EVERY BREWER HIS OWN ANALYST.

A plain and brief Summary of

Reliable Chemical and other Practical Tests

Which are applicable to

ALL BREWING WATERS AND MATERIALS, TO WORTS AND TO BEER,

And which can be performed readily by every Brewer.

BY

J. A. NETTLETON,

AUTHOR OF "STUDY OF ORIGINAL GRAVITY;" "STUDY OF THE HISTORY AND ART OF BREWING."

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NOTICE.

THE purpose of this little book is to assist rather than to instruct brewers in testing for themselves the Quality of their Brewing Waters, the Quality of their various Brewing Materials, and the Quality—as to soundness and purity—of their Worts and Beers.

The book contains nearly seventy distinct tests. It explains the significance of the chemical and other tests as given; it explains also the worth or worthlessness, as the case may be, of a full or a partial chemical analysis of brewing waters. It suggests methods for improving the quality of brewing waters.

No previous knowledge is assumed nor required of chemical or of physical science.

British standard weights and measures and the ordinary Fahrenheit thermometer are adopted throughout, mainly for the sake of their homely simplicity, not because the metrical system and the Centigrade thermometer are depreciated.

The Author has endeavoured to express in the plainest and shortest manner possible the results of scientific study, so far as this has been applied to brewing subjects, feeling assured that such study will be much better appreciated when it is stripped somewhat of its technical garb and is adapted to ordinary routine experience.

In most cases the tests given are qualitative ones, though when found possible quantitative ones are also introduced. The intelligent operator will be able to modify or to extend the tests so as to suit his own special purpose.

It is not pretended—such pretence would be dishonest—that all the tests explained, especially so with the quantitative ones, will give precise accuracy, but for all practical purposes this claim is advanced.

Finally, the Author confidently looks for the cordial support of the Brewing Trade in this his endeavour; his previous works are well known and have been generously approved of.

J. A. NETTLETON,
Author of "Study of Original Gravity,"
AND OF
"Study of the History and Art of Brewing."

EAST GRINSTEAD,
SUSSEX.
October, 1884.

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EVERY BREWER HIS OWN ANALYST.

INTRODUCTORY.

PRECAUTIONS.

(1) *In Evaporating.*

In evaporating down or condensing over a flame or in a bath, always commence very carefully, with the vessel perfectly dry outside and with a low flame or a gentle heat.

Always end very carefully with a low flame, and thus avoid the spluttering of the liquid or the breaking of the evaporating vessel. When a dry deposit is to be ignited use the same precautions as to the heat.

A smokeless flame is directed to be used, this may be from a Bunsen or from an Argand gas burner, or from a spirit lamp. A sand or a water bath can be used instead in many cases.

When a pint or a half-pint of a liquid is directed to be evaporated in a beaker or in a porcelain basin, the whole of such liquid need not as a rule be placed in the vessel at one time, but only a portion of it, the rest being added as there is room for it.

(2) *In Filtering.*

When filtering a hot solution or anything hot through a glass funnel, have the funnel well warmed first, and so avoid breaking it. For the same reason the vessel into which the filtrate falls should be warmed.

Let the filter paper fit closely into the funnel.

Pour the liquid to be filtered into the filter very gradually, not suddenly or the filter paper is likely to burst, and pour the liquid down a glass rod which is held closely over the filter paper.

Wash the deposits on the filter paper with a little pure water, when such deposits or the filtrate from them is required. Collect these washings with the main body of the filtrate.

(3) *Acids.*

Keep all acids, strong or dilute, in glass-stoppered bottles. Get pure concentrated acids, and dilute a portion of each when a dilute acid is required with distilled water, and with several times the bulk of water to one bulk of acid.

(4) *Ammonia.*

Keep this, whether strong or dilute, in well-stoppered glass bottles, and in a cool place. Use distilled water for diluting, and in diluting any portion of strong ammonia use several times its bulk of water.

(5) *Sensitive Re-agents.*

These, whether dry or in solution, should be kept in a dark or a dull place. Such re-agents for instance as Nitrate of Silver, Solution of Iodine, Nessler's Solution. This latter should be colourless or nearly so.

PERSONAL PRECAUTIONS.

In using strong re-agents exercise great care. Spillings on the clothes or on carpets will often burn holes through them. Spilling will stain or will burn the fingers. In pouring strong re-agents from one vessel or tube into another keep the face at a respectful distance, especially so with strong ammonia. The same care must be used in pouring alkaline or basic solutions into acid ones. Sulphuric Acid wants special care in its use, for great heat is evolved when it mixes with water or with other liquids, therefore, always add this liquid to any other one very carefully and gradually, so as to avoid breakages. In mixing with water, pour Sulphuric Acid slowly into the water, not the water into the acid.

Keep every bottle distinctly marked with the name of its contents, and, if practicable, keep all re-agents locked up and in a cool place.

LIST OF CHEMICALS AND APPARATUS REQUIRED.

CHEMICALS.

NOTE.—The dry salts may be kept in the same state, but it is very convenient to have small quantities of each in solution, and in stoppered bottles.

Distilled water must be used in making the solutions.

Lead Acetate should be dissolved in water made acid by Acetic Acid.

Iodine is best kept dry. *See* Test for Starch in Sugar, Test No. 58.

Acids.—A few ounces of each of Acetic, Hydrochloric, Nitric, Sulphuric.

Salts, Bases, &c.—A few ounces of each by weight or measure, unless otherwise specified.

