THINGS THAT CAN'T BE DONE

Presidential Address

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One of the few impressions remaining from my grade school training is the great care that was taken in arithmetic to impress on us that we must not try to add different things together. We could add three cows and four cows or three horses and four horses, but adding three cows and four horses just couldn't be done. Actually of course, every farm boy knows that three cows and four horses make seven head of stock. While this is true only by implication, since what you really add is three head of stock and four head of stock, yet for practical purposes you have succeeded in doing what the teacher said could not be done. In this case it has been done by the use of a different name.

In multiplication we are in worse difficulties because we cannot multiply three cows by four horses, nor even three head of stock by four head of stock, because the result would have no physical meaning. In another case however, such a meaning might be possible. For example, we might calculate the area of this table by saying that it is so many inches wide and so many feet long, and consequently, so many inches-feet in area. In practice we would not use this particular complex unit, although the lumberman uses a unit which is literally a square-foot-inch, although he calls it a board foot. And in physics we quickly learn to multiply a lever arm of so many centimeters by a force of so many grams and call the result a moment or torque of so many gram-centimeters, or to multiply a force in pounds by a movement measured in feet, and speak easily of so many foot-pounds of work. These compound units do have physical meaning, so through increased knowledge we have again succeeded in accomplishing in certain cases that which earlier we were told could not be done.

Again, our arithmetic teachers were careful to impress upon us that we could not, for example, subtract seven from four, because we could not take away something we did not have. No sooner did we arrive at high school algebra however, than we learned that after all, seven **could** be subtracted from four if you called the result "minus three." This has a physical meaning, for in commerce or bookkeeping it signifies indebtedness or borrowed money and is customarily inscribed in red ink. Most of us in South Dakota have been working in red ink for some years. Here again we learned to do something that until the acquisition of a new technique could not be done—subtract a large number from a smaller one. Similarly here there is a practical limit, for even the Federal Government will be unable to continue to do this indefinitely.

Sometimes acquisition of new technique has led to reversals. For example in 1815 Prout advanced the hypothesis that all elements were polymers of the same unit, hydrogen. New techniques in atomic weight determination soon led to a certainty that not all atomic weights were integral either on the hydrogen or oxygen bases, and the hypothesis was rejected. Still further advances, the discovery of isotopes, and other studies of atomic structure, particularly the discovery of the existence of isotopes of hydrogen and oxygen, has again shown the possibility that Prout's basic hypothesis may after all have been correct. At present we must regard this problem as incompletely solved, although continuous advance is being made toward the solution.

Of the Greek's four elements, earth, air, fire and water, only the latter contained the possibility of being regarded even as a pure substance. Pure and impure, it has continued to be perhaps the most important single chemical; certainly one of the most interesting and one with which all scientists are concerned. It will serve as a more complex example of the effect of new techniques. It was early discovered that natural waters were more or less impure, the production of salt from sea water being one of the most primitive industries. The distillation process must have been used for water purification very early, although even such a product, made in the crude earthen ware or base-metal apparatus of the early periods, would be regarded as anything but pure today. Probably little advance in knowledge of its nature was made until 1800 when the Voltaic pile was discovered. Current electricity opened up a new technique; something new could be done. Almost immediately it was found that water could be decomposed and that the region around the electrodes became acid or alkaline. Sir Humphrey Davy found that it could be decomposed even in separate vessels if they were connected by a moist material or even the hands of the operator, and in 1806 he proved that the acid and alkali at the electrodes was due to impurities in the water. He advanced, however, no theory to account for any of the phenomena.

Further study, increased accuracy of technique, produced further advances in practice and theory. Wollaston in 1801 showed that voltaic and frictional electricity were of the same nature and Faraday that the differences were only in quantity and potential. Davy and others proved the essential differences between metallic and electrolytic conductors, and in 1805 Grotthius advanced the first theory to explain the phenomena. He postulated a succession of decompositions and recombinations and likened electrolytic conductivity to men and women dancing, with a progressive interchange of partners, the women migrating gradually to one, and the men to the other, end of the dance floor.

Arrhenius and Plank independently in 1887 first assumed any **extensive** decomposition of the molecules, and they believed that it took place only on the application of the electromotive force. At this point, however, a new technique introduced a disturbing factor. Osmotic pressure measurements of various types showed that extensive dissociation was present without the electromotive force. This necessitated a revision of the theory and inspired more quantitative measurements. These led in turn to the theory of limiting conductivity, the theory, that as a substance in solution was diluted the percentage of molecules decomposed, and the conductivity per gram molecule of dissolved substance increased and gradually approached as a limit complete dissociation and a conductivity characteristic thereof. This period too led to the preparation of the purest water ever prepared before or since. Kohlrausch in 1894, by distilling water back and forth forty-two times in a vacuum at low temperatures and collecting directly in a conductivity cell in which pure water had been stored for ten years to dissolve all soluble material from the glass, prepared a few cubic centimeters with a conductivity only a few one hundredths that of what is today regarded as usable conductivity water. Several attempts have been made since to equal this purity but all have been unsuccessful.

Once more the development of new techniques led to the disruption of a period of satisfaction with the status quo. Increased accuracy of freezing and boiling point measurements and development of the Poggendorf potentiometric method of measuring electromotive force, showed that in the first place determinations of the degree of ionization by these methods did not agree completely with those from conductivity methods. In the second place measurements by none of these methods were in agreement with the theory when made on the so-called strong electrolytes. Furthermore, in spite of all the experiments which we can now see showed that water was anything but an inert solvent, it was still so treated, tacitly at least. Even Stieglitz, in his text on Qualitative Analysis published in 1916 and still a classic reference on analytical theory, does not mention water itself as contributing to the principle of the solubility product constant, the principle that in a saturated solution of a sparingly soluble salt in water, the product of the molar concentration of the ions maintains a contant value irrespective of the ratio between the concentrations of the separate ions. He simply states that the principle cannot be rigorously derived from the theory but that it is a useful empirical one.

In the early 1920's Bronstad showed theoretically that the constant, for solutions of uni-univalent salts, was a real thing, but that in solutions of salts of more complicated valence type the ion product should no longer be constant: for example in cases where the valence of one ion was unity and the other three, the value of the ion product actually reached a minimum at certain concentrations of the common ion in solution. He was able to check this theory with experiment by the use of complex cobalt-ammonia salts, of such solubilities that solutions as low as 0.005 molar could be studied and analyzed by refined volumetric methods. Simultaneously Debye and Huckel, with later modifications by Onsager and others, developed another marked contribution to the theory of solutions. They started by assuming strong electrolytes were completely dissociated into ions in solution, as many of them had been shown to be in their crystals, and considered that each ion was surrounded by a sort of sphere of influence or atmosphere of ions of like and unlike sign. From considerations of the distortion of this ionic atmosphere as an ion moved through it, and other effects such as viscosity, they derived an equation which, while complicated, came much closer to exact agreement with experiment than anything previously available.

Thus did the development of new techniques advance our knowledge of water and solutions and enable new things to be done. In this case, as in that of atomic structure, we find ourselves left at an intermediate stage, with much remaining unknown at the present. First even the Debye-Huckel-Onsager equation is in agreement with experiment for strong electrolytes only in very dilute solution, and its complete test awaits, at least as a partial requirement, actual improved mathematical technique, in order that some of the

inaccuracies introduced with the simplifying assumptions now necessary for its solution, can be removed. Secondly, while Bronstad's cobalt-ammonia-salt solutions could be analyzed for ammonia by the Kjeldahl method and the solubilities determined, no technique has been developed for solutions of the more common salts, such as the heavy-metal sulfides used in qualitative analysis, other than indirect methods such as conductivity, electromotive force measurements, etc. Thus although calculations used constantly for analytical work are founded on values for the solubility product constants of these substances from the literature, the values given are really dependable for little more than their order of magnitude.

These difficulties are far from being solved, yet I doubt if there is a chemist among you who is not calmly taking for granted that some day, if not in our lifetime, after the development of further techniques and further advance in theory, they will be solved. Just as we during our schooling progress gradually acquired increased ability; just as new techniques have made possible the wonderful advances which have been made so far; so science will eventually learn how to do these things which cannot now be done.

South Dakota too has her unsolved problems—her things that can't be done. I can still remember elementary geographies in which this territory was labled "The Great American Desert." Twenty years ago in our satisfaction with things as they were, it was a fashion to laugh at these old labels, but there has not been so much laughing done the last five years. New and unforeseen difficulties have arisen and our satisfaction has been superseded by trouble and uncertainty. Nevertheless we are here, the state is here, and the problems are here, and for most of us there is no place else to go, for we have too much of money and life work invested; so if we and the state are to survive these problems must be solved: these things must be done. As I see the future there are two general possibilities: either the climate is going to continue dry, much as it is now, indefinitely, or the present condition is a part of a long-time cycle, and we may look eventually for a return to conditions of more abundant rainfall. In the first case we must obviously learn to live in the climate as it is, while in the second case we must learn not only how to live during this dry cycle, but how to conduct ourselves during the abundant cycle so that the state may be better prepared for the next dry cycle which is just as sure to follow the abundant period. A good deal of work is being done toward solution of the problems, but unfortunately much of it is now in the hands of those who, through the necessity of holding a job, are more interested in making an immediate spectacular showing, than in a more sound long-time program.

A number of principles have been advanced as aids: soil and surface water conservation, soil erosion control, arid climate crops, industrial use of farm crops (the so-called chemurgic farming) and the expansion of the state's present and development of her potential industries. All of these probably have something to contribute toward the problem, but just as probably no single one offers a complete solution. Neither are these particularly new, since most of them have been advocated by our own people for long periods. For example the people of the state have been repeatedly warned by our state geologist of the danger of allowing the soil water table to become lowered and our artesian water supply to become dissipated, yet the large artesian well at the old cement plant west of Yankton continues to run as it has for more than twenty years, and the W. P. A., after last year's dry summer of all dry summers, talks of cleaning out the Yankton-Clay County drainage ditch. Only in the last year or two has there been any serious consideration of the desirability of conserving, rather than draining, surface water.

Two years ago I had the opportunity of seeing a soil erosion control project in Boone County, Nebraska. While it seemed to me that with the expensive machinery and engineering being used it was not practical in its entirety unless backed by large groups cooperatively, it was probably intended as an ideal toward which to work, and did contain many minor features which could be handled on a single farm. It offered, however, nothing from the standpoint of controlling wind erosion. Here again our own Prof. J. Gladden Hutton has been showing for years that the desert would surely return if the depletion of humus in the soil was allowed to continue; but only recently, when it is in many places too late, has the general public listened at all.

The Black Hills contain most of our present industries not connected with farming. While some of these are probably capable of further development, I am not qualified to discuss this phase of it. We do have, however, one or two potential industries which changing economic conditions might assist. For example, the manganese, beryllium, tin and chalk used in the United States is imported at present. A small increase in tariff, or river transportation, agitation for which is growing, might make the required difference necessary for the development of these resources. I noticed in a recently purchased package of loaf sugar a plea for an increased tariff on refined sugar to assist the workers in the refineries, but nothing was said about any tariff on raw sugar to assist the cane and beet growers.

The agricultural experiment stations of this and neighboring states have been working for years developing crops which will produce more profit in this climate, and wonderful progress has been made. They will doubtless continue to work along this line and probably now will get cooperation which will enable them to experiment on a larger scale. Running right along with this experimentation in arid climate crops is the work on chemurgic crops, that is, crops which have some use in industry distinct from or in addition to their food value. The sugar beet is rather on the border line, although it does support refineries. Another borderline crop is the soy bean, having both food and industrial value. Iowa already has at least one factory producing oil from it. Flax and hemp are of ancient lineage and primarily industrial. Paper of good quality has been made from hemp hurds—the hard shell just inside the fiber layer—and from the fiber several textile products are possible such as coarse toweling, rugs, etc. The hemp which was grown around Hartington, Nebraska, the last few years is now being processed and marketed, much of it going to the cigarette paper industry. Perhaps the most outstanding chemurgic achievement of recent years is that of Dr. Charles G. Herty. He has succeeded in manufacturing news print paper, heretofore requiring spruce pulp, out of southern yellow pine, thus opening up a new industry which is already making itself felt in relieving the depression in the south-eastern states.

The production of alcohol for fuel purposes is at present a much discussed proposal. Whether or not this alone would induce any improvement other than in the immediate vicinity of the distillery no one can say at present. We must admit however, that by the increase in the use of the automobile and tractor we have lost the income from a substantial acreage formerly used to produce feed for the animals used in driving and draft. If we can turn part of that acreage into producing fuel for the motors it should help some at least. Jerusalem artichokes have been much publicized for this purpose. They can be grown and will produce alcohol. I got just a few weeks ago a yield of twenty-six gallons per ton on a laboratory scale from tubers grown without artificial watering in a garden at Yankton last year. As to whether or not storage and other difficulties can be overcome, remains to be seen. This is really a minor matter except from the standpoint of development of some kind of crop which will produce under conditions unfavorable to corn, for the Chemical Foundation plant at Atchison, Kansas has produced alcohol from about ten different materials, from Irish potatoes to wheat, so this may at least serve as an outlet for culls and surplusage in times of low prices. The grain sorghums too, may help. In spite of all these possibilities some land will probably have to be returned to grass.

In the chemical industry when a new process has proved feasible in the laboratory and before it is attemped on a full sized industrial scale, it is tried out in what is known as a pilot plant, that is, a small replica of the industrial apparatus, complete. Generally many difficulties must be there ironed out before the full plant scale is attempted. It seems to me that many of these means of solving our problems are now only in the laboratory state. They need to be tried out on the pilot plant scale; that is, for such an example as these new crops, sufficient acreages put out for a sufficient number of years, to constitute a real test, yet scattered sufficiently so that no farmer will be crippled if they fail. When the complete test from seed to final product has been made on this scale, as it has of course in some cases, we can feel safe in investing more heavily. Such of us who are qualified, or can make ourselves qualified, to judge any of these proposed remedies for our state and its difficulties must meanwhile act, not as brakes, but as balance wheels for the projects, helping wherever advisable, cautioning where necessary.

The great Pasteur made his name immortal by solving the immediate, necessary problems of his community and state. We cannot all be Pasteurs—far from it. But just as we solved our little problems of arithmetic as further knowledge was acquired, just as chemists work confidently toward the solution of problems such as the determination of the nature of the atom and of solutions, so we must do, through the years to come, all in our power to solve the grave problems facing our state; to make these things that can't be done eventually possible, and enable our state to once again support on a decent scale of living, its proper proportion of the population of our United States.