which keeps the earth around in constant tremor. But the part played by gravitation in any of its forms in chemical phenomena is trifling in comparison with the interaction of heat and chemical forces. Heat is at once a cause and an effect of chemical change. We can rarely form or decompose any chemical compound without either absorbing or liberating heat. The quantity of heat lost or gained in such cases has been proposed as a means of measuring chemical affinity, for which, unlike heat, electricity, or light, we have no direct method of estimation. The special study of this subject, known as thermo-chemistry, was undertaken in a rudimentary manner by Lavoisier and Rumford in the last century. Lavoisier laid down the law that as much heat is required to decompose a compound as is liberated by the combination of its constituent elements. The thermo-chemical process was studied more completely by Hess, Andrews, Graham, and Favre, about 1840. In the mean time the mechanical theory of heat was developed by Joule and Clausius, and was applied in 1853 to thermo-chemistry by Julius Thomsen, of the University of Copenhagen. This chemist is still continuing his researches, in which he has been joined since 1863, with occasional controversies, by M. Berthelot. Their results have shed a novel light both upon pure chemistry and upon the chemical arts. In both we thus obtain the power not merely of explaining results, but often of foreseeing them. An exposition of thermo-chemical laws would be too technical for the present article.

The interaction of light with chemical activity, though not less important, is less conspicuous. From the consideration that every objective optical phenomenon can be photographed, it follows that the geometrical laws of light hold good for the chemically-active portion of radiant energy. As a rule, rays of short wave length—those, that is, in which the number of vibrations in a second is greatest—are most capable of chemical activity. In the most important case, however, namely, the decomposition of carbonic acid in the tissues of green plants, the rays of greater wave length are most active. In the act of sight, which depends on an irritation of the retina and is probably a chemical process, the yellow and green rays are the most efficient.

Chemical change appears also as a cause and an effect of electricity. We no longer find ourselves able to accept the electro-chemical theory of Berzelius, according to which two elements enter into combination and remain combined because the one is relatively electro-negative and the other electro-positive. This theory led its illustrious originator to oppose Faraday's law of electrolytic equivalents and the theory of substitution proposed by Dumas, both of which have since been accepted as perfectly true. But we have not yet succeeded in establishing in its place a sounder electro-chemical theory, which is still one of the wants of our science. We know, as a general rule, that a positive element is eliminated from a combination by a stronger positive element, and that a negative element is driven out in like manner by a stronger negative one. But we are not able, in virtue of such reactions, to ascertain the place of an element in the series of electric tensions. Such a series is needed, but its preparation will prove no easy task. We now make extended use of electric action in the analysis and assay of mineral matters, and even in metallurgical operations on a large scale. We have been convinced, thanks to the researches of Arrhenius, that solutions of salts and of powerful acids and bases contain these substances, as such, only to a small extent, the greater part of them being dissociated into ions. We find, too, that chemical properties may be greatly altered by an electrical charge.

The greatest portion of the activity of chemists is at present turned to the discovery of new compounds, especially organic compounds. To such an extent is this the case that an entire number of the FORUM would not suffice for a bare catalogue of the novelties thus brought to light. Some of these compounds are, or may be hereafter, of technical or commercial importance; but the great majority of such discoveries throw no light on the principles of the science, and are devoid of interest except to the chemical specialist. Some discoveries, however, have lately been made which may teach important lessons, and to a few of these I must briefly draw attention. In the dreams of the alchemists a body figured under the name of "alcahest," which was supposed to be a universal solvent, and which, consequently, if obtained, would be incapable of preservation. It has long been conjectured that fluorine, if it could be produced in a free state, would probably possess the very properties attributed to this mysterious alcahest. Many attempts, made by Knox, Baudrimont, Louyet, and others, proved vain; but lately a French chemist, H. Moissan, has obtained free fluorine. It is interesting to find that fluorine possesses the very properties which were expected on theoretical grounds, and which the old alchemists had assigned to their alcahest. It is curious to note that this formidable element exists free in nature, although in very small quantities. On crushing fluor spar a corrosive gas is sometimes emitted which possesses the general properties of fluorine.

Much doubt has existed concerning the ultimate source of the combined nitrogen that exists in plants and forms a necessary item in their food. Some chemists of the highest eminence have maintained that, while plants are capable of absorbing and fixing in their tissues the ammonia and oxides of nitrogen present in the atmosphere, they are utterly incapable of utilizing the free nitrogen that exists in such vast quantities in the air. This question is not merely of deep theoretical interest as relating to the balance of life upon the globe, but it is of supreme importance to man on account of its reference to the fertility of the soil and to our future supply of food. It has been fully demonstrated that, at least in Europe, the yearly amount of combined nitrogen brought down upon an acre of soil by the agency of rain and dew does not make up for the quantity taken away in the various crops. Hence, even if we return to the land all the animal and vegetable refuse into which its products are ultimately converted, the fertility of any given plot must in the long run decline, unless, in some manner or other, a portion of the free nitrogen in the atmosphere is absorbed and rendered available for the nutrition of plants. Source after source has been suggested as probable, and finally declared to be inefficient. At last one has been found in a most unlooked-for quarter. Practical agriculturists have long since reached the conclusion that certain green crops, such as peas, beans, lentils, and vetches, are not so exhaustive to the soil as wheat, maize, turnips, and potatoes. Now if we examine the rootlets, say of kidney beans, we find them studded more or less thickly with small knots or tubercles, which are the abode of a special kind of bacteria. These bacteria have the power of fixing the free atmospheric nitrogen in such a manner that it may serve as a food for the plant. Accordingly if we sow a field with such vegetables and plow them into the soil at the end of the season, they prove efficient fertilizers. On the other hand, if the formation of these tubercles on the roots has been prevented, the plants do not flourish and the soil is not enriched. But even if it is demonstrated that the soil is benefited by a rotation of crops in which leguminous plants are duly prominent, this result does not justify our present profligate system of running the organic waste of our cities into the sea or destroying it by fire.

