CHEMISTRY IN THE NATIONAL SERVICE.[1]

SINCE the autumn of 1914 a great change has taken place in the public attitude towards the natural sciences, and towards chemistry in particular. One of the recognised duties of the spokesmen of science during the past sixty years or more has been that of endeavouring to bring home to the general public and to its administrators the danger of neglecting the cultivation of pure and applied science. The eloquent discourses of our predecessors, Lyon Playfair, Roscoe, Meldola, and the veterans happily still with us, Tilden and Armstrong, all past-presidents of our society, on the national importance of chemistry are well known to all of us, but we cannot claim that these utterances produced an effect compatible with their gravity.

Recent events have, however, given a stimulus to the popular appreciation of the need for wider application to scientific investigation of all kinds which is incomparably greater than had been excited by the previous half-century of the spoken and written word. It may be useful at the present time to consider a few of the causes for this change in public opinion, partly because of the clarification of ideas which emerges from free discussion, partly because of the desirability of recording certain facts and particulars which may be of value to future historians of the strenuous period now ending and giving place to another still more strenuous.

At this time four years ago an urgent call was made for the services in a military capacity of all the chemists who could be spared from civil life. Large numbers were taken into the Army, and formed the nucleus of the magnificent Gas Warfare Service which has been slowly but efficiently developed. Many of these colleagues of ours are now returning to their legitimate spheres in the industrial and scientific life of the Empire, but many will not return; among those who have fallen I would refer more particularly to one who was well known to most present for the invaluable services which he rendered on the defensive side of chemical warfare. Lt.-Col. Harrison was one of the great discoveries of the war, and his death on the eve of the armistice was one of its many great tragedies; the protection against gas-poisoning which has been employed by our own and Allied troops, a protection far more efficient than that ensured by the devices elaborated at leisure by the Central Powers, was due mainly to his wide knowledge, great organising ability, and unfailing resourcefulness in emergency. A movement for the establishment of a memorial to Col. Harrison was set on foot by the Chemical Warfare Committee, of which he was the Controller at the time of his death, and a considerable sum has been collected from those who had been associated with him in his work for the Services. The Chemical Warfare Committee has approached the council of the Chemical Society, and has offered, under certain conditions, to place a memorial tablet or other suitable permanent memorial in these rooms, and also, under certain further conditions, to establish a trust fund to be held by the society. The council has with great pleasure intimated its willingness to accept these gifts, and one of the first duties of your new council will be to decide how best to carry out the provisions of the trust deed.

The efficiency of the British gas protection, which called for the exhibition of so much scientific skill both in research and in manufacture, and led to its adoption by our Allies, is one striking illustration of the paramount importance of science which has appealed to the general public. This subject is, however, but a small branch of the enormous chemical problem which presented itself to the nation nearly five years ago, and led to the organisation under Lord Moulton of the Department of Explosives Supplies. During the working out of this problem issues presented themselves which are probably dissimilar from any which have ever arisen before.

Thus, as the magnitude of the struggle became gradually obvious, it was realised that the whole of the resources of the Empire would have to be utilised fully if success was to be attained. A census of all available chemical products had to be taken and schemes for their exploitation laid down; all materials had to be apportioned out in accordance with the principle that whatever was used for the manufacture of one particular war material left a corresponding shortage of raw material in connection with the manufacture of some other, and perhaps equally essential, product. The intricacy of gauging the chlorine output of the country, of determining how to increase it at the maximum rate without unduly disturbing other interests, of apportioning it most advantageously for use as liquid chlorine and for the manufacture of phosgene, sulphur chloride, carbon tetrachloride, bleaching powder, and many other war materials, is such as would disarm criticism even if the result had been failure instead of brilliant success. This novel mode of presentment, involving recognition of the principle that the Empire could only dispose of certain limited and measurable quantities of raw materials, was but one of the many fresh views which forced themselves upon a newly created Ministerial Department. Labour, fuel, and transport had to be discussed in an analogous manner.

The cessation of hostilities found this country manufacturing, roughly, 100,000 tons per annum each of nitric acid and sulphur trioxide with an efficiency of about 93 and 91 per cent. respectively of that theoretically obtainable; we were also making 60,000 tons of T.N.T. and 35,000 tons of cordite per annum. These productions were for all practical purposes upon a permanent basis, and could have been continued indefinitely. The factories necessary for securing this huge production were erected by the Government, and for several reasons. First, for economy in production. In spite of the large initial cost of installation, and including rapid amortisation, the national production of cordite was better in quality than, and of approximately one-half the cost of, that imported from America. Secondly, for certainty of supply, which could be ensured only by a home production not subject to the risks of oversea transport.

