

structors' offices and laboratories; two balance rooms, toilet and wash rooms. The east wing is devoted entirely to quantitative analysis.

SECOND FLOOR

The library of the department is located in the west wing. It has approximately 3,000 volumes. It contains sets of the important journals of chemistry and metallurgy, together with the current files of these journals and many reference books. In the west wing there is, also a lecture room seating about 80 students, together with its preparation room. This lecture room is equipped for demonstrating experiments, or processes, in electrochemistry and electrometallurgy; the switchboard control and recording instruments are visible to the class. The east wing is occupied by the laboratory of organic chemistry which is adjacent to a balance room, a combustion room and a room for sealed tube experiments and experiments with gases. The other rooms include two instructors' offices and laboratories, a special laboratory and office for the head of the department, a classroom, and a special methods room.

THIRD FLOOR

The elementary course in general chemistry is given in the laboratory located in the west wing. The table tops are provided at each working place with a hood in which a suction is produced by fan systems. The east wing contains a laboratory now used for qualitative analysis, and is equipped with the same kind of equipment as that of the laboratory of general chemistry. The stock-room from which supplies and apparatus are issued is on this floor; from this stock-room the materials used in all of the laboratories are distributed. A passenger elevator which serves to carry students from other floors, enabling them to reach the

stock-room without unnecessary delay, is adjacent to it. The stock-room is two stories high, the upper story being formed by a penthouse above the roof. In this second or balcony floor of the stock-room are located the controls for the distilled water system and the hydrogen sulfide generators, each in separate rooms in the attic. The fans connected with the various rooms in the building where suction is needed in addition to the general ventilation are controlled from the stock-room.

BASEMENT

The west wing is used entirely by the Department of Metallurgy. Here the rough and more elementary types of work are carried out, such as moulding and casting, the making of samples for testing in metallography, cutting of samples, heat treating, annealing, etc., and the use of gas furnaces, electric furnaces, pot furnaces, cupola, electric welders, etc. In a separate room in the rear of the building is located the electrical equipment for experimental work, consisting of motor generator sets, rotary converter with transformers and necessary switchboards. The laboratory for applied electrochemistry, situated in the cross bar, is also adjacent to the motor room. The east wing is planned for experimental work in industrial chemistry. It will contain typical units of machinery used in industrial work, such as stills, autoclaves, filter presses, nitrating kettles, pumps, fusion pots, vacuum dryers, centrifuges, grinders, etc. A shop, to be put in charge of a mechanic, is located near this room. In addition to these laboratories the basement contains a storage room for supplies, a cleaning room, a fire-proof storage room for combustible materials, a stock-room, a grinding room, instructors' office and laboratory, a storage battery room and the general ventilating system for the entire building.

ADDRESSES

THE CHEAP PRODUCTION OF ALCOHOL

By A. M. BRECKLER

Received March 19, 1917

The possible uses for denatured alcohol are two: as raw material in manufacture and as fuel.

After eight years of existence, the net result of the denatured alcohol act was the production of 17,000,000 proof gallons of denatured alcohol in 1914, most of which was used in the industries. Here it displaced the potable article, but with so little benefit to the ultimate consumer, according to the Commissioner of Internal Revenue, that in his report he advised a small tax to cover the cost of inspection by government officers during the manufacture.

In 1915, the manufacture of munitions had stimulated the production somewhat, but the benefits to the American people as a whole are doubtful and had the alcohol used in this industry (about 5,000,000 gallons) paid tax, a good portion of our present deficit might not have existed.

It is, of course, as a fuel for explosion engines that we look for the greatest demand for alcohol and it is the production of alcohol for this purpose which will eventually determine the price.

The total alcohol produced in 1914 in the United States from all raw materials was 182,000,000 proof gallons, equivalent to about 5 per cent of our present gasoline consumption. By far the largest source of this alcohol was grain, from which 142,000,000 gallons were produced. To produce enough alcohol to cover our gasoline demands as a motor fuel would take 16 per cent of our total cereal production or about 26 per cent of our total corn production.

The average cost of alcohol from grain (corn) has been 17.5 cents per proof gallon for the past five years. This probably

is a minimum figure as it is based on the cost in large distilleries and allows for the sale of the feed recovered at the average market price. The cost this season will not be far from 25 cents per proof gallon or about 45 cents per gallon of 90 per cent alcohol. If the alcohol is furnished in barrels, 2 cents must be added to this per proof gallon. This cost could not be cheapened materially. The overhead here figured is about 3 cents. So far as increasing the yield of alcohol per bushel, the possibility permits of an increase of only 5 per cent at most. It must be remembered that these figures carry no allowance for profit, selling expense and freight.

