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CHEMISTRY AND THE STATE[1]

IT should be premised that in this account of the relationship of the state to chemistry in Great Britain an attempt has been made to limit it to a description of the more or less direct assistance given by that science to various departments as they came into being or took form. Only in recent years, and as a result of the war, has there been a direct recognition of a corresponding obligation on the other side.

It is obvious that it is to the universities, and, as was the case to a greater extent in the past, to private workers, that the great advances made by British chemists are due. Departmental requirements have, of course, reaped the advantage of these advances, but examples of important contributions to chemical knowledge emanating from the departments themselves are not lacking. The collected story of their connection with the activities of the state may be worth reciting, if it should show the development of its appeal to chemistry and illustrate the gradual breakdown of the view held by the chief of the tribunal before which Lavoisier came that "the state has no need for chemists."

We will find that their employment in an official capacity was in the first instance in connection with the state's pressing necessities, such as its defence, the regulation of its currency and the collection of its revenue, all of them subjects warranting the maintenance of equipment and staff.

As the need for safeguarding the nation's health, well-being and the quality of its food supply became recognized, legislation followed, frequently based on the work of commissions on which sat distinguished chemists of the day, and it became necessary to set up a state chemical department to assist in carrying this into effect.

For some time the science of chemistry had received a limited and vicarious assistance from state grants to the late science and art department and to the universities, but it was reserved for the war to establish definitely and finally the position that the whole future existence of a state might and probably would depend on the existence of a flourishing and efficient chemical industry. This resulted in the definite steps of assisting the application of science to industry and providing direct encouragement for workers in the purely academic field.

It is proposed, therefore, to sketch the develop-

[1] From the address of the president of section B—Chemistry—of the British Association for the Advancement of Science, Toronto, August 7, 1924.

ment of the main chemical activities of the state and to review the conditions in Great Britain in the hope that it may be of use generally to define the present position, and perhaps of interest to this Dominion in the present stage of its chemical development.

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In the middle of 1915, at a time when our shortage of many essential materials brought out the need for the application of more scientific methods to our industries if we were to succeed in competition with other countries after the war, the Department of Scientific and Industrial Research was founded. It set out to assist firms in an industry to cooperate with one another and employ a staff of scientific men to solve their problems and develop their industry, to assist other government departments desirous of having investigations carried out, to organize research into problems of practical utility of wide importance and to foster the prosecution of researches in pure science. With the exception of the last, these aims can be considered as coming under the designation of organized applied research. The department has always strongly insisted that it is this type of work only that it seeks to organize, the assisted worker in pure research being left entirely free to follow his bent.

As regards scientific policy, the minister in charge of the department is advised directly by a council of independent scientific men, and these are represented also on the various boards and committees entrusted with the supervision of such investigations as are directed by the department itself.

RESEARCH ASSOCIATIONS

From the success attending applications of scientific research in military and industrial problems during the war, the lesson was drawn that our industries in peace time should be infused with fresh and more vigorous life by methods which had proved their worth at our time of need. Foresight in these matters was necessary, since it behooved Great Britain, no longer with the industrial world at its feet, to make the utmost use of its resources by adopting the methods that were most efficient and solidly based on science, in order to produce material that would maintain the tradition of the excellence of British goods. While it was recognized that the most powerful chemical industries maintained efficient research staffs, it was decided to encourage separate industries to organize themselves for the cooperative prosecution of research. To the associations erected under this scheme grants, for a term of years only and usually on a pound-for-pound basis, are made from a fund of a million pounds voted by Parliament in order to demonstrate to the industries the advantage of investigating their own technical problems, for it was recognized that many industries would have to carry out research themselves before they could properly appreciate its application.

In its last published report the department remarks on the continuance of these grants to the associations beyond the originally intended period of five years, as this period has proved insufficiently long for the equipment of laboratories and the effective launching of important investigations, especially during a time of industrial depression.

A very wide field is covered by the research associations. Among those that have been set up in which chemistry is important are associations for the textile industries, for rubber, leather and shale oil, for flour and sugar, for non-ferrous metals, cast-iron, glass, refractories and Portland cement, and for scientific instruments and the photographic industry.

