fore conclude that this useful work is little known. Phipson cites the experience of Audouin in 1814. In August that year some persons came to him at Choissy-le-Roi, near Paris, where he was on holiday, and told him they had seen an immense number of luminous earthworms in a chicory field not far away. These earthworms turned out to be centipedes. In another chapter Phipson tells us that in 1840 Forester wrote to the Academy of Sciences recording luminous earthworms. When this letter was communicated to the Academy, M. Audouin rose and said that he knew of no authentic case of luminous earthworms, but that he could cite numerous cases where luminous centipedes and worms had been confused. Whereupon Duméril, to prove that earthworms sometimes are phosphorescent, quoted the experience of Flaugergues and that of the naturalist Bruguière. It seems that M. Audouin was afterwards convinced of the fact that earthworms were sometimes luminous by the experience of Saigey and Moquin-Tandon, who found them so at Toulouse in 1837. Phipson quotes other evidence, and closes an interesting chapter with words which may confirm Prof. Newbery's suggestion about the relation between the quantity and quality of phosphorescence and the food supply:—

"I may add here," says Phipson, "that I distinctly remember witnessing, when quite a child, the phosphorescence of the earthworm; the light appeared connected with the slimy matter that covers the animal's body. It was whilst digging at night, in a large dunghill, for worms to supply baits for a fishing excursion that my schoolfellows and myself turned up many hundred Lumbrics in a highly luminous condition; but I cannot recollect in what month this happened."

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16 Bank Street, Darwen, Lancashire,
September 13.

CATALYSIS IN CHEMICAL INDUSTRY.

THE catalytic agent is penetrating peacefully, yet effectively, into modern chemical industry. In explanation, to the lay mind, of the *rôle* of a catalyst in chemical reaction, comparison was recently cleverly drawn between the catalyst and the matrimonial agency. Both serve to bring together and to facilitate the union of others. Both are free after the consummation of the one process to renew their activities in like manner. The catalytic substance has played an important part in the many industries which have been necessary to the maintenance and equipment of the fighting Services with munitions of war. Not less distinctive a part has it played on the home front in the work of victory. The catalyst has been largely employed in the supply of margarine, to which we have grown accustomed. The soap with which we have been cleansed calls, in the process of its manufacture, for the assistance of the catalyst. The glucose which has helped to sweeten our lives, in time of a sugar shortage, is the resultant of yet another catalytic process.

Let us survey a few of the more striking applications of catalysis in industry. Glycerine for dynamite and nitroglycerine is obtained from fats by catalytic hydrolysis, using alkalis or acids as splitting agents. In the modern developments of fat-splitting the discovery of the Twitchell catalyst facilitated, owing to its combined acidic and fatty nature, the rapid working-up of low-grade fats and greases for glycerine and soaps. Sulphuric acid is made by one or other of two catalytic processes. The old or "lead chamber" process uses oxides of nitrogen to assist the process of oxidation of sulphur dioxide. For the stronger acid, the "oleum" or fuming sulphuric acid required in the nitration of toluene and phenol for high explosive, the modern "contact" process is more suitable. The sulphur dioxide and oxygen are caused to combine in the presence of solid contact agents such as platinum or oxide of iron. Chlorine, as well for poison-gas as for the more peaceful requirements of bleaching-powder of sanitation and water purification, is generated from hydrochloric acid by oxidation in the presence of copper chloride as catalyst. That very inert but plentiful constituent of the atmosphere, nitrogen, may now, with the assistance of a suitable catalyst, be caused to combine with hydrogen directly to form ammonia. This may be used for the production of ammonium sulphate for fertiliser, or oxidised in contact with a hot platinum gauze to form oxides of nitrogen, and thus lead to the manufacture of nitric acid or ammonium nitrate. The hydrogen which is necessary for ammonia synthesis is obtained most cheaply and effectively by another catalytic reaction, using water-gas and steam as the raw materials. Town gas and fuel gases generally are freed from obnoxious sulphur compounds present as impurities by catalytic processes of sulphur removal.

It is a matter of difficulty fully to characterise the developments which have attended in several instances the discovery of successful catalytic processes. Perhaps, however, an illustration involving the application of the researches of the brilliant French chemist, M. Paul Sabatier, will serve to demonstrate potentialities and possibilities inherent in academic research. M. Sabatier is the discoverer of the principle of catalytic hydrogenation, and has conducted an exhaustive series of researches into the phenomenon. The application of his results to industry has solved the century-old problem of the economic utilisation of liquid fats. During the last ten years, in ever-increasing measure, liquid fats and oils have been catalytically hydrogenated in presence of reduced nickel as catalyst to yield the more valuable hardened fats which are used in the soap and candle industry, as well as for purposes of food. The economic results of such application are tremendous. Whole tracts of tropical country are being opened up for the production of palm nut and other nut oils. Fish oils are being hardened and deodorised for use in the industry. New uses are being found for hardened cotton-seed, linseed, and similar largely available oils.

