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Co-operation in Science and Industry.

THE past ten years has witnessed a wonderful development of organised Industry and organised Science in this country, and although conditions are still rapidly changing it is nevertheless possible to look forward and in some measure to determine the position in which we stand and the prospects for the future. The War, although one of the greatest economic disasters the world has yet experienced, gave without question a stimulus to discovery and production which no other event could have occasioned. Especially was this the case in the engineering and chemical industries, for the need of new appliances and methods, and the necessity for producing materials in large quantities and in the shortest possible time, caused the keenest intellects to be brought to bear on the problems at hand, and led to the discovery of new and important processes many of which have now been introduced into industry.

It is a principle conceded now even by the enlightened leaders of labour that the universal demand for a higher standard of living necessitates a general increase in the national productive capacity, the term " productive capacity " being used to mean the capacity to render available the potential wealth of the nation in a suitable form. It is chiefly to the chemical and allied industries, mining, metallurgy, etc., that the country turns, because it is their peculiar function, aided by the engineer, to make available its mineral, vegetable, animal and atmospheric wealth. Provided chemical and allied industries are properly organised, they should be in a particularly strong position not only to increase the availability of wealth, but also to guide national policy in questions strongly affecting material prosperity. The age is at hand, if it is not already here, in which the changing majorities of Governments will no longer be able to determine major policies as of war, financial and fiscal, except in directions approved by organised industry. Control by those who hold the keys of national prosperity, that is, of organised industry, is one of the alternatives to class control and is not only a desirable but also an eminently practicable ideal. To achieve it Science and Industry must organise so that they may become strong politically and financially.

Four kinds of co-operation are essential to strength : (1) internal co-operation, (2) co-operation with pure science, (3) co-operation with Government, (4) co-operation with labour. The last, that is co-operation with labour, is a human question rather than one of science or of policy dependent on science and need not be further discussed, especially since enlightened opinion on the part of employers now realises that labour relations are as vital to prosperity as any other factor.

Internal Co-operation.

Apart from more purely chemical or scientific factors there are two immediate advantages, to be gained by the formation of big combines, in the pooling of capital and the pooling of engineering resources; the establishment of a balance in commodities produced and in the method used for their production being determined mainly by chemical and engineering conditions.

It is evident that very great advantages must attach to the prevention of internal competition in the production of some substance required by more than one member of the combine, as, for example, in the preparation of some common intermediate product required by several manufacturers; but also much is to be gained by the pooling of engineering resources and experience, because many of the new processes which have been devised in recent times depend more upon good engineering for their success than upon any other factor. The chemist calls upon the engineer for workmanship, design and material of the very highest class, and it is precisely in these directions that our engineering science excels. This is particularly true in the case of modern high-pressure processes, none of which was in existence till the end of the war. It is not too much to say that in this branch of chemical engineering Great Britain now leads the world.

The standardisation of methods and the co-ordination of interests as regards production and distribution, the question of price and the prevention of over-production are problems which mainly concern the business organisation of industry, and do not directly affect the relations between Industry and Science. Yet their importance is manifest and in some instances, especially in connexion with the standardisation of methods, the help of the chemist is essential. The need for obtaining a balance in all these factors, a consummation which can only be reached by a pooling of like interests, is obvious.

Probably the best example of the common use of a chemical substance by a number of different manufacturers is that of hydrogen, which is at the present time used in vast quantities for the production of (*a*) methyl alcohol, (*b*) liquid fuels from coal,

(c) ammonia, to mention three of its most recent applications. In pre-war days it was used in large quantities, and still is so used, for the hardening of fat. Nevertheless, the three industrial operations mentioned also represent in a remarkable degree examples of progress and development that have taken place within the last ten years.

Pressure Reactions.—The influence of pressure on reactions was recognised by the organic chemist from the earliest times. The fact that most reactions lead to a diminution in volume gave rise to the obvious suggestion that by the aid of pressure such reactions could be facilitated and possibly in some cases directed. Consequently the organic chemist was accustomed to use autoclaves, sealed tubes and other pressure devices in order to attain the ends he had in view. Later, when the need for catalysts or surface reactants became apparent, the utilisation of pressure in order to further the particular interaction disclosed became essential. The chief difficulties which had to be overcome before such processes could be applied industrially were engineering ones, because it was evident that in order to obtain economical production larger units would be necessary and not only had such units to be made sufficiently strong to withstand the very considerable pressures necessary, but joints had to be made which would remain tight under varying temperatures. That such difficulties have been overcome and that pressure apparatus of very considerable size and capacity are now being used in the chemical industry throughout the world, is an engineering achievement of the very highest order.

