BEET SUGAR ANALYSIS.

A COMPLETE SYSTEM OF INSTRUCTION FOR ANALYSTS IN BEET SUGAR FACTORIES.

BY

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OF THE

CHINO VALLEY BEET SUGAR CO.

1897.
E. C. HAMILTON, PUBLISHER.
CHINO, CAL.

69144

1897.
PRESS OF WARDEN, THE PRINTER.
LOS ANGELES, CAL.

PREFACE.

THE great interest now being manifested in the development of the beet sugar industry in this country seems to leave little room for doubt but that the present beet sugar production of the United States will be multiplied many times within the next few years. With the establishment of the industry reference books will become a necessity, and BEET SUGAR ANALYSIS was written in the hope that it will prove of value in the very important matter of chemical control of factories.

It is intended primarily as a complete school for the beginner, but the experienced chemist may occasionally find it useful for reference. I have given what I consider to be the most practical and accurate methods for testing every substance and solution the chemist is called upon to analyze in beet sugar work, describing also the proper way to take samples and prepare them for analysis. The "Pointers" given, which are hints on methods for facilitating work and avoiding sources of error, it is hoped will help the young chemist, as he could otherwise learn them only by experience. After Chapter I the "Pointers" are not separated, but are written in the text. In addition to the analysis of all sugar-containing substances, I have also given methods for analyzing water, limestone, coke and coal, and all other supplies which must be examined chemically to determine their availability for sugar work. A description of the most practical apparatus for use is given as an aid to new factories. The reference tables given have nearly all been compiled for this work and they are guaranteed to be absolutely correct.

In the study of which this book was born, Mr. James G. Oxnard gave me many valuable "Pointers," and to Mr. E. Turck and Dr. C. Portius, of the Chino Valley Beet Sugar Company, I am also greatly indebted for suggestions and advice.

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REFERENCES CONSULTED.

The works of reference named below, which were consulted in the preparation of BEET SUGAR ANALYSIS are all to be recommended to the student :

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Bulletin No. 46, Chemical Division United States Department of Agriculture.

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LANDOLT, H., *Handbook of the Polariscope.*

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VON LIPPMAN, E., "Die Zuckerarten und ihre Derivate."

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WINKLER, C., *Handbook of Technical Gas Analysis.*

WIECHMANN, F. G., *Sugar Analysis.*

WALLIS-TYLER, A. J., *Sugar Machinery.*

ABBREVIATIONS AND CONTRACTIONS.

USED IN THIS WORK.

C.—Centigrade.
CC.—Cubic Centimeters.
F.—Fahrenheit.
F.—Frontispiece.
Fig.—Figure (Illustration).
Gr.—Gramme or Grammes.
Kilo.—Kilogramme.
L.—Liter.
M.—Meter.
Mg.—Milligramme or Milligrammes.
MM.—Millimeter or Millimeters.
M.—Full page Illustration of Apparatus for Samples.
Phenol.—Phenolphtalein.
Sp. g.—Specific gravity.

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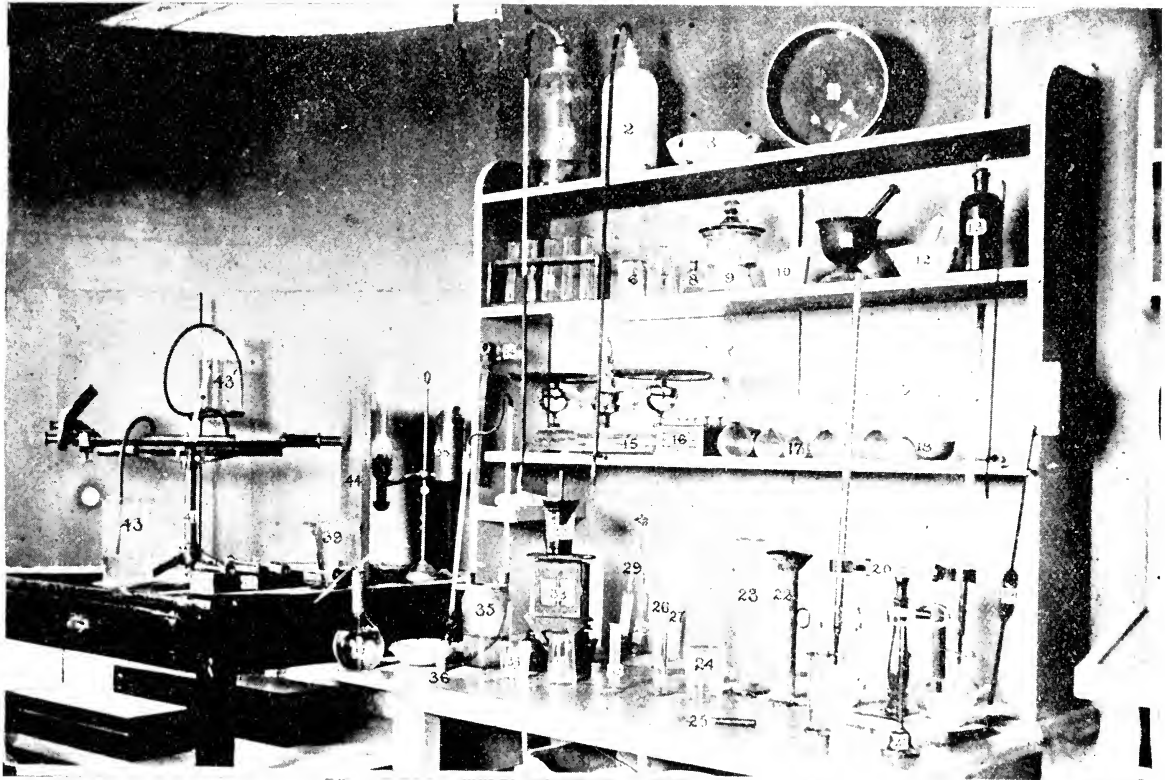
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APPARATUS IN FRONTISPIECE.

1 and 2.—Siphon bottles for water and lead acetate.
3.—Porcelain evaporating dish.
4.—Sieve for lime samples.
5.—Test tubes and rack for alkalinity samples.
6 —Griffin beaker.
7.—Conical assay flask.
8.—Ether or indicator bottle.
9.—Dessicator.
10 and 11.—Mortars for chemical analysis.
12.—Mortar for lime-cake analysis.
13.—Siphon bottle for acetic acid.
14 —Alkalinity sampler.
15.—Scale for lime-cakes.
16.—Box with weights.
17.—Flasks for sugar analysis.
18 —German silver scoop.
19.—Sucrose pipette.
20 —Burette stand with Mohr's burettes.
21 —Westphal specific gravity balance.
22.—Tin cylinder.
23.—Glass cylinder.
24.—Tumbler for dissolving samples.
25.—Spatula for saccharate samples.
26 and 30.—Test tubes with foot.
27 —Thermometer.
28 and 29 —Hydrometers.
31 —Beaker with lip.
32.—Air funnel for syrup test.
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CHAPTER I.

INSTRUMENTS FOR ANALYSIS AND THEIR USE.

1. Cylinders are the most convenient vessels for holding solutions to be tested. For syrups, massecuites, cossettes, and other regular laboratory tests, use glass cylinders about 12 inches high and 2 inches in diameter, without a lip. (Fig. 1.) For beet tests use tin cylinders about 10½ inches high and 1¾ inches in diameter, having a form similar to Fig. 3. For Steffens' hot waste water and other solutions having a low brix, a 10-inch test tube 1 inch in diameter may be used. The Steffens' cold waste water sample is usually a small one, on account of the trouble in filtering a large sample, and its density may be taken in a 6x¾ test tube, preferably one with a foot (Fig. 2), the hydrometer used being the Brix 5-9 described in **2b.** In using a cylinder or a test tube, incline it slightly and pour in the solution down the sides to avoid foam. In cossette

Fig. 1.

Fig. 2.

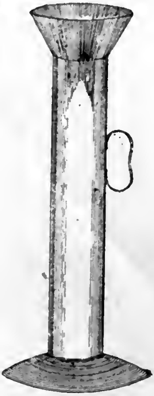

Fig. 3.

and beet juices the air, which is usually contained, will come to the top and the bubbles formed may be skimmed off with a spoon. A little ether may be used in allaying any unavoidable foam, but it should always be allowed to evaporate, as it influences the reading of the hydrometer.

POINTERS.

Clean glass cylinders immediately after using.

Tin cylinders should be cleaned thoroughly with a rag every day when in use. If dirt is left in them it will ferment.

Do not make a habit of using ether to allay foam in cylinders. Use it only when absolutely necessary.

The cylinder in use should always be set on a level place.

2. Specific Gravity.—There are a number of instruments made for determining exact specific gravity, one of the best of which is the Westphal balance shown in F. 21. However, the author's experience has been that for beet sugar laboratory work there is no method as practical as actual weighing.

(*a*) **The Pycnometer,** a glass flask with a long tubular stopper (Fig. 4) is made for this purpose. The best size is made to hold 50^{cc} of distilled water at 17½°C. This is also considered to be 50^{gr}. The gramme is equal in weight to 1^{cc} of water weighed in vacuo at its maximum density—4°C. It is more practical in sugar work to take 17½°, and polariscopes are constructed for solutions made up at this temperature. To find the specific gravity of any solution, thoroughly clean and dry the pycnometer

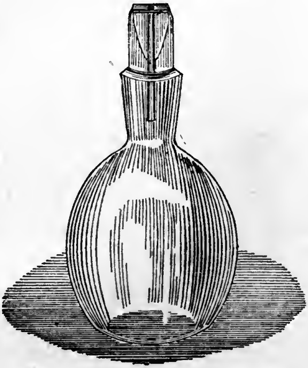

Fig. 4.

and weigh. Then fill with the fluid at 17½°C., seeing that no air is contained. Put in the stopper and wipe off carefully any solution that comes through the tube. Weigh again and subtract the weight of the pycnometer to find the weight of the solution. Multiply this by two, and remove the decimal point two places to the left to find the specific gravity.

Example :

Weight of pycnometer and fluid.............	78.642 gr.	
Weight of pycnometer......................	26.856 gr.	
Weight of fluid.............................		51.786 gr.
Multiplying by.............................		2
		103.572 gr.
Moving decimal point two places...........		1.03572 sp. g.

The specific gravity of a liquid or a solid is the ratio of its weight to the weight of the same volume of water. In the example given the weight of the fluid is 51.786^{gr}. and the weight of the same volume of water is 50^{gr}. $50 : 51.786 :: 1 : x$, or $x = 51.786 \div 50 = 1.03572$. If 100^{cc} were taken, the division by 100 would be accomplished by moving the decimal point two places to the left. As this figuring is much easier, we can multiply by two and consider that 100 has been taken instead of 50.

Common 50^{cc} flasks can be used instead of pycnometers and, in fact, are more practical for most analyses, the only advantage in the latter being that the stopper prevents evaporation. In using a flask, select one with as small a neck as possible and cut off about a quarter of an inch above the mark. Test by weighing it in 50^{gr} of water at 17½C. (See **4**.)

(*b*) **Hydrometers** are used for determining the density of fluids in analysis and in factory work. The Brix hydrometer is used for analysis. It is graduated according to a scale, by which it indicates the percentage by weight of sugar when immersed in a solution of pure sugar. (See **19**.) It is properly called a "Saccharometer." The Balling saccharometer is the same as the Brix. The Beaumé hydrometer is generally used for taking the density of thick fluids in the work of the factory. It is a specific gravity hydrometer, graduated according to an arbitrary scale adopted by Antoine Beaumé, a Parisian chemist. He dissolved 15 parts of common salt (by weight) in 85 parts of water. The point to which the hydrometer sunk in this solution was marked 15° and the scale between this and zero was divided into 15 parts, divisions of the same size then being made from the 15° below to the bulb. The Beaumé hydrometer for liquids lighter than water (See **76**) also has a salt solution for its basis. The point on the stem to which it sinks in water is marked 10° and the zero is the point where it stands in a solution of 10 parts common salt and 90 parts water. This is divided into 10 parts, the same divisions then being made on the rest of the scale up to 100.

The Beaumé hydrometer best adapted to general factory work is graduated from 0 to 50 in ½ degrees. Of the

Fig. 5.

Brix and Balling saccharometers there should be a well selected variety. The 30 to 60 in 1-5 degrees and the 60 to 100 in ½ degrees may be used for taking densities in factory work. Sweet waters are taken with a– 5 to + 5 Brix, graduated in ½ degrees. For beet analysis an instrument graduated from 10 to 30, or 10 to 20, in 1-10 degrees is used; for cossettes and sugarhouse analyses one graduated from 10 to 20 in 1-10 degrees (See Fig. 5); for diffusion juice one graduated from 5 to 15 in 1-10 degrees, and for waste waters one from 0 to 5 in 1-10 degrees. A Brix graduated from 0 to 25 in 1-10 degrees is an excellent instrument for general work, and it may be used for nearly all analyses. Many chemists prefer it for beet analysis. When the Steffens process is used the best saccharometer for cold waste waters is the 5 to 9 Brix graduated in 1-10 degrees. The instrument has a bulb 2¾ inches long and ½ inch in diameter, and is especially adapted for the test tube described in **1.** When a special saccharometer is desired for hot waste waters, an instrument graduated from 3 to 7 in 1-10 degrees may be obtained. All instruments should be made for a temperature of 17½°C.

In taking the density of a solution with a hydrometer, it must be entirely free from air bubbles. Have the instrument clean and dry before using and immerse it carefully in the fluid, keeping it from touching the sides of the cylinder. When it has come to rest, read the graduation. The fluid is raised around the stem of the instrument by capillary attraction and the correct reading is at the bottom of this, being on a level with the top of the solution. In Fig. 6 the correct reading is 11.0 instead of 10.8, as it appears to be. In taking the density of a solution, the temperature is taken at the same time. If a solution is colder or hotter than normal temperature it is obvious that its density is greater or less than normal, so that a correction must be made for temperature.* (See Table I.)

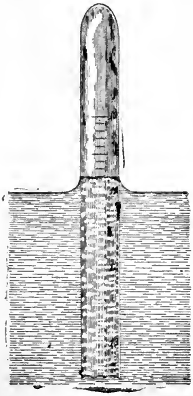

Fig. 6.

Hydrometers are most easily tested by immersing them in a solution the specific gravity of which is known and comparing the reading with the sp. g. (See Table II.) It is a good plan to have at least three "control" saccharometers graduated from 0 to 10, 10 to 20, and 20 to 30, in 1-10 degrees. These instruments, when found to be absolutely accurate, may be used for testing other saccharometers by comparison.

POINTERS.

Keep the hydrometers in an earthen slop jar or tin bucket filled with water and having a sheet of rubber covering the bottom.

Do not buy saccharometers with short, thick bulbs. They cannot be used with accuracy in a cylinder of the size that is most practical for sugar work. The 10–20 Brix, which is most often used, should have a bulb about 4½ inches long and a 6-inch stem.

(*c*) **The Dry Substance** is the percentage of total solids found by weight. It is generally determined in order to find the "real purity" (See **19**) of syrups and masse-

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* Taking the density of a hot solution is not as accurate as taking it after the solution has cooled to nearly normal temperature. In a hot solution the temperature may change during the operation and the correction for temperature will be incorrect.

cuites. To find the dry substance, weigh a scoop containing about 15^{gr} of powdered glass or sand(See **140**) and a small glass rod to be used for stirring. Add about 2^{gr} of the substance to be tested and weigh again. Mix the sand (or glass) and the substance thoroughly by using the glass rod. Place in a drying oven for two hours and keep a temperature of 100°C, but be careful that it does not get higher. Then, after cooling in a dessicator, weigh and return to drying oven. Repeat this until the scoop and contents has a constant weight, *i. e.*, that there is no further loss by drying, proving that all the water has been driven off. Determine the amount of water lost by subtracting the weight after drying from the weight before drying. The weight of the water lost divided by the weight of the substance used will give the per cent. of water lost, and subtracting this from 100 will give the per cent. of dry substance.

Example:

Weight of scoop, sand, rod, and substance	51.613 gr.
Weight of scoop, sand, and rod	49.381 gr.
Subtracting, gives weight of substance	2.232 gr.
Weight of scoop and contents before drying	51.613 gr.
Weight of scoop and contents after drying	51.402 gr.
Subtracting, gives weight of water lost	.211 gr.

.211÷2.232=.0945=9.45 per cent. of water lost.
100—9.45=90.55 per cent. dry substance.

3. Sucrose Pipettes are in general use in this country for most analyses, although they have not been adopted in Europe. (See **10**). They are so made that when a solution is drawn into the pipette to the graduation corresponding to the reading of the brix of the solution the amount of solution in the pipette will weigh 52.096^{gr}.

The instrument should be graduated from 10 to 25. (Fig. 7.) In using a pipette, first rinse it inside with the solution to be tested and then draw in the solution, by aspiration, to the graduation corresponding to the reading of the brix* ; let the solution drop into the 100^{cc} flask and run a stream of water through the pipette, to wash every particle of the solution into the flask. In washing the pipette, hold the flask in the third and little fingers of the left hand, using the index finger and thumb to twirl the instrument while the water is passing through. (See Fig. 8.) In testing a pipette, if a solution of a known brix is drawn in to the proper graduation and dropped into the scoop of a scale or tared vessel, if its weight is nearly, but not quite, 52.096^{gr} the pipette may be adjudged correct.

Fig. 7.

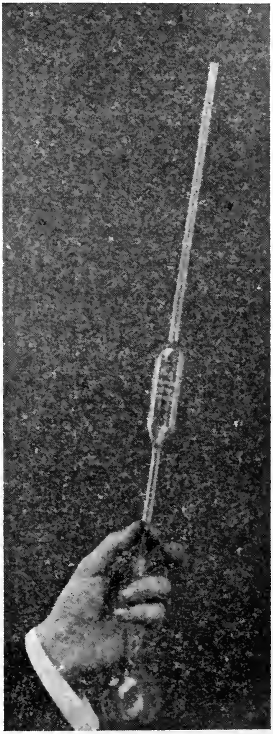

Fig. 8.

POINTERS.

To read the graduation in a pipette, always take the bottom of the meniscus, the same as in a flask. (See Fig. 9.)

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* This refers to the reading without temperature correction.

Be sure there are no bubbles in the pipette. They will come to the top if present, and can be drawn out into the mouth.

Pipettes in constant use should be thoroughly cleaned every few days. Rinse with gun shot and diluted muriatic acid. Pipettes used for beet analysis should be cleaned every evening with gunshot and strong muriatic acid.

The graduations on a pipette may be more easily observed if red lead is rubbed into the marks. Take a small ball of red lead and rub it up and down the graduations. Wipe off with a cloth and the lead will remain in the marks. Chalk or lamp-black (mixed with turpentine) may be used for the same purpose.

4. Flasks for Sugar Analysis are graduated to hold 50^{cc}, 50 and 55^{cc}, 100^{cc}, 100 and 110^{cc}, and 201.4 and 221.4^{cc}. The last is for beet analysis (See **23C**), and should have a neck wide at the top and narrowing down to the graduation. The 100–110 flask should have a neck ⅝ of an inch in diameter, but the other flasks should all be small-necked for accurate work. When the 100–110 flask is used for any other volumetric (**14**) analysis than pulp it should also have a small neck. In filling flasks let the bottom of the meniscus of the fluid come to the graduation. (See fig 9.) This rule also applies to the reading of pipettes and burettes. Any foam that forms in a flask may be gotten rid of by the use of ether. The bottle shown in F 8 is a convenient ether bottle. A small glass tube is fitted in a ground glass stopper, and is of such length that when the stopper is in the bottle, the tube reaches nearly but not quite to the bottom. Ether is taken from the bottle by putting a finger over the top of the tube, as with a pipette. The dropping bottle shown in Fig. 10 is often used for ether, but it is not as good as the one above described.

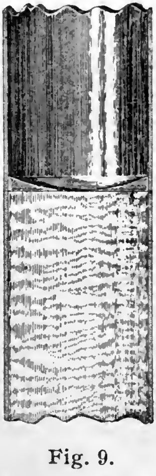

Fig. 9.

Fig. 10.

To test a flask, clean and dry it thoroughly, weigh, fill with water at 17½°C to the mark, and weigh again. The weight of the water should be as many gr. as the flask holds cc. (See **2a.**) It is usual to test all flasks as soon as they are purchased and either of the following methods will be found quick and accurate when a large number of flasks are to be tested.

Test a flask by water as above, to use as a standard. Fill it with clean mercury to the mark. Clean and dry all flasks to be tested,* then pour the mercury into each one until all are tested. The mercury for this method must be perfectly clean and dry. The writer has always found it advisable to test 4 or 5 flasks and then return the mercury to the standard flask, to be sure that none has been lost. Keep the flask in a clean mortar while pouring in the mercury, to prevent loss in case of accident.

The following method by pipette is preferable to the use of mercury in the fact that it is more rapid, although greater care must be exercised. Use a pipette graduated for the same number of cc as the flasks to be tested. Determine its accuracy by filling to the mark with water at 17½°C, then letting the water run out into a tared vessel. Gently blow through the pipette, so that no drops of water remain. The weight should be 1^{gr} for every cc for which the pipette is graduated, and if it is either more or less, find by repeated weighings where the mark should be to make the pipette hold the exact number of gr., and re-mark accordingly. To test a flask, clean and dry it thoroughly; fill the pipette to the mark with water at 17½°C, wiping the outside dry, and let the water run into the flask, blowing out the last drops. For flasks having two

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* After cleaning the flask with water, rinse it with a small amount of alcohol or ether and it will dry quickly.

graduations, determine the correctness of the lower mark as above and add immediately, with a smaller pipette, the number of cc of water for which the additional mark is made. Any flasks which are found to be incorrect by at least two tests should be re-marked.

POINTERS.

Be sparing in the use of ether. It is usually sufficient to hold the end of the ether bottle tube in the foam.

Flasks may be kept conveniently by inverting them over wooden pegs driven in the edge of the shelf over the analyst's table. The pegs should be about three inches high, about 5-16 inch in diameter, and should incline at a slight angle toward the operator.

A quarter inch glass tube six inches long may be used as a pipette for taking out the extra solution whenever, in analysis, a flask is accidentally filled above the mark.

5. Funnels and Filter Paper.—Funnels for sugar analysis should be about 3¼ inches in diameter and of either glass or hard rubber. The rubber funnel is much more serviceable, but most chemists prefer the glass funnel, as dirt or sugar can be detected on the latter more readily than on the former. The stems on funnels should not be more than half an inch long.

Filter paper should be in sheets 23 inches square. When a sheet of this size is cut into nine equal square parts, each part folded will be of the proper size for use in analysis. After folding, cut each filter paper round and of such size that the edges will not extend above the funnel. Heavy white paper is the best for sugar analysis; gray paper is much cheaper but it filters too slowly.

POINTERS.

In trimming filter papers save the scraps for cleaning polarization tubes.

When a solution filters slowly, cover the funnel with a watch glass to prevent evaporation.

Creasing a filter paper makes a solution filter faster.

6. Beakers to receive the filtrates in analysis are usually small common glass tumbers, which are lipped in the laboratory where they are employed. Tumblers of the following size will be found very convenient: Three inches high, two inches inside bottom diameter, and two and one-half inches inside top diameter. The writer has used tumblers slightly smaller than this, each measurement being an eighth of an inch less, and believes that they cannot be excelled for practical work. They each weigh about 92^{gr}. Lips are not at all necessary on beakers of this size. (See F 34.) Another good form of beaker is shown in F 31. It is 4 inches high, with a diameter of 1¾ inches at the top and of 2¼ inches at the bottom, inside measurement. One American factory tried aluminum beakers, but found them unsatisfactory as they were too hard to clean.

POINTERS.

Discard the first few drops of a filtrate.

When the filtrate of syrups and juices is too dark to be read in the polariscope, add about 1 gr. of finely powdered bone dust to the filter paper and filter again. As the bone dust may absorb a small amount of sugar, discard the first half of the second filtrate.

Beakers are more easily cleaned with cold water than with hot, on account of the lead on them. (J. E. VARNER.) They must be thoroughly dried.

7. (*a*) **Polariscopes.***—When a ray of light passes through a crystal of Iceland spar it is divided into two rays of equal intensity, one of which is called the ordinary ray and the other the extraordinary ray. The former is in the principal plane and the latter is in a plane at right angles to the principal plane. When the rays possess this

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* The explanation of the polariscope here given is necessarily very brief. The student is referred to Ganot's Physics or Landolt's Handbook of the Polariscope for a complete and clear description of the instrument.

peculiarity they are said to be polarized. Polarization may also be effected by reflection, as on water, mirrors, etc. In most polariscopes the light is polarized by means of a Nicol's prism which is so constructed that it transmits only one ray, while the other is suppressed by reflection out of the prism. The prism is placed in the polariscope so that the transmitted ray goes straight through the instrument. Two lenses are used to intensify the light from the lamp before it meets the Nicol's prism. The use of the polarized ray may be described as follows :

Polariscopes designed for sugar analysis (called saccharimeters) are based on what is termed rotatory polarization. This is the effect produced by certain substances (most notably quartz) and solutions (e. g., sugar) which have the power of rotating to a different degree the planes of polarization of the various colored rays which compose white light. To illustrate : If a thin section of a quartz crystal cut at right angles to its axis is placed so that a ray of polarized light passes through it and falls upon a mirror, the image of the quartz will appear in color in the mirror. If the mirror is on an angle and is slowly turned, the colors of the image will change and appear in the same order as is found in the solar spectrum—red, yellow, green, blue and violet. In some varieties of quartz these colors are shown in the order named when the mirror is turned to the right, and in others when it is turned to the left. Violet rotates the plane of polarization to the greatest degree and red to the least, and the extent of the rotation depends upon the thickness of the quartz plate which is traversed. Sugar solutions have the power of rotating planes of polarization, and, as in the case of quartz crystals, some solutions rotate the plane to the right and others to the left. The former are said to be dextrogyrate, as sucrose and raffinose, and the latter lævogyrate, as lævulose and sorbinose. The rotatory power of a concentrated sugar solution is only about 1–36 of that of quartz, hence the column of solution to be traversed by the polarized light must be of considerable length. The plane of the polarized light is rotated to a greater or less extent, according to the concentration or dilution of the solution. Saccharimeters are constructed so that this angle of rotation may be determined. After the polarized light passes through the column of sugar of known length it is met by a layer of quartz which has a variable thickness and can be moved either to the right or to the left, to compensate for the rotation produced by the sugar solution. This movement is effected by means of a rackwork and pinion turned by a milled head, and as the plate is moved its thickness at the point where the light passes through is measured by a scale. The thickness of a plate necessary to compensate the rotation of a definite amount of pure sugar made up in a certain way is marked as 100 on the scale, and the thickness of the plate which gives a clear view when no active substance is in the polariscope, is marked as zero. The scale is then sub-divided into 100 parts, and when a solution of sugar prepared in the necessary way, is read in the instrument, the scale not only measures the thickness of the plate which compensates for the rotation of the solution, but in doing so shows the percentage of sugar the solution contains. The reading of this scale will be described later. After passing through the movable plate the light meets a double refracting prism (usually a Nicol's prism) which is called the analyzer. This prism gives a field of vision by which the polariscopist, in reading the instrument, can tell when the movable quartz plate is in proper position. This field is circular and is divided in half by a perpendicular line. The observation of it is described in the next paragraph.

The optical arrangement of a single compensation Schmidt and Haensch polariscope,* is shown in the following figure:

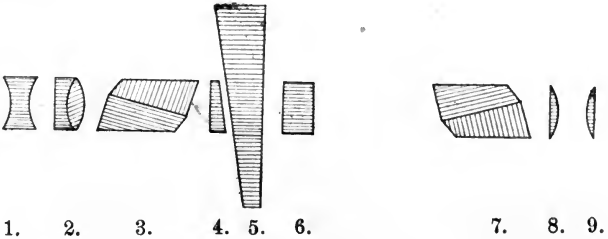

Fig. 11.

1.—Eye-piece.
2.—Objective.
3.—Nicol prism, analyzer.
4.—Quartz wedge, fixed, bearing vernier.
5.—Quartz wedge, moveable, bearing scale.
6.—Quartz wedge, having rotatory power opposite to 4 and 5.
7.—Nicol prism, polarizer.
8.—Lens.
9.—Lens.

In Fig. 12, the arrangement of the double compensation polariscope is shown. The two prisms **N1** and **N2** are of opposite rotatory power, one being dextro- and the other lævo-rotary. At **H** is the screw for adjusting the analyzer. The screw for setting the scale (see next paragraph,) is on the left side of the instrument, between the two moveable wedges. The inclined mirror above **K** is one of the latest Schmidt and Haensch improvements, and is for the purpose of doing away with a second lamp for reading the scale.

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* The Schmidt and Haensch polariscope is the only instrument described here, as it has been adopted by the U. S. Government, and most of the sugar factories in operation in this country.

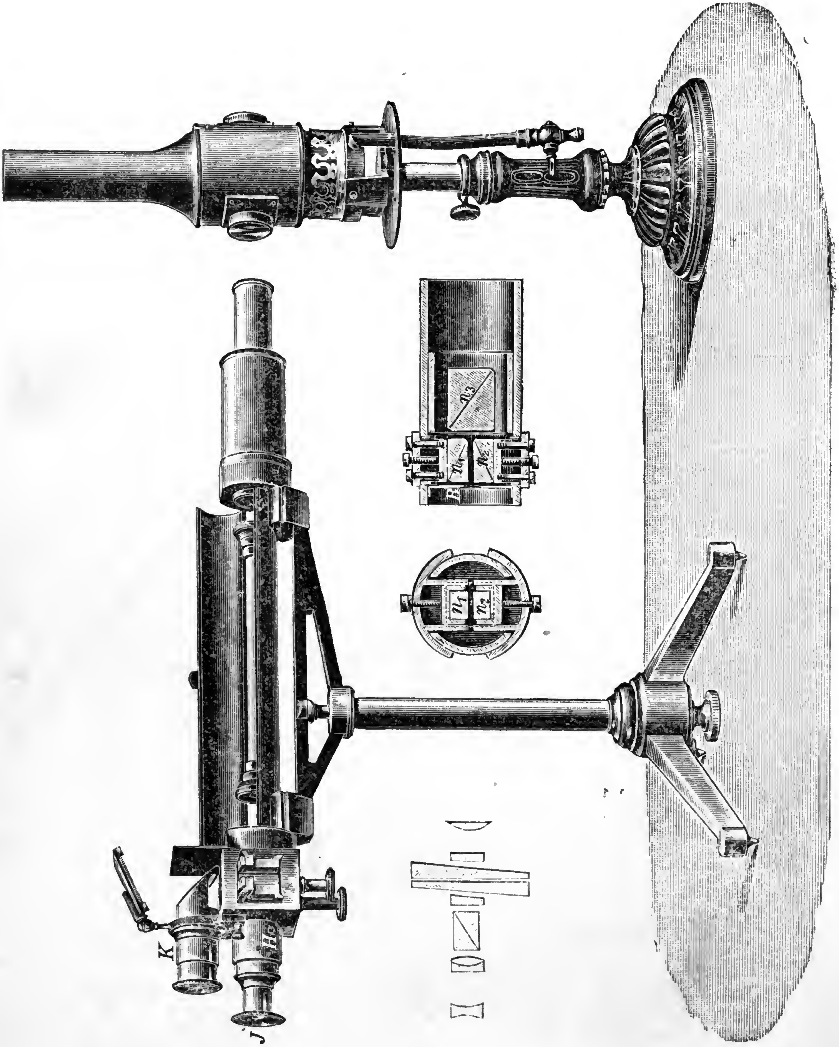

Fig. 12.

(*b*) **Operation.**—Adjust the lamp so that it gives a bright steady light. Turn the polariscope towards the lamp and look through the telescope **J.** (See Fig. 12.) A round luminous field will be seen, and the telescope should be focused by moving it in or out until the field is clear, and has a well defined line passing through the center. One side of the line may be darker than the other, but by turning the milled head which operates the moveable quartz plate the two halves of the field may be made to have an equal intensity of light.

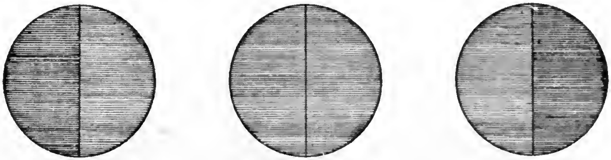
L. E. R.

Fig. 13.

In Fig. 13 **R** shows a picture of the field when the milled head must be turned to the right (the thumb of the hand moving toward the lamp) to effect neutrality, **L** a picture when it must be turned in the opposite direction and **E** shows the field when neutral.

When the vision is that illustrated in **E**, look through the reading glass **K** (see Fig. 12,) and read the scale. The small scale appearing above is called the "vernier," and its zero should exactly correspond to the zero of the larger scale below. If they are not in line, they should be made to coincide by turning the nipple, provided for the purpose. This should be done only by some one acquainted with the polariscope, as in single compensation instruments this screw is easily mistaken for the screw in connection with the analyzer.

Now fill a polarization tube with a properly prepared solution (see next paragraph,) and place it in the polariscope. Make the observation as above, bringing the two halves of the field of vision to an equal shade. Then make the reading. Find the number of whole degrees the zero of the scale has moved from the zero of the vernier. In Fig. 14 it is 29. To determine the tenths, note the point at which a line on the vernier coincides with a line on the scale. In this illustration it is at 4. Therefore, the reading is 29.4, and the solution read contains 29.4 per cent. of sugar.

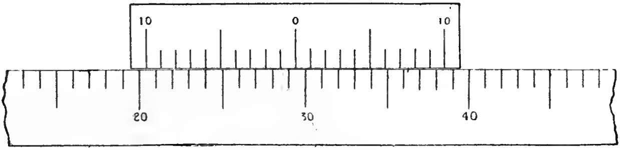

Fig. 14.

A polariscope fitted with the double compensators and two scales, gives four checks on the correctness of the reading. The upper scale and the milled head which moves it are black. The lower scale is red, and its milled head brass. In making a test, set the red scale at zero and use the black scale. Then remove the polarization tube from the instrument and make the field neutral by using the brass screw. The readings of the two scales should correspond. For an invert reading, set the black scale at zero and use the red scale.

(*c*) **Testing a Polariscope.**—No instrument should be used unless it has been found to be accurate. The examination is most easily made by means of the control-tube or quartz plates. The control-tube can be lengthened or shortened and, as a scale is attached which shows the length of the tube in millimeters, the reading which the instrument ought to give may be easily calculated. If quartz testing plates are used, their value should be determined by check analyses, *e.g.*, with cc "known sugar" solutions. Table III gives the number of gr. of chemically pure sugar which must be made up to 100^{cc} to give any desired polariscope reading. By the use of the control-tube, quartz testing plates, and "known sugar" solutions, it may easily be determined whether the instrument is correct for readings on all points of the scale. Uneven quartz wedges will make a polariscope accurate for some readings and inaccurate for others.

The accuracy of the zero point may be found by reading the instrument itself, and a solution of chemically pure sugar may be used for the 100 mark. Chemically pure sugar is prepared as follows :

> Wash a quantity of the best granulated sugar repeatedly with an 85 per cent. alcohol. Three to five times the volume of sugar is sufficient alcohol to use. After washing, dry the sugar thoroughly at 100 degrees Centigrade and keep in an air-tight jar. 26.048 grammes of this sugar dissolved in 100^{cc} of water at 17½ °C should have a specific gravity of I.IIII.

In the laboratory, a polariscope that is accurate under normal conditions may become incorrect through the influence of heat or some other cause. The instrument should be thoroughly examined at least once a week, and each chemist should read for the zero point at least twice a day, say at the beginning of each half-day. These examinations ought to be sufficient to insure its accuracy.

(*d*) **Tubes and Weights.**—The Schmidt and Haensch polariscopes are so constructed that 26.048^{gr} of chemically pure sugar dissolved in 100^{cc} of water will read 100° in the polariscope, when a polarization tube 200^{mm} long is used. In sugar analysis, when these instruments are used, 26.048^{gr} is called "normal weight," 13.024^{gr} "half normal weight," and 52.096^{gr} "double normal weight." A polarization tube 100^{mm} long is called a "half tube," and one 400^{mm} long a "double tube," the "normal" tube being 200^{mm}. Any one of these weights and tubes may be used in analysis, but it is always best to use the largest weight and longest tube practicable. All readings must be figured on a basis of normal weight and normal tube, hence if a shorter tube or a lower weight is used, the reading must be multiplied, and if a larger weight or a longer tube is used the reading must be divided. In case of an error, if the reading is multiplied the error is multiplied, and if the reading is divided the error is divided. In very dark solutions the half tube must sometimes be used, and when there is only a small amount obtainable of the solution to be analyzed, half normal weight must be used. In general the most practical combination is double normal weight and normal tube. The double tube cannot be used accurately except with very light solutions. All readings may be figured to normal by the following table:

Length of Tube Used.	Weight Used.	To Make Normal.
100^{mm}.	13.024	Multiply by 4.
100^{mm}.	26.048	Multiply by 2.
100^{mm}.	52.096	Reading shows per cent. sugar.
200^{mm}.	13.024	Multiply by 2.
200^{mm}.	26.048	Reading shows per cent. sugar.
200^{mm}.	52.096	Divide by 2.
400^{mm}	13 024	Reading shows per cent. sugar.
400^{mm}.	26.048	Divide by 2.
400^{mm}.	52.096	Divide by 4.

The continuous polarization tube (Fig. 15) may be used when a large number of solutions of comparatively the same sugar content are to be tested, as in beet analysis. A funnel is fitted to one end and a rubber tube is attached to the other, the opposite end of the tube being in a bucket on the table when the tube is in the instrument. The solution to be read is poured in the funnel, the surplus fluid going out of the tube. After reading, the next solution is poured in the funnel, and so on. The use of this tube saves a great deal of time in beet tests and the results are accurate.

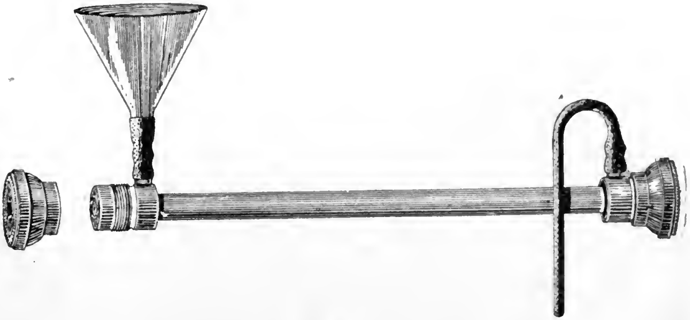

Fig. 15.

POINTERS:

The preparation and polarization of a solution should be made at the same temperature.

Readings are made more quickly when the polariscope is covered with a box, or is in a place darkened by curtains.

The lamp should be about 200mm from the end of the polariscope and the instrument should be protected from the heat by a wooden partition or screen, with an opening about ¾ of an inch in diameter for the light to pass through. (See F 44.)

When gas is obtainable, the lamp shown in Fig. 16 is a good form to use. It may be raised or lowered on the stand A. The shade B gives a concentrated light. The Students' is a good oil lamp. (See F. 38.)

Always turn the polariscope away from the light when you have finished reading. Heat affects the cement holding the prisms.

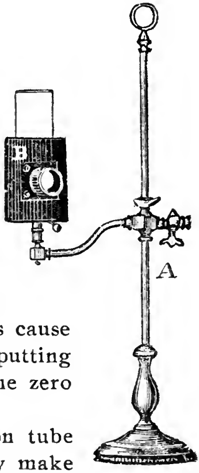

Fig. 16.

Polarization tube discs (glasses) sometimes cause inaccurate readings. They may be tested by putting them in polarization tubes and reading for the zero point.

Do not screw on the ends of the polarization tube too tight. The compression of the discs may make them double refracting, and the reading will be wrong.

Discs may be wiped off with the pocket handkerchief. It is the quickest way to clean them. A scrap of filter paper is also good.

Rinsing the tube three times is nearly always sufficient to insure its cleanliness. This, of course, means to rinse it with the solution to be read.

In every test with a single compensation polariscope, make three readings and take the average. Rest the eye for 15 or 20 seconds after each reading.

When the zero point in an instrument is .1 or .2 wrong it is unnecessary to adjust it, but a correction must be made for readings. If, instead of the polariscope showing zero, it shows .2 then .2 should be subtracted from every reading of solutions, and vice versa. Thus, if the reading is 18.6, the correct reading would be 18.4, because the polariscope shows .2 more sugar than is really contained, and if the zero point is .2 to the left then 18.6 would be 18.8, for the polariscope shows .2 less than is really contained.

Each analysist doing general work should have two or three polarization tubes, to be used for special tests. For example, a tube for only pulp and waste waters, one for cosettes, syrups, etc., and one for high tests, such as sugars and massecuites.

8. Scales.—Four different kinds of scales are necessary in beet sugar analysis. The common scale with platform and scoop is used for weighing beet samples, a druggists' balance is most convenient for weighing lime cakes, a balance having a carrying capacity of 300^{gr} and sensible to 1^{mg} is necessary for sugar analysis and specific gravity determinations, and a delicate balance with agate bearings made for a charge of 100^{gr} and sensible to $1\text{-}20^{mg}$ is used for finer analytical work. These scales are shown respectively in Figs. 26, 30, 24 and 41.

To test the sensibility and accuracy of a balance, first adjust it properly by its regulating screws. The smallest weight the balance is sensible to is placed on one scale pan and the balance must turn very distinctly. Each pan is then charged to its full carrying capacity and the small weight added again. The balance will oscillate more slowly than before, but should turn to the same extent.

Place the same weight, say 50^{gr}, on each scale pan, and if necessary adjust the scale so that the index for marking oscillations will be exactly in the middle. Interchange the weights and the balance should remain in equilibrium. Remove the weights and set the balance in slight motion. It must resume its original equilibrium. Load one scale pan and repeated weighings of it should give same result.

The regular weights used for analytical purposes and sugar weights (normal, half normal and double normal) should be verified when purchased, but if taken care of properly they are not liable to either lose or gain in weight, and need not be tested unless there is special reason to believe they have been affected. Scoops constantly lose in weight by daily use, and the counterpoise weights must be repeatedly filed down. If any weight is too light, unscrew the plug on top and insert tinfoil. If it is too heavy, file off the surplus weight.

POINTERS.

Do not touch weights with the fingers.

FRESENIUS says: "The balance ought to be arrested every time any change is contemplated, such as removing weights, substituting one weight for another, etc., or it will soon get spoiled."

A substance when hot creates a draught upward and, if weighed, its weight is less than it would be at normal temperature.

Weights should be kept in a box away from the fumes of acid, but the tarnishing coat which forms on brass weights is so extremely thin that it is of no consequence.

There is a circular spirit level on every good balance. If the bubble is not in the center, adjust the scale by the screws underneath.

Have a camel's hair brush two inches wide for dusting the wood-work around a balance.

9. Other Apparatus. — *Water and Lead Bottles.* —The siphon bottle shown in Fig. 17, is used for water and lead. The following points should be observed in making one of these bottles: Use a gallon bottle, ¼ inch glass tubing, and rubber tubing to match; have the rubber tube long enough so that when the bottle is on the shelf the lower end of the tube will be on a level with the eye; have the air-tube bent down so as to exclude dust, make the nozzle about two inches long, and for rapid work the point should not be drawn too small; and have a Mohr's pinch-cock immediately above the nozzle.

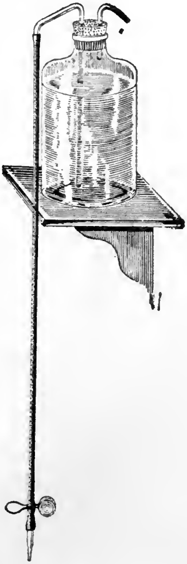

Fig. 17.

(*b*) **Acetic Acid Bottles** for lime cake analysis are made as above described but smaller. (See F. 13.)

(*c*) **Washing Bottle.**—This is shown in Fig. 18. It is a bottle of about 750^{cc} to 800^{cc} capacity, and the neck is wrapped with twine to protect the hand when hot water is used. Heavy glass tubing of 3-16 inch inside diameter may be used. The nozzle is drawn to a fine point, and a rubber tube is used to connect the siphon tube with the nozzle so that it may be turned in any direction. The air-tube should be on a plane with the nozzle as the operator can better direct the stream.

Fig. 18.

(*d*) **Burettes** for Fehling's Solution, normal acids, etc., may be placed in a burette stand like that shown in F. 20. The cheapest and very satisfactory burettes are Mohr's, for use with pinch-cocks shown in the illustration. A T-tube connection for filling burettes is shown in Fig. 19. The use of red lead or chalk, as described in **3** makes the graduations clearer. If Erdmann's floats are used with burettes, the graduation on the burette corresponding to the line on the float is the correct reading. If floats are not used, the reading is at the bottom of the meniscus (**4**).

Fig. 19.

(*e*) **Thermometers** for sugar analysis are preferably those with large enough bulbs so that they will only be about half immersed when placed in a fluid. (See Fig. 20.) They may be graduated from 0° to 130° F., or 20° to about 130°, and should be of the common kind, that do not register too quickly, as the reading might change during the time the instrument is taken from the fluid to be read.

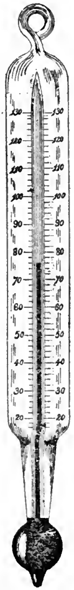

Fig. 20.

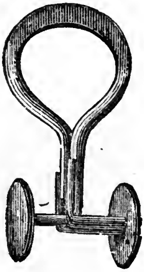

Fig. 21.

(*f*) **Mohr's Pinchcocks** — (fig. 21) are the most handy clamps for water-bottles, burettes, etc. They are made in three sizes, the middle size being the one most often used in sugar work.

(*g*) **Kipp's Apparatus** shown in Fig. 22 may be used for the generation of carbonic acid in experimenting with lime and to neutralize alkaline solutions. Limestone is placed in the middle bulb and crude muriatic acid is poured in the safety tube at the top. The apparatus may also be used for the generation of hydrogen sulphide and other gases in chemical analysis.

Fig. 22.

(*h*) **Indicator Bottles** may be either a dropping flask or an ether bottle, both of which are described in **4**. The former is preferable. Phenol is considered the most suitable indicator for sugar work.

CHAPTER II.

GENERAL METHODS OF ANALYSIS.