As the results obtained by the associations are primarily for the benefit of their constituent members, the onlooker has a chance of gauging the chemical work carried on only from the communications which, following an enlightened policy, the management of some of them permits to be published; and as many of these are contributions to "pure" chemistry, an example is afforded of the opportunity as well as of the necessity for work of this kind in the case of investigations undertaken primarily for an industrial purpose.

It would be impossible to review the work of the research associations for all these industries, even if the data were available, and so reference will be made only to some of their publications, including those of the group which is concerned with the textile fibers, cotton, flax, wool and silk, as the work published presents many interesting features. Thus there are being studied the products of the hydrolysis of cotton, with an obvious bearing on the constitution of cellulose, the chemical constituents of cotton-waxes, and the action of micro-organisms on cotton fibers and fabrics. Flax, hemp and ramie fibers are being investigated as to their distinguishing characteristics and behavior with reagents that affect their luster and absorption of dyes. Wool has been found to have a selective action, whereby it absorbs the alkali from the soap used in scouring, and methods have been evolved for accurately following the action in practice. Similarly with silk, a systematic study is being made of the action of acids and alkalis on the components of this fiber. In the respective laboratories the chemical and physical properties of each of these fibers are being studied and correlated for the purpose of explaining, for example, their strength and luster, and at a recent meeting of the Faraday Society the methods and results of workers in all these fibers were reviewed in a general discussion.

A close scientific scrutiny is being applied to the tanning of leather and the chemical and physical changes involved, together with a bacteriological study of the process. Equally important for this industry and for that of making photographic plates is the study of gelatin, whose chemical and physical properties are being elucidated, while work of benefit to pure science has been published on the effect of light on the photographic plate.

The study of the chemistry of glass and the physical properties associated with changes in its composition is another example of work that has been reported in the literature for improvement of an industry.

The record, as has been stated, must be incomplete, but the subjects mentioned present the appearance of being valuable in the scientific study of material and process and can scarcely fail to lead to the betterment of the respective industries.

BOARDS

The boards and committees under the department may be broadly divided into those which undertake the investigation of work of national importance and those which undertake work of specific importance to government departments and correlate the scientific work that these carry out.

A large amount of chemical work is carried out by these boards. The departmental research boards and committees dealing with chemical subjects are concerned with the cause of the deterioration of fabrics by organisms and light, and their fireproofing; with the changes that food undergoes under varying conditions of storage and the constitution of fats; with the chemistry of the treatment of timber; with the survey of our coal resources and the economic usage of coal; with the production of alcohol and liquid fuel from waste vegetable matter; with the chemical aspects of the problems of adhesion, lubrication, restoration of museum exhibits; with building materials, paints and the preservation of stone, and with the properties of several of the minor metals. For subjects of the magnitude and importance of some of these, staff and equipment have in several instances been provided on a considerable scale, and a growing number of monographs and communications to the literature issues from the respective boards.

The Coordinating Board for Chemistry, like the similar boards for other sciences, was founded for the purpose of securing interchange of information among government technical establishments, seeing that outside interests are informed, when this is practicable, and arranging for researches not otherwise provided for. The board carries out these duties in consultation with representatives of the Fighting Services and of other government departments materially affected, and with independent chemists, when departmental schemes of work are reviewed in the light of information that may be in the possession of any of the members of the board. To this board are referred questions of wider importance than are within the purview of any one department, and it keeps under its consideration the development of the natural resources of the country. With further facilities for undertaking investigations, it will be in the position to extend such work and to arrange for subjects not otherwise provided for, as well as for those at present under investigation.

GENERAL RESEARCH

Apart from the indirect help afforded to the universities by means of government grants, direct assistance is given by the Department of Scientific and Industrial Research to research workers who may be students or independent workers, and to important pieces of pure research. To these grants no conditions are attached; they are given for the extension of knowledge.

One of the objects of these grants is to encourage the supply of highly trained scientific research workers to meet the growing needs of the government, the industries of the country, and indeed of the empire. The lack of such was felt acutely during the war, although now, for chemists with the usual qualification at any rate, the conditions have changed.