With this necessity for gigantic production the urgency for economy in manufacture necessarily went hand in hand. One of the most interesting documents of the war is the second report on costs and efficiencies for H.M. factories controlled by the Department of Explosives Supplies, which has been recently issued. This report contains a minute analysis of the working costs for each period of each factory engaged upon individual items of manufacture; it states what proportion of the cost per ton of product is borne by labour, raw materials, fuel, maintenance, etc., and provides an incitement to further effort towards economy of working by giving a "bogey" cost-sheet made up of the most efficient details of cost selected from the complete analysis of expenses. It will be clear that an immense amount of organising power was required to achieve this stupendous result; it was due largely to the genius and energy of Mr. K. B. Quinan.

It must be remembered, however, that this permanent memorial to British chemical activity in production was rendered possible only by the intense

[1] Presidential address delivered to the Chemical Society on March 27 by Sir William J. Pope, K.B.E., F.R.S.

effort of the army of chemists and engineers enlisted under the command of Lord Moulton. The necessity for utilising all the chemical resources of the country to the utmost led, in direct relationship with the census of raw materials previously mentioned, to the attempt to extract the last possible fraction of efficiency in each component process. The huge production just indicated made it very profitable to carry out a vast amount of careful scientific investigation of details of manufacture; so many fellows of this society devoted their best efforts to this work that it would be invidious to mention names. Our colleagues have had ample opportunity to realise that the romance of war is now to be found in the laboratory, the workshop, and the factory quite as much as on the battlefield.

An instructive example of the operations of the struggle for economy in the production of a given effect is found in the rivalry which arose between picric acid and ammonium nitrate for use as high explosives. Picric acid costs about 185*l.* per ton to make, ammonium nitrate about 50*l.*, and T.N.T. about 100*l.* per ton; the high cost of picric acid means, of course, limited production. A mixture of eighty parts of ammonium nitrate with twenty parts of T.N.T., known as amatol, was introduced early by the Research Department at Woolwich as being about 5 per cent. more powerful as a high explosive, less *brisant*, and more difficult to detonate, and, of course, far less costly to manufacture. The course of the war has been marked by continued progress at the hands of our research chemists in the preparation and application of amatol; the growing appreciation of the merits of this material led to the discontinuance of the manufacture of picric acid in this country last summer, to the adoption of amatol in place of picric acid as the American standard high explosive, to the approaching elimination of picric acid from the Italian military programme, and to the replacement, in the main, of picric acid by amatol in the French service.

A very pertinent question arises in connection with the fact that our production of the chemical materials needed for a great European war was negligibly small in 1914 and has gradually attained satisfactory dimensions. We know that the great chemical factories of Central Europe could divert their peace production of chemical products to a war output at very short notice. None of these huge installations requires much time for the design and construction of chemical plant for new purposes; all possess a series of standard items of equipment which can be fitted together rapidly to form a piece of plant capable of use for throwing any ordinary laboratory operation into large-scale practice. Stills, condensers, pressure vessels, filter presses, cooling arrangements of coils, and the like, are available in standard sizes and with standard fittings in such a manner that the installation on a works scale of a laboratory operation is deprived of its most formidable difficulties. The question which demands an answer is why, when the German works were in existence and could attain a war production so quickly, were the Allied nations given time gradually to develop their war production of explosives, noxious materials, etc., from nothing? The question is best answered by an example.

In July, 1917, the Germans first used against the Allies a new offensive material, ββ-dichloroethyl sulphide, $(CH_2Cl.CH_2)_2S$, and with very great success. This substance, the so-called "mustard gas," has but little odour, and exposure to it causes comparatively few fatalities; inhalation of, or contact with, its vapour gives rise to acute pneumonia when inhaled, to the production of painful sores, and to temporary, or even permanent, blindness. Whilst, as has been stated, the actual mortality is low, and the use of the substance may to this extent be described as humane, the casualties produced are very numerous; slight exposure to a material so toxic and so difficult to detect leads, in general, to six weeks in hospital. The preparation of ββ-dichloroethyl sulphide was described by Victor Meyer in 1886, and involved the several operations indicated by the following set of equations:—

(1) $CH_2 : CH_2 + HClO = CH_2Cl.CH_2OH$.
(2) $2CH_2Cl.CH_2.OH + Na_2S = (HO.CH_2.CH_2)_2S + 2NaCl$.
(3) $(HO.CH_2.CH_2)_2S + 2HCl = (CH_2Cl.CH_2)_2S. + 2H_2O$.