Ammonia (concentrated).
do. sp. g. 998.6.
Ammonic Acetate.
do. Carbonate.
do. Chloride.
do. Molybolate (¼ oz.)
do. Oxalate (1 oz.)
do. Sulphocyanide (1 oz.)
do. Sulphide.
Baric Chloride (1 oz.)
Ferrous Sulphate, $Fe.\ S.O_4$.
Iodine (1 oz.)
Lead Acetate.
Magnesic Sulphate.
Methylated Spirit.
Distilled Water (a few quarts).
Nessler's Solution.
Potash (Caustic).
Potassic Ferricyanide, $K_6.\ Fe_2.\ Cy_{12}$.
Potassic Permanganate.
do. Bichromate.
Silver Nitrate Solution or (Dry 1 oz.)
Sodic (Disodic) Phosphate.
do. Bicarbonate.
Sulphuretted Hydrogen.

For Test for Hardness:—

(1) Methylated Spirit (1 quart).
Castile Soap (¼ lb.)
or,
(2) Soap Test Solution, ready-made

For Quantitative Ammonia Test:—

Ammonic Chloride Solution (1 grain in 1 quart of water).

Apparatus, &c.

Bottles, stoppered for chemicals,
1 doz. 8 oz. capacity,
1 doz. 4 oz. capacity,
1 doz. 4 oz. capacity, with wide stoppers, 1 inch diameter.
Brushes, for cleaning tubes (2 or 3).
Basins, Porcelain (½ doz. assorted sizes).
Bunsen or Argand Gas Burner, with stand, or Spirit Lamp, with stand.
Crucibles, Porcelain (½ doz.)
Filter Stand.
do. Papers.
Funnels, glass (2 or 3).
Glass Rods, for stirring.
Glass (clear) Cylinders, 7 in. deep and about 6 oz. capacity (½ doz.)
Test Papers, Litmus, blue and red.
do. Tubes (1 or 2 doz., assorted sizes).
do. Tube Holder.
do. do. Stand.
Tubes, Glass, graduated for 1,000 grains (2).
Tubing, Glass, straight and bent.
do. India Rubber, for connections and for ends of stirring rods (12 inches)
Water Bottle, fitted up for Distilled Water.

Extra Apparatus, if all the Quantitative Tests are carried out.

Balance and Grain Weights.
Brewers' or a Specific Gravity Saccharometer.
Burette, graduated for 1,000 grains
Burette, graduated for Cubic Inches and tenths and hundredths.
Specific Gravity Bottle, 1,000 grains.
Platinum Wire (3 or 4 inches).

ALSO

Glass Retort, 3 pints capacity, Liebig Condenser, or other kind, Glass Cylinders, 7 inches high (½ doz.) and 6 ounce capacity,	For the Albuminoid Ammonia Quantitative Test.

AND

Microscope or Lens, for examination of Yeast, Mould and Disease Ferments.

PART I.

BREWING WATERS.

TESTS APPLICABLE TO BREWING WATERS.—SIGNIFICANCE AND VALUE OF THE VARIOUS TESTS.—INTERPRETATION OF THE RESULTS OF A CHEMICAL ANALYSIS OF WATER.—PREVIOUS SEWAGE CONTAMINATION OF WATER.—SIMPLIFICATION OF THIS EXPRESSION AND OF ITS INDICATIONS FOR BREWING PURPOSES.—STANDARDS OF PURITY OF WATER FOR BREWING PURPOSES.—SCHEME OF ANALYSIS FOR BREWING PURPOSES.—TABLE OF ANALYSIS OF VARIOUS WATERS.

Tests Nos. 1 to 3.—*To test the Specific Gravity of Water.* Three methods.

Test No. 1.—The first method. Take a pint of the water, bring it to a temperature of 60° F., place it in a glass sampling jar, and by means of a Saccharometer showing degrees of gravity read off the number of degrees and parts of the same as shown on the stem above the surface of the water. This number added to 1000 is the specific gravity.

Take care that no air bubbles adhere to the instrument either above or below water, any such bubbles must be shaken off. Prove the correctness of the reading by repeating the experiment with another sample of the water at the same temperature. In pure distilled water at 60° Fah. the Saccharometer should float at the water mark.

Test No. 2.—The second method. Take a Brewers' Saccharometer showing "pounds per barrel." Proceed exactly as in No. 1 Test, the water being at 60° F. Read very carefully the indications on the stem, multiply the number read by 2¾ to get degrees of gravity, and add these degrees to 1000 for the specific gravity.

Test No. 3.—The third method. The greatest accuracy can be secured by using a specific gravity bottle which holds at 60° F. exactly 1000 grains weight or measure of distilled water. A balance is required. The empty bottle, verified as correct, is exactly counterpoised, it is then filled with the water and weighed. The weight of this water is read off to a hundredth of a grain, and this weight corresponds to the specific gravity to a hundreth of a degree.

Significance and Value of the Tests for Specific Gravity.

The specific gravity of water does not indicate directly the weight of solid matters dissolved or suspended in it, but like the brewers' expression "pounds per barrel" the specific gravity indicates the excess weight over that possessed by a given weight of pure water. The excess weight is of course due to organic and mineral matter in the water. The effect of using water of a high specific gravity in advancing the gravity of the wort must not be over estimated. Much of the matter giving the additional matter to the water is thrown down in the heating, mashing and boiling operations, and only the comparatively small residue helps to swell the gravity of the wort. Besides this, in order to give pure water one additional degree, from 140 to 240 grains of the ordinary mineral and organic impurities might be present per gallon, not merely 70 as stated on page 122 of Mr. HOOPER's work on Brewing.

Test No. 4.—*To test for Acidity, Alkalinity or Neutrality in Water.*

Take a blue and a red litmus paper and place them side by side on a clean white surface. Then place, by means of a clean glass rod, two or three drops of the water on each test paper. Leave for a minute, then observe if any change of colour has occurred beneath the drops on either paper;—

If the blue paper has turned slightly red or pink, the water is acid;
If the red paper has turned slightly blue, the water is alkaline;
If neither paper has changed colour the water is neutral.

NOTE.—The special acid or alkali that has caused the change in colour can be tested for as shown in tests which follow.