Students are given grants on the recommendation of their professor that they are a type likely to be greatly benefited by spending two years at research work after taking their degree. In this case the award is for promise and not for achievement, and the hope is entertained that the necessity for these grants will gradually disappear when university finance is on a sounder basis.

Grants are given to independent workers who have shown their capacity for research, and who are handicapped by lack of facilities which they may not be able to secure from private or other sources. Further, in the case of work of unusual importance, very substantial financial assistance may be given when it appears desirable.

In this way comes recognition of the national importance of the highest type of scientific work, and to this, of course, no conditions are imposed as to the lines on which it should be carried out.

The state's appeal to chemistry has developed through the gradual recognition of the need for the application of that science to matters relating to its preservation, its currency, its financial support, its health, its food supply, its industries and finally to academic science.

In the course of this development, advantage has

been taken, if sometimes tardily, of the general advance in chemical knowledge, and frequent recourse has been had to the advice of well-known chemists of the day, and collectively of the Royal Society; thus for various purposes the following chemists, as officials or consultants, have in the past afforded assistance in the solution of specific problems referred to them, or by taking part in commissions: Boyle, Newton, Davy, Faraday, Daniell, Graham, Hofmann, Redwood, Abel, Roberts-Austen, Percy, Dupré, Playfair, Frankland, Ramsay and Dewar. It has happened in several instances that as a result of these commissions and references to chemists some definite chemical activity of the state has emerged.

It will be convenient in this summary to review the state's chemical activities before, during and after the war.

BEFORE THE WAR

Defence: For its defence, establishments for the production of explosives were early maintained, and when this ultimately took the form of a chemical manufacture the government factory took the lead in devising efficient processes, while from the various state research establishments has issued during the last fifty years an important body of original contributions to the theory of explosives and to the knowledge of their properties.

Metallurgy: The metallurgical progress of the country has always been a concern of the state by reason of its application to defence by land and sea, and close touch has been maintained with successive developments in the manufacture and use of cast-iron, wrought iron, steel and non-ferrous alloys. While the main advances in process have been made in the great iron and steel works, material contributions to knowledge in this sphere have been made by chemists in the government service.

Revenue: For its revenue, imposts were applied in early times, but with great uncertainty, until the charge was put on a scientific basis. Very accurate tables for the strength of alcohol were worked out under the supervision of the Royal Society at the end of the eighteenth century, to be superseded by revised ones issued only a few years ago, when, in addition, new tables were issued also by the Government Laboratory for determining the gravity of worts before fermentation. The question of rendering alcohol unpotable, but still useful for industrial purposes, has occupied much attention. As some misapprehension still exists as to the availability of alcohol for industrial purposes, a statement has been included in which the main facilities are indicated. It was on account of the necessity for safeguarding the revenue that the Government Laboratory was primarily erected, although it now performs chemical work for all state departments.

Health: The three main steps with regard to public health and sanitation in this period were the forcing of these questions into prominence by Playfair, with the consequent commissions and legislation leading to the formation of the Local Government Board and its successor, the Ministry of Health, which has many varied activities in preserving purity of air and water and protecting the workman in dangerous trades; secondly, the determination of standards for a safe water supply by the pioneering work of Frankland; and thirdly, the appointment of public analysts by the local authorities, with the Government Laboratory as referee, for safeguarding the supply of food.

Agriculture: Science was being applied to agriculture about the end of the eighteenth century, and at the beginning of the next Davy did pioneering chemical work for the Board of Agriculture. Private endeavor is responsible for the next development, state action being limited to the prevention of fraud in the sale of fertilizers and feeding stuffs. In 1909, however, the annual allocation of a sum of money to the Development Commission for the advancement of agriculture stimulated research in a large number of institutions engaged in the scientific study of problems in which chemistry plays an important part.

Other Activities: In addition to the chemical work reviewed in the foregoing sections, there is a variety of subjects connected with state departments to which chemists have contributed, such as the composition of the sea, and the composition and physical chemistry of rocks and building-stone. At the Government Laboratory a large number of investigations have been conducted on matters directly referred from government departments.