When it is realised that operation No. 1 is difficult, and that the products of reactions (1) and (2) are soluble in water, it will be understood that no small difficulties must present themselves in the manufacture of ββ-dichloroethyl sulphide by this process on a large scale. The examination of the German product made it quite clear, however, that the process of manufacture adopted was that indicated by the above set of equations; the over-all yield of product is perhaps 40 to 60 per cent. of the theory. In view of the difficulties of manufacture, it was fairly certain that no chemical installation for its production could be established under the control of the Allies within any reasonable time; the Central nations thus supposed that they held the monopoly of a very powerful instrument of war.

Most British organic chemists were, I think, amazed at the method of production adopted by the German manufacturers; to apply such a technically cumbrous process for the manufacture of so simple a compound seemed quite irrational. By the end of January, 1918, a process for making ββ-dichloroethyl sulphide had been worked out in the British laboratories which consisted of the reaction expressed by the following equation:—

$$2CH_2 : CH_2 + S_2Cl_2 = (CH_2Cl.CH_2)_2S + S.$$

The yield obtained in the laboratory was 98 to 99 per cent. of that theoretically possible. The new method was communicated to France and America, and installed by the three great Allies on a large scale; at the conclusion of the armistice the available daily production of mustard gas by the Allies was equal to the monthly production of the Central nations.

The answer to the question just put is now available. The German Chemical Service was inefficient; the scientific chemists under its control were incompetent.

The Allied production of mustard gas had a potentiality of the order of thirty times as great as that of the German; the cost of the German material was of the order of thirty times as great as that of our product. Cost of production under the conditions prevailing for this particular material means, in the end, expenditure in labour; that we were able to produce at something of the order of one-thirtieth of the cost of the German production means that by the allocation of the same quantity of raw materials we could secure thirty times the output. The relative strain on the productive resources of the Allies and the Central nations caused by the demand for a certain quantity of mustard gas is measured, roughly, by the ratio of one to thirty.

Whilst many instances similar to that of mustard gas might be quoted to show that Germany has been badly served by her scientific men during the war, it would be difficult to overrate the effects of the skill and perseverance exhibited by the German chemical manufacturer. The command of great and long-established factories for fine chemical manufacture enabled the German technologist to throw faulty academic projects rapidly into large-scale production. The cost—namely, the strain on national resources—

was enormous, but that an output could have been achieved is a significant tribute to the potentialities represented by the large German fine chemical factories. Both in Britain and in Germany production in chemical manufacture has been multiplied during the war, but necessarily in a different manner. Our large production is almost entirely of war importance, and most of the works installed during the war must now be dismantled as a result of the cessation of hostilities; the German expansions, on the other hand, constitute a permanent addition to the potentialities of peace manufacture of staple marketable products. The war has left Germany with vastly increased resources as a manufacturer of much-needed chemical products.

The view that our country is superior to Germany in the possession of creative scientific power has always been maintained in modern times by students of philosophy and history; the correctness of the view has been amply demonstrated during the last four years. Whilst our nation has overcome its initial handicap by a continuous flow of novel scientific devices of military value, our enemies passed through the war with little more in the shape of novel effects than those laboriously elaborated during the preceding years of peace. The more brilliant position which Germany has so long held in applied science arose from the keen appreciation exhibited by German public and official authorities of the rich economic fruits to be reaped from the systematic exploitation of scientific industry as compared with the neglect of scientific effort shown by corresponding classes in this country. Even yet but small encouragement exists for those who desire to see pure and applied science flourish as it deserves in Great Britain. Although it may be long before the scientific industries of Central Europe regain their former predominance, there seems but little prospect of sufficient official encouragement being given in this country to scientific and industrial initiative to ensure our position in the competition with other nations.