SOURCES OF CHEAP ALCOHOL

The possibility of making alcohol cheaper on the farm has been given prominence. The idea is to make alcohol and feed the slop to cattle. There are several reasons which would make this impractical in all except rare cases. The cattle fed on slop do not furnish meat which packs well. It is very tender and juicy and perfectly healthful, but becomes flabby on keeping. Therefore, it must be sold on a market which can absorb a large amount of it at a time. The experience of distillers who have fed large numbers of cattle (as many as 12,000 head at one distillery) is that such feeding is more or less of a speculation depending on the markets and the location of the plant, accessibility being necessary in order to enable them to take advantage of favorable prices. Aside from this there are fuel and water requirements which will be taken up later.

In 1912, the Minnesota Agricultural Experiment Station operated a 200-bushel distillery on grain. They employed an experienced distiller, had most careful chemical supervision of the plant and credited the feed at a very good price. Their yield was about 4 per cent under the average prevailing that season. The price charged for the corn was the average farm

price as against the market price. The net result was that they were unable to produce alcohol for what they could buy it. If under these favorable conditions, the alcohol cannot be produced at a profit, what can the farmer expect?

The other large source of alcohol is black strap molasses which five years ago was a drug on the market and sold as low as 2 cents per gallon at the sugar house. Coincident with the sudden increase in the demand for alcohol, the demand for black strap increased until to-day it is selling for 12 to 14 cents per gallon. The high price of sugar has stimulated the sugar houses to carry their extraction of sugar as far as possible and hence the yield of alcohol possible has decreased very much.

From black strap of good quality at 5 cents delivered, the cost of production would be around 10 cents per proof gallon, it is true, but if we assume that all the sugar produced in the United States and Cuba represents 80 per cent of that in the juice and all the remaining 20 per cent would be available for fermentation, we would have raw material available for about 162,000,000 gallons of alcohol or enough to supply about 5 per cent of our present demand for motor fuel. It is probable that not more than 25 per cent of this amount is actually available, owing to the increasing yields possible from better sugar extraction processes.

A third source of alcohol is wood waste. Enough money has been spent on sawdust plants to evolve several processes for cracking oils. The fact is that after seventy years of experimenting there are two plants running in this country and were it not for the high price of alcohol at the present time, it is doubtful whether they would run. The bulk of the material handled, the use of strong acids, the complex machinery for leaching and the rapid stripping of the timber tracts under cutting all operate against the process even were other conditions satisfactory. As both the plants now operating are financed by large corporations, it is evident that lack of money has not held the process back and it is very probable that if the process were really profitable, more plants would be in existence.

The sulfite liquors from pulp mills offer a cheap source of carbohydrates. None of the existing processes are exactly satisfactory. Just how much of this is available is a little uncertain. One thing is certain, that the amount of fermentable carbohydrates in this liquor is very variable. At present there are about three plants operating in America on this liquor.

Any process for making alcohol must give careful consideration to the question of yeast nutriment. As the amount of yeast formed is dependent on the volume of liquid rather than the concentration of the fermentable matter, the most economical process in this respect will evidently be that in which the concentration of the fermentable is the greatest practical. About 8 lbs. of dry yeast are formed from every 1000 lbs. of fermented liquor of which 6 per cent or $\frac{1}{2}$ lb. is nitrogen. If a liquid contains 10 per cent of fermentable, the amount of nitrogen required is one-thirtieth lb. per gallon 160 proof. The potash requirements are about one-fifth of the nitrogen. Just as much attention to yeast poisons is desirable. This is one of the drawbacks to the use of sulfite liquor for the production of alcohol. Even such a common substance as caramel acts as a yeast poison.