We have next to take a glance at an alleged elementary body, said to have been discovered in Damara Land, South Africa, and named hence damarium. Two prospectors observed small jets of a gas issuing from the sand. It proved to be specifically lighter than hydrogen, hitherto the lightest body known, and, as far as could be roughly ascertained, was of a lower atomic weight. I should not have noticed this discovery, had it not been given to the world in a paper of such standing as the "*Chemiker Zeitung*." If the existence and properties of damarium are verified, it will have to figure in the first line of our tables of atomic weights and to serve in place of hydrogen as the standard of comparison for the specific gravities of gases. It may, perhaps, prove to be identical with "helium," a body which on spectroscopical evidence is believed to exist in the sun.

A discovery, not yet generally accepted, has been made by Professor Kruss, of Munich, and Dr. W. Schmidt. They have found, it is alleged, in the purest nickel and cobalt, from one to three per cent. of a metal which has hitherto escaped detection. This is the more curious as these two metals have been closely scrutinized by Liebig, Woehler, Fresenius, and other chemists of high eminence.

Until very lately an element figured in our text books under the name of didymium. Its properties, and especially its atomic weight, had been determined in certain masterly researches; and it was recognized, according to one of the most familiar definitions of an element, as a "something to which we may add, but from which we can take nothing." But Dr. Auer von Welsbach, on examining this supposed simple body in a manner hitherto untried, was able to resolve it into two simpler bodies, which have received the names neodymium and praseodymium. Still this is not the end of the matter. Later researches, in which the present writer has had a part, show that neodymium and praseodymium are not the simplest bodies into which didymium can be broken up. Another case of this kind is that of Nordenskiold's gadolinium. This body had a fixed atomic weight, yet it has been broken up into yttrium, erbium, and ytterbium. I have found that yttrium consists of five or more constituents, previously unknown, and each of these constituents may prove further divisible if examined in some novel manner. Space does not permit me to develop the lessons of the "rare earths," which promise to throw a new light on the very foundations of our science and on the nature of the elements. In all probability they have been formed by a process of evolution, in which the "survival of the most inert" plays a role similar to that which the "survival of the fittest" is considered to take in biology.

Multitudes of discoveries have lately been made in the department of organic chemistry. Compounds which were formerly obtained by the aid of plants and animals are now formed synthetically; that is, built up, if not from their elements, yet from simpler combinations. The present labors in this direction, however, can possess none of the high philosophic interest which attached to Woehler's artificial production of urea. That grand discovery disproved the dogma that organic compounds are capable of formation only under the influence of life. This having been effected, further disproof is needless. Many of the recent organic syntheses may be described simply as a war against agriculture. But there is a limit which is sometimes not taken into account. We shall ultimately, doubtless, be able to reproduce artificially every organic compound existing in nature. But there is no prospect that we shall be able to make artificially any organism or any part of an organism. Suppose we should be able to form synthetically malic acid, fruit sugar, and cellulose; we should not be in the least nearer to the power of making an apple. Wherever there is not merely peculiar chemical composition, but peculiar tissue, there the scope of chemistry is at an end. Hence, though the formation of starch and gluten may ultimately come within our power, we have no prospect of ever being able artificially to produce a grain of wheat.

Among the chief triumphs of organic synthesis must rank the formation of so-called "saccharine" by Professor Remsen and Dr. Fahlberg. This substance, we must bear in mind, has none of the properties of sugar except sweetness. It does not in any way contribute to nutrition. It has its uses, doubtless, for sweetening the food of invalids to whom sugar would prove injurious, such as diabetic patients. On the other hand, it opens the door to a series of frauds, as a small quantity of it may enable various worthless substances, so long as they are soluble, to be sold as sugar. Its taste, moreover, is not exactly like that of sugar. Bees and wasps turn from it with an angry hum, and even flies will not touch it. But we must remember that the senses of many insects are not only more delicate than our own, but reveal differences which we cannot detect even with our instruments of precision. A bee will not touch beet-root sugar if cane sugar is at hand. It is, however, perfectly possible that chemical science may yet put us in possession of a true artificial sugar.