Methyl Alcohol and Higher Alcohols.—Organic chemistry, although it covers more compounds than any other section of the science, enjoys this advantage that every one of those compounds can be made, on paper, by using the three commonly occurring substances carbon dioxide, water and ammonia in various proportions. In the early days of the science before the structural theory enabled the organic chemist to produce at will any substance he might require, the sole means of guidance was that derived from a knowledge of the empirical formula indicating the numbers of each atom present in the molecule. Consequently research followed the lines suggested by equations on paper which were based on the same plan as that adopted with inorganic substances. As is well known, the discovery of mauveine by Perkin in 1856 was of this character, and many of Baeyer's earlier researches were of the same nature. Indeed, if one reads Kekulé's " Lehrbuch der Organischen Chemie," which was published at Erlangen in 1861, that is to say, only a few years before the structural theory came into use, the extraordinary difficulties under which research workers in organic chemistry laboured become apparent. For example, Kekulé gives nineteen formulae for acetic acid which at that time were either in use or had been seriously suggested.

At the present time, although we have the structural theory to help us, we are nevertheless faced with a new unknown quantity, and that is the action and nature of the catalyst by which so many important industrial reactions are brought about. In the earlier days of the science, important and valuable discoveries were made hap-hazard by mixing various substances together and hoping for the best, and even by false reasoning, as, for example, when the photographer, in attempting to fix the colour of methyl-violet by the aid of sodium thiosulphate in the same way as he did the image on his photographic plate, transformed it into a green dye.

At the present time we know nothing of the reasons which determine the action of a catalyst and although we have to hand a vast number of reactions which may be regarded as reasonable and likely to occur should the right conditions be discovered, the search for a catalyst is always attended with difficulty and often ends in disappointment. Prior to the original German patent for the production of methyl alcohol from carbon monoxide and hydrogen, many attempts had been made to realise this very simple reaction even on the laboratory scale. Other reactions readily suggest themselves, such as, for example, the formation of acetic acid from methane and carbon dioxide. As a matter of fact this, and other reactions of a similar type, form the subject of patent specifications, but whether they have been actually realised experimentally must remain an open question in the absence of definite evidence. Our patent system unfortunately lends itself admirably to the production of " blocking " patents, and there is no subject so suitable as organic chemistry as a medium for such patents. The High Pressure Committee of the Department of Scientific and Industrial Research is investigating the nature of catalytic reactions under pressure at Teddington and it is confidently to be expected that Professor G. T. Morgan and his co-workers will be able to help us considerably in our search for the meaning of catalysis as applied to organic reactions, a hope which is justified by the work already published from this laboratory.

The Formation of Liquid Fuels from Coal.—The original process of Bergius, carried out with Westphalian brown coal, has been applied to bituminous coal, but not with the same degree of success. The general method, which consists in " cracking " the coal substances under pressure in the presence of hydrogen, seems over-elaborate to produce a substance of which there is at present too much in the world. Nevertheless a home supply of petrol and fuel and lubricating oil is highly desirable apart from that produced from Scotch shale oil, which is far too small in quantity to meet a general demand. The solution appears to lie in low-temperature carbonisation, although the economic success of this process seems to depend on the adoption by the public of the coke obtained. This product, which was initially to be called Fuelite but is now to be known as Gloco, is, nevertheless, the Coalite of twenty years ago. Whether it is possible to induce the householder to give up his coal fire is a question that the future alone can answer, but it must be remembered that in town areas where gas is the most valuable product the high-temperature method of carbonisation will still be the more economical financially. It is possible, however, that the liquid products of low-temperature carbonisation which are rich in aromatic phenols will lend themselves to the production of valuable petrols when subjected to vapour-phase "cracking." Indeed, this subject of vapour-phase "cracking" is of the highest importance in connexion with the conversion of higher fractions of the petroleum distillate into petrols, the petrols produced by this method being high in "anti-knock" value. Moreover, the gas formed as a by-product, which is mainly olefinic in character, can be utilised for the formation of numerous alcohols. It is of interest to observe in passing that the reverse process, that is to say, the building up of higher hydrocarbons from those lower in the series, has also received attention and that the production of benzene from ethane, and also from methane by pyrolysis, has been shown by Wheeler and his collaborators to be a practical proposition. The importance of such a conversion to countries like Canada where, daily, millions of cubic feet of natural gas (mainly methane and ethane) are wasted cannot be over-rated.* At the same time the very difficult question of the production of sufficient benzene for the world's needs—a hydrocarbon which has hitherto only been obtainable from coal—is in a fair way to being solved.