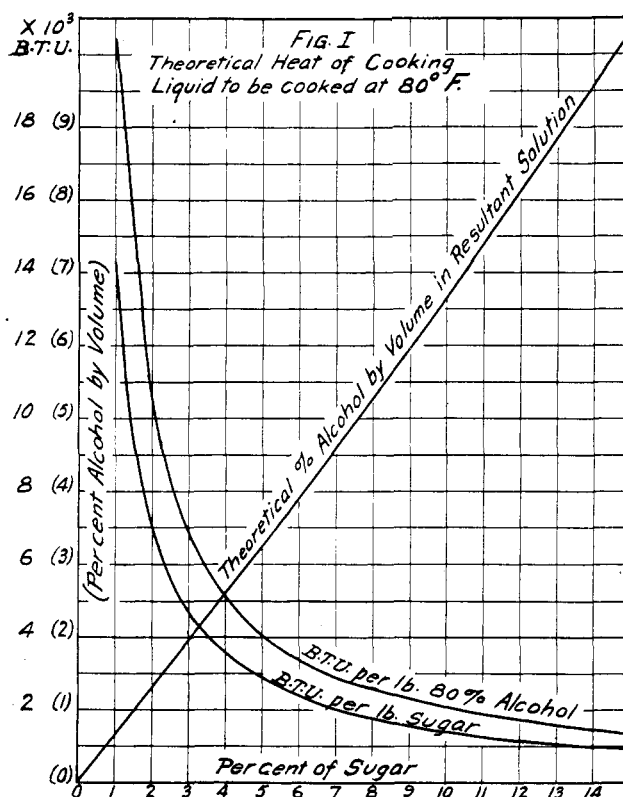
FUEL AND WATER SUPPLY IMPORTANT FACTORS

The factors which most often determine the feasibility of making alcohol from low-grade material are fuel and water supply. The writer has prepared a curve (Fig. I) showing the theoretical heat consumption at various concentrations for distillation of 1 lb. of 160 proof (80 per cent by volume) alcohol. This concentration was selected as being the lowest which would meet all fuel requirements and the highest which could be prepared with comparatively simple apparatus. The values for 95 per cent alcohol are about 1.5 times as great, owing to the heat necessary for the rectification and lower yield in gallons. The

factor 3.5 gives the minimum heat consumption while five times the theoretical would give about the average heat consumption.

For example, let us consider the distillation of 160 proof alcohol from sulfite liquor. As concentrated for fermentation, this liquor ordinarily contains 4 per cent fermentable. As this is hexose sugar, the resultant solution will contain theoretically 2.61 per cent alcohol. With a yield of 85 per cent (an average usually obtained), the resultant solution will contain about 2.2 per cent alcohol by volume. The theoretical heat of distillation per lb. 160 proof alcohol from such a concentration is 4,000 B. t. u. As the weight of one gallon of 160 proof alcohol is 7.2 lbs., the heat required under best conditions would be 126,000 B. t. u. while probably it would approach 180,000. Using a good coal running 13,000 B. t. u. per lb., the coal required under favorable conditions would be 10 to 14 lbs. Assuming such coal to cost \$3.00 per ton laid down at the paper mill, the costs under good conditions for distillation of 160 proof alcohol would run 1.5 to 2.1 cents per gallon.

