London Section.

Meeting held at Burlington House on Monday, Nov. 2nd.

DR. J. LEWKOWITSCH IN THE CHAIR.

The CHAIRMAN, in opening the proceedings, referred to the loss, by death, since the last meeting, of Sir Thomas Stevenson, a prominent member of the London Section.

He also drew the attention of members to the Decennial Index, just published, which had entailed a great deal of time, labour, and expenditure of money; he hoped that members who had not yet obtained a copy would send in their applications.

This session would be, in more than one respect, a memorable one; at the close of it would come the International Congress of Applied Chemistry, which would meet in London, and in which the Society would take a very prominent part with regard to the arrangements. In a few days details would be sent out; but he desired now to appeal to all the members of the Section loyally to support the Congress by preparing papers or announcing their desire to take part in the discussions.

Another important event would mark the close of the Session, namely, the annual meeting of their own Society, which would commence in London one day before the opening of the Congress, and then be held concurrently with it for three days until the end of the week. That would entail a great deal of preparatory work, which would be undertaken by committees which had been appointed; and he appealed to the generosity of the members to furnish their committees with the necessary financial support.

Lastly, he had to mention that the committee of the London Section had taken in hand the arrangement of general papers to be given by the foremost specialists in their subjects. To put it briefly, it was intended to collect in a series of rounded-off papers, a "Chemical Technology," as it were, on all the subjects with which Chemical Industry and Chemical Engineering dealt. These papers were to be contributed by the most prominent specialists, who would deal, in the first instance, with groups of subjects from a general point of view, then with the individual industries belonging to these groups, and descend finally to the latest details in their particular branches. All sections of the Society would be invited through the Council of this Society to take part in this scheme, which no doubt would keep all the Sections busy for a good many years to come.

The first paper of that kind was the one to be brought forward that evening; and he very much regretted that its author, Professor Adolf Frank, could not be present. Professor Frank had not only consented most readily to prepare this paper, but had offered to come himself to read it; after the paper had been sent in, he was unfortunately struck down by illness, and was unable to be present. He had, however, urgently insisted that no alteration in the programme of the Section be made.

CHEMICAL INDUSTRY IN RELATION TO AGRICULTURE.

BY PROF. ADOLF FRANK, PH.D.

Between agriculture and industry, both members of the same family and both supporters of the welfare of a State, a certain antagonism of interest has long existed. The gulf which threatened to separate them would have become still wider owing to the more rapid extension and the greater mobility of industry, had not science and technical practice fortunately come between them as mediators at the opportune moment. A large share of this beneficent action was taken by chemistry. By a happy concatenation of circumstances I have been working for more

than 50 years on the borderland between agriculture and applied chemistry, and I am therefore very pleased to accede to your chairman's invitation to communicate some details and relate some incidents that I have seen and taken part in during that period.

In order to mark the connection between chemical research and agricultural practice, it is sufficient to recall the name of Liebig. In his works published about 1840, among which may be mentioned "On the chemical process of the nourishment of the plants and the natural laws of agriculture" and the "Chemical Letters," he clearly and correctly defined the lines upon which the development of modern agriculture has taken place and which alone offered the possibility of giving and securing bread with peace to a rapidly increasing population living on a restricted area. With reference to Liebig's principles, which form the foundation of a new era in the political as well as in the social life of nations, another great chemist, Hermann Kolbe, has expressed himself as follows:—"It seems marvellous and almost incredible to the uninitiated that, after a pursuit of agriculture for thousands of years, and after the establishment of the general belief that agriculture was being rationally carried out on the basis of a thousand years of experience, a chemist, who had never been a farmer, had never held the plough, never tilled the ground, should from his desk teach the agriculturists how to treat the soil, in order to impart to it constant productivity; and that only through Liebig's doctrine of the treatment of the soil and of the natural laws governing the cultivation of the ground a truly rational system of agriculture has been inaugurated."

Not only did Liebig enunciate new views upon agriculture, but he also devised processes for the production of artificial manures; and when chemical industry took possession of the ground thus prepared, most things were ready and there only remained to be carried out what the mind of the great master had devised and foreseen. In the seventh edition of his "Agricultural Chemistry," published shortly before his death, Liebig restated his doctrine, as follows:—

1. The nourishment of all green plants consists of inorganic and mineral substances;

2. Plants require carbonic acid, ammonia, nitric acid, water, phosphoric acid, sulphuric acid, silicic acid, lime, magnesia, potash, soda, and iron; in addition, some also require common salt;

3. Between all the component parts of the soil, water, and air, which participate in the life of the plant, between all parts of animals and plants, there is a connection in the sense that, if but one single link is missing in the chain of phenomena which bring about the conversion of inorganic matter into supporters of organic activity, the plant or the animal cannot thrive;

4. Manure, the excrements of man and animals, does not influence vegetable life by its organic elements, but acts on it indirectly through the products of its decomposition, in consequence of the transformation of its carbon into carbonic acid and of its nitrogen into ammonia or nitric acid. Organic manure, which is composed of parts or remnants of plants or animals, may therefore be replaced by the inorganic compounds into which it is decomposed in the soil.

When, by numerous analyses of the ashes of cultivated plants, Liebig had shown which mineral substances were required, and when it had been ascertained that soil suitable for certain plants contained a sufficiency of these substances in a condition suitable for absorption by the plants, the conclusion followed that the incapacity of the tilled ground to produce satisfactory crops, or, in other words, the decrease of the products harvested under normal climatic conditions, could only be attributed to the deficiency of one or more of the mineral substances required for the nourishment of the plants. It thus became easy to understand the effect of manure

and of the rotation of crops and fallow, the latter serving to give the soil a rest, i.e., time for a sufficient decomposition of insoluble mineral matter. All these expedients were, however, insufficient and thus furnished proof that the soil was deprived by the crops of more mineral substances than could be supplied by means of the time-honoured procedure, or, in other words, that the soil had become exhausted. Where the entire residue of the crop was almost wholly returned to the soil in the shape of manure, as in the case of small agricultural holdings which consume their products themselves, the soil, with the assistance of the natural processes of decomposition, retained its fertility. Where, however, part of the crop, as for instance, grain, or large quantities of animal products, were carried away for other purposes, without suitable substitutes being procured, the fertility of the soil gradually lessened. Practical proof for the correctness of this theory was supplied by Liebig not only by reference to the barrenness of those countries which had formerly supplied Rome with corn, but also by showing that the present system of agriculture, by which many important plant-nourishing substances were permanently lost to the soil, could but bring about a similar disastrous state of affairs. But as the development of our commercial life does not admit of a return to primitive conditions of agriculture, the only rational course left is to replace the vegetable and animal manure withdrawn from the soil by natural or artificial manures from fresh sources. It is hardly necessary to point out that a supply of that kind, expensive as it is rendered by freight, can only pay in the case of those plant-nourishing substances which are really deficient in the soil and which—unlike lime, silicic acid, etc.—cannot be procured in the immediate neighbourhood. Through the investigations of Liebig and his followers it was shown that two mineral substances, indispensable for the cultivation of plants, viz., phosphoric acid and potash, are not, in most cases, rendered available rapidly enough, by the decomposition of the soil, to replace the loss which the soil had suffered through the crop. A third indispensable requisite of the soil in addition to the above two substances, is nitrogenous manure, as represented by ammonia and nitric acid.

In the widespread alarm produced by Liebig's proof of the exhaustion of the soil and of the consequent and unavoidable decrease of agricultural production, over-zealous disciples of the new theory arrived at conclusions and made proposals which called for a complete revolution in our economical and social conditions. The immense value of plant-nourishing substances constantly withdrawn from agriculture in the waste products of the inhabitants of towns was calculated and it was concluded that only the extreme care shown by the Chinese in the conservation of excrements might be a means of rescue. The number of projects worked out for the utilisation of town refuse and even of sewage by transformation into manures, was legion, and much capital was spent in carrying out such ideas. But others, better informed, on calmly examining Liebig's principles, soon recognised that, to replace the mineral nourishing substances of plants, less complicated means might be found by using mineral deposits, which, like coal, might have accumulated in some spots of the earth. The correctness of this view was confirmed first through the discovery of rich deposits of phosphates, then through the opening up of the nitrate fields of Chili, followed just at the right time, by the discovery of enormous deposits of potash salts and, finally, in the last decade, by the technical utilisation of the immeasurable quantity of nitrogen stored up in our atmosphere.

I shall now proceed to discuss briefly the production of the raw materials thus found, and of their working up, as this represents one of the most important branches of chemical industry, and I shall begin with the oldest manufacture, that of phosphates, first founded in Great Britain.

The advantage obtained by manuring fields with bone meal had long been known in Great Britain, and large quantities of bones were imported from other countries for the requirements of British agriculture.

It was, however, left to Liebig, whose theories Great Britain was the first to appreciate fully, to prove that the efficacy of this manure was mainly due to its contents of easily soluble phosphates (i.e., phosphates easily absorbed by plants), like the readily soluble phosphates in guano. To render the mineral phosphates then known, such as the coprolites of Norfolk and Suffolk, equally effective, Liebig recommended converting them into the soluble monophosphate by treatment with acid. This operation, which soon proved to be attended with success by practical experiments in the field, formed the basis of the superphosphate industry, which in its turn reacted beneficially on the expansion of the manufacture of sulphuric acid. Starting from Great Britain, the superphosphate industry rapidly spread over all civilised countries. As the known deposits of phosphates did not suffice for the rapidly increasing demand, all parts of the world were searched for phosphates, in order to procure the raw material required for the manure works at present existing in Europe and in the United States. The statistics of the world's production of native phosphates show with what energy this search has been carried out. The production was in 1900, 2,800,000 tons (in round figures), and had risen to 3,800,000 tons in 1905. Of these the United States produced 1,515,000 tons in 1900, and 2,000,000 tons in 1905, 620,000 and 935,000 tons respectively being exported. Algeria and Tunis together shipped abroad 440,000 tons of phosphates in 1900, and 800,000 tons in 1905. To these native phosphates (the conversion of which into superphosphate requires 3,000,000 tons of chamber acid) must be added the valuable source of supply which has been thrown open during the last decades, in the shape of the so-called Thomas, or basic slags.

It is well known that the production of ingot steel in the Bessemer converter from pig-iron containing a high percentage of phosphorus has only become possible through the process, invented by Thomas and Gilchrist in 1878, whereby the phosphorus contained in the iron ore is transformed into phosphoric acid, which combines with the lime added to the liquid iron, to form basic quadruphosphate. Whilst native phosphates are as a rule composed of triphosphates which are not readily soluble, the quadruphosphate is not only soluble in weak organic acids, such as citric acid, but also, if sufficiently finely divided, in those weaker acids formed by the slow chemical changes which take place in the soil. Hence quadruphosphate may be used directly as a manure with success.

Germany being very poor in iron ores free from phosphorus which alone were suitable for the old Bessemer process, but owning enormous deposits of ores containing more or less phosphorus (*minette*), which formerly were considered of very low value, quickly adopted the Thomas-Gilchrist process, which was somewhat improved by German metallurgists. When the basic process was introduced in Germany in 1879, the production of German iron ore amounted to 7,240,000 tons and that of pig-iron to 2,730,000 tons. In 1906 the output of iron ore had risen to 26,700,000 tons, of which 21,000,000 tons were phosphoric minette ores, and the pig-iron production had increased to 12,478,000 tons, of which 8,000,000 tons were worked up by the Thomas-Gilchrist process. The 1,500,000 tons of basic slag, containing from 18 to 20 per cent. of phosphoric acid, have been used in Germany as a cheap and efficient phosphatic fertiliser, especially in admixture with potash salts, and the income derived from this by-product represents a valuable item in the balance sheets of German steel makers. The total quantity of Thomas phosphate produced in the world in 1907 is estimated at 2,700,000 tons. The phosphorus contained in 400 kilos. of Thomas iron can supply sufficient phosphoric acid to restore to 1 hectare (2½ acres) of soil what has been taken away from it by one crop of wheat or rye.

I now pass to the production of potash, the second important mineral foodstuff of plants. The advantages of manuring with wood ashes were known in practice long before Liebig's time, but it was impossible to obtain sufficient material for agricultural purposes on account

of the steady diminution of forests and the increasing requirement of potash for industrial purposes. Trials made by Ward, in Great Britain, to obtain potash from felspar did not lead to commercially successful results. True, some muriate and sulphate of potash was obtained in France and in Scotland as a by-product in the treatment of seaweed (kelp, varech) for the production of iodine and bromine, but those quantities were very small. The most abundant source of potash was found in beet-root, which extracts from the soil large quantities of potash, which is then found in the sugar molasses. From these molasses, which still contain much sugar, but are unfit for consumption on account of their salty taste, alcohol was produced by fermentation, and, after distilling off the alcohol, potash was obtained by evaporating and charring the residual liquors. As much as 250 kilos. of potash per hectare (2½ acres) may be extracted from the soil by a good beet-root crop. Hence it is clear that considerable quantities of potash could be obtained by growing beet, and as a matter of fact, the quantity of potash so produced towards the end of the 'fifties in the beet-root district of Magdeburg alone amounted to 4500 tons per annum. But this apparently easily gained profit was followed by large losses, as owing to the withdrawal of the potash salts necessary for the growth of the beet-roots, the fertility of the soil, notwithstanding abundant manuring with guano and superphosphate, decreased so rapidly, that the very existence of the beet-root sugar industry was jeopardised. Here there was direct proof, obvious even to the practical farmer, of the correctness of Liebig's theories. At this critical moment and precisely at the time when Balard and Merle had concluded their protracted studies on the production of potash salts from the mother liquors of the "salt gardens," came the opening up of the Stassfurt Salt Mines in 1857. It is well known that in 1852, in the course of sinking a shaft for the mining of rock-salt at Stassfurt, enormous layers of impure salts were found overlaying the true rock-salt. These "overburdens" contained large proportions of potassium chloride, magnesium chloride, and magnesium sulphate. These coloured "bitter salts," unfit to be used as rock-salt, were at first termed "waste salts" (*Abraumsalze*) and their whole quantity, which had to be removed before the rock-salt was reached, was thrown on the waste heap as so much refuse.

At that time I was working as chemist in a beet-root factory at Stassfurt and, being a zealous disciple of Liebig, my mind was full of thoughts regarding the decrease—both as regards quality and quantity—of the crops, which then made itself felt on the beet-root fields. I therefore took up the study of these waste salts, the composition of which had already been ascertained by Heinrich Rose and Marchand, and I soon found that they represented suitable material for the production of potash salts for industrial as well as for agricultural purposes. After having overcome a great number of difficulties and obstacles, I succeeded, in 1861, in establishing the first potash salts factory, which was designed to work up no more than 5 tons of waste salts per day. This factory supplied potash manures, in addition to potassium chloride, for the manufacture of potassium nitrate. Whereas before the practical execution of my plans I had found but little support, the successful working of my factory, soon became known, and brought me more credit than I desired, in the shape of a number of rapidly constructed competing works. At the end of 1862, four potash works had been erected at Stassfurt, among which were those of Vorster and Grüneberg and of Leissner-Townsend. These manufacturers being possessed of larger capital and of greater experience in the manufacture of saltpetre and potash, considerably advanced the new industry. The number of new works rose to 18 in 1864, and worked up a total quantity of 139,000 tons of material. In the course of that year the neighbouring salt mine of Leopoldshall, belonging to the Duke of Anhalt, was also opened up. In 1872 a total of 500,000 tons of crude salts was worked up in 33 potash works.

The salt mining industry proper was at first a monopoly of the Governments, but after it became free by virtue of the Mines Act of 1865, private capital began to take

an interest in it, and the great financial success obtained therein at the beginning gave rise to extended experimental boring and to opening out of new deposits. It was supposed at first that the deposits of potash salts were restricted to the relatively small district of the so-called Magdeburg-Halberstadt Valley; it was then found that they extended to Hanover, Mecklenburg, and Thuringia, and when it was ascertained recently that they also stretched towards the south, Germany passed through a period of speculation and company-promotion in many respects like the gold-mining fever in other countries. Partly in consequence of this over-speculation, and partly with a view to check ruinous over-production, free mining of potash salts was again abolished in Prussia last year, and the Prussian Government has reserved to itself all salt deposits which have, so far, not passed into private hands, as also all coal fields not opened at that time. The number of private potash mines started in the years 1872 to 1907 has risen to 50, while 26 more concerns have begun to sink shafts and 500 new potash companies have carried out experimental boring with more or less success.

The production and sale of raw potash salts increased from 514,000 tons in 1872 to 5,129,000 tons in 1905, representing a value of £4,250,000. The salts raised are partly worked up into refined products, such as potassium chloride, sulphate and carbonate, magnesium salts, bromine, etc.—the work being carried out mostly in the factories belonging and adjacent to the mines—and partly sold in the crude state, as manure. Almost all potash mines have combined to form a syndicate which fixes the production, allots to each member a certain quota, determines the price of the various products, and also attends to the propaganda for introducing potash manures, and increasing their consumption by the encouragement of scientific investigations and the establishment of agencies in various countries.

Of the total potash salt production 16 per cent. are used in chemical industry and 84 per cent. in agriculture. The far larger portion of the latter quantity is, of course, consumed by German farmers. This consumption amounted to 43,000 tons in 1879, 803,000 tons in 1899, and 1,685,000 tons in 1905. As the use of potash manures began in 1862 with the cultivation of beet-root, I may mention here the respective output of the years 1862 and 1907, as a measure of the effect of rational manuring. The quantity of beet-root worked up in Germany in 1862 amounted to 1,580,000 tons, yielding 125,000 tons of sugar, so that 12½ tons of beet-root were required to produce one ton of sugar. At that time no sugar was exported; on the contrary, a small quantity, about 9000 tons, was imported. In 1907, 14,186,000 tons of beet-root were worked up, yielding 1 ton of sugar per 6.66 tons of beet-root, or a total yield of 2,242,000 tons of raw sugar, of which 1,103,000 tons were exported.

Among other countries where potash manures are employed on a large scale, the United States takes the first place. England and Scotland also use large quantities, while Ireland might largely increase her consumption, for she would derive the greatest advantage from the utilisation of potash manure for the cultivation of flax and for the reclamation of her large bogs. Potash manures have also obtained a footing on the tea and cocoa plantations of Ceylon and on the sugar cane fields of Australia.

From the figures I have given regarding the extension of the German potash deposits and the large number of potash mines already in existence, you will gather that, even if no large deposits should be found in any other part of the world, those so far discovered are sufficient to satisfy every requirement.

Less favourable are, or at least have been up to recently, the conditions for supplying nitrogenous substances, that third class of manure which the farmer quite as urgently requires as the foregoing ones. The two important sources available hitherto were ammonium sulphate, obtained as a by-product from coal on coking it, or making gas from it, and the sodium nitrate deposits occurring on the high plateau of Chili. The production of ammonium sulphate from gas liquor

was commenced in Great Britain about 1850, and amounted to 9700 tons in 1860. Later on, ammonia was also obtained as a by-product in the dry distillation of shale, the recovery of waste gases from blast furnaces, coke ovens, and gas generators, so that the British production rose to 293,000 tons in 1906. Germany takes the second place among the countries producing ammonium sulphate, its output having been 235,000 tons in 1906, mostly from coke ovens. All the other industrial countries together produced only 19,000 tons. Although the successful process of Mond, by which power gas and ammonia are obtained simultaneously, is securing a steady increase in the production of sulphate, it must not be overlooked that ammonia is in every case but a by-product of other manufactures. Hence, unfavourable business conjunctures, such as occurred last year, must bring about a decrease in the production of ammonia, so that agriculture cannot depend, with certainty, upon obtaining a sufficient supply. As the demand for nitrogenous manures increased more rapidly than the production of ammonium salts, assistance was sought in the extensive deposits of nitrate of soda. Although these had been opened up on the West Coast of South America, on the high plateau of Chili, as far back as 1830, the nitrate had, up to 1860, been used for chemical purposes only. The export of nitrate of soda from Chili was 68,000 tons in 1860; it rose to 1,023,000 tons in 1890, and to 1,600,000 tons in 1906. Of this latter quantity, about 1,200,000 tons came to Europe, 20 per cent. of it being used in industry for the production of chemical products, explosives, etc., whilst the remainder was absorbed by agriculture. Germany, on account of its climate, as well as on account of its extensive cultivation of beet-root, uses the largest quantity of Chili saltpetre. In 1906, Germany imported about 590,000 tons. Next comes France, whilst the consumption of British agriculture is but small. The demand for saltpetre in the United States is rapidly increasing, the import figure having risen from 177,000 tons in 1901 to 364,000 tons in 1906. The price of Chili saltpetre, which stood at £7 to £8 per ton in Europe at the beginning of the present century, has been raised to £10 per ton, not only on account of higher cost of production, but also in consequence of the formation of a syndicate of producers. European industry and agriculture have, therefore, to pay about £12,000,000 a year for their present import of nitrate of soda. Since the cost of Chili saltpetre serves as a standard by which the price of the other nitrogenous manures is regulated, ammonium salts have also risen in value at a corresponding rate, namely, from £10 to £12 10s. per ton. This tribute, heavy and steadily increasing with the growing requirements, and mainly borne by agriculture, was indeed felt as an oppressive burden. Yet over and above there had to be faced the danger that the Chili deposits might be advancing towards exhaustion, just as was the case with the Peruvian guano deposits. Although the opinions given by experts on the available stock of Chili saltpetre vary widely, the exhaustion of the supply of saltpetre, whether it occur in 30 or in 50 years, must be reckoned with, apart from the fact that the increase in price is already beginning to prove burdensome. The probability that other saltpetre deposits may be discovered is slight, because the special climatic and geological conditions which combined to build up the large masses of saltpetre in Chili, are hardly met with elsewhere.

In the presence of these facts it is easy to understand why one of our greatest authorities, Sir William Crookes, has sounded a warning note, just as Liebig did in his time, as to the danger threatening the whole human race through the want of nitrogenous manure, that indispensable agent in the fertilisation of the soil. As far back as 1897, Sir William Crookes showed that the food—as measured by the consumption of wheat—which will be required by mankind at the present rate of increase 30 to 40 years hence, can only be produced if the fertility of the soil is improved in a corresponding degree. For this purpose more abundant manuring with nitrogenous substances is necessary. Even before Sir William Crookes had pointed out the necessity of solving the problem, numerous

investigators had been searching for means of warding off the threatened danger.

Since Rutherford in 1772 had ascertained the fact that the largest part of our atmosphere consists of nitrogen, attempts have not been wanting to utilise this inexhaustible store which, taking the weight of the air resting on 1 hectare (2½ acres) as 100,000 tons, represents a total quantity of about 4 trillion tons of nitrogen. Priestley in 1775 discovered that the nitrogen of the atmosphere, under the action of the electric spark combined with oxygen to form nitric acid, and he also ascertained that the amount of nitric acid in the air increased through a thunder-storm. Berthelot in 1869 observed the formation of hydrocyanic acid when a mixture of acetylene and nitrogen was submitted to the action of the electric spark. Fownes and Young, as well as Bunsen and Playfair, ascertained afterwards that cyanogen and ammonia were formed on passing nitrogen over a highly heated mixture of coal and alkalis. Marguerite and Sourdeval, and later on Solvay, and especially Ludwig Mond, carried out extensive experiments on the technical utilisation of this reaction, by passing nitrogen over mixtures of caustic baryta and coal, but all these attempts were thwarted by the impossibility of constructing apparatus capable of resisting the necessary high temperature. The great improvements made in the course of the last decades in the realm of electricity have been instrumental in solving this problem. The advent of the dynamo supplied the means of generating electric currents approaching in their effect the electric discharges of the atmosphere, and the electric furnace constructed by Werner Siemens and Sir William Siemens made it possible to obtain degrees of temperature as had been unattainable before. Attempts were made at first, by means of electric discharges in various forms, to effect the direct combination of the elements of the air, oxygen and nitrogen, so as to form nitric acid. But the expectations aroused by the experiments carried out at Niagara Falls by the Atmospheric Products Company, and elsewhere, were not realised. Only the process invented about five years ago by Birkeland and Eyde, in continuance of earlier experiments made by Siemens and Halske, and since then further developed by Schönherr in conjunction with the Badische Anilin und Sodafabrik, has opened up a practicable road towards the solution of the problem. However, as happens so often in industry, an apparently longer and more tedious way ultimately proved to be a successful one.

In 1894 the technical world was astounded by the invention of Moissan and Willson which led to the manufacture of calcium carbide in the electric furnace on a large scale. The product thus obtained was first used for the manufacture of acetylene. Careful studies which I made immediately after the publication of Moissan's work with calcium carbide and barium carbide, showed that both were possessed of qualities rendering them suitable also for purposes other than illumination. Reviewing the earlier experiments of Marguerite and Sourdeval, and especially those made by Mond, I considered it likely that also in those newer experiments the combination of nitrogen and the production of cyanogen and of other nitrogen compounds might be preceded by the formation of carbides. Contrary to Moissan's views, who had not found carbides to be capable of absorbing nitrogen, I pointed out as far back as in 1895, in a paper published in the Proceedings of the Verein für Gewerbefleiss, the possibility of producing cyanides, amides, and eventually also more complicated nitrogen compounds, starting with carbides as raw material. Experiments which I carried out in conjunction with Dr. N. Caro, in the beginning of 1895, on calcium carbide and barium carbide, especially on the latter, yielded results so favourable that at the end of March, 1895, we were in a position to apply for patents claiming the combination of atmospheric nitrogen with carbides of the alkalis and alkaline earths. But rapid and satisfactory as was the first success, the further development was troublesome and wearisome. For the purpose of carrying out the work on a technical scale we combined with the well-known firm of Siemens und Halske which for some time past had directed its attention to the problem of the

fixation of nitrogen. With the assistance of third parties a company was then formed to find the by no means small capital required for our work. The new concern took the name of "Cyanidgesellschaft," and all patents obtained previously and later on were transferred to this Company.

In the middle of the "90's" the demand for, and the price of potassium cyanide had become considerably enhanced through the introduction of the MacArthur-Forest cyanide process of gold extraction. We therefore kept in view the production of cyanides and ferrocyanides, they being the most valuable compounds of nitrogen. For our purposes barium carbide appeared to be most suitable, as the fixation of nitrogen took place easily, $\text{BaC}_2 + \text{N}_2$ combining readily to yield $\text{Ba}(\text{CN})_2$. Moreover, the barium cyanide so obtained could be transformed, by simple methods, into potassium ferrocyanide and cyanide. The behaviour of calcium carbide to nitrogen at first appeared to be less favourable, for, in spite of apparently strong absorption, only very small quantities of cyanides were found. But a closer examination of the products of the reaction afterwards revealed the interesting fact, that whilst only very small quantities of calcium cyanide resulted from the absorption of nitrogen by calcium carbide, calcium cyanamide had been formed, with the separation of one atom of carbon, thus: $-\text{CaC}_2 + \text{N}_2 = \text{CaCN}_2 + \text{C}$. Now, although the conversion of calcium cyanamide into cyanide is technically quite feasible, and is indeed carried out by us on a large scale, the low atomic weight of calcium as compared with that of barium pointed to the advisability of producing directly from atmospheric nitrogen with the aid of the calcium compound cheap nitrogen products, such as ammonia, etc., which would therefore be available for manuring purposes. Our anticipations were confirmed by further experiments, when it was found that the whole amount of nitrogen contained in calcium cyanamide, as also that contained in the pure cyanamide, produced therefrom, could be easily converted into ammonia, by heating with water under high pressure; this is expressed by the following equations:—

Thus the long looked-for method for the production of ammonia and ammonium salts from atmospheric nitrogen had been found.

The consideration of this simple reaction led my son, Dr. Albert Frank, to the conclusion that, under suitable conditions, crude calcium cyanamide might in itself represent a suitable fertiliser that could be used directly for the nutrition of plants. As this supposition was only based on theoretical observations, it became necessary to prove its correctness by practical tests. These were carried out first in 1901 and 1902 by Prof. Wagner of Darmstadt and Prof. Gerlach of Posen. A great number of tests were made, under varying conditions, in pots, as well as in the open field, and the results proved that crude calcium cyanamide containing 20 per cent. of nitrogen could be considered equivalent to ammonium sulphate and therefore, if used in the right place, might serve as a suitable fertiliser for plants. These trials having been successfully repeated in the following year in numerous agricultural testing stations as also in agricultural practice, we had to develop and improve the manufacture of the product—which we termed "Kalkstickstoff," "nitrolime"—so as to enable it to enter into successful competition with ammonium sulphate and Chili saltpetre. The raw materials required, viz., lime, coal, and atmospheric nitrogen, are easily obtainable everywhere, but the production of pure nitrogen in such large quantities required further investigations. The process first used by us to separate oxygen from nitrogen by leading the air over heated copper turnings proved to have many drawbacks, because, in consequence of the necessary reduction of the oxide formed, work could only be carried on intermittently. We therefore turned our attention to the Linde method of separating the two constituents of our atmosphere by liquefaction and fractional distillation. This method also presented difficulties, for we had to devise first an expensive plant

for the supply of the large quantity of pure nitrogen (300 cub. metres per hour) which we required.

In the course of the last years we have, however, successfully developed both methods of producing nitrogen on a large scale, so that both are applicable, the choice of the method depending in each case on local circumstances.

The second raw material required for the manufacture of calcium cyanamide is calcium carbide. 100 kilos. of commercial calcium carbide—of 80 per cent. purity—can, theoretically, absorb 35 kilos. of nitrogen. In practical working, the absorption amounts to 25 kilos. only, so that the resulting product is 125 kilos. of "nitrolime" containing 20 per cent. of nitrogen. Thus, in order to fix one ton of nitrogen, four tons of calcium carbide are required. The production of this quantity of calcium carbide forms, of course, the basis of the subsequent manufacturing operations. Carbide factories now produce two tons of carbide per kilowatt-year; consequently we require 2 kilowatts-year equalling 2.66 h.p.-year for the 4 tons of carbide necessary to fix 1 ton of nitrogen. Adding to this amount 0.34 h.p.-year for other mechanical work, etc., we require a total of 3 h.p.-year. It is, therefore, evident that the cost of electric energy represents an important factor in the competitive struggle of the new product with the old nitrogenous manures, ammonia and saltpetre. In order to introduce nitrolime into agricultural practice with success, it is necessary to supply the unit of nitrogen at a price at least equal to, and if possible lower than that of the unit contained in ammonia and saltpetre.

Since water power, necessary for the production of energy at a low price, is very scarce and hence can only be obtained at a high cost in Germany, the Cyanidgesellschaft combined with the largest Italian carbide works to found the "Società Generale per la Cianamide" in Rome, to whom all patents were transferred. The first plant equipped for production on a large scale was, at the end of 1905, started at Pizzo d'Orta, utilising the large hydraulic power of the Pescara River; the production of this plant, laid out first for 4000 tons a year, has already been increased to 10,000 tons a year. Further large plants in Italy have since been erected at Terni, in connection with the carbide works which already existed there, and near San Michele in the Aosta Valley. On the other side of the Adriatic, at Sebenico in Dalmatia, at Fiume, and especially at Abissna, where water power of 50,000 h.p. is available, some factories are being constructed, whilst others are already working. Licences for France have been granted to the "Société Française des Produits Azotés," which has erected a plant for 4000 tons a year, at Notre Dame de Briançon. In Switzerland, the "Société Suisse des Produits Azotés" has begun manufacturing in works situated in the Rhone Valley. In the United States, the "American Cyanamid Company" has erected, on the Canadian side of the Niagara Falls, a factory for an output of 5000 to 6000 tons, which, when the installation is complete, will be increased to 10,000 tons a year. I may also mention that a plant is now in course of construction on the Kiusku Islands, in Japan; it is designed to produce, for the present, 4000 tons a year. In Great Britain, "The North Western Cyanamide Company, Ltd.," was founded in 1906. This Company acquired from the Birkeland-Eyde concern water power, to the extent of 50,000 h.p., near Odde on the Hardanger Fjord in Norway and established there a plant for the production of 12,500 tons of nitrolime to begin with, an extension to 50,000 tons a year being provided for. In Germany, owing to the want of cheap water power, only two small factories, for a production of 2000 tons and 6000 tons respectively, have been started; there will, however, soon be added a third plant for 15,000 tons a year, now in the course of erection in Bavaria, which will utilise the water power of the Alz. When all the above plants are at work, their total production will correspond to the nitrogen contained in 250,000 tons of Chili saltpetre.

The thought that Germany, the largest consumer of nitrogenous manure, would have to import nitrogenous manure, as she is now importing Chili saltpetre, acted as a strong stimulus to discover other hitherto unused

sources of power. The solution of this problem, so important in many respects from the economic standpoint, has now been found, by utilising the large stores of energy accumulated in the German bog areas. About the middle of the 'sixties I paid attention to the investigation of those districts, whilst endeavouring to introduce there potash manures and whilst interested in a plant for the utilisation of meadow-ore (bog-iron ore) which was being raised there. At that time I fully recognised the difficulties which had to be overcome to utilise successfully those extensive deposits of peat. When, in the 'nineties, the improvement in the construction of electric generators offered the possibility of an easy transport of the energy produced, and since, as mentioned before, large quantities of energy are required for the production of nitrogen, I resumed my former studies. As I knew from my own experience, and as I had also learned from the failure of others that the physical properties of the peat, especially its large proportion of water, made it absolutely impossible to convert the material into a fuel easy of transport and fit to compete with coal, I recommended the erection of large electric power stations in the middle of the bog district so as to utilise the heating power of the peat for the production of steam with the least possible expenditure of labour. The improvement of the gas engine and the work of Mond on the simultaneous production of power gas and ammonium salts in the gas generator helped to mature further plans. If it was possible to gasify in a generator the raw peat, first dried to a certain extent, and to obtain thereby not only power gas, but also to extract at the same time, in the shape of ammonium salts, a large portion of the frequently high percentage of nitrogen contained in the peat, then the problem of cheap production of power was solved. Experiments which my collaborator, Dr. Caro, made with the assistance of Dr. Mond, at the works of the "Power Gas Corporation" at Stockton and Winnington, and, later on, at the works of the "Deutsche Mondgas Gesellschaft" in Westphalia, furnished the very favourable result that peat containing 50 to 55 per cent. of water could be gasified without difficulty. It was found that in addition to a power gas, yielding 1400 kilo.-calories per cub. metre, a quantity of ammonium sulphate was obtained which corresponded to 75–80 per cent. of the nitrogen originally contained in the peat. At a lengthy trial carried out last May at the works of the German Mond Gas Company at Sodingen in Westphalia, when 40 tons of wet peat were worked up per day, 2 tons of peat containing 50 per cent. of water furnished 2400 cub. metres of power gas and 38 kilos. of ammonium sulphate. As the nitrogen contents of the dry peat amounted to 1.05 per cent., this yield of ammonia represents about 75 per cent. of the total nitrogen. On using the power gas in a large Deutz gas engine, the consumption per h.p.-hour was 2.4 cub. metres. Hence, not taking into account the production of steam required for working the generator, the above 2400 cub. metres of power gas are capable of supplying 1000 h.p.-hours.

Thus, a source of power has been found for the production of calcium carbide and of nitrolime, which can compete even with the cheapest water power of mountainous countries. As Germany owns an area of 22,000 square kilometres (=8500 English sq. miles) of bogs, she can not only produce the nitrogenous manure required for her agricultural requirements, but she can, in addition, supply large quantities of power for other industrial and agricultural purposes, as, for instance, for railway and canal traffic, whilst the land from which the peat has been removed, is suitable for cultivation, as long experience in Holland has demonstrated. Similar conditions obtain in Great Britain, especially in the Irish bogs. Ireland, for her area, owns more peat deposits than any other country in the world; almost one-seventh of her surface, viz., 4250 sq. miles, is covered with peat deposits of a quality rarely found elsewhere in Europe, and the percentage of nitrogen in the peat is often very considerable. The zealous endeavours made for years to improve Irish agriculture and industry, can therefore be assisted to a great extent by the rational utilisation of the bogs.

More important still than the fixation of nitrogen in the shape of calcium cyanamide, is the application of large and cheap sources of energy for the production of nitric acid and nitrates direct from the atmospheric nitrogen by means of the electric arc. This process is a thermal one, but whilst the combination of nitrogen with calcium carbide represents an exothermic process (i.e., heat is set free), the combustion of nitrogen with oxygen is an endothermic process. Consequently, the consumption of energy is considerably larger in the latter process, amounting theoretically to nearly 2.8 times the consumption of the former process per unit of nitrogen fixed. In practice, according to Eyde's own statement, the consumption is even higher. The product obtained by the Birkeland-Eyde process, namely, nitrate of lime, has proved itself to be, for the same percentage of nitrogen, a manure fully equal to nitrate of soda. The employment of neutral nitrate of lime is, however, attended with some difficulty on account of the hygroscopic property of this salt. Hence, it became necessary to manufacture the less hygroscopic basic nitrate, which in its commercial form contains only 11 to 12 per cent. of nitrogen. Other methods for the production of nitric acid, by combustion of ammonia with oxygen, wherein the necessary heat is produced by the oxidation of the hydrogen, have lately been worked out by Prof. Ostwald of Leipzig, as also by Dr. Caro and myself. Ostwald's process is based upon the catalytic action of platinum, whilst Caro and myself obtain the same effect by using a mixture of thorium and cerium oxides, the incandescent bodies of the Auer burners. The products obtained in the experiments we have carried out so far, on a small scale, have utilised as much as 85 per cent. of the nitrogen contained in the ammonia. Large plants are said to have been erected to work Ostwald's process, but reports on their practical results are, so far, wanting. Considering that, as mentioned already, by treating nitrolime with steam under high pressure, pure ammonia can be easily produced with a yield of 98 per cent., it is quite within the limits of possibility that our process may also become a useful one for the production of nitric acid. Meanwhile the production of ammonia on a large scale with the aid of nitrolime is only carried out in the Piano d'Orta works for the manufacture of ammonium sulphate. As a matter of fact, the fertilising effect is only brought about by the transformation in the soil of the amide into nitric acid, this process of nitrification being effected, as has been ascertained by Löhms and Perotti, by certain bacteria which abound in all soils that are rich in humus.

The calcium cyanamide supplied for agricultural purposes contains on an average 20–21 per cent. of nitrogen and 40–42 per cent. of calcium, corresponding to 56–59 per cent. of caustic lime, further 17–18 per cent. of carbon and some impurities consisting of mixtures of silicic acid, clay, traces of phosphoric acid, etc., originally contained in the crude carbide. When this material is mixed with the cultivated soil, the calcium cyanamide under the influence of the carbonic acid and of the moisture contained in the soil, is decomposed first into calcium carbonate and free cyanamide. The latter then, with absorption of moisture, is probably transformed into urea:

from which ammonia, and by subsequent nitrification nitric acid, is formed. The chemistry of this process of transformation has not yet been fully worked out, but the formation of nitric acid is acknowledged by all investigators to be the final product. Thus, while nitrate of soda and nitrate of lime offer the nitric acid to the plant ready for absorption, nitrolime must first be transformed into nitric acid in the soil, in the same manner as are the ammonia salts and nitrogenous manures of animal origin. This feature constitutes a guarantee that both kinds of nitrogen manures, nitrates, as well as amides, will be used in future side by side. Saltpetro will always be used, especially as top dressing, in all cases where vegetation must be rapidly assisted, i.e., especially in spring, while nitrolime must be introduced into the soil before the seed is sown in order to enable it to show an effect equal to that produced by ammonium

sulphate. Moreover, it offers the advantage that its decomposition products are absorbed and retained by the soil, whereas in moist years the nitrates are washed out and carried away. Only prolonged practical experience can supply a knowledge of the most favourable conditions for the use of this new manure in different soils and for the different plants cultivated. The same thing occurred in connection with the introduction of potash manures, when their high chlorine content at first gave rise to apprehensions.

I will now mention a few other developments which have arisen from the fixation of atmospheric nitrogen.

There is the production of potassium and sodium cyanides, for the manufacture of which a large plant has now been erected near Charlottenburg. The use of the cyanide process has now greatly extended, for it can be employed in the extraction of silver from refractory ores, thus replacing the old Mexican Patio process. It was this fact which induced our chemists to produce crude cyanide of soda by simply melting nitrolime with common salt, as in this process cyanamide is transformed into cyanide together with absorption of carbon. The mass so produced, which we term "surrogate," contains about 25 per cent. of sodium cyanide, and, according to experiments made in England, has proved useful in the extraction of gold and silver. The production of this "surrogate" can be effected without difficulty in an installation near the mines. Similarly, by smelting nitrolime with fluxes, a material may be prepared which serves as a substitute for ferrocyanide of potassium and other hardening substances for tempering iron and steel. This material, sold under the name of "ferrodur," has already found extensive application in the tool industry. Crude calcium cyanamide further serves for the technical production of a large number of organic compounds. The transformation of cyanamide into urea, which I have mentioned already, forms the basis for the technical production of this substance as also of thiourea on a large scale.

Further products are diacyandiamide, resulting through the polymerisation of cyanamide, and diacyandiamidine and its salts. The salts and nitroderivatives of guanidine can also be obtained from nitrolime. In addition to the use of these substances in the colour industry, I may mention, as of special interest, that they are used as "cooling material," i.e., to reduce the temperature of combustion, in the case of explosives and of gunpowder. Owing to its high contents of inert nitrogen, gunpowders manufactured with the additions of this "cooling material" produce a high pressure in ordnance, whereas in contradistinction to the other components of the explosive, which mostly consist of carbon and hydrogen, they only develop a low degree of heat. This is of special importance for ordnance powder which contains large quantities of nitrocellulose and which rapidly destroys the rifling of the pieces.

Among other organic preparations obtainable from calcium cyanamide, which is produced by the heat of the electric furnace, I will, in conclusion, only mention the efficient component of Liebig's extract of meat, namely Creatine, which can be artificially produced by the combination of sarcosine with cyanamide.

Chemical science having succeeded in producing artificially such compounds as alizarin, indigo, and similar complex substances, which not only replace, but even supplant the natural products, the opinion has often been expressed, that we shall be able to build up, artificially, from their elements the substances necessary for the nourishment of man, namely, carbohydrates, and even proteins, and thus render ourselves independent of the fluctuating production of the soil. Although I, as a chemist, believe in the possibility of such syntheses in the chemical laboratory—proved, already, in the case of sugar—I greatly doubt whether we shall ever compete successfully with the natural production of the soil. True, agricultural production ultimately rests upon the same chemical laws and processes which we employ in laboratories and works, but the energy which is required to bring about these processes and which sun, atmosphere, and soil furnish directly to the farmer, can only be supplied to industry indirectly and hence at far greater cost,

quite apart from the fact that the utilisation of energy is far more perfect in the organism of plants and animals than in the apparatus of the chemist.

From the economical point of view we shall, consequently, fare best, if we are careful to further and increase the growth of our food plants, by supplying them with the substances which the soil cannot offer to them in sufficient quantity.

The old utterance of Dean Swift: "The man who makes two ears of corn or two blades of grass to grow, where only one grew before, is a great benefactor to his country," supplemented by that of the late Marquis of Salisbury: "If farmers would only manure their land with brains, as the painter mixes his paints, there would be much less heard about agricultural depression," are and will remain the practical principles guiding the relation of chemical industry to agriculture.

DISCUSSION.

Professor MELDOLA said one could not help feeling struck at the extremely harsh way in which this country had been dealt with by nature in the way of necessary materials for agricultural purposes. John Bull was always represented as a typical farmer; but it appeared that he had to rely either on natural or manufactured products from other parts of the world. Not the least interesting part of this paper was the historical introduction to the various sections. Dr. Frank, of course, had touched lightly on the early steps in the utilisation of those different materials. As to the influence exercised by Liebig on agricultural procedure, it should not be forgotten that the late Lord Playfair was really the intermediary between this great chemist and English agriculturists. It was he who first realised the importance of Liebig's work, translated his books, invited him over to England, and himself went about the country lecturing to farmers and making them see the importance of those discoveries. In writing the history of this chapter, therefore, English chemists and agriculturists should never forget to associate with it the name of Lord Playfair.

Another point which he wished to bring forward had reference to the utilisation of the potash from beet-sugar waste. Everyone now recognised the importance, and in fact the necessity for potash for certain crops; and the question of beet-sugar cultivation had been raised over and over again in England. In his younger days, about 1869 or 1870, the late James Duncan endeavoured to introduce beet cultivation into Suffolk; but, apparently it did not succeed, nor, he understood, had later efforts in that direction. A point which might profitably be considered in connection with this paper, was the question whether beet could be grown in this country, and if so, why was it not undertaken?

With respect to the nitrogen question, one could not help feeling from the purely chemical point of view that, although the author had proved, theoretically and practically, that atmospheric nitrogen was fixable in the form of cyanamide, still it was a long cry from cyanamide to nitrate, which was the only form in which the plant could use it. The question, therefore, still remained: What was the fertilising value of cyanamide as compared with Chili saltpetre? On that point he believed experiments had been made at various stations; and it would be well to have some definite statement of results.

Lastly, he would cordially endorse the opinion expressed in the paper, that it would be a very long time, if ever, before a chemical process could compete with living organisms in the synthesis of protoids.

But even from the biological point of view, the living organism had already solved the question of the fixation of nitrogen. As they were all now aware, leguminous crops got their nitrogen through the intervention of an organism, by a sort of symbiotic arrangement. The so-called nodules of leguminous plants were composed of organisms which were in some way able to fix the atmospheric nitrogen directly and pass it on to the leguminous crops. So that that problem had been solved by some of the very lowest organisms in Nature.

Sir WILLIAM RAMSAY said there was one point which had already been brought before the Society by Professor Guye some years ago, which ought to be

mentioned. Obviously, the manufacture of calcium cyanamide should be undertaken concurrently with the combination of nitrogen and oxygen. As they had heard from Dr. Frank, in his process a great quantity of pure nitrogen was required; and he understood that the oxygen was thrown away—which was a very uneconomical process. On the other hand, for the combination of nitrogen with oxygen, as carried on in the Birkeland-Eyde process, it was greatly to the advantage of the latter that the gases which entered the arc should be richer in oxygen than air; so that if those two processes were worked together, each would utilise the by-products of the other.

The only other remark which struck him was one in which he should have to refer to the results of an investigation which was still in progress, and which had not gone far enough to allow him to say much. They had heard from the Chairman that this process of Dr. Frank's was one in which energy was evolved; and that the Birkeland-Eyde process was one which absorbed energy from end to end. It looked absurd to speak of experiments made with quantities consisting of only milligrams; but he had made some experiments recently, with a very curious result. It was known that nitrogen and hydrogen would combine above a certain temperature; and every young chemist knew that if a spark were passed through a mixture of nitrogen and hydrogen, a little ammonia was formed, and that if water of sulphuric acid was present to absorb it, the combination went on until the whole of the mixture was converted into ammonia; but at any given moment the amount of ammonia present was excessively small compared with the amount of nitrogen and hydrogen which remained uncombined. Experiments had been lately made at Karlsruhe, at various temperatures, and it turned out that at a high temperature the decomposition was at its greatest; and that as the temperature was lowered, a greater and greater amount of ammonia formed in proportion to the constituent gases; but that below a certain temperature, about 500°, the nitrogen and hydrogen ceased to act on each other, or acted so slowly that practically it was not worth considering. In the presence of radium emanation, which was a source of energy, not merely ammonia rapidly decomposed, but hydrogen and nitrogen rapidly combined. Whether the radium emanation really acted as a catalyser and greased the wheels, or whether the energy it evolved contributed to the operation, he did not know; but the combination of nitrogen and hydrogen was an exothermic operation. One did not want to put extra energy in. As far as they had yet gone, the combination of nitrogen and hydrogen took place just as rapidly as the decomposition of ammonia. Now if that occurred with such a substance as radium emanation, it suggested the question whether there were no other substances which could do it; and if there were the problem would be solved. There was no trouble in producing hydrogen in any quantity; and the combination should be merely a question of applying the right means.

After some remarks by Mr. F. J. LLOYD,

Mr. A. H. LYNN said there was one process which had been touched upon in which England was undoubtedly pre-eminent, namely, the recovery of nitrogen in the shape of sulphate of ammonia from coal and combustible matters generally. It was well known that Dr. Mond,

15 years ago, was recovering sulphate of ammonia from coal at the rate of 80 lb. of sulphate per ton. That had gradually developed, and the latest phase in the utilisation of the Mond process was that of recovering ammonia from peat. And in this connection he should like to correct an evident misapprehension in this paper, viz., that it was Dr. Caro who, with Dr. Mond, worked out the Mond process in its application to peat. It was true that Dr. Caro gave assistance in the working out of that process as applied to the utilisation of waste colliery products, and also of a certain material from Germany called "Seeschlick" (Lake slime), which contained a large amount of nitrogen and which was very successfully treated. But as regards peat, he wished to make it clear that a year or two before either Dr. Mond or himself met Dr. Caro, peat was already being gasified by the Power-Gas Corporation of London, and as a fact by himself, under ammonia-recovery conditions, at Stockton-on-Tees in 1903; and it was this Company who had built and supervised the operation of the plant in Germany, whereof the results had been stated by Professor Frank, indeed two further plants to gasify peat were now being built by this Company, one of them for a new Electricity Supply Station in Italy. At the same time he must draw attention to the eminently valuable work of Prof. Frank and Dr. Caro in Germany, in recognising the "Mond" process as the best adapted for making use of the peat bogs which cover so large an area there. It was probably not generally known that in many places there were peat bogs, at all events in this country and in Ireland, so rich in nitrogen that they could be profitably gasified, for ammonia only, the gas being looked upon as a by-product which for lack of power users might in some cases have to be treated as a waste product. The sulphate of ammonia obtainable from a ton of theoretically-dry peat varied naturally according to the nitrogen; but in his experience it ranged from 80 to 160 lb. per ton. That showed the enormous total value of the peat in the United Kingdom as a source of nitrogenous fertilisers. Peat could be produced in a suitable condition for gas-producers at a cost of from 2s. 6d. to 3s. 6d. per theoretically-dry ton. Of course, the theoretically-dry ton was simply mentioned as a standard; it naturally contained in its air-dried condition from 25 to 30 per cent. of moisture.

The conditions he had just mentioned might also apply to waste small coal, a very large plant being now under construction in the Midlands to gasify this fuel for ammonia only, the gas being temporarily a by-product.

Mr. C. REVIS said since the discovery of the nodule bacteria, a company had been started for the purpose of producing cultures of these bacteria; but it had not been very successful, as no good effects resulted from the use of such cultures; further work had, however, elucidated the difficulties, and enabled the cultures to be used quite successfully in parts of Canada and America. They could now be supplied to the farmer in such a condition that he could use them, and remarkable results in the increase of crops had followed. He did not think the cultures had been tried on any commercial scale in England. But they must not forget the work of Professor Bottomley; it was thought for a long time that the use of these nodule bacteria was limited to the leguminous plants; but he had now shown that they were not specific in their character and could be trained for use with other species.