Significance and Value of the Tests for Acidity and Alkalinity.

Natural waters sometimes contain free acid. The cause is usually from local strata circumstances well known in the particular neighbourhood; or pollution may be the cause. The free acids present in any case are usually Carbonic Acid Gas, or Sulphuretted Hydrogen. Of course acid derivatives exist in nearly all waters, but these are considered under the heading of the various salts built up. Foul waters from sewage pollution are usually acid.

Free alkalies or alkaline salts giving similar reactions to litmus paper occur at other times in natural waters, owing to contamination of one kind or another.

As a rule thorough boiling in an open vessel will remove all traces of either free acid or free alkali from a water. But water polluted by outputs from manufactories and giving either reaction cannot always be thus altered, as the acid or the alkali may be non-volatile. Filtration is the best remedy for these waters.

Test No. 5.—*To test the Stability or Keeping Qualities of Water.*

The very simple test to be described here is based upon the more elaborate one which M. PASTEUR has applied to wort and beer. It is a simplification of the Forcing Tray Process so popular with brewers. If malt, wort, and beer can be made to render such valuable indications of their future history, why cannot water, the purity of which is at least of equal importance with the other brewing materials, be also brought to account in the same manner? The forcing tray, so far as it is applied to an actual brewing—to the wort or beer from such—must often cast blame upon the mashing materials when these—the malt and the sugar—are quite pure enough, whilst the brewing water does the mischief. Of course, if malt is taken and treated with distilled water, the results from the forcing process can then be brought home to this material, but not so when in an actual brewing the wort or the beer is taken. The wort or the beer may justly be condemned, but why should the malt or the sugar be accordingly suspected, when perhaps the water is really the guilty party.

Applied to water, none of the intricate manipulation or delicate apparatus of the forcing tray is required; a water will be forced to tell its future history without any of this. M. PASTEUR has said in effect, that every unhealthy change in the quality of beer coincides with the development of microscopic germs, and that proofs of these existing or having existed can be found in the beer. The gist of these words can be applied to water. If a water is taken which appears clear to the eye, is inoffensive in any other way, and which even to microscopic examination reveals nothing unusual, if such water after a day or a few days gives very different indications, then probably some germ or growth—call it of disease—has developed itself in the water.

For the present purpose it matters not whether the water has been exposed or not to air, and although raw water might be taken, yet to give it every fair chance and to make the results comparable to those of an ordinary brewing, the water should be treated the same as it is treated in the brewing process. Proceed thus:—

Take a quart of the water and raise it gradually to a temperature of 170° F. in an open vessel, as if for mashing. When at this temperature, remove the source of heat and let the water rest, so that any sediment in it may settle, then pour off the water into another clean vessel leaving the sediment behind. Now boil the water, let the boiling be thorough for fifteen minutes, then let it cool and then pour about a pint of it into a clean white glass bottle, cool the water down quickly to 70° F. Now place the bottle of water on a tray or a bath, where it should remain for a day or two at the least at about the same temperature. Moderate exposure to air should be allowed, this being the case with beer that is working or cleansing. Most good waters thus treated will remain perfectly clear for many days, so will indifferent waters which have been efficiently filtered, and this too even when, as in the test for Phosphates, (Test No. 33), a little sugar has been added to the water. Other waters, according to their impurities, will sooner or later turn cloudy, and will develop various growths visible enough to the naked eye. A foul water will soon begin to smell offensively, and will show an acid reaction to blue litmus paper.

This test is a very simple one, but it proves in a practical manner the degree of stability of a water. It resembles the Sugar Test for Phosphates (Test No. 33). Its simplicity should not cause the test to be despised. It is sometimes necessary to defend a simple test, when a far more difficult but less accurate one would command respect.

Tests Nos. 6 to 8.—*To estimate the Total Solids per gallon of Water.* (A) *Total Solids.* (B) *and* (C) *Total Mineral and Organic Solids (approximately).*

Test No. 6.—*To estimate the Total Solids in Water.*

Take half a pint of the water and let it gradually—as there is room for it—into a convenient weighed vessel, such as a glass beaker or a porcelain basin. Evaporate the water down gradually over a smokeless flame. Apply the heat gradually at first and moderate it again towards the end, so that spluttering may be avoided. When dry and cool, weigh the vessel and its contents, deduct the weight of the vessel, the remainder is the total weight of solids in half-a-pint of the water, and this weight multiplied by 16 gives the total weight of solids per gallon.

Test No. 7.—*To estimate the Total Mineral Solids per gallon of Water (approximately).*

The total solids, including both organic and mineral matter, have just been estimated in the foregoing (Test No. 6). This dry matter, if not already in a porcelain or a platinum basin, must be carefully transferred to one, avoiding if possible any loss in such transference. Use if necessary the brush of a quill to complete the removal of the solid matter to the new vessel. Now place the dish or the basin over a Bunsen or an Argand burner, or over any smokeless flame. Apply heat very gradually at first, and again graduate it toward the end of the operation. The organic matter, in burning, turns black, the residue eventually turns grey. When this occurs, and after a good hour's burning, let the residue cool, then weigh. Deduct the weight of the vessel, the remainder is that of the total mineral matter from half-a-pint of the water, and therefore when multiplied by 16 the weight of it per gallon is known.

Test No. 8.—*To estimate the Total Organic Matter per gallon of Water (approximately).*

The weight of the organic matter in the half-pint of water taken is the difference between the weight of the total solids and of the mineral matter, as found in Tests No. 6 and 7 respectively. The weight of such matter in a gallon is found by multiplying this difference by 16.

Significance and Value of the tests for Total Solids and for Mineral and Organic Matter.

The value of a brewing water bears no relation to the quantity of solid matter per gallon, but rather it depends upon the quality of that matter.