Similarly it may be figured that 160 proof alcohol from sorghum

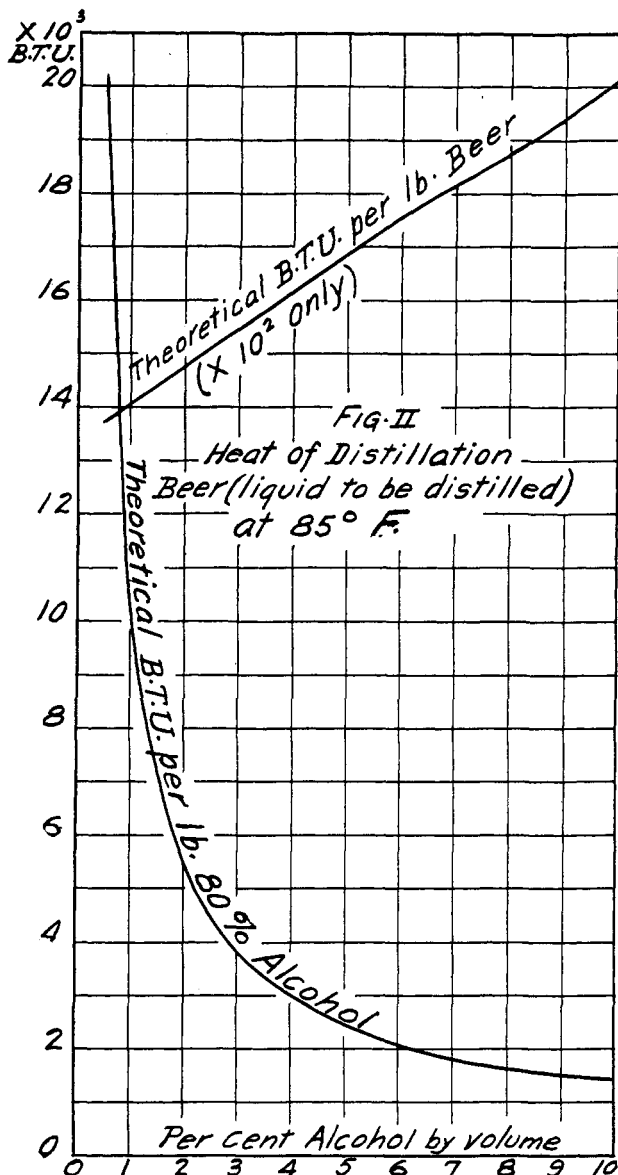


juice containing 15 per cent as hexose will cost 0.4 to 0.6 cent per gallon for distillation with coal at \$3.00 per ton. This probably represents as concentrated a liquor as it would be possible to ferment, since the resultant alcohol from stronger liquor would probably affect the yeast before the attenuation was complete. In Germany, where thicker mashes are used, the practice is to thin out with cold water during fermentation.

In the case of nearly any material containing starch, and most other materials, a preliminary cooking is necessary and here again the cost is greater the lower the concentration. Fig. II shows the B. t. u. per lb. hexose sugar and likewise per lb. 80 per cent alcohol at various concentrations of sugar. Starch multiplied by 1.11 of course gives the hexose concentration. The factor of 2.5 probably gives the closest figure to actual heat put under the boilers. Fig. II is based on cooking to 212°F. only. In a great many cases, the material is cooled to 310°F. in which case the figures given should be multiplied by 1.69 also.

Considering the case of garbage mash, a sample recently sub-

mitted to the writer contained 5 per cent fermentable hexose. This gave a figure of 4,100 B. t. u. per lb. of 80 per cent alcohol theoretically, but as the average yield is 85 per cent of the theoretical, this would become 4,800 B. t. u. Multiplying by 7.2 and 2.5, we would have a theoretical consumption of 86,500 B. t. u. or 6.65 lbs. coal which, at \$3.00 per ton, represents 1 cent per gallon for cooking. If the mash should have to be cooked under pressure, the cost would be 1.8 to 1.7 cents per gallon 80 per cent alcohol, making a cost of 2.2 to 2.27 cents for cooking under atmospheric pressure and distilling, and of 2.9 to 3.4 cents at high pressure and distilling. In addition to this, power must be furnished for comminution, pumping, etc., all of which re-



quires fuel. In a grain distillery, the fuel required for this purpose is about half of that for all other purposes. It is, of course, difficult to state this cost for all materials, but this relation would probably not give excessive figures for any other material.

Coal, we can nearly always get, but unfortunately, the problem of cooling is just as pressing. Artificial refrigeration has never been used in distilleries in the United States because of its cost, most reliance being placed on water cooling. For plants which can obtain artesian water or lake water, or plants on the ocean, such a problem is not difficult, but for any proposed inland distillery too much consideration cannot be given to the matter.

The water required for condensing a gallon of 80 or 95 per cent alcohol and cooling to 80° F. is theoretically, as in Table I, assuming perfect efficiency. In practice, the amount found thus should be raised to the 3/2 power; this relation is based on experiments made by the writer in distilleries.

TABLE I—GALLONS WATER REQUIRED TO CONDENSE ONE GALLON ALCOHOL AND COOL TO 85° F.

Temperature of Cooling Water:	55	60	65	70	75	80° F.
GALLONS WATER FOR ALCOHOL:						
80 Per cent by Volume.....	4.3	4.5	4.7	4.9	5.1	5.4
95 Per cent by Volume.....	3.4	3.6	3.7	3.9	4.2	4.3

It can be seen that a plant producing 100 gallons 80 per cent alcohol per day will require from 900 gallons water at 55° to 1,250 gallons at 80°, though probably the last figure is too low.

If the mash is heated considerably, more water will be required as is evident by Table II. It is not possible to correlate these figures with practice, unfortunately, as owing to the extreme viscosity of highly concentrated mashes, the factor is much greater here than that calculated as above, and owing to the more efficient apparatus used, the factor for thin mashes much less. At any rate, the figures given are minimal, though a safe margin would be five times the figures given.