In this connection it is interesting to notice what is happening in the United States. Immediately after her entry into the war America initiated a census of chemists, and in July, 1917, a fully detailed description was available of some 15,000 chemists resident in the States; a research staff consisting of 1200 technical men, with appropriate assistance, was enlisted for the Research Division of the Chemical Warfare Service alone. Since America was only in the war for about eighteen months, this powerful organisation had not time to make its efforts properly felt. Apart from small improvements or changes in detail, practically all the American chemical equipment, for both offence and defence, was manufactured on the detailed plans furnished by Great Britain or France; the available time was too short to allow full play to American genius for novelty and for magnitude of production. The necessity for co-operation brought large numbers of young and active American chemical officers to Europe; it gave those officers for eighteen months the entry to practically every chemical works of importance in England and France, and unrivalled opportunities for accurately judging European chemical methods and markets. Those men have now returned to their ordinary scientific and technical pursuits in the States, and it cannot be expected that they have left behind them the unique experience which they have gained of European conditions.

We may anticipate that competition in pure and applied chemistry between Europe and America will become increasingly keener during the years to come. The competition is already intense, and gives little promise as yet of turning in our favour; it is, in fact, difficult to see how many of the staple products of fine chemical manufacture can hold their own in Great Britain against American competition under the conditions which arose during the first three years of the war. During these years peace production flourished in the States free from Government control, whilst in this country the establishment of a fine chemical industry in war-time was naturally rendered far more difficult by State control of works, materials, and labour.

The bearing of this may be made clearer by an instance. The manufacture of saccharin was installed in England after the outbreak of war, but the production was controlled in that the manufacturers were only permitted to sell at a profit of 10 per cent. on the cost, this profit being, in turn, subject to the excess profits tax; further, to prevent the economic difficulties which were foreseen if saccharin competed with sugar, the price of English-made saccharin was fixed at a figure which involved the very large addition of 30*s*. per lb. to the price, this addition being appropriated by the Government. Simultaneously, saccharin was manufactured free of all control in the States; it came into this country unrestricted and on such terms that the American producer took the 30*s*. per lb. just mentioned in addition to the considerable profit previously made by reason of lower cost of manufacture. America, having thus been assisted by our Government to build up a large reserve of profits, is now actually selling saccharin in England at 11*s*. per lb.—a price at which it cannot be produced here—apparently with the legitimate trade purpose of destroying the English manufacture and afterwards running up the price.

Many cases may be quoted as closely analogous to that of saccharin, notably in connection with acetic acid, glycerol, acetone, and methyl alcohol and their products, in which British procedure has facilitated profiteering in foreign countries during the war. The excess profits tax operated insidiously in tempting British manufacturers to keep prices high so as to retain a margin with which to write off capital expenditure in spite of the tax; the foreign competitor, free from Government control of raw materials and exempt from the excess profits tax, was able to take full advantage of the ruling high rates. It will be of interest to see how the problems introduced by these actual occurrences are to be solved advantageously for Great Britain in the great reconstruction upon which our administrators are now engaged.

Sufficient has probably now been said in justification of the rapid appreciation of science, and especially of that branch of science with which we are particularly concerned, in the public and administrative eye. The sudden incidence of new scientific modes of military and naval attack, and the quick improvisation and development of equally scientific means of reply, both of which have been so frequently exhibited during the past five years, must have seemed uncanny to the lay observer, who only realised the effects, but did not understand the causes.

At the present time, however, most fellows of this society have little leisure to reflect upon the ghastly tragedy in which it has been our privilege to assist; the curtain has fallen upon this, but is rising again upon the greatest epoch in the history of the world. The coming struggle for scientific and industrial position, upon the results of which must rest the whole intellectual, artistic, and material future of our race, will call for longer, greater, more persistent, and more intelligent effort than any which we have hitherto exerted. We are forced to consider whether we have reason to hope that the recent lessons have been well brought home, and whether the free play given to scientific creation and production during the last five years is to persist unhampered in the future. For

purposes of war our administrators gave every incentive to scientific investigation; money, men, and material were provided for the asking, free from Treasury control—free, in fact, from all control other than that of the scientific worker able and willing to organise and execute a necessary piece of work.

I see no reason to think that the lesson has been properly learnt, and every reason to anticipate a re-establishment of that parsimonious treatment of scientific effort which seems now to belong to a past age, but with which we were all well acquainted five years ago. The control of scientific research is again leaving the hands of the scientific man and being resumed by the lay administrator. The old remark has been resuscitated quite recently that "it is a commonplace among administrators to fear the expert." The non-technical administrator has no means of distinguishing the expert from the charlatan; he has, perforce, to regard the scientific expert as the lineal descendant of the "adept" of alchemical times, whose main claim to recollection is based upon the adroitness with which he was able to divert public funds to his own base purposes.

