of constancy in the speed of the kymograph. Decrease in amplitude shows muscular fatigue.

le-nerve preparation had been made twenty-five hours before using.

Hydrogen, Its Technical Production and Uses*
By A. F. Seeker

IN recent years the cheap production of hydrogen on a large scale for technical purposes has become a problem of some importance. Formerly it was used occasionally for filling balloons and in the oxy-hydrogen flames of the so-called "calcium light." Being the lightest of the common gases and of a correspondingly high sustaining power, it has become essential for the filling of dirigible balloons with their heavy burden of propelling machinery. Such uses, however, have become of rather secondary importance, and it will probably be only a short time before the dirigible balloon and the "calcium light" will have been permanently discarded in favor of heavier than air machines and varied forms of projected lights operated by electricity.

The oxy-hydrogen flame is now becoming a common tool in the hands of the artisan in working refractory metals; liquid oils and soft greases are now "hydrogenated" to produce acceptable lard and butter substitutes, and also solid fat suitable for the manufacture of hard soaps; and lastly, the use which promises to consume enormous quantities, ammonia is manufactured from hydrogen and atmospheric nitrogen. All these uses tend to make the problem of the production of cheap hydrogen one of considerable importance.

The employment of the oxy-hydrogen torch is too well known to require description here. The commercial "hydrogenation" of oils and fats is of recent introduction. The process consists in treating the oil or grease in a suitable vessel containing a catalyzing agent, generally nickel, with hydrogen under pressure. The oil is violently agitated in order to bring it into intimate contact with the hydrogen and catalyzer. The result is that the glycerol esters of the unsaturated fatty acids, which generally consist for the most part of oleic acid, become saturated, and the mono-, di-, or triolein, as the case may be, is converted into the corresponding stearin. The oleins are either liquid or semi-solid at ordinary temperature, and produce soft soap or soap that will not hold much water without becoming soft. The stearins are solid fats at ordinary temperatures and produce hard soaps. Thus by the process of hydrogenation, cotton seed and corn oils are to-day being converted into lard and butter substitutes, and the soft waste grease which formerly could only be used sparingly in soap on account of their softening effect can now be employed alone as soap stock. The importance of this is understood when the soaring prices of animal tallows are taken into consideration.

In view of the impending exhaustion of the Chile nitro beds, the problem of the fixation of atmospheric nitrogen for the manufacture of artificial fertilizers has received constantly increased attention. Electrical methods for the production of cyanimid from calcium carbide and nitrogen, and the flaming arc process for making nitric acid directly from the air have been established upon a successful commercial footing, but these require such an enormous expenditure of energy that they can only be operated profitably where there is an abundance of cheap water-power. If only these processes were available, countries lacking in water-power would be placed at a distinct disadvantage, and for this reason many chemists, particularly those of Germany, have labored to find a process better suited to the conditions surrounding them. The details of this search were described in a most interesting manner before the Eighth International Congress of Applied Chemistry, by Hofrat Dr. H. A. Bernthsen, who is the Chemical Director of the Badische Anilin und Soda Fabrik, the owners of a synthetic ammonia factory now in successful operation at Oppau.

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The process, which has been named after Haber, its inventor, consists in passing a mixture of pure nitrogen and hydrogen under a pressure of 150 to 250 atmospheres through a tube filled with a catalyzer and heated to 650 deg. to 700 deg. Cent. The hot gases then pass through a heat regenerator and thence through an ammonia absorber, after which they are replenished with fresh gas mixture and forced by a pump back over the outer walls of the contact tube and then through the contact mass to repeat the circulatory course already described. Only a part of the gas mixture is converted into ammonia by a single passage through the converter, but the gases are made to circulate continuously through the apparatus, the ammonia being absorbed each time as the mixture issues from the heat regenerator at the end of the contact tube. The gases are replenished with fresh hydrogen-nitrogen mixture as required. The contact mass consists of pure iron containing small amounts of certain so-called promoters which may consist of oxides, hydroxides, or salts of the alkalis or of the alkaline earths, and also many other substances of the most varied nature, especially metallic compounds or the metals themselves.

There have been many ways proposed for the producing of hydrogen on a large scale, the most important of which are the electrolytic and the water gas process. The studies of A. Wegener and others lead to the belief that at an altitude of about 75 miles the atmosphere consists of pure hydrogen and nitrogen that would be ideal for the Haber process. Unfortunately no means of piping these gases down to our sphere of action are known and we must content ourselves with more laborious methods of production.

