

truly wonderful state, not presuming to have reached it in its perfection.

But let me return to the question of the perceptive phase of the physical sciences. A splendid example of almost pure perception is the recent work of Rutherford and others on radio-activity which is based on what would seem to be an absurdly slender group of observable effects. No one can overestimate the power of men who do such work as this. My chief business, however, is the *teaching* of physics; as a teacher I am concerned with average men; and every year I am more and more amazed to see the feebleness with which men hold things in the mind, and more and more impressed with the tremendous power with which men hold things in the hand, a power which, as Plato says, encompasses with eternal security an ancient polity and ancient divisions of rank founded on possession, but which also, alas! as Ruskin says, too often takes the name of Christ in vain and leagues itself with his chief enemy covetousness, which is idolatry.

W. S. FRANKLIN

WHAT CAN BE DONE TO ENHANCE THE VALUE OF
THE WORK OF THE BUREAU OF STANDARDS
TO THE CHEMICAL INDUSTRIES?

THE greater part of the scientific work done in the United States is accomplished through two agencies, the universities and technical schools on one hand and the bureaus of the government on the other. As regards the latter, the principle that the government should undertake, in the main, only such work as can not efficiently be handled by unofficial enterprise, is generally accepted as sound and has, with some exceptions, been adopted as a policy by the bureaus. It must be admitted that it would not be well to draw such a distinction, or any distinction, too sharply or rigidly. To attempt this would certainly impair the usefulness of the work of the governmental departments. But, broadly speaking, it is not impracticable to avoid needless competition with scientific research carried on by other instrumentalities.

It is an indubitable fact that some lines of scientific research lie farther away from prac-

tical applications than do others. Those can be and are well cared for by educational institutions. On the other hand, experience has shown that scientific investigations which bear more directly upon the industries can not be so satisfactorily undertaken without government aid and are more or less seriously neglected when left wholly to private enterprise. Such technical researches are by their nature (costliness, necessity of continuity, direct bearing on legislation, etc.) appropriate subjects for governmental treatment. The success and value of the official work of the United States authorities on road building, on the testing of materials of construction and of foods and drugs, and on standards of measurement, are approved and appreciated alike by scientific men and by the general public, and scarcely require special emphasis here.

It is fortunate that popular recognition is accorded to this branch of governmental work, not only in a liberal degree, but also in a way that harmonizes with the principle enunciated above. So long as the bureaus concentrate their labors on the solution of problems of practical interest, so long will they enjoy the approval and support of the public. Just in the measure that they allow themselves to be diverted to the study of scientific questions lying far afield from practical industrial applications, will the public interest cool and the necessary appropriations become increasingly more difficult to obtain, and this quite apart from the intrinsic interest or importance of the work done. As an example of the sort of scientific questions referred to, determinations of the atomic weights of the elements may be cited as typical. If the considerations advanced here have any validity, such determinations had better be left for other institutions and remain untouched by the government. We are free to admire the excellence of the work as much as we like, and to extoll its importance, and we may still without inconsistency take the stand that such work is not within the proper scope of governmental departments, because, (1) it can be and is well taken care of by other agencies, (2) it is not of direct industrial or so-called "practical" application, (3) it is not calculated to com-

mand the cordial approval of the people and therefore of congress, (4) it withdraws to an appreciable degree the energies of the bureaus undertaking it from the attack of a class of problems that demand a sort of investigation which other organizations or individuals have been unable or unwilling to give. The question of atomic weights has been selected as typical of a class of scientific inquiries, for the reason that the work done in that direction by the Bureau of Standards is of the highest character and the argument in favor of its inclusion in the scope of bureau activities is the strongest that can be brought in behalf of any scientific work of the category to which it belongs. It is, however, not a question, as I apprehend it, of whether this bureau can do such work well, but rather of whether any bureau should do it at all.

The reply is obvious, that, if the public does not approve of the government doing such work it is because the public does not understand it; therefore educate the public, but do not stop the work. It is possible, however, that the public understands the wider bearings of the questions involved very well, although not very familiar with details. Every one of the bureaus doing scientific work was organized explicitly and absolutely for utilitarian purposes. Every argument used before the congress to secure appropriations needed for organization and maintenance was based on the direct practical usefulness of the bureaus to the commerce and industries of the country and to the transaction of the business of the government itself. Those arguments are looked upon by the people at large as pledges, and in my opinion it is right that it should be so. The utilitarian aim should be first. It can not be doubted that, if this aim is conscientiously kept in mind, incidentally much that possesses a wider scientific interest will be brought out, in the end as much perhaps as if the aim had been primarily scientific in the narrower sense. After all, it should not be forgotten that the industries have contributed no less to the sciences than the sciences to the industries.