MAXIMUM RAW MATERIAL COSTS

Assuming a concentration of 10 per cent fermentable in the liquid as finally prepared for fermentation, Table III represents about the maximum allowable cost per lb. fermentable for pro-

TABLE II—GALLONS WATER PER GALLON 160 PROOF ALCOHOL FOR COOLING MASH TO 70° F.

Per cent Sugar in mash	Water at 55° F.	60° F.	65° F.	70° F.
1	112.5	116.2	120.2	124.4
2	56.3	58.1	60.1	62.2
3	37.5	38.7	40.1	41.5
4	28.1	29.1	30.1	31.1
5	22.5	23.2	24.0	24.9
6	18.8	19.4	20.1	20.8
7	16.1	16.6	17.2	17.8
8	14.1	14.6	15.0	15.6
9	12.5	12.9	13.4	13.8
10	11.3	11.6	12.0	12.4
11	10.2	10.5	10.9	11.3
12	9.4	9.7	10.0	10.4
15	7.5	7.7	8.0	8.3

ducing alcohol of any given cost per proof gallon, assuming an 85 per cent yield. Any feeding value of the residue should be added allowable to raw material cost. As this table is based on an overhead of 2 cents per proof gallon, which is the minimum possible under the most favorable conditions, the figures for raw material cost give the maximum allowable value.

TABLE III—MAXIMUM ALLOWABLE COSTS FERMENTABLE COST FERMENTABLE per lb. Hexose Delivered MINIMUM COST ALCOHOL per Proof Gallon

1.0 cent	9.6 cents
1.2	11.2
1.4	12.6
1.6	14.2
1.8	15.7
2.0	17.2
2.2	18.7
2.4	20.2
2.6	21.8
2.8	23.3
3.0	24.4

Let us suppose that we wished to compete with gasoline at 30 cents. Assuming that absolute alcohol and gasoline deliver the same amount of power per gallon, we must take the cost of alcohol at 15 cents per proof gallon. The raw material must, therefore, cost not over 1.7 cents per lb. fermentable. Alcohol potatoes contain 20 per cent starch. This is the equivalent of 22.2 per cent dextrose. We have the relation $0.222 \times 1.7 \times 0.38$ cent as the maximum allowable cost per lb. of potatoes delivered, provided the feed is not utilized. The feeding value of the residue of 1 lb. of potatoes is generally taken at about 0.1 cent. This would make the maximum allowable cost 0.48 cent or 28.8 cents per bushel delivered.

At present gasoline is selling about 20 cents per gallon. If the Utopian ideas of certain automobile manufacturers were realized, potatoes would have to be laid down at the distillery

for not to exceed 20 cents per bushel in order that alcohol might replace this gasoline. The average farm value for potatoes from 1907 to 1915 inclusive was 61.4 cents per bu. It is hard to see how the farmer could be stimulated to produce more potatoes if a lower price were offered as must be if potatoes are to figure as alcohol producers. The popular mind has become so obsessed with the idea of cheap alcohol from potatoes that it is forgotten that the German idea of cheap alcohol is alcohol at about 40 cents per gallon 180 proof.

CONCLUSIONS

Water, fuel and cost of raw material represent about all the factors susceptible of approximate calculation. In addition labor, insurance and depreciation must be taken into account. If starchy substances are used, malt or acids must be used for conversion which is an additional cost. It cannot be too strongly impressed on the prospective manufacturer that sporadic sources of material such as fruit, cornstalks, canning wastes, must always be used under the disadvantage of long periods of idleness resulting in increased depreciation, and disorganization of the working force.

It must not be understood that the writer intends to depreciate the possibility of producing alcohol at a cost to enable it to be used as a motor fuel. Quite the contrary. But it has seemed to him that unless more care is used in experiments on the production of alcohol that capital will abandon the field as unpromising. The newspapers are full of stories about the possibilities of production of cheap alcohol and even our own JOURNAL has not been entirely free from them. As a matter of fact, the production of cheap alcohol presents as many difficulties as the manufacture of cheap gasoline. The alcohol industry is one that requires experience as much as any other chemical industry and in spite of opinions to the contrary, uses at present about as scientific methods as any.

AUTHOR'S NOTE (Received May 16, 1917): Owing to recent increases in grain costs, it is probable that grain alcohol costs will be over fifty cents per proof gallon for the year 1917.