Other experimentalists have turned their attention to perfumes. The so-called fruit essences, which are supposed to communicate to confectionery and to liqueurs the flavors of pineapples, of the jargonelle pear, and of apples, are open to grave suspicion. It is not proved that their physiological action is identical with that of the fruits whose flavors they simulate. Some of the ptomaïnes and alkaloids extracted from putrid or diseased animal matter, though highly poisonous, possess the odors of cinnamon, of the rose, or of the syringa. An artificial musk, recently obtained, not only gives off the exact odor of the natural product, but is said to have the same medicinal action. Hence the musk deer may consider itself disestablished.

The synthetic chemists have been most active and most successful in making dyes. Some natural coloring matters, such as turmeric, archil, and safflower, have been nearly superseded. But the two most important dyes, alizarine and indigo, have been not only imitated, but actually made artificially. The history of both is no longer novel, but I may mention that quite lately two chemists, one a Swiss and the other a German, have succeeded in producing artificial indigo at a price which will enable it to compete with the natural product. A recent inventor brings forward a so-called artificial silk. His product, however, is not silk, but merely cotton fiber modified so as to imitate some of the properties of silk. Hence it forms no exception to the rule that we cannot reproduce organic structures.

Attempts have been made, not without success, to form minerals. Artificial ultramarine has long been an article of commerce. The formation of the diamond is said to have been actually effected, but in the opinion of the inventor the process is so difficult and so dangerous, that the diamond-miner and the diamond-merchant need not feel uneasy. The ruby and the sapphire have lately been reproduced in Paris, and, curiously enough, the coloring matter in both is found to be due to one and the same metal—chromium—in different states of combination. Red and blue stones, or an intermediate violet form which might be likened to the rare and beautiful oriental amethyst, have been obtained in one and the same operation, from the same lot of material. The jewels thus produced have so far all been small; large enough to form the pivots of superior watch works, but not large enough to rank as rare and costly ornamental objects.

Passing, in conclusion, to more general considerations, we may note that our conceptions of atoms and molecules, as the component parts of matter, have been extended. Dalton and most of the chemists of the present day conceive of the atom as a body, minute indeed, but not infinitely so; divisible in the imagination of the mathematician, but not capable of being actually broken up by any means at our command. The conflicting theory of Boscovitch, which was adopted by Faraday, regards atoms as mere mathematical points, centers of forces, or, as we should now say, forms of energy. To compare these two views in detail would be here impracticable, but several advances have been lately made in our insight into the conformation of matter. It has long been considered that the atoms are grouped together in so-called molecules. Each such molecule is composed of a fixed number, generally small, of atoms. These molecules, if they belong to one and the same chemical species, are alike in the number and the kind of atoms of which they are composed. But we find, on analysis, bodies which contain the very same substances in exactly the same proportions; and yet such bodies may differ in their boiling and congealing points, in their colors, in their odors, and in their physiological action. The only way of explaining these differences is by supposing that the atoms in each molecule are arranged differently, and that this modifies the properties of the substance. The arrangement of atoms in the molecules of a compound body is known as its "constitution," which must not be confounded with its composition. The constitutions of compound bodies have until lately been represented by certain formulas, which show the symbols of their elements disposed on a plane surface. It is now found that the mutual relations of such elementary atoms may be shown forth more clearly by supposing them to be disposed on a body of three dimensions. But this is not all. It appears now that the atoms in the molecule are not motionless, but that they are in a state of vibration or rotation—motion, in short, comparable to that of the bodies of the solar system. So minute are the atoms that, in a molecule which is not even visible to our senses, and which might be thought a concrete whole, they may be relatively as far apart as the sun and the planets.

We see thus that in chemistry, though we have gained much truth, though we have acquired the powers of creation and prediction, there are still not mere gaps, but abysses, to be filled up. For this task not one Curtius, but many, will be needed.

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# THE BERTILLON SYSTEM OF IDENTIFICATION.

In all ages questions of identity have excited the interest of men. Is it not at bottom a problem of this sort that forms the basis of the everlasting popular melodrama about lost, exchanged, and recovered children? Actual history is not less rich in facts and stories of this kind. Almost all the French historians, for example, have striven to identify the celebrated prisoner of Louis XIV., known as "The Man with the Iron Mask," not to mention the pretended descendants of J. J. Rousseau and of Louis XIV., who, in the face of all evidence, have succeeded in making some people take their claims seriously.

But it is naturally the world of criminals that has furnished, and yet furnishes, the greatest number of such attempts at deceit. It is not generally known by the honest public how large a number of malefactors have recourse to concealment of identity. We may assert without exaggeration that there is not a single habitual criminal who does not seek to hide his individuality when the circumstances of his arrest permit. The immensity of modern cities and the increasing facility of communication make this course more and more easy. International criminals, such as bank-robbers and pickpockets, traverse two continents, changing their names from country to country. The greater, therefore, becomes the necessity of some methodical system of identification.

It was believed for a short time, thirty years since, that photography was to give the solution of the problem. But the collection of criminal portraits has already attained a size so considerable that it has become physically impossible to discover among them the likeness of an individual who has assumed a false name. It goes for nothing that in the past ten years the Paris police have collected more than 100,000 photographs. Does the reader believe it practicable to compare successively each of these with each one of the 100 individuals who are arrested daily