10. Introductory.—Nearly all sugar analyses are figured for "purity." (See **19**.) In exact analysis the "real purity" is obtained by weight, but in analysis where only approximate exactness is required, the "apparent purity" is determined by some method which combines the greatest accuracy with the quickest operation. Three of these methods are given in the following paragraphs. All are theoretically correct and it is a matter of opinion which is the most practical for general work.* The analysis by pipette is distinctly American, as is also the gravimeter method, while the volumetric method is used in Europe. For solutions having a small percentage of sugar, such as pulp and waste waters, there can be no doubt but that the volumetric method is the best, as a large amount of the solution is necessary in order to secure accurate results. Natural water is used in sugar analysis, but it should be tested to see that it has no optical activity.

The beginner is advised to read Chapter I. carefully to learn the manipulation of all the apparatus used in analysis before studying this chapter.

11. The Preparation of the Sample for analysis varies with the different substances, and is given for each one under its proper paragraph.

12. Clarification.—After the solution to be tested is measured, or is weighed out into the flask, the impurities must be precipitated to render it clear and colorless enough for polarization. This is done by the use of a sub-acetate

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* **Note.—Solutions having a brix of over 24 must be diluted, in order to make an apparent purity test by the methods here outlined.**

of lead solution. The amount of the lead to use varies with the color and impurity of the solution to be tested—but no more than is necessary should be used. In low-grade syrups 5 to 7^{cc} is often necessary, while a granulated sugar solution can be polarized without clarification. Add a few drops of the lead solution, and rotate the flask gently to mix the contents. Then let a drop flow down the neck and side of the flask; if this drop is lost upon entering the solution, it indicates that the precipitation is not complete and that more lead solution must be added, but if it can be traced after entering the solution by its clear track down the side of the flask, it shows that the clarification is complete.

The U. S. Department of Internal Revenue, in its regulations* relative to the bounty on domestic sugar, gives the following: "The use of sub-acetate of lead should, in all cases, be followed by the addition of 'alumina cream' (aluminic hydrate suspended in water), (†) in about double the volume of the sub-acetate solution used, for the purpose of completing the clarification, precipitating excess of lead, and facilitating filtration. In many cases of high grade sugars, especially beet sugars, the use of alumina alone may be sufficient for clarification without the previous addition of sub-acetate of lead."

In ordinary work it is not generally considered necessary to use any other clarifying agent than lead acetate. The precipitate given by the lead solutions causes a very

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* U. S. Internal Revenue, Series 7 to 17, Revised.

† See paragraph 128 for preparation of "Alumina Cream."

slight error in polarization, on account of its volume. In the presence of this precipitate the fluid tested is not actually diluted up to 100^{cc}, but to 100^{cc}, minus the volume of the precipitate. In beets this error is about .17 per cent., and in diffusion juice, .27 per cent., while in green syrup it is estimated to be as high as .63 per cent.‡ This refers to tests made by the volumetric method.

When invert sugar is present a serious error very often result by the formation of lævulosate of lead, which is a salt of low specific rotary power, and sometimes the left-hand rotation is almost, if not entirely, destroyed. (G. L. SPENCER.) The addition of enough acetic acid to give the solution an acid reaction will prevent this error.

13. Filling the Flask.—After the addition of sufficient lead solution, the flask is filled to the proper mark and is well shaken, the thumb being placed over the top of the flask In nearly all cases the solution should stand for from 5 to 10 minutes before being filtered. When it is known that there is only a small amount of sugar contained this is unnecessary, and in beet, cossette, and diffusion juice tests if allowed to stand the solution soon becomes too dark to polarize.

14. The Volumetric Method of analysis is used in Europe for determining all "apparent purities," but in the United States it is generally used only for solutions containing a very small amount of sugar such as pulp and waste waters. A flask graduated to 100 and 110^{cc} or to 50 and

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‡ See Tucker's Manual of Sugar Analysis, third edition, page 166.

55^{cc} is rinsed with the solution to be tested, and is then filled with it to the lower mark (50 or 100). Add sufficient lead acetate to precipitate the impurities and fill to the higher mark (55 or 110) with water. Filter and polarize a part of the filtrate in a 200^{mm} tube. The reading multiplied by *.286 was formerly taken to show the percentage of sugar in the solution, but this multiplication is now divided by the specific gravity as the increase in density lowers the specific rotatory power of the sugar.

Table V. may be used for determining the per cent. sugar from the polariscope reading. For example, the brix of a solution is 16.5 and the temperature correction .3, making the corrected brix 16.8, and the polariscope reading is 33.6. By referring to the table we first find at the top of the page, the degree brix 17.0 as it is nearest to 16.8. In the column under 17 we find the line of polariscope degree 33, as it is the whole degree of the polariscope reading obtained, and the percentage of sugar given is 8.82. The tenths obtained is 6, and at the side of the table under "degree brix from 12.5 to 20.0," we find .6= .16. Adding .16 to 8.82 gives 8.98, the percentage of sugar in the solution tested. The per cent. sugar is divided by the brix and multiplied by 100 to give the apparent purity, 8.98 ÷ 16 8 x 100 = 53 45, apparent purity.

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* A polariscope is made for 26.048 gr. of a solution made up to 100cc to show the percentage of sugar it contains, and if a solution containing 26.048 per cent. of sugar is read directly in the polariscope, the instrument will show 100 per cent. Hence each reading of 1 shows .26048 per cent. of sugar. When a solution is diluted 10 per cent. to allow for lead acetate (as above,) each reading of 1 will show 10 per cent. more than .26048 or .286 in round numbers.

15. The Pipette Test is made as follows: Carefully take the brix and also the temperature of the solution to be tested. Fill the pipette to the graduation corresponding to the reading of the brix. (**3**.)† Drop the solution into a 100^{cc} flask and wash the pipette, as described in **3**. Add enough lead acetate to the flask to precipitate all impurities and leave a clear fluid above. Then fill to the mark with water. After filtering, fill a 200^{mm} tube with a portion of the filtrate, and polarize. Divide the reading by two, as the pipette contained double normal weight. The per cent. of sugar thus obtained, divided by the brix, with the temperature correction and multiplied by 100, will give the apparent purity.

16. The Gravimeter, invented by W. K. Gird, is a mechanical device by which the solution is measured off and placed in the flask by the operation of taking the density. It is based on the principle that a substance immersed in a fluid displaces its own weight of the fluid. The following explanation of the apparatus was prepared for "Beet Sugar Analysis" by the inventor.

"In the illustration (Fig. 23) A represents the main tube, to hold the solution under treatment; B, overflow pipe; C, air vent, to prevent siphonage, constructed in funnel form, to facilitate cleaning; D, an index finger pointing to the saccharometer, constructed so as to swing out of the way when necessary, and to stand, for convenience of reading, say five graduations above the surface of the fluid; E, saccharometer, weighing exactly $.26048^{gr}$. and F, point of discharge into the flask; G, drip funnel; and H is cock for letting out the fluid from A.

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† Finding the per cent. sugar is done by weight, hence it is not influenced by temperature, and the uncorrected reading of the brix is drawn into the pipette.

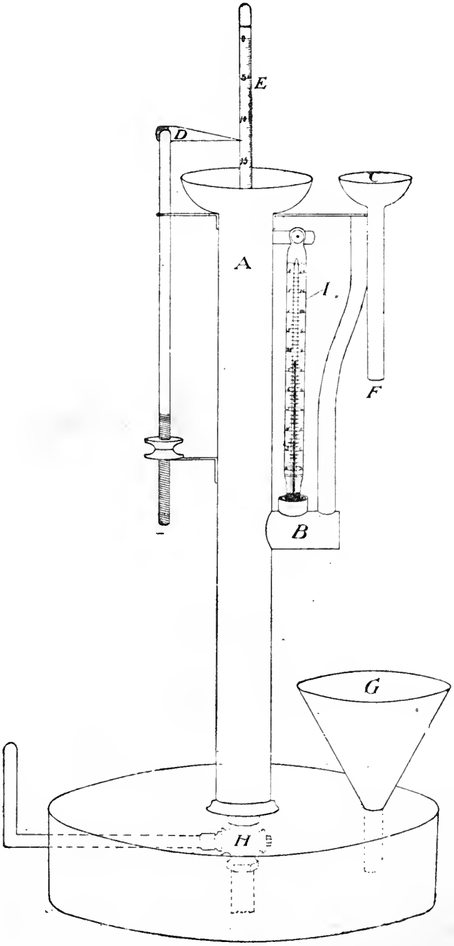

Fig. 23.

The operator closes the aperature F with his finger and fills the main tube with the solution until it shows full at C. Skimming off the foam from the top of the main tube, he removes his finger and permits the excess to escape to the last drop, which must be removed. This will leave the tube B moistened with the fluid under analysis so that the condition will be left precisely the same as it will be after the delivery of the discharge hereafter explained. There can be no loss or no gain, either in quantity or quality. Next, place a 100^{cc} flask under the overflow F and insert the saccharometer in the usual manner, letting it go down slowly until it floats free. The fluid will come out at E; bring up the mouth of the flask so as to catch the last drop. The fluid in the flask will now weigh exactly *e. g.* 26.048^{gr}, being the quantity displaced by the saccharometer having that weight. Now, bring the point D to the index on the saccharometer and note the reading, to which add (10), representing the height of the finger above the surface."

The solution in the flask is cleared with lead acetate, filtered and the filtrate polarized in a 200^{mm} tube, the reading giving the direct per cent. sugar. In taking the brix, note the temperature on the thermometer I, and divide the per cent. sugar by the corrected brix and multiply by 100 to find the apparent purity.

The principal source of error in using the gravimeter is in having saccharometers incorrect in weight. Either normal or double normal weight instruments may be used, but it is difficult to make them exact. Another error to guard against is allowing the saccharometer to sink down too far. This is simply a matter of care, and can be easily avoided. The gravimeter may be used for solutions having a medium and low brix, but is hardly adapted for thick juices and syrups.

17. Analysis by Weight is usually made where great accuracy is required, and sometimes it is necessary when only a small amount is obtainable of the substance to be analyzed. For thin solutions and beets take double normal weight, but for thick solutions and massecuites which are not so easily dissolved, use normal weight. Half normal weight is used when only a small sample is to be had. The substance to be tested is carefully weighed in a tared scoop and then washed from the scoop into a 100^{cc} flask, or with beets, into the special beet flask. The scoops best suited for this method of analysis are of German silver, with long lips. (See F. 18.) After the substance is all in the flask, clear with lead acetate, fill to the mark, filter and read. In solutions where the purity by weight is to be determined, the specific gravity is found (**2a**) and the per cent. sugar is divided by the degree brix which equals the specific gravity obtained. This is multiplied by 100. In the analysis of massecuites, and sometimes of solutions, the dry substance is found (**2c**), the division of the per cent. sugar by

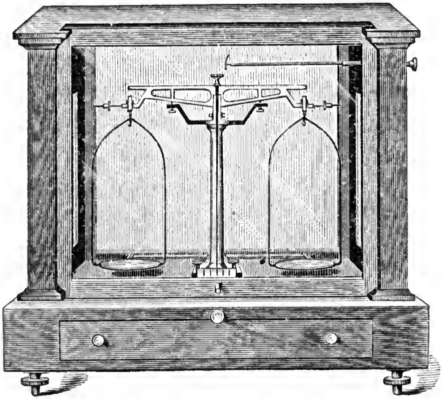

Fig. 24.

the dry substance, and multiplying by 100, giving the real purity. Fig. 24 will show the kind and quality of balance suited for weighings in sugar analysis.

Examples :

Per cent. Sugar found by weight, — 75.1.
Per cent. Dry Substance, — 85.3.
75.1 ÷ 85.3 x 100=88.0+, the real purity.
Per cent. Sugar found by weight — 50.0.
Specific gravity, 1.4375 or 83.2 Brix.
50.0 ÷ 83.2 x 100 = 60.09 or 60.1, purity by weight.

18. Non-Normal Analysis.—It rarely, yet sometimes happens that some other weight than normal or half-normal weight must be taken for polarization. In this case the substance is carefully weighed out, dissolved and made up to 100^{cc}, with the addition of lead acetate, and polarized in a 200^{mm} tube, the per cent. of sugar being calculated according to the formula

$$\frac{P \times 26.048}{W},$$

In which P represents the polarization and W the weight used.

Example :

A sample of 11 gr. of a massecuite is weighed out and polarized, the polarization being 36.8. According to the formula

$$\frac{36.8 \times 26.048}{11} = \frac{958.57}{11} = 87.14, \text{ per cent. sugar in sample.}$$

19. Quotient of Purity is the percentage of sugar contained in the total solids. It is always spoken of simply as "purity." The only exact method for determining the quotient of purity is described in **17**, and is called the "real purity." The "purity by weight" described in the same paragraph is considered in some factories to be sufficiently exact for syrup analysis. The "apparent purity" (**14**, **15** and **16**,) is used for nearly all analyses in the chemical control of the daily run of factories. It is not exact, as the Brix saccharometer is used for determining the total solids, and this instrument is based on a scale which assumes all the solids to be pure sugar. The presence of other solids in an impure solution makes the brix reading too high and the purity consequently too low. It is not affected alike by all impurities*, hence its inaccuracy varies, but the purity found is usually from 2 to 4° lower than the real purity. After obtaining the per cent. sugar and the degree Brix, the apparent purity can be determined by the use of Table VI.

20. The Value Coefficient is used by some European factories in the purchase of beets, the price paid being according to the coefficient. It is also used to some extent in determining the value of juices in factory work. The formula is

$$\frac{\text{Sucrose x purity}}{100} = \text{value coefficient.}$$

21. The Saline Quotient is considered by French chemists to show how near a substance is exhausted of crystallizable sugar. The superintendents of French factories pay more attention to it than to purity ; in fact, they practically neglect figuring on purity bases (E. E. BRYSSELBOUT). Some chemists consider it of especial value to new factories in the study of beets and juices. The formula is:

$$\text{Per cent Sucrose} \div \text{per cent. Ash} = \text{Saline Quotient.}$$

For the analysis of ash see **34b**. Determine the sugar by weight.

22. The Rendement is a formula for determining the amount of refined sugar that can be made from a substance or solution. It is :

$$\text{Per cent. Sucrose} - (\text{per cent ash x } 5) = \text{per cent. refined sugar.}$$

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* See Tucker's *Manual of Sugar Analysis*, 3rd edition, page 112.

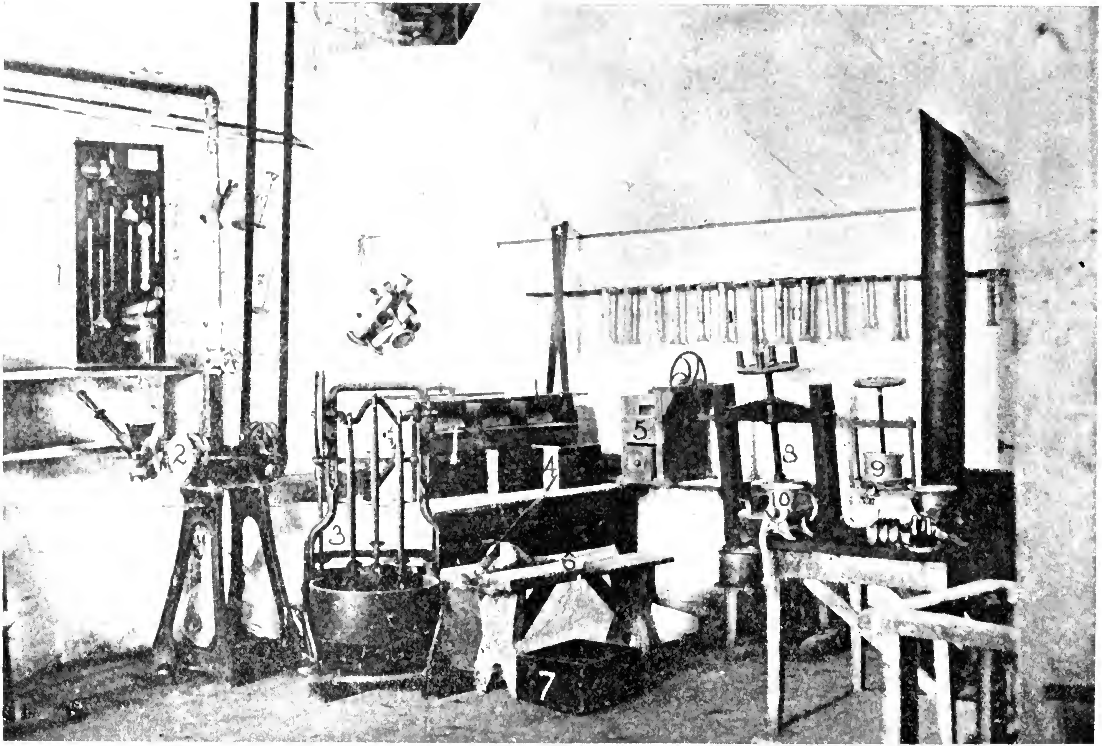

Fig. M.

Apparatus in M.

1.—Apparatus for testing CO_2 in gas.
2.—Kiehle machine for beets and cossettes.
3.—Meat chopper for cossettes.
4.—Power grinder for beets.
5.—Hand grinder for beets.
6.—Beet block and knife.
7.—Beet box for beet samples.
8.—Press for obtaining juice from beets or cossettes.
9.—Press for pulp.
10.—Hand grinder for pulp.
11.—The same in parts.

CHAPTER III.

INDIVIDUAL SUGAR ANALYSES.

23. (*a*) **Beets.** — A bushel basket full of beets is taken as a sample from each wagon, or samples from two or three wagon loads (from the same farmer) may be tared and analyzed as one sample. The sample is dumped on the floor in one pile and mixed. From this pile the "tarer" takes a sample weighing 50 pounds, using a shovel to take the beets from the floor. The beets are cleaned thoroughly in a washing machine and are then tared by cutting off the tops squarely at the point where the first leaves have grown (see Fig. 25.) All hairs are scraped off, and all roots that are ¼ of an inch, or less, in diameter, are removed. The sample is then reweighed and the difference between its weight and 50 pounds, multiplied by 2, gives the per cent. of tare. Twenty average beets are then taken from the sample to test in the laboratory. They are weighed (preferably with metric weights) and the average weight is recorded. The common platform scales with scoop are used in weighing. Each beet is then cut perpendicularly as equally as possible, into four parts, and one of the quarter sections of each beet is taken to make up the sample for analyzing. The

Fig. 25.

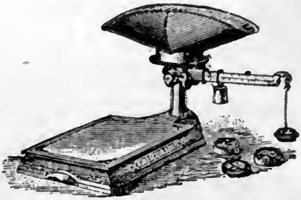

Fig. 26.

beet block and knife used for this purpose are shown in **m6**. There are a number of machines constructed for cutting out certain parts of the beets which are considered to give the best average sample, but the above method is very practical, being both rapid and accurate.

(*b*) The sample is grated up similarly to horse radish and the juice from the pulp thus obtained is squeezed through a cloth by pressure. The grater and press generally used are shown in **m4** and **m8**. The cylinder of the grater should make about 500 revolutions a minute. After being grated up the sample is in a box (**m4**) and is dumped upon a clean, dry cloth. The edges of the cloth are then folded together. placed in the press and pressure applied. The juice flowing out should be received in a bucket which is clean and dry inside. All the juice possible should be squeezed out. From the bucket a portion of the juice is poured into a cylinder very carefully, so as to make as little foam as possible, and is allowed to stand as long as may be necessary (from 10 to 20 minutes), to let all the bubbles of air come to the top. Skim off the foam with a spoon and analyze by either the volumetric method or pipette test. The use of too little or too much lead will give a dark solution after filtering. The continuous polarization tube described in **7d** is of especial value in beet work when a large number of samples are to be tested, and is as accurate as the ordinary tube when used properly. The per cent. sugar is figured into apparent purity. On account of the fibre in the beet the per cent. of sugar is less than is found by analysis to be in the juice. The sugar in beets is usually considered to be 95 per cent. of the sugar in juice, but in dry years it is often taken as 94 per cent. For determining the amount of fibre in beets see (**f**) of this paragraph. The analysis of the beet may be recorded in this way:

Average weight	348 gr.
Brix	19.1.
Per cent. Sugar in juice	15.4.
Per cent. Sugar in beet (95 per cent)	14.6.
Purity	80.6.

(*c*) **Water Digest.**—A flask is especially made for this test, being graduated to 201.4^{cc} and 221.4^{cc}. It is the same as a 200^{cc} plus 20 per cent. flask with 1.4^{cc} allowed for the fibre in the beet. Grind the beets to be tested as fine as possible. Weigh out double normal weight and wash into flask using an amount of water which will bring the contents of the flask up to a volume of about 180^{cc}. Add 5^{cc} of lead acetate and heat in a water bath at 75°C. A stick about eight inches long and slightly thicker than a lead pencil may be placed in the flask to use in pushing down any foam that may rise. The length of time required for heating varies according to the way the beets are ground. MR. E. TURCK and the author in a series of experiments found that the beets ground with a horse radish grater had to be heated for 45 minutes to give accurate results, while beets crushed to an exceedingly fine pulp in a specially made machine (the Kiehle) could be thoroughly diffused in 15 minutes. After heating sufficiently, cool to 17½°C and make up to the 201.4^{cc} mark. Very often in this test it will be found necessary to fill to the upper mark, in which case deduct 10 per cent. of the reading. When the lower mark is used, the reading in a 200^{mm} tube shows the per cent. of sugar in the beet.

This test may be made as above in a 100^{cc} flask, but the foam which usually forms make the operation more difficult than with the larger flask. It is also slightly less accurate as no provision is made for the fibre in the beet.

(*d*) **The Alcohol Extraction** is considered by many chemists to be the only exact method for determining the percentage of sugar in beets. The apparatus for this analysis is shown in Fig. 27. A wide-mouthed 200^{cc} flask containing 150^{cc} of ~~80~~ per cent. alcohol is placed in a water bath, which is well covered. The top of the flask is connected by a rubber stopper with an extraction apparatus, preferably the Sickel-Soxhlet which is shown in the illustration. Into the cylinder **A** of the apparatus is placed 52.096^{gr} of the sample which is prepared in the same way as the sample for the water digestion. The cylinder should be of such size and so made that the substance to be tested does not come higher than the upper turn of the siphon **D**. The sample may be washed into the cylinder with alcohol, and more alcohol added until the fluid comes up in **D** to the upper turn. A Liebig condensor is now attached to the upper part of the extraction apparatus by a rubber stopper and some suitable arrangement made to keep a flow of cold water through the condensor. This can be done by siphonage, as shown in the illustration. Heat is now applied and the alcohol distilled. The gas passes up through the tube **C** to the condensor, where it is condensed, and falls into the tube **A**, going back to the flask through the siphon **D**. This distillation and redistillation is kept up until the fluid coming back through the siphon is colorless. The length of the operation varies, but is usually about two hours, and the fluid in the apparatus goes back about four times. When finished, the flask is separated from the apparatus and cooled. About 4^{cc} of lead acetate are then added and the contents made up to the mark with alcohol. Shake well, filter with precautions against evaporation, and polarize, the reading being the per cent. sugar in beet.

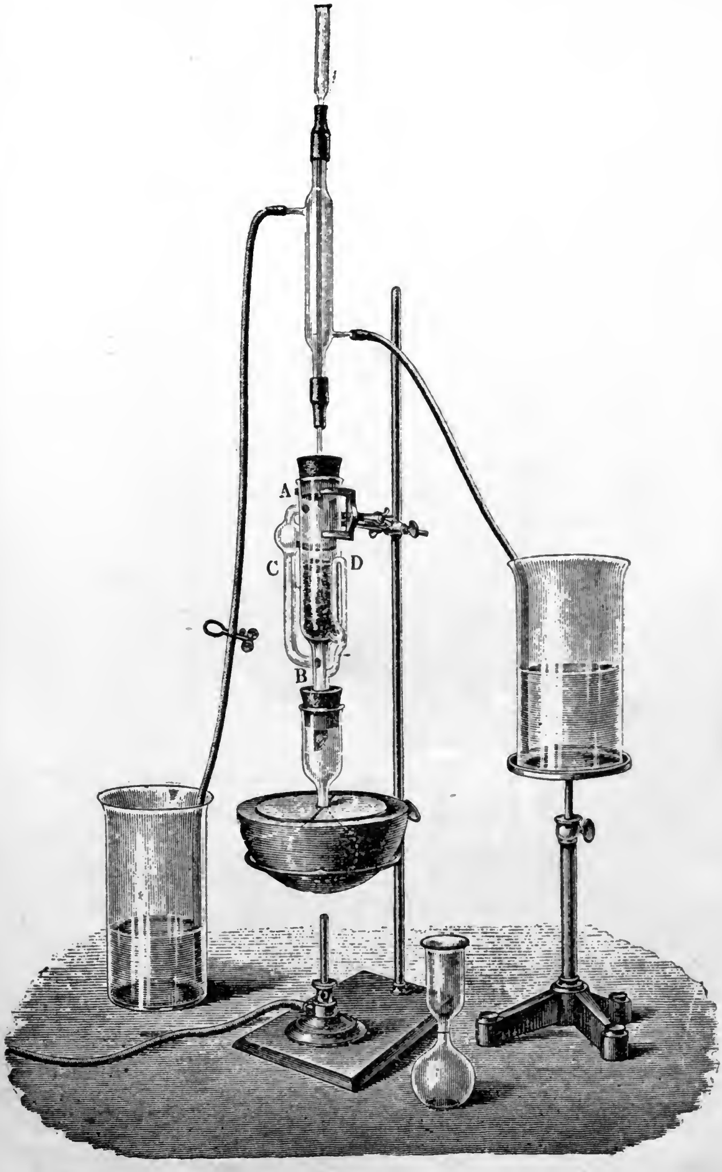

Fig. 27.

(*e*) **Alcohol Digest.**—This is made the same as the water digestion, alcohol being used instead of water. Care must be taken to prevent evaporation of the alcohol. It may be avoided by slanting the flask in the water bath and connecting to the top of the flask by a rubber stopper, a straight glass tube 1^{cm} in diameter and about 65^{cm} long, the tube acting as a condensor (Fig. 28.)

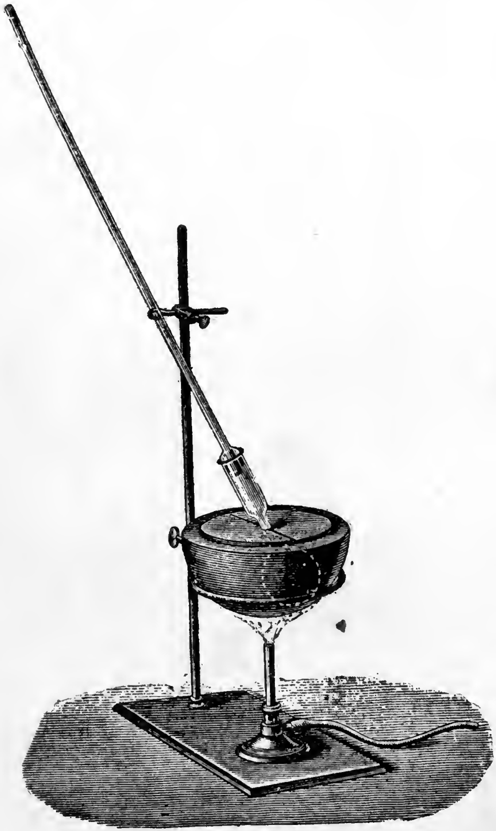
Fig. 28.

(*f*) **The Fibre in Beet** is usually determined indirectly by a comparison of the tests of sugar in beet by the alcohol extraction, and of sugar in juice by the volumetric or pipette method. A large sample is ground up and well mixed and is then divided, a smaller portion being used for the alcohol digest and the larger portion for the juice test, the juice being pressed out and tested as in *B*, dividing the per cent. sugar found to be in the beet by the per cent. sugar in the juice, the ratio of the sugar in beet to sugar in juice is found. This percentage subtracted from 100 will give the percentage of fibre.

Example :

Per cent. sugar by alcohol digest = 15.2.
Per cent. sugar found in juice = 16.1.
15.2 ÷ 16.1 = 94.4 per cent.
100—94.4 = 5.6, the per cent. of fibre.

A direct determination of the fibre may be made by taking the residue remaining in the cylinder **A** (Fig. 20,) after the alcohol extraction*, and drying first at 90°C and finally at 100°C to constant weight. The weight of the residue divided by 52.096 and multiplied by 100 will give the per cent. of fiber. This is Scheibler's method.

(*g*) **Beets in the Field.**—When a beet is young the weight of the leaves is proportionately much greater than that of the root, but as the plant grows the difference becomes gradually less until at maturity the condition is reversed and the root weighs much more than the leaves. The knowledge of the relation between the roots and the leaves is of value to the agriculturist in many ways, one indication being that an increase in the proportion of roots is an increase in the contents of sugar. Hence, in testing beets before maturity, a record should always be made of the weight of the roots and of the tops, the relation of the roots to the total weight being calculated by dividing the

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* To be sure that all soluble matter is extracted, the residue should be washed with ether.

former by the latter. The leaves are cut off squarely at the point where the first leaves have grown, as shown in Fig. 25.

Example :

Four beets are tested, the leaves of which weigh 2324^{gr} and the roots 1828^{gr}.

$2324^{gr} \div 4 = 581^{gr}$, average weight of leaves.
$1828^{gr} \div 4 = 457^{gr}$, average weight of roots.

$\frac{457}{(581 + 457)}$ $\frac{457}{1038}$ = .44 or 44 per cent., proportion of roots to total weight. In recording the analysis, the average weight of the leaves and the roots and the proportion of roots to total weight are written first, the results of analysis (as in *B*) following.

24. Cossettes.—The diffuser takes a small sample (handful) of cossettes from each cell as the battery is being filled, placing it in a large can with a closely fitting top. This can when full contains the laboratory sample.* After mixing thoroughly, the sample, or a portion of it, is chopped to a fine pulp with a sausage-meat cutter (**m3**) or some similar machine. After being reduced to fine particles the sample is again thoroughly mixed and a small portion is taken for the determination of the per cent. sugar in the cossettes. This is done either by the water digest (**23c**) or the alcohol extraction (**23d**). The juice is squeezed out of the remaining portion and is analyzed the same as beet juice (**23b**). In laboratories possessing the Kiehle machine (**m2**,) the portion for direct sugar in cossettes can be ground up separately in this machine. In many factories this latter analysis is the only one made of cossettes.

25. Wet Pulp.—The sample is taken as the pulp comes from the diffusion battery. It should be well-mixed,

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* In hot countries the can of samples should be emptied in at least two hours after the first sample is put in, on account of the danger of fermentation.

not all being taken from the same place, and should be picked up with the hand so that a surplus of water is avoided. Large chips of beets are sometimes mixed with the pulp, and care should be taken that none of these are in the sample. The sample is mixed thoroughly and is ground up in a hand sausage machine (**m10**,) after which the liquid is pressed out through a cloth. The usual press is shown in **m9** and in Fig. 29. Both the grinder and the press should be at some distance from the machine used in preparing beet and cossette samples. The analysis of pulp is very important, and the slightest addition of sugar from a foreign source would cause an error. The liquid pressed out as above is analyzed by the volumetric method, a 100–110^{cc} flask being used. Table IV. is prepared especially for pulp analysis and it should be tacked up in a convenient place in the laboratory.

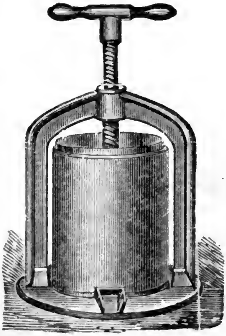

Fig. 29.

26. Pressed Pulp.—Take a somewhat larger sample than is used in the wet pulp analysis described in the above paragraph and proceed in the same way.

27. Waste Water from the diffusion battery can usually be tested by filtering a small quantity into a beaker and reading in the polariscope. When read directly in this way multiply the reading by .26 (see **14.**) Sometimes the addition of a small pinch of common salt will make a clearer filtrate. If the water is too dark to be read without clearing with lead acetate, make the analysis by the volumetric method and use Table IV. for determining the per cent. sugar. The disposal of waste water varies so greatly in different factories that no directions can be given for taking the sample.

28. Diffusion Juice.—From each measuring tank full of juice 50^{cc} are taken and placed in a bucket to make up the sample for analysis. In warm countries there is danger of fermentation if the sample stands too long. The addition of definite volumes of lead acetate, or common salt, or carbolic acid, are sometimes recommended to prevent this fermentation. None of these are satisfactory, as no accurate correction can be made, either for the influence of the foreign matter on the brix or on the polariscope reading. The best method is to empty the sample and make the analysis before it has had time to ferment. The juice will keep longer if the bucket is uncovered. Analyze by either the pipette or volumetric method and make purity. The same precaution as in beet analysis must be observed in regard to the use of too little or too much lead.

29. Lime Cakes.—There are two methods employed for determining the per cent. of sugar remaining in lime cakes, the water test and the acetic acid test. Samples are usually taken from several filter presses and mixed together as one sample. When the cake is hard and firm a sample taken from any part of the press is an average of the whole press. Theoretically in center-feed presses there is more sugar

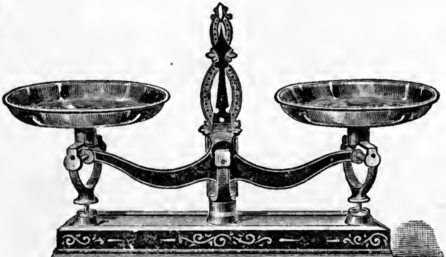

Fig. 30.

contained in the outer edges of the cake than nearer the center, and the opposite is theoretically true in side-feed presses. When a sample is taken it should be kept covered until analyzed to prevent evaporation of the water. Fig. 30 is the most convenient scale for weighing.

(*a*) **Water Test.**—Weigh out 25^{gr}* of the cake taking a small portion from each sample. Put in a shallow porcelain mortar (F 12 or Fig. 31,) add about 15^{cc} of hot water and mix thoroughly. Transfer to a 100^{cc} flask, washing the mortar with about 75^{cc} of water. Add 2 or 3^{cc} of lead acetate and heat slowly to about 95°C. Cool, make up to 100^{cc}, filter and polarize. The reading is the per cent. sugar contained.

Fig 31.

(*b*) **Acid Test.**—Weigh out 25^{gr} as above. Transfer to a porcelain mortar and add enough water to make a thick paste, using a pestle to thoroughly dissolve the lumps. Neutralize with acetic acid, using phenol as an indicator. Add the acid carefully to prevent foaming over. Pour into a

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* If normal weight were made up to 100cc the dilution would be insufficient on account of the insoluble matter in the lime-cakes. The amount of the insoluble matter varies with the condition of the cake, but for normal weight of good hard cake is taken as 4cc. Hence the dilution is up to only 96cc instead of 100cc. By taking 25gr (96 per cent. of normal weight) an allowance is made for the insoluble matter and precipitate. It could also be accomplished by making normal weight up to 104.2cc.

100^{cc} flask, add a few cc of lead acetate and make up to the mark with water. Then filter and read, the reading being the per cent. sugar contained.

30. Thin Juices of all kinds may be tested by either the volumetric or the pipette method. In factories using the Steffens' process there is a hydrate juice which contains a great deal of lime. It should be neutralized with carbonic acid gas and filtered before being analyzed. If gas used in the factory is employed for neutralizing, it should pass through some condensing chamber which will free it from water. The juice may be neutralized in a glass cylinder, phenol being used as an indicator. In analyzing thin juices, after the addition of lead acetate, make up to the mark, shake well and let stand about five minutes.

31. Sweet Waters are tested in the same way as thin juices, and when distinctly alkaline are neutralized by carbonic acid gas and filtered before analyzing, as in **30**. The volumetric method is generally employed in analysis of sweet waters on account of their low sugar content, a $100–110^{cc}$ flask being used.

32. Thick Juice is usually tested for its apparent purity and purity by weight. For the apparent purity take a large tumbler half full of the juice and dilute by the addition of water. When in thorough solution transfer to a glass cylinder and make the pipette test, or analyze by volume. For the purity by weight use normal weight and transfer to a 100^{cc} flask. It is best to mix the juice thoroughly with water in the scoop, as it can be poured more easily into the flask and can be cleared more readily with lead acetate. After precipitating the impurities, fill to the mark, shake well, and let stand about 10 minutes. Divide the polariscope reading by the brix obtained by pycnometer method to find the purity by weight.

33. Syrups.—Samples may be taken from a tank or from the trough leading away from the centrifugal machines, but should never be taken directly from the spout of a machine, except in very special cases. In case the latter is necessary care should be taken to get a fair sample. There are often drops of almost pure sugar on the end of the spout; avoid them. Mix every sample thoroughly with the hand before it is analyzed. No instrument is equal to the fingers in mixing the tiny grains of sugar with the rest of the sample.

Syrups are tested for apparent purity or for purity by weight and real purity. For apparent purity use a large tumbler; fill about one-third full with the syrup and dilute with water. Dissolve the syrup as much as possible by stirring. Let stand for a minute, pour off the fluid at the top into a glass cylinder and add more water to the tumbler. Completely dissolve the remainder of the syrup and transfer to the cylinder, washing the tumbler perfectly clean and adding the washings to the cylinder. In this operation care should be taken to not spill any of the solution from the time the syrup is put in the tumbler until the solution has been well shaken in the cylinder. The solution should brix from about 18 to 20. Apparent purity may be made volumetrically or by pipette. For purity by weight all the air must be driven from the sample to be analyzed. This is effected most easily by the apparatus shown in F 26. A glass funnel (sugar size) with a stick fitting water-tight in the stem is placed in a common tin can half filled with water. The stem of the funnel should be about half an inch above the top of the water. Fill the funnel nearly full of the syrup to be analyzed and place the can over a burner or stove, letting the water heat without boiling until all the air in the syrup has been driven to the top. A funnel with a ground glass stop cock may also be used. Cool to normal temperature. The funnel can now be placed in the ring of an iron lamp-stand and the syrup will flow from the stem by raising the stick. Discard the first 5^{cc} as it may contain a small amount of water from the bottom of the stick and the stem of the funnel. Let that which follows flow into a pycnometer, and when a sufficient amount has been obtained stop the flow by shutting down the stick. Determine the brix by comparison with the sp. g. obtained by the pycnometer. After the specific gravity has been taken the syrup in the pycnometer can be used for weighing to obtain the per cent. sugar. Weigh out normal weight, dilute with water and make a solution in the scoop; transfer to a 100^{cc} flask, washing out the scoop thoroughly. After clearing with lead acetate, fill to the mark, and let stand for about ten minutes. For the real purity determine the dry substance, as in **2c**, and make the sugar by weight as above dividing the per cent. sugar by the per cent. dry substance.

34. (*a*) **Massecuites and Sugars** are tested for apparent purity and real purity. In either case take the sample in a small pan and mix thoroughly with the hand, being careful to crush all the lumps. The "tryer" is used when possible in taking samples. This instrument resembles the half of an inch steel pipe cut longitudinally and sharpened at the end. Insert the "tryer" in the massecuite or sugar to be sampled, rotate it completely, and withdraw. In cold weather sample cans brought in should be allowed to attain the temperature of the room (WIECHMANN). For the apparent purity a solution must be made in the same way as syrups. Dissolve every grain of sugar in the tumbler before transferring to the cylinder. Massecuite dissolves very much more readily in hot than in cold water and in laboratories where ice is obtainable the quickest method is to dissolve the sample in boiling water and then cool to normal temperature with ice. This is particularly valuable in testing samples taken from the vacuum pan to see if the strike is ready to be dropped. Make the apparent purity by volumetric method or pipette test. For the real purity make the dry substance (**2c**) and determine the sugar by weight. Use normal weight and dissolve as much as possible in the scoop with hot water. Pour the fluid, but no grains of sugar, into a 100^{cc} flask and add more warm water to the scoop. Dissolve the remaining grains and wash into the flask. A glass rod flattened out at one end should be used in effecting this solution. Cool to normal temperature, clear with lead acetate and make up to the mark. Shake well and let stand several minutes (about 6 or 8.) Filter and read, dividing the reading by the per cent. of dry substance to find the real purity.

(*b*) **The Full Analysis** of massecuites usually comprises the folowing :

Apparent purity.
Real purity.
Per cent. sugar.
Per cent. water.
Per cent. mineral matter (ash.)
Per cent. organic matter.

The first three are found according to the above paragraph, and the water is 100—the dry substance. To find the ash weigh about 3^{gr} in a tared platinum dish and add about 20 drops of sulphuric acid. This is done to make the massecuite yield sulphate salts instead of carbon salts as the latter burn away and the former do not. Burn the massecuite until it gives a white ash. Heat gradually at first to prevent the substance from rising suddenly and going over the sides, but as soon as the water has been driven off, burn over an exceedingly hot flame. After burning, cool in a dessicator and weigh. The weight of the ash divided by the weight of the massecuite used will give the per cent. of the ash. The addition of the sulphuric acid causes an error, making the ash weigh more than it would if the natural carbon salts were present. This error is generally accepted to be 10 per cent. and is so figured.

Example :

Weight of dish and massecuite.	18.615 gr.
Weight of dish	15.597 gr.
Weight of massecuite used	3.018 gr.
Weight of ash and dish	15.763 gr.
Weight of dish	15.597 gr.
Weight of ash	.166 gr.
Ten per cent. for sulphuric acid error	.017 gr.
Correct weight of ash	.149 gr.

.149 ÷ 3.018 = .049 = 4.9 per cent. of ash.

The organic matter of a massecuite is 100 less the sum of the per cent. sugar, the per cent. water and the per cent. ash.

Example :

Total in massecuite		100.00 per cent.
Sugar	80.6 per cent.	
Water	9.45 "	
Ash	4.9 "	94.95 "
Organic matter		5.05 "

The following are two results obtained from average pans in two American factories:

Apparent purity	85.3	82.9
Real purity	88.9	85.4
Per cent. sugar	80.5	78.2
Per cent. water	9.05	8 5
Per cent. ash	4.5	6.6
Per cent. organic matter	5.95	6.7

CHAPTER IV.

LIME, ALKALINITIES AND SATURATION GAS.

35. (*a*) **Lime** is analyzed for its percentage of CaO. Weigh out one gr. of a finely powdered average sample, transfer to a porcelain dish and neutralize with a normal acid. Either Nitric, Sulphuric or Hydrochloric acid may be used in a normal solution, but the latter has been generally adopted by the American beet sugar factories. Take the acid from a burette graduated to 1–10 of a cubic centimeter. Use a few drops of phenol as an indicator and add the acid slowly until the red color is gone. Note the reading of the burette before the test is begun and after the powder has been completely neutralized. The difference between the two readings gives the number of cc of acid necessary to effect neutralization. Multiply this number by .028* to find the per cent. of CaO in the lime. Table VII. saves the operation of multiplication.

Example :

Reading of burette before neutralizing	35.6
Reading of burette at beginning	8.9
Number of cc of acid used	26.7

26 7 x .028 = .7476 = 74.76, the per cent. CaO in the lime.

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* One cc of a normal acid neutralizes .028gr of CaO. To illustrate, the action of normal HCl will be described : In neutralizing the lime the chlorine in the acid combines with the calcium in the lime to make calcium chloride, and the hydrogen in the acid combines with the oxygen in the lime to make water. Two parts of acid must be used. The formula is :

$$CaO + 2HCl = CaCl_2 + H_2O.$$

The atomic weight of CaO is 55.87 (Ca = 39 91 and O = 15.96) and the atomic weight of 2HCl is 72.74 (2H = 2 and 2Cl = 70.74.) Therefore, it takes 72.74 parts by weight of HCl to combine with 55.87 parts of CaO. In normal acid there are 36.37 parts of HCl in 1,000, or .03637 gr in 1cc. As HCl combines with CaO in the proportion of 72.74 to 55 87 to find how much CaO 1cc of normal acid will neutralize, we have this equation.

$$72.74 : 55.87 :: .3637 \text{ gr} : x.$$

x is .028 gr.

Therefore, as in the example, if it takes 26.7cc of acid to combine with the CaO in 1gr of lime, multiplying by .028 gives the weight of CaO which has combined with the acid. In this case it is .7476gr, which is 74.76 per cent of the 1gr of lime used. The action of normal sulphuric acid and normal nitric acid may be figured out in a similar manner.

H. Rieckes has proposed a test for finding the "available lime" or lime that will go into solution with sugar, the test being particularly applicable to the Steffens' process. It is made by weighing out a certain amount and dissolving with water and sugar solution. The amount used is preferably 1^{gr} of lime for every 100^{cc} of water and sugar solution. Weigh, for example, 3^{gr} of a finely powdered average sample, and dissolve as much as possible in the scoop, adding sugar solution to assist the operation. No prescribed amount of sugar solution is necessary but about 80 or 90^{cc} of a solution of 50 brix should be used in a 300^{cc} test. As fast as any appreciable amount is dissolved, pour into a 300^{cc} flask, and repeat this until all the lime possible has been dissolved; then wash the remaining particles into the flask. Fill to the mark with water and shake well. Filter 100^{cc} and neutralize with normal acid, using phenol as an indicator. Multiply the number of cc of acid used by .028, as in the above paragraph, to find the percentage of "available lime." The results from this test have not proved to be reliable thus far, often being from 5 to 10 per cent. less than determinations of the same samples by direct titration of the powder. However, the test has a certain value in Steffens' work. It should always be made at as low a temperature as possible, and always at the same temperature with sufficient sugar solution. For testing CaO in saccharate the results are good.

(*b*) **Milk of Lime** is tested only for CaO and density. The CaO is found by neutralizing 1^{gr} with normal acid as in (*a*). Shake well and find the density with a Brix or a Beaumé hydrometer.

(*c*) **The Slacking Tests** of lime are given in **¶ 39**.