Organic Matter.—This includes all animal and vegetable substances, living or dead, and also, generally speaking, all substances derived directly from these. It includes too all matter which cannot be regarded as merely earthy or mineral. The presence of organic matter in a brewing water is undesirable, to say nothing more, and this is the case regardless of the kind or of the source of such, for however harmless the matter may be in itself, yet it impairs the keeping and other qualities of the beer. Organic matter finds its way into water in many different ways—from the soil; from aqueous vegetable or animal life existing in streams, rivers, lakes, &c.; from various sources of pollution, such as the refuse from factories and from drains, and from many other sources. A water's quality can as a rule be judged by the total absence of or by the comparative absence or presence of organic matter. It is, however, hardly possible to get a water entirely free from organic matter, yet many deep well waters contain very little indeed of it.

There are many practicable ways of improving a water which contains much organic matter, if only these methods had fair play, but they are generally performed too hurriedly. Such methods are—efficient sand filtration, hardening processes, softening processes, treatment with Chloride of Lime, or all or any of these combined.

Mineral Matter.—More or less of this is always present in every natural water, and although the safest water for drinking purposes is one which contains the least possible amount of it, yet, for brewing purposes, the presence of a small or even of a large quantity of certain mineral salts is rather a point in its favour than otherwise, provided of course the mineral is unaccompanied by much organic matter. Thus the presence of a few grains per gallon of common Salt, of Sulphate of Lime, of Sulphate of Magnesia, of Carbonate of Magnesia, and of the Bicarbonate of Lime is regarded as beneficial to a brewing water, especially so for ale brewing.

Test No. 9.—*To test for Gases in Water.*

The gases usually tested for are only such as give some distinctive property to the water or accompany that property. They are not likely to be found in abnormal quantities except in mineral waters or in the foulest waters. The following gases may be mentioned as occasionally present in solution:—Ammonia, Carbonic Acid Gas, Sulphuretted Hydrogen, and Oxygen and Nitrogen from the Air.

For Ammonia, *see* Tests Nos. 10 to 15.
For Carbonic Acid, *see* Test No. 30.
For Sulphuretted Hydrogen, *see* Tests Nos. 23 to 25.

For Oxygen and Nitrogen from the Air.

Anyone wishing to estimate the quantities of these two gases in water will find the method briefly described and well illustrated in *Miller's Inorganic Chemistry*, under the heading "Natural Water." In performing the test it would be necessary first, to render the water distinctly alkaline with a little caustic potash, and thus absorb the Carbonic Acid or the other acid gases, and secondly, on boiling the water, the air evolved should be made to pass through a bulb of concentrated Sulphuric Acid or through a tube containing pumice stone moistened with this acid, and thus any Ammonia evolved would be absorbed. The air could then be collected and measured.

Usually a gallon of water will contain 6 or 7 cubic inches of Oxygen and Nitrogen in solution, and in each three volumes of these gases two are usually Nitrogen, the other one is Oxygen. The absence of these gases would be remarkable, and in the case of Oxygen would throw suspicion on the water. Special strata circumstances might explain the fact however, as many deep wells contain water very rich in Nitrogen but poor in Oxygen.

Tests Nos. 10 to 15.—*To test for Free Ammonia, for Salts of Ammonia and for so-called Albuminoid Ammonia in Water.*

Note.—Free Ammonia is such which exists merely in solution in water.

Salts of Ammonia, like free Ammonia, give the water an alkaline reaction. The usual salts are the chloride, the carbonate, the sulphate and the nitrate of ammonia.

Albuminoid Ammonia is merely an expression signifying that the water contains nitrogenous organic matter, which by the proper treatment is partly decomposed and then gives off ammonia. The production of ammonia under this treatment is therefore a proof that the water contains nitrogenous organic matter. The tests for and the significance of this Albuminoid Ammonia are given and considered under Tests Nos. 16 and 17, for Nitrogenous Organic Matter.

Test No. 10.—*To test for Free Ammonia and for Salts of Ammonia in Water.*

Place a drop or two of the water on a red litmus paper, the paper itself being placed on a white surface. Leave for a minute, then observe if the litmus paper has at the wetted parts turned faintly blue, if so, then Ammonia either free or as salts is probably present.

Test No. 11.—*To test for Free Ammonia and for Salts of Ammonia in Water.* (Tests continued).

Take a test tube 6 inches long and nearly fill it with some of the water, then add a drop or two of Nessler's Solution, shake up, and then leave for a minute. Stand the tube upon or by the side of something white, then notice if the water has turned in colour to a yellowish or a brownish tinge, if so, Ammonia is present either free or as salts.

Be careful that the Nessler's Solution is clear. The delicacy of the test and the kind of colour to be expected may be exemplified by taking a little pure water, adding to it a drop of weak ammonia solution, and then a drop of Nessler's Solution.

Test No. 12.—*To test for Free Ammonia and for Salts of Ammonia in Water.* (Tests continued). *For Free Ammonia only.*

Take about 250 grains measure of the water in a test tube, and gently heat the water over a flame, raising the temperature gradually to the boiling point. The presence of Free Ammonia will now be indicated in three different ways:—(1st) By a distinct ammoniacal smell at the mouth of the tube; (2nd) By the action of the ammoniacal vapours given off turning the colour of a piece of moistened red litmus paper, which is held a little way from the tube's mouth, to blue; (3rd) By the dense fumes which will be created when a glass rod moistened with dilute Hydrochloric Acid is held at the mouth of the tube.

Test No. 13.—*To test for Free Ammonia and for Salts of Ammonia in Water.* (Tests continued). *Salts of Ammonia alone.*

If the water contains no Free Ammonia, but yet contains—as is most likely—Salts of Ammonia, their presence may be proved by a continuation of the above test (Test No. 12). Take about 350 grains of the water in a test tube, and test first for Free Ammonia as in the above test. Let the water boil for a good five minutes. Then add to it a little of a solution of Caustic Potash, or a little Lime Water, till the water is distinctly alkaline to test paper. Now continue the boiling, testing the evolved vapours in the same three ways as directed in the test above (Test No. 12). The added alkali or the lime water will decompose the Ammonia Salts on boiling the liquid, and Ammonia will be given off

Test No. 14.—*To test for Free Ammonia and for Salts of Ammonia in Water.* (Tests continued).

When the water contains only small quantities of Ammonia or of its Salts, the following test may be used to deduce the presence of the same:—

Place a quart of the water in a glass still, apply heat gently by means of an Argand burner, raising the water gradually to boiling point. Have the still perfectly dry outside and have a condenser attached to it. At the end of the still place a clear glass cylinder about 7 inches deep, and containing a little distilled water, so that the end of the still can just dip below water in this glass, and thus none of the evolved ammonia will escape. As soon as the water begins to boil, the three simple indications given in Test No. 12 may be looked for at the end of the still, and the distilled water as it collects in the glass cylinder, will, if ammonia is present, turn a red litmus paper to blue. Besides these tests the main one must be carried out. The distilled water gradually collects in the cylinder, and when the water has reached the height of 5 or 6 inches, the cylinder is replaced by another one, containing just sufficient pure water to cover the end of the still which dips into the cylinder. Now place the first cylinder on a white surface, add a drop or two of Nessler's Solution, leave for a minute after stirring, and then look for the usual brown or yellow colour. Successive cylinders are similarly treated, and the more ammonia there is given off the deeper will be the brown colour on the addition of Nessler's Solution. If, however, no colour is produced in the first cylinder, then the original water contains no Free Ammonia, but it may yet contain Salts of Ammonia. To decompose these and to prove their presence either alone or in addition to Free Ammonia, add to the water in the still, which water has now been boiling for some time, a little of a solution of Caustic Potash, making the water distinctly alkaline. Then continue the distillation, testing the distillate as it is collected in the cylinders by Nessler's Solution, and applying the three simple tests described under Test No. 12.

Test No. 15.—*To test for Free Ammonia and for Salts of Ammonia in Water.* (Tests continued).

Quantitative Test, showing total weight of Ammonia existing free and as salts. This test is built up from the foregoing one, No. 14.

Take a quart of the water, make it strongly alkaline by adding a little Caustic Potash solution, and place the whole in a glass still over an Argand burner and attached to a condenser. Let the still be dry outside, then apply heat gradually and raise the water's temperature to the boiling point. Let boiling continue till about half the water has distilled over, namely one pint, collecting this distillate in four glass cylinders, five ounces in each. The cylinders are made of clear glass and are of such a shape that the five ounces of water in each occupies a stratum 6 or 7 inches deep. The end of the still just dips under a little pure water placed in each cylinder. When ready, replace the first cylinder by another, and to the distillate in the first add 10 grains measure of Nessler's Solution, if after a time and a little stirring the water turns brownish, continue the distillation till four cylinders have each collected five ounces of the distillate. These four cylinders, filled to the same height, are ranged in order from No. 1 to No. 4, placed on a clean white surface, and each one as its contents are collected is treated with 10 grains measure of Nessler's Solution, which solution must be gently stirred up in the water. Very little Ammonia will now be left behind in the still, and such as there is left may be ignored.

Previous to this distillation a standard solution of Ammonia Chloride must be prepared as follows, or it may be bought ready made:—

One grain of pure dry Ammonic Chloride is dissolved in distilled water, the bulk being made up to one quart exactly. As each 53½ parts of this Salt contains 17 of Ammonia, therefore each cubic inch of the solution of the salt contains ·0046 grain of Ammonia.

To find then the weight of Ammonia which existed free and as salts in the quart of water taken, four more glass cylinders are required, and they may be marked No. 1a to No. 4a. Into each of these place 10 grains measure of Nessler's Solution, and then about two ounces of pure distilled water. Some of the prepared Standard Solution is placed in a burette which shows cubic inches, tenths and hundredths of the same. From the burette the solution is now let very gradually into No. 1a cylinder, stirring the contents in the latter by means of a glass rod all the time. Continue adding till the brown colour produced is of the same intensity as the colour in No. 1 cylinder. This similarity in colour is tested by placing the two cylinders side by side on a white surface. No. 2a cylinder is then compared with No. 2, and so on, the total quantity of the Ammonia Chloride Solution used is then read off. This comparison experiment can easily be repeated with another series of four cylinders, keeping of course the first series containing the water under treatment for this purpose. Say that in testing a foul water 20½ cubic inches of the Standard Solution were used so as to bring the colour in the second series of cylinders to the same intensity as that in the first series, namely, 8½ cubic inches for No. 1a cylinder, 6 for No. 2a, 4 for No. 3a, and 2 for No. 4a. As each cubic inch of the Ammonic Chloride Solution contains virtually ·0046 grain of Ammonia, therefore in the quart of water taken there was either free or as salts, Ammonia amounting to ·0046 grain multiplied by 20½, that is ·0943 grain. Therefore in a gallon there would be ·0943 multiplied by 4, that is ·3772 grain.

Note.—If the Ammonic Chloride Solution be found too strong in testing any particular water, it can be diminished in strength to one-half or to one-tenth by diluting a certain bulk of it with distilled water, and making the resulting volume to just twice or ten times that of the original volume taken. In such a case the results in calculating must be similarly reduced.

Significance and Value of the Tests for Ammonia, free or as salts.

In judging the fitness of a water, either for drinking or for brewing, the Ammonia tests are of primary importance, especially when considered along with those for Organic Matter. If Ammonia is found in any considerable quantity, either free or as salts, the water is liable to suspicion, for the usual argument from the presence of such is contamination by sewage, either actual or recent. Sewage contains per gallon, Ammonia, varying according to the dilution of the sewage, from 2 to 20 or 30 grains; the average quantity is about 5 grains per gallon. The nearer the quantity of Ammonia in a water approaches this amount the worse such water is.

Very small quantities of Ammonia existing in wate need not render it suspicious. *See* Table of Analysis of Water, page 49.

Tests Nos. 16 and 17.—*To test for Nitrogenous Organic Matter in Water.*

Test No. 16.—*The so-called Albuminoid Ammonia Test.*

Take a quart of the water, make it strongly alkaline with a little of a solution of Caustic Potash, and then evaporate the water down in a glass breaker or other open vessel, and over a smokeless flame, to one-half its original bulk. Then place the remaining bulk—one pint—in a glass still, connected with a condenser and placed over an Argand burner. Add to the water a solution of Potassic Permanganate, (about 1 grain weight of the salt in 1 ounce of pure water), then distil over, collecting the distillate in a clear glass cylinder 6 or 7 inches high, and capable of holding about 6 ounces of water. The end of the still must dip just under a little pure water placed in this cylinder.

Or commence thus:—Place the quart of water direct into the still, add the Caustic Potash solution, and distil over, collecting four successive lots of 5 ounces each in as many cylinders of the size and kind mentioned above. Tests No. 14 and 15 can now be applied to the contents of these four cylinders. The original water being thus reduced to half its bulk, and freed from the Ammonia, is now treated with the ounce of Potassic Permanganate solution mentioned above, and the distillate is collected in two or three successive cylinders. This second distillate is now tested for Ammonia by adding to each cylinder containing the distillate a few drops of Nessler's Solution, and stirring up. Any Ammonia now found may be assumed to have been formed by the decomposition of the Nitrogenous Organic Matter in the water, the Potassic Permanganate having caused this to take place. The cylinders should in each case be filled to the height of 5 or 6 inches, and should then be placed on a white surface. The brown colour is looked for a short time after the addition of the Nessler's Solution.

NOTE.—This test forms part of Professor Wanklyn's method of Water Analysis, but as without much experience it will not permit of a quantitative interpretation, only a qualitative test is described here. Care should be taken that all Ammonia present, either in the free state or as salts, has been brought over or got rid of during the first distillation or the boiling with the Caustic Potash. If on testing the first distillate very little colouring occurs towards the end, but on testing the second (distilled with the Potassic Permanganate) the brown colour again appears, the increase may be ascribed to the decomposition of Nitrogenous Organic Matter.

Test No. 17.—*To test for Nitrogenous Organic Matter in Water.* (Tests continued).

The three simple observations described in Test No. 12 can be applied here. After a quart of the water has been treated with the Caustic Potash solution, and the Ammonias driven off, the Permanganate solution is added, as shown in the foregoing test, No. 16. At the end of the still the three simple observations can now be made.

Note.—Other tests for Organic Nitrogenous Matter are Dr. Frankland's Combustion Process, and other combustion processes.

Significance and Value of the Tests for Nitrogenous Organic Matter.

Perhaps no tests in water analysis require more caution in interpreting their value than these do. By whatever method the existence of Nitrogenous Organic Matter is proved, it is certain that water containing it must be regarded suspiciously. For drinking purposes, if the origin of this Nitrogenous Matter can be traced to vegetable matter, such as peat, leaves of trees, &c., then its existence may be harmless, a good filter is all that is required. For brewing, however, the presence of Nitrogenous Matter is objectionable, from whatever source it may come, though of course animal contamination is worse than vegetable. Unless strong reasons to the contrary exist, Nitrogenous Organic Matter must be assumed to result from animal contamination, and if it is present in any considerable quantity (*see* Table of Analysis, page 49) then the existence of not only previous but of actual sewage contamination is argued.

Ordinary sewage, besides the Nitrogen present in Ammonia and its salts, and in Nitrates, contains also sufficient Nitrogenous Matter to yield from 1½ to 3 grains of Nitrogen per gallon, so that the nearer a water approaches this condition the worse it is.

Brewers, in accepting an analytical report upon their brewing water, should devote special attention to, and should even regard with the greatest suspicion, any reference to the amount of Nitrogen existing in the organic matter, or to the amount of Ammonia derived from the so-called Albuminoids. Nothing in water analysis is so unsatisfactory either to the analyst or the brewer as this item of Nitrogenous Organic Matter, yet nothing in it is of so much importance. Unfortunately, it must be added, nothing is so difficult to determine as this item. Without mentioning the usual combustion methods, there are two methods in vogue for determining the quantity of Nitrogenous Organic Matter, namely:—

1st.—Dr. Frankland's Combustion Process.
2nd.—Professor Wanklyn's Albuminoid Ammonia Process.

The first, Dr. Frankland's, will in skilful hands give most accurate results. The process is most admirable, but at the same time it is very elaborate and difficult. Being comparatively a new process, and involving the use of expensive apparatus and requiring a special study of its own, it is seldom used except by a few—very few—of the first-rate analysts.

The second, Professor Wanklyn's process, is older than the first, is comparatively easy to learn and to work, and involves only simple calculations and but little apparatus. It is used very largely, but unfortunately it is regarded by the best authorities as less reliable than the first process. Between any two waters of similar history this second process can—when other analytical points are properly considered—permit a sound comparison to be made, but in dealing with any particular water it is doubtful whether the amount of Organic Nitrogenous Matter deductively estimated by this process will approach within a large margin of the truth. Although this process would never condemn an innocent water it might fail to condemn a guilty one. This process being the usual one adopted, a brewer who relies upon the report in respect to the amount of Nitrogenous Organic Matter in his brewing water ought to be aware whether this process has been used in his case, otherwise he may be lulled into a false security. As a qualitative test, however, the process is valuable.

Test No. 18.—*To test for Nitrates and Nitrites in Water.*

Take a pint of the water and evaporate it down in a glass beaker or in a porcelain basin, over a smokeless flame, to one-fifth its bulk. Let cool, stir up any deposit there may be, and then filter through a filter paper placed in a glass funnel. Take a small portion of the filtrate, about 150 grains measure, in a test tube, and add to it nearly its own bulk of pure concentrated Sulphuric Acid, letting this acid into the test tube very slowly, pouring it down the side of the tube, which should be held horizontally. Most of the acid will thus pass right down, and will form a layer distinctly visible at the bottom of the tube. The acid must be let in slowly to avoid as far as possible an increase of heat. Cool the tube and its contents now, by placing the tube in a little cold water. Whilst this cooling is going on, take a very small portion—two or three crystals—of common Iron Sulphate $Fe.\ S.O._4$ and dissolve it in 200 grains of pure distilled water in a test tube. If clear, this solution is fit for use, if not clear, filter it through a filter paper, collecting the filtrate in another test tube. Now pour about 100 grains of this Iron Solution gently down the side of the tube which contains the acid and the water. As some heat is again evolved, let the whole mixture cool again in some cold water, and let the tube and its contents remain quite still for two minutes. Then observe if a black ring, more or less clearly defined, is forming just above the bottom layer—the concentrated acid—if so, the presence of nitrates in the original water is proved. If, however, after waiting two minutes, no black ring nor dark colouring is visible, move the tube gently up and down two or three times from the perpendicular to the horizontal, then let it stand again. Sometimes this motion will instantly cause the black ring or the dark colouring to appear, to appear that is, just above the layer of Sulphuric Acid. This test requires very careful manipulation, and it is sometimes necessary to repeat the experiment two or three times with separate portions of 150 each of the evaporated and filtered water.

To aid the operator, the following simple experiment is recommended:—Take 200 grains measure of pure distilled water in a test tube, dissolve in it a very small portion of any nitrate, say of Potassic Nitrate, then add, with all the precautions pointed out above, nearly its own bulk of concentrated Sulphuric Acid, and to this, when cool, a little of the Ferrous Sulphate solution, and proceed exactly as in the test just given. Unless the operator has made some blunder, a black ring will soon form when the test tube and its contents are allowed to cool. The operator will know what to look for in any future experiment. If the ring does not appear, move the tube as directed above.

Note.—For other valuable qualitative and quantitative tests for Nitrates and Nitrites, *see*

(1) Dr. Frankland's Water Analysis. Mercury and Sulphuric Acid Process.

(2) The Indigo Process.

These two tests are too difficult to be recommended here, but are most useful to professional analysts.

Significance and Value of the Test for Nitrates and Nitrites.

The presence of nitrates and nitrites in water, in any but the smallest quantities, argues the previous contamination of such water with either animal or vegetable matter. The best authorities agree, however, that for drinking purposes, a water even when rich in nitrates is often preferable to a water from which they are absent, but which yet shows all other indications of contamination. If water is rich in nitrates but free, or comparatively so, from all other accompaniments of pollution, such as Organic Matter, Ammonia and Phosphates, then it may be a good drinking water, but if the nitrates accompany these other signs of pollution, then the water is a bad one. A deep well or spring water is thus often rich in nitrates but almost free from organic matter and from ammonia, and in such a case, and in others, the nitrates, if alone, may be quoted as a point in favour of the water, at least for drinking. For brewing purposes, however, another consideration arises. It is alleged that nitrates have a bad effect upon the yeast, and therefore upon the fermentation. The beer's keeping qualities are also said to suffer by the presence of nitrates in the brewing water.

Tests Nos. 19 to 22.—*To test for Sulphates and Sulphites in Water.*

(A) *Sulphates and Sulphites generally.*

(B) *do. do. of Lime.*

(C) *do. do. of Magnesia and of the Alkalies (Soda, Potash and Ammonia).*

Test No. 19.—*To test for Sulphates and Sulphites in Water (generally).*

Take about 200 grains measure of the water in a test tube, acidify it slightly with a few drops of Hydrochloric Acid, shake it up a little and gently warm it. Then add a drop or two of a clear solution of Baric Chloride in pure water. In a few seconds, if any Sulphates or Sulphites are present, the water will turn cloudy, and eventually a deposit of Baric Sulphate will occur.

Test No. 20.—*To test for Sulphates and Sulphites generally.* (Tests continued).

If the above test (No. 19) gives only a doubtful indication of Sulphates, take a pint of the water, acidify it slightly with Hydrochloric Acid, and then evaporate it down in an open vessel, over a smokeless flame, to one-fourth its bulk. Take a little of this concentrated solution, keep it acid with Hydrochloric Acid, and complete the experiment as in Test No. 19.

Test No. 21.—*To test for Sulphates and Sulphites of Magnesia and of the Alkalies (Soda, Potash and Ammonia) in Water.*

Take a pint of the water and evaporate it down in a glass beaker or in a porcelain basin, and over a smokeless flame, to at lesast one-tenth its bulk, namely, to 2 ounces. No spluttering must be allowed to occur. Stir up any deposit there may be and, whilst hot, filter through a filter placed in a warm glass funnel, collect the filtrate also in a warm vessel; little chance is thus given for any Sulphate of Lime to pass through with the filtrate. Of the filtrate take about 200 grains in a test tube, acidify this slightly with Hydrochloric Acid, stir or shake up the water slightly, and then add a few drops of a clear Baric Chloride solution. If after a few seconds a cloudiness forms, followed by a white precipitate, then Magnesic or Alkaline Sulphates or Sulphites are present. If no Magnesic Salts are present (*see* Tests Nos. 39 and 40) then these sulphates just found are alkaline ones.