DURING THE WAR

In all the activities described the war requisitioned the work of the chemist, but, naturally, predominantly to meet the demands of active warfare.

Defence: The attention that had been bestowed on the subject of propellants enabled expansion to take place with no important alteration in the technique of their manufacture, to which was adapted a new type of cordite, ultimately made on the largest scale, without using an imported solvent. For high explosives we were in much worse case, as these had not been made by the government, and were manufactured in Great Britain only in small quantity. Their study at Woolwich led to a rapid evolution of new processes, substances and methods of use. Thus a method was worked out for the manufacture of trinitrotoluene, and to save this substance a new high explosive, amatol, devised. This explosive, consisting of ammonium nitrate and trinitrotoluene, passed exhaustive trials and was ultimately produced at the rate of 4,000 tons a week. The production of

the ammonium nitrate for the mixture was in itself a stupendous undertaking, and the methods of filling the explosive into shell and other munitions gave rise to much ingenuity. In the Research Department, Woolwich, the number of qualified chemists engaged in the study of explosives in all their aspects ultimately exceeded a hundred, while for manufacture and inspection over a thousand were employed. The ideal set before himself by Lord Moulton in 1914, to produce nothing less than the maximum of explosives of which the country was capable, was realized, and they assumed a quality and character that caused them to be copied by our Allies and in reliability proved themselves superior to those of the enemy.

Starting unprepared, and without the advantage of a well-developed fine-chemical industry, we were able ultimately to make a reply in the field of chemical warfare that was rapidly becoming more and more effective; at the same time, by study and often self-sacrificing experiment, protecting the soldier by the development of very efficient respirators. In this connection and in that of explosives nearly every professor of chemistry in the country and many from beyond the sea were engaged.

Metallurgy: The enormous demand for metals for munitions and countless other war requirements led to an unprecedented concentration of the metallurgical industries on the needs of the state, and to an equal concentration of metallurgical science on investigation devoted to improvement in quality of materials for new and special war purposes. The work of the Aircraft Production Department, aided by many metallurgists and engineers, on alloy steels, of the National Physical Laboratory on aluminium alloys and of the Metallurgical Branch of the Research Department, Woolwich, on the heat-treatment of heavy forgings and on the drawing of brass is typical of the successful effort made in every quarter. The knowledge thus gained was disseminated in the form of specifications, instructions and reports, and has had a great and permanent effect on manufacture.

Health: A committee of the Royal Society had been studying food values, and were able to afford the food controller, when he took office, valuable data bearing on the rationing of food. They had considered subjects which shortly became of much importance, such as a better recovery of flour in milling wheat. The chemical examination of the food for the army in the war, carried out by the Government Laboratory, employed a large staff of chemists. For the supply of many fine-chemical substitutes used in medicine and surgery, formerly imported from abroad, such provisional arrangements had to be made as the organization of a large number of university laboratories on a semi-manufacturing basis.

Agriculture: Effects on agriculture during the war were shortage of the usual feeding stuffs for cattle and of fertilizers. The chemists stationed at Rothamsted gave special attention to the shortage of manures and prepared instructions for the guidance of farmers; and several sources of supply of potash were exploited, including kelp, felspar and the flue-dust of furnaces. As sulphuric acid was required for explosive work, fine grinding of phosphates and basic slag was found to be more efficient than was expected. Shortage also directed the attention of chemists to the use of little known food-stuffs, especially for cattle, and the information gained as to their feeding value was important.

Other Activities: In many other activities in connection with the war chemists were directly involved, such as in affording advice on the conservation of materials, on the numerous questions arising from the operations of the War Trade Department, on the restriction of imports and exports, and on matters of contraband.

AFTER THE WAR

The magnitude of the chemical effort, it can be claimed, was a factor in winning the war which must be reckoned as of importance only second to that of the bravery of our forces in the field. But it has left a lasting mark and given to chemistry a value which, were it not for the rapidity with which the achievements of science are forgotten, ought to keep before the public its connection with almost every phase of activity.