36. Alkalinities.—In beet sugar making the alkalinity of juices is nearly always figured as lime, although it is partly ammonia, and sodium and potassium compounds. It is usual in testing alkalinities to have a special acid of $\frac{N}{28}$ which 1^{cc} will neutralize .0020^{gr} of lime, so that if 20^{cc} of a juice is used every cc of acid necessary to neutralize it $\frac{N}{14}$ will show 1-100 of 1 per cent. alkalinity. The special acid is made by adding 570^{cc} of a normal acid to 7430^{cc} of water. To explain, take the special Hydrochloric acid as an example. Every cc of this acid contains .00259^{gr} of HCl, and as it combines with lime in the proportion of 72.74 to 55.87 each cc will neutralize .0020^{gr} of lime (see **35a**). Therefore, when 20^{cc} of a juice is taken every cc of acid combines with .0001^{gr} of lime in each cc of juice, and the number of cc of acid used show. the number of hundredths of 1 per cent. lime in the sample. If, for example, 20^{cc} of a juice is neutralized by 5^{cc} of acid, it has an alkalinity of 5-100 of 1 per cent. This is usually written .05 and is called an alkalinity of 5. In analyzing measure off 20^{cc} of the sample (a tin cup—F 36—holding 20^{cc} may be used for this,) and transfer to a porcelain dish. Use phenol as an indicator and neutralize by the addition of the special acid described above. A burette graduated to 1-10 of a cc should be used for measuring the acid. There are several forms of apparatus for filling the burettes used in alkalinity determinations, one of which is shown in F 35 and another in Fig. 32. The burette is usually of 10^{cc}

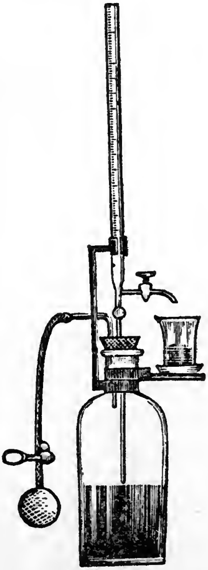

Fig. 32.

capacity, and the apparatus has a siphon arrangement by which the burette is always filled exactly to the zero mark.

A form of apparatus which can be easily made in any laboratory and which is preferred by many chemists is shown in Fig. 33.

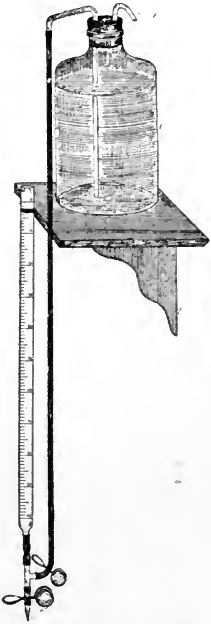

Fig. 33.

The juices sampled for alkalinities are usually taken from a filter press after the first carbonation, a press after the second carbonation, a Daneck or mechanical filter after the sulphuring process, the last effect in the evaporation, and a filter after treatment of thick juice. A 4-oz. bottle with a wooden handle attached (F 14) is convenient for taking the samples. They are transferred to test-tubes in a rack, as shown in F 5. Each test-tube should be first rinsed with the juice sampled. The sample from a filter press should be taken when the press is running at full force, and not when it is either first opened or nearly filled.

37. CO_2 in Saturation Gas.—Carbonic acid is readily absorbed by water containing either caustic soda or caustic potassium, and it is usual in laboratories to have an apparatus constructed on this principle for testing the per cent. of CO_2 in saturation gas. A form of this apparatus is shown in **m1**. There are others of different construction, but so made that 100^{cc} of water are displaced by the gas to be tested, the gas then being forced through a reservoir filled with a solution of caustic soda. The gas which passes through meets a tube bearing a scale divided in cubic centimeters and containing 100^{cc} of water. As much of this water is displaced as there are cc of gas passing through the reservoir. The amount of water remaining in the tube is of the same volume as the gas which was combined with the caustic soda, hence the number of cc remaining shows the percentage of CO_2 in the gas.

As a control for the apparatus, tests should be made at least once every day with a burette, as follows: Use a graduated 100^{cc} burette with a ground glass stop-cock (Fig. 34). Attach it to a rubber tube connected with the gas pipe, leaving the open end in cold water. Let the gas pass through the burette for two or three minutes, then close the stop-cock and disconnect the rubber tube. Raise the burette until the zero mark is even with the top of the water and open the stop-cock just long enough to allow the water to come up to the mark. There are now exactly 100^{cc} of gas in the burette. Insert a piece of caustic soda (stick) about half an inch long, in the open end, keeping it under water. Then close this end with the thumb or index finger and turn the burette upside down several times, letting the soda go from one end to the other. Replace the end of the burette in water and by taking away the finger, water will rise in the burette to take the place of CO_2 that has been absorbed by the caustic soda. Repeat the above operation until the water ceases to rise in the burette. The number of cc of water now in the burette will show the percentage of carbonic acid absorbed, which is the percentage

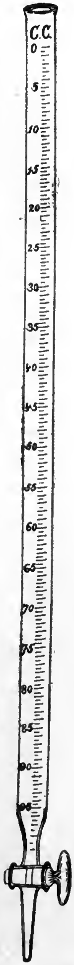

Fig. 34.

of CO_2 in the gas tested. In determining the amount of water in the burette it is best to place the instrument deeply enough in water so that the surface of the water in the vessel used is even with the water in the burette. This prevents the weight of water in the burette from affecting its reading.

CHAPTER V.

STEFFENS' PROCESS ANALYSES.

38. (*a*) **Saccharate of Lime** is of two kinds, hot and cold, and each is tested for sugar, purity and CaO. To determine the sugar, weigh out 13.024^{gr}. Neutralize in the scoop with acetic acid, using phenol as an indicator. Dissolve the saccharate thoroughly and pour the contents of the scoop into a 100^{cc} flask. Cool to normal temperature, add sufficient lead acetate, and make up to the mark with water. Filter and read in the polariscope, multiplying the reading by two to find the per cent. sugar.

(*b*) **To Find the Purity** of a saccharate, mix the sample with water. Use about 1 kilo. of saccharate and dilute to about 15 or 20 brix. Neutralize with carbonic acid gas and filter. Evaporate the filtrate to 30 or 40 brix and filter again. Find the brix by pycnometer and determine the sugar by weight, using 26.048^{gr}. Divide the sugar by the brix for the purity. If the purity of a solution that has a high alkalinity is made without neutralizing, multiply the alkalinity by 3 and subtract from the brix. However, nearly every chemist prefers to have the solution neutral.

(*c*) **CaO in Saccharate** is found according to the Rieckes' method for "available CaO" in lime (**35a**). For the cold saccharate use 3^{gr} in 300^{cc} of water and sugar solution, but as the hot saccharate dissolves much more readily 4 or 5^{gr} of it may be used in 300^{cc}. In the latter case if 5^{gr} are used the result must be divided by 1.666, for there are that many gr of saccharate in the 100^{cc} used for the test.

39. Lime Powder is tested for CaO and grit, and occasionally a slacking test is made. The CaO is found according to **35a**. The grit is the lime that will not pass through the sieves used in the process. These sieves are usually of 120 mesh, but whatever size is used must be taken for the laboratory test. Weigh out 20^{gr} of the powder and transfer to a perfectly clean sieve. Sift out as much as possible, being careful that none is lost over the top. Weigh that remaining and multiply by 5 to determine the per cent. of grit. This is the same as dividing by 20 and multiplying by 100, which is the theoretically correct way.

Example:

Weight of lime used—20.0 gr.
Weight remaining in sieve—6.5 gr.
6.5 ÷ 20 = .325. .325 x 100 = 32.5 per cent. grit.
or
6.5 x 5 = 32.5 per cent. grit.

The slacking test of BAUR and PORTIUS is made as follows: Weigh out 20^{gr} of the powder and transfer to a beaker. Fill a 100^{cc} flask to the mark with water and note its temperature. Quickly pour the water over the lime in the beaker and stir with a centigrade thermometer. Take the temperature 15 seconds after starting, again in 15 seconds, and then in 30 seconds, noting it at the end of each minute thereafter until the temperature begins to go down.

Example:

Temp. at start	18	After 8 min.	35
After 15 sec.	19	" 9 "	36
" 30 "	21	" 10 "	37
" 1 min.	23	" 11 "	37½
" 2 "	25½	" 12 "	38
" 3 "	27½	" 13 "	38½
" 4 "	29	" 14 "	39
" 5 "	31	" 15 "	39
" 6 "	32½	" 16 "	38½
" 7 "	34	" 17 "	38

The object of the slacking test is to see how long it takes the lime to slack after the addition of water. A solution of molasses is substituted for the water when it is desired to learn the length of time required for slacking in the coolers, and the test is carried out the same as with water. The syrup solution should be of the same density as that regularly used in the Steffens' process.

40. (*a*) **Waste Waters.**—*Cold Waste Water* is tested for density and sugar. It is not necessary to figure out the purity. The sample is put in a small test-tube with a foot (**1**) and the density taken with the 5-9 brix spindle described in **2b**. A correction is made for temperature and is usually a subtractive one. Half normal weight is weighed out or if there is sufficient fluid, normal weight is taken, and is washed from the scoop into a 100^{cc} flask. Two or three drops of phenol are added and neutralization is effected with acetic acid. Use only enough acid to make the sample neutral, or very slightly acid, and if by accident too much is added, use enough sodium carbonate solution to bring the fluid back to nearly the neutral point. Clear with lead acetate if necessary, make up to the mark, filter and polarize. If half normal weight is used, multiply the reading by 2.

(*b*) **Hot Waste Water** may be made by the pipette method or by weight, using double normal weight. In either case neutralize with acetic acid, as in the above paragraph. Only the brix and per cent. sugar are recorded.

41. Molasses Saccharate is usually tested only for CaO, which is found by neutralizing 10^{cc} with a normal acid. Multiply the number of cc of acid used by 10 and by 028 for the per cent.

42. Molasses Solution.—The purity is made by pipette or volumetrically. If alkaline, neutralize as in **30**, filter, and make the purity of the filtrate.

43. Saccharate Milk is tested for per cent. sugar, density, and CaO. The sugar is found according to **38a**, the density is taken with a brix spindle, and the CaO is found by neutralizing 10^{cc} with normal acid, as in **41**.

CHAPTER VI.

INVERT SUGAR AND RAFFINOSE.*

44. The Correct Percentage of Sucrose cannot be determined by means of the polariscope when any other sugar is present, such as raffinose, dextrose or lævulose, and whenever the presence of any of these is suspected, an analysis must be made by the inversion method given below. If the polarization before and after inversion is equal, only sucrose is present, but if it is either higher or lower after inversion than it was before, other sugars are contained. If higher, test for invert sugar, and if lower, test for raffinose. The other sugars need not be considered in beet work, dextrose or lævulose, when present being combined as invert sugar.

To invert the substance to be analyzed weigh out half normal weight and transfer to a 100^{cc} flask, washing out the scoop with about 75^{cc} of water. After complete dissolution add with a pipette 5^{cc} of hydrochloric acid of 1.188 sp. g. (at 15°C). Put the flask immediately into a water bath heated to 70°, and leave for exactly 10 minutes, moving occasionally. During this time the water must be kept at a temperature of from 67° to 70°. At the expiration of the ten minutes cool the fluid quickly to 20° by setting the flask in cold water. Then fill to the 100^{cc} mark with water, shake well and filter. Clearing by lead acetate is not admissable, as it effects the turning of invert sugar considerably. If the solution is dark add about half a gramme of bone dust to the flask before filtering.

45. Sucrose in the Presence of Invert Sugar. — Polarize the substance in the usual way, using a polarization

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* ¶¶ 45 and 46 adapted from Fruhling and Schulz.

tube having a water jacket and introduced thermometer,* (F 42) noting the temperature at which the polarization is made. Then polarize the substance after inversion, as above described, at the same temperature as the original substance was polarized. The polarization, after inversion, must be multiplied by 2, as only half normal weight is used. From both polarization figures, by means of a formula, is found the percentage of sucrose in the sample tested. This formula expresses only the optical action of the sucrose, as the inversion does not change either dextrose or invert sugar. It has been determined that a pure cane sugar solution which polarizes 100° at 0°C in the 200^{mm} tube of the apparatus with Ventzke's scale (13.024^{gr} to 100^{cc}), revolves—42.66, so that the entire diminishing of revolution (at 0°C) amounts to 142.66°. If the observation is not made at 0°C, but at a higher temperature, there occurs, owing to a peculiar property of the invert sugar, a corresponding lessening of revolution, a diminishing of 0.5° for 1°C increase in temperature. Upon this observation is based the above-mentioned formula, named after Clerget. Let **S** represent the whole diminishing of revolution before and after inversion, **T** the temperature (in Centigrade degrees), which the inverted solution shows at the polarization, and **Z**, the true contents of cane sugar, can be found according to the following formula:

$$Z = \frac{100 \times S}{142.66-(.5 \times T)}$$

Example I: A sample of syrup polarizes before inversion 14.8, and after inversion 12.7. The latter polarization must be doubled on account of using half-normal

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* This thermometer should be graduated in 1-10 degrees, Centigrade.

weight so that the entire diminishing of revolution **S** is 14.8 + (2 x 12.7) = 40.2. The temperature at both polarizations was 19°. Therefore,

$$Z = \frac{100 \times 40.2}{142.66 - (.5 \times 19)} = \frac{4020}{133.16} = 30.2$$

Example II: A mixture of cane sugar and starch syrup polarizes + 71.4 before inversion, and after inversion + 8.4. Doubling the latter quality, the diminishing of revolution **S** is 71.4—16.8 = 54.6. The temperature is 18°. Therefore,

$$Z = \frac{100 \times 54.6}{142.66 - (.5 \times 18)} = \frac{5460}{133.66} = 40.85$$

Using Table **A**, the percentage of cane sugar can be found by multiplying the diminishing of revolution by the factor corresponding to the temperature at which the test was made.

TABLE A.

Temp. C.	Factor.	Temp. C.	Factor.	Temp. C.	Factor.
10°	0.7257	17°	0.7454	24°	0.7653
11	0.7291	18	0.7482	25	0.7683
12	0.7317	19	0.7510	26	0.7712
13	0.7344	20	0.7538	27	0.7742
14	0.7371	21	0.7567	28	0.7772
15	0.7397	22	0.7595	29	0.7802
16	0.7426	23	0.7624	30	0.7833

The use of the table may be illustrated by the two examples given above.

In Example I. the total diminishing of revolution is 40.2 and the temperature is 19°. Therefore, 40.2 x .7510 = 30.19 or 30.2, the cane sugar.

In Example II. 54.6 is multiplied by .7482, giving a result of 40.85.

46. Sucrose in the Presence of Raffinose.— The analysis follows exactly the directions given in the above paragraph, with the exception that the observation of the inverted fluid must always take place at 20°C. The formula is also different, as it must consider, besides the difference in the optical relation of cane sugar, also that of the raffinose, the revolution to the right of which goes back considerably through inversion. The formula based upon the above-mentioned ratio of figures at the inversion of cane sugar, as well as upon the polarization of pure crystallized raffinose (13.034^g to 100^{cc}) before inversion (+ 157.15) and after inversion (+ 80.53) at 20°C is as follows:

$$Z = \frac{(0.5124 \times P) + J}{0.839},$$

wherein Z represents the contents of cane sugar, **P** the polarization of the substance before inversion, and **J** the polarization of the inverted solution, doubled on account of the use of half normal weight. As this formula is reckoned only for the temperature of 20°C, the expression **T** is omitted.

Example: The after-product of a refinery polarized before inversion + 94.5 and after inversion + 13.8 (at 20°C.) From these figures a cane sugar content of 90.6 is calculated according to the above formula.

$$Z = \frac{(.5124 \times 94.5) + (2 \times 13.8)}{.839} = \frac{76.0218}{.839} = 90.6$$

47. The Percentage of Raffinose is found by subtracting the true contents of cane sugar from the polarization before inversion, and dividing by 1.852. In the example in the above paragraph

$$94.5 - 90.6 = 3.9.$$
$$3.9 \div 1.852 = 2.1 \text{ per cent. raffinose.}$$

48. Invert Sugar is determined by the use of the mixed Fehling's solution described in **141**. The execution of the test is as follows:

Weigh out a definite amount of the syrup or massecuite, dissolve and make up to 100^{cc}. The amount weighed out depends upon how much invert sugar is in the sample; but it should be some multiple of five gr. to make an easy calculation, and should be sufficient to give a burette reading of from 15 to 20^{cc} in the operations which follow. The diluted sample is placed in a burette graduated in 1.10^{cc}.

In a porcelain casserole put 10^{cc} of the mixed Fehling's solution and add 30^{cc} of distilled water. Heat to boiling, add a portion of the solution to be tested and boil two minutes. Repeat this, adding the solution very slowly at the last, until the blue color of the fluid has apparently disappeared. Pour 3 or 4^{cc} of the hot fluid on a small filter, and test the filtrate for copper by adding a few drops of potassium ferrocyanide (solution of 20^{gr} to 1 liter,) after acidifying with a few drops of a 10 per cent. solution of acetic acid. If a brownish-red color shows, add 2^{cc} of the sugar solution to the copper fluid and boil again, repeating the ferrocyanide test. Continue this until the point is reached when there is no further reaction of copper. The reading of the burette is then observed to see how many cc of the sugar solution were necessary for the reduction of the copper. The test should always be repeated to insure accuracy. The calculation of the invert sugar is as follows:

The value of the Fehling solution must be known, *i. e.* how much invert sugar is necessary to reduce 10^{cc} of the solution. For this purpose add to 9.5 grammes of chemically pure sugar in a 100^{cc} flask, 5^{cc} of hydrochloric acid and invert according to the directions in **44**. Make up to the mark and the flask contains 10^{gr} of invert sugar. Making 20^{cc} of this (2^{gr} of invert sugar) up to 1 liter and neutralizing with sufficient sodium carbonate to turn a piece of litmus paper blue, gives a solution in which every cc contains 0.002^{gr} of invert sugar. Making the test as above described it is found how many cubic centimeters of this solution correspond to the 10^{cc} of copper solution. For example, if 25.6^{cc} of the solution are used, it takes $25.6 \times .002 = 0.0512^{gr}$ of invert sugar to reduce 10^{cc} of the Fehling solution. This 0.0512 is the factor **F** in the formula given below, but any other factor may be obtained in the same way :

$$.002 \times \text{number of cc of standard solution used} = F.$$

From this the percentage of invert sugar is obtainable by the formula

$$\frac{100\ F}{X\ Y}$$

in which X represents the number of cc of unknown sugar solution required to precipitate the copper from 10^{cc} of Fehling solution and Y equals the weight of the material tested in each 1^{cc} of the solution.

Example :

5^{gr} of massecuite are dissolved in 100^{cc} of water, hence

$$Y = 0.05^{gr}$$

Let 18.5 represent the number of cc of the solution tested which are necessary to reduce the copper solution. Then

$$X = 18.5.$$

Let 0.0512 represent the factor F, obtained as above described. According to the formula,

$$\frac{100 \times .0512}{18.5 \times .05} = \frac{5.12}{.925} = 5.53, \text{ per cent. invert sugar.}$$

49. Soxhlet's Exact Method, as used by the ASSOCIATION of OFFICIAL AGRICULTURAL CHEMISTS is as follows :

A preliminary titration is made to determine the approximate percentage of reducing sugar in the material under examination. A solution is prepared which contains approximately 1 per cent. of reducing sugar. Place in a beaker 100^{cc} of the mixed copper reagent and approximately the amount of the sugar solution for its complete reduction. Boil for two minutes. Filter through a folded filter and test a portion of the filtrate for copper by use of acetic acid and potassium ferrocyanide. Repeat the test, varying the volume of sugar solution, until two successive amounts of sugar solution are found which differ by 0.1^{cc}, one giving complete reduction and the other leaving a small amount of copper in solution. The mean of these two readings is taken as the volume of the solution required for the complete precipitation of 100^{cc} of the copper reagent.

Under these conditions 100^{cc} of the mixed copper reagent require 0.475 gram of anhydrous dextrose, or 0.494 gram of invert sugar, for complete reduction. The percentage is calculated by the following formula:

W = the weight of the sample in 1^{cc} of the sugar solution;

V = the volume of the sugar solution required for the complete reduction of 100^{cc} of the copper reagent.

$$\text{Then } \frac{100 \times 0.475}{VW} = \text{per cent. of dextrose,}$$

$$\text{or } \frac{100 \times 0.494}{VW} = \text{per cent. of invert sugar.}$$

PART II.

ANALYSIS OF SUPPLIES

AND OTHER

CHEMICAL WORK.

CHAPTER VII.

APPARATUS FOR CHEMICAL ANALYSIS.

50. The Apparatus used in the chemical analysis in beet sugar work is the same that is found in nearly all analytical laboratories, hence only a short description will be given of the apparatus most necessary, with a few suggestions as to their use.

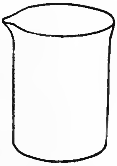

Fig. 35.

Fig. 36.

Beakers are preferably of the Griffin form, with lip, shown in Fig. 35. The sizes which will be most often used are the 5 and the 8 ounce, and the 10, 12 and 15 ounce are occasionally used. The larger sizes 30 and 40 ounce are often serviceable for mixing solutions. The conical assay flask (Fig. 36) of 4 oz. capacity is the best form for dissolving metals or stones with acids, as in the limestone analysis.

Glass Rods tipped with rubber are used for stirring and for pouring precipitated solutions on filter paper as in Fig. 37. Tallow is rubbed with the greased finger under the lip of the beaker before this operation. Rods ¼ inch in diameter are of the best size. For cleaning residues from platinum or porcelain dishes, a glass rod bent at right angles about half an inch from one end, and covered with a short piece of rubber tubing may be used.

Funnels used in chemical analysis are from 1 to 2½ inches in diameter, the 2-inch size being the one most generally needed. They should have long stems and should be on an angle of 60°. In filtering, the stem of the funnel should be placed against the side of the beaker receiving the filtrate to prevent splattering of the fluid.

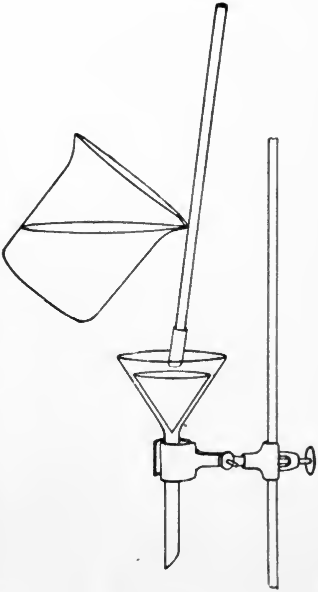

Fig. 37.

Filter Paper should be of the Swedish quality. It leaves the least ash of any filter paper known, and in the analyses outlined in the following chapters, no account is taken of the weight of the ash of the filter paper after incineration, as it is insignificant except in the most delicate determinations. The paper should be cut round and of such size that it will be about half filled with the precipitate. In all cases, except those specially noted, the filter paper should be fitted on the funnel and moistened with distilled water. One of the principal sources of error in analysis is that precipitates are not thoroughly washed. In nearly all cases it is better to wash the precipitate by decantation as described in **59**. After the precipitate is on the filter, it should be washed with distilled water until no trace of solid matter is given in the filtrate. This is tested by letting

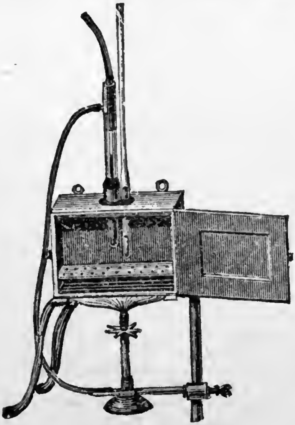

Fig. 38.

a drop from the stem of the funnel fall upon the perfectly clean surface of a small piece of platinum foil or crucible cover. Dry, and if a residue remains, the precipitate has been thoroughly washed. Wash again and repeat the test until no residue remains. Another method is described in the paragraph above cited (**59**) by testing with silver nitrate, and can be used in many instances in sugar laboratories, as solutions often contain hydrochloric acid or chlorine in some other form. After filtering, the funnel containing the precipitate is placed in a drying oven (Fig. 38) the funnel being covered with a moistened piece of filter paper turned down over the rim to keep out dust.

Dessicators are for the purpose of keeping hot substances from absorbing moisture while cooling, and for carrying them to the balance. A good form is shown in Fig. 39. The bottom is filled with fused calcium chloride to keep the air dry. The lid and the part of the dessicator where it joins are ground, and tallow is used to make the apparatus air-tight.

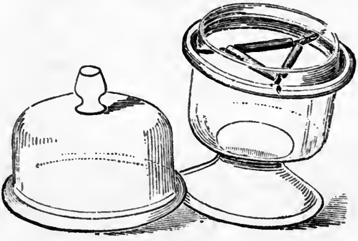

Fig. 39.

Crucibles and Dishes for incinerating should be of platinum, but in some analyses porcelain is to be used. Sapolio is one of the best agents for cleaning dishes and crucibles of all kinds. After a magnesium precipitate is burned with nitric acid (**58**) the crucible should be partly filled with concentrated hydrochloric acid and allowed to stand until the precipitate is loosened or dissolved.

Lamps and Stoves.—Gas burners are to be preferred, of course, but sugar factories are generally so located that gas is not obtainable. The gasoline stove shown in Fig. 40 is to be recommended, as enough heat can be generated by it to effect any incineration liable to be made, and the flame can be lowered when necessary, to give a very moderate heat. To give a good flame, the reservoir of the stove should never be filled more than two-thirds full. Alcohol lamps should be used for evaporating and for heating solutions. The best form has a side tubulation for filling. Coal-oil lamp stoves (F. 33) may be used in place of the alcohol lamps, but great care must be taken with them, on account of the danger of smoking and the accumulation of soot. The blue flame kerosene stoves of recent invention are excellent for laboratory use, the only objection to them being that they occupy too much space.

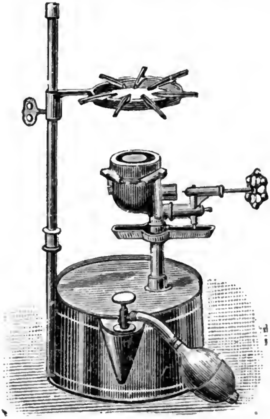

Fig. 40.

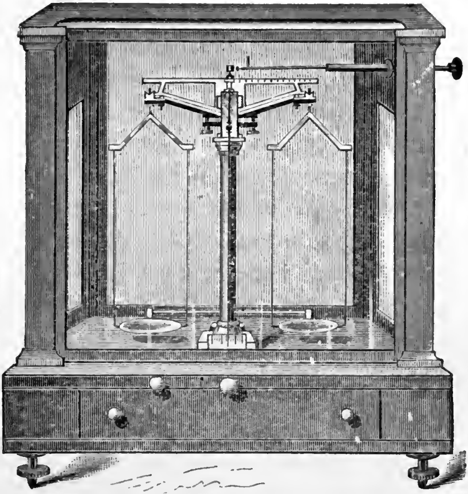

Fig. 41.

Other Apparatus.—*Evaporation* dishes should be of porcelain as described in **53**. *Scales and Weights* are described in **8**. Fig. 41 shows the short-arm chemical scale, which form is generally accepted to be the best. *Washing Bottles* for containing alcohol, dilute, acids, etc., should be of about 300^{cc}capacity and made as in **9c** (see F 37). *Burettes* are the same as those used in sugar analysis (**9d**). *Pipettes* most used are graduated to 5, 10, 25, 50 and 100^{cc}. They are tested as described in **4**. *Lampstands* should be fitted with two extension rings and an extension clamp, the rings being of about two and four inches inside diameter. *Water Baths* are of copper with a covering of concentric rings, and should be six or seven inches in diameter. *Crucible Tongs* are of various forms, one of the best being shown in Fig. 42. The tips should be nickel plated. *Graduated Cylinders* or the usual graduates divided into cubic centimeters (F) may be used for measuring fluids, 250^{cc} being the most desirable capacity. *Mortars* for powdering lime stone and other samples should be of porcelain and of the form shown in F 10. The iron mortar shown in F 11 is also often serviceable. *Volumetric Flasks* of 500^{cc} and 1 liter capacity are necessary for making solutions of known strength. Flasks of 200^{cc} or 250^{cc} capacity are used in many analyses. ALKALIMITERS and other special apparatus are described under the paragraphs in which their use is noted.

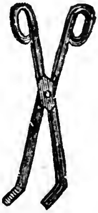
Fig. 42.

CHAPTER VIII.

WATER ANALYSIS.

51. Water.— The examination of water for use in beet sugar manufacture is usually confined to the estimation of carbonic and sulphuric acids, chlorine, silica, iron and aluminium oxides, calcium oxide, magnesium oxide, and the alkalies, sodium and potassium. As potassium is usually present in only very minute quantities, as compared with sodium, it is not necessary, except in very exact analysis, to determine it separately. The two alkalies are estimated together and are called sodium, the potassium not being counted. Nitric acid is present in such small quantities in water that it its determination is not considered of importance in sugar work. The analysis as outlined above may be called the "actual analysis;" the "figured analysis" is described in **62**.

52. The Sample.—About 4 liters of the water should be taken for analysis. A gallon demijohn is a convenient vessel for holding the sample. It should be thoroughly cleaned and well corked and no luting of any kind should be used on the cork. The sample should be as near an average as possible, and if taken from a faucet the water should be allowed to run for a considerable time. In case of a river, take the sample from the middle of the stream. Collect the water with a cup or other small vessel, taking the samples at short intervals until sufficient is obtained for the large sample.

53. The Mineral Substance. — Filter 2 liters of the water and evaporate to dryness. This is best effected in a porcelain dish over a direct flame. Do not use a glass vessel, as the water attacks it. A dish about 8 inches in diameter, and of the shape shown in Fig. 43, is convenient. When the water has evaporated to about 50^{cc}, transfer to a weighted platinum dish and complete the evaporation on a water bath. The substance remaining on the sides of the porcelain dish may be washed into the platinum dish as fast as the evaporation makes room. Use a glass rod tipped with rubber for cleaning the porcelain dish. After evaporation, place in the drying oven at 105°C, until the last water is driven off. Cool in a dessicator and weigh. The weight is *the total residue* and is figured, as in the whole analysis, on 100,000 parts of water. Ignite slowly to a dull red heat, until all organic matter is consumed. This also occasions a loss of constitutional (hydrate) water and a slight loss by reduction of nitrates. After cooling and weighing, the amount found to have been burned away is written *lost by combustion.* The *total residue* minus the amount *lost by combustion* is called *the mineral substance.*

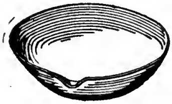

Fig. 43.

Example :

Weight of residue after drying	28.195^{gr}
Weight of platinum dish	26.421^{gr}
Weight of total residue	1.776^{gr}
Weight of residue after drying	28.195
Weight of residue after burning	27.957
Weight lost by combustion	.238
Weight of total residue	1.776
Weight lost by combustion	.238
Weight of mineral substance	1.538

These weights are obtained from 2,000^{cc} and, as the analysis is figured on 100,000 parts of water, we multiply by 50, or divide by 2 and multiply by 100, which is an easier way to figure. This gives a result of

Total residue	88.8	parts in	100,000
Lost by combustion	11.9	"	"
Mineral substance	76.9	"	"

54.* **Carbonic Acid** which is in combination with bases is determined by means of an alkalimeter. The form generally preferred is Geissler's apparatus, a modification of which is the Peffer alkalimeter shown in Fig. 44. This apparatus is designed especially for the determination of carbonic acid (CO_2, carbon dioxide) in water, its form being such that the substance used for the CO_2 test can be easily removed for use in other analyses. Its manipulation is as follows:

Pure hydrochloric acid is introduced into **B** through the opening **D**. Having seen that the cock **F** is perfectly tight, both **B** and **I** are removed and placed standing in a beaker, clamps of a lamp-stand, or some other safe and convenient place. The residue, after burning away the organic matter (**49**), is taken up with the least amount of water and transferred to the

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* WANKLYN measures carbonic acid in water by "taking advantage of the insolubility of carbonate of lime in the presence of lime-water. For this purpose lime-water is prepared by taking slaked lime and shaking it up with distilled water, and then allowing to settle, and ultimately decanting the clear supernatent lime-water. One liter of lime-water contains 1.372 gr. of CaO." Use 500cc of the water to be analyzed and mix it with 215cc of the lime-water in a stoppered vessel. "The mixture is allowed to stand until the precipitate of $CaOCO_2$ has settled and the supernatent liquid becomes clear. The liquid is decanted and the precipitate placed on a filter, slightly washed, burned in a platinum dish or crucible, and finally weighed." This precipitate must be burned as described in **57** Multiply the resulting weight of calcium carbonate by 2 and by 100 to find the amount in 100,000 parts of water, and multiply this by .44 (the factor) to find the amount of CO_2.

flask **A**, through the opening **H**. The substance in the flask should not be higher than that shown in the illustration to effect an accurate analysis. Replace **B** and **I** in the apparatus and add pure sulphuric acid to **I** through the opening **E**. All the joints should be made air-tight by the use of a very slight amount of tallow. Wipe off the apparatus thoroughly, dry and weigh carefully, recording the weight. Now open the cock **F** and allow a small amount of the HCl to go into **A**. Carbonic acid is freed and passes in **C**, through **I**, and out at **E**, the sul-

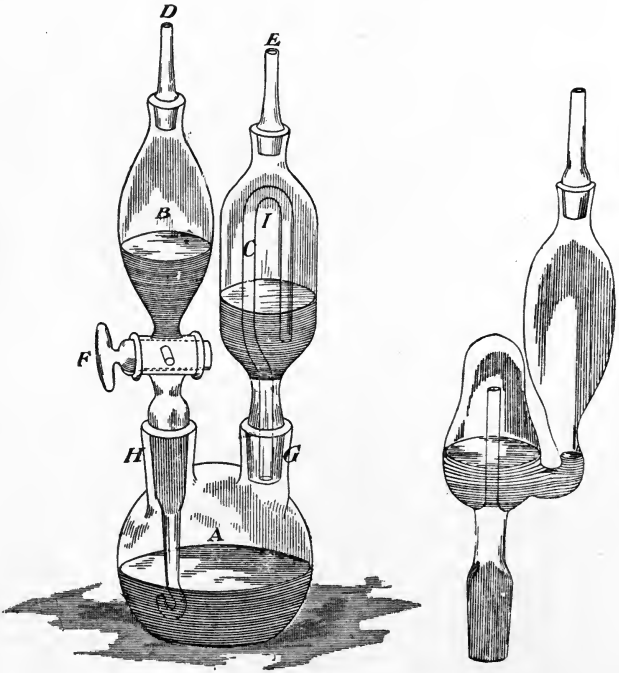

Fig. 44.

phuric acid drying it. As fast as effervesence ceases, add more of the acid until all the HCl is in **A**. Then carefully heat the bottom of the apparatus until the contents are nearly to boiling point. This is best done by fixing the alkalimeter on a lamp stand and gently moving the flame to and fro under it. Five minutes' heating is usually sufficient. Allow the apparatus to cool and attach a small rubber tube, about ten inches long, to the top of **E**. Open the cock **F** and, by aspiration, draw out slowly through the tube any gas that may remain in **A**. Detach the tube, wipe off the alkalimeter and weigh again. The weight lost is CO_2.

Example:

Weight of apparatus and contents before operation	75.547^{gr}
Weight of apparatus and contents after operation	75.383^{gr}
Weight of CO_2 lost	.164^{gr}

Dividing by 2 and multiplying by 100 = 8.2, the amount of CO_2 in 100,000 parts of water.

55. Silica.—Transfer the contents of the alkalimeter to a platinum dish and evaporate to dryness. This coagulates silicic acid that would otherwise go into solution in the operation which follows. Take up the substance in the dish with water and a little diluted hydrochloric acid, and filter into a 200^{cc} flask. Wash the paper and residue thoroughly with hot water. The residue may contain some insoluble iron and aluminum and calcium sulphate (STILLMAN) but it is nearly all silica (SiO_2) and is dried, burned and weighed as such.

Example:

Weight of crucible and residue	11.148^{gr}
Weight of crucible	11.090^{gr}
Weight of residue (silica)	$.058^{gr}$

Dividing by 2 and multiplying by 100 = 2.9, the silica.

56. Iron and Aluminum Oxides. — The 200^{cc} flask containing the filtrate in **55** is allowed to cool and is then filled to the mark and well shaken. Transfer 50^{cc} of this solution to a beaker and make slightly alkaline with ammonia water. This may be tested by dropping a small piece of litmus paper in the fluid. Heat to nearly boiling and iron and aluminum oxides will be precipitated. The use of an excess of ammonia is to be avoided. Filter and wash with the smallest amount of hot water necessary. Dry and burn the precipitate as iron and aluminum oxides.

Example:

Weight of crucible and precipitate	11.095
Weight of crucible	11.090
Weight of precipitate (Fe_2O_3 and Al_2O_3)	.005

As two liters are represented in the 200^{cc} filtrate, 50^{cc} of it corresponds to 500^{cc}, hence the weight obtained above must be multiplied by 2 and by 100, to give the parts in 100,000 parts water.

$.005 \times 2 \times 100 = 1.0$, amount of Fe_2O_3 and Al_2O_3.

57. Calcium Oxide.—Make the filtrate in **56** slightly acid by the addition of acetic acid*. Heat to nearly

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* Acetic acid is added to prevent the precipitation of any magnesium as magnesium oxalate. Chemists are not agreed as to whether this is necessary, but the acid does no harm, and may do good.

boiling, and add ammonium oxalate when calcium oxalate will be precipitated. Keep the above heat for about five minutes and then allow to cool. If the precipitate subsides immediately it is usually evidence that all the calcium has been precipitated, but if the supernatent fluid remains milky for some time, heat again and add ammonia oxalate. Even if the precipitate subsides almost immediately, add a slight amount of the reagent to see if this addition causes a precipitation. After cooling, filter and wash with warm very dilute acetic acid. Wash the precipitate all into the apex of the filter paper. Dry, and burn as follows: Separate the precipitate from the filter paper with a clean knife blade; burn the paper until it gives a white ash, then lower the flame, add the precipitate to the crucible and burn at a heat which turns the part of the crucible nearest the flame to a dull red. In burning, the calcium oxalate becomes calcium carbonate,

$$CaC_2O_4 = CaCO_3 + CO \text{ (burned away.)}$$

At a high heat the CO_2 would also be driven off, leaving only calcium oxide (CaO). The precipitate turns black and when it has become white again it has been sufficiently burned. At this point moisten with ammonium carbonate and heat carefully until all odor of ammonia is driven off. This will restore any CO_2 that may have been burned away. Cool and weigh as calcium carbonate, multiplying by .56 to get the weight of calcium oxide.

Example:

Weight of crucible and precipitate	11.237gr
Weight of crucible	11.090gr
Weight of precipitate ($CaCO_3$)	.147gr

As in the above paragraph, multiplying by 2 and by 100 = 29.4, the calcium carbonate.

29.4 x .56 = 16.464 or 16.46, the calcium oxide.

58. Magnesium Oxide.—When the filtrate in **57** is cool, add to it ammonia water in excess,* and sodium phosphate. (In very dilute solutions, the addition of 2 or 3^{gr} of crystallized ammonium chloride will hasten precipitation.) Let stand (not in a warm place) for 12 hours and magnesium ammonium phosphate will be precipitated. Filter and wash with the precipitate with a mixture of strong ammonia diluted with an equal amount of water (WANKLYN). Magnesium ammonium phosphate is soluble in water to some extent, and this is prevented almost entirely by the liberal use of ammonia. Dry the precipitate and burn. In burning, the magnesium ammonium phosphate becomes magnesium pyrophosphate:

$$2NH_4\,MgPO_4 = 2NH_3 + H_2\,O + Mg_2\,P_2\,O_7.$$

The addition of nitric acid to the crucible after burning for a little while will make the pyrophosphate yield a white residue. Cool the crucible before adding the acid, and then apply the heat slowly to prevent any loss of substance. When ignition is complete, cool and weigh, and multiply by .3602 to find the amount of magnesium oxide.

Example:

Weight of crucible and precipitate	11.160^{gr}
Weight of crucible	11.090^{gr}
Weight of precipitate ($Mg_2\,P_2\,O_7$)	$.070^{gr}$

.07 x 2 x 100 = 14, the magnesium pyrophosphate.

14 x .3602 = 5.04, the magnesium oxide.

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* Add ammonia water to about ⅓ the amount of the original filtrate.—KISSEL.

59. Sulphuric Acid.—Measure off 50^{cc} of the solution in **56**, and put in a beaker. Heat nearly to boiling point and add barium chloride in slight excess. The precipitate is barium sulphate. Heat for a few minutes longer and allow to stand for about three hours in a warm place. Filter off the supernatent fluid, then add boiling water to the precipitate in the beaker and stir well. Allow to settle and again filter off the fluid. Add boiling water and repeat the above operation until the filtrate gives no traces of chlorine. This can be tested by allowing a few drops from the stem of the funnel to fall into a small test tube containing a solution of silver nitrate. A white precipitate indicates chlorine. When the filtrate is free from chlorine, transfer the precipitate to the filter paper, wash with hot water, dry and burn at a moderate red heat. Weigh as barium sulphate and multiply by .3431 to find the weight of sulphuric acid (sulphuric anhydride, SO_3.)

Example:

Weight of crucible and precipitate	11 553
Weight of crucible	11.090
Weight of precipitate ($BaSO_4$)	.463

.463 x 2 x 100 = 92 6, the barium sulphate.

92.6 x .3431 = 31.77, the sulphuric acid.

The determination of sulphuric acid requires the greatest care and attention, to give accurate results. The precipitate is very liable to carry down with it such foreign salts as the alkalies, alkali-earth metals and iron oxide, and if the barium chloride solution is too concentrated, there will be traces of it in the barium sulphate. A thorough washing, as above described, will usually give accurate results. Sulphuric acid is precipitated more readily in dilute than in concentrated solutions, and some analysts prefer to make the determination with a separate portion of water, evaporating 200^{cc} or 500^{cc} to about ½, and continuing as above.

60. Sodium.—Use 50^{cc} of the 200^{cc} solution in **56**. If the solution is very strongly acid, add sufficient ammonia to bring it nearly neutral. Heat nearly to boiling and add an excess of baryta water. The salts of calcium, magnesium, iron and aluminum, and also silicic and sulphuric acids, will be precipitated. Filter while hot and wash with hot water. Heat again to nearly boiling point and add a few drops of ammonia and then sufficient ammonium carbonate to precipitate the barium present. Filter and evaporate to dryness, with the addition of a few drops of ammonium oxalate solution, to precipitate any traces of calcium salts which may have remained. Dry at 120°, and over a low flame burn carefully until all odor of ammonia is gone. Take up the residue with hot water and filter. To the filtrate add a few cc of hydrochloric acid and evaporate to dryness in a weighed platinum dish. The residue consists of the alkali chlorides, the addition of the hydrochloric acid having made the chlorine combination. As stated before, potassium is present in natural waters in such small quantities in comparison to sodium, that the whole residue is called sodium chloride. It is calculated to sodium by multiplying with the factor 0.3940.

Example:

Weight of dish and residue	26.388
Weight of dish	26.276
Weight of residue (NaCl)	.112

.112 x 2 x 100 = 22.4, the sodium chloride.

22.4 x .3940 = 8.82, the sodium.

61. Chlorine is determined by use of a standard solution of silver nitrate (**140**), of which one cubic centimeter will precipitate one milligramme of chlorine. Add a few drops of potassium chromate to 100^{cc} of the water sample, or to a larger volume evaporated to about 100^{cc}, which should be made faintly alkaline by the addition of a little sodium carbonate. From a burette carefully add the silver nitrate solution, stirring constantly. Each drop of the solution forms a red spot of silver chromate, which decomposes upon stirring. At the very earliest point when this red coloration becomes permanent, the burette should be read, and the number noted of the cc of solution used. As each cc denotes the number of milligrammes of chlorine in the sample, the calculation of the percentage is easy.

Example:

1000^{cc} of water are evaporated to about 100^{cc} and tested as above, 32.1^{cc} of solution being necessary to precipitate the chlorine.

32.1^{cc} solution = 32.1 mg of chlorine, or 0.0321^{gr}.
$.0321^{gr}$ in $1000^{cc} = 3.21^{gr}$ in $100{,}000^{cc}$,
or, 3.21 parts chlorine in 100,000 parts water.

62. The Figured Analysis is a calculation which shows in what form the bases and acids found in the *actual analysis* are combined in the water. The arrangement is usually the same, but if the chemist has reason to believe that another combination is more correct, he is allowed a certain latitude.

Silica is put down in the free state, unless there should be an insufficient amount of CO_2, SO_3 and Cl to combine with the bases, in which case enough silica is used to combine with whatever sodium may remain to form sodium silicate (Na_2SiO_3.) Iron and aluminum oxides are recorded as such.

The figuring is begun with chlorine. It is combined with sodium as sodium chloride ($NaCl$). If there is an excess of chlorine, it is combined with magnesium ($MgCl_2$) but if the sodium is in excess, the remainder is combined with sulphuric acid as sodium sulphate (Na_2SO_4). In this case oxygen has to be "borrowed." The remainder of the sulphuric acid is combined with magnesium oxide as magnesium sulphate ($MgSO_4$) and if there is not sufficient magnesium oxide, whatever sulphuric acid may then remain is combined with calcium oxide as calcium sulphate ($CaSO_4$). On the other hand, if magnesium oxide is in excess of the remaining sulphuric acid, the excess is combined with carbonic acid as magnesium carbonate ($MgCO_3$) and the calcium oxide combined with the remaining carbonic acid, as calcium carbonate ($CaCO_3$). The calcium oxide and carbonic acid should almost invariably be combined as much as possible. However, when the evaporated water is strongly alkaline, sodium carbonate (Na_2CO_3) is present, and part of the carbonic acid should be combined with sodium.

All calculations may be performed by the use of factors. To illustrate the figured analysis, the examples given in this chapter will be taken.

Resume :

Carbonic Acid (CO_2)	8.20
Silica (SiO_2)	2.90
Iron and Aluminium Oxides (Fe_2O_3 and Al_2O_3)	1.00
Calcium Oxide	16.46
Magnesium Oxide	5.04
Sulphuric Acid (SO_3)	31.77
Sodium	8.82
Chlorine	3.21

77.

The following is the figured analysis:

$NaCl$= 5.29 (all Cl x 1.6503)...............		2.09 Na used.	
Na_2SO_4=20.75 (6.73 Na x 3.083)	11.69 SO_3 used,	6.73 "	2.33 O used
$MgSO_4$=15.13 (all MgOx3.0015)	10.09 "	8.82 all of Na.	
$CaSO_4$=16.98(9.99SO_3x1.6996)	9.99 "	6.99 CaO used.	
$CaCO_3$=16.91(9.47CaOx1.7856)	31.77 all of SO_3	9.47 "	
			7.44 CO_2 used
CO_2= .76 (in excess). ...	16.46 all of CaO		.76 "
SiO_2= 2.90...............................			8.20 all of CO_2
Fe and Al= 1 00.			