Catalytic hydrogenation has also been applied to the enrichment of gaseous fuels. The carbon monoxide of water-gas may be hydrogenated in presence of reduced nickel to give methane with consequent production of a gas of high calorific value and illuminating power. The production of hexahydro-benzol in bulk, by hydrogenation of benzene, is as yet in its infancy, but has a certain future owing to the utility of the product as a volatile fuel for internal-combustion engines. The fact that it is a single compound gives it marked advantages over petrol as a fuel for air transit, since the variability of petrol is a distinct drawback in the case of a fuel upon which such rigorous demands are necessary.

The development of the fine chemical industry in this country involves also an extended use of catalytic reactions. The successful production of synthetic indigo was facilitated by the discovery of the catalytic acceleration of the oxidation of naphthalene by mercuric sulphate, discovered owing to the breakage of a thermometer bulb in the reaction mixture. The production of dye intermediates involves, more and more, the aid of catalysis. Especially, however, in the large-scale preparation of solvents will catalysis contribute convincingly to success. Industrial alcohol may be cited in illustration. Every method by which this important solvent is produced is catalytic. The ordinary process of fermentation and distillation involves the participation of the living catalysts, the enzymes and ferments. The production of alcohol from potato and rice starch is a combined process of hydrolysis and fermentation with the catalytic action of acids followed by enzymes. Similarly, alcohol of the future will be obtained by catalytic degradation of the cellulose content of wood waste, or, synthetically, from acetylene and ethylene, by processes of catalytic hydration and hydrogenation. The potentialities of alcohol as a fuel in the future must not be forgotten, in view of the increasing consumption and prospective exhaustion of oil-fuel reserves. In the meantime these latter, as a result of more rigid scientific control, are being more economically utilised. The "cracking" of oils to yield the more volatile fractions usable in motor-engines is a modern development, the catalytic features of which have not, as yet, been completely realised.

From alcohol as starting-point, catalysis is involved in the production of acetic acid and acetone, the solvents largely required in the preparation of aeroplane dopes and varnishes. From methyl alcohol, a distillation product of wood, catalytic oxidation or dehydrogenation in presence of metallic copper yields formaldehyde, a powerful germicide and disinfectant, and itself the starting-point in the manufacture of bakelite, the artificial vulcanite or amber, a polymerised product formed under the influence of catalytic agents, and increasingly produced for use in electrical insulators and for fancy articles. The demand for formaldehyde is already so great that investigations are in progress with the object of production from sources other than methyl alcohol. The hydrocarbon methane has been suggested in this connection. A process of fractional oxidation of methane should yield formaldehyde. Alcohols and organic acids of varied complexity may be largely utilised in the production of synthetic essential oils and perfumes by processes of catalytic condensation.

The catalogue is not exhaustive, but sufficient has been said to show the paramount importance of catalysis in modern chemical industry. It is evident, therefore, that the modern curriculum of theoretical chemistry should concern itself largely with the scientific principles involved in catalytic reactions. An extended experience with catalysis, both pure and applied, has demonstrated that, from a complete realisation of the theoretical aspects of the problem, progress in the application follows the more rapidly and the more certainly. It is astonishing to note the facility with which new progress is attained by the employment of the scientific principles which have been acquired in a totally different application of catalysis to industrial progress. The records of certain of the Government Departments of investigative work, during the last few years, would be instructive in this regard. The need, therefore, is urgent for a well-trained force of young students, versed in the fundamentals of this modern branch of chemistry, and equipped to take their place in the further developments which lie so close at hand. There are manifold possibilities ahead—numerous processes and agencies catalytic awaiting the facile brain and hand of the investigator.

HUGH S. TAYLOR.

FROSTS AND AGRICULTURE IN THE UNITED STATES.

THE United States Department of Agriculture has recently issued a publication on "Frost and the Growing Season." This consists of a series of maps in colours and some diagrams from which the probable date of the last frost in spring and the earliest in autumn may be seen at a glance. An article on a paper by Mr. W. G. Reed on this subject appeared in the issue of NATURE for May 23, 1918, and the present publication is also by the same author.

Frosts are divided into three classes: "light," "heavy," and "killing." The first two terms apply to the amount of the deposit in the form of hoar-frost; the last only is dealt with in the paper, and is defined on an occasion on which the screen temperature fell below 32° F. In a country like the United States there is naturally great variation in the length of the period that is free from frost; not only is there variation in latitude from Florida to the Canadian border, but there is also much difference in the height above mean sea-level. The local topography is also important, for while, in general, frost is more prevalent at the greater altitudes, yet locally a small elevation will prevent a frost, and in enclosed valleys the hill-sides and the hill-tops may be less subject to frosts than the valley bottoms.

Frost records are available from about four thousand regular stations of the Weather Bureau, and of these about six hundred have a twenty years' record. The most noteworthy feature of the