Defence: To take our subjects in the same order, we may consider some of the effects of the energy spent on the production of munitions. The intensive study of explosives and of other chemical substances used in the war has led to a more complete knowledge of their chemistry, their physical and explosive properties and has advanced chemical theory. These advantages are not of military importance only, but are reflected in the production of trade explosives. The collected records of the Department of Explosives Supply afford examples of treatment of many problems of interest to the general chemical technologist and not only to the explosives expert.

A further benefit was reaped by chemists in every position, from the professor to the youngest graduate, coming into direct contact with manufacturing methods and thus gaining insight into the applications of their science. While it is true that the opportunity came to few of these to take part in the design of plant and primary choice of process, nevertheless the experience was a novel one, as it led them into the field of technology, and can not fail to have widened their outlook. It became apparent that there was a

shortage of a type of chemist which had been developed in Germany, skilled in the transference of the chemical process from the laboratory to the works scale in the largest enterprises. A chemist of this type is one who, besides having a sound knowledge of chemistry and physics, has had experience in the materials of construction used on the large scale and in the operation of the usual types of plant for carrying out the operations of chemical manufacture, and who is capable of working out flow-sheets illustrating the process, and operating plant with every regard to economy. The need for instruction in such subjects had been borne in on men like the late Lord Moulton, and as a direct result of the war-time experience of our deficiencies in this direction has arisen the movement for erecting chairs of chemical engineering in some of our universities. It is to be expected that from these schools, especially where the instruction is super-imposed upon a full graduate course, will emanate men who will lead the way in the application of academic science to industry.

Metallurgy: While the interest of metallurgical science in war material has fortunately fallen to a peace-time level, state participation in the support of scientific research remains far greater than before the war. In metallurgy it is exercised through the Department of Scientific and Industrial Research, with its organizations of the National Physical Laboratory and the Industrial Research Associations, as, for example, those dealing with the non-ferrous metals and with cast iron. The state also continues to maintain efficient research establishments for the Fighting Services, but it is significant that the largest of these is undertaking industrial metallurgical research on a considerable scale, for the benefit of the brass and other industries. State support and encouragement are undoubtedly powerful factors in the rapid progress now taking place in every branch of metallurgical science in this country, and there is scarcely any related industry which can fail to benefit.

Revenue: Since the war the principal matters affecting the revenue are the higher duties, which have rendered necessary a further denaturation of alcohol. Improved facilities have been granted for the use of alcohol for scientific purposes and in industry; regulations have been formulated for the use of power alcohol and duties have been established on imported fine chemicals and synthetic dyestuffs.

Health: The food shortage during the war called attention to the nature and quantity of our food supplies and led to further investigations being undertaken by the Department of Scientific and Industrial Research on food preservation and storage. Activity is also shown by the appointment of committees which are working on the subject of preservatives and coloring matter in food and on the pollution of rivers by sewage and trade effluents. A great field is open in the cooperation of chemistry with medicine in the discovery of substances suitable for the treatment of the numerous diseases now traced to parasites in the blood.

Agriculture: So far as fertilizers are concerned, the lack of a supply of fixed nitrogen from the air which obtained throughout the war has now been rectified, and Great Britain for the first time is no longer exceptional among the nations by neglecting to provide itself with synthetic ammonia for agriculture and for munitions. Such war-time expedients as the use of niter-cake instead of sulphuric acid for making ammonium sulphate and superphosphate and the recovery of potash from flue-dust have not survived, but there has been a gain in the further development of "synthetic farmyard manure" and the increased use of basic slag. The present activity in research in agricultural chemistry of a fundamental character is leading to a better understanding of problems of the soil and of plant and animal nutrition and can not fail to be of ultimate benefit to farming.

Organized Applied Research and Assisted General Research: Established during the war as a result of an appreciation of the contrast between the successful application of scientific method to military purposes and the want of such application to many of our manufactures, the Department of Scientific and Industrial Research has extended over a wide field. Its main activities have been sketched in the directions of state encouragement to industry to apply chemistry to its problems, of state investigation of vital problems beyond the sphere of private enterprise, and of assistance to workers in the purely academic field. In all these spheres activity is shown by the contributions to knowledge already forthcoming.