At European army posts, hydrogen for military balloons is commonly generated from scrap iron and sulphuric acid, the reaction being accelerated by heating the mixture to about 55 deg. Cent. For field operations zinc is used in place of iron and the generators are mounted on wheels to facilitate transportation. Three other, and more modern means, of generating hydrogen are used for field purposes and will no doubt be adapted for other than military uses in places difficult of access where the gas is needed. These processes were invented by G. F. Jaubert, a Frenchman, and were named by him respectively, the "Hydrolith," "Silicol" and "Hydrogenite" processes.

Hydrolith is formed by heating metallized calcium in an atmosphere of hydrogen, producing a hydride, CaH_2 , which when treated with water reacts as follows:

just as calcium carbide generates acetylene. Hydrolith is a white crystalline powder, decomposing at 600 degrees in a vacuum, and usually contains about 90 per cent of CaH_2 , the rest being nitride and oxide. One kilogram yields about one cubic meter of hydrogen. The apparatus designed for using hydrolith in the French army is very ingenious, can readily be transported and has a capacity of 1,200 cubic meters per hour. An army dirigible can be filled in four hours. The high cost of hydrolith, \$1.33 per kilogramme, will at present seriously restrict its use outside of military operations.

The Silicol process consists in treating powdered ferrosilicon, or mangano-silicon with water and caustic soda. It does not appear to have gained extended use because of the more troublesome manipulations and the greater difficulty of controlling the evolution of gas as compared with the other methods.

Hydrogenite is composed of ferrosilicon (containing 90 to 95 per cent of metallic silicon) 25 parts, caustic soda 60 parts and dry slaked lime 20 parts. The ingredients are reduced to a very fine powder, intimately mixed, and pressed into brick weighing 25 to 50 kilo-

grammes. Being very hygroscopic, each brick must be sealed in a tin box to prevent decomposition. In generating hydrogen the brick is placed in a metal chamber having double walls, the space between the two walls being filled with water. Vents are placed in the upper part of the inner wall leading to the central chamber containing the hydrogenite so that the steam formed during the combustion may gain access to the charge and increase the yield. The cover of the tin containing the hydrogenite is opened, the tightly fitting lid of the generator fastened in place and through a small hole in the latter a red hot wire is thrust into the charge. The mass burns quickly, without flame, generating heat and evolving hydrogen according to the equation:

One volume of the compressed hydrogenite yields 800 volumes, or 270 to 370 liters per kilogramme, of pure hydrogen, at a cost of about 32 cents per cubic meter. The requisite apparatus for field purposes weighs about 900 kilogrammes.

The methods employed upon a large scale are, of course, capable of producing the gas much more cheaply. In one of these an iron, clay lined retort is filled seven-eighths full of coke, ignited and raised to a white heat by an air-blast. The retort is then closed and a cheap hydrocarbon like crude petroleum or coal tar is injected into it from the top for about 20 minutes or until the temperature has fallen below the proper cracking point, the gas thus generated passing through a sprinkling tower and filtered into the gasometer. The oil injector is then shut off, the retort opened, the air blast again turned on, and the process repeated indefinitely with periodical renewal of the coke and removal of the ashes. The product contains about 2.7 per cent CO , 96.0 per cent H_2 , and 1.3 per cent N_2 , and has a specific gravity of 0.1. The gas can be still further purified to a content of 98.4 per cent H_2 , by passing it through suitable absorbents, and is produced at a total cost of 3 to 4 cents per cubic meter, according to the size of the plant and the materials used.

Large amounts of hydrogen are obtained as a by-product in the electrolysis of salt solutions in the manufacture of chlorine and of caustic soda. The electrolysis is effected in a cell having a cement diaphragm which is not attacked by chlorine or caustic soda. The electrodes are iron and carbon, the latter being used as an anode. The reaction which is as follows:

yields 7,000 cubic feet of hydrogen for every ton of salt. A cell operates on 15,000 horse-power at Griesheim, Germany, producing 245 million cubic feet of hydrogen per annum.

Two other methods, now little used, consist, (1) in passing superheated steam over red hot iron, and (2) in conducting water gas through suitable absorbents so that the carbon-monoxide and hydro-carbons are removed, leaving behind the hydrogen and nitrogen. A third process which is increasing in application was devised by Linde, Frank and Caro. In this, water gas which consists mainly of carbon monoxide and hydrogen is compressed and cooled to the liquefying point of the carbon monoxide. Upon relieving the pressure the mixture expands and in so doing is cooled still further so that the carbon monoxide and most of the impurities separate out in liquid form, allowing the hydrogen to pass off in a fairly clean (97 to 98 per cent H_2) condition. The mixture containing the liquid carbon monoxide is later vaporized and used in combustion motors for power.

The growing demand for cheap hydrogen for industrial uses will act to promote improvements in both the electrolytic and the water gas processes because both require comparatively cheap raw material.