The Utilisation of Atmospheric Nitrogen.—The "cosmic scare" raised by Sir William Crookes in his Presidential address to the British Association in 1898 led, indirectly, to the introduction of the arc process for the utilisation of atmospheric nitrogen—a process which is still carried out in Norway.

This was followed by the cyanamide process in 1906 and during the War by the Haber process. From 1913 to well after the

* During 1927, 5,241,000 tons of petroleum were obtained from the Persian oil fields. It is estimated that in the production of this quantity approximately 25,000,000 cubic feet of gas are liberated daily. This gas is mainly methane and ethane, but contains also about 20 per cent. of hydrogen sulphide. At the present time the larger portion of this vast volume of gas is burnt to waste; its utilisation is therefore a problem of urgent moment.

War, the Haber process was the only method of direct synthesis in use commercially, and its rapid development in Germany during the War was the direct outcome of the isolation of that country and the complete absence of the nitrates and nitric acid so essential for the manufacture of explosives and the production of artificial fertilizers. The first plant of this type was established at Oppau in 1913 and operates at a pressure of 200 atmospheres and at a temperature of approximately 500° C. This method is also employed at the Billingham works of Imperial Chemical Industries Ltd., but since the War several new processes have been introduced such as the Claude, the Casale, the Fauser, the Jöst and the Harter processes. These newer methods are in most cases simpler to operate than the original Haber process, and it is now relatively easy to establish a nitrogen fixation process in any country. Moreover, these newer processes enable small synthetic plants to be operated economically and in consequence manufacture can be decentralised. For example, during a recent visit to the United States it was noticed that at the Gibbstown works of the Du Pont company the nitric acid required for the manufacture of the nitro-explosives produced there was being obtained by one of these newer methods. It is evident, therefore, that while the vast quantities of nitrates required for agricultural purposes will continue to be made at the great factories established for that purpose, each industry involving the use of nitric acid for chemical purposes will instal its own plant for its production. In this way the two great uses of nitrogen, that is, as a component of explosives and as a plant food, will become separated and the two types of manufacture will be carried out in different localities. The lesson learnt by Germany during the War is not likely to be lost sight of by other countries, and it can confidently be predicted that every country will ultimately become self-contained as a producer of its own fertilizers and explosives.

Hydrogen.—In all these matters the need for a cheap supply of hydrogen is essential. In the earlier part of the present century the hydrogen required for fat-hardening was produced by the electrolytic decomposition of water. The hydrogen produced in this way is exceptionally pure, but an abundant supply of electricity is necessary, approximately 140 kw.h. per 1000 cu. ft. of gas, that is to say, a quantity that can only be obtained economically in places where abundant electric power is available. Moreover, in this process the oxygen which is also formed cannot be utilised except under special conditions. Modifications of this method are now in operation mainly in the direction of producing the gas from electrolytic cells under high pressure, but although a considerable quantity of hydrogen is still made electrolytically, by far the greater quantity is now produced by the reduction of steam. The " steam-iron " process, in which red-hot iron is the reducing medium, was the first of these; the Bosch process, which involves the passing of a mixture of steam and water-gas over a catalyst at 400—500° C., followed. It has been estimated that approximately 15% of the hydrogen used is made electrolytically, whereas 70% is made by the water-gas catalytic process. About 12% is made from coke-oven gas by a method which involves the separation of the hydrogen by liquefaction of the impurities present. Coke-oven gas contains approximately 50% of hydrogen and owing to the low calorific value of hydrogen the gas is actually improved in calorific power by its removal. Moreover, during the process of purification considerable quantities of ethylene are isolated—a substance now in demand for the preparation of nitroglycol, a constituent of non-freezing nitro-explosives. It is probable, therefore, that this source of supply will be drawn on more freely in the future and it may even be found economical under special conditions to remove the hydrogen from the gas produced by high-temperature carbonisation in our gas works.

The water-gas catalytic method of producing hydrogen is in use in those places where the original Haber process was installed, namely, at Billingham in Great Britain, in the French Government Plant at Toulouse, and in the great works of the I. G. Farben Industrie at Oppau and Merseburg. In Germany the extensive deposits of brown coal, which is particularly suitable for use in the Bosch hydrogen process, are available.

The moral underlying the whole of what has been said above is that full industrial prosperity demands still larger chemical combines and trade associations. The vast chemical organisation which has been built up in this country under the inspiration and guidance of Lord Melchett and the great combine known as the I. G. in Germany are indications of the increasing tendency for nations to pool their resources in particular industries and thus stand four-square to their competitors in the world's markets. By the elimination of internal competition, by the pooling of chemical and engineering resources and knowledge, by the standardisation of methods of production on the most economical lines, by the sharing of raw materials, and above all by co-operation with labour the whole strength of the nation is focused to a point which enables it to exert the full force of its internal mental and physical power.

Co-operation with Pure Science.

Training.—Chemical trade is at present in the midst of the most rapid expansion it has ever known and nowhere is the development more noticeable than on the research side. This is as it should be, for the researchers are the scouts and it is essential that they should be far ahead of the army (the working process). It is necessary also that the scouts should operate on a broad front in order that no channel of advance should be overlooked merely because it does not lie in the expected direction. The realisation of this principle by the greater manufacturers has led to a strong demand for University-trained men, and the number of research chemists in industry in this country has been estimated at twenty times the number before the War; the demand is still increasing. The Universities have had and are having their work cut out to supply this larger number of adequately trained men, for they have to fulfil the majority if not all of the demands made by chemical industry. Manufacturers have come to realise that training should be essentially fundamental and that a wide knowledge of the principles of chemical science is a necessity. The vexed question—In what manner is this to be attained ?—is being answered by the gradual adoption of at least a four years' course, although the still more important one—that of the post-graduate course—is not yet settled. In straightforward cases, that is to say, instances involving preparation for those industries which are concerned with the so-called borderland sciences, the issue is clear. For example, the great demand at the present time for chemists with a knowledge of bacteriology, mycology, physiology, and so forth must be met by supplying a post-graduate training in these subjects. Where the branch of science to be followed lies within the scope of general chemistry, specialisation in that particular branch should form the subject of the fourth-year course. This is undoubtedly the case with that important branch of organic chemistry which deals with the intermediate products from the coal-tar hydrocarbons and the dyes derived from them.

Not only has the far-sighted policy which led the Worshipful Company of Clothworkers to found what is now the Department of Colour Chemistry and Dyeing in this University been fully justified, but the principles laid down and followed by each successive Head of the Department have served as a model which has been freely followed, both in this country and abroad. The Colour Chemistry and Dyeing Department was, in conjunction with the Textile Industries Department, one of the first buildings to be erected on the present University site. In 1880 these two departments were unique and their subsequent growth has been continuous. For many years the Clothworkers' Company provided their entire maintenance, but on the formation of the University of Leeds in 1904, the rights and management were transferred to the University. The Company's total monetary contribution towards the provision of this form of University education at Leeds approximates to £250,000, and the most recent extension of these departments, provided by the Clothworkers', was opened in October last.

Each head of the Department (J. J. Hummel, A. G. Green, A. G. Perkin, and F. M. Rowe) has considered it essential that students of colour chemistry and dyeing must be trained primarily as chemists in close co-operation with the pure chemistry, physics, mathematics, engineering, etc., departments, in which a large proportion of the students' time is spent. Merely mechanical, vocational training has never been provided, but the courses have been developed on an increasingly scientific basis in preparation for a career in any branch of industry in which the chemistry of colouring matters, of textile fibres, and of the processes to which they are submitted, plays an important part. Detailed large-scale practice is not taught, although the laboratories are equipped with all types of modern machinery for processing wool, cotton, and artificial silks, the aim being to instil the scientific foundations of such operations. Actually, the training of a student of colour chemistry and dyeing is superimposed upon the normal preliminary training in the pure sciences and is merely a continuation of the latter from the point of view of certain industries. The value and adaptability of this thorough and fundamental scientific and technical training is illustrated by the fact that at the end of his course a student may obtain a position as a chemist in such widely different branches of industry as the manufacture of intermediates and dyes, or of lake pigments, the distillation of tar, the manufacture of artificial silks or other cellulose products, calico printing, or the various specialised branches of bleaching and dyeing, including garment dyeing and cleaning. Although examples of all those industries are to be found in or near Leeds, former students of the Department also occupy important positions in these industries in all parts of this country and abroad. The Department is in close touch with industry and owes much to the interest and generosity of individual firms.

I have thought it desirable to give the above particulars of the Department of Colour Chemistry and Dyeing in the University of Leeds, because they illustrate in a remarkable manner the way in which purely chemical and technical education have been combined to produce men thoroughly trained on both the fundamental and the practical side and who are thus able not only to deal with problems of the moment but also to appreciate and adopt such developments as may occur in the future. It is not the question of the principle that is involved, because, at the present time, it is fortunately unnecessary to emphasize the truism that mere mechanical or vocational training without fundamental knowledge is useless and cannot meet the needs of rapidly developing industry. It is rather the question of method that is in doubt, and it is therefore important to realise that, so far as the particular industries dealt with are concerned, the Leeds organisation has succeeded in supplying an answer.

A long experience of University teaching has shown me that it is exceedingly difficult to determine whether any particular individual is more fitted to succeed as a process chemist or whether he has that peculiar aptitude which will enable him to carry out effective work in the research laboratory. Unfortunately the positions are not interchangeable. A student who has shown aptitude for research may, if occasion demands, make an excellent process chemist; indeed it often happens that he will have to develop a laboratory method so as to place it, with the help of the engineer, on the unit factory scale. But it is very doubtful if the individual who has shown that he possesses no aptitude for research can be usefully employed in that connexion excepting under control. The only manner in which the presence of the research aptitude can be discovered is by direct trial and therefore it is always desirable to subject a student to one year's training in research after graduation in order to discover if he possesses this characteristic. After one year's observation it is usually possible to determine whether a man possesses (*a*) originality of thought and method such as will enable him to become a research originator, (*b*) the aptitude for research which will make him a good team worker under direction, (*c*) no aptitude for research of any kind.

Those falling within class (*a*) are rare; those within class (*b*) form the majority. Those falling within class (*c*) are also comparatively rare, because the usual course of training followed in an Honours School is such as to instil a desire for enquiry. But when found, they should be advised to seek one of the minor industrial posts or to secure training in some special branch of technology which will enable them to act effectively as process chemists.

The term " research training " must be interpreted in its widest sense to include training in special branches of chemistry related to the industries as well as more general training in the higher branches of chemical technology. It is evident, therefore, that the field of choice open to a student who has finished his course of fundamental instruction is very large, since it also includes the borderland subjects to which reference has already been made. The choice has to be made by the man himself, guided by such advice as his teacher can give him. Such guidance will be based on a knowledge of the man's capacity and of the requirements of the moment, but, unfortunately, conditions change so rapidly that the needs apparent at the time the advice is given may be no longer present two years later when the period of training is finished. Nevertheless, the call for men thoroughly trained in the various branches of applied chemistry and in the subjects based on chemistry is likely to increase rather than diminish and it is not correct to say that there is, at the present time, a superfluity of chemists who are unable to obtain employment. There is, naturally, in this branch of science, as indeed in any branch of knowledge, a difficulty in placing second or third class men. The term "third class Honours" ought to be eliminated from our vocabulary, as has been done by at least one of our Universities recently, and it is an open question whether the second class ought not to follow the same path. Nevertheless, one does not make a second class man into a first class one by calling him such, and the need for adjustment evidently belongs to an earlier stage. Men who have shown, during the earlier stages of their studentship, that they are unlikely to obtain anything but a low class in their Degree examination ought to be rigorously excluded from an Honours School. If this were done effectively, we should hear less about the lack of employment for unsuitable men.

Industrial Research in Universities.—At no distant period in the past the great potentiality for research residing in our University laboratories, and in the personnel controlling them, was not available for industrial purposes. The reasons for this were many. For example, industrial research was not regarded as of sufficiently "pure" character to allow of its inclusion in the academic curriculum. There was considered to be something essentially different between "applied" and "pure" chemistry, and this was emphasized in the "eighties" by the formation of the Society of Chemical Industry as a distinct body from our own Society. The Americans knew better than this. They have kept their chemists together as a homogeneous body and the American Chemical Society with its membership of 17,000 represents in no uncertain manner the considered opinion of the whole body of chemists of that country.

The fault lay mainly with our Universities, which were loth to introduce science other than "pure" into their courses of instruction. Hence there arose the multitude of Technical Schools which were originally intended to supply the need for a vocational training without undue reference to the science upon which the training was based. The establishment of new Universities in industrial centres, a period of reform ushered in by the breaking up of the old Federated Victoria University, soon produced a marked change, and research and instruction in the fundamental principles underlying industrial science gradually passed into the hands most competent to deal with them.

Industrial research both of the fundamental kind and that which arises as the daily outcome of works practice should be and now is carried out for the most part by the firms themselves in their works laboratories. But there are a number of problems, mainly of a "long-sighted" character, which are intimately related to industry. The personnel on the scientific staffs of our Universities are people who have throughout their lives specialised in some particular branch of research, and are therefore eminently fitted to solve problems in their special field. This is now recognised by many leading firms who supply grants to enable post-graduate research workers to investigate specific problems under the guidance of Professors of Chemistry and other directors of research laboratories, and in this connexion must be mentioned the far-sighted policy of Imperial Chemical Industries, Ltd., who give yearly substantial grants to research laboratories in order to enable them to obtain special types of apparatus and appliances which it would otherwise be difficult to procure. Great advances have been made in the country since the War in the development of scientific industry, and every effort must be made to maintain and strengthen the causes which have led to this condition. From the point of view of national prosperity it is essential that active research centres should be maintained and still further developed in our Universities, not only to supply the scientific ability to foster and improve the industries of our own generation, but also to pave the way by discoveries in science for future commercial prosperity.

Team Work.—During the War very valuable work was accomplished by means of team work, by which is meant the solution of some problem by the united efforts of a team of workers under a directing head. There can be no question that this method of attack is usually most effective, especially in a works laboratory where some specific problem may require rapid solution. Its application to the University laboratory is subject to the difficulty that under team conditions the intellectual stimulus which attaches to the individual attack on specific problems is sometimes lacking, and it is in the highest degree desirable that this stimulus should be developed and maintained. Nevertheless, it is always possible so to divide a major problem as to make each section in itself a self-contained research and thus to give each investigator what is essentially a definite subject on which he can work in his own way and according to his own mentality. This, as a matter of fact, is being done in many research laboratories, and probably one of the best examples is that supplied by the Safety in Mines Research laboratory at Sheffield. Here Professor R. V. Wheeler directs a team of research workers who are engaged on problems connected with the conditions necessary to ensure adequate safety for miners working in coal mines. The problems involved relate to the spontaneous combustion of coal, the use of safety explosive, and the conditions leading to the prevention of the propagation of flame should an ignition of firedamp occur underground. These and many related enquiries are dealt with by a team of research workers employed either at Sheffield or in the new experimental station at Buxton, but each particular problem is assigned to one or two workers and the intellectual stimulus provided by specific investigation is always present.

Frequent meetings and discussions as well as the delivery of lectures by outside workers keep the members of the team in touch with one another and with development generally. There is nothing more destructive of a man's mentality than the feeling that he is merely a cog in a wheel of some machinery of which he has no knowledge; that he is being used as a means of obtaining some substance or result which, as soon as prepared or obtained, passes to someone else for further treatment. Production and sometimes research on these lines is doubtless effective, but it is secured at the expense of individual loss of initiative and craftsmanship. It is the very worst form of instruction that can be imparted in the earlier years of a research worker's training and should be rigorously excluded from our schools of research.

Co-operation with Government.

The Government of this country has already discovered the two most valuable ways in which it can co-operate to the benefit of present and future chemical industry, namely, (*a*) by protecting young and struggling industries against competition from similar but established industries abroad and against competition arising from deflated foreign currency, and (*b*) by promoting research in pure and applied chemistry by financial assistance.

Safeguarding.—The first action under (*a*) was the passing of the Dyestuffs (Import Regulation) Act in December, 1920, an Act which came into operation on January 15th, 1921. It prohibited for a period of ten years the importation into the United Kingdom of all synthetic dyestuffs and all intermediate products used in their manufacture. The position was a peculiar one, because it was obvious that our great textile industries depended on the production of certain types of dyestuffs which had hitherto only been obtainable from

Germany and that several of these dyestuffs could not, at that time, be produced in this country. Definite prohibition was therefore impracticable, and the provision of a tariff would have entailed so high a rate of duty—in order to meet the determined effort which Germany would have made to re-establish its pre-war predominance—that a hardship would have been placed on the consumer. It was generally agreed, therefore, that prohibition tempered by licence was the best solution and the truth of this view is shown by the fact that last year—seven years after the passing of the Act—approximately 10%, about 5,000,000 lb., of the total dyestuffs used in this country were imported under licence, the remaining 90% being produced by home manufacture; an exceedingly satisfactory state of affairs when the position of Great Britain in this connexion before the war is considered. The next application of the safeguarding principle took the form of the Safeguarding of Industries Act, 1921. This Act had two purposes: (1) The safeguarding of a definite list of "key industries" against competition from any source, and (2) provision for the safeguarding of any industry against the effects of the depreciation of the currencies of certain foreign countries.

The schedule of this Act was necessarily couched in very general terms and enacted that an "ad valorem" duty of 33⅓ per cent. could be imposed on certain classes of commodities which experience during the war had shown to be essential for the maintenance and well-being of other industries of national importance.

It was necessary to give the Board of Trade power under the Act to draw up lists embodying the commodities included in the items enumerated in the schedule, and such lists were in due course prepared. The Act also provided that any complaints against the inclusion or omission of any article in the list should be referred to the arbitration of a referee appointed by the Lord Chancellor, whose decision should be final. The schedule of the Act enumerated a variety of commodities, including such general phrases as "synthetic organic compounds" and "fine chemicals," and these were duly interpreted in specific terms in the Board of Trade lists. But it was found extraordinarily difficult to define these phrases in a legal sense. It will be remembered how difficult it was to say whether calcium carbide was an organic or an inorganic chemical, expert opinion by our leading chemists being about equally divided as to the correct answer to the question. In the same way grave difficulties arose as to the correct definition of a fine chemical and the referee found himself faced with a mass of contradictory evidence supplied by persons fully competent to express an opinion. Some twenty cases came before the referee (Mr. Cyril Atkinson, K.C.) and in every case he supplied a closely reasoned written judgment. The legal interpretation of scientific evidence by scientific experts on scientific matters, especially of definition, is always, however, difficult, and when the desirability of extending the Act beyond the five years provided came up for consideration before a Committee appointed by the President of the Board of Trade, of which Sir William Pope was a member, it was unanimously decided, in a report dated March, 1926, that in place of the Referee alone a tribunal should be set up consisting of the Referee and two scientific referees drawn from a panel appointed by the Lord Chancellor for the purpose. Effect was given to this and other recommendations contained in the Report by the Finance Act of 1926, which continued safeguarding for ten years from August 19th, 1926. Only two cases have so far come up for decision before the newly-constituted tribunal.

The second object of the Act of 1921, namely, the imposition of a duty of $33\frac{1}{3}$ per cent. on "any goods imported from a foreign country with a depreciated currency if owing to that depreciation such goods were being offered for sale in the United Kingdom at prices below those at which similar goods could profitably be made there and employment in the corresponding industry here was or was likely to be adversely affected," was rendered to some extent abortive, because it was also provided that no order should be made which was at variance with any British treaty or convention with a foreign country. In effect this meant that duties could not be imposed against countries having by treaty or understanding a most-favoured-nation agreement with this country and in consequence duties were only levied against goods of German origin. A wider policy was adopted by the present Government in a White Paper issued in February, 1925, which announced the adoption of a policy by which British industries of substantial importance would be safeguarded if it could be shown that they were suffering from unfair competition owing to (*a*) depreciation of currency operating so as to create an export bounty, (*b*) subsidies, bounties, or other artificial advantages, and (*c*) inferior conditions of employment in the competing foreign industries. This policy was given effect to by the Finance Acts of 1925, 1926, 1927 and 1928, by which duties were imposed in a number of cases on articles falling within the above categories.

Agricultural Research.—Of all the industries which are and have been served by chemistry, agriculture stands in a special position in so far as the Government have placed at its disposal an organised and free advisory service. There are at present 21 Advisory Chemists in England and Wales, each having his headquarters at some appropriate educational centre. Every bona-fide farmer is entitled to their advice (which normally involves a visit to the farm) without being involved in any expense whatever. Farmers are availing themselves of this service more and more every year and the industry is consequently in a far more favourable position than it was twenty years ago.

There is a great deal of valuable reciprocity here. The Advisory Chemist is expected to carry out fundamental scientific investigations that relate or appear to relate to the farming problems he meets. This work has enlarged our knowledge of the constitution of the soil, which new knowledge has in turn enhanced the utilitarian functions of the Advisory Chemist.

For generations farmers in many areas have suffered a complete failure of their barley crop. In more recent years, sugar beet—for no reason apparent to the farmer—has similarly and unexpectedly failed. It is not too much to say that the work of the Advisory Agricultural Chemists has now made it possible for a farmer to know almost with certainty before he arranges his cropping where those crops are likely to fail and to be informed of the only measures which will ensure their success.

No less in animal husbandry than in crop husbandry are the services of the chemist of great economic value to the farmer. It is no unusual thing for the Advisory Chemist to adjust uneconomical and ill-balanced rations to stock in a way which has saved the farmer a deal of money. The cost of producing milk has been reduced by as much as 4*d.* a gallon and the economy effected in feeding fairly large herds is sometimes between £40 and £50 a month.

The Promotion of Research.—The scheme for the organisation and development of scientific and industrial research was given in Mr. Arthur Henderson's memorandum of 23rd July, 1915, which was issued as a White Paper (Cd. 8005). The Advisory Council was constituted by an Order in Council of the 28th July, 1915, the terms of reference being " to recommend proposals (i) for instituting specific researches; (ii) for establishing or developing special institutions or departments of existing institutions for the scientific study of problems affecting particular industries and trades; and (iii) for the establishment and award of Research Studentships and Fellowships."

The Order also stated that " The said Council may itself initiate such proposals and may advise the Committee (*i.e.*, the Committee of Council for the organisation and development of scientific and industrial research, constituted by the same Order) on such matters whether general or particular relating to the advancement of trade and industry by means of scientific research."

The 13th Annual Report of the Department has recently been issued and shows that development along all the lines indicated in the terms of reference has been initiated, and that great progress has been made in giving effect to the intention of the scheme.