It is quite clear that if scientific research is to be assisted by the State—and unless so aided it will languish, and carry with it into decadence every activity of the Empire—it must be administered by men of scientific training and eminence; any other mode of procedure will necessarily lead to the strangulation of scientific effort by departmental red tape. In this connection it is again instructive to refer to American practice. Our blood-relatives across the Atlantic had three years in which to study in peace the efforts which we were making in war, and it cannot but be useful to observe the manner in which they propose to profit by our experience.

In 1916 President Wilson, a university professor and an expert, now one of the most imposing figures in terrestrial affairs, called upon the National Academy of Sciences at Washington to nominate the members of a "National Research Council"; the object of this new organisation was stated to be that of co-ordinating the scientific work of the country in order that the scientific problems both of war and of peace might be more efficiently solved. The National Research Council is under the presidency of one of the most eminent among the active American men of science, Prof. George E. Hale, of the Mount Wilson Observatory, and has large funds at its command for research purposes. Two points are conspicuous in connection with the American programme—first, the substitution of the professional lay administrator by the ordinary office staff; secondly, the recognition of the close interdependence of pure and applied science. The contention which has long been advanced in this country, that an adequate output of purely academic chemical research work and the existence of a flourishing fine chemical industry are mutually essential, is here tacitly accepted; the former seeks in the industries remunerative positions for the products of its training, and the fine chemical industry looks to the scientific investigator for inspiration and new directions for enterprise. The nation which possesses an extensive organic chemical industry controls chemical warfare, the production of pharmaceutical and photographic products, the textile industry, and many other great departments of human activity.

The operations of the great American organisation for the stimulation of scientific research work are already making themselves felt. They have produced just recently an entirely novel method for oxidising naphthalene to phthalic acid, presumably by the use of atmospheric oxygen and a catalyst, which gives a 95 per cent. yield, and are responsible for the huge nitrogen fixation scheme now under installation in the States. These two illustrations alone, the one small and the other large, leave us in no doubt as to the influence which the National Research Council is destined to exert on scientific and technical progress throughout the world.

If British science is to make itself adequately felt in the great intellectual and material advances of the near future, British men of science must be entrusted with the initiative power and the command of money which they have enjoyed during the past few years; unless this is done our Empire will, as before, continue to fall behind other great nations as a contributor to the increasing mass of pure and applied scientific knowledge.

In an address which I had the honour of delivering in this room a year ago attention was directed to the necessity for closer co-operation between the large societies representing the various chemical interests in Great Britain. During the past year action has been taken in this matter, and some fifteen of the societies have now collaborated in the establishment of a Federal Council for Pure and Applied Chemistry, the function of which is to advance, safeguard, and voice the interests of chemical science. The Federal Council consists of representatives nominated by the component bodies, and is already occupying itself actively with the questions within its purview; it has moved with some success in connection with the claims of experimental science to recognition in the recently established scheme for education within the Army, with the provision of fine chemicals for research purposes, with the remuneration of scientific posts, and with other matters. The Federal Council will continue to apply itself to those questions which are of importance to chemists as a class, leaving more specific chemical interests to be dealt with by the appropriate constituent societies. A very similar project for the consolidation of the larger chemical interests is in course of execution by our French colleagues.

It is beyond question that a central house for accommodating the chemical societies in a manner more proportionate to their importance than is at present possible should be provided; that a common chemical library far more complete than any now available in this country should be at our service: and that some comprehensive scheme for the publication of compendia of chemical knowledge should be put into operation. A very imposing and costly programme confronts the recent amalgamation of chemical interests, but the universal approval which greeted the proposition for creating a Federal Council for Pure and Applied Chemistry is a happy augury for the future usefulness of the new organisation.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

BIRMINGHAM.—At a meeting in Birmingham on May 8 of representatives of the engineering profession and others, the Lord Mayor presiding, a provisional scheme for celebrating the centenary of the death of James Watt was agreed upon. We are glad to note that the scheme includes the endowment of a chair of engineering at the University. A point which is sometimes overlooked in such matters was made by Sir Oliver Lodge, who reminded the meeting that endowments of this kind, though most desirable, should not be regarded as gifts conferring benefit only on the University. The University acted as a trustee, and every new chair endowed involved expense. Apparently no definite opinion was expressed as to the salary which should be attached to the chair; this would no doubt depend upon the sum collected for the memorial.