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WILLARD GIBBS MEDAL AWARD

The Willard Gibbs Medal for the year 1917 was conferred upon Dr. Edward Williams Morley, former Professor Emeritus in Chemistry, Western Reserve University, Cleveland, Ohio, at the meeting of the Chicago Section of the American Chemical Society, held May 18, 1917, in the Louis XVI Room of the Hotel Sherman. One hundred and forty-six members and friends of the Chicago Section were present.

Mr. A. V. H. Mory, Chairman of the Chicago Section, opened the meeting and introduced Dr. W. A. Noyes, Professor of Chemistry, University of Illinois, and Editor of the *Journal of the American Chemical Society*, who made the presentation address. The medal address, entitled "Early Researches in Hydrogen and Oxygen," will appear in full in the *Journal of the American Chemical Society*, and we are printing below an abstract prepared by Dr. Morley at our request.

Dr. Morley spoke in his usual happy vein. He showed the distinguishing quality of his mind—that keen sense of proportion that made possible his great work, by fully appreciating the sort of treatment of his subject that would be most acceptable to a mixed audience, including many who had no knowledge of chemistry. There was a personal touch to Dr. Morley's talk that was much enjoyed and he skilfully employed an occasional narrative to drive the points home.

Letters of regret were received from a number of invited guests, including the presidents of the Middle West universities, and a number of the prominent chemists of the country, among them Secretary Charles L. Parsons.

At the speakers' table, besides the chairman, Professor Morley, and Professor Noyes, were President Stieglitz; Harry Pratt Judson, President of the University of Chicago; F. I. Moulton, President of the City Club of Chicago; John H. Long, Professor in Chemistry at the Northwestern University Medical College; William H. Burton, Vice-President of the Standard Oil Company of Indiana; and Edward Bartow, Director of the Illinois Water Survey, each of whom spoke briefly and entertainingly. President Stieglitz was able to give some interesting information concerning the work of our society in these stirring times.

The occasion was a memorable one and established even more completely, if it were possible, the high character of the Willard Gibbs Award.

Edward Williams Morley was born in Newark, N. J., in 1838. He received the degrees of A.B. (1860) and A.M. (1863) from Williams College, and an honorary Ph.D. from University of Wooster (1878). He has also received the honorary LL.D.

degree from Adelbert College (1891), Williams College (1901), Lafayette College (1907), University of Pittsburgh (1915), and the Sc.D. degree from Yale (1909). Dr. Morley was professor of chemistry from 1869 to 1906 at Western Reserve College, formerly at Hudson, Ohio, and afterwards removed to Cleveland. He also held the chair of professor of chemistry in the Cleveland Medical College from 1873 to 1888. Dr. Morley is an honorary member of the Royal Institute of London; corresponding member of the British Association for the Advancement of Science; associate fellow of the American Academy of Arts and Sciences; fellow of the American Association for the Advancement of Science, of which he was president, 1895–1896; a member of the National Academy of Sciences, American Philosophical Society, Astronomical and Astrophysical Society of America, the Chemical Society of London, and the American Chemical Society, of which he was president, 1899–1900.

Dr. Morley was honorary president of the Eighth International Congress of Applied Chemistry which met in New York City in September, 1912. The photograph of which a copy is shown here was made at about that time.

The *Chicago Chemical Bulletin* furnished us with the following brief account of Dr. Morley's most important work:

"The attention of chemists was first attracted by his work on a very accurate series of analyses of air which demonstrated that the per cent of oxygen in the air varies between narrow limits and is probably smaller in the higher strata of the atmosphere.

"In 1842 Dumas had made a series of determinations of the composition of water, on the basis of which the value 15.96 was accepted as the atomic weight of oxygen for nearly fifty years. Toward the end of this period a number of different chemists worked upon the problem and it gradually became clear that the value found by Dumas was in serious error, but it was not until Dr. Morley's paper appeared in 1895 that the chemists of the world accepted a quite different value as fully demonstrated. In an elaborate series of investigations, to which he gave more than ten of the best years of his life, the densities of hydrogen and of oxygen gases were determined with an accuracy that has not been excelled or even reached by any other observer. Dr. Morley also effected for the first time a complete quantitative synthesis of water, weighing both the oxygen and hydrogen and also the water formed by their union. The results of all of his studies gave the value 15.879 as the atomic weight of oxygen, or 1.00762 as the atomic weight of hydrogen, and it seems quite certain that these values will never be essentially changed.