In the expansion that has occurred in the chemical sections of state departments since the war, it is interesting to note the increase in the number of chemists that are employed. As far as can be gathered, the number of chemists working in departments maintained wholly by the state is 375 for the present year, compared with 150 in 1912, while in establishments to which the state affords partial support, such as those under the Development Commission and the Research Associations, the corresponding numbers are 150 and 50. In addition, grants are made to 145 research students and to 11 independent research workers, involving a yearly sum of about £50,000.

From the foregoing account of the connection of

the departments of state in the United Kingdom with chemistry, it is possible to trace a gradual development and ultimately a change in attitude, in passing through the stages of compulsion, expediency and assistance.

From motives of security the state was compelled to give heed to chemical matters involved in its defence, such as those which appertained to munitions of war, including metals used in their manufacture; it was constrained to uphold the standard of its currency; and it was obliged to secure a revenue. As a consequence, the first chemical departments were set up in connection with these activities and from them have emanated notable additions to chemical knowledge, improvements in methods of manufacture and specifications for government requirements that have led to improved material becoming available for civilian use. Although mostly conducted with inadequate staff, the study of these questions, it can be claimed, proved of national advantage when the time of need arose.

In the next stage, the public conscience having been awakened by the pioneering work of Playfair, it appeared expedient to safeguard health by attention to sanitation, and, as the quality of food was unsatisfactory, to set up a chemical control. Although a start was made by Davy, a member of the then Board of Agriculture, progress in this subject passed to private enterprise, and a century elapsed before direct assistance was afforded to this important matter. Out of these activities come our present system of supervision over the purity of air, water and food, and also the recent progress made in the application of chemistry and physics to problems of the soil.

The last and more recent stage is in the nature of a recognition that the state is under an obligation to assist science, and in this case the science of chemistry, on which so many important industries are based. It took the war to bring home the danger that, although the record of the country as regards discovery in pure science was unrivalled, its systematic application was too often left to other countries, with the result of lamentable shortages during war and the risk of many industries being ineffective in peace. A measure of government intervention and action appeared requisite, and research became the business of a government department. Outside of the great firms which maintain progressive chemical staffs, the firms in numerous industries have been encouraged and assisted to cooperate in the betterment of their manufactures by the application of the methods of science, and from these associations and the organizations dealing with national problems begins to flow a stream of communications indicative of useful work accomplished. Nor is the foundation of it all neglected, for encouragement is given to workers in the academic field to follow out their ideas, whithersoever they may lead them, in accordance with the truth that "research in applied science might lead to reforms, but research in pure science leads to revolutions."

It is important to be able to record an advance in securing an interchange of information among government departments, and between their work and that of universities, a matter which before the war was unsatisfactory, as it was mainly personal and sporadic.

And it is a hopeful sign also that, although the knowledge and appreciation of the methods and capabilities of science are still generally wanting, there have been of late signs that these matters are coming to engage the attention of those who guide the policy of the state.

ROBERT ROBERTSON

PUBLICATION OF JOURNALS IN THE FUNDAMENTAL MEDICAL SCIENCES

THERE appears to be a general belief that adequate publication facilities for investigators in medical science are lacking, on account of financial difficulties in the publication of the journals representing the fundamental medical sciences. The Division of Medical Sciences of the National Research Council therefore appointed a committee (C. W. Greene, D. R. Hooker and C. M. Jackson, chairman) to gather information on this subject. Questionnaires were sent to the editors of 23 American journals in this general field, and more or less complete replies were received from the following 19:

American Journal of Anatomy.
American Journal of Hygiene.
American Journal of Physical Anthropology.
American Journal of Physiology.
Anatomical Record.
Endocrinology.
Genetics.
Journal of Bacteriology.
Journal of Biological Chemistry.
Journal of Comparative Neurology.
Journal of Experimental Medicine.
Journal of Experimental Zoology.
Journal of Immunology.
Journal of Infectious Diseases.
Journal of Medical Research.
Journal of Metabolic Research.
Journal of Parasitology.
Journal of Social Hygiene.
Physiological Reviews.

The questions asked, together with a brief summary of the replies, are as follows: