the proton and electron is about one million volts. The combination of all this evidence can leave little doubt that the neutron really does exist and has been detected.

This discovery of a new kind of matter, a new element, is an outstanding event in the history of physics, and it is to be anticipated that important advances in our knowledge of the laws governing protons and electrons will be reached from investigation of its properties. Entirely new fields of speculation about the structure of atomic nuclei are opened up by the discovery that in at least two cases neutrons form part of the structure, but it is far too early to discuss matters of this kind.

Quite apart from the interest attached to the discovery of the neutron itself, it appears that it offers new possibilities of investigation in the field of artificial disintegration. Chadwick, in collaboration with Feather and Dee, has found that neutrons can also effect the disintegration of the nuclei with which they collide. This will constitute again another type of nuclear reaction, different from that produced either by α -particles or protons. For example, if it involved capture of the neutron and ejection of the proton, the resulting nucleus would have the same mass as before, but the atomic number would be lower by one.

There are important experimental advantages connected with the use of neutrons. The neutron is almost selective; it produces no effect unless it makes an almost direct collision, and when this happens the probability is quite considerable that a disintegration will occur. For example, Feather has obtained 180 tracks in nitrogen, of which 30 were due to disintegration. Observation in the expansion chamber of disintegration by neutrons is much easier than the corresponding effect with α -particles, for since the neutron produces very little ionisation, a very large number of neutrons may be passed into the chamber per expansion without confusing the photographs. On the other hand, the interpretation of the disintegrations is more difficult, for neither the direction of the neutron nor its velocity at the moment of collision can be deduced from the photographs.

Important contributions to the discussion were made by many others, but they will not be referred to now. It is excusable on this occasion if the well-established branches of the subject are asked to give way to two such promising newcomers. It is not intended to prejudge their ultimate importance, but only to conform to the interest which everyone will feel in these new discoveries.

C. D. ELLIS.

Oil and Petrol from Coal*

By Prof. C. H. LANDER, C.B.E.

BY 1927 the technical aspect of the hydrogenation of coal had reached so promising a stage that Imperial Chemical Industries, Ltd., thought it

Billingham factory, where a full-scale plant capable of dealing with ten or fifteen tons of coal per day has since been developed. Fig. 2 shows the modified process as it is carried out at

FIG. 2.—Flow diagram of hydrogenation plant and refinery.

worth while to explore independently the possibility of its commercial exploitation, and for this purpose a large research section was set up at its

* Continued from p. 641.

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Billingham. The converters are now vertical, and are heated internally; thus the serious difficulties caused in the earlier plant, by the action of hydrogen upon metals at high temperatures, have been obviated. The material passes into the converters at a fairly high temperature, and the heat of the reaction, which is exothermic, is more than sufficient to maintain the process. A relatively thin paste is used, which can be injected into the converter at a pressure of 200-250 atmospheres, where it is treated with hydrogen at a temperature of 450° C.

The hydrocarbon vapours, the volatile fractions of oil, the water, ammonia, etc., are carried away at the top of the converter in the stream of excess hydrogen. The liquid products are condensed under pressure, and the permanent gases are passed on for oil scrubbing, after which they are recirculated through the plant. The hydrocarbons scrubbed out of the gas are passed to a 'methane-steam' plant for the production of

hydrogen. The oils are distilled, and the heavier fractions used for pasting the coal. The petrol obtained requires only a slight purification treatment prior to use.

The intermediate oils are passed to a vapour-phase converter, where further hydrogen is added, and the mixture of hydrogen and oil vapours is passed over a catalyst; a petrol is obtained from this vapour-phase hydrogenation product by distillation after reduction of pressure. The residual oil obtained in this phase may be re-cycled, or may be sold as diesel oil. The heavy oil residue from the first converter can be blown out, and the liquid product recovered, the residue from which is a solid

coal consumption is therefore 3.15 tons (reckoned dry and ash-free), or 3.65 tons of actual coal, per ton of petrol produced. The overall thermal efficiency is 43 per cent, as will be seen in Fig. 4.

The figures for cost given by Imperial Chemical Industries, Ltd., now work out at about 7*d.* a gal., of which 2*d.* is the cost of the coal. It will be seen that this petrol cost is actually less than the present duty, so that at the moment, in a plant of sufficient size, petrol from coal could compete very easily with petrol from foreign sources. Some time ago I was given an opportunity of examining both the technical and financial sides of the Billingham plant, and although at that time so low a figure as 7*d.* a gal. had not been reached, it was already evident that 8*d.* or 9*d.* a gal. would not be exceeded.

HYDROGENATION OF TAR

The treatment of high and low temperature tar by hydrogenation is another method of producing from home sources a supply of motor spirit. Work on this subject has been carried out by Ormandy and Varga, and at the Fuel Research Station. The Gas Light and Coke Co. is also investigating the method in order to find a more favourable market for certain of its tar fractions which are at present almost a drug on the market. A small continuous plant for the hydrogenation of tar has been erected at the Fuel Research Station. The low temperature tar obtained by carbonising coal at 700° C. with 10 per cent steam has been treated in this plant; 150 gal. of motor spirit and 65 gal. of diesel oil were obtained per ton of low temperature tar treated, whereas by straight distillation the corresponding figures would be 15 gal. of motor spirit, 117 gal. of heavier oils, and 884 lb. of pitch.

MECHANISM OF THE HYDROGENATION REACTION

Much further experimental work will be needed to explain the precise effect of hydrogenation on the various constituents of coal, crude oil, or tar, which are all very complex substances, but we already know that the hydrogenation action is a progressive one. When coal is subjected to hydrogenation, the first action is that it becomes plastic, and if hydrogenation is stopped at this stage a pitch-like material is obtained. If a non-coking coal is mildly hydrogenated, it is converted into a material possessing marked coking properties, and so we have for the first time the possibility of converting non-coking coal into coking coal, which, it must be admitted, is not at present an attractive commercial proposition.

An interesting paper describing investigations into the "Thermal Decomposition of Hydrocarbons", namely, methane, ethane, ethylene, and acetylene, was given by Bone and Coward to the Chemical Society in 1908. The character of the products formed when these gases were heated, either alone or in the presence of hydrogen, was examined, and it was concluded that "in the cases of ethane and ethylene, it may be supposed that the *primary* effect of high temperature is to cause an elimination of hydrogen with a simultaneous loosen-

FIG. 3.—Diagram showing ingoing and outgoing products in a hydrogenation plant of 1000 tons a day.

material containing ash, together with some 5 per cent of the original coal; it could be used only under the boilers. A diagram showing the ingoing and outgoing products in a plant designed for the hydrogenation of 1000 tons of coal a day is shown in Fig. 3.

By re-cycling, etc., in the plant at the Fuel Research Station, some 140 gal. of motor spirit per ton of coal as charged could be obtained, but this has been appreciably exceeded in the large-scale Billingham plant. In this, 100 tons of coal (reckoned on the dry, ash-free basis) is capable of yielding 62 tons of petrol and 28 tons of gas, leaving a residue of about 6 tons of partially converted material. The gas can be used for hydrogen manufacture, and the residue for firing boilers.

For each ton of coal hydrogenated, a further ton is required for raising steam for hydrogen manufacture and power generation, and for making the producer gas required for the process. The overall

ing or dissolution of the bond between the carbon atoms, giving rise (in the event of dissolution) to residues such as $\cdot\text{CH}_2$ and $\cdot\text{CH}$. These residues, which can only have a very fugitive separate existence, may subsequently either (a) form $\text{H}_2\text{C}:\text{CH}_2$ and $\text{HC}:\text{CH}$, as the result of encounters with other similar residues; or (b) break down directly into carbon and hydrogen; or (c) be directly 'hydrogenised' to methane in an atmosphere already rich in hydrogen. These three possibilities may all be realised simultaneously in the same decomposing gas in proportions dependent

in a hot tube and maintained them at 800°C . for one hour, with the following result:

Original mixture.	Percentage methane obtained.				Mean.
$\text{C}_2\text{H}_6 + 3\text{N}_2$	18.5	17.15	18.3	18.7	18.15
$\text{C}_2\text{H}_6 + 3\text{H}_2$	42.9	38.0	43.9	40.15	41.25
Ratio $\frac{41.25}{18.15} = 2.27$					

From this it appears that with an inert gas the result corresponded very nearly with the equation

whereas with active hydrogen the change appears to be principally

In the latter equation the theoretical yield of methane is 50 per cent, whereas the actual amount obtained was 41.25 per cent, or 82.5 per cent of the theoretical yield.

These and other experiments give a clue to the effect on a hydrocarbon molecule of a plain cracking treatment or a hydrogenation treatment. In the former treatment, using ethane, it will be seen that the methane produced is about 18 per cent, while hydrogenation gives about 41 per cent of methane. Little work has been done on the cracking and hydrogenation of the more complex hydrocarbons in their pure state, but, in 1896, Haber, using hexane, proved conclusively that between 600°C . and 800°C . the primary cracking took place by the elimination of methane and the formation of the lower olefine C_5H_{10} thus:

Haber regarded this action as typical of the behaviour of other bodies when subjected to cracking.

So far as I am aware, no experimental work has been done on the hydrogenation of hexane, but by analogy from the work of Bone it appears probable that, if excess hydrogen had been present in Haber's experiments, some of the olefines would have been hydrogenated to pentane. This assumption is confirmed to some extent by the fact that in hydrogenating low temperature tar and other heavy oils the separation of carbon can be practically eliminated and the production of permanent gases lessened.

The above considerations, while admittedly incomplete, provide a useful picture of the reactions taking place during the hydrogenation of such substances as coal, oil, or tar.

SYNTHETIC ALCOHOLS AND HYDROCARBONS

It would be undesirable to conclude without touching shortly on the third possible method of producing motor spirit from coal, namely, the synthetic production of alcohols and hydrocarbons. Only in exceptional circumstances could this process compete with carbonisation or hydrogenation for the production of liquid fuels, but for the production of alcohol for solvents it has already become the basis of a large industry. The raw coal is first carbonised to produce coke, the liquid and

FIG. 4.—Diagram showing heat value of materials used in producing 1 ton of petrol. Areas are proportional to heat values.

on the temperature, pressure, and amount of hydrogen present. The whole process may be represented by the following scheme, the dotted line indicating the tendency to dissolve the bond between the carbon atoms:

In one of his experiments Bone heated mixtures of ethane and nitrogen and ethane and hydrogen

gaseous products finding their normal markets ; the coke is then subjected to the water-gas process so as to produce a mixture of carbon monoxide and hydrogen. By the use of various catalysts, together with, if necessary, additional hydrogen, liquids of various types are obtainable. Such catalytic conversion has been investigated in Germany by Fischer and the Badische Anilin und Soda Fabrik, in France by Patart and his co-workers, and in England by Prof. G. T. Morgan at the Chemical Research Laboratory, by Prof. W. A. Bone at the Imperial College of Science and Technology, and by Imperial Chemical Industries, Ltd. Dr. Franz Fischer, of Mulheim, working at atmospheric pressures, has produced liquid and solid hydrocarbons of the petroleum series. Oxygen-containing products are absent, and a yield of 100 gm. of solid, liquid, and liquefiable hydrocarbons is claimed from each cubic metre of water-gas.

CONCLUSION

On the technical side much has been achieved. By the carbonisation of coal, liquid products suitable for use in internal combustion engines or in furnaces can be obtained directly, but not in large quantities compared with the amount of coal used ;

in such processes the greatest stress must be laid upon the markets for the solid and gaseous products, oil and petrol being merely by-products. By the hydrogenation of petroleum, or of low temperature tar and certain fractions of high temperature tar, large percentage yields of motor spirits can be obtained.

By the direct hydrogenation of a suitable coal some 160 gal. of motor spirit per ton of coal treated can be made, and even when the additional coal for the process is taken into account the yield is 80 gal. and the thermal efficiency is 43 per cent. Alternatively, motor spirit can be obtained synthetically either in the form of alcohols or of hydrocarbons, by first converting the coal into carbon monoxide and hydrogen, but not, under present conditions, so cheaply as by hydrogenation.

In view of the mechanical difficulties of working, on a large scale, a process involving simultaneously high pressures and high temperatures, the technical progress of coal hydrogenation has been surprisingly rapid. It is now undoubtedly possible to manufacture petrol from coal. The commercial prospects of the process are, nevertheless, uncertain, for it is always difficult to forecast the future of a synthetic, in competition with a natural, product.

The Royal Academy

ENTERING the galleries of Burlington House with a mandate to seek for "points of particular scientific interest", I went first to the Sculpture Rooms, where my attention was arrested by the bust of Sir Patrick Geddes (1427), whose recent death has left a gap in the ranks of science which will not easily be filled. The character which emerges in Mr. Pibworth's rendering is that of the acute analytical mind ; the contemplative philosopher does not appear. It is interesting to consider in this connexion the appreciations which have appeared in the Press from a number of Geddes's friends, each reflecting a different facet of his many-sided mind. His influence in the world was undoubtedly due in large measure to the great variety of persons with whom he was able to make sympathetic contact.

The full-size model of the Native War Memorial, Lagos (1382), by Mr. James A. Stevenson, admirably illustrates the statuesque character which is so marked in many of the African peoples. I suggest that such successful generalisation of the attributes of existing races is of "more particular scientific interest" than the emphasis of simian characters, now so popular, which inevitably suggests the 'missing link' as the true ideal of the human form.

Among the oil paintings, well placed at the end of Gallery II., "Spoleto, Italy" (103), by Mr. Osmund Pittman, is a fine composition, showing the hill town above a river spanned by an arched bridge (the water reflecting the colour of the sky), the architectural forms pleasing in the simplicity common to Mediterranean building, with plain plastered wall, small windows, low roofs, and ab-

sence of chimneys. In "Old Mill House, Avila, Spain" (150), by Mr. Oliver Hall, R.A., severity of architecture and a stern landscape are in fine accord, and the scheme of tone and colour is skilfully continued in the design of frame which this painter habitually employs.

"Last Rays : Northern Ireland" (194), by Mr. Julius Olsson, R.A., is one of those studies of sunset colour upon the sea which cannot be too often repeated, for the effect is as fleeting as it is beautiful. Mr. S. J. Lamorna Birch has a study of the columnar granite cliffs of the Land's End (225) rising from smooth, flat sands, across which the long, low waves come gliding in. "Harbour" (262), by Mr. George Graham, recalls for our pleasure the perfection with which the forms of hull and sail, of spars and rigging, are outlined by the plain background of water and sky in the estuaries of a low-lying shore.

Mr. Joseph Farquharson, R.A., has a most poetic study of the stately columns of a fir forest among the mountains (339), with solemnity of deep, rich colour.

Mr. Guy Kortright's "Springtime in Dalmatia" (557) and "August Heat : Corsica" (623) are remarkable studies in the essential forms of the land, although not, I think, equally successful in conveying the transitory qualities of the seasons. "Twilight in the Downs" (604), by Mr. William Clarkson, renders in a harmony of tones the mystery of the dying day.

Among the water-colours, Mr. Frank Baker's "Widcombe-in-the-Moor" (781) gives us the ever-welcome scene of church and hamlet backed by swelling hills, seen in the soft sunshine of the