In any event, raising the question whether and how the Bureau of Standards may be

made still more useful to those engaged in the technical or scientific practise of chemistry, ought not—and I am sure will not—be construed as a reflection upon the valuable work done by it in the past.

The same reasons which have made it necessary to supply the industries with official standards of weight and of volume make it desirable that chemical standards should also be furnished for those industries which are dependent upon chemical processes. It is scarcely to be assumed that the chemical laboratories devoted to commercial technical work should in all or most instances command the time or the skill to establish their own standards. Such laboratories employ methods of analysis that yield results reasonably concordant among themselves, but that are not necessarily in conformity with absolute standards nor with those obtained by other laboratories of the same type. In a word, the methods are, to a certain degree, empirical. This is a fact not subject to control. It is conditioned by the nature of the work and must as such be reckoned with. It is an evil which constantly gives rise to friction between buyer and seller, between manufacturer and consumer. A remedy for this evil which has repeatedly been and still is advocated is the introduction of uniform methods of analysis. This remedy is, however, both inadequate and dangerous. Inadequate, because it is impossible so to specify every step of an analytical process as to secure with certainty identical execution and identical results from it at the hands of workers in different laboratories. Dangerous, because it hampers the development of improved methods and tends to make a mere machine of the technical chemist. A better remedy is at hand. This is, to place at the disposal of all laboratories interested, chemicals which are officially standardized, so that by whatever process a given chemist operates, he may check his results by the standard material, just as he now checks his thermometers or his weights through the aid of the Bureau of Standards. He will thus, if his methods are bad, soon discover the fact and abandon them; if they are concordant among themselves, but not with the absolute

standard, he will apply the proper correction. In cases of dispute between two laboratories, an analysis by each of the standardized sample, each working by its usual method, will usually lead to a satisfactory agreement.

The materials which it is proposed to standardize fall into two groups. The first group comprises substances to be employed for standardizing volumetric solutions. These may be either the solutions themselves, or compounds of exactly known content used in establishing the true titer of the solutions belonging to the industrialist's laboratory. In the case of about six of the most used and most permanent, it would probably be well to furnish the solutions and also the standard compounds. The second group comprises standardized samples of commercial materials, by the use of which the manufacturer can control his entire analytical process. This work has already been begun. Its development must naturally be slow, since the field is immense, and in some cases special industrial laboratories have perfected methods of analysis which for commercial reasons have never been published and which are superior to those in general use or to those which would be at the command of the bureau. Exceptional cases of this kind need not, however, stand in the way of the adoption of the general scheme. To decide what portion of the whole field should be first occupied and what left to future growth is a matter that would require very careful study and need not be even touched on here. The question whether the standard solutions or substances should be furnished by the consumer and standardized by the bureau or whether they should be furnished outright by the bureau is a matter of detail which practical considerations would settle. The cost of executing such a programme as that suggested need not be a serious obstacle. From the standpoint of the manufacturer it would be economy to pay very liberal fees for the work, especially in view of the fact that the standardized materials would be consumed in small quantities only and mainly for the purpose of establishing secondary standards.

Whether it is desirable for the bureau to

undertake to work out standard methods of analysis, is a question that may fairly be looked upon as an open one. For myself I should be inclined to answer it in the negative. The scope of work is wide enough without this. The difficulty which any institution must have in deciding for the industrial laboratory which are the methods that would be practical for it are insuperable. A method that would be eminently practical for one would be the reverse for another having command of facilities more or less wide. Moreover it is impossible for any outsider to know what the analytical problems are which the industrialist has to handle, and in very many cases the latter will on no account furnish the information. Nevertheless, while for the reasons stated, the writer does not believe it to be wise for the bureau to make the investigation of analytical methods a part of its functions, yet it must of necessity investigate many such methods as an incident in the carrying out of other work, and it will, of course, not refrain from giving to the world the benefit of such work by timely publication.

The chemical profession in this country is only now coming to a consciousness of itself. When it has fully done so, it will doubtless have a Bureau of Applied Chemistry of its own, together with other good things, but the day is probably still distant. It owes it to itself, in the meantime, neither to be backward in acknowledging the great work that the Bureau of Standards has already accomplished, nor in demanding that its scope should be extended and its relations be made more intimate with our chemical industries, whose future is already looming up greater than any man can now fully realize or forecast.

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