Specific Researches.—Apart from the work which is being carried out by the special research stations founded by the Department, notably the Fuel Research Station, the Forest Products Research Station, the Chemical Research Laboratory, Teddington, and the Low Temperature Research Station of the Food Investigation Board, many other specific researches are in progress at various research institutions throughout the country. At the same time the Department supports specific researches of a fundamental kind which are of wide interest both from the scientific and the practical point of view and the furtherance of which is likely to lead to results of national importance. Examples of these may be given in the work on *X*-rays, which is now entering a stage which shows not only that the information procurable by this method of analysis is certain to give us knowledge of intimate molecular structure, but that it is also applicable to such important practical uses as the determination of the structure and properties of alloys. Assistance is also given to the work which is being carried out by Professor Bone at the Imperial College on gaseous reactions at high pressures, and this laboratory, which has also received substantial financial assistance from Imperial Chemical Industries, Ltd., is now adequately equipped to prosecute research in this most important field.

Research Associations.—The policy instituted by the Department, by which Research Associations in various industries were founded on the basis of annual grants equivalent to the annual subscriptions o members of the Associations, has led to the formation of twenty-four of these bodies. At the outset it was considered that a period of five years was sufficient to give this experiment in co-operative research a fair trial and that at the end of this period State assistance could cease. Experience showed, however, that except in certain special cases five years was not long enough to enable an Association to prove its value by the results of the work accomplished, and an extension of State aid was granted for a further period of five years. The report of the Department for 1927—28 shows that a memorial was received from nineteen Research Associations praying for a continuance of financial assistance on the same basis for a further period of ten years. There can be no question that the experiment has proved a success and that the value of co-operative research in industry has been established. The Department has, therefore, rendered a valuable service to the industrial community and its initial policy has been fully justified. Nevertheless the time has arrived when the varying appeal which the necessity for scientific investigation makes to different industries has made itself manifest and the Department feels that any further support on general lines would no longer be justified. It proposes, therefore, to treat each case on its merits.

Research Studentships and Fellowships.—The third term of reference, namely, " for the establishment and award of Research Studentships and Fellowships," was rendered necessary in order that properly trained personnel should be available to meet the requirements of rapidly growing industry and also that the Research Associations which were about to be set up should be adequately staffed by men thoroughly trained in the methods of research.

Prior to the war research training was imparted only to a comparatively few students who had passed high in their final examinations and had thus obtained one or other of the post-graduate scholarships or fellowships provided by most Universities. Schools of research were small, because those whose parents could not afford to pay for a five years' course had to seek employment as soon as they had taken their Honours Degree. The provision of Students' Maintenance Allowances by the Department has, therefore, enabled many men who would otherwise have had to pass into industry at the end of the three years' course to stay at the University for one or two years longer and in this way many students, fitted by temperament to make useful research workers, have been prevented from taking too early employment. This policy is undoubtedly in the national interests, because it provides for a steady stream of research workers which could not otherwise be produced. That the policy has been justified is shown by the figures given for the year 1926—27, for out of 165 students provided with maintenance grants 59 only sought renewal, the remaining 106 being either absorbed into industry or into posts of other kinds. The call for adequately trained research workers in science and especially in chemistry is increasing. Every head of a research school knows that he can always place a thoroughly trained man and he is frequently in the position of having no men available when application is made to him for research workers. It is therefore very disquieting to realise that the policy of the Department in connexion with the provision of maintenance grants for students in training appears to be changing, for whereas the number of such grants (including research workers and assistants) was 275 in 1925—26, it has fallen to 186 in 1927—28. The outlook is serious, because it is quite impossible for the Universities to provide funds for post-graduate training in any way commensurate with the present-day requirements of industry, and as the average science student is usually drawn from a comparatively poor class it is not likely that the necessary money for an extended course will always be obtainable from parental sources. No doubt in the future the Universities will be able to acquire adequate funds for this purpose from benefactors who appreciate the need, but that time is not yet come and meanwhile it is essential that the State should provide the means for helping to meet this very real national difficulty.

Every director of a research school has had to tell some promising student who wishes to undergo post-graduate training and who is, without question, likely to profit by such training, that no funds are available to enable him to extend his course and that he must, therefore, seek any minor post that may be open to him. The loss of such a man is a national loss, because his training is broken off at the stage where even one extra year would have enabled him to become a useful member of a research organization, whereas, in the circumstances, he has to take up some position, probably one involving merely routine work, where the value of his early training will be lost and his initiative and enthusiasm destroyed. It is, therefore, to be hoped that the diminution in the number of research grants is merely a temporary expedient and that it does not indicate a reversal of a policy which has proved so fruitful during the past twelve years and has shown itself to be an essential part of research development in this country.