In the above calculation it is necessary to take 2.33 parts of oxygen for combination with sodium sulphate. and 0.76 parts of carbonic acid are in excess. Both these are recorded in the following form of "full analysis:"

In 100,000 parts water.

Total solids	88.8
Lost by combustion	11.9
Mineral substance	76.9

Silica.....................	2.90	*or*	Silica	2 90
Iron and Aluminum Oxides	1.00		Iron and Aluminum Oxides	1.00
Carbonic Acid (CO_2)	8.20		Carbonic Acid (CO_2)......	.76
Calcium Oxide	16.46		Calcium Carbonate	16.91
Sulphuric Acid (SO_3)......	31.76		Calcium Sulphate	16.98
Magnesium Oxide.........	5.04		Magnesium Sulphate	15.13
Chlorine	3.21		Sodium Chloride	5 29
Sodium	8 82		Sodium Sulphate..... ...	20.75
(Oxygen for Na_2SO_4)	2 33			
	79.72			79.72

This method of analysis gives a double check on the results. The total of the "actual analysis" should be the same as the total of the "figured analysis," and each should be equal to or only slightly more than the mineral substance found by direct analysis. In the example above given the mineral substance is 76.9 and the total found by individual analyses is 79.72, a difference of 2.82. It rarely occurs, on account of unavoidable errors, that the two will exactly agree, but the difference ought not to exceed that in the example*.

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* The student is referred to Fresenius' quantitative analysis (second American edition) pages 207, 208 and 209, also pages 842 and 843.

CHAPTER IX.

LIMESTONE ANALYSIS.

63. A Complete Analysis of limestone is unnecessary in sugar work. It is sufficient to find the principal constituents, which are silica, iron and aluminium oxides, calcium carbonate, magnesium carbonate and calcium sulphate. It is also usual to make a moisture determination. Organic matter, phosphoric acid, alkali silicates, etc., are not determined.

64. Preparation of Sample.—The sample consists of six or eight small stones, which represent an average of the quarry from which they are taken. The stones are broken and from each one a couple of pieces weighing about half a gramme each are taken to make up the sample for analyzing. The pieces should not be taken from the outside of the stone, which may have suffered decomposition, and should be free from any streaks of iron, or sulphides, or other matter which is not generally present in the stone. Transfer to a clean porcelain mortar and reduce to a very fine powder.

65. Moisture.—Weigh out 2½^{gr} of the powdered sample on a watch glass and dry for an hour at 110-120°C. Cool in a dessicator and weigh again. The weight lost is water; divided by 2½, the weight of substance used, and multiplied by 100, will give the percentage.

Example:

Weight of watchglass and stone before drying	35.942^{gr}
Weight of watchglass and stone after drying	35.934^{gr}
Weight lost (moisture)	.008^{gr}

$.008 \div 2.5 = .0032$. $.0032 \times 100 = .32$ per cent. moisture.

66. Carbonic Acid. (Carbon dioxide, CO_2.) The dried sample, after the moisture is determined, is transferred to an alkalimeter, and the percentage of CO_2 is determined, as in **54**.

Example:

Weight of apparatus and contents	77.803^{gr}
Weight of same after operation	76.766^{gr}
Weight lost (CO_2)	1.037^{gr}

$1.037 \div 2.5 = .4148$. $.4148 \times 100 = 41.48$ per cent. carbonic acid.

67. Silica. (SiO_2) The contents of the alkalimeter are transferred to a platinum dish and evaporated to dryness. Take up the residue with dilute hydrochloric acid (1 part acid, 4 parts water) and filter into a 250^{cc} flask. Wash the residue in the filter thoroughly with hot water, and then dry it at 100°. Burn in a tared crucible, over a moderate flame. Cool and weigh. As the substance tested weighed $2\frac{1}{2}^{gr}$, the weight of silica obtained must be divided by 5 and multiplied by 2, to determine the weight in 1^{gr}. This multiplied by 100 will give the percentage of silica.

Example :

Weight of crucible and residue	11.146^{gr}
Weight of crucible	11.088^{gr}
Weight of residue (silica)	$.058^{gr}$

$.058 \div 5 = .0116$. $.0116 \times 2 = .0232$.

$.0232 \times 100 = 2.32$ per cent. silica.

68. Iron and Aluminum Oxides. (Fe_2O_3 and Al_2O_3.) When the filtrate in **67** is cool, fill the flask to the mark with water. Shake well and measure off 50^{cc}. Make alkaline with ammonia and precipitate, filter and burn the iron and aluminium oxides, as described in **56**. The weight obtained corresponds to $\frac{1}{2}^{gr}$ of the stone and must be multiplied by 2 and 100 to give the percentage.

Example:

Weight of crucible and precipitate	11.094^{gr}
Weight of crucible	11.088^{gr}
Weight of precipitate ($Fe_2 O_3$ and $Al_2 O_3$)	.006^{gr}

.006 x 2 x 100 = 1.2 per cent iron and aluminium oxide.

69. Calcium Oxide (CaO). The filtrate from the iron and aluminum precipitation is heated with the addition of acetic acid, and calcium oxide is determined as in **57**. The resulting weight must be multiplied by 2 and 100 to give the percentage of CaO in the stone.

Example:

Weight of crucible and precipitate	11.557^{gr}
Weight of crucible	11.088^{gr}
Weight of precipitate ($CaCO_3$)	.469^{gr}

.469 x 2 + 100 = 93.8 per cent. $CaCO_3$.
93.8 x .56 = 52.528 or 52.53 per cent. CaO.

70. Magnesium Oxide (MgO) is determined as in **58**. The percentage is found by multiplying the weight of magnesium oxide by 2 and 100 as above.

Example:

Weight of crucible and precipitate	11.103^{gr}
Weight of crucible	11.088^{gr}
Weight of precipitate ($Mg_2P_2O_7$)	.015^{gr}

.015 x .3602 = .0054, weight of magnesium oxide.
.0054 x 2 x 100 = 1.08 per cent. magnesium oxide.

71. Sulphuric Acid (SO_3) is determined by precipitation as barium sulphate as in **59**. From the 250^{cc} flask containing the original solution (**67** and **68**) 50^{cc} is measured off and used for the determination. The weight obtained is multiplied by 2 and 100 to find the percentage.

Example:

Weight of crucible and precipitate	11.103^{gr}
Weight of crucible	11.088^{gr}
Weight of precipitate ($BaSO_4$)	$.015^{gr}$

$.015 \times .3431 = .00515$, weight of SO_3.

$.00515 \times 2 \times 100 = 1.03$ per cent. sulphuric acid.

72. The Figured Analysis is calculated in the same manner as that described in water analysis with the difference that there are fewer constituents to consider. Moisture, silica and the oxides of iron and aluminum are set down as determined. Sulphuric acid is combined with calcium oxide, the remaining calcium oxide being combined with carbonic acid. The remaining carbonic acid is combined with magnesium oxide. It usually happens that the carbonic acid is a trifle too much or too little to make the combinations exact, but the excess of CO_2 or MgO must always be recorded.

The form given below may be used for recording analyses, the actual analysis being on the left and the figured analysis on the right. In the latter the calcium sulphate is determined by multiplying the sulphuric acid by 1.6996, the factor; the calcium oxide which remains is multiplied by 1.7856, to give the calcium carbonate; and the carbonic acid which remains, multiplied by 1.9091, gives the magnesium carbonate, an excess of magnesium carbonate being left.

Limestone Sample :

Moisture	.32	*or*	Moisture	.32
Silica	2.32		Silica	2 32
Iron and Aluminum Oxides	1.20		Iron and Aluminum Oxides	1.20
Calcium Oxide	52.53		Calcium Carbonate	92 51
Magnesium Oxide	1.08		Calcium Sulphate	1.75
Sulphuric Acid (SO_3)	1 03		Magnesium Carbonate	1.49
Carbonic Acid (CO_2)	41.48		Excess Magnesium Oxide	37
Undetermined	.04		Undetermined	.04
	100.00			100.00

The value of the limestone depends upon the amount of good lime which can be burned from it at the least cost. The best stone usually has 95 or 96 per cent. calcium carbonate, and no calcium sulphate. When the Steffens' process is used, the best stone is dependent both upon the salts in the molasses and the time it takes for the lime to slake, which is burned from the stone.

73. Lime may be analyzed according to the method given for limestone. If any sulphuric acid is present it is combined with calcium oxide. The carbonic acid is combined with magnesium oxide, and the excess with calcium oxide. The remaining calcium oxide is recorded as lime.

CHAPTER X.

COAL, COKE, AND FUEL OIL.

74. Coal. The estimation of moisture, coke and volatile matters, and ash are required in coal analysis. To determine the moisture weigh out 10^{gr} of a powdered average sample and heat at 110–115°C for one hour. This is a sufficient length of time to drive off all the water, and in a longer heating there is danger of the sample gaining in weight by the oxidation of sulphides and hydrocarbons. (Fresenius.) Cool in a dessicator and weigh. The loss is moisture.

Take 1-10 of the dried coal (representing 1^{gr} of the original sample) and burn over an exceedingly hot flame until all carbonaceous matter is consumed and the ash is white or reddish colored. Cool in a dessicator and weigh. The loss is put down as coke and volatile matters and the remainder is ash. The complete analysis is figured as follows:

Weight of dish and coal	36.282^{gr}
Weight of dish	26.282^{gr}
Coal taken	10.000^{gr}

Dish and coal before drying	36.282^{gr}
Dish and coal after drying	36.222^{gr}
Water lost	$.060^{gr}$

$.060 \div 10 \times 100 = .60$ per cent. mosture.

$10^{gr} - .060^{gr} = 9.940^{gr}$ remaining, 1-10 of $9.94^{gr} = .994^{gr}$.

Weight of crucible and coal	15.337^{gr}
Weight of crucible	14.343^{gr}
Coal taken	$.994^{gr}$

Weight of crucible and coal before burning	15.337^{gr}
Weight of crucible and ash after burning	14.396^{gr}
Coke and volatile matters lost	$.941^{gr}$

.941 ÷ 1 x 100 = 94.1, per cent. coke and volatile matters.

Weight of crucible and ash	14.396^{gr}
Weight of crucible	14.343^{gr}
Weight of ash	$.053^{gr}$

.053 ÷ 1 x 100 = 5 3, per cent. ash.

Resume :

Moisture	.60
Coke and volatile matters	94.10
Ash	5.30
	100.00

75. **Coke** is tested the same as coal, excepting that about 30^{gr} should be used for the moisture test, and it may be dried at a higher temperature, 140°C, and only half a gr is used for the ash. 100 per cent., minus the sum of the water and ash, is called the "combustible matter," instead of "coke and volatile matters," as above.

76. **Fuel Oil.** The most important and most usual test of oil is the determination of its specific gravity. This is done with Beaumé's hydrometer for liquids lighter than water (Fig. 45), the reading of the hydrometer being com-

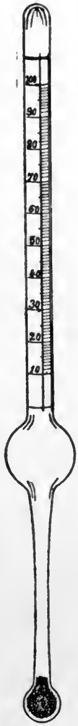

Fig. 45.

pared with the corresponding specific gravity by use of the following table:

TABLE B.

Comparison of Degrees on the Beaume Hydrominor Spindle with Specific Gravity.

Degree.	Sp. G.	Degree.	Sp. G.	Degree.	Sp. G.	Degree	Sp. G.
10	1 000	24	.913	38	.839	52	.777
11	.993	25	.907	39	.834	53	.773
12	.986	26	.901	40	.830	54	.768
13	.980	27	.896	41	825	55	.764
14	973	28	.890	42	820	56	.760
15	.967	29	.885	43	.816	57	.757
16	.960	30	.880	44	811	58	.753
17	.954	31	874	45	807	59	.749
18	948	32	.869	46	.802	60	.745
19	.942	33	.864	47	.798	65	726
20	.936	34	.859	48	.794	70	.709
21	.930	35	.854	49	.789	80	.676
22	.924	36	.849	50	785	90	.646
23	.918	37	.844	51	.781	100	.619

The above table is calculated for a temperature of 15°C. or 59°F., and all observations should be made at this temperature. However, a difference of 2 Farenheit degrees either way does not introduce an error of consequence.

The specific gravity may also be taken with a pycnometer, a specific gravity hydrometer, or any of the specific gravity balances for liquids. The Beaumé hydrometer is preferable to other methods in the fact that it is generally used in oil commerce.

Water is so seldom present in oil that it is determined only qualitatively. A quantity of oil of known specific gravity is poured over fused calcium chloride, which may be contained in a basket of wire screen. The specific gravity of the treated oil is then taken, and if it is less than before, water was present and was taken up by the calcium chloride. A simpler method, but one requiring more time, is to fill a glass tube (about 3-16 of an inch in diameter and 12 inches long) with the oil, having one end closed. By standing the tube on the closed end, if any water is present it will separate from the oil in a few days and go to the bottom.

Ashes. Evaporate 5^{gr} of the oil in a porcelain dish until it is sufficiently dry for ignition. This may be done first on a water bath and then on an asbestos plate over a direct flame. Burn carefully until a completely incinerated ash is obtained. The weight of the ash remaining divided by 5 and multiplied by 100 will give the per cent.

Example:

Weight of dish and oil	26.370^{gr}
Weight of dish	21.370^{gr}
Weight of oil used	5.000^{gr}
Weight of dish and ash	21.373^{gr}
Weight of dish	21.370^{gr}
Weight of ash	$.003^{gr}$

$.003 \div 5 = .0006$. $.0006 \times 100 = .06$ per cent.

Flash and Fire Test. The temperature at which the development of inflammable gases begins is called the flash point of oil, and the degree of temperature where the oil itself will burn is called the fire-point. Both may be tested at the same time, as the test for the latter is only a continuation of the test for the former. These determinations can be made with sufficiently accurate results by the simple apparatus mentioned as follows, but for absolutely exact determinations the Saybolt or some other apparatus with electric sparks should be used:

A porcelain crucible holding about 90^{cc} is nearly filled with the oil and placed on the ring of a lamp-stand, over a sheet (4 inches square) of asbestos, about ⅛ of an inch thick. A chemical Farenheit thermometer, supported by a clamp above, is inserted in the oil so that the mercury bulb is just covered. Heat is applied, the flame being just large enough to cause a rise of 2 or 3 degrees in temperature a minute. At the end of every minute after heat is applied a "test-flame" is passed over the oil. The "test-flame" should be as small as possible, but a match generally has to be used in sugar factory laboratories. The temperature degree, when the passing of the "test-flame" first causes a flash of light, is recorded as the flash point, and the degree when the oil ignites permanently is recorded as the fire point. In crude petroleum the latter is from 6 to 15° higher than the former.

CHAPTER XI.

ANALYSIS OF BONEBLACK.*

77. The Outward Appearance of boneblack often indicates its usefulness in sugar manufacture. Well-burned boneblack should be of a deep black color and show a faint velvety cracking. If it is sufficiently porous each broken piece when held to the tongue should produce a slight suction. If the boneblack is boiled with caustic potash or caustic sodium and then allowed to settle, the supernatent fluid should be completely colorless; a brown coloring is caused by undestroyed organic substance (glue, gristle).

78. The Analysis of Boneblack generally comprises determinations of moisture, calcium carbonate, calcium sulphate, calcium sulphide, organic matter and decolorizing power. The composition of good boneblack is about as follows:

Moisture	7	per cent
Carbon	7 to 8	"
Sand and Clay	2 to 4	"
Calcium Phosphate	70 to 75	"
Calcium Carbonate	7 to 8	"
Calcium Sulphate	.2 to .3	"
Phosphates of Iron and Aluminum	.5	"
Magnesium Phosphate	.6 to 1	"

79. Moisture.—The boneblack is coarsely powdered and 10^{gr} are dried at 120°C. It usually takes several hours for the sample to become thoroughly dry. The weight lost is moisture; divided by 10 and multiplied by 100 will give the percentage.

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* Adapted from "Leitfaden fur Zuckerfabrichemiker" by Dr. E. Preuss.

80. Carbon, Sand and Clay.—Into a porcelain dish put 10^{gr} of the finely pulverized sample and add some water. Then digest with 50^{cc} of concentrated hydrochloric acid, the dish being covered with a glass plate to prevent loss by spirting. Filter through a dry filter, the weight of which is known, and wash with hot water until the acid reaction of the filtrate has disappeared (test with litmus paper). The filter and contents are dried and weighed, the total, minus the weight of the paper, being carbon, sand and clay, the remaining constituents of the boneblack having been taken out by the digestion with acid. After weighing, incinerate in a tared crucible. The residue is sand and clay, and this weight subtracted from the weight of the contents of the filter paper will give the weight of the carbon. The re-results obtained, divided by 10 and multiplied by 100, will give the percentage.

The filtrate from the above, made up to a liter, serves in the determination of calcium sulphate, calcium sulphide, oxide of iron and aluminum, lime, magnesia and phosphoric acid.

81. Calcium Sulphate.—Measure off 200^{cc} of the above filtrate, corresponding to 2^{gr} of the original substance, and heat to nearly boiling point. Add a slight excess of barium chloride, precipitating barium sulphate, and filter as in **59**. After burning and weighing, the resulting weight is divided by 2 to give the weight in 1^{gr}, and is then multiplied by the factor .5832 to give the weight in calcium sulphate. Multiplying by 100 will give the per cent.

In factories and refineries having "boneblack houses" the examination of the boneblack as to its contents of calcium sulphate and its removal by treatment with soda solution is very important. The gypsum strongly influences the crystallization of sugar and in the re-burning of the boneblack leads to considerable losses, the calcium sulphate being reduced to calcium sulphide, and carbon escapes in the form of carbon monoxide gas.

$$CaSO_4 + 4C = CaS + 4CO.$$

The calcium sulphide thus formed has an injurious effect, as in contact with metals it produces colored combinations which lessen the value of the product. Therefore it is also necessary to determine the calcium sulphide.

82. Calcium Sulphide. Place 5^{gr} of the finely powdered sample in a porcelain dish and moisten with water. The dish is now put on a water bath and 10^{cc} of fuming nitric acid gradually added. Heat for half an hour, frequently stirring, and then add 10^{cc} of concentrated hydrochloric acid a few drops at a time. The mixture is heated 20 minutes longer and is stirred as before. By this means all the sulphur is oxidized and TUCKER prefers the method to all others. At the end of the heating dilute to about 100^{cc} by the addition of water and filter. Heat the filtrate nearly to boiling and precipitate with barium chloride, filter, burn, and weigh in the usual manner. The weight of barium sulphate is divided by 5 to give the weight in 1^{gr} and is multiplied by .1374 and 100 to give the per cent. of sulphur. The per cent. of the calcium sulphate obtained in the above paragraph multiplied by .2356 will give the per cent. of sulphur in the boneblack which is in combination as gypsum, and this subtracted from the total sulphur as just determined will give the sulphur in combination as calcium sulphide. Multiply the per cent. sulphur by 2.248 to obtain the per cent. of calcium sulphide.

83. Sugar Contents.—Powder 50^{gr} and boil with 100^{cc} of water for 20 minutes. Let the mixture settle and filter off the clear fluid. Add water to the sediment and boil again, filtering as before, and repeat the operation. The sediment is now placed on the filter and thoroughly washed with boiling water. Evaporate the combined filtrates to about 75 or 80^{cc} and rinse into a $100–110^{cc}$ flask. When cool make up to the mark and determine the sugar volumetrically. The result obtained is divided by 50 as 50^{gr} were used.

84. Calcium Carbonate.—During filtration the boneblack takes up calcium carbonate from the juices, and the pores are gradually closed. This excess is removed down to 7 per cent. (not below this, as it would affect the calcium phosphate present as a normal constituent) by washing the boneblack with hydrochloric acid, and the amount of acid necessary is calculated from the determination of calcium carbonate present. In making this estimation, Scheibler's apparatus, shown in Fig. 46, is generally used. The execution of the analysis is as follows:

Put the weighed quantity (1.7^{gr}) of finely pulverized boneblack into the developing bottle **A**; fill the caoutchouc cylinder **S** about half-full with concentrated hydrochloric acid (1.12 sp. g.) and place it carefully, with pincers and without spilling, into the bottle **A**. Fill by pressure on the bulb **W** of Woulff's bottle **E** (which contains water), the two communicating tubes **D** and **C**, with water, until the fluid in **C** is at zero, the water in **D**

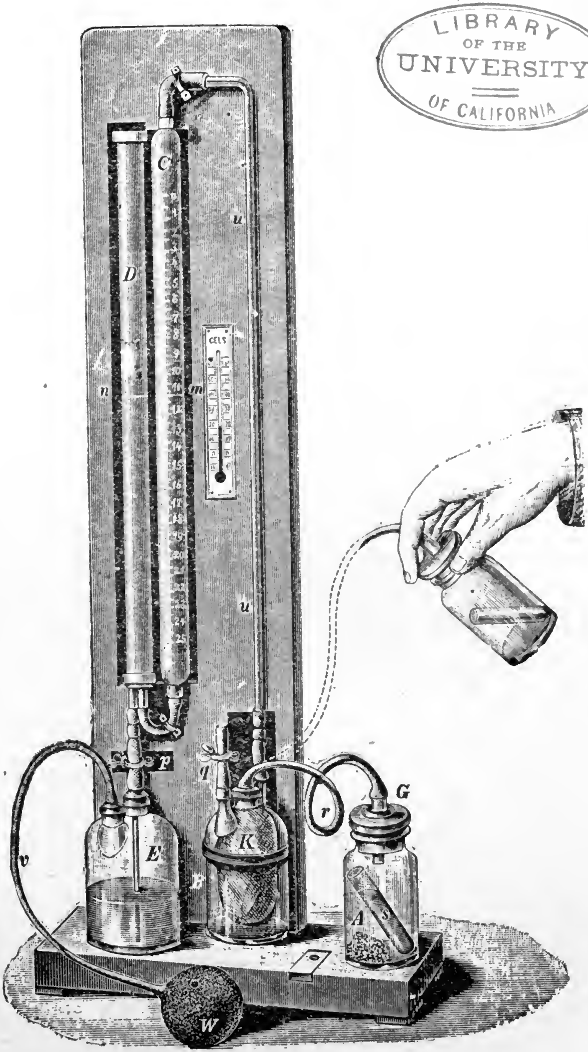

Fig. 46.

TABLE C.

For determining the percentage of Calcium Carbonate in Boneblack from the volume of Carbonic Acid.

Vol. Read.	TEMPERATURE CENTIGRADE.																		
	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
1	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.77	0.77	0.77	0.76	0.76	0.76	0.75	0.75	0.74	0.74	0.73	0.73
2	1.88	1.87	1.86	1.86	1.85	1.84	1.83	1.82	1.81	1.80	1.79	1.79	1.78	1.77	1.76	1.75	1.74	1.73	1.72
3	2.95	2.94	2.92	2.91	2.90	2.89	2.87	2.86	2.85	2.83	2.82	2.80	2.79	2.77	2.76	2.74	2.73	2.72	2.71
4	4.01	4.00	3.98	3.96	3.94	3.93	3.91	3.89	3.87	3.85	3.83	3.81	3.79	3.77	3.75	3.73	3.71	3.70	3.68
5	5.07	5.05	5.03	5.00	4.98	4.96	4.93	4.91	4.89	4.86	4.84	4.81	4.79	4.76	4.74	4.71	4.69	4.67	4.65
6	6.11	6.09	6.06	6.03	6.01	5.98	5.95	5.92	5.89	5.86	5.83	5.81	5.78	5.75	5.71	5.68	5.65	5.63	5.61
7	7.14	7.12	7.09	7.06	7.02	6.99	6.96	6.92	6.89	6.86	6.82	6.79	6.75	6.72	6.68	6.65	6.61	6.58	6.56
8	8.17	8.14	8.11	8.07	8.03	8.00	7.96	7.92	7.88	7.84	7.80	7.76	7.72	7.68	7.64	7.60	7.56	7.53	7.49
9	9.19	9.16	9.12	9.07	9.03	8.99	8.95	8.90	8.86	8.82	8.77	8.73	8.68	8.64	8.59	8.55	8.50	8.46	8.42
10	10.20	10.16	10.12	10.07	10.02	9.98	9.93	9.88	9.83	9.79	9.73	9.68	9.63	9.58	9.53	9.48	9.43	9.39	9.34
11	11.20	11.15	11.10	11.05	11.00	10.95	10.89	10.84	10.79	10.74	10.68	10.63	10.57	10.52	10.46	10.41	10.35	10.30	10.25
12	12.20	12.15	12.09	12.03	11.98	11.92	11.87	11.81	11.75	11.69	11.64	11.58	11.52	11.46	11.40	11.33	11.27	11.22	11.16
13	13.20	13.14	13.08	13.02	12.96	12.90	12.84	12.78	12.72	12.65	12.59	12.53	12.46	12.40	12.33	12.26	12.20	12.14	12.07
14	14.20	14.14	14.07	14.01	13.94	13.88	13.81	13.75	13.68	13.61	13.54	13.48	13.41	13.34	13.26	13.19	13.12	13.05	12.99
15	15.20	15.13	15.06	14.99	14.92	14.85	14.78	14.71	14.64	14.57	14.50	14.42	14.35	14.27	14.20	14.12	14.04	13.97	13.90
16	16.20	16.13	16.05	15.98	15.91	15.83	15.76	15.68	15.61	15.53	15.45	15.37	15.29	15.21	15.13	15.05	14.97	14.89	14.81
17	17.20	17.12	17.04	16.97	16.89	16.81	16.73	16.65	16.57	16.49	16.41	16.32	16.24	16.15	16.07	15.98	15.89	15.81	15.72
18	18.20	18.12	18.03	17.95	17.87	17.79	17.70	17.62	17.53	17.45	17.36	17.27	17.18	17.09	17.00	16.91	16.82	16.73	16.63
19	19.20	19.11	19.03	18.94	18.85	18.76	18.67	18.59	18.50	18.40	18.31	18.22	18.13	18.03	17.94	17.84	17.74	17.64	17.55
20	20.20	20.11	20.02	19.93	19.83	19.74	19.65	19.55	19.46	19.36	19.27	19.17	19.07	18.97	18.87	18.77	18.66	18.56	18.46
21	21.20	21.10	21.01	20.91	20.81	20.72	20.62	20.52	20.42	20.32	20.22	20.12	20.01	19.91	19.80	19.70	19.59	19.48	19.37
22	22.20	22.10	22.00	21.90	21.80	21.70	21.59	21.49	21.39	21.28	21.17	21.07	20.96	20.85	20.74	20.63	20.51	20.40	20.28
23	23.20	23.09	23.99	22.88	22.78	22.67	22.56	22.46	22.35	22.24	22.13	22.02	21.90	21.79	21.67	21.55	21.44	21.31	21.20
24	24.20	24.09	23.98	23.87	23.76	23.65	23.54	23.43	23.31	23.20	23.08	22.97	22.85	22.73	22.61	22.48	22.36	22.23	22.11
25	25.20	25.08	24.97	24.86	24.74	24.63	24.51	24.39	24.28	24.16	24.04	23.91	23.79	23.67	23.54	23.41	23.28	23.15	23.02

being on the same level. The pinch-cock **q** is opened during the filling, to allow air to escape. Care must be taken not to overflow any of the water into **B**, for the apparatus would have to be taken apart and dried.

Now place the glass stopper, fastened to the rubber tube **r** upon the developing vessel **A** (greasing the joint with tallow), and close the pinch-cock **q**. Hold the bottle **A** at the upper end with two fingers, to avoid warming it, and incline it so that the hydrochloric acid is poured over the substance. The carbonic acid developed rises through **r** into the rubber bulb **K** and crowds out an equivalent amount of air in **B** which, in turn, reduces the water in **C**. The pinch-cock **p** is opened, whenever necessary, to make the level of the fluid in **C** and **D** equal. **A** is shaken to generate the lost gas and when no further development occurs, the volume of water in **C** is read and the temperature observed. From these the percentage of calcium carbonate is determined by the accompanying Table C.

Example :

The volume of gas generated is 11.2 (see **n m** Fig. 45) at a temperature of 21°. By referring to the table we find that 11 volumes at 21° is 10.74 and 2 volumes is 1.80. Dividing the latter by 10 gives .18 for the .2 of a volume. Therefore, the per cent. of $CaCO_3$ is

$$10.74 + .18 = 10.92 \text{ per cent.}$$

As boneblack often contains caustic lime it is advisable, before making the analysis as above, to dampen the sample with ammonium carbonate and evaporate to dryness. An error is introduced when calcium sulphide is present as sulphuretted hydrogen is developed as well as carbonic acid. TUCKER avoids this error by adding a

TABLE D.

Quantities of Hydrochloric acid necessary for the solution of from 1 to 9 parts of Calcium Carbonate.

Degree Baume.	Sp G. at 15° C.	Per Cent. of Hydrochloric Acid	Percentage $CaCo_3$ Dissolved by Acid.	1	2	3	4	5	6	7	8	9
25	1,210	42,4	58,088	1,7217	3,4434	5,1651	6,8868	8,6080	10,3302	12,0519	13,7736	15,4953
24,5	1,205	41.2	56 444	1,7718	3,5437	5,3155	7,0874	8,8592	10,6310	12.4029	14,1747	15,9466
24	1,199	39,8	54.526	1,8342	3,6683	5,5025	7,3367	9,1709	11,0050	12,8392	14,6734	16 5075
23,5	1,195	39,0	53,430	1,8718	3,7436	5,6154	7,4872	9,3590	11,2308	13 1026	15,9744	16 8462
23	1,190	37,9	51,923	1,9261	3,8522	5,7784	7,7045	9,6306	11,5567	13 4828	15,4090	17,3351
22,5	1,185	36,8	50,416	1,9837	3,9674	5,9511	7,9348	9,9185	11,9022	13,8859	15.8696	17,8533
22	1,180	35,7	48,901	2,0448	4,0896	6,1344	8,1792	10,2240	12,2688	14,3136	16,3584	18,4032
21,5	1,175	34,7	47,539	2,1037	4,2075	6,3112	8,4150	10,5187	12,6224	14,7262	16,8299	18,9337
21	1,171	33 9	46,443	2,1534	4,3068	6,4602	8,6136	10,7670	12,9204	15.0738	17 2272	19,3806
20,5	1,166	33,0	45 210	2,2121	4,4242	6,6363	8,8484	11,0605	13,2726	15 4847	17,6968	19,9089
20	1,161	32,0	43,840	2,2813	4,5625	6,8438	9,1250	11,4063	13,6875	15,9688	18 2500	20,5313
19,5	1,157	31,2	42,744	2,3997	4,6795	7,0192	9,3590	11,6987	14,0384	16,3782	18,7179	21,0577
19	1,152	30,2	41,374	2,4172	4,8344	7,2517	9,6689	12,0861	14,5033	16,9205	19,3378	21,7550
18	1,143	28,4	38,908	2 5704	5,1408	7,7113	10,2817	12,8521	15.4225	17 9929	20,5634	23 1338
17	1 134	26,6	36,442	2,7444	5,4887	8.2331	10,9774	13,7218	16,4662	19,2105	21 9549	24,6992
16	1,125	24,8	33,976	2,9436	5,8871	8,8307	11,7742	14,7178	17.6613	20 6049	23,5484	26,4920
15	1,116	23,1	31,647	3,1602	6,3203	9,4807	12,6407	15,8009	18,9610	22 1212	25 2814	28,4415
14	1,108	21,5	29,455	3,3954	6,7907	10,1861	13 5814	16,9768	20,3721	23,7675	27.1628	30,5582
13	1.100	19,9	27,263	3,6683	7,3367	11,0050	14,6734	18,3417	22.0100	25,6785	29,3467	33.0151

small amount of copper chloride to the hydrochloric acid used.

Considering 7 per cent. as the normal amount of calcium carbonate, the quantity of acid of any strength necessary to remove the excess may be calculated by the use of Scheibler's Table **D**.

Example :

The calcium carbonate obtained in the above sample is 10.92, an excess of 3.92 over the normal 7 per cent. The amount of acid, say 1.175 sp. g. or 21.5 Beaumé, necessary to reduce this excess is determined by referring to the table as follows:

3. parts of calcium carbonate = 6.3112 parts of acid.
0.9 " " " = 1.8934 "
0.02 " " " = .0409 "

3.92 parts of calcium carbonate = 8.2455 parts of acid.

In a ton of 2,000 lbs. of boneblack having the above percentage of $CaCO_3$ would take

2,000 x 8 2455 per cent. = 164.91 lbs.
of acid of 1.175 sp. g. to remove the excess.

85. Decolorizing Power.—Equal amounts of a molasses solution are treated, during the same length of time, with equal parts of a new efficacious char and the boneblack to be analyzed. From the difference of color of the two filtered solutions the efficacy of the boneblack can be approximately determined. Stammer's color instrument should be used where frequent analyses of boneblack are made.

CHAPTER XII.

ANALYSIS OF CHIMNEY GASES.

86. Smoke Gases consist largely of carbonic acid, oxygen, nitrogen and carbon monoxide gas; marsh gas, sulphuric acid, etc., are found only in small quantities.

The analysis is most easily made by use of an apparatus which removes each constituent by absorption, the percentage of each being determined by the diminution of volume of the sample used. The apparatus most commonly used is Orsat's, or a modification of it.

87. Preparation of Reagents.—Concentrated solutions of caustic potash, pyrogallic acid and copper chloride are used for the absorption of the most important gases—carbonic acid, oxygen and carbon monoxide. The caustic potash solution is made by diluting 1 part of potassium hydrate with 2 parts of water. An alkaline solution of pyrogallic acid is made by mixing 1 volume of a 25 per cent. solution of pyrogallic acid with a 60 per cent. solution of potassium hydrate. The solution for absorbing carbonic oxide is made by shaking a mixture of equal parts of a saturated ammonium chloride solution and ammonia with copper shavings, until the fluid has turned dark blue.

88. Orsat's Apparatus (Fig. 47) consists of a gas measuring-tube **A** which, in the lower narrow portion, has a scale divided into half-cubic centimeters from 0 to 40, and is surrounded by a glass jacket filled with water, to avoid deviations of temperature. The lower end of the gas burette **A** is connected with the aspirator bottle **E** by a rubber tube. By raising and lowering this bottle, containing water, the gas burette can be filled with water and emptied, thereby drawing the gas mixture to **A**, or pressing the gas therein contained into the upper conduit pipe. The upper portion of **A** leads into a glass tube at right angles to it, which has three rests furnished with the cocks **a**, **b**, **c**; these cocks make communication possible with the absorption vessels **B**, **C**, **D**, each of which is again connected with a reservoir of like shape (**B′**, **C′**, **D′**.)

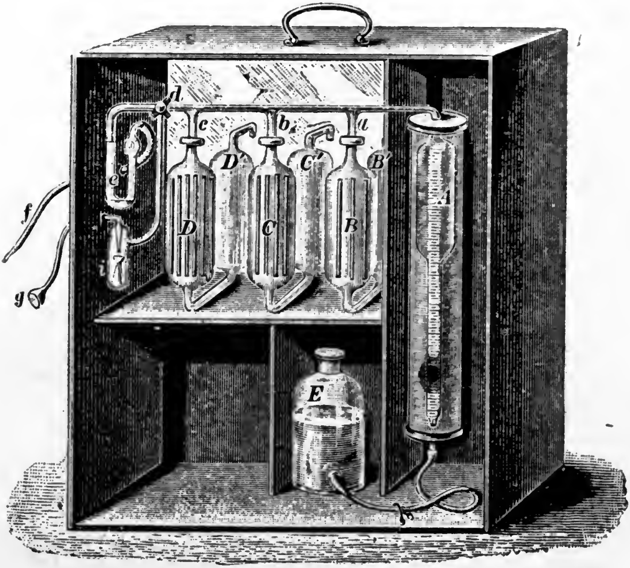

Fig. 47

The absorption vessels are filled with many narrow tubes of glass, in order to give the absorption liquids as large a surface as possible. (In the diagram only a few are denoted to give clearness.) The horizontal tube previously mentioned has at its end a tube bent like a U (**e**), the shanks of which are filled with cotton for the filtration of the smoke gases entering through **f**, while in the curve of the same there is a layer of water. Between the curve of the horizontal tube and the cock **c** there is a Winkler's three-way-cock, by which the tube, and thereby the entire apparatus, can be connected with the tube **f**, leading to the gas line, as well as with the air-injector **i**. The injector is for the purpose of pumping out the air in the tube **f** before using the apparatus, being done by blowing into the mouthpiece **g**.

89. Execution of the Test.—First, the absorption liquids from the reservoirs in the rear must be brought to **B**, **C**, **D**, which is done as follows: Close the cocks **a**, **b**, **c**; fill the burette **A** with water by placing the three-way-cock into such a position that **A** communicates with the outer air. Lift the bottle **E** and close the cock **d** against the atmosphere; then lower the bottle **E** again, open cock **a**, whereby the water flows from the burette to **E** and an air-diluted space is formed in **B**. The air-pressure then forces the absorption liquid from the reservoir to **B**, and **a** must be closed at the moment when the fluid reaches exactly to the mark. In the same manner the vessels **C** and **D** are filled. By means of the injector **i** the air must be pumped out of the tubes, which is done in the manner above mentioned. Now, the tube **e** must be connected by **f** with the gas-line and the three-way-cock must be placed in such a position that the filled burette **A** is connected with the atmosphere and the gas-line. By raising and lowering the bottle **E** repeatedly, the burette **A** and the tubes are rinsed with smoke-gas until the operator is sure that the air is completely crowded out.

After the water in **A** is set in again to the mark, the three-way-cock is turned so that **A** as well as the gas-line is closed against the atmosphere and the smoke-gas line communicates only with the burette **A**. By opening the pinch-cock in front of **E** and lowering the aspirator bottle, the burette is filled with the gas to be analyzed to a little below the mark (100^{ccm}). Whereupon the same is closed against the atmosphere and the gas-line. Now set in the fluid exactly to the zero point and allow the excess of pressure to escape into the atmosphere by opening once quickly **D**. The cock **a** is opened, and by raising the bottle **E**, the gas is pressed into **B**, which contains caustic potash. Repeat this operation several times and finally hold **E** at such a height that the level of the water is equal to the mark on **B**. Cock **a** is then closed and the height of the liquid in **A** is read off. Difference to 100 will give the percentage of carbonic acid in the gas. In the remainder of the gas mixture, determine as above, one after another, the contents of free oxygen and carbon oxide gas. The gas volume which remains is calculated as nitrogen.

The absorption liquids can be saved from spoiling by pouring some solar oil into the rear reservoirs, thus excluding the atmospheric air. If thus protected, the fluids will suffice for several hundred analyses.

90. Franke's Gas Burette (Fig. 48) may also be used for smoke-gas analysis. It has an advantage over the Orsat's apparatus, in being more simple in construction.

The burette consists of the measuring space **M**, the lower cylindric part of which is graduated into whole and half cubic centimeters, and the space **R** serving for holding the absorption liquids. The connection between the two can be produced by the glass-cock **r**, which has a wide double boring. The measuring space **M**, between the two cocks **m** and **r**, holds exactly 100^{ccm}. Into a socket at the lower end of the space **R** the glass cock **a** can be placed to close it air-tight.

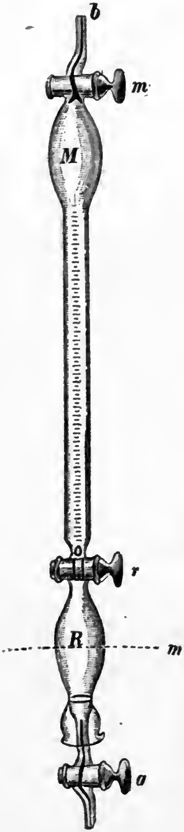

Fig. 48.

91. The Execution of the Analysis with Franke's burette is accomplished in the following manner: Fill the burette completely with water (space **M** and **R**), connect the point **b** with the gas-line and let so much of the gas enter that the space **R** is about half-filled. Then close the cocks **m** and **r** and remove the water in **R**, so as to fill **R** completely with the absorption liquid.

In order to exclude the air completely, pour into **R** so much of the reagent that even the funnel-shaped widening is partly filled with it. Now place the opened cock **a** carefully into the socket, so that from the boring as well as from the point below the cock the air is completely excluded. The excess of the absorption liquid accumulated in the widening is poured back into the storing-bottle after cock **a** is closed.

In order to put the gas-volume in the measuring space under atmospheric pressure, raise for a moment the cock **m**. The absorption of the constituent to be determined in the gas mixture is accomplished easily by opening the cock **r**, so that the reagent enters into the opening space. By shaking the burette, this operation can be hastened. After this is done, place the burette on the point **a** and wait until the absorption liquid has completely returned into **R** from the measuring space. The space **R** must then be filled again completely to the boring of the cock **r**. Now take out the cock **a**, pour out the reagent, and replace the same with water, with the precaution that now, even in the point, no air remains. The whole burette is now turned with the point **a** downward, placed into a high cylinder filled with water, and below water the cocks **a** and **r** are opened. On account of the air-diluted space, produced by the absorption, the water will now rise to a certain height into the measuring space. The reading off of the percentage contents is done after an equal level of water is produced inside and outside. In order to determine the constituents yet left in the remainder of the gas-mixture, remove the water in the measuring space by means of a suction bottle before the reagent is put in; especially must this be done by the determining of carbonic oxide gas. The burette with the water must be shaken several times before reading off the height, in order to let the remains of ammonia, which always evaporate, be absorbed by the water.

CHAPTER XIII.

*ANALYSIS OF FERTILIZERS.**

92. Artificial Fertilizers for beet fields generally contain principally either nitrogen, phosphoric acid or potash, although some fertilizers contain two of the constituents and others all three. In analysis, it is usual to make only the determination of the constituents upon which the value of the fertilizer depends. For example, in nitrate of soda, a very common fertilizer, it is necessary to estimate only the nitrogen, and in superphosphates, the soluble form of phosphoric acid is determined. The methods outlined in the following paragraphs may be used in the analysis of all fertilizers.

The refuse lime from sugar factories is of great value as a fertilizer, as it returns the calcium and magnesium which is taken from the soil. As it is often of interest to know the other elements present in the refuse, a full method of analysis is given in the next chapter.

93. The Sample is prepared by mixing it thoroughly, after which it is ground in a mortar fine enough to pass through a 25-mesh sieve. The operations should be performed rapidly, to prevent loss or gain of moisture.

94. Moisture determinations should be made in all fertilizer analysis. Weigh out 2^{gr} and dry at 100°. For potash salts, sodium nitrate and ammonium sulphate fertilizers, the sample may be dried at 130°. The drying usually takes from 3 to 5 hours. Determine the per cent. moisture in the usual way.

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* The preparation of the reagents used in these analysis will be found in Part III. The preparation of all but baryta solution is given according to the methods adapted by the Association of Official Agricultural Chemists. See Bulletin No. 76, U. S. Department of Agriculture, Division of Chemistry. Paragraph 94 is in part (**a** and **b**) adapted from this report, also Paragraph 96.

95. Phosphoric Acid is in two forms, soluble and insoluble, the soluble being the form of value as a fertilizer. In contact with certain basic hydroxides and water some of the soluble acid will become insoluble and is said to be "reverted." A determination of the reverted acid is usually unnecessary. In analysis of phosphoric acid, calculation is based on the formula of the anhydride—P_2O_5.

(*a*) **The Total Phosphoric Acid** is estimated as follows: The 2^{gr} dried as above are ignited in a crucible to burn away organic matter, and are then dissolved in hydrochloric acid. After solution, transfer to a 200^{cc} flask, cool, make up to the mark, shake well and pass through a dry filter into a beaker or flask. Measure off half of the solution, corresponding to 1^{gr} of the sample, and neutralize with ammonia. If the solution is not clear, add a few drops of nitric acid. The addition of about 10^{gr} of dry ammonium nitrate will assist the precipitation which follows. Heat to 65°C and add molybdic solution. About 5^{cc} of the reagent must be used for every milligramme of P_2O_5 present in the solution tested. Stir and keep covered 1 hour at 65°C. Filter and wash the precipitate with a solution containing 15^{gr} of ammonium nitrate in 100^{cc} of water, to which about 3 to 5^{cc} of molybdic solution has been added, and the whole slightly acidified with nitric acid. Test the filtrate for phosphoric acid by additional molybdic solution. The precipitate on the filter is now dissolved with ammonia and the filter washed with a hot mixture of 3 parts of water and 1 part of ammonia. Nearly neutralize with hydrochloric acid, cool, and add magnesia mixture slowly, preferably with a burette, while stirring constantly. About 10^{cc} of the mixture is necessary for every milligramme of P_2O_5 in the solution tested. After a few minutes add about 30^{cc} of ammonia and let stand for twelve hours. Filter, wash with a 5 per cent. ammonia solution, dry and ignite to whiteness, or to a grayish white. Cool and weigh, the weight being multiplied by .6396 to give the weight phosphoric acid (P_2O_5). Dividing this by 100 will give the per cent.

(*b*) **Soluble Phosphoric Acid.**—Place 2^{gr} of the sample upon a filter and wash with water into a 200^{cc} flask. Use successive small portions of water, allowing each portion to pass through before adding more. When the flask is filled to the mark, measure off 100^{cc} and test as under the above paragraph.

(*c*) **Insoluble Phosphoric Acid** may be determined by difference, subtracting the soluble acid from the total. This will also include any reverted acid which may be present, but the error may be overlooked.

96. Nitrogen is determined according to GUNNING'S method, which does not include the nitrogen of nitrates (**97**). Weigh out 3.0^{gr} of the sample and transfer to a 500^{cc} Kjeldahl digestion flask*. In a sample containing much nitrogen, a less amount of the substance may be used for analysis. Add to the flask 10^{gr} of pulverized potassium sulphate and about 20^{cc} of pure sulphuric acid (free from nitrates) with a sp. g. of 1.84. Fix the flask in an inclined position and heat gradually, until all frothing ceases; then boil until the liquid is colorless, or nearly so. Cool and wash into a distillation flask of about 550^{cc} capacity, with about 200^{cc} of water. Add a

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* Kjeldahl flasks are pear-shaped and round-bottomed, with a long, tapering neck. They should be made of Jena or of the best Bohemian glass.

few drops of phenol and then a saturated solution of sodium hydroxide until the reaction is strongly alkaline. The flask is now fitted with a rubber stopper and a bulb tube, as in Fig. 49 (**A** and **a**), the latter being connected with the condensor **B** by a rubber tube. Another bulb tube **b** is attached to the condensor at **d** and extends to nearly the bottom of the Erlenmeyer flask **C**, which contains 20^{cc} of a normal acid. Half normal acid may be used or, if only a small amount of nitrogen is present in the sample, tenth-normal is to be recommended. Heat is now applied, and the nitrogen present in **A** is distilled as ammonia, and passes over and is absorbed in **C**. The operation is completed when 150^{cc} of the distillate has been collected. The time required is from three-quarters of an hour to an hour and a half.

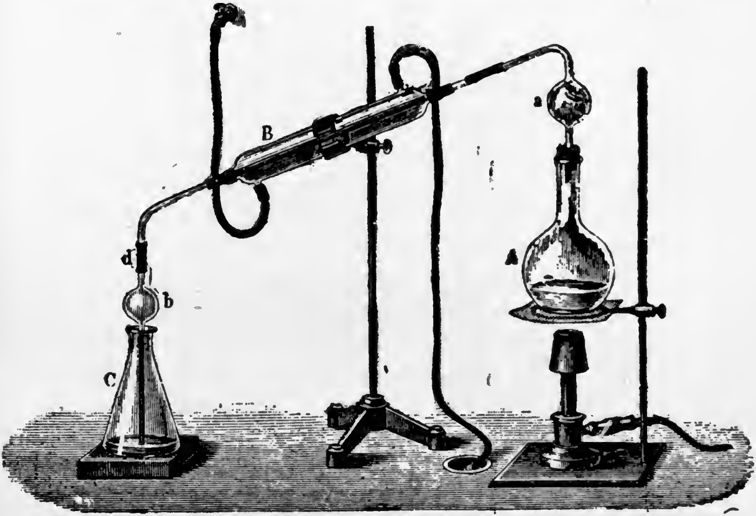

Fig. 49.

The contents of **C** are now cooled and titrated with caustic baryta water solution*. This solution must be of a known strength, which is determined by finding how many cc of it are necessary to neutralize a certain amount of normal acid. Tincture of litmus is used as an indicator and the baryta solution is added from a burette until the color just turns red. The quantity of the solution used is measured, and from this the amount of nitrogen is calculated as shown in the following

Example:†

It takes 50.1^{cc} of baryta solution to neutralize the 20^{cc} of normal acid, used with the distillate, from 1^{gr} of a sample. The baryta solution is of such strength that 20^{cc} of normal acid requires 99.9^{cc} of the solution for neutralization. As one liter of normal acid corresponds to 14.01^{gr} of nitrogen, 20^{cc} corresponds to 0.2802^{gr}. Therefore, 99.9^{cc} of baryta solution corresponds to 0.2802^{gr} of nitrogen and 1^{cc} corresponds to 0.002799^{gr}.

Now, as 50.1^{cc} of the baryta solution are used, the nitrogen denoted is

$$50.1 \times 0.002799 = 0.14023^{gr}.$$

As 20^{cc} of Normal Acid $= 0.28020^{gr}$ Nitrogen
and 50.1^{cc} Caustic Baryta $= 0.14023^{gr}$ "
There remain.......... 0.13997^{gr} "

Which is, in round numbers, 14 per cent. of the 1^{gr} used.

97. Total Nitrogen, including the nitrogen of nitrates, is determined as follows: To the substance in the digestion flask, as in **96**, add 30^{cc} of a salicylic acid

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* Any standard alkali solution may be used instead. The Association of Official Agricultural Chemists recommend ammonia, a one-tenth solution, having 1.7051 gr. of ammonia to the liter.

† Fruhling and Schulz.

mixture, which is prepared by mixing 30^{cc} of concentrated sulphuric acid with 1^{gr} of commercial salicylic acid. The mixing requires about 10 minutes. Then add 5^{gr} of sodium hyposulphite and 10^{gr} of potassium sulphate. Heat and then distill and determine the nitrogen, as in **96.**

98. Potash. Boil* 10^{gr} of the sample with from 250^{cc} to 300^{cc} of water for half an hour. Make the hot solution alkaline by the addition of ammonia and precipitate the calcium present with ammonium oxalate. Cool, dilute to 500^{cc} and filter through a dry filter. In the analysis of muriate of potash, the mixture is diluted without the addition of ammonia and the precipitation of calcium. Heat 50^{cc} of the filtrate, corresponding to 1^{gr} of the sample, to boiling point and add, a drop at a time, and with constant stirring, sufficient barium chloride to precipitate the sulphuric acid present. Without filtering, add in the same manner baryta water in slight excess. Filter while hot and wash well. Heat the filtrate nearly to boiling and precipitate the barium by the addition of ammonium carbonate, previously adding a few drops of ammonia. Filter and wash thoroughly. Evaporate the filtrate to dryness and burn carefully over a low flame until all ammonium salts have been expelled. Dissolve the residue in hot water and filter. Acidify the filtrate with a few drops of hydrochloric acid, in a porcelain dish. Add an excess of a concentrated solution of platinic chloride (from 5 to 10^{cc}) and evaporate nearly to dryness, keeping the matter in the water-bath below boiling point. Add 80 per cent. alcohol (sp.g. 0.8645) to

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* Fertilizers which contain much organic matter, the 10 gr. are ignited at a gentle heat, with the addition of enough concentrated sulphuric acid to saturate the sample, before being boiled with water.

the dish and let stand for some time; then filter off the alcoholic solution. Repeat this operation until the residue in the dish consists of small reddish-yellow octahedra, which is the appearance of potassium platinic chloride. Bring this residue upon the filter and wash with alcohol. Dry the filter and contents until the alcohol has volatalized, and then carefully transfer the contents to a watch glass. The small amount of the precipitate which cannot be removed is washed out with hot water. The filtrate is evaporated to dryness in a weighed porcelain dish, the contents of the watch glass being also added. Dry for 30 minutes at 100°, cool, and weigh. The weight, less the weight of the dish, is potassium platinic chloride. Multiplying by .1931 will give the weight of potassium oxide (K_2O), and as 1^{gr} was used for the analysis, the percentage is obtained by multiplying by 100.

CHAPTER XIV.

ANALYSIS OF REFUSE LIME.

99. Refuse Lime* analysis consists of determinations of water, sugar, organic matter, silica, iron and aluminum oxides, calcium oxide, magnesium oxide, caustic lime, phosphoric acid, sulphuric acid and carbonic acid.

100. The Sample is a carefully selected average, small samples being taken from several places and mixed together. As the substance usually contains too much moisture to handle easily, about 20^{gr} are dried, powdered as in **93**, and preserved in an air-tight jar. The determinations are made with the dry substance, and, by taking into account the per cent. of water found in the moisture determination, are figured into the original substance (see **110**).

101. Water is determined by weighing out 2^{gr} and drying at 100°. The weight lost, divided by 2 and multiplied by 100 will give the per cent. of water.

102. Sugar.—Of the original substance, take 100^{gr} and treat as described in **83**, determining the per cent. sugar volumetrically.

103. Organic Matter.—Burn $2\frac{1}{2}^{gr}$ of the dry substance over a low flame, heating not quite to redness. Cool and weigh. The loss is put down as organic matter. The per cent. of dry substance is found by dividing by 2.5 and multiplying by 100.

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* Refuse lime, as referred to here, includes not only the filter press cakes but any other refuse from the factory which is disposed of in the same pile or reservoir with the filter press cakes.

104. Silica.—After burning away the organic matter from $2\frac{1}{2}^{gr}$, as in the above paragraph, the remainder is dissolved in hydrochloric acid, with the addition of heat, and is filtered into a 250^{cc} flask. The substance remaining on the filter is washed, dried, weighed, and percentage on dry substance figured as in **67**. This is usually recorded as silica, but might be more properly written "Insoluble in Hydrochloric Acid," as other substances are often in excess of silica.

105. Iron, Aluminum, Calcium and Magnesium oxides are determined from the filtrate in the above paragraph as described in **68**, **69** and **70**, the percentage being found on dry substance.

106. Caustic Lime is found by titrating 1^{gr} with a normal acid, as described in **35a**. The CaO found by this method is that which is uncombined, not being in the form of a salt. Either the dry or the original substance may be taken for this determination.

107. Phosphoric Acid is estimated by taking 2^{gr} of the dry substance and proceeding as described in **95a**.

108. Sulphuric Acid.—From the 250^{cc} filtrate of **104** take 50^{cc} and determine the sulphuric acid (SO_3) as in **71**.

109. Carbonic Acid is determined by means of the alkalimeter described in **54**, 2^{gr} of the dry substance being taken. The weight lost, divided by 2 and multiplied by 100, will give the per cent.

110. The Percentages which are figured on dry substance are calculated to the original substance by multiplying the percentage found by the part which the dry substance is to the original substance. For example, if the water is 43 per cent., the dry substance is 100—43 or 57 per cent., and if the percentage of phosphoric acid to the dry substance is 1.58, then 1.58 x .57 is equal to the percentage of phosphoric acid to the original substance, or .909.

111. The Figured Analysis. Water, sugar, organic matter, silica, iron and aluminum oxides and caustic lime are recorded as found. From the calcium oxide found by precipitation with ammonium oxalate, the caustic lime is subtracted to give the calcium oxide in combination with acids. Phosphoric acid and sulphuric acid are combined with calcium oxide, and carbonic acid is combined with the remainder of the calcium oxide and with the magnesium oxide. The combining is effected, as usual, with factors. For example, let the following represent the actual analysis of a sample of refuse lime:

Water	43.00
Organic Matter	6.79
Sugar	1.14
Silica	5.28
Iron and Aluminum Oxides	.75
Caustic Lime (CaO)	4.05
Total Calcium Oxide	25.75
Carbonic Acid (CO_2)	16.55
Phosphoric Acid (P_2O_5)	.90
Sulphuric Acid (SO_3)	.28
Magnesium Oxide	.47

The acids phosphoric, sulphuric and carbonic are first combined with calcium oxide:

.90 (P_2O_5) x 2.1827 = 1.96, per cent. calcium phosphate.
.28 (SO_3) x 1.6996 = .48, per cent. calcium sulphate.

For CaP_2O_8 1.06 per cent. CaO is used, for $CaSO_4$ 0.20 per cent. and the caustic lime is 4.05 per cent. The total calcium oxide is 25.75, hence the amount to be combined with carbonic acid is

25.75—(1.06 + .20 + 4 05 = 5.31) *or* 20.44 per cent.
20.44 x 1 7856 = 36 50, per cent. calcium carbonate.

The amount of carbonic acid used is 16.06, leaving 0.52 per cent. for combination with magnesium oxide.

0.52 x 1.9091 = .99, per cent. magnesium carbonate.

This is exactly sufficient to combine with all the magnesium, for

0.47 (MgO) x 2 1 = .99, per cent. magnesium carbonate.

Resume :

Water	42.00
Organic Matter	6.79
Sugar	1.14
Silica	5 28
Iron and Aluminum Oxides	0.75
Caustic Lime (CaO)	4.05
Calcium Phosphate	1.96
Calcium Sulphate	0.48
Calcium Carbonate	36.50
Magnesium Carbonate	0.99
Undetermined	0.06
	100.00

CHAPTER XV.

ANALYSIS OF SYRUP OR MASSECUITE ASH.

112. The Sample. A sufficient amount of the substance should be taken to yield from 1.5 to 2^{gr} of ash. The amount necessary may be determined by incineration with sulphuric acid as in **34b**. The portion taken is concentrated as much as possible by evaporation, and is then charred at a moderate heat until no more gases escape. The charcoal is then powdered and digested with hot water. The solution, but none of the charcoal, being filtered into a porcelain dish. This is done repeatedly until all the soluble matter is extracted. The sediment is then burned completely to ashes, cooled, treated with a solution of ammonium carbonate and burned again, moderately, until all ammonia is driven off. It is now united with the filtrate containing the soluble matter. This is evaporated to dryness in a weighed platinum dish, heated moderately, cooled and weighed, the weight in excess of the dish being the total ashes. This weight divided by the weight of the original substance taken and multiplied by 100, will give the per cent. In the determinations which follow the per cent. is figured both on the ash and on the original substance. The former is obtained according to **119**, and the latter is determined by multiplying whatever the per cent. of the constituent is to the ash by the per cent. which the ash is to the original substance. For example, if one of the constituents of the ash is 12 per cent. of the ash and the ash is 10 per cent. of the original substance, the per cent. of the constituent to the original substance is found by multiplying .12 by .10, which gives .0120 or 1.2 per cent.

113. Carbonic Acid.—All the ashes obtained as above are transferred to an alkalimeter and carbonic acid determined as in **52**.

114. Silica—Magnesium Oxide. The contents of the alkalimeter are filtered into a 250^{cc} flask, the sediment on the filter paper being silica, and 50^{cc} of the contents of the flask, after being made up to the mark, are used for the determination of iron and aluminum, calcium and magnesium oxides, the estimation of each being the same as in limestone analysis (see **119** for calculation of weighings).

115. Sulphuric Acid is also determined as in limestone analysis by using 50^{cc} of the filtrate as above.

116. Sodium and Potassium Oxides.—The total alkali chlorides are determined as in **60**, 50^{cc} of the 250^{cc} filtrate being used. The residue remaining after this determination is then treated with platinic chloride and the potassium oxide found as described in **98**. The sodium oxide is estimated by difference.

117. Phosphoric Acid.—Another 50^{cc} portion of the filtrate above is used for the phosphoric acid determination, which is made according to **94a**.

118. Chlorine.—A new and smaller portion of the substance to be analyzed is taken for this determination. It is charred at a moderate heat, and the sediment which remains is moistened and pulverized, then being rinsed into a 250^{cc} flask and boiled a short time with water. After cooling, without further consideration of the suspended coal particles, make up to the mark with water, shake well, and filter through a dry filter. Half the filtrate is used for the chlorine estimation, which is made by precipitation with silver nitrate, as in **51**. On account of the strong alkaline condition of the ash extract, it should be neutralized by the addition of nitric acid.

119. Calculation of Weighings.—In analyses where a certain number of grammes are made up to a certain number of cubic centimeters, an aliquot portion represents either a gramme or such a fraction of a gramme, that the calculation of weighings can be made by a simple multiplication. But in ash analysis the whole ash is made up to 250^{cc}, no matter what its weight may be, for if a certain definite portion were weighed off it might not be an accurate average of the whole. Consequently, each weight must be figured upon the whole weight of the ash used. The weights of silica and carbonic acid are each divided by the weight of the substance used, and multiplied by 100 to give the per cent. For example, if 1.83^{gr} of ash are used and the carbonic acid lost weighs $.020^{gr}$, the per cent. of carbonic acid is

$$.020 \div 1.83 \times 100 = 1.09.$$

In determinations made from 50^{cc} of the 250^{cc} filtrate, each weight is multiplied by 5 to make it correspond to the original substance, and is then divided by the weight of the ash and multiplied by 100 to give the per cent. For example, the weight of calcium carbonate is $.0096^{gr}$ which is multiplied by the factor .56, to give the weight of calcium oxide; $.0096 \times .56 = .0054^{gr}$. This is multiplied by 5 to give the weight in 250^{cc}, or in the whole original substance; $.0054 \times 5 = .027^{gr}$. Taking 1.83, as above, for the weight of ash used, the per cent. of calcium oxide is

$$.027 \div 1.83 \times 100 = 1.48.$$

The weight of chlorine is multiplied by 2, divided by the weight of the ash used and multiplied by 100 to give the per cent.

120. The Figured Analysis.—As the combination of acids and bases is almost always the same, the figured analysis will be illustrated by an example. Let it be considered that the following is the result of the actual analysis of a molasses ash, only the percentages relative to the ash being given:

Carbonic Acid (CO_2)	21.00
Silica (SiO_2)	0.21
Iron and Aluminum Oxides	0.93
Calcium Oxide	1.48
Magnesium Oxide	0.26
Sulphuric Acid (SO_3)	5.32
Sodium Oxide	6.90
Potassium Oxide	50.88
Phosphoric Acid (P_2O_5)	0.50
Chlorine	11.00

(*1*) The first operation is to combine all the chlorine and phosphoric acid with potassium oxide. These and all other combinations are effected by the use of factors.

11 0 (Cl) x 2.1035 = 23.14, per cent. potassium chloride.
0 5 (P_2O_5) x 2 9903 = 1.50, per cent. potassium phosphate.

12.14 per cent. of potassium oxide is used in forming the chloride and 1 per cent. in forming the phosphate, making a total of 13.14 per cent., and leaving 37.74 per cent. (50.88—13.14) for other combinations.

(*2*) All sodium oxide is combined with carbonic acid.

.69 (Na_2O) x 1.7067 = 11.78, per cent. sodium carbonate.
4.88 per cent. carbonic acid is used.

(*3*) The magnesium oxide is combined equally with sulphuric acid and carbonic acid.

0.13 (half MgO) x 3.0015 = 0.39, per cent. magnesium sulphate.

0.13 (half MgO) x 2.1 = 0.27, per cent. magnesium carbonate.

0.26 per cent. sulphuric acid and 0.14 per cent. carbonic acid are used.

(*4*) The calcium oxide is combined equally with sulphuric acid and carbonic acid.

0.74 (half CaO) x 2.4294 = 1.80, per cent. calcium sulphate.

0.74 (half CaO) x 1.7856 = 1.32, per cent. calcium carbonate.

1.04 per cent. sulphuric acid and 0.58 per cent. carbonic acid are used.

(*5*) The potassium oxide remaining in (1) is combined with the remaining sulphuric and carbonic acids.

The sulphuric acid used in (3) and (4) amounts to (0.26 + 1.04) 1.30 per cent., leaving 4.02 (5.32–1.30) for combination with potassium oxide.

4.02 x 2.1773 = 8.75, per cent potassium sulphate.

The potassium oxide used is 4.73 per cent., leaving 33.01 (37.74–4.73) for combination with carbonic acid.

The carbonic acid used in (2), (3) and (4) amounts to 5.60 per cent. (4.88 + 0.14 + 0.58), leaving 15.40 per cent. (21.0–5.60) for combination with potassium oxide.

33.01 (remaining K_2O) x 1.4668 = 48.41, per cent. potassium carbonate.

The carbonic acid used in this combination is 15.40, exactly the amount remaining. In analyses where combinations do not come out correctly, the constituent in excess is set down as described in **72**.

The above figures are each multiplied by the per cent. the ash is to the original substance to give the respective per cent. of each constituent to the original substance.

If, for example, the ash is 11 per cent. of the molasses used, the whole analysis may be recorded as follows:

	Per Cent. of Ash.	Per Cent. of Molasses.
Silica	0.21	.023
Iron and Aluminum Oxides	0 93	.102
Calcium Carbonate	1.32	.145
Calcium Sulphate	1 80	.198
Magnesium Carbonate	0.27	.029
Magnesium Sulphate	0 39	.042
Sodium Carbonate	11 78	1.296
Potassium Chloride	23.14	2 545
Potassium Phosphate	1.50	.165
Potassium Sulphate	8.75	.962
Potassium Carbonate	48 71	5.358
Undetermined	1.30	.143
	100 00	11.008

CHAPTER XVI.

MISCELLANEOUS ANALYSES.

121. Beet Seed.—The value of beet seed is determined by the test for per cent. moisture, the test of non-seed and the germination test. If a number of sacks of the same seed are to be tested, take a small sample from each one, inserting a sampler into the sack. Make one large sample from the smaller ones and mix very thoroughly. The moisture is found by weighing out 10 or 20^{gr} and drying at 95°C, until there is no further loss of water. The weight lost divided by the weight used will give the per cent. moisture.

Weigh 10^{gr} of the average sample and shake in a sieve freeing the seeds from all dust. Discard any foreign matter that is not seed, such as dried leaves and the blossoms which come from the top of the seed stem. The latter look like small dead seeds. Weigh the sample again, and the weight lost by the above operations divided by 10 (the weight used) will give the per cent. of non-seed.

From the pure seed obtained by the non-seed test weigh out 2^{gr} for the germination test and count the number of seeds in this weighing. Plant these seeds an inch apart, in squares, a half inch deep in very light soil, mostly sand. For this purpose use a box (Fig. 50) about ten inches wide, about 25 inches long and not less than 2 nor more than 3 inches deep. These are inside measurements. The box is fitted with nails an inch apart and threads are stretched between the opposite nails on the sides and also on the ends. The seeds are planted where the crossings are made by these strings, so the operator knows where to look for the plants to come up.

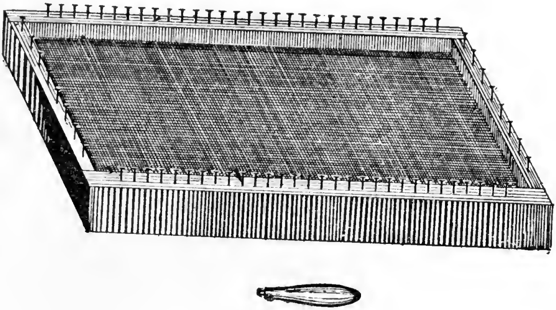

Fig 50.

The germination test lasts fifteen days from the time of planting. During this period keep the soil moist on top all the time, watering every morning and when necessary during the day. Use the water from a bucket kept standing near the germination box, for it must be of the same temperature as the room. Keep the box in a hot house having a temperature of from 75 to 85° Far., and give it all the sun possible. Make a record every day at the same hour of the number of seeds which have sprouted up to that time, and also of the number which have come up and died. At the end of the fifteen days count the total number of plants (germs) living, also the number that have died, figuring the number of germs per seed. Also count the number of seeds having 1 germ, 2 germs, 3 germs, etc. From the total number of germs is figured the monetary value of the seed. It is usual to consider a 2^{gr} sample having 150 germinations as the standard, and a sample having more or less germs has a greater or less value in proportion. Some fixed value, *e. g.*, 20 cents per kilo, is taken as a standard and all germination tests are figured on this basis.

Example:

A test shows 140 germinations. Its value on the basis of 20 cents per kilo for standard seed figured by the proportion:

$$150 : 140 :: 20 : x$$

$x = 18.67$, the value in cents per kilo.

The following is a form which may be used for recording a number of germination tests :

No of Sample.	Seeds in Sample.	Date Planted.	Germinations Each Day.															Died	Germs.						Value per Kilo.
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		0	1	2	3	4	5	
No. 1	103	Feb. 28th	0	0	0	0	2	16	41	73	90	105	114	121	124	127	129	1	35	26	23	15	3	...	17.20
" 2	89	"	0	0	0	0	3	18	64	117	140	152	157	167	167	168	170	0	14	20	25	20	10	..	22 66
" 3	136	"	0	0	0	1	2	7	17	28	55	89	127	141	152	165	172	0	43	42	33	16	4	...	22.93
" 4	97	"	0	0	0	0	1	3	18	62	96	123	131	144	147	152	152	0	18	28	32	16	3	...	20.26
" 5	94	"	0	0	0	1	13	64	106	127	141	153	161	161	161	162	162	0	20	16	33	21	3	1	21 60

122. Sulphur.—In the examination of sulphur for decolorizing purposes it is usual to determine the water, organic matter and ash, the sum of these subtracted from 100 giving the per cent. of sulphur. Weigh out 10^{gr} of the coarsely powdered sample in a porcelain crucible for the moisture determination and dry at 100°C. Weigh and estimate the per cent. of water lost. In this determination the weighings must be made as quickly as possible, as the sample readily absorbs moisture from the air. After determining the water, heat the crucible and contents over a low flame and light the sulphur with a match. The crucible is now removed from the flame and placed where the fumes will readily go off in the air. When the sulphur is all burned, cool the crucible in a dessicator and weigh, recording the weight. The contents now consist of the ash and the organic matter. The latter is burned away over a moderate flame and the crucible cooled and weighed again. The difference between this weight and the one just recorded, is the weight of organic matter and is calculated into percentage, and the difference between the last weighing and the weight of the crucible is the ash, which is also calculated into percentage. As before stated, the sum of the per cent. moisture, organic matter and ash is subtracted from 100 to give the per cent. sulphur.

Sulphur can usually be obtained in a very pure state, the following being two sample analyses :

Per Cent. Moisture	.10	.17
Per Cent. Organic Matter	.38	.30
Per Cent. Ash	.03	.01
Per Cent. Sulphur	99.49	99.52
	100.00	100.00

123. Anhydrous Ammonia.—In factories having Steffen's plants, where the cooling is done artificially by a refrigerating machine, it is of considerable importance to determine the quality of anhydrous ammonia used. Henry Faurot, in an article in Cassier's *Magazine*, gives the determination of boiling point as the principal test. The lower the boiling point, the freer the ammonia is of impurities. Also, the lower the temperature at which the ammonia expands, the cheaper it is to use. Mr. Faurot determines the boiling point as follows: "Draw off (from the ammonia cylinder) about six to eight ounces of liquid ammonia into a cylindrical-shaped glass or chemical beaker. Place this on a wet plate or surround it with water, and when it boils insert into it the bulb only of a special low standard chemical thermometer, reading off through the walls of the glass, and observing the temperature when the mercury remains stationary, as the boiling point. Commercially pure liquid ammonia should boil at not higher than 28.6 degrees below zero F; lower temperature denotes purer ammonia, while a less pure ammonia boils at a higher temperature. In testing for the boiling point, the thermometer should be held as stationary as possible, and not moved about in the liquid."

It is of importance to determine whether inflammable gases are present in the ammonia, as they are the principal impurities, and are especially harmful in the fact that they decompose the ammonia and lessen its refrigerating power. The following qualitative test is sufficient: A short iron pipe is screwed into the valve of the ammonia cylinder and is so bent that the ammonia can be discharged into the bottom of a bucket of cold water. Submerge over the mouth of the pipe a glass funnel, with the end of the stem tightly corked. Allow the ammonia to flow in a small stream and the ammonia gas will be absorbed by the water, while the other gases will rise to the top of the funnel. If methane or other inflammable gases are present, they will, if released and lighted with a match, burn with a blue flame.

124. Lubricating Oils* are often adulterated by the addition of low grade oils and other matters. The examination of the principal lubricants is conducted as follows, the tests given being for the most common substances used in adulteration :

Castor Oil.—Dissolve in alcohol and if black poppy oil is present it will remain as a residue.

Cocoanut Oil should dissolve completely in cold ether. If adulterants are present, the etheral solution will be muddy. The oil also has a more grayish color when adulterated than when pure. Mutton suet, beef marrow and other animal greases are most commonly used for adulteration.

Lard.—Melt at a low temperature, and if water is present it will separate from the grease. Digest the lard with hot distilled water and test with silver nitrate for chlorides (common salt). Melt the lard in warm water, and if plaster of paris is present it will go to the bottom in the form of a white powder.

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*Adapted from R. S. CHRISTIANI.

Linseed Oil.—The oil if pure will become a pale pink if treated with hyponitric acid and dark yellow if treated with ammonia, giving a thick soap in the latter case.

Neatsfoot Oil.—Test the same as castor oil.

Olive Oil.—Test the same as castor oil.

Rapeseed Oil.—Ammonia gives a yellowish colored soap when added to the oil containing mustard and whale oil, and a white soap when the oil is pure. Chlorine gas colors the oil brown when it contains whale oil, but if pure it remains colorless.

Tallow.—Dissolve in ether and foreign substances will remain as a residue. Test this residue for starch by the addition of iodine water, a blue color indicating starch. Other parts of the residue may be tested in the well-known ways (with ammonia and with ammonium oxalate) for aluminum and calcium, the former indicating the presence of kaoline and the latter marble dust. Test also for sulphuric acid with barium chloride, as barium sulphate is also used as an adulterant. Intermix a small portion of the tallow with half its volume of dried and powdered copper sulphate. If water is present, the mixture will turn blue if the tallow is white, and green if the tallow is yellow.

The Purity of lubricating oils is often approximately determined by taking their specific gravity by means of a pycnometer or with the Beaumé hydrometer (see **76**) and comparing them with the known specific gravities of standard samples. If, in this test, there is any wide divergence found, the sample is assuredly impure. The following is WALLIS-TAYLER's table of specific gravity for oils:

TABLE E.

Standard Specific Gravities of Lubricants.

NAME.	SP. G.	NAME.	SP. G.
Castor	.9611	Palm	.9680
Cocoanut	.9202	Paraffin, volatile	.7 to .865
Cocoanut Butter	.8920	Paraffin, heavy	.865 to 9
Cod Liver	917 to .92	Paraffin, solid	.9 to .93
Colza	.9136	Petroleum	.8800
Cotton Seed	.9252	Piney Tallow	.9260
Flax	3.9347	Rape	.9136
Grape Seed	.9202	Rosin	.9900
Hemp	.9276	Sperm	.8810
Lard	.9380	Sun-fish	874to.879
Linseed	.9347	Sunflower	9262
Neatsfoot	.9250	Tar	1 2600
Nut	.9260	Turpentine	.8640
Olive	.9176	Whale	.911to.922

Oxidation of Oils.—The length of time an oil is fit for lubrication is tested by finding how long it takes to oxidize. NASMYTH recommends for this a common plate of iron 6½ feet long by 4 inches wide, such as may always be found in the blacksmith shop of a sugar factory. On one surface are cut, with a planing machine, a number of parallel longitudinal grooves. One end of the plate is raised about 8 inches higher than the other and equal small portions of the different oils to be tested are poured into the grooves at the upper end. The distance each oil traverses down its particular groove is noted, and also the length of time that elapses before each oil becomes thickened by oxidation and ceases to flow. This often takes several days.

Flash Test.—The power of lubricants to resist overheating in work is determined by the flash test described in **76**. Animal and vegetable oils should not flash under 400° and mineral oils should not flash under 300°.

125. Fluxes and Rust Joints.—It is not at all an infrequent occurrence that a machinist comes to the laboratory and asks for some chemical to use as a flux in soldering or welding certain metals, or for some compound to use in making a rust joint. The following is a list of fluxes for common metals ;

Brass	Sal Ammoniac	Lead	Resin (or Tallow)
Copper	Sal Ammoniac	Lead and Tin	Resin and Sweet Oil
Iron	Borax	Zinc	Zinc Chloride
Iron (tinned)	Resin		

A quick-setting rust cement for calking joints in cast-iron pipes, tanks, etc., is made with 1 part sal ammoniac, 2 parts powdered sulphur, and 80 parts iron borings. Add water and make a thick paste. A better rust joint, but one which sets more slowly, is made, according to MOLESWORTH, with 2 parts sal ammoniac, one part powdered sulphur, and 200 parts of iron borings. Make into a thick paste with water.

126. Crude Acids for boiling out evaporators are tested only for sp. g., and this is done with a Beaumé spindle, being compared with Table II. The strength of the acids increase with their specific gravity. The accompanying tables, **F**, **G** and **H**, show the strength of hydrochloric, sulphuric and nitric acid for the corresponding specific gravity.

127. Soda used in boiling out multiple effects is tested only for its percentage of sodium carbonate. Weigh out 2^{gr} of the sample, transfer to an alkalimeter and find the weight of carbonic acid lost (see **52**), Divide this weight by 2 (the weight used) and multiply by 100 to obtain the percentage of carbonic acid. This percentage multiplied by the factor 2.4117, gives the percentage of sodium carbonate.

Example:

Weight of alkalimeter and soda	75.956^{gr}
Weight of same after operation	75.147^{gr}
	0.809^{gr}

$$0.809 \div 2 \times 100 = 40.45 \text{ per cent. } CO_2.$$

$$40.45 \times 2.4117 = 97.55 \text{ per cent. sodium carbonate.}$$

TABLE F.

Showing the strength of Hydrochloric Acid (Muriatic Acid) Solutions

TEMPERATURE, 15° C.

[Graham-Otto's Lehrb. d. Chem. 3 Aufl. II. Bd. 1. Abth. p. 382.]

Sp. Gr.	HCl.	Cl.	Sp. Gr.	HCl.	Cl.	Sp. Gr.	HCl.	Cl
1.2000	40.777	39.675	1.1328	26.913	26.186	1.0657	13.456	13.094
1.1982	40.369	39.278	1.1308	26.505	25.789	1.0637	13.049	12.697
1.1964	39.961	38.882	1.1287	26.098	25.392	1.0617	12.641	12.300
1.1946	39.554	38.485	1.1267	25.690	24.996	1.0597	12.233	11.903
1.1928	39.146	38.089	1.1247	25.282	24.599	1.0577	11.825	11.506
1.1910	38.738	37.692	1.1226	24.874	24.202	1.0557	11.418	11.109
1.1893	38.330	37.296	1.1206	24.466	23.805	1.0537	11.010	10.712
1.1875	37.923	36.900	1.1185	24.058	23.408	1.0517	10.602	10.316
1.1857	37.516	36.503	1.1164	23.650	23.012	1.0497	10.194	9.919
1.1846	37.108	36.107	1.1143	23.242	22.615	1.0477	9.786	9.522
1.1822	36.700	35.707	1.1123	22.834	22.218	1.0457	9.379	9.126
1.1802	36.292	35.310	1.1102	22.426	21.822	1.0437	8.971	8.729
1.1782	35.884	34.913	1.1082	22.019	21.425	1.0417	8.563	8.332
1.1762	35.476	34.517	1.1061	21.611	21.028	1.0397	8.155	7.935
1.1741	35.068	34.121	1.1041	21.203	20.632	1.0377	7.747	7.538
1.1721	34.660	33.724	1.1020	20.796	20.235	1.0357	7.340	7.141
1.1701	34.252	33.328	1.1000	20.388	19.837	1.0337	6.932	6.745
1.1681	33.845	32.931	1.0980	19.980	19.440	1.0318	6.524	6.348
1.1661	33.437	32.535	1.0960	19.572	19.044	1.0298	6.116	5.951
1.1641	33.029	32.136	1.0939	19.165	18.647	1.0279	5.709	5.554
1.1620	32.621	31.746	1.0919	18.757	18.250	1.0259	5.301	5.158
1.1599	32.213	31.343	1.0899	18.349	17.854	1.0239	4.893	4.762
1.1578	31.805	30.946	1.0879	17.941	17.457	1.0220	4.486	4.365
1.1557	31.398	30.550	1.0859	17.534	17.060	1.0200	4.078	3.968
1.1537	30.990	30.153	1.0838	17.126	16.664	1.0180	3.670	3.571
1.1515	30.582	29.757	1.0818	16.718	16.267	1.0160	3.262	3.174
1.1494	30.174	29.361	1.0798	16.310	15.870	1.0140	2.854	2.778
1.1473	29.767	28.964	1.0778	15.902	15.474	1.0120	2.447	2.381
1.1452	29.359	28.567	1.0758	15.494	15.077	1.0100	2.039	1.984
1.1431	28.951	28.171	1.0738	15.087	14.680	1.0080	1.631	1.588
1.1410	28.544	27.772	1.0718	14.679	14.284	1.0060	1.124	1.191
1.1389	28.136	27.376	1.0697	14.271	13.887	1.0040	0.816	0.795
1.1369	27.728	26.979	1.0677	13.863	13.490	1.0020	0.408	0.397
1.1349	27.321	26.583						

TABLE G.

Showing the Strength of Sulphuric Acid of Different Densities, at 15° Centigrade.—(Otto's Table.)

Per. Cent of H_2SO_4.	Specific Gravity	Per Cent. of SO_3.	Per Cent. of H_2SO_4.	Specific Gravity	Per Cent. of SO_3.
100	1.8426	81.63	50	1.3980	40.81
99	1.8420	80.81	49	1.3866	40.00
98	1.8406	80.00	48	1.3790	39.18
97	1.8400	79.18	47	1.3700	38.36
96	1.8384	78.36	46	1.3610	37.55
95	1.8376	77.55	45	1.3510	36.73
94	1.8356	76 73	44	1.3420	35.82
93	1.8340	75 91	43	1.3330	35.10
92	1.8310	75 10	42	1.3240	34.28
91	1.8270	74 28	41	1.3150	33.47
90	1.8220	73.47	40	1.3060	32.65
89	1.8100	72.65	39	1.2976	31.83
88	1.8090	71 83	38	1.2890	31.02
87	1.8020	71 02	37	1.2810	30.20
86	1.7940	70 10	36	1.2720	29.38
85	1.7860	69.38	35	1.2640	28.57
84	1.7770	68.57	34	1.2560	27.75
83	1.7670	67 75	33	1.2476	26.94
82	1.7560	66 94	32	1.2390	26.12
81	1.7450	66.12	31	1.2310	25.30
80	1.7340	65 30	30	1.2230	24.49
79	1.7220	64.48	29	1.2150	23.67
78	1.7100	63 67	28	1.2066	22.85
77	1.6980	62 85	27	1.1980	22.03
76	1.6860	62 04	26	1.1900	21.22
75	1.6750	61 22	25	1.1820	20.40
74	1.6630	60 40	24	1.1740	19.58
73	1.6510	59.59	23	1.1670	18.77
72	1.6390	58 77	22	1.1590	17.95
71	1.6270	57 95	21	1.1516	17.14
70	1.6150	57 14	20	1.1440	16.32
69	1.6040	56 32	19	1.1360	15.51
68	1.5920	55 59	18	1.1290	14.69
67	1.5800	54 69	17	1.1210	13.87
66	1.5860	53.87	16	1.1136	13.06
65	1.5570	53 05	15	1.1060	12.24
64	1.5450	52 22	14	1.0980	11.42
63	1.5340	51 42	13	1.0910	10.61
62	1.5230	50 61	12	1.0830	9.79
61	1.5120	49 79	11	1.0756	8.98
60	1.5010	48 98	10	1.0680	8.16
59	1.4900	48 16	9	1.0610	7.34
58	1.4800	47 34	8	1.0536	6.53
57	1.4690	46 53	7	1.0464	5.71
56	1.4586	45.71	6	1.0390	4.89
55	1.4480	44.89	5	1.0320	4.08
54	1.4380	44.07	4	1.0256	3.26
53	1.4280	43 26	3	1.0190	2.44
52	1.4180	42.45	2	1.0130	1.63
51	1.4080	41 63	1	1.0064	0.81

TABLE H.

Showing the Strength of Nitric Acid by Specific Gravity. Hydrated and Anhydride.

TEMPERATURE 15°.
(Fresenius, Zeitschrift f. analyt. Chemie. 5.449.)

Sp. Gr. at 15° C.	100 PARTS CONTAIN—		Sp. Gr. at 15° C.	100 PARTS CONTAIN—	
	N_2O_5	NO_3H		N_2O_5	NO_3H
1.530	85.71	100.00	1.488	75.43	88.00
1.530	85.57	99.84	1.486	74.95	87.45
1.530	85.47	99.72	1.482	73.86	86.17
1.529	85.30	99.52	1.478	72.16	85.00
1.523	83.90	97.89	1.474	72.00	84.00
1.520	83.14	97.00	1.470	71.14	83.00
1.516	82.28	96.00	1.467	70.28	82.00
1.514	81.66	95.27	1.463	69.39	80.96
1.509	80.57	94.00	1.460	68.57	80.00
1.506	79.72	93.01	1.456	67.71	79.00
1.503	78.85	92.00	1.451	66.56	77.66
1.499	78.00	91.00	1.445	65.14	76.00
1.495	77.15	90.00	1.442	64.28	75.00
1.494	76.77	89.56	1.438	63.44	74.01
1.435	62.57	73.00	1.295	39.97	46.64
1.432	62.05	72 39	1.284	38.57	45.00
1.429	61.06	71.24	1.274	37.31	43.53
1.423	60.00	69.96*	1.264	36.00	42.00
1.419	59.31	69.20	1.257	35.14	41.00
1.414	58.29	68.00	1.251	34.28	40.00
1.410	57.43	67.00	1.244	33.43	39.00
1.405	56.57	66.00	1.237	32.53	37.95
1.400	55.77	65.07	1.225	30.86	36.00
1.395	54.85	64.00	1.218	29.29	35.00
1.393	54.50	63.59	1.211	29.02	33.86
1.386	53.14	62.00	1.198	27.43	32.00
1.381	52.46	61.21	1.192	26.57	31.00
1.374	51.43	60.00	1.185	25.71	30.00
1.372	51.08	59.59	1.179	24.85	29.00
1.368	50.47	58.88	1.172	24.00	28.00
1.363	49.71	58.00	1.166	23.14	27.00
1.358	48.86	57.00	1.157	22.04	25.71
1.353	48.08	56.10	1.138	19.71	23.00
1.346	47.14	55.00	1.120	17.14	20.00
1.341	46.29	54.00	1.105	14.97	17.47
1.339	46.12	53.81†	1.089	12.85	15.00
1.335	45.40	53.00	1.077	11.14	13.00
1.331	44.85	52.33	1.067	9.77	11.41
1.323	43.70	50.99	1.045	6.62	7.22
1.317	42.83	49.97	1.022	3.42	4.00
1.312	42.00	49.00	1.010	1.71	2.00
1.304	41.14	48.00	0.999	0.00	0.00
1.298	40.44	47.18			

* Formula: $NO_3H + 1\frac{1}{2}H_2O$.

† Formula: $NO_3H + 3H_2O$.

PART III.

Preparation of Reagents.

CHAPTER XVII.

PREPARATION OF REAGENTS.

128. Lead Acetate (*Basic Acetate of Lead Solution*).—Put 900^{gr} of acetate of lead and 300^{gr} of lead oxide in 1 liter of water at 150°F. Let stand in a warm place for two days, shaking every few hours. Solutions of other densities can be made by using different amounts of the acetate and oxide, but in the same proportion of 3 to 1. In most German factories a solution with a sp. g. of 1.20 to 1.25 is used. The beet analysts at Chino prefer a solution having a sp. g. of from 1.30 to 1.35, for rapid beet work, and G. L. SPENCER says the U. S. Department of Agriculture analysts also prefer a very concentrated solution.

129. Alumina Cream, according to the directions of the U. S. Department Internal Revenue, is prepared as follows: Shake up powdered commercial alum with water at ordinary temperature until a saturated solution is obtained. Set aside a little of the solution, and to the residue add ammonia, little by little, stirring between additions, until the mixture is alkaline to litmus paper. Then drop in additions of the portions left aside, until the mixture is just acid to litmus paper. By this procedure a cream of aluminum hydroxide is obtained suspended in a solution of ammonium sulphate, the presence of which is not at all detrimental for sugar work when added after subacetate of lead, the ammonium sulphate precipitating whatever excess of lead may be present.

130. Normal Sodium Solution. — 53.08^{gr} of pure sodium carbonate (Na_2CO_3) previously ignited to dull redness, are dissolved in water, and the solution is diluted to exactly 1 liter.

131. Normal Hydrochloric Acid. — Dilute 200^{cc} of pure hydrochloric acid of 1.10 sp. g. with water to 1 liter. Normal acid should be of such strength that a certain amount of it will exactly neutralize an equal amount of normal sodium solution. The proportion above given will make an acid that is too strong. Take 20^{cc} of normal sodium solution, color with phenol, and add enough of the acid made to neutralize the sodium, measuring the amount of acid used with a burette. If, for example, it is found by repeated experiments that 17.8^{cc} of acid neutralizes the 20^{cc} of sodium solution, then the acid must be diluted to 20^{cc} by adding 2.2^{cc} of water, and all the acid must be diluted in the same proportion.

Example:

60^{cc} has been used to find the strength of the acid; then 940^{cc} of acid remain.

$$17.8 : 2.2 :: 940 : x$$

$$x = 116\ 2,$$

The number of cc of water that must be added to the 940^{cc} of acid to make a normal solution. After adding this water, verify by seeing if 20^{cc} of the acid will neutralize the 20^{cc} of the sodium solution.

132. Normal Sulphuric Acid.—Pour, while constantly stirring, one part of concentrated sulphuric acid into 15 equal parts of water, and, after cooling, make 110^{cc} of the solution up to 1100^{cc} with water. Mix thoroughly and measure off 100^{cc}. In three parts of 25^{cc}

each of this amount determine the weight of sulphuric anhydride (SO_3) in each 1^{cc} of the solution, analyzing with barium sulphate, as described in **59**. Three tests are made to insure accuracy. From the contents of sulphuric acid, as determined by the tests, estimate how much water must be added to the remaining liter of solution so that each cc will contain 0.040^{gr} of SO_3.

Example :

The average of the three tests gives 0.313^{gr} of barium sulphate in 25^{cc} of the acid or 1.252^{gr} in 100^{cc}. Converting to SO_3 by use of the factor,

$$1.252 \times .3432 = 0.4297^{gr}.$$

Therefore each 100^{cc} must be diluted according to the formula :

$$0.40 : 0.4297 :: 100 : x$$
$$x = 107.425,$$

A dilution of 7.425^{cc} for each 100^{cc} or 74.25^{cc} for the liter. After adding this amount of water to the liter of acid it is well to make a final test.

133. Normal Nitric Acid.—Dilute 200^{cc} concentrated nitric acid of 1.2 sp. g. with water to 1 liter, and then proceed exactly as with the formation of normal hydrochloric acid.

134. The Special Acid for alkalinities is made according to **36**. It may be made from hydrochloric, nitric or sulphuric acid.

135. Phenol (Phenolphtalein).—Dissolve the phenolphtalein powder in the smallest amount of alcohol and dilute with water to 4 or 5 times the volume of alcohol. This indicator turns red in the presence of alkalies.

136. Rosolic Acid.—Dissolve 1 part in 100 parts of alcohol. This indicator becomes colorless in the presence of free acid.

137. Cochineal.—Mix 3^{gr} of pulverized cochineal with 50^{cc} of strong alcohol and 200^{cc} of water. Let stand for 48 hours, shaking frequently.

138. Litmus Solution.—Digest 1 part of powdered litmus with 6 parts of alcohol on a water bath until the coloring matter soluble in alcohol is dissolved. Pour off the alcoholic solution and digest the residue with distilled water. Filter and divide the fluid into two portions. In one portion stir with a glass rod dipped in very dilute nitric acid until the color just appears red. Add enough of the second portion to bring back the blue color and then turn the mixture red with the rod and acid as before. Add the remainder of the second portion and the whole should be perfectly neutral. Mix with an equal part of 90 per cent. alcohol and preserve in an unstoppered bottle away from acid fumes.

139. Litmus Paper.—Prepare a litmus solution as above and divide in two portions. Make one portion red by the addition of a drop or two of nitric acid and the other a distinct blue by a drop or two of caustic soda solution. Dip strips of Swedish filter paper in the red solution for acid paper and into the blue for alkaline paper. Dry away from laboratory fumes and preserve in an unstoppered bottle. For ordinary work any unglazed paper may be used but in chemical analysis where small pieces of the paper are often burned with the precipitates, the Swedish paper must be used. Acid solutions turn blue litmus paper red and alkaline solutions turn the red paper blue.

140. Turmeric Paper.—Boil 1 part of powdered turmeric with 4 parts of alcohol and 2 of water. Filter and dip strips of unglazed paper into the filtrate. Dry and preserve in a stoppered bottle away from the light. Free alkalies turn the yellow color of the paper to brown.

141. Silver Nitrate Solution (*Standard*).—Dissolve 4.794^{gr} of pure crystallized silver nitrate in 1 liter of water. Each cc of this solution will precipitate 1^{mg} of chlorine, and in a solution of common salt the precipitate formed from the use of 25^{cc} of the silver nitrate solution should weigh 0.101^{gr}.

142. Fehling's Solution (*Soxhlet's Modification*) is prepared as follows:

(*1*) Dissolve 34.639^{gr} of copper sulphate (free from nitric acid) in water and dilute to 500^{cc}.

(*2*) Dissolve 173^{gr} of sodium and potassium tartrate (Rochelle salts) in water and dilute to 400^{cc}, mixing the solution with 100^{cc} of sodium hydroxide solution. The latter is prepared by dissolving 500^{gr} of caustic soda in 1 liter of water, and should be of 1.393 sp. g. at 15°C.

Mix *1* and *2* in equal volumes immediately before using.

143. Solution for Standardizing Fehling's. — The method for determining the amount of invert sugar necessary to reduce the copper in 10^{cc} of Fehling's mixed solutions is given in **48**. For determining how much dextrose is necessary for the same purpose, dissolve 4^{gr} of pure anhydrous dextrose in distilled water and make up to 1 liter. Each cc of this solution will then contain 0.004^{gr} dextrose. Make the test as usual and the number of cc of the solution used, multiplied by 4, will give the number of milligrammes of dextrose which reduce the copper.

144. Pipette Solution (for cleaning).—Dissolve 1 part bichromate of potash in 10 parts water and add 1 part concentrated sulphuric acid. This solution is used to cleanse pipettes from the film of fat which sometimes forms on the inside. Fill the pipette with the solution, cork one end and stand on the stopped end for twenty-four hours.

145. Molybdic Solution.—Dissolve 50^{gr} of molybdic acid in 200^{gr} or 208^{cc} of ammonia, specific gravity, 0.96, and pour the solution thus obtained into 750^{gr} or 625^{cc} of nitric acid, specific gravity 1.20. Keep the mixture in a warm place for several days, or until a portion heated to 40° deposits no yellow precipitate of ammonium phosphomolybdate. Decant the solution from any sediment and preserve it in glass-stoppered vessels.

146. Magnesia Mixture.—Dissolve 11^{gr} of recently ignited calcined magnesia in dilute hydrochloric acid, avoiding an excess of the latter. Add a little calcined magnesia in excess, and boil a few minutes to precipitate iron, alumina, and phosphoric acid; filter; add 140^{gr} of ammonium chloride, 350^{cc} of ammonia of specific gravity 0.96, and water enough to make a volume of 1 liter. Instead of the solution of 11^{gr} of calcined magnesia, 155^{gr} of crystallized magnesium chloride ($MgCl_2.6H_2O$) may be used.

147. Ammonium Citrate Solution. — Dissolve 185^{gr} of commercial citric acid in 750^{cc} of water; nearly neutralize with commercial ammonia; cool; add ammonia until exactly neutral (testing with alcoholic solution of rosolic acid), and bring to volume of 1 liter. Determine the specific gravity, which should be 1.0900 at 20°, before using.

148. Baryta Solution.—Pour 300 or 400^{cc} of boiling water over 25^{gr} of crystallized barium hydrate, and filter the hot solution quickly through a folded filter, into a bottle, then diluting to 1 liter. Utmost speed is necessary as the fluid is liable to become dim by the formation of barium carbonate, carbonic acid being attracted from the air. The making of a normal baryta solution is not advisable, as it is unstable, and the value of the solution, as made above, must always be determined before using (see **96**). Litmus solution should always be used as an indicator with this preparation.

149. Orsat's Apparatus Reagents are described in **87**.

150. Powdered Glass or Sand for use in determining the dry substance of massecuites should be thoroughly digested with warm and dilute hydrochloric acid to dissolve all foreign material, then washed with water, dried at 100° and preserved in a perfectly air-tight jar.

TABLE I.

PREPARATION OF REAGENTS.

NAME.	Symbol.	PREPARATION.
Aqua Regia	....	Prepare when required by adding three or four parts of concentrated HCl to 1 part concentrated HNO_3.
Sodium Hydrate	$NaOH$	Dissolve 1 part pure caustic soda in 20 parts of water.
Potassium Hydrate	KOH	Dissolve 1 part pure caustic potassium in 20 parts of water.
Baryta Water	BaO_2H_2	Dissolve 1 part barium hydrate in 5 parts of water.
Calcium Hydrate	CaO_2H_2	Digest slacked lime with cold water, shaking occasionally. Filter off the clear liquid.
Sodium Carbonate......	Na_2CO_3	When required dissolve 1 part of the salt in 5 parts of water. Do not let stand in a glass bottle.
Ammonium Chloride....	$(NH)_4Cl$	Dissolve 1 part in 6 parts of water.
" Sulphate ...	$(NH_4)_2SO_4$	Dissolve 1 part in 5 parts of water.
" Oxalate	$(NH_4)_2C_2O_4$	Dissolve 1 part of the pure salt in 20 parts of water.
" Carbonate ..	$(NH_4)_2CO_3$	Dissolve 1 part in 5 parts of water and add 1 part of ammonia water.
" Sulphide ...	$(NH_4)_2S$	Pass sulphuretted hydrogen thro'gh ammonia until saturated. Then add ⅔ of the volume of the same ammonia.
Potassium Sulphate.....	K_2SO_4	Dissolve 1 part of the salt in 12 parts of water.
" Iodide	KI	Dissolve 1 part in 25 parts of water.
" Chromate	K_2CrO_4	Dissolve 1 part in 10 parts of water.
" Ferricyanide..	$K_6Fe_2Cy_{12}$	Prepare only when required by dissolving 1 part of the salt in 12 parts of water.
" Ferrocyanide.	K_4FeCy_6	Dissolve 1 part of the salt in 12 parts of water.
Barium Chloride	$BaCl_2$	Dissolve 1 part of the salt in 10 parts of water.
" Carbonate	$BaCO_3$	Add sufficient water to the carbonate to give it a thick consistency.
" Hydrate	....	[See Baryta water.]
Copper Sulphate	$CuSO_4$	Dissolve 1 part in 10 parts of water. [See **142** for Fehling's solution.]
Platinum Bichloride ...	$PtCl_4$	The cheapest way to obtain this reagent is to buy the 5 per cent. solution of commerce.
Silver Nitrate...........	$AgNO_3$	Dissolve 1 part in 20 parts of water. [See **141** for standard solution.]
Acetic Acid	$C_2H_4O_2$	Both in chemical work and in lime-cake analysis use the No. 8 acid which contains 30 per cent. $C_2H_4O_2$.
Sodium Phosphate......	HNa_2PO_4 $+12H_2O$	Dissolve 1 part of pure salt in 10 parts of water.

TABLE I—CONTINUED.

PREPARATION OF REAGENTS.

NAME.	Symbol.	PREPARATION.
Hydrogen Disodium Phosphate	... .	[See sodium phosphate.]
Calcium Sulphate	$CaSO_4$	Digest in cold water and pour off the clear liquid for use.
Hydrochloroplatinic Acid	H_2PtCl_6	Dissolve 1 part of the acid in 10 parts of water. [See platinum bi chloride.]
Ammonium Nitrate	....	Dissolve 1gr in 10 parts of water.
Magnesia Mixture	....	[See **146**.]
Molybdic Solution	....	[See **145**.]
Magnesium Nitrate Solution	....	[See **95a**.]
Potassium bichromate ..	$K_2Cr_2O_7$	Dissolve 1 part of the salt in 10 parts of water.
" Ferrocyanide.	$K_6Fe_2Cy_{12}$	For Fehling's test dissolve 2gr of the salt in 100cc of water.
Acetic Acid	$C_2H_4O_2$	No. 8 acetic acid (30 per cent $C_2H_4O_2$) is best for general work.

PART IV.

TABLES.

TABLE 1.

BRIX TEMPERATURE CORRECTION.

For Variations from Normal, 17½C (63½F).

Temp. C	Temp. F	APPROXIMATE DEGREE BRIX AND CORRECTION.												
		0	5	10	15	20	25	30	35	40	50	60	70	75
0	32.	.27	.30	.41	.52	.62	.72	.82	.92	.98	1.11	1.22	1.25	1.29
5	41.	.23	.30	.37	.44	.52	.59	.65	.72	.75	.80	.88	.91	.94
10	50.	.20	.26	.29	.33	.36	.39	.42	.45	.48	.50	.54	.58	.61
11	51.8	.18	.23	.26	.28	.31	.34	.36	.39	.41	.43	.47	.50	.53
12	53.6	.16	.20	.22	.24	.26	.29	.31	.33	.34	.36	.40	.42	.46
13	55.4	.14	.18	.19	.21	.22	.24	.26	.27	.28	.29	.33	.35	.39
14	57.2	.12	.15	.16	.17	.18	.19	.21	.22	.22	.23	.26	.28	.32
15	59.0	.09	.11	.12	.14	.14	.15	.16	.17	.16	.17	.19	.21	.25
16	60.8	.06	.07	.08	.09	.10	.10	.11	.12	.12	.12	.14	.16	.18
17	62.6	.02	.02	.03	.03	.03	.04	.04	.04	.04	.04	.05	.05	.06

[Add the correction to readings above 17½C (63½F) and subtract the correction from those below this temperature.]

18	64.4	.02	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.02
19	66.2	.06	.06	.08	.08	.09	.09	.10	.10	.10	.10	.10	.08	.06
20	68.0	.11	.14	.15	.17	.17	.18	.18	.18	.19	.19	.18	.15	.11
21	69.8	.16	.20	.22	.24	.24	.25	.25	.25	.26	.26	.25	.22	.18
22	71.6	.21	.26	.29	.31	.31	.32	.32	.32	.33	.34	.32	.29	.25
23	73.4	.27	.32	.35	.37	.38	.39	.39	.39	.40	.42	.39	.36	.33
24	75.2	.32	.38	.41	.43	.44	.46	.46	.47	.47	.50	.46	.43	.40
25	77.0	.37	.44	.47	.49	.51	.53	.54	.55	.55	.58	.54	.51	.48
26	78.8	.43	.50	.54	.56	.58	.60	.61	.62	.62	.66	.62	.58	.55
27	80.6	.49	.57	.61	.63	.65	.68	.68	.69	.70	.74	.70	.65	.62
28	82.4	.56	.64	.68	.70	.72	.76	.76	.78	.78	.82	.78	.72	.70
29	84.2	.63	.71	.75	.78	.79	.84	.84	.86	.86	.90	.86	.80	.78
30	86.0	.70	.78	.82	.87	.87	.92	.92	.94	.94	.98	.94	.88	.86
35	95.0	1.10	1.17	1.22	1.24	1.30	1.32	1.33	1.35	1.36	1.39	1.34	1.27	1.25
40	104.0	1.50	1.61	1.67	1.71	1.73	1.79	1.79	1.80	1.82	1.83	1.78	1.69	1.65
50	122.0		2.65	2.74	2.74	2.78	2.80	2.80	2.80	2.80	2.79	2.70	2.56	2.51
60	140.0		3.87	3.88	3.88	3.88	3.88	3.88	3.88	3.90	3.82	3.70	3.43	3.41
70	158.0			5.18	5.20	5.14	5.13	5.10	5.08	5.06	4.90	4.72	4.47	4.35

For practical work the table given below is sufficiently accurate unless the solution has a brix of under 5 or over 25. In some factories the temperature correction for diffusion juice is given in tenths and hundredths of a degree, but for all other tests the tenths is a sufficient correction :

TEMPERATURE CORRECTION.

Temperature. C.	Temperature. F.	Subtract from Brix.
14	57	.2
15	59	.1
16	61	.1
17	63	.0
		Add to Brix.
18	64	.0
19	66	.1
20	68	.2
21	70	.2
22	72	.3
23	73	.4
24	75	.4
25	77	.5
26	79	.6
27	81	.6
28	82	.7
29	84	.8
30	86	.9
31	88	.9
32	90	1.0
33	91	1.0
34	93	1.1
35	95	1.2

TABLE II.

Comparison of Degrees Brix and Baume and Specific Gravity

FOR PURE SUGAR SOLUTIONS.

Temperature 17½ ° C = 63.5 Far.

Degrees Brix.	Specific Gravity.	Degrees Baume.	Degrees Brix.	Specific Gravity.	Degrees Beaume.
0.0	1.00000	0.00	4.0	1.01570	2.27
0.1	1.00038	0.06	4.1	1.01610	2.33
0.2	1.00077	0.11	4.2	1.01650	2.38
0.3	1.00116	0.17	4.3	1.01690	2.44
0.4	1.00155	0.23	4.4	1.01730	2.50
0.5	1.00193	0.28	4.5	1.01770	2.55
0.6	1.00232	0.34	4.6	1.01810	2.61
0.7	1.00271	0.40	4.7	1.01850	2.67
0.8	1.00310	0.45	4.8	1.01890	2.72
0.9	1.00349	0.51	4.9	1.01930	2.78
1.0	1.00388	0.57	5.0	1.01970	2.84
1.1	1.00427	0.63	5.1	1.02010	2.89
1.2	1.00466	0.68	5.2	1.02051	2.95
1.3	1.00505	0.74	5.3	1.02091	3.01
1.4	1.00544	0.80	5.4	1.02131	3.06
1.5	1.00583	0.85	5.5	1.02171	3.12
1.6	1.00622	0.91	5.6	1.02211	3.18
1.7	1.00662	0.97	5.7	1.02252	3.23
1.8	1.00701	1.02	5.8	1.02292	3.29
1.9	1.00740	1.08	5.9	1.02333	3.35
2.0	1.00779	1.14	6.0	1.02373	3.40
2.1	1.00818	1.19	6.1	1.02413	3.46
2.2	1.00858	1.25	6.2	1.02454	3.52
2.3	1.00897	1.31	6.3	1.02494	3.57
2.4	1.00936	1.36	6.4	1.02535	3.63
2.5	1.00976	1.42	6.5	1.02575	3.69
2.6	1.01015	1.48	6.6	1.02616	3.74
2.7	1.01055	1.53	6.7	1.02657	3.80
2.8	1.01094	1.59	6.8	1.02697	3.86
2.9	1.01134	1.65	6.9	1.02738	3.91
3.0	1.01173	1.70	7.0	1.02779	3.97
3.1	1.01213	1.76	7.1	1.02819	4.03
3.2	1.01252	1.82	7.2	1.02860	4.08
3.3	1.01292	1.87	7.3	1.02901	4.14
3.4	1.01332	1.93	7.4	1.02942	4.20
3.5	1.01371	1.99	7.5	1.02983	4.25
3.6	1.01411	2.04	7.6	1.03024	4.31
3.7	1.01451	2.10	7.7	1.03064	4.37
3.8	1.01491	2.16	7.8	1.03105	4.42
3.9	1.01531	2.21	7.9	1.03146	4.48

TABLE II.—Con.

Degrees Brix.	Specific Gravity.	Degrees Baume.	Degrees Brix.	Specific Gravity.	Degrees Baume.
8.0	1.03187	4.53	12.4	1.05021	7.02
8.1	1.03228	4.59	12.5	1.05064	7.08
8.2	1.03270	4.65	12.6	1.05106	7.13
8.3	1.03311	4.70	12.7	1.05149	7.19
8.4	1.03352	4.76	12.8	1.05191	7.24
8.5	1.03393	4.82	12.9	1.05233	7.30
8.6	1.03434	4.87	13.0	1.05276	7.36
8.7	1.03475	4.93	13.1	1.05318	7.41
8.8	1.03517	4.99	13.2	1.05361	7.47
8.9	1.03558	5.04	13.3	1.05404	7.53
9.0	1.03599	5.10	13.4	1.05446	7.58
9.1	1.03640	5.16	13.5	1.05489	7.64
9.2	1.03682	5.21	13.6	1.05532	7.69
9.3	1.03723	5.27	13.7	1.05574	7.75
9.4	1.03765	5.33	13.8	1.05617	7.81
9.5	1.03806	5.38	13.9	1.05660	7.86
9.6	1.03848	5.44	14.0	1.05703	7.92
9.7	1.03889	5.50	14.1	1.05746	7.98
9.8	1.03931	5.55	14.2	1.05789	8.03
9.9	1.03972	5.61	14.3	1.05831	8.09
10.0	1.04014	5.67	14.4	1.05874	8.14
10.1	1.04055	5.72	14.5	1.05917	8.20
10.2	1.04097	5.78	14.6	1.05960	8.26
10.3	1.04139	5.83	14.7	1.06003	8.31
10.4	1.04180	5.89	14.8	1.06047	8.37
10.5	1.04222	5.95	14.9	1.06090	8.43
10.6	1.04264	6.00	15.0	1.06133	8.48
10.7	1.04306	6.06	15.1	1.06176	8.54
10.8	1.04348	6.12	15.2	1.06219	8.59
10.9	1.04390	6.17	15.3	1.06262	8.65
11.0	1.04431	6.23	15.4	1.06306	8.71
11.1	1.04473	6.29	15.5	1.06349	8.76
11.2	1.04515	6.34	15.6	1.06392	8.82
11.3	1.04557	6.40	15.7	1.06436	8.88
11.4	1.04599	6.46	15.8	1.06479	8.93
11.5	1.04641	6.51	15.9	1.06522	8.99
11.6	1.04683	6.57	16.0	1.06566	9.04
11.7	1.04726	6.62	16.1	1.06609	9.10
11.8	1.04768	6.68	16.2	1.06653	9.16
11.9	1.04810	6.74	16.3	1.06696	9.21
12.0	1.04852	6.79	16.4	1.06740	9.27
12.1	1.04894	6.85	16.5	1.06783	9.33
12.2	1.04937	6.91	16.6	1.06827	9.38
12.3	1.04979	6.96	16.7	1.06871	9.44

TABLE II.—Con.

Degrees Brix.	Specific Gravity.	Degrees Baume.	Degrees Brix.	Specific Gravity.	Degrees Baume.
16.8	1.06914	9.49	21.2	1.08869	11.96
16.9	1.06958	9.55	21.3	1.08914	12.01
17.0	1.07002	9.61	21.4	1.08959	12.07
17.1	1.07046	9.66	21.5	1.09004	12.13
17.2	1 07090	9.72	21 6	1.09049	12.18
17.3	1.07133	9.77	21.7	1.09095	12.24
17.4	1.07177	9.83	21.8	1.09140	12 29
17.5	1.07221	9.89	21.9	1.09185	12.35
17.6	1.07265	9.94	22.0	1.09231	12.40
17.7	1.07309	10.00	22.1	1.09276	12.46
17.8	1.07358	10.06	22.2	1.09321	12.52
17.9	1.07397	10.11	22.3	1.09367	12.57
18.0	1.07441	10.17	22.4	1.09412	12.63
18.1	1.07485	10.22	22.5	1.09458	12.68
18.2	1.07530	10.28	22.6	1.09503	12.74
18.3	1.07574	10.33	22.7	1.09549	12.80
18.4	1.07618	10.39	22.8	1.09595	12.85
18.5	1.07662	10.45	22.9	1.09640	12.91
18.6	1.07706	10.50	23.0	1.09686	12.96
18.7	1.07751	10.56	23.1	1.09732	13.02
18.8	1.07795	10.62	23.2	1.09777	13.07
18.9	1.07839	10.67	23.3	1.09823	13.13
19.0	1.07884	10.73	23.4	1.09869	13.19
19.1	1.07928	10.78	23.5	1.09915	13.24
19.2	1.07973	10.84	23.6	1.09961	13.30
19.3	1.08017	10.90	23.7	1.10007	13.35
19.4	1.08062	10.95	23.8	1.10053	13.41
19.5	1.08106	11.01	23.9	1.10099	13.46
19.6	1.08151	11.06	24.0	1.10145	13.52
19.7	1.08196	11.12	24.1	1.10191	13.58
19.8	1.08240	11.18	24.2	1.10237	13.63
19.9	1.08285	11.23	24.3	1.10283	13.69
20.0	1.08329	11.29	24.4	1.10329	13.74
20.1	1.98374	11.34	24.5	1.10375	13.80
20.2	1.08419	11.40	24.6	1.10421	13.85
20.3	1.08464	11.45	24.7	1.10468	13.91
20.4	1.08509	11.51	24.8	1.10514	13.96
20.5	1.08553	11.57	24.9	1.10560	14.02
20.6	1.08599	11.62	25.0	1.10607	14.08
20.7	1.08643	11.68	25.1	1.10653	14.13
20.8	1.08688	11.73	25.2	1.10700	14.19
20.9	1.08733	11.79	25.3	1.10746	14.24
21.0	1.08778	11.85	25.4	1.10793	14.30
21.1	1.08824	11.90	25.5	1.10839	14.35

TABLE II.—Con.

Degrees Brix.	Specific Gravity.	Degrees Baume.	Degrees Brix.	Specific Gravity.	Degrees Baume.
25.6	1.10886	14.41	30.0	1.12967	16.85
25.7	1.10932	14.47	30.1	1.13015	16.90
25.8	1.10979	14.52	30.2	1.13063	16.96
25.9	1.11026	14.58	30.3	1.13111	17.01
26.0	1.11072	14.63	30.4	1.13159	17.07
26.1	1.11119	14.69	30.5	1.13207	17.12
26.2	1.11166	14.74	30.6	1.13255	17.18
26.3	1.11213	14.80	30.7	1.13304	17.23
26.4	1.11259	14.85	30.8	1.13352	17.29
26.5	1.11306	14.91	30.9	1.13400	17.35
26.6	1.11353	14.97	31.0	1.13449	17.40
26.7	1.11400	15.02	31.1	1.13497	17.46
26.8	1.11447	15.08	31.2	1.13545	17.51
26.9	1.11494	15.13	31.3	1.13594	17.57
27.0	1.11541	15.19	31.4	1.13642	17.62
27.1	1.11588	15.24	31.5	1.13691	17.68
27.2	1.11635	15.30	31.6	1.13740	17.73
27.3	1.11682	15.35	31.7	1.13788	17.79
27.4	1.11729	15.41	31.8	1.13837	17.84
27.5	1.11776	15.46	31.9	1.13885	17.90
27.6	1.11824	15.52	32.0	1.13934	17.95
27.7	1.11871	15.58	32.1	1.13983	18.01
27.8	1.11918	15.63	32.2	1.14032	18.06
27.9	1.11965	15.69	32.3	1.14081	18.12
28.0	1.12013	15.74	32.4	1.14129	18.17
28.1	1.12060	15.80	32.5	1.14178	18.23
28.2	1.12107	15.85	32.6	1.14227	18.28
28.3	1.12155	15.91	32.7	1.14276	18.34
28.4	1.12202	15.96	32.8	1.14325	18.39
28.5	1.12250	16.02	32.9	1.14374	18.45
28.6	1.12297	16.07	33.0	1.14423	18.50
28.7	1.12345	16.13	33.1	1.14472	18.56
28.8	1.12393	16.18	33.2	1.14521	18.61
28.9	1.12440	16.24	33.3	1.14570	18.67
29.0	1.12488	16.30	33.4	1.14620	18.72
29.1	1.12536	16.35	33.5	1.14669	18.78
29.2	1.12583	16.41	33.6	1.14718	18.83
29.3	1.12631	16.46	33.7	1.14767	18.89
29.4	1.12679	16.52	33.8	1.14817	18.94
29.5	1.12727	16.57	33.9	1.14866	19.00
29.6	1.12775	16.63	34.0	1.14915	19.05
29.7	1.12823	16.68	34.1	1.14965	19.11
29.8	1.12871	16.74	34.2	1.15014	19.16
29.9	1.12919	16.79	34.3	1.15064	19.22

TABLE II.—Con.

Degrees Brix.	Specific Gravity.	Degrees Baume.	Degrees Brix.	Specific Gravity.	Degrees Baume.
34.4	1.15113	19.27	38.8	1.17327	21.68
34.5	1.15163	19.33	38.9	1.17379	21.73
34.6	1.15213	19.38	39.0	1.17430	21.79
34.7	1.15262	19.44	39.1	1.17481	21.84
34.8	1.15312	19.49	39.2	1.17532	21.90
34.9	1.15362	19.55	39.3	1.17583	21.95
35.0	1.15411	19.60	39.4	1.17635	22.00
35.1	1.15461	19.66	39.5	1.17686	22.06
35.2	1.15511	19.71	39.6	1.17737	22.11
35.3	1.15561	19.76	39.7	1.17789	22.17
35.4	1.15611	19.82	39.8	1.17840	22.22
35.5	1.15661	19.87	39.9	1.17892	22.28
35.6	1.15710	19.93	40.0	1.17943	22.33
35.7	1.15760	19.98	40.1	1.17995	22.38
35.8	1.15810	20.04	40.2	1.18046	22.44
35.9	1.15861	20.09	40.3	1.18098	22.49
36.0	1.15911	20.15	40.4	1.18150	22.55
36.1	1.15961	20.20	40.5	1.18201	22.60
36.2	1.16011	20.26	40.6	1.18253	22.66
36.3	1.16061	20.31	40.7	1.18305	22.71
36.4	1.16111	20.37	40.8	1.18357	22.77
36.5	1.16162	20.42	40.9	1.18408	22.82
36.6	1.16212	20.48	41.0	1.18460	22.87
36.7	1.16262	20.53	41.1	1.18512	22.93
36.8	1.16313	20.59	41.2	1.18564	22.98
36.9	1.16363	20.64	41.3	1.18616	23.04
37.0	1.16413	20.70	41.4	1.18668	23.09
37.1	1.16464	20.75	41.5	1.18720	23.15
37.2	1.16514	20.80	41.6	1.18772	23.20
37.3	1.16565	20.86	41.7	1.18824	23.25
37.4	1.16616	20.91	41.8	1.18877	23.31
37.5	1.16666	20.97	41.9	1.18929	23.36
37.6	1.16717	21.02	42.0	1.18981	23.42
37.7	1.16768	21.08	42.1	1.19033	23.47
37.8	1.16818	21.13	42.2	1.19086	23.52
37.9	1.16869	21.19	42.3	1.19138	23.58
38.0	1.16920	21.24	42.4	1.19190	23.63
38.1	1.16971	21.30	42.5	1.19243	23.69
38.2	1.17022	21.35	42.6	1.19295	23.74
38.3	1.17072	21.40	42.7	1.19348	23.79
38.4	1.17132	21.46	42.8	1.19400	23.85
38.5	1.17174	21.51	42.9	1.19453	23.90
38.6	1.17225	21.57	43.0	1.19505	23.96
38.7	1.17276	21.62	43.1	1.19558	24.01

Degrees Brix.	Specific Gravity.	Degrees Baume.	Degrees Brix.	Specific Gravity.	Degrees Baume.
43.2	1.19611	24.07	47.6	1.21964	26.43
43.3	1.19663	24.12	47.7	1.22019	26.49
43.4	1.19716	24.17	47.8	1.22073	26.54
43.5	1.19769	24.23	47.9	1.22127	26.59
43.6	1.19822	24.28	48.0	1.22182	26.65
43.7	1.19875	24.34	48.1	1.22236	26.70
43.8	1.19927	24.39	48.2	1.22291	26.75
43.9	1.19980	24.44	48.3	1.22345	26.81
44.0	1.20033	24.50	48.4	1.22400	26.86
44.1	1.20086	24.55	48.5	1.22455	26.92
44.2	1.20139	24.61	48.6	1.22509	26.97
44.3	1.20192	24.66	48.7	1.22564	27.02
44.4	1.20245	24.71	48.8	1.22619	27.08
44.5	1.20299	24.77	48.9	1.22673	27.13
44.6	1.20352	24.82	49.0	1.22728	27.18
44.7	1.20405	24.88	49.1	1.22783	27.24
44.8	1.20458	24.93	49.2	1.22838	27.29
44.9	1.20512	24.98	49.3	1.22893	27.34
45.0	1.20565	25.04	49.4	1.22948	27.40
45.1	1.20618	25.09	49.5	1.23003	27.45
45.2	1.20672	25.14	49.6	1.23058	27.50
45.3	1.20725	25.20	49.7	1.23113	27.56
45.4	1.20779	25.25	49.8	1.23168	27.61
45.5	1.20832	25.31	49.9	1.23223	27.66
45.6	1.20886	25.36	50.0	1.23278	27.72
45.7	1.20939	25.41	50.1	1.23334	27.77
45.8	1.20993	25.47	50.2	1.23389	27.82
45.9	1.21046	25.52	50.3	1.23444	27.88
46.0	1.21100	25.57	50.4	1.23499	27.93
46.1	1.21154	25.63	50.5	1.23555	27.98
46.2	1.21208	25.68	50.6	1.23610	28.04
46.3	1.21261	25.74	50.7	1.23666	28.09
46.4	1.21315	25.79	50.8	1.23721	28.14
46.5	1.21369	25.84	50.9	1.23777	28.20
46.6	1.21423	25.90	51.0	1.23832	28.25
46.7	1.21477	25.95	51.1	1.23888	28.30
46.8	1.21531	26.00	51.2	1.23943	28.36
46.9	1.21585	26.06	51.3	1.23999	28.41
47.0	1.21639	26.11	51.4	1.24055	28.46
47.1	1.21693	26.17	51.5	1.24111	28.51
47.2	1.21747	26.22	51.6	1.24166	28.57
47.3	1.21802	26.27	51.7	1.24222	28.62
47.4	1.21856	26.33	51.8	1.24278	28.67
47.5	1.21910	26.38	51.9	1.24334	28.73

TABLE II.—Con.

Degrees Brix.	Specific Gravity.	Degrees Baume.	Degrees Brix.	Specific Gravity.	Degrees Baume.
52.0	1.24390	28.78	56.4	1.26889	31.10
52.1	1.24446	28.83	56.5	1.26946	31.16
52.2	1.24502	28.89	56.6	1.27004	31.21
52.3	1.24558	28.94	56.7	1.27062	31.26
52.4	1.24614	28.99	56.8	1.27120	31.31
52.5	1.24670	29.05	56.9	1.27177	31.37
52.6	1.24726	29.10	57.0	1.27235	31.42
52.7	1.24782	29.15	57.1	1.27293	31.47
52.8	1.24839	29.20	57.2	1.27351	31.52
52.9	1.24895	29.26	57.3	1.27409	31.58
53.0	1.24951	29.31	57.4	1.27467	31.63
53.1	1.25008	29.36	57.5	1.27525	31.68
53.2	1.25064	29.42	57.6	1.27583	31.73
53.3	1.25120	29.47	57.7	1.27641	31.79
53.4	1.25177	29.52	57.8	1.27699	31.84
53.5	1.25233	29.57	57.9	1.27758	31.89
53.6	1.25290	29.63	58.0	1.27816	31.94
53.7	1.25347	29.68	58.1	1.27874	32.00
53.8	1.25403	29.73	58.2	1.27932	32.05
53.9	1.25460	29.79	58.3	1.27991	32.10
54.0	1.25517	29.84	58.4	1.28049	32.15
54.1	1.25573	29.89	58.5	1.28107	32.20
54.2	1.25630	29.94	58.6	1.28166	32.26
54.3	1.25687	30.00	58.7	1.28224	32.31
54.4	1.25744	30.05	58.8	1.28283	32.36
54.5	1.25801	30.10	58.9	1.28342	32.41
54.6	1.25857	30.16	59.0	1.28400	32.47
54.7	1.25914	30.21	59.1	1.28459	32.52
54.8	1.25971	30.26	59.2	1.28518	32.57
54.9	1.26028	30.31	59.3	1.28576	32.62
55.0	1.26086	30.37	59.4	1.28635	32.67
55.1	1.26143	30.42	59.5	1.28694	32.73
55.2	1.26200	30.47	59.6	1.28753	32.78
55.3	1.26257	30.53	59.7	1.28812	32.83
55.4	1.26314	30.58	59.8	1.28871	32.88
55.5	1.26372	30.63	59.9	1.28930	32.93
55.6	1.26429	30.68	60.0	1.28989	32.99
55.7	1.26486	30.74	60.1	1.29048	33.04
55.8	1.26544	30.79	60.2	1.29107	33.09
55.9	1.26601	30.84	60.3	1.29166	33.14
56.0	1.26658	30.89	60.4	1.29225	33.20
56.1	1.26716	30.95	60.5	1.29284	33.25
56.2	1.26773	31.00	60.6	1.29343	33.30
56.3	1.26831	31.05	60.7	1.29403	33.35

TABLE II.—Con.

Degrees Brix.	Specific Gravity.	Degrees Baume.	Degrees Brix.	Specific Gravity.	Degrees Baume.
60.8	1.29462	33.40	65.2	1.32111	35.68
60.9	1.29521	33.46	65.3	1.32172	35.73
61.0	1.29581	33.51	65.4	1.32233	35.78
61.1	1.29640	33.56	65.5	1.32294	35.83
61.2	1.29700	33.61	65.6	1.32355	35.88
61.3	1.29759	33.66	65.7	1.32417	35.93
61.4	1.29819	33.71	65.8	1.32478	35.98
61.5	1.29878	33.77	65.9	1.32539	36.04
61.6	1.29938	33.82	66.0	1.32601	36.09
61.7	1.29998	33.87	66.1	1.32662	36.14
61.8	1.30057	33.92	66.2	1.32724	36.19
61.9	1.30117	33.97	66.3	1.32785	36.24
62.0	1.30177	34.03	66.4	1.32847	36.29
62.1	1.30237	34.08	66.5	1.32908	36.34
62.2	1.30297	34.13	66.6	1.32970	36.39
62.3	1.30356	34.18	66.7	1.33031	36.45
62.4	1.30416	34.23	66.8	1.33093	36.50
62.5	1.30476	34.28	66.9	1.33155	36.55
62.6	1.30536	34.34	67.0	1.33217	36.60
62.7	1.30596	34.39	67.1	1.33278	36.65
62.8	1.30657	34.44	67.2	1.33340	36.70
62.9	1.30717	34.49	67.3	1.33402	36.75
63.0	1.30777	34.54	67.4	1.33464	36.80
63.1	1.30837	34.59	67.5	1.33526	36.85
63.2	1.30897	34.65	67.6	1.33588	36.90
63.3	1.30958	34.70	67.7	1.33650	36.96
63.4	1.31018	34.75	67.8	1.33712	37.01
63.5	1.31078	34.80	67.9	1.33774	37.06
63.6	1.31139	34.85	68.0	1.33836	37.11
63.7	1.31199	34.90	68.1	1.33899	37.16
63.8	1.31260	34.96	68.2	1.33961	37.21
63.9	1.31320	35.01	68.3	1.34023	37.26
64.0	1.31381	35.06	68.4	1.34085	37.31
64.1	1.31442	35.11	68.5	1.34148	37.36
64.2	1.31502	35.16	68.6	1.34210	37.41
64.3	1.31563	35.21	68.7	1.34273	37.47
64.4	1.31624	35.27	68.8	1.34335	37.52
64.5	1.31684	35.32	68.9	1.34398	37.57
64.6	1.31745	35.37	69.0	1.34460	37.62
64.7	1.31806	35.42	69.1	1.34523	37.67
64.8	1.31867	35.47	69.2	1.34585	37.72
64.9	1.31928	35.52	69.3	1.34648	37.77
65.0	1.31989	35.57	69.4	1.34711	37.82
65.1	1.32050	35.63	69.5	1.34774	37.87

TABLE II.—Con.

Degrees Brix.	Specific Gravity.	Degrees Baume.	Degrees Brix.	Specific Gravity.	Degrees Baume.
69.6	1.34836	37.92	74.0	1.37639	40.14
69.7	1.34899	37.97	74.1	1.37704	40.19
69.8	1.34962	38.02	74.2	1.37768	40.24
69.9	1.35025	38.07	74.3	1.37833	40.29
70.0	1.35088	38.12	74.4	1.37898	40.34
70.1	1.35151	38.18	74.5	1.37962	40.39
70.2	1.35214	38.23	74.6	1.38027	40.44
70.3	1.35277	38.28	74.7	1.38092	40.49
70.4	1.35340	38.33	74.8	1.38157	40.54
70.5	1.35403	38.38	74.9	1.38222	40.59
70.6	1.35466	38.43	75.0	1.38287	40.64
70.7	1.35530	38.48	75.1	1.38352	40.69
70.8	1.35593	38.53	75.2	1.38417	40.74
70.9	1.35656	38.58	75.3	1.38482	40.79
71.0	1.35720	38.63	75.4	1.38547	40.84
71.1	1.35783	38.68	75.5	1.38612	40.89
71.2	1.35847	38.73	75.6	1.38677	40.94
71.3	1.35910	38.78	75.7	1.38743	40.99
71.4	1.35974	38.83	75.8	1.38808	41.04
71.5	1.36037	38.88	75.9	1.38873	41.09
71.6	1.36101	38.93	76.0	1.38939	41.14
71.7	1.36164	38.98	76.1	1.39004	41.19
71.8	1.36228	39.03	76.2	1.39070	41.24
71.9	1.36292	39.08	76.3	1.39135	41.29
72.0	1.36355	39.13	76.4	1.39201	41.33
72.1	1.36419	39.19	76.5	1.39266	41.38
72.2	1.36483	39.24	76.6	1.39332	41.43
72.3	1.36547	39.29	76.7	1.39397	41.48
72.4	1.36611	39.34	76.8	1.39463	41.53
72.5	1.36675	39.39	76.9	1.39529	41.58
72.6	1.36739	39.44	77.0	1.39595	41.63
72.7	1.36803	39.49	77.1	1.39660	41.68
72.8	1.36867	39.54	77.2	1.39726	41.73
72.9	1.36931	39.59	77.3	1.39792	71.78
73.0	1.36995	39.64	77.4	1.39858	41.83
73.1	1.37059	39.69	77.5	1.39924	41.88
73.2	1.37124	39.74	77.6	1.39990	41.93
73.3	1.37188	39.79	77.7	1.40056	41.98
73.4	1.37252	39.84	77.8	1.40122	42.03
73.5	1.37317	39.89	77.9	1.40188	42.08
73.6	1.37381	39.94	78.0	1.40254	42.13
73.7	1.37446	39.99	78.1	1.40321	42.18
73.8	1.37510	40.04	78.2	1.40387	42.23
73.9	1.37575	40.09	78.3	1.40453	42.28

TABLE II.—Con.

Degrees Brix.	Specific Gravity.	Degrees Baume.	Degrees Brix.	Specific Gravity.	Degrees Baume.
78.4	1.40520	42.32	82.8	1.43478	44.48
78.5	1.40586	42.37	82.9	1.43546	44.53
78.6	1.40652	42.42	83.0	1.43614	44.58
78.7	1.40719	42.47	83.1	1.43682	44.62
78.8	1.40785	42.52	83.2	1.43750	44.67
78.9	1.40852	42.57	83.3	1.43819	44.72
79.0	1.40918	42.62	83.4	1.43887	44.77
79.1	1.40985	42.67	83.5	1.43955	44.82
79.2	1.41052	42.72	83.6	1.44024	44.87
79.3	1.41118	42.77	83.7	1.44092	44.91
79.4	1.41185	42.82	83.8	1.44161	44.96
79.5	1.41252	42.87	83.9	1.44229	45.01
79.6	1.41318	42.92	84.0	1.44298	45.06
79.7	1.41385	42.96	84.1	1.44367	45.11
79.8	1.41452	43.01	84.2	1.44435	45.16
79.9	1.41519	43.06	84.3	1.44504	45.21
80.0	1.41586	43.11	84.4	1.44573	45.25
80.1	1.41653	43.16	84.5	1.44641	45.30
80.2	1.41720	43.21	84.6	1.44710	45.35
80.3	1.41787	43.26	84.7	1.44779	45.40
80.4	1.41854	43.31	84.8	1.44848	45.45
80.5	1.41921	43.36	84.9	1.44917	45.49
80.6	1.41989	43.41	85.0	1.44986	45.54
80.7	1.42056	43.45	85.1	1.45055	45.59
80.8	1.42123	43.50	85.2	1.45124	45.64
80.9	1.42190	43.55	85.3	1.45193	45.69
81.0	1.42258	43.60	85.4	1.45262	45.74
81.1	1.42325	43.65	85.5	1.45331	45.78
81.2	1.42393	43.70	85.6	1.45401	45.83
81.3	1.42460	43.75	85.7	1.45470	45.88
81.4	1.42528	43.80	85.8	1.45539	45.93
81.5	1.42595	43.85	85.9	1.45609	45.98
81.6	1.42663	43.89	86.0	1.45678	46.02
81.7	1.42731	43.94	86.1	1.45748	46.07
81.8	1.42798	43.99	86.2	1.45817	46.12
81.9	1.42866	44.04	86.3	1.45887	46.17
82.0	1.42934	44.09	86.4	1.45956	46.22
82.1	1.43002	44.14	86.5	1.46026	46.26
82.2	1.43070	44.19	86.6	1.46095	46.31
82.3	1.43137	44.24	86.7	1.46165	46.36
82.4	1.43205	44.28	86.8	1.46235	46.41
82.5	1.43273	44.33	86.9	1.46304	46.46
82.6	1.43341	44.38	87.0	1.46374	46.50
82.7	1.43409	44.43	87.1	1.46444	46.55

TABLE II.—Con.

Degrees Brix.	Specific Gravity.	Degrees Baume.	Degrees Brix.	Specific Gravity.	Degrees Baume.
87.2	1.46514	46.60	91.6	1.49628	48.68
87.3	1.46584	46.65	91.7	1.49700	48.73
87.4	1.46654	46.69	91.8	1.49771	48.78
87.5	1.46724	46.74	91.9	1.49843	48.82
87.6	1.46794	46.79	92.0	1.49915	48.87
87.7	1.46864	46.84	92.1	1.49987	48.92
87.8	1.46934	46.88	92.2	1.50058	48.96
87.9	1.47004	46.93	92.3	1.50130	49.01
88.0	1.47074	46.98	92.4	1.50202	49.06
88.1	1.47145	47.03	92.5	1.50274	49.11
88.2	1.47215	47.08	92.6	1.50346	49.15
88.3	1.47285	47.12	92.7	1.50419	49.20
88.4	1.47356	47.17	92.8	1.50491	49.25
88.5	1.47426	47.22	92.9	1.50563	49.29
88.6	1.47496	47.27	93.0	1.50635	49.34
88.7	1.47567	47.31	93.1	1.50707	49.39
88.8	1.47637	47.36	93.2	1.50779	49.43
88.9	1.47708	47.41	93.3	1.50852	49.48
89.0	1.47778	47.46	93.4	1.50924	49.53
89.1	1.47849	47.50	93.5	1.50996	49.57
89.2	1.47920	47.55	93.6	1.51069	49.62
89.3	1.47991	47.60	93.7	1.51141	49.67
89.4	1.48061	47.65	93.8	1.51214	49.71
89.5	1.48132	47.69	93.9	1.51286	49.76
89.6	1.48203	47.74	94.0	1.51359	49.81
89.7	1.48274	47.79	94.1	1.51431	49.85
89.8	1.48345	47.83	94.2	1.51504	49.90
89.9	1.48416	47.88	94.3	1.51577	49.94
90.0	1.48486	47.93	94.4	1.51649	49.99
90.1	1.48558	47.98	94.5	1.51722	50.04
90.2	1.48629	48.02	94.6	1.51795	50.08
90.3	1.48700	48.07	94.7	1.51868	50.13
90.4	1.48771	48.12	94.8	1.51941	50.18
90.5	1.48842	48.17	94.9	1.52014	50.22
90.6	1.48913	48.21	95.0	1.52087	50.27
90.7	1.48985	48.26	95.1	1.52159	50.32
90.8	1.49056	48.31	95.2	1.52232	50.36
90.9	1.49127	48.35	95.3	1.52304	50.41
91.0	1.49199	48.40	95.4	1.52376	50.45
91.1	1.49270	48.45	95.5	1.52449	50.50
91.2	1.49342	48.50	95.6	1.52521	50.55
91.3	1.49413	48.54	95.7	1.52593	50.59
91.4	1.49485	48.59	95.8	1.52665	50.64
91.5	1.49556	48.64	95.9	1.52738	50.69

Degrees Brix.	Specific Gravity.	Degrees Baume.	Degrees Brix.	Specific Gravity.	Degrees Baume.
96.0	1.52810	50.73	98.1	1.54365	51.70
96.1	1.52884	50.78	98.2	1.54440	51.74
96.2	1.52958	50.82	98.3	1.55515	51.79
96.3	1.53032	50.87	98.4	1.54590	51.83
96.4	1.53106	50.92	98.5	1.54665	51.88
96.5	1.53180	50.96	98.6	1.54740	51.92
96.6	1.53254	51.01	98.7	1.54815	51.97
96.7	1.53328	51.05	98.8	1.54890	52.01
96.8	1.53402	51.10	98.9	1.54965	52.06
96.9	1.53476	51.15	99.0	1.55040	52.11
97.0	1.53550	51.19	99.1	1.55115	52.15
97.1	1.53624	51.24	99.2	1.55189	52.20
97.2	1.53698	51.28	99.3	1.55264	52.24
97.3	1.53772	51.33	99.4	1.55338	52.29
97.4	1.53846	51.38	99.5	1.55413	52.33
97.5	1.53920	51.42	99.6	1.55487	52.38
97.6	1.53994	51.47	99.7	1.55562	52.42
97.7	1.54068	51.51	99.8	1.55636	52.47
97.8	1.54142	51.56	99.9	1.55711	52.51
97.9	1.54216	51.60	100.0	1.55785	52.56
98.0	1.54290	51.65			

TABLE III.

FOR MAKING "KNOWN SUGAR" SOLUTIONS.

Polari-scope Degrees.	Grammes C. P. Sugar in 100cc Solution.	Polari-scope Degrees	Grammes C. P. Sugar in 100cc Solution.	Polari-scope Degrees.	Grammes C. P. Sugar in 100cc Solution.
1	0.260	35	9.097	69	17.954
2	0.519	36	9.357	70	18.216
3	0.779	37	9.618	71	18.476
4	1.039	38	9.878	72	18.738
5	1 298	39	10.138	73	18.998
6	1.558	40	10.398	74	19.259
7	1.817	41	10.659	75	19.519
8	2.078	42	10 919	76	19.781
9	2 337	43	11.180	77	20.042
10	2.597	44	11.440	78	20.302
11	2.857	45	11.701	79	20.564
12	3.117	46	11.961	80	20.824
13	3.376	47	12.222	81	21.085
14	3.637	48	12.482	82	21.346
15	3.896	49	12.743	83	21.608
16	4.156	50	13.003	84	21 868
17	4.416	51	13.264	85	22.130
18	4.676	52	13.524	86	22.391
19	4.936	53	13.784	87	22.652
20	5 196	54	14.044	88	22.912
21	5.456	55	14.305	89	23.174
22	5.716	56	14.566	90	23 435
23	5.976	57	14.826	91	23.696
24	6 236	58	15.087	92	23.957
25	6.496	59	15.347	93	24.219
26	6.756	60	15.608	94	24.480
27	7.016	61	15.868	95	24 742
28	7.276	62	16.130	96	25.002
29	7.536	63	16.390	97	25 265
30	7.796	64	16.651	98	25.525
31	8.056	65	16.912	99	25.787
32	8.316	66	17.173	100	26.048
33	8.577	67	17.433		
34	8.837	68	17.694		

TABLE IV.

PER CENT. SUGAR IN PULP BY THE VOLUMETRIC METHOD.

Pol.	Pr Cent Sugar	Pol.	Pr Cent Sugar	Pol.	Pr Cent Sugar.	Pol.	Pr Cent Sugar.	Pol.	Pr Cent Sugar.
05	.014	1 45	.415	2 85	.817	4 25	1.218	5 65	1.619
.10	029	1 50	.430	2 90	.831	4 30	1 232	5 70	1 633
.15	.043	1 55	.444	2.95	.845	4.35	1.246	5.75	1.648
.20	.057	1.60	.458	3.00	.860	4.40	1 261	5.80	1.662
.25	072	1.65	.473	3.05	.874	4.45	1.275	5.85	1.676
.30	.086	1 70	.487	3 10	.888	4 50	1.289	5 90	1.691
.35	.100	1 75	501	3 15	.903	4 55	1 304	5.95	1.705
.40	.115	1 80	.516	3 20	.917	4.60	1 318	6.00	1 719
.45	129	1.85	.530	3 25	.931	4 65	1 332	6.05	1.733
.50	.143	1 90	.544	3 30	.946	4.70	1 347	6 10	1.748
.55	.158	1 95	.559	3 35	.960	4.75	1.361	6.15	1 762
.60	.172	2.00	.573	3.40	974	4.80	1 375	6 20	1 776
.65	.186	2 05	.587	3.45	.989	4 85	1 390	6 25	1 791
.70	201	2 10	.602	3 50	1 003	4.90	1.404	6.30	1 805
.75	215	2 15	.616	3.55	1.017	4 95	1.418	6.35	1.819
.80	229	2.20	.630	3.60	1.032	5.00	1 433	6 40	1 834
.85	.244	2 25	.645	3 65	1.046	5 05	1.447	6.45	1.848
.90	258	2.30	.659	3.70	1 060	5 10	1.461	6 50	1 862
.95	.272	2 35	673	3.75	1 074	5.15	1.476	6 55	1 877
1.00	287	2.40	.688	3.80	1.089	5 20	1.490	6.60	1.891
1.05	.301	2.45	.702	3.85	1.103	5.25	1.504	6.65	1 905
1.10	.315	2.50	.716	3.90	1.117	5.30	1.519	6.70	1.920
1.15	.330	2 55	.731	3.95	1.132	5.35	1.533	6 75	1.934
1 20	.344	2 60	.745	4.00	1.146	5.40	1.547	6.80	1.948
1 25	.358	2.65	.759	4.05	1.160	5.45	1.562	6.85	1.963
1.30	.372	2.70	.773	4.10	1 175	5.50	1.576	6.90	1 977
1 35	.387	2.75	.788	4.15	1.189	5.55	1.590	6.95	1 991
1 40	.401	2.80	.802	4.20	1.203	5.60	1.605	7.00	2.006

TABLE

ESTIMATION OF PERCENTAGE OF SUGAR BY VOLUMETRIC METHOD

Degree Brix From 0 5 to 12 0.		Polariscope Degrees.	Approximate								
Tenths of a Degree.	Per Cent Sucrose.		0.5	1.0	1 5	2.0	2.5	3.0	3.5	4.0	4.5
0.1°	0.03	1°	0 29	0 29	0.29	0.28	0.28	0.28	0.28	0.28	0.28
0 2	0 06	2		0 57	0.57	0 57	0.57	0.56	0.56	0.56	0.56
0.3	0 08	3		0.85	0.85	0 85	0.85	0.85	0.85	0.84	0.84
0.4	0 11	4			1.14	1.13	1.13	1.13	1.13	1.13	1.12
0.5	0.14	5			1.42	1 42	1.41	1.41	1.41	1.41	1.40
0.6	0.17	6				1 70	1 70	1.69	1.69	1.69	1.68
0.7	0.19	7				1 98	1.98	1.98	1.97	1.97	1.96
0.8	0.22	8					2 26	2.26	2.26	2.25	2.25
0.9	0.25	9						2.54	2.54	2.53	2.53
		10						2.82	2.82	2.81	2.81
		11							3.10	3.09	3.09
		12							3.38	3.38	3.37
		13								3.66	3.65
		14								3.94	3.93
Degree Brix. From 12.5 to 20.0.		15									4.21
		16									4.49
		17									
Tenths of a Degree.	Per Cent. Sucrose.	18									
		19									
0.1°	0 03	20									
0.2	0.05	21									
0.3	0 08	22									
0.4	0.11	23									
0.5.	0.13	24									
0 6	0.16	25									
0.7	0.19	26									
0.8	0.21	27									
0.9	0 24	28									
		29									
		30									
		31									
		32									
		33									
		34									
		35									
		36									
		37									
		38									
		39									

V.

FOR USE WITH SOLUTIONS PREPARED BY ADDITION OF 10 PER CENT. LEAD ACETATE.—(SCHMITZ.)

DEGREE BRIX.											Polariscope Degrees.
5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	
0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	1°
0.56	0.56	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.55	2
0.84	0.84	0.84	0.84	0.83	0.83	0.83	0.83	0.83	0.83	0.82	3
1.12	1.12	1.12	1.11	1.11	1.11	1.11	1.11	1.10	1.10	1.10	4
1.40	1.40	1.40	1.39	1.39	1.39	1.38	1.38	1.38	1.38	1.37	5
1.68	1.68	1.67	1.67	1.67	1.66	1.66	1.66	1.66	1.65	1.65	6
1.96	1.96	1.95	1.95	1.95	1.94	1.94	1.93	1.93	1.93	1.92	7
2.24	2.24	2.23	2.23	2.22	2.22	2.22	2.21	2.21	2.20	2.20	8
2.52	2.52	2.51	2.51	2.50	2.50	2.49	2.49	2.48	2.48	2.47	9
2.80	2.80	2.79	2.79	2.78	2.78	2.77	2.76	2.76	2.75	2.75	10
3.08	3.08	3.07	3.06	3.06	3.05	3.05	3.04	3.03	3.03	3.02	11
3.36	3.36	3.35	3.34	3.34	3.33	3.32	3.32	3.31	3.30	3.30	12
3.64	3.64	3.63	3.62	3.61	3.61	3.60	3.59	3.59	3.58	3.57	13
3.92	3.92	3.91	3.90	3.89	3.88	3.88	3.87	3.86	3.85	3.85	14
4.20	4.19	4.19	4.18	4.17	4.16	4.15	4.15	4.14	4.13	4.12	15
4.48	4.47	4.47	4.46	4.45	4.44	4.43	4.42	4.41	4.40	4.40	16
4.77	4.76	4.75	4.74	4.73	4.72	4.71	4.70	4.69	4.68	4.67	17
	5.03	5.02	5.01	5.00	4.99	4.99	4.97	4.97	4.96	4.95	18
	5.32	5.31	5.29	5.28	5.27	5.26	5.25	5.24	5.23	5.22	19
		5.58	5.57	5.56	5.55	5.54	5.53	5.52	5.51	5.50	20
		5.86	5.85	5.84	5.83	5.82	5.81	5.79	5.78	5.77	21
			6.13	6.12	6.11	6.09	6.08	6.07	6.06	6.05	22
			6.41	6.40	6.38	6.37	6.36	6.35	6.33	6.32	23
				6.67	6.66	6.65	6.64	6.62	6.61	6.60	24
					6.94	6.93	6.91	6.90	6.89	6.87	25
					7.22	7.20	7.19	7.17	7.16	7.15	26
						7.48	7.46	7.45	7.44	7.42	27
						7.76	7.74	7.73	7.71	7.70	28
							8.02	8.00	7.99	7.97	29
								8.28	8.26	8.25	30
								8.55	8.54	8.52	31
								8.83	8.81	8.80	32
									9.09	9.07	33
										9.35	34
										9.62	35
											36
											37
											38
											39

TABLE

DEGREE BRIX.
From 0.5 to 12.0.

Tenths of a Degree.	Per Cent. Sucrose.
0.1°	0.03
0.2	0.06
0.3	0.08
0.4	0.11
0.5	0.14
0.6	0.17
0.7	0.19
0.8	0.22
0.9	0.25

DEGREE BRIX.
From 12.5 to 20.0.

Tenths of a Degree.	Per Cent. Sucrose.
0.1°	0.03
0.2	0.05
0.3	0.08
0.4	0.11
0.5	0.13
0.6	0.16
0.7	0.19
0.8	0.21
0.9	0.24

Polariscope Degrees.	APPROXIMATE								
	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5
1°	0.28	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
2	0.55	0.55	0.55	0.55	0.54	0.54	0.54	0.54	0.54
3	0.82	0.82	0.82	0.82	0.82	0.81	0.81	0.81	0.81
4	1.10	1.10	1.09	1.09	1.09	1.09	1.08	1.08	1.08
5	1.37	1.37	1.36	1.36	1.36	1.36	1.35	1.35	1.35
6	1.64	1.64	1.64	1.64	1.63	1.63	1.62	1.62	1.62
7	1.92	1.91	1.91	1.91	1.90	1.90	1.89	1.89	1.89
8	2.19	2.19	2.18	2.18	2.18	2.17	2.17	2.16	2.16
9	2.47	2.46	2.46	2.45	2.45	2.44	2.44	2.43	2.43
10	2.74	2.74	2.73	2.73	2.72	2.71	2.71	2.70	2.70
11	3.02	3.01	3.00	3.00	2.99	2.99	2.98	2.97	2.97
12	3.29	3.28	3.28	3.27	3.26	3.26	3.25	3.24	3.24
13	3.56	3.56	3.55	3.54	3.54	3.53	3.52	3.51	3.51
14	3.84	3.83	3.82	3.82	3.81	3.80	3.79	3.78	3.78
15	4.11	4.11	4.10	4.09	4.08	4.07	4.06	4.06	4.05
16	4.39	4.38	4.37	4.36	4.35	4.34	4.33	4.33	4.32
17	4.66	4.65	4.64	4.63	4.62	4.62	4.61	4.60	4.59
18	4.93	4.93	4.91	4.91	4.90	4.89	4.88	4.87	4.86
19	5.21	5.20	5.19	5.18	5.17	5.16	5.15	5.14	5.13
20	5.49	5.47	5.46	5.45	5.44	5.43	5.42	5.41	5.40
21	5.76	5.75	5.74	5.73	5.71	5.70	5.69	5.68	5.67
22	6.03	6.02	6.01	6.00	5.99	5.97	5.96	5.95	5.94
23	6.31	6.30	6.28	6.27	6.26	6.24	6.23	6.22	6.21
24	6.58	6.57	6.56	6.54	6.53	6.52	6.50	6.49	6.48
25	6.86	6.84	6.83	6.82	6.80	6.79	6.78	6.76	6.75
26	7.13	7.12	7.10	7.09	7.07	7.06	7.05	7.03	7.02
27	7.41	7.39	7.38	7.36	7.35	7.33	7.32	7.30	7.29
28	7.68	7.66	7.65	7.63	7.62	7.60	7.59	7.57	7.56
29	7.96	7.94	7.92	7.91	7.89	7.87	7.86	7.84	7.83
30	8.23	8.21	8.20	8.18	8.16	8.15	8.13	8.11	8.10
31	8.50	8.49	8.47	8.45	8.44	8.42	8.40	8.39	8.37
32	8.78	8.76	8.74	8.73	8.71	8.69	8.67	8.66	8.64
33	9.05	9.03	9.02	9.00	8.98	8.96	8.94	8.93	8.91
34	9.33	9.31	9.29	9.27	9.25	9.23	9.22	9.20	9.18
35	9.60	9.58	9.56	9.54	9.53	9.51	9.49	9.47	9.45
36	9.88	9.86	9.84	9.82	9.80	9.78	9.76	9.74	9.72
37	10.15	10.13	10.11	10.09	10.07	10.05	10.03	10.01	9.99
38		10.40	10.38	10.36	10.34	10.32	10.30	10.28	10.26
39		10.68	10.66	10.64	10.61	10.59	10.57	10.55	10.53

Degree Brix.											Polariscope Degrees.
15.0	**15.5**	**16.0**	**16.5**	**17.0**	**17.5**	**18.0**	**18.5**	**19.0**	**19.5**	**20.0**	
0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.26	1°
0.54	0.54	0.54	0.54	0.53	0.53	0.53	0.53	0.53	0.53	0.53	2
0.81	0.81	0.80	0.80	0.80	0.80	0.80	0.80	0.79	0.79	0.79	3
1.08	1.08	1.07	1.07	1.07	1.07	1.06	1.06	1.06	1.06	1.06	4
1.35	1.34	1.34	1.34	1.34	1.33	1.33	1.33	1.32	1.32	1.32	5
1.62	1.61	1.61	1.61	1.60	1.60	1.60	1.59	1.59	1.59	1.58	6
1.88	1.88	1.88	1.87	1.87	1.86	1.86	1.86	1.85	1.85	1.85	7
2.15	2.15	2.15	2.14	2.14	2.13	2.13	2.12	2.12	2.12	2.11	8
2.42	2.42	2.41	2.41	2.40	2.40	2.39	2.39	2.38	2.38	2.37	9
2.69	2.69	2.68	2.68	2.67	2.67	2.66	2.65	2.65	2.64	2.64	10
2.96	2.95	2.95	2.94	2.94	2.93	2.92	2.92	2.91	2.91	2.90	11
3.23	3.22	3.22	3 21	3.20	3.20	3.19	3.18	3.18	3.17	3.17	12
3.50	3.49	3.49	3.48	3.47	3.46	3.46	3.45	3.44	3.44	3.43	13
3.77	3.76	3.75	3.75	3.74	3.73	3.72	3.72	3.71	3.70	3.69	14
4.04	4.03	4.02	4.02	4.01	4.00	3.99	3.98	3.97	3.97	3.96	15
4.31	4.30	4.29	4.28	4.27	4.26	4.26	4.25	4.24	4.23	4.22	16
4.58	4.57	4.56	4.55	4.54	4.53	4.52	4.51	4.50	4.49	4.48	17
4.85	4.84	4.83	4.82	4.81	4.80	4.79	4.78	4.77	4.76	4.75	18
5.12	5.11	5.10	5.09	5.08	5.06	5 05	5.04	5.03	5.02	5.01	19
5.39	5.38	5.36	5.35	5.34	5.33	5.32	5.31	5.30	5.29	5.28	20
5.66	5.65	5.63	5.62	5.61	5.60	5.59	5.58	5.56	5.55	5.54	21
5.93	5.91	5.90	5.89	5.88	5.87	5.85	5.84	5.83	5.82	5.80	22
6.20	6.18	6.17	6.16	6.14	6.13	6.12	6.11	6.09	6.08	6.07	23
6.46	6.45	6.44	6.43	6.41	6.40	6.39	6.37	6.36	6.35	6.33	24
6.73	6.72	6.71	6.69	6.68	6.67	6.65	6.64	6.63	6.61	6.60	25
7.00	6.99	6.97	6.96	6.95	6.93	6.92	6.90	6.89	6.88	6.86	26
7.27	7.26	7.24	7.23	7.21	7.20	7.18	7.17	7.15	7.14	7.13	27
7.54	7.53	7.51	7.50	7.48	7.47	7.45	7.44	7.42	7.40	7.39	28
7.81	7.80	7.78	7.77	7.75	7.73	7.72	7.70	7.68	7.67	7.65	29
8.08	8.06	8.05	8.03	8.02	8.00	7.98	7.97	7.95	7.93	7.92	30
8.35	8.33	8.32	8.30	8.28	8.27	8.25	8.23	8.21	8.20	8.18	31
8.62	8.60	8.58	8.57	8.55	8.53	8.51	8.50	8.48	8.46	8.45	32
8.89	8.87	8.85	8.84	8.82	8.80	8.78	8.76	8.75	8.73	8.71	33
9.16	9.14	9.12	9.10	9.09	9.07	9.05	9.03	9.01	8.99	8.97	34
9.43	9.41	9.39	9.37	9.35	9.34	9.31	9.30	9.28	9.26	9.24	35
9.70	9.68	9.66	9.64	9.62	9.60	9.58	9.56	9.54	9.52	9.50	36
9.97	9.95	9.93	9.91	9.89	9.87	9.85	9.83	9.81	9.79	9.77	37
10.24	10.22	10.20	10.18	10.15	10.13	10.11	10.09	10.07	10.05	10.03	38
10.51	10.49	10.46	10.44	10.42	10.40	10.38	10.36	10.34	10.32	10.29	39

DEGREE BRIX.
From 11.5 TO 22 5.

Tenths of a Degree.	Per Cent Sucrose.
0.1°	0.03
0.2	0.05
0.3	0.08
0.4	0.11
0.5	0.13
0.6	0.16
0.7	0.19
0.8	0.21
0.9	0.24

DEGREE BRIX.
From 23.0 to 24.0

Tenths of a Degree.	Per Cent. Sucrose.
0.1°	0.03
0.2	0.05
0.3	0.08
0.4	0.10
0.5	0.13
0.6	0.16
0.7	0.18
0.8	0.21
0.9	0.23

Polariscope Degrees.	APPROXIMATE					
	11.5	12.0	12.5	13.0	13.5	14.0
40°	10.93	10.91	10.89	10.86	10.84	10.82
41		11.18	11.16	11.14	11.12	11.09
42		11.46	11.43	11.41	11.39	11.36
43			11.71	11.68	11.66	11.64
44			11,98	11.95	11.93	11.91
45			12.25	12.23	12.20	12.18
46				12.50	12.47	12.45
47					12.74	12.72
48					13.02	12.99
49						13.26
50						
51						
52						
53						
54						
55						
56						
57						
58						
59						
60						
61						
62						
63						
64						
65						
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69						
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72						
73						
74						
75						
76						
77						
78						
79						
80						

DEGREE BRIX.							Polariscope Degrees.
14.5	**15.0**	**15.5**	**16.0**	**16.5**	**17.0**	**17.5**	
10.80	10.78	10.76	10.73	10.71	10.69	10.67	40
11.07	11.05	11.03	11.00	10.98	10.96	10.94	41
11.34	11.32	11.29	11.27	11.25	11.23	11.20	42
11.61	11.59	11.56	11.54	11.52	11.49	11.47	43
11.88	11.86	11.83	11.81	11.79	11.76	11.74	44
12.15	12.13	12.10	12.08	12.05	12.03	12.01	45
12.42	12.40	12.37	12.35	12.32	12.30	12.27	46
12.69	12.67	12.64	12.61	12.59	12.56	12.54	47
12.97	12.94	12.91	12.88	12.86	12.83	42.81	48
13.23	13.21	13.18	13.15	13.13	13.10	13.07	49
13.50	13.48	13.45	13.42	13.40	13.37	13.34	50
13.78	13.75	13.72	13.69	13.66	13.64	13.61	51
	14.02	13.99	13.96	13.93	13.90	13.88	52
	14.29	14.26	14.23	14.20	14.17	14.14	53
		14.53	14.50	14.47	14.44	14.41	54
		14.80	14.77	14.74	14.71	14.68	55
			15.03	15.00	14.97	14.94	56
			15.30	15.27	15.24	15.21	57
			15.57	15.54	15.51	15.48	58
				15.81	15.78	15.75	59
					16.05	16.01	60
					16.31	16.28	61
						16.55	62
						16.82	63
							64
							65
							66
							67
							68
							69
							70
							71
							72
							73
							74
							75
							76
							77
							78
							79
							80

Degree Brix. From 11.5 to 22.5.		Polariscope Degrees.	Approximate					
Tenths of a Degree.	Per Cent. Sucrose.		18.0	18.5	19.0	19.5	20.0	20.5
		40°	10.64	10.62	10.60	10.58	10.56	10.54
0.1°	0.03	41	10.91	10.89	10.87	10.85	10.82	10.80
0.2	0.05	42	11.18	11.16	11.13	11.11	11.09	11.07
0.3	0.08	43	11.45	11.42	11.40	11.38	11.35	11.33
0.4	0.11	44	11.71	11.69	11.66	11.64	11.62	11.59
0.5	0.13	45	11.98	11.96	11.93	11.91	11.88	11.86
0.6	0.16	46	12.25	12.22	12.20	12.17	12.15	12.12
0.7	0.19	47	12.51	12.49	12.46	12.44	12.41	12.39
0.8	0.21	48	12.78	12.75	12.73	12.70	12.67	12.65
0.9	0.24	49	13.05	13.02	12.99	12.97	12.94	12.91
		50	13.31	13.29	13.26	13.23	13.20	13.18
		51	13.58	13.55	13.52	13.50	13.47	13.44
		52	13.85	13.82	13.79	13.76	13.73	13.70
		53	14.11	14.08	14.05	14.03	14.00	13.97
		54	14.38	14.35	14.32	14.29	14.26	14.23
		55	14.65	14.62	14.59	14.56	14.53	14.50
Degree Brix. From 23.0 to 24.0.		56	14.91	14.88	14.85	14.82	14.79	14.76
		57	15.18	15.15	15.12	15.09	15.06	15.02
Tenths of a Degree.	Per Cent. Sucrose.	58	15.45	15.42	15.38	15.35	15.32	15.29
		59	15.71	15.68	15.65	15.62	15.58	15.55
		60	15.98	15.95	15.92	15.88	15.85	15.82
0.1°	0.03	61	16.25	16.21	16.18	16.15	16.11	16.08
0.2	0.05	62	16.52	16.48	16.45	16.41	16.38	16.35
0.3	0.08	63	16.78	16.75	16.71	16.68	16.64	16.61
0.4	0.10	64	17.05	17.01	16.98	16.94	16.91	16.87
0.5	0.13	65	17.32	17.28	17.24	17.21	17.17	17.14
0.6	0.16	66		17.55	17.51	17.47	17.44	17.40
0.7	0.18	67		17.81	17.78	17.74	17.70	17.67
0.8	0.21	68			18.04	18.00	17.97	17.93
0.9	0.23	69			18.31	18.27	18.23	18.19
		70				18.53	18.50	18.46
		71					18.76	18.72
		72					19.03	18.99
		73						19.25
		74						19.52
		75						19.78
		76						
		77						
		78						
		79						
		80						

DEGREE BRIX.							Polariscope Degrees.
21.0	**21.5**	**22.0**	**22.5**	**23.0**	**23.5**	**24.0**	
10.52	10.49	10.47	10.45	10.43	10.41	10.38	40°
10.78	10.76	10.74	10.71	10.69	10.67	10.65	41
11.04	11.02	11.00	10.97	10.95	10.93	10.90	42
11.31	11.28	11.26	11.24	11.21	11.19	11.17	43
11.57	11.55	11.52	11.50	11.47	11.45	11.42	44
11.83	11.81	11.78	11.76	11.73	11.71	11.69	45
12.09	12.07	12.05	12.02	12.00	11.97	11.94	46
12.36	12.33	12.31	12.28	12.26	12.23	12.21	47
12.62	12.60	12.57	12.54	12.52	12.49	12.47	48
12.88	12.86	12.83	12.81	12.78	12.75	12.73	49
13.15	13.12	13.09	13.07	13.04	13.01	12.99	50
13.41	13.39	13.36	13.33	13.30	13.27	13.25	51
13.68	13.65	13.62	13.59	13.56	13.53	13.51	52
13.94	13.91	13.88	13.85	13.82	13.79	13.77	53
14.20	14.17	14.14	14.11	14.08	14.06	14.02	54
14.47	14.44	14.41	14.38	14.35	14.32	14.29	55
14.73	14.70	14.67	14.64	14.61	14.58	14.55	56
14.99	14.96	14.93	14.90	14.87	14.84	14.81	57
15.26	15.23	15.19	15.16	15.13	15.10	15.07	58
15.52	15.49	15.46	15.42	15.39	15.36	15.33	59
15.78	15.75	15.72	15.69	15.65	15.62	15.59	60
16.05	16.01	15.98	15.95	15.91	15.88	15.85	61
16.31	16.28	16.24	16.21	16.18	16.14	16.11	62
16.57	16.54	16.51	16.47	16.44	16.40	16.37	63
16.84	16.80	16.77	16.73	16.70	16.66	16.63	64
17.10	17.07	17.03	17.00	16.96	16.92	16.89	65
17.37	17.33	17.29	17.26	17.22	17.19	17.15	66
17.63	17.59	17.56	17.52	17.48	17.45	17.41	67
17.89	17.86	17.82	17.78	17.74	17.71	17.67	68
18.16	18.12	18.08	18.04	18.00	17.97	17.93	69
18.42	18.38	18.35	18.31	18.27	18.23	18.19	70
18.68	18.65	18.61	18.57	18.53	18.49	18.45	71
18.95	18.91	18.87	18.83	18.79	18.75	18.71	72
19.21	19.17	19.13	19.09	19.05	19.01	18.97	73
19.48	19.44	19.40	19.35	19.31	19.27	19.23	74
19.74	19.70	19.66	19.62	19.57	19.53	19.49	75
20.00	19.96	19.92	19.88	19.84	19.80	19.75	76
20.27	20.22	20.18	20.14	20.10	20.06	20.01	77
	20.49	20.45	20.40	20.36	20.32	20.27	78
	20.75	20.71	20.66	20.62	20.58	20.54	79
		20.97	20.93	20.88	20.84	20.80	80

TABLE VI.

For the Determination of Coefficients of Purity.—(KOTTMANN.)

Per Cent. Sucrose.	PER CENT. OF NON-SUCROSE = DEGREE BRIX MINUS PER CENT. SUCROSE.									Per Cent. Sucrose.
	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	
8.0	88.9	87.9	87.0	86.0	85.1	84.2	83.3	82.5	81.6	8.0
8.2	89.1	88.2	87.2	86.3	85.4	84.5	83.7	82.8	82.0	8.2
8.4	89.4	88.4	87.5	86.6	85.7	84.8	84.0	83.2	82.3	8.4
8.6	89.6	88.7	87.8	86.9	86.0	85.1	84.3	83.5	82.7	8.6
8.8	89.8	88.9	88.0	87.1	86.3	85.4	84.6	83.8	83.0	8.8
9.0	90.0	89.1	88.2	87.4	86.5	85.7	84.9	84.1	83.3	9.0
9.2	90.2	89.3	88.5	87.6	86.8	86.0	85.2	84.4	83.6	9.2
9.4	90.4	89.5	88.7	87.8	87.0	86.2	85.5	84.7	83.9	9.4
9.6	90.6	89.7	88.9	88.1	87.3	86.5	85.7	85.0	84.2	9.6
9.8	90.7	89.9	89.1	88.3	87.5	86.7	86.0	85.2	84.5	9.8
10.0	90.9	90.1	89.3	88.5	87.7	87.0	86.2	85.5	84.7	10.0
10.2	91.1	90.3	89.5	88.7	87.9	87.2	86.4	85.7	85.0	10.2
10.4	91.2	90.4	89.7	88.9	88.1	87.4	86.7	86.0	85.2	10.4
10.6	91.4	90.6	89.8	89.1	88.3	87.6	86.9	86.2	85.5	10.6
10.8	91.5	90.8	90.0	89.3	88.5	87.8	87.1	86.4	85.7	10.8
11.0	91.7	90.9	90.2	89.4	88.7	88.0	87.3	86.6	85.9	11.0
11.2	91.8	91.1	90.3	89.6	88.9	88.2	87.5	86.8	86.2	11.2
11.4	91.9	91.2	90.5	89.8	89.1	88.4	87.7	87.0	86.4	11.4
11.6	92.1	91.3	90.6	89.9	89.2	88.5	87.9	87.2	86.6	11.6
11.8	92.2	91.5	90.8	90.1	89.4	88.7	88.1	87.4	86.8	11.8
12.0	92.3	91.6	90.9	90.2	89.6	88.9	88.2	87.6	87.0	12.0
12.2	92.4	91.7	91.0	90.4	89.7	89.1	88.4	87.8	87.1	12.2
12.4	92.5	91.9	91.2	90.5	89.9	89.2	88.6	87.9	87.3	12.4
12.6	92.6	92.0	91.3	90.6	90.0	89.4	88.7	88.1	87.5	12.6
12.8	92.7	92.1	91.4	90.8	90.1	89.5	88.9	88.3	87.7	12.8
13.0	92.8	92.2	91.5	90.9	90.3	89.7	89.0	88.4	87.8	13.0
13.2	92.9	92.3	91.7	91.0	90.4	89.8	89.2	88.6	88.0	13.2
13.4	93.0	92.4	91.8	91.2	90.5	89.9	89.3	88.7	88.2	13.4
13.6	93.1	92.5	91.9	91.3	90.7	90.1	89.5	88.9	88.3	13.6
13.8	93.2	92.6	92.0	91.4	90.8	90.2	89.6	89.0	88.5	13.8
14.0	93.2	92.7	92.1	91.5	90.9	90.3	89.7	89.2	88.6	14.0
14.2	93.3	92.8	92.2	91.6	91.0	90.4	89.9	89.3	88.8	14.2
14.4	93.4	92.9	92.3	91.7	91.1	90.6	90.0	89.4	88.9	14.4
14.6	93.5	93.0	92.4	91.8	91.3	90.7	90.1	89.6	89.0	14.6
14.8	93.6	93.1	92.5	91.9	91.4	90.8	90.2	89.7	89.2	14.8
15.0	93.7	93.2	92.6	92.0	91.5	90.9	90.4	89.8	89.3	15.0
15.2	93.8	93.3	92.7	92.1	91.6	91.0	90.5	89.9	89.4	15.2
15.4	93.9	93.3	92.8	92.2	91.7	91.1	90.6	90.1	89.5	15.4
15.6	94.0	93.4	92.8	92.3	91.8	91.2	90.7	90.2	89.7	15.6
15.8	94.1	93.5	92.9	92.4	91.9	91.3	90.8	90.3	89.8	15.8
16.0	94.1	93.6	93.0	92.5	92.0	91.4	90.9	90.4	89.9	16.0
16.2	94.2	93.7	93.1	92.6	92.0	91.5	91.0	90.5	90.0	16.2
16.4	94.3	93.7	93.2	92.6	92.1	91.6	91.1	90.6	90.1	16.4
16.6	94.3	93.8	93.3	92.7	92.2	91.7	91.2	90.7	90.2	16.6
16.8	94.4	93.9	93.3	92.8	92.3	91.8	91.3	90.8	90.3	16.8
17.0	94.4	93.9	93.4	92.9	92.4	91.9	91.4	90.9	90.4	17.0

TABLE VI.—Con.

Per Cent. Sucrose.	Per Cent. of Non-Sucrose = Degree Brix Minus Per Cent. Sucrose.									Per Cent. Sucrose.
	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	
8.0	80.8	80.0	79.2	78.4	77.7	76.9	76.2	75.5	74.8	8.0
8.2	81.2	80.4	79.6	78.8	78.1	77.4	76.6	75.9	75.2	8.2
8.4	81.5	80.8	80.0	78.2	78.5	77.8	77.1	76.4	75.7	8.4
8.6	81.9	81.1	80.4	78.6	78.9	78.2	77.5	76.8	76.1	8.6
8.8	82.2	81.5	80.7	79.0	79.3	78.6	77.9	77.2	76.5	8.8
9.0	82.6	81.8	81.1	79.4	79.6	78.9	78.3	77.6	76.9	9.0
9.2	82.9	82.1	81.4	79.7	80.0	79.3	78.6	77.9	77.3	9.2
9.4	83.2	82.5	81.7	80.0	80.3	79.9	79.0	78.3	77.7	9.4
9.6	83.5	82.8	82.1	80.4	80.7	80.0	79.3	78.7	78.0	9.6
9.8	83.8	83.1	82.4	80.7	81.0	80.3	79.7	79.0	78.4	9.8
10.0	84.0	83.3	82.6	81.9	81.3	80.6	80.0	79.4	78.7	10.0
10.2	84.3	83.6	82.9	82.1	81.6	81.0	80.3	79.7	79.1	10.2
10.4	84.6	83.9	83.2	82.5	81.9	81.2	80.6	80.0	79.4	10.4
10.6	84.8	84.1	83.5	82.7	82.2	81.5	80.9	80.3	79.7	10.6
10.8	85.0	84.4	83.7	83.1	82.4	81.8	81.2	80.6	80.0	10.8
11.0	85.3	84.6	84.0	83.4	82.7	82.1	81.5	80.9	80.3	11.0
11.2	85.5	84.8	84.2	83.5	83.0	82.4	81.8	81.2	80.6	11.2
11.4	85.7	85.1	84.4	82.8	83.2	82.6	82.0	81.4	80.9	11.4
11.6	85.9	85.3	84.7	83.1	83.5	82.9	82.3	81.7	81.1	11.6
11.8	86.1	85.5	84.9	83.3	83.7	83.1	82.5	81.9	81.4	11.8
12.0	86.3	85.7	85.1	83.5	83.9	83.3	82.8	82.2	81.6	12.0
12.2	86.5	85.9	85.3	83.7	84.1	83.6	83.0	82.4	81.9	12.2
12.4	86.7	86.1	85.5	83.9	84.4	83.8	83.2	82.7	82.1	12.4
12.6	86.9	86.3	85.7	84.1	84.6	84.0	83.4	82.9	82.4	12.6
12.8	87.1	86.5	85.9	84.3	84.8	84.2	83.7	83.1	82.6	12.8
13.0	87.2	86.7	86.1	84.5	85.0	84.4	83.9	83.3	82.8	13.0
13.2	87.4	86.8	86.3	84.7	85.2	84.6	84.1	83.5	83.0	13.2
13.4	87.6	87.0	86.5	84.9	85.4	84.8	84.3	83.7	83.2	13.4
13.6	87.7	87.2	86.6	85.1	85.5	85.0	84.5	83.9	83.4	13.6
13.8	87.9	87.3	86.8	85.3	85.7	85.2	84.7	84.1	83.6	13.8
14.0	88.1	87.5	87.0	85.4	85.9	85.4	84.8	84.3	83.8	14.0
14.2	88.2	87.7	87.1	85.6	86.1	85.5	85.0	84.5	84.0	14.2
14.4	88.3	87.8	87.3	85.7	86.2	85.7	85.2	84.7	84.2	14.4
14.6	88.5	88.0	87.4	85.9	86.4	85.9	85.4	84.9	84.4	14.6
14.8	88.6	88.1	87.6	86.1	86.5	86.0	85.5	85.1	84.6	14.8
15.0	88.8	88.2	87.7	86.2	86.7	86.2	85.7	85.2	84.7	15.0
15.2	88.9	88.4	87.9	86.4	86.9	86.4	85.9	85.4	84.9	15.2
15.4	89.0	88.5	88.0	86.5	87.0	86.5	86.0	85.6	85.1	15.4
15.6	89.1	88.6	88.1	86.6	87.2	86.7	86.2	85.7	85.2	15.6
15.8	89.3	88.8	88.3	87.8	87.3	86.8	86.3	85.9	85.4	15.8
16.0	89.4	88.9	88.4	87.9	87.4	87.0	86.5	86.0	85.6	16.0
16.2	89.5	89.0	88.5	88.0	87.6	87.1	86.6	86.2	85.7	16.2
16.4	89.6	89.1	88.6	87.2	87.7	87.2	86.8	86.3	85.9	16.4
16.6	89.7	89.2	88.8	87.3	87.8	87.4	86.9	86.5	86.0	16.6
16.8	89.8	89.4	88.9	87.4	88.0	87.5	87.0	86.6	86.2	16.8
17.0	89.9	89.5	89.0	87.5	88.1	87.6	87.2	86.7	86.3	17.0

TABLE VI.—Con.

Per Cent. Sucrose.	Per Cent. of Non-Sucrose = Degree Brix Minus Per Cent. Sucrose.									Per Cent. Sucrose.
	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	
8.0	74.1	73.4	72.7	72.1	71.4	70.8	70.2	69.6	69.0	8.0
8.2	74.5	73.9	73.2	72.6	71.9	71.3	70.7	70.1	69.5	8.2
8.4	75.0	74.3	73.7	73.0	72.4	71.8	71.2	70.6	70.0	8.4
8.6	75.4	74.8	74.1	73.5	72.9	72.3	71.7	71.1	70.5	8.6
8.8	75.9	75.2	74.6	73.9	73.3	72.7	72.1	71.5	71.0	8.8
9.0	76.3	75.6	75.0	74.4	73.8	73.2	72.6	72.0	71.4	9.0
9.2	76.7	75.8	75.4	74.8	74.2	73.6	73.0	72.4	71.9	9.2
9.4	77.0	76.4	75.8	75.2	74.6	74.0	73.4	72.9	72.3	9.4
9.6	77.4	76.8	76.2	75.6	75.0	74.4	73.8	73.3	72.7	9.6
9.8	77.8	77.2	76.6	76.0	75.4	74.8	74.2	73.7	73.1	9.8
10.0	78.1	77.5	76.9	76.3	75.8	75.2	74.6	74.1	73.5	10.0
10.2	78.5	77.9	77.3	76.7	76.1	75.6	75.0	74.5	73.9	10.2
10.4	78.8	78.2	77.6	77.0	76.5	75.9	75.4	74.8	74.3	10.4
10.6	79.1	78.5	77.9	77.4	76.8	76.3	75.7	75.2	74.6	10.6
10.8	79.4	78.8	78.3	77.7	77.1	76.6	76.1	75.5	75.0	10.8
11.0	79.7	79.1	78.6	78.0	77.5	76.9	76.4	75.9	75.3	11.0
11.2	80.0	79.4	78.9	78.3	77.8	77.2	76.7	76.2	75.7	11.2
11.4	80.3	79.7	79.2	78.6	78.1	77.6	77.0	76.5	76.0	11.4
11.6	80.6	80.0	79.4	78.9	78.4	77.9	77.3	76.8	76.3	11.6
11.8	80.8	80.3	79.7	79.2	78.7	78.1	77.6	77.1	76.6	11.8
12.0	81.1	80.5	80.0	79.5	78.9	78.4	77.9	77.4	76.9	12.0
12.2	81.3	80.8	80.3	79.7	79.2	78.7	78.2	77.7	77.2	12.2
12.4	81.6	81.0	80.5	80.0	79.5	79.0	78.5	78.0	77.5	12.4
12.6	81.8	81.3	80.8	80.3	79.7	79.2	78.8	78.3	77.8	12.6
12.8	82.1	81.5	81.0	80.5	80.0	79.5	79.0	78.5	78.0	12.8
13.0	82.3	81.8	81.2	80.7	80.2	79.8	79.3	78.8	78.3	13.0
13.2	82.5	82.0	81.5	81.0	80.5	80.0	79.5	79.0	78.6	13.2
13.4	82.7	82.2	81.7	81.2	80.7	80.2	79.8	79.3	78.8	13.4
13.6	82.9	82.4	81.9	81.4	81.0	80.5	80.0	79.5	79.1	13.6
13.8	83.1	82.6	82.1	81.7	81.2	80.7	80.2	79.8	79.3	13.8
14.0	83.3	82.8	82.3	81.9	81.4	80.9	80.5	80.0	79.5	14.0
14.2	83.5	83.0	82.5	82.1	81.6	81.1	80.7	80.2	79.8	14.2
14.4	83.7	83.2	82.7	82.3	81.8	81.4	80.9	80.4	80.0	14.4
14.6	83.9	83.4	82.9	82.5	82.0	81.6	81.1	80.7	80.2	14.6
14.8	84.1	83.6	83.1	82.7	82.2	81.8	81.3	80.9	80.4	14.8
15.0	84.3	83.8	83.3	82.9	82.4	82.0	81.5	81.1	80.6	15.0
15.2	84.4	84.0	83.5	83.1	82.6	82.2	81.7	81.3	80.8	15.2
15.4	84.6	84.2	83.7	83.2	82.8	82.4	81.9	81.5	81.0	15.4
15.6	84.8	84.3	83.9	83.4	83.0	82.5	82.1	81.7	81.2	15.6
15.8	84.9	84.5	84.0	83.6	83.2	82.7	82.3	81.9	81.4	15.8
16.0	85.1	84.7	84.2	83.8	83.3	82.9	82.5	82.0	81.6	16.0
16.2	85.3	84.8	84.4	83.9	83.5	83.1	82.7	82.2	81.8	16.2
16.4	85.4	84.9	84.5	84.1	83.7	83.2	82.8	82.4	82.0	16.4
16.6	85.6	85.1	84.7	84.3	83.8	83.4	83.0	82.6	82.2	16.6
16.8	85.9	85.2	84.8	84.4	84.0	83.6	83.2	82.8	82.4	16.8
17.0	85.9	85.4	85.0	84.6	84.2	83.7	83.3	82.9	82.5	17.0

TABLE VI.—Con.

Per Cent Sucrose	Per Cent. of Non-Sucrose = Degree Brix Minus Per Cent. Sucrose.									Per Cent Sucrose.
	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	
8.0	68.4	67.8	67.2	66.7	66.1	65.6	65.0	64.5	64.0	8.0
8.2	68.9	68.3	67.8	67.2	66.7	66.1	65.6	65.1	64.6	8.2
8.4	69.4	68.8	68.3	67.7	67.2	66.7	66.1	65.6	65.1	8.4
8.6	69.9	69.3	68.8	68.3	67.7	67.2	66.7	66.2	65.6	8.6
8.8	70.4	69.8	69.3	68.8	68.2	67.7	67.2	66.7	66.2	8.8
9.0	70.9	70.3	69.8	69.2	68.7	68.2	67.7	67.2	66.7	9.0
9.2	71.3	70.8	70.2	69.7	69.2	68.7	68.1	67.6	67.2	9.2
9.4	71.8	71.2	70.7	70.1	69.6	69.1	68.6	68.1	67.6	9.4
9.6	72.2	71.6	71.1	70.6	70.1	69.6	69.1	68.6	68.1	9.6
9.8	72.6	72.1	71.5	71.0	70.5	70.0	69.5	69.0	68.5	9.8
10.0	73.0	72.5	71.9	71.4	70.9	70.4	69.9	69.4	69.0	10.0
10.2	73.4	72.9	72.3	71.8	71.3	70.8	70.3	69.9	69.4	10.2
10.4	73.8	73.2	72.7	72.2	71.7	71.2	70.7	70.3	69.8	10.4
10.6	74.1	73.6	73.1	72.6	72.1	71.6	71.1	70.7	70.2	10.6
10.8	74.5	74.0	73.5	73.0	72.5	72.0	71.5	71.1	70.6	10.8
11.0	74.8	74.3	73.8	73.3	72.8	72.4	71.9	71.4	71.0	11.0
11.2	75.2	74.7	74.2	73.7	73.2	72.7	72.3	71.8	71.3	11.2
11.4	75.5	75.0	74.5	74.0	73.5	73.1	72.6	72.2	71.7	11.4
11.6	75.8	75.3	74.8	74.4	73.9	73.4	73.0	72.5	72.0	11.6
11.8	76.1	75.6	75.2	74.9	74.2	73.8	73.3	72.8	72.4	11.8
12.0	76.4	75.9	75.5	75.0	74.5	74.1	73.6	73.2	72.7	12.0
12.2	76.7	76.2	75.8	75.3	74.8	74.4	73.9	73.5	73.1	12.2
12.4	77.0	76.5	76.1	75.6	75.2	74.7	74.3	73.8	73.4	12.4
12.6	77.3	76.8	76.4	75.9	75.4	75.0	74.6	74.1	73.7	12.6
12.8	77.6	77.1	76.6	76.2	75.7	75.3	74.9	74.4	74.0	12.8
13.0	77.8	77.4	76.9	76.5	76.0	75.6	75.1	74.7	74.3	13.0
13.2	78.1	77.6	77.2	76.7	76.3	75.9	75.4	75.0	74.6	13.2
13.4	78.4	77.9	77.5	77.0	76.6	76.1	75.7	75.3	74.9	13.4
13.6	78.6	78.2	77.7	77.3	76.8	76.4	75.0	75.6	75.1	13.6
13.8	78.9	78.4	78.0	77.5	77.1	76.7	76.2	75.8	75.4	13.8
14.0	79.1	78.7	78.2	77.8	77.3	76.9	76.5	76.1	75.7	14.0
14.2	79.3	78.9	78.5	78.0	77.6	77.2	76.8	76.3	75.9	14.2
14.4	79.6	79.1	78.7	78.3	77.8	77.4	77.0	76.6	76.2	14.4
14.6	79.8	79.3	78.9	78.5	78.1	77.6	77.2	76.8	76.4	14.6
14.8	80.0	79.6	79.1	78.7	78.3	77.9	77.5	77.1	76.7	14.8
15.0	80.2	79.8	79.4	78.9	78.5	78.1	77.7	77.3	76.9	15.0
15.2	80.4	80.0	79.6	79.2	78.8	78.4	77.9	77.6	77.2	15.2
15.4	80.6	80.2	79.8	79.4	79.0	78.6	78.2	77.8	77.4	15.4
15.6	80.8	80.4	80.0	79.6	79.2	78.8	78.4	78.0	77.6	15.6
15.8	81.0	80.6	80.2	79.8	79.4	79.0	78.6	78.2	77.8	15.8
16.0	81.2	80.8	80.4	80.0	79.6	79.2	78.8	78.4	78.0	16.0
16.2	81.4	81.0	80.6	80.2	79.8	79.4	79.0	78.6	78.3	16.2
16.4	81.6	81.2	80.8	80.4	80.0	79.6	79.2	78.8	78.5	16.4
16.6	81.8	81.4	81.0	80.6	80.2	79.8	79.4	79.0	78.7	16.6
16.8	82.0	81.6	81.2	80.8	80.4	80.0	79.6	79.2	78.9	16.8
17.0	82.1	81.7	81.3	80.0	80.6	80.2	79.8	79.4	78.1	17.0

TABLE VII.

For Determining Per Cent. CaO in Lime with a Normal Acid.

C. C. Acid.	Per Cent. CaO.	C. C Acid.	Per Cent. CaO.	C. C. Acid.	Per Cent. CaO.
22.0	61.6	24.7	69.2	27.4	76.7
22.1	61.9	27.8	69.4	27.5	77.0
22.2	62.2	24.9	69.7	27.6	77.3
22.3	62.4	25.0	70.0	27.7	77.6
22.4	62.7	25.1	70.3	27.8	77.8
22.5	63.0	25.2	70.6	27.9	78.1
22.6	63.3	25.3	70.8	28.0	78.4
22.7	63.6	25.4	71.1	28.1	78.7
22.8	63.8	25.5	71.4	28.2	79.0
22.9	64.1	25.6	71.7	28.3	79.2
23.0	64.4	25.7	72.0	28.4	79.5
23.1	64.7	25.8	72.2	28.5	79.8
23.2	65.0	25.9	72.5	28.6	80.1
23.3	65.2	26.0	72.8	28.7	80.4
23.4	65.5	26.1	73.1	28.8	80.6
23.5	65.8	26.2	73.4	28.9	80.9
23.6	66.1	26.3	73.6	29.0	81.2
23.7	66.4	26.4	73.9	29.1	81.5
23.8	66.6	26.5	74.2	29.2	81.8
23.9	66.9	26.6	74.5	29.3	82.0
24.0	67.2	26.7	74.8	29.4	82.3
24.1	67.5	26.8	75.0	29.5	82.6
24.2	67.8	26.9	75.3	29.6	82.9
24.3	68.0	27.0	75.6	29.7	83.2
24.4	68.3	27.1	75.9	29.8	83.4
24.5	68.6	27.2	76.2	29.9	83.7
24.6	68.9	27.3	76.4	30.0	84.0

TABLE VIII.

CaO WITH A NORMAL ACID.

C. C. of Acid.	Per Cent. of CaO.	C. C. of Acid.	Per Cent. of CaO.	C. C of Acid.	Per Cent. of CaO.
1	2.8	13	36.4	25	70.0
2	5.6	14	39.2	26	72.8
3	8.4	15	42.0	27	75.6
4	12.2	16	44.8	28	78.4
5	14.0	17	47.6	29	81.2
6	16.8	18	50.4	30	84.0
7	19.6	19	53.2	31	86.8
8	22.4	20	56.0	32	89.6
9	25.2	21	58.8	33	92.4
10	28.0	22	61.6	34	95.2
11	30.8	23	64.4	35	98.0
12	33.6	24	67.2	35.7	100.0

ADD FOR TENTHS OF A CUBIC CENTIMETER.

C. C. of Acid.		Per Cent. of CaO.
.1	——	.28
.2	——	.56
.3	——	.84
.4	——	1.22
.5	——	1.40
.6	——	1.68
.7	——	1.96
.8	——	2.24
.9	——	2.52

TABLE IX.

COMPARISON OF THERMOMETRIC SCALES.

Centigrade and Fahrenheit.

Centigrade	Fahrenheit	Centigrade.	Fahrenheit.	Centigrade.	Fahrenheit.
100°	212°	53°	127.4°	6°	42.8°
99	210.2	52	125.6	5	41
98	208.4	51	123.8	4	39.2
97	206.6	50	122	3	37.4
96	204.8	49	120.2	2	35.6
95	203	48	118.4	1	33.8
94	201.2	47	116.6	0	32
93	199.4	46	114.8	—1	30.2
92	197.6	45	113	—2	28.4
91	195.8	44	111.2	—3	26.6
90	194	43	109.4	—4	24.8
89	192.2	42	107.6	—5	23
88	190.4	41	105.8	—6	21.2
87	188.6	40	104	—7	19.4
86	186.8	39	102.2	—8	17.6
85	185	38	100.4	—9	15.8
84	183.2	37	98.6	—10	14
83	181.4	36	96.8	—11	12.2
82	179.6	35	95	—12	10.4
81	177.8	34	93.2	—13	8.6
80	176	33	91.4	—14	6.8
79	174.2	32	89.6	—15	5
78	172.4	31	87.8	—16	3.2
77	170.6	30	86	—17	1.4
76	168.8	29	84.2	—18	0.4
75	167	28	82.4	—19	—2.2
74	165.2	27	80.6	—20	—4
73	163.4	26	78.8	—21	—5.8
72	161.6	25	77	—22	—7.6
71	159.8	24	75.2	—23	—9.4
70	158	23	73.4	—24	—11.2
69	156.2	22	71.6	—25	—13
68	154.4	21	69.8	—26	—14.8
67	152.6	20	68	—27	—16.6
66	150.8	19	66.2	—28	—18.4
65	149	18	64.4	—29	—20.2
64	147.2	17	62.6	—30	—22
63	145.4	16	60.8	—31	—23.8
62	143.6	15	59	—32	—25.6
61	141.8	14	57.2	—33	—27.4
60	140	13	55.4	—34	—29.2
59	138.2	12	53.6	—35	—31
58	136.4	11	51.8	—36	—32.8
57	134.6	10	50	—37	—34.6
56	132.8	9	48.2	—38	—36.4
55	131	8	46.4	—39	—38.2
54	129.2	7	44.6	—40	—40

TABLE IX.—Con.

COMPARISON OF THERMOMETRIC SCALES.

Fahrenheit and Centigrade.

Fahrenheit.	Centigrade	Fahrenheit.	Centigrade.	Fahrenheit.	Centigrade.	Fahrenheit.	Centigrade.
212°	100°	165°	73.89°	118°	47.78°	71°	21.67°
211	99.44	164	73.33	117	47.22	70	21.11
210	98.99	163	72.78	116	46.67	69	20.55
209	98.33	162	72.22	115	46.11	68	20
208	97.78	161	71.67	114	45.55	67	19.44
207	97.22	160	71.11	113	45	66	18.89
206	96.67	159	70.55	112	44.44	65	18.33
205	96.11	158	70	111	43.89	64	17.78
204	95.55	157	69.44	110	43.33	63	17.22
203	95	156	68.89	109	42.78	62	16.67
202	94.44	155	68.33	108	42.22	61	16.11
201	93.89	154	67.78	107	41.67	60	15.55
200	93.33	153	67.22	106	41.11	59	15
199	92.78	152	66.67	105	40.55	58	14.44
198	92.22	151	66.11	104	40	57	13.89
197	91.67	150	65.55	103	39.44	56	13.33
196	91.11	149	65	102	38.89	55	12.78
195	90.55	148	64.44	101	38.33	54	12.22
194	90	147	63.89	100	37.78	53	11.67
193	89.44	146	63.33	99	37.22	52	11.11
192	88.89	145	62.78	98	36.67	51	10.55
191	88.33	144	62.22	97	36.11	50	10
190	87.78	143	61.67	96	35.55	49	9.44
189	87.22	142	61.11	95	35	48	8.89
188	86.67	141	60.55	94	34.44	47	8.33
187	86.11	140	60	93	33.89	46	7.78
186	85.55	139	59.44	92	33.33	45	7.22
185	85	138	58.89	91	32.78	44	6.67
184	84.44	137	58.33	90	32.22	43	6.11
183	83.89	136	57.78	89	31.67	42	5.55
182	83.33	135	57.22	88	31.11	41	5
181	82.78	134	56.67	87	30.55	40	4.44
180	82.22	133	56.11	86	30	39	3.89
179	81.67	132	55.55	85	29.44	38	3.33
178	81.11	131	55	84	28.89	37	2.78
177	80.55	130	54.44	83	28.33	36	2.22
176	80	129	53.89	82	27.78	35	1.67
175	79.44	128	53.33	81	27.22	34	1.11
174	78.89	127	52.78	80	26.67		
173	78.33	126	52.22	79	26.11		
172	77.78	125	51.67	78	25.55		
171	77.22	124	51.11	77	25		
170	76.67	123	50.55	76	24.44		
169	76.11	122	50	75	23.89		
168	75.55	121	49.44	74	23.33		
167	75	120	48.89	73	22.78		
166	74.44	119	48.33	72	22.22		

TABLE X.

PARTIAL LIST OF ATOMIC WEIGHTS.—(REMSEN.)

NAME.	Symbol.	Atomic Weight.	NAME.	Symbol.	Atomic Weight.
Aluminum ...	Al.	27.04	Lead	Pb.	206.4
Antimony ...	Sb.	119.6	Lithium . ..	Li.	7.01
Arsenic	As.	74.9	Magnesium ..	Mg.	23.94
Barium	Ba.	136.9	Manganese ..	Mn.	54.8
Bismuth	Bi.	207.3	Mercury	Hg.	199.8
Boron	B.	10.9	Molybdenum	Mo.	95.9
Bromine	Br.	79.76	Nickel	Ni.	58.56
Cadmium	Cd.	111.7	Nitrogen	N.	14.01
Calcium	Ca.	39.91	Oxygen	O	15.96
Carbon	C.	11.97	Phosphorus ..	P.	30.96
Chlorine....	Cl.	35.37	Platinum	Pt.	194.3
Chromium ...	Cr.	52.45	Potassium ..	K.	39.03
Cobalt	Co.	58.74	Silicon	Si.	28.1
Copper	Cu.	63.18	Silver	Ag.	107.66
Fluorine.....	F.	19.06	Sodium	Na.	23.0
Gold	Au.	196.7	Strontium ...	Sr.	87.3
Hydrogen ...	H.	1.	Sulphur	S.	31.98
Iodine	I.	126.54	Tin..........	Sn.	117.4
Iridium	Ir.	192.5	Uranium	U.	239.8
Iron	Fe.	55.88	Zinc	Zn.	65.1

TABLE XI.

FACTORS USED IN QUANTITATIVE ANALYSIS.

Found.		Sought.		Multiply By
Ammonia	NH_3	Nitrogen	N	.8236
Barium Sulphate	$BaSO_4$	Calcium Sulphide	CaS	.3089
Barium Sulphate	$BaSO_4$	Calcium Sulphate	$CaSO_4$	.5832
Barium Sulphate	$BaSO_4$	Sulphuric Anhydride	SO_3	.3431
Barium Sulphate	$BaSO_4$	Sulphur	S	.1374
Calcium Oxide	CaO	Calcium Carbonate	$CaCO_3$	1.7856
Calcium Oxide	CaO	Calcium Sulphate	$CaSO_4$	2.4294
Calcium Carbonate	$CaCO_3$	Calcium Oxide	CaO	.5600
Calcium Carbonate	$CaCO_3$	Carbon Dioxide	CO_2	.4400
Calcium Sulphate	$CaSO_4$	Calcium Oxide	CaO	.4116
Calcium Sulphate	$CaSO_4$	Sulphur	S	.2356
Carbon Dioxide	CO_2	Calcium Carbonate	$CaCO_3$	2.2730
Carbon Dioxide	CO^2	Magnesium Carbonate	$MgCO_3$	1.9091
Carbon Dioxide	CO_2	Sodium Carbonate	Na_2CO_3	2.4117
Carbon Dioxide	CO_2	Potassium Carbonate	K_2CO_3	2.4689
Chlorine	Cl	Potassium Chloride	KCl	2.1035
Chlorine	Cl	Sodium Chloride	$NaCl$	1.6503
Copper Oxide	CuO	Copper	Cu	.7983
Magnesium Carbonate	$MgCO_3$	Magnesium Oxide	MgO	.4762
Magnesium Oxide	MgO	Magnesium Carbonate	$MgCO_3$	2.1000
Magnesium Oxide	MgO	Magnesium Sulphate	$MgSO_4$	3.0015
Magnesium Pyrophosphate	$Mg_2P_2O_7$	2 Magnesium Carbonate	$2MgCO_3$	.7565
Magnesium Pyrophosphate	$Mg_2P_2O_7$	2 Magnesium Oxide	$2MgO$	.3602
Magnesium Pyrophosphate	$Mg_2P_2O_7$	Phosphoric Anhydride		.6396
Magnesium Sulphate	$MgSO_4$	Magnesium Oxide	MgO	.3332
Magnesium Sulphate	$MgSO^4$	Sulphuric Anhydride	SO_2	.6668
Phosphoric Anhydride	P_2O_5	Calcium Phosphate	CaP_2O_8	2.1827
Phosphoric Anhydride	P_2O_5	2 Potassium Phosphate	$2K_3PO_4$	2.9903
Potassium	K	Potassium Chloride	KCl	1.9062
Potassium Oxide	K_2O	Potassium Carbonate	K_2CO_3	1.4668
Potassium Oxide	K_2O	Potassium Chloride	KCl	.7913
3 Potassium Oxide	$3K_2O$	2 Potassium Phosphate	$2K_3PO_4$	1.5024
Potassium Oxide	K_2O	Potassium Sulphate	K^2SO_4	2.2645
Silver Chloride	$AgCl$	Chlorine	Cl	.2473

TABLE XI.—Con.

Found.		Sought.		Multiply By
Sodium	Na	Sodium Chloride	$NaCl$	2.5378
Sodium	Na	Sodium Carbonate	Na_2CO_3	2.3010
Sodium	Na_2	Sodium Sulphate	Na_2SO_4	3.0830
Sodium Carbonate	Na_2CO_3	Carbon Dioxide	CO_2	.4146
Sodium Carbonate	Na_2CO_3	Oxygen	O	.1508
Sodium Chloride	$NaCl$	Chlorine	Cl	.6060
Sodium Chloride	$NaCl$	Sodium	Na	.3940
Sodium Chloride	$NaCl$	Sodium Oxide	Na_2O	.2906
Sodium Oxide	Na_2O	Sodium Carbonate	Na_2CO_3	1.7067
Sodium Oxide	Na_2O	Sodium Sulphate	Na_2SO_4	2 2889
Sodium Sulphate	Na_2SO_4	Sodium	Na	.3244
Sodium Sulphate	Na_2SO_4	Sulphuric Anhydride	SO_3	.5631
Sodium Sulphate	Na_2SO_4	Oxygen	O	.1125
Sulphuric Anhydride	SO_3	Calcium Sulphate	$CaSO_4$	1.6996
Sulphuric Anhydride	SO_3	Magnesium Sulphate	$MgSO_4$	1.4996
Sulphuric Anhydride	SO_3	Potassium Sulphate	K_2SO_4	2.1773
Sulphuric Anhydride	SO_3	Sodium Sulphate	Na_2SO_4	1.7759

TABLE XII.

TABLES FOR THE CONVERSION OF METRIC WEIGHTS AND MEASURES INTO CUSTOMARY UNITED STATES EQUIVALENTS AND THE REVERSE.

[A metric ton is about the same as a ton of 2240 pounds. A kilogramme or kilo is about 2 pounds. A gramme is about 15 grains or about .03 ounces. (A nickel weighs about 5 grains.) A liter is about 1 quart (either liquid or dry measure.) A cubic centimeter is about 1-12 of a cubic inch (a teaspoon holds about 5 cubic centimeters.) A meter is about 39 inches. A centimeter is about ⅓ of an inch. A millimeter is about 1-32 of an inch.]

ENGLISH TONS INTO METRIC TONS.

English Tons.	0	1	2	3	4	5	6	7	8	9
	M. Tons.	M. Tons	M. Tons.	M Tons.	M. Tons.	M. Tons.	M. Tons.	M Tons	M. Tons.	M. Tons.
0	0.000	1.016	2.032	3.048	4.064	5.080	6.096	7.112	8.128	9.144
10	10.160	11.176	12 192	13.208	14.224	15.240	16.256	17.272	18.288	19.304
20	20.320	21.336	22.352	23.368	24.384	25.400	26.416	27.434	28.448	29.464
30	30.480	31.496	32.512	33.528	34.544	35.560	36.576	37.592	38.608	39.624
40	40.640	41.656	42.672	43.688	44.708	45.720	46.736	47.752	48.768	49.784
50	50 800	51.816	52.832	53.848	54.864	55.880	56.896	57.912	58.928	59 944
60	60.960	61.976	62.992	64.008	65.024	66.040	67.056	68.072	69.088	70.104
70	71.120	72.136	73.152	74.168	75.184	76.200	77.216	78.232	79.248	80.264
80	81.280	82.296	83.312	84.328	85.344	86.360	87.376	88.392	89.408	90.424
90	91.440	92.456	93.472	94.488	95.504	96.520	97.536	98.552	99.568	100.58
100	101.60	102.62	103.63	104.65	105.66	106.68	107.70	108.71	109.73	110.74

TABLE XII.—Con.

METRIC TONS INTO ENGLISH TONS.

Metric Tons.	0	1	2	3	4	5	6	7	8	9
	E. Tons.	E. Tons.	E. Tons.	E. Tons.	E. Tons.	E. Tons	E. Tons	E. Tons.	E. Tons.	E. Tons.
0	0.000	0.984	1.968	2.952	3.936	4.920	5.904	6.888	7.872	8.856
10	9.840	10.824	11.808	12.792	13.776	14.760	15.744	16.728	17.712	18.696
20	19.684	20.668	21.652	22.636	23.620	24.605	25.589	26.573	27.557	28.541
30	29.526	30.510	31.494	32.478	33.462	34.447	35.431	36.415	37.399	38.383
40	39.368	40.352	41.336	42.320	43.304	44.289	45.273	46.257	47.241	48.225
50	49.210	50.194	51.178	52.162	53.146	54.131	55.115	56.099	57.083	58.067
60	59.052	60.036	61.020	62.004	62.988	63.972	64.956	65.940	66.935	67.919
70	68.903	69.887	70.871	71.856	72.840	73.824	74 808	75.792	76.777	77.761
80	78.745	79.729	80.713	81.698	82.682	83.666	84.650	85.634	86.619	87.603
90	88.587	89.571	90.555	91.540	92.524	93.508	94.492	95.476	96.461	97.445
100	98.429	99.413	100.40	101.38	102 37	103.35	104.33	105.32	106.30	107.29

AVOIRDUPOIS POUNDS INTO KILOGRAMMES.

Kilos	0	1	2	3	4	5	6	7	8	9
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	0.000	0.4535	0.9071	1.3607	1.8143	2.2679	2.7215	3.1751	3.6287	4.0823
10	4.5359	4.9894	5.4430	5.8966	6.3502	6.8038	7.2574	7.7110	8.1646	8.6182
20	9.0718	9.5254	9.9789	10.432	10.886	11.339	11.793	12.246	12.700	13.154
30	13.607	14.061	14.514	14.968	15.422	15.875	16.329	16.782	17.236	17.690
40	18.143	18.597	19.050	19.504	19.957	20.411	20.865	21 318	21.772	22.225
50	22.679	23.132	23.586	24.039	24.493	24.946	25.400	25.854	26.308	26.761
60	27.215	27.668	28.122	28,576	29.029	29.483	29.936	30.390	30.844	31.297
70	31.751	32 204	32.658	33.112	33.565	34.019	34.472	34.926	35.380	35.833
80	36.287	36 740	37.194	37 647	38.101	38.555	39.008	39.462	39.915	40.369
90	40.823	41.276	41.730	42.183	42.637	43.091	43.544	43.998	44.451	44.905
100	45 359	45.812	46 266	46.719	47.173	47.626	48.080	48.534	48.987	49.441

KILOGRAMMES INTO AVOIRDUPOIS POUNDS.

English Lbs.	0	1	2	3	4	5	6	7	8	9
	Kilos.	Kilos.	Kilos.	Kilos	Kilos.	Kilos.	Kilos.	Kilos.	Kilos.	Kilos.
0	0.000	2.20462	4.4092	6.6139	8.8185	11.023	13.228	15.432	17.637	19.842
10	22.046	24.250	26.455	28.660	30.864	33.069	35.273	37.478	39.683	41.887
20	44.092	46.297	48.501	50.706	52.910	55.115	57.320	59.524	61.729	63.933
30	66.138	68.343	70.547	72.752	74.957	77.161	79.366	81.570	83.775	85.980
40	88.184	90.389	92.594	94.798	97.003	99.207	101.41	103.61	105.82	108 02
50	110.23	112.43	114.64	116.84	119.04	121.25	123.45	125.66	127.86	130.07
60	132.27	134.48	136.68	138.89	141.09	143.30	145.50	147.70	149.91	152.11
70	154.32	156.52	158.73	160.93	163.14	165.34	167.55	169.75	171.96	174.16
80	176.36	178.57	180.77	182.98	185.18	187.39	189.59	191.80	194.00	196.21
90	198.41	200.62	202.82	205.02	207.23	209.43	211.64	213.84	216.05	218.25
100	220.46	222.66	224.87	227.07	229.28	231.48	233.68	235.89	238.09	240.30

AVOIRDUPOIS OUNCES INTO GRAMMES.

Eng. Ozs.	0	1	2	3	4	5	6	7	8	9
	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
0	0.000	28.3495	56.6990	85.0485	113.398	141.747	170.097	198.446	226.796	255.145
10	283.495	311.844	340.194	368.543	396 893	425.242	453.592	481 941	510.291	538.640
20	566.990	595.339	623.689	652.038	680.388	708.737	737.087	765.436	793.786	822.135
30	850.485	878.834	907.184	935.533	963.883	992.232	1020.58	1048 93	1077.28	1105.63
40	1133.98	1162 32	1190.67	1219.02	1247.37	1275.72	1304.07	1332.42	1360.77	1389.12
50	1417.47	1445.82	1474.17	1502.52	1530.87	1559.22	1587.57	1615.92	1644.27	1672.62
60	1700.97	1729.31	1757.66	1786.01	1814.36	1842.71	1871.06	1899.41	1927.76	1956.11
70	1984.46	2012.81	2041.16	2069.51	2097.86	2126.21	2154.56	2182.91	2211.26	2239.61
80	2267.96	2296.30	2324.65	2353.00	2381.35	2409.70	2438.05	2466.40	2494.75	2523.10
90	2551.45	2579.80	2608.15	2636.50	2664.85	2693.20	2721.55	2749.90	2778.25	2806.60
100	2834.95	2863.29	2891.64	2919.99	2948.34	2976.69	3005.04	3033.39	3061.74	3090.09

TABLE XII.—Con.

GRAMMES INTO AVOIRDUPOIS OUNCES.

Grammes	0	1	2	3	4	5	6	7	8	9
	Oz.	Oz.	Oz.	Oz.	Oz.	Oz.	Oz.	Oz.	Oz.	Oz.
0	0.0000	0.03527	0.07054	0.10582	0.14100	0.17637	0.21164	0.24691	0.28219	0.31746
10	0.35274	0.38801	0.42328	0.45856	0.49383	0.52911	0.56438	0.59965	0.63493	0.67020
20	0.70548	0.74075	0 77602	0.81130	0 8465	0.88185	0.91712	0.95239	0.98767	1.02294
30	1.05822	1.09349	1.12876	1.16404	1.19931	1.23459	1.26986	1.30513	1.34041	1.37568
40	1.41096	1.44623	1.48150	1.51678	1.55205	1.58733	1.62260	1.65787	1.69315	1.72842
50	1.76370	1.79897	1.83424	1.86952	1 90479	1.940007	1.97534	2.01061	2.04589	2.08116
60	2.11644	2.15171	2.18691	2.22226	2.25753	2.29281	2.32808	2.36335	2.39863	2.43390
70	2 46918	2.50445	2.53972	2.57500	2.61027	2.64555	2.68082	2.71609	2.75137	2.78664
80	2.82192	2.85710	2.89246	2.92774	2.96301	2.99829	3.03356	3.06883	3 10411	3.13938
90	3.17466	3.20993	3.24520	3.28048	3.31575	3.35103	3.38630	3.42157	3.45685	3.49212
100	3.52740	3.56267	3.59794	3.63322	3.66849	3.70377	3.73904	3.77431	3.80959	3 84486

GALLONS INTO LITERS.

Gallons.	0	1	2	3	4	5	6	7	8	9
	Lit.	Lit.	Lit.	Lit.	Lit.	Lit.	Lit.	Lit.	Lit.	Lit.
0	0.0000	3.7854	7.57086	11.3562	15.1417	18.9271	22.7125	26.4980	30.2834	34.0688
10	37.8543	41.6397	45.4251	49.2105	52.9960	56.7814	60.5668	64.3523	68.1377	71.9231
20	75.7086	79.4940	83.2794	87.0648	90.8503	94.6357	98.4211	102.206	105.992	109.777
30	113.562	117.3483	121.133	124.919	128.704	132.490	136.275	140.060	143.846	147.631
40	151.417	155.202	158.988	162.773	166.558	170.344	174.129	177.915	181.700	185.486
50	189.271	193 056	196.842	200.627	204.413	208.198	211.984	215.769	219.554	223.340
60	227.125	230.911	234.696	238.482	242.267	246.052	249.838	253.623	257.409	261.194
70	264.980	268.765	272.550	276.336	280.121	283.907	287.692	291.478	295.263	299.048
80	302.834	306.619	310.405	314.190	317.976	321.761	325.546	329 332	333.117	336.903
90	340.688	344.464	348.249	352.034	355.830	359.615	363.401	367.186	370.972	374.757
100	378.543	382.328	386.113	389.899	393 684	397.470	401.255	405.041	408.826	412 611

LITERS INTO GALLONS.

Liters.	0	1	2	3	4	5	6	7	8	9
	Gal.	Gal.	Gal.	Gal.	Gal.	Gal.	Gal.	Gal.	Gal.	Gal.
0	0.0000	0.26417	0.52834	0.79251	1.05668	1.32085	1.58502	1.84919	2.11336	2.37753
10	2.64170	2.90587	3.17004	3.43421	3.69838	3.96255	4.22672	4.49089	4.75506	5.01923
20	5.28340	5.54757	5.81174	6.07591	6.34008	6.60425	6.86842	7.13259	7.39676	7.66093
30	7.92510	8.18927	8.45344	8.71761	8.98178	9.24595	9.51012	9.77429	10.0384	10.3026
40	10.5668	10.8309	11.0951	11.3593	11.6234	11.8876	12.1518	12.4159	12.6801	12.9443
50	13.2085	13.4726	13.7368	14.0010	14.2651	14.5293	14.7935	15.0576	15.3218	15.5860
60	15.8502	16.1143	16.3785	16.6427	16.9068	17.1710	17.4352	17.6993	17.9635	18.2277
70	18.4919	18.7560	19.0202	19.2844	19.5485	19.8127	20.0769	20.3410	20.6052	20.8694
80	21.1336	21.3977	21.6619	21.9261	22.1902	22.4544	22.7186	22.9827	23.2469	23.5111
90	23.7753	24.0394	24.3036	24.5678	24.8319	25.0961	25.3603	25.6244	25.8886	26.1528
100	26.4170	26.6811	26.9453	27.2095	27.4736	27.7377	28.0019	28.2660	28.5302	28.7944

FEET INTO METERS.

Feet.	0	1	2	3	4	5	6	7	8	9
	Met.	Met.	Met.	Met.	Met.	Met	Met.	Met.	Met.	Met.
0	0.000	0.30480	0.60960	0.91440	1.21920	1.52400	1.82880	2.13360	2.43840	2.74320
10	3.04801	3.35281	3.65761	3.96241	4.26721	4.57201	4.87681	5.18161	5.48641	5.791212
20	6.09602	6.40082	6.70562	7.01042	7.31522	7.62002	7.92482	8.22962	8.53442	8.83922
30	9.14403	9.44883	9.75363	10.0584	10.3632	10.6680	10.9728	11.2776	11.5824	11.8872
40	12.1920	12.4968	12.8016	13.1064	13.4112	13.7160	14.0208	14.3256	14.6304	15.9352
50	15.2400	15.5448	15.8496	16.1544	16.4592	16.7640	17.0688	17.3736	17.6784	17.9832
60	18.2880	18.5928	18.8976	19.2024	19.5072	19.8120	20.1168	20.4216	20.7264	21.0312
70	21.3360	21.6408	21.9456	22.2504	22.5552	22.8600	23.1648	23.4696	23.7744	24.0792
80	24.3840	24.6888	24.9936	25.2984	25.6032	25.9080	26.2128	26.5176	26.8224	27.1272
90	27.4320	27.7368	28.0416	28.3464	28.6512	28.9560	29.2608	29.5656	29.8704	30.1752
100	30.4801	30.7849	31.0897	31.3945	31.6993	32.0041	32.3089	32.6137	32.9185	33.2233

METERS TO FEET.

METERS.	0	1	2	3	4	5	6	7	8	9
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0	0.0000	3.28083	6.56166	9.84249	13.1233	16.4041	19.6849	22.9658	26.2466	29.5274
10	32.8083	36.0891	39 3699	42.6507	45.9316	49.2124	52.4932	55.7741	59.0549	62.3357
20	65.6166	68.8974	72.1782	75.4590	78.7399	82.0207	85.3015	88.5824	91.8632	95.1440
30	98.4249	101 705	104.986	108.267	111.548	114.829	118.109	121.390	124.67	127.95
40	131.233	134.514	137.794	141.075	144.356	147.637	150.918	154.199	157 479	160.760
50	164.041	167.322	170.603	173.883	177.164	180.445	183.726	187.007	190.288	193.568
60	196.849	200.130	203.411	206.692	209.973	213.253	216.534	219.815	223.096	226.377
70	229 658	232.938	236.219	239.500	242.781	246.062	249.343	252.623	255.904	259.185
80	262.466	265.747	269.028	272.308	275.589	278.870	282.151	285.432	288.713	291.993
90	295.274	298.555	301.836	305.117	308.398	311.678	314.959	318.240	321.521	324.802
100	328.083	331.363	334.644	337.925	341.206	344.487	347.767	351.048	354.329	357.610

INCHES INTO CENTIMETERS.

INCHES.	0	1	2	3	4	5	6	7	8	9
	Ct Mt.	Ct. Mt.	Ct. Mt.	Ct. Mt.	Ct. Mt.	Ct. Mt.	Ct. Mt.	Ct Mt.	Ct. Mt.	Ct Mt.
0	0.000	2.540	5.080	7.62	10.16	12.70	15.24	17.78	20 32	22.86
10	25.40	27.94	30.48	33.02	35.56	38.10	40.64	43.18	45.72	48.36
20	50.80	53.34	55.88	58 42	60.96	63.50	66.04	68.58	71.12	73.66
30	76.20	78.74	81.28	83.82	86.36	88 90	91.44	93.98	96.52	99.06
40	101.60	104.14	106.68	109.22	111.76	114.30	116.84	119.38	121.92	124.46
50	127.00	129.54	132.08	134 62	137.16	139.70	142.24	144.78	147.32	149.86
60	152.40	154.94	157.48	160.02	163 56	165.10	167 64	170.18	172.72	175.26
70	177.80	180.34	182.88	185.42	187.96	190.50	193.04	195.58	198.12	200.66
80	203.20	205.74	208.28	210.82	213.36	215.90	218.44	220 98	223.52	226.06
90	228.60	231.14	233.68	236.22	238 76	241.30	243 84	246.38	248.92	251 46
100	254.00	256.54	259.08	261.62	264.16	266.70	269.24	271.78	274 32	276.86

CENTIMETERS INTO INCHES.

Centimeters	0	1	2	3	4	5	6	7	8	9
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
0	0.0000	0.3937	0.7874	1.1811	1.5748	1.9685	2.3622	2.7559	3.1496	3.5433
10	3.9370	4.3307	4.7244	5.1181	5.5118	5 9055	6.2992	6.6929	7 0866	7 4803
20	7.8740	8.2677	8.6614	9.0551	9.4488	9.8425	10.2362	10.6299	11.0236	11.4173
30	11.8110	12.2047	12.5984	12.9921	13 3858	13.7795	14.1732	14.5669	14.9606	15.3543
40	15.7480	16.1417	16.5354	16.9291	17.3228	17.7165	18.1102	18.5039	18.8976	19.2913
50	19.6850	20.0787	20.4724	20.8661	21 2598	21.6535	22.0472	22 4409	22.8346	23.2283
60	23.6220	24.0157	24 4194	24.8131	25.2068	25.6005	25.9942	26.3879	26 7816	27.1753
70	27.5690	27.9627	28 3564	28.7401	29 1338	29.5275	29.9212	30.3149	30.7086	31.1023
80	31.4960	31.8897	32.2834	32.6771	33.0708	33.4645	33.8582	34.2519	34.6456	35.0393
90	35.4330	35.8267	36.2204	36.6141	37.0078	37.4015	37.7952	38.1889	38.5826	38.9763
100	39 3700	39.7637	40.1574	40.5511	40.9448	41.3385	41 7322	42.1259	42 5196	42.9133

SQUARE INCHES INTO CENTIMETERS.

In2.	0	1	2	3	4	5	6	7	8	9
	Cm2.	Cm2.	Cm2.	Cm2.	Cm2.	Cm2.	Cm2.	Cm2.	Cm2.	Cm2.
0	0.0000	6.452	12.904	19.356	25.808	32.260	38.712	45 164	51.616	58.068
10	64.520	70 972	77.424	83.876	90.328	96.780	103 232	109.684	116.136	122.588
20	129 040	135.492	141 944	148.396	154.848	161.300	167.752	174.204	180.656	187.108
30	193.560	200.012	206.464	212 916	219 368	225.820	232.272	238.724	245.176	251.628
40	258.080	264 532	270.984	277.436	283.888	290.340	296.792	303.244	309 696	316.148
50	322 600	329 052	335.504	341.956	348.408	354.860	361.312	367.764	374.216	380.668
60	387.120	393.572	400.024	406.476	412.928	419.380	425.832	432.284	438.736	445.188
70	451.640	458.092	464.544	470.996	477 448	483.900	490 352	496 804	503 256	509.708
80	516.160	522.612	529.064	535.516	541.968	548 420	554.872	561 324	567.776	574 228
90	580.680	587.132	593.584	600.036	606.488	612.940	619.392	625.844	632.296	638 748
100	645.200	651.652	658.104	664 556	671.008	677 460	683 912	690.364	696 816	703.268

TABLE XII.—CON.

SQUARE CENTIMETERS INTO SQUARE INCHES.

CM2.	0	1	2	3	4	5	6	7	8	9
	In2.	In2.	In2.	In2.	In2.	In2.	In2.	In2.	In2.	In2.
0	0.0000	0.1550	0.3100	0.4650	0.6200	0.7750	0.9300	1.0850	1.2400	1.3950
10	1.5500	1.7050	1.8600	2.0150	2.1700	2.3250	2.4800	2.6350	2.7900	2.9450
20	3.1000	3.2550	3.4100	3.5650	3.7200	3.8750	4.0300	4.1850	4.3400	4.4950
30	4.6500	4.8050	4.9600	5.1150	5.2700	5.4250	5.5800	5.7350	5.8990	6.0450
40	6.2000	6.3550	6.5100	6.6650	6.8200	6.9750	7.1300	7.2850	7.4400	7.5950
50	7.7500	7.9050	8.0600	8.2150	8.3700	8.5250	8 6800	8.8350	8.9900	9.1450
60	9.3000	9.4550	9.6100	9.7650	9.9200	10 075	10.230	10.385	10 540	10.695
70	10.850	11.005	11.160	11.315	11.470	11 625	11.780	11.935	12.090	12.245
80	12.400	12.555	12.710	12 865	13.020	13.175	13.330	13.485	13.640	13.795
90	13.950	14.105	14 260	14.415	14.570	14.725	14.880	15.035	15.190	15.345
100	15.500	15.655	15.810	15.965	16.120	16.275	16.430	16.585	16.740	16.895

CUBIC INCHES INTO CUBIC CENTIMETERS.

CNT. IN.	0	1	2	3	4	5	6	7	8	9
	Cm3	Cm3.	Cm3.	Cm3.	Cm3.	Cm3.	Cm3.	Cm3.	Cm3.	Cm3.
0	0 0000	16.387	32.774	49.161	65.548	81.935	98.322	114.709	131.096	147.483
10	163.870	180.257	196.644	213.031	229.418	245.805	262.192	278.579	294.966	311.353
20	327.740	344 127	360.514	376.901	393 288	409.675	426.062	442.449	458.836	475.223
30	491.610	507.997	524.384	540.771	557.158	573.545	589.932	606.319	622 706	639.093
40	655.480	671.867	688 254	704.641	721.028	737.415	753.802	770 189	786.576	802.963
50	819.350	835.737	852.124	868.511	884.898	901.285	917.672	934.059	950 446	966.833
60	983 220	999.607	1015.99	1032.38	1048.77	1065.16	1081.54	1097.93	1114.32	1130.70
70	1147.09	1163 48	1179.86	1196.25	1212.64	1229.03	1245.41	1261.80	1278.19	1294 57
80	1310.96	1327.35	1343.73	1360.12	1376.51	1392.90	1409.28	1425.67	1442.06	1458.44
90	1474.83	1491.22	1507.60	1523.99	1540.38	1556.77	1573.15	1589.54	1605.93	1622.31
100	1638.70	1655.09	1671.47	1687.86	1704.25	1720.64	1737.02	1753.41	1769 80	1786.18

TABLE XII.—Con.

CUBIC CENTIMETERS INTO CUBIC INCHES.

Cm3.	0	1	2	3	4	5	6	7	8	9
	In3.	In3.	In3	In3	In3.	In3.	In3.	In3.	In3.	In3.
0	0.0000	0.0610	0.1220	0.1830	0.2440	0.3050	0.3660	0.4270	0.4880	0.5490
10	0.6100	0.6710	0.7320	0.7930	0.8540	0.9150	0.9760	1.0370	1.0980	1.1590
20	1.2200	1.2810	1.3420	1.4030	1.4640	1.5250	1.5860	1.6470	1.7080	1.7690
30	1.8300	1.8910	1.9520	2.0130	2.0740	2.1350	2.1960	2.2570	2.3180	2.3790
40	2.4400	2.5010	2.5620	2.6230	2.6840	2.7450	2.8060	2.8670	2.9280	2.9890
50	3.0500	3.1110	3.1720	3.2330	3.2940	3.3555	3.4160	3.4770	3.5380	3.5990
60	3.6600	3.7210	3.7820	3.8430	3.9040	3.9650	4.0260	4.0870	4.1480	4.2090
70	4.2700	4.3310	4.3920	4.4530	4.5140	4.5750	4.6360	4.6970	4.7580	4.8190
80	4.8800	4.9410	5.0020	5.0630	5.1240	5.1850	5.2460	5.3070	5.3680	5.4290
90	5.4900	5.5510	5.6120	5.6730	5.7340	5.7950	5.8560	5.4170	5.9780	6.0390
100	6.1000	6.1610	6.222	6.2830	6.3440	6.4050	6.4660	6.5270	6.5880	6.6490

CUBIC CENTIMETERS INTO FLUID OUNCES.

Cm3.	0	1	2	3	4	5	6	7	8	9
	Fl. Ozs.	Fl. Ozs.	Fl. Ozs.	Fl. Ozs.	Fl. Ozs.	Fl. Ozs.	Fl. Ozs.	Fl. Ozs.	Fl. Ozs.	Fl. Ozs.
0	0.0000	0.0338	0.0676	0.1014	0.1352	0.1690	0.2028	0.2366	0.2704	0.3042
10	0.3380	0.3718	0.4056	0.4394	0.4732	0.5070	0.5408	0.5746	0.6084	0.6422
20	0.6760	0.7098	0.7436	0.7774	0.8112	0.8450	0.8788	0.9126	0.9464	0.9802
30	1.0140	1.0478	1.0816	1.1154	1.1492	1.1830	1.2168	1.2506	1.2844	1.3182
40	1.3520	1.3858	1.4196	1.4534	1.4872	1.5210	1.5548	1.5885	1.6224	1.6562
50	1.6900	1.7238	1.7576	1.7914	1.8252	1.8590	1.8928	1.9266	1.9604	1.9942
60	2.0280	2.0618	2.0956	2.1294	2.1632	2.1979	2.2308	2.2646	2.2984	2.3322
70	2.3660	2.3998	2.4336	2.4674	2.5012	2.5350	2.5688	2.6026	2.6364	2.6702
80	2.7040	2.7378	2.7716	2.8054	2.8392	2.8730	2.9068	2.9406	2.9744	3.0082
90	3.0420	3.0758	3.1096	3.1434	3.1772	3.2110	3.2448	3.2786	3.3124	3.3462
100	3.3800	3.4138	3.4476	3.4814	3.5152	3.5490	3.5828	3.6166	3.6504	3.6842

TABLE XII.—CON.

FLUID OUNCES INTO CUBIC CENTIMETERS.

FLUID OZ.	0	1	2	3	4	5	6	7	8	9
	Cm3.	Cm3.	Cm3.	Cm3.	Cm3	Cm3.	Cm3.	Cm3.	Cm3.	Cm3.
0	0.0000	29.5858	59.1716	88.7574	118.343	147.929	177.504	207.100	236.686	266.272
10	295.858	325.443	355.029	384.615	414.201	443.787	473.372	502.958	532.544	562.130
20	591.716	621.301	650.887	680.473	710 059	739.645	769.230	798.816	828.402	857.988
30	887.574	917.159	946.745	976.331	1005.92	1035.50	1065.09	1094.67	1124.26	1153.85
40	1183.43	1213.02	1242.60	1272.19	1301.78	1331.36	1360.95	1390.53	1420.12	1449.70
50	1479.29	1508.88	1538.46	1568.05	1597.63	1627.22	1656.80	1686.39	1715.98	1745.56
60	1775.15	1804.73	1834.32	1863.91	1893.49	1923.08	1952 66	1982.25	2011.83	2041.42
70	2071.01	2100.59	2130.18	2159.76	2189 35	2218.94	2248.52	2278.11	2307.69	2337.28
80	2366.86	2396.45	2426.04	2455.62	2485.21	2514.79	2544.38	2573.96	2603.55	2633.14
90	2662.72	2692.31	2721.89	2751.47	2781.07	2810.65	2840.24	2869.82	2899.41	2928.99
100	2958.58	2988.17	3017.75	3047.34	3076.92	3106.51	3136.09	3165.68	3195.27	3224.85

INDEX.

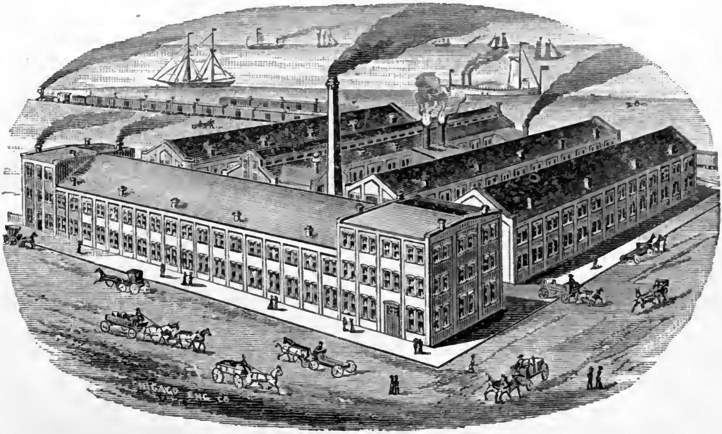
KEYSTONE

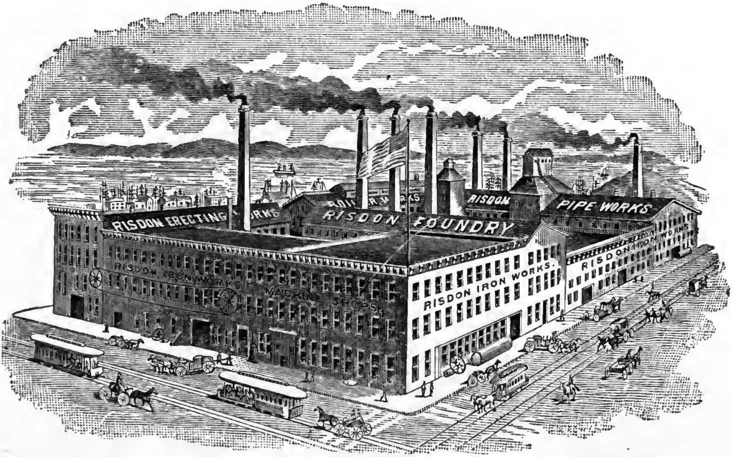
Saw, Tool, Steel and File Works

HENRY DISSTON & SONS

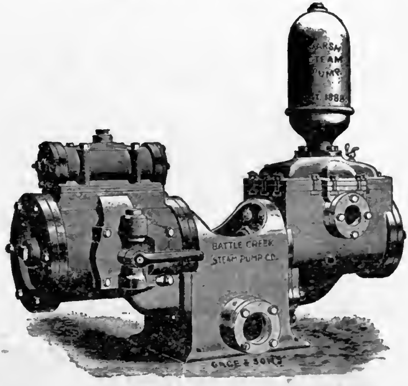
PHILADELPHIA, PENNA.

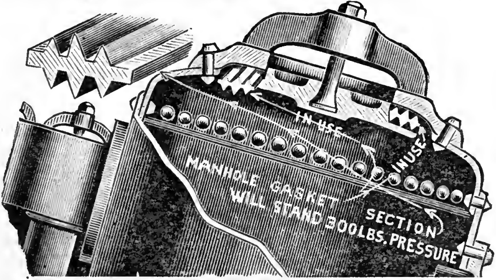
U. S. A.





RISDON ERECTING WORKS
BOILER WORKS
RISDON FOUNDRY
RISDON
PIPE WORKS
RISDON IRON WORKS
MACHINE SHOPS
RISDON IRON WORKS
RISDON IRON WORKS


MARSH STEAM PUMP
PAT. 1888
BATTLE CREEK STEAM PUMP CO.
GAGE & SONS


IN USE
IN USE
MANHOLE GASKET WILL STAND 300 LBS. PRESSURE
SECTION

The Audubon Sugar School,
Louisiana State University,
Agricultural and Mechanical College,

uccessfully conducted for several years by Dr. Wm. C. Stubbs at he Sugar Experiment Station, Audubon Park, New Orleans, has een removed to the University at Baton Rouge.

Dr. Stubbs, Professor of Agriculture in the University and irector of its Experiment Stations, will continue in charge of the ugar School, and conduct it on a more extensive scale.

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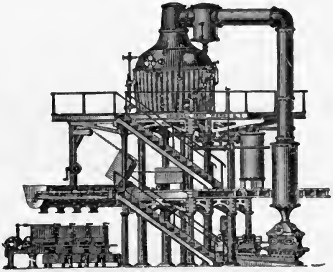

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