Test No. 22.—*To test for Sulphates and Sulphites in Water. Quantitative Test for total of these salts.*

Take a quarter of a pint of the water in a glass beaker, acidify it slightly with a few drops of Hydrochloric Acid, and warm the water till it nearly boils. Then add a few drops of a clear solution of Baric Chloride in pure water, and stir this up with the acidified water in the beaker. Place the beaker containing the mixture in some hot water, and, when the water in this beaker is clear, add a little more of the Baric Chloride solution, gently stirring at the time. When clear again, filter the liquid through a filter paper placed in a glass funnel. Test a small portion of the filtrate, which should be distinctly acid, by adding a little more of the Baric Chloride solution to it, if it remains clear for a minute then all the filtrate may be thrown away, but if it does not, then the whole of the filtrate must be treated with a little more of the Baric Chloride. This filtrate must then be allowed to clear itself and then filtered again through the same filter paper. This done, wash the deposit on the filter paper by pouring a little warm distilled water on to it, letting these washings filter throngh. Now remove carefully the whole of the deposit into a small weighed porcelain basin, place the basin in a sand bath or over a smokeless flame, and so dry the matter contained in it. When the matter is quite dry, turn on the flame a bit so as to burn off any organic matter which may be with the Baric Sulphate. Then let cool and weigh, deduct the weight of the basin, the remainder is the weight of the Baric Sulphate. Multiply this by ·42, and so get the corresponding weight of Sulphuric Acid which existed as salts in the quarter-pint of water taken. If this weight is multiplied by 32 the weight of acid per gallon is known.

Significance and Value of the Tests for Sulphates and Sulphites.

It is a very rare thing to meet with a natural water entirely free from these salts. The best drinking waters contain them, the worst do so too; whilst for brewing the most esteemed waters contain Sulphates in large quantities. The test for Sulphates, then, does not alone allow us to judge of the brewing value of a water, but when other tests are considered along with that for Sulphates, a far better opinion can be formed. The soil or the strata through which the water has passed must first be considered. A deep well water or a spring water rich in Sulphates will most likely be very pure in respect to organic matter and ammonia, but it will also very likely be rich in nitrates and chlorides. It would be a first-rate brewing water, (leaving the presence of nitrates out of the question), it would be a hard—a permanently hard—and valuable water. But a shallow well water or a river water rich in Sulphates and also containing organic matter, ammonia and chlorides, would very likely be a contaminated and dangerous water. It appears then, that for brewing, a good water is all the better for the presence of Sulphates, whilst with a bad water these salts still further condemn it.

Tests Nos. 23 to 25.—*To test for Sulphides and for Sulphuretted Hydrogen in Water.*

Test No. 23.—Take half a pint of the water in a glass beaker or in a porcelain basin and evaporate down, over a a smokeless flame, to one-fourth of its bulk. Stir up any deposit there may be, and then take about 200 grains measure of the water in a test tube, acidify it slightly with a few drops of Nitric Acid, stir up again, and then add a few drops of a clear solution of Lead Acetate. This solution is made by placing a little of the dry acetate in some pure water, and adding to it Acetic Acid until the lead salt dissolves. If, on adding the Lead Acetate solution to the water under treatment in the test tube, a black colouring and eventually a black precipitate occurs, then the original water contains Sulphides.

Test No. 24.—*Test for Sulphides in Water* (continued).

(1) Take half a pint of the water and evaporate it down in a glass beaker to one-fourth its bulk. Then, whilst hot, add some strong Hydrochloric Acid to the water, making the latter distinctly acid, and at the sams time cover the top of the beaker tightly with a filter paper which is moistened and saturated with a solution of Lead Acetate. Now continue the heating gently, and observe whether the steam and gases given off, and which impinge against the inner side of the filter paper, gradually turn the paper black, if so, Sulphuretted Hydrogen is the cause of it, and the original water contains Sulphides.

(2) Evaporate half a pint of the water down as directed above, sub-test (1). Stir up any deposit and place about 300 grains of the liquid in a test tube, add to it a few drops of strong Hydrochloric Acid till it is strongly acid, and place a tight-fitting cork in the top of the test tube. The cork has a piece of glass tubing leading out of it, the tubing is bent over so that it may reach nearly to the bottom of a second test tube. In the first tube the tubing must not penetrate below the cork, but in the second, which is half filled with a solution of Lead Acetate, the tubing must reach well below the surface of this. Now gently heat the acidulated water in the first test tube, bringing the temperature to the boiling point. Watch the action of the evolved steam and gases upon the Lead Acetate solution in the second test tube, if this solution turns black, then the original water contains Sulphides.

Test No. 25.—*To test for free Sulphuretted Hydrogen in Water.*

(1) As this is an acid, a few drops of the water placed on a litmus paper should give the reaction shown in Test No. 4, for free acids. If the reaction does not occur it is no use proceeding further.

(2) Water containing free Sulphuretted Hydrogen will probably have a most offensive smell.

(3) Place 300 grains of the water in a test tube, do not acidify but adjust the cork as directed in Test No. 24. If a blackening occurs on carrying out the Test No. 24, then the water contains free Sulphuretted Hydrogen.

Significance and Value of the Tests for Sulphides and for Sulphuretted Hydrogen.

The presence of either Sulphides or of Sulphuretted Hydrogen in water is an indication of either mineral or of animal contamination, but in judging the purity of a water containing Sulphides or the free gas, regard must be had to the amount of accompanying organic matter and ammonia. Sometimes Sulphides and Sulphuretted Hydrogen exist in waters which are organically pure but are rich in mineral matter. These waters are known as mineral or as sulphurous waters, and are usually much appreciated in certain localities.

Tests No. 26 to 30.—*To test for Carbonates, Bicarbonates and Carbonic Acid in Water.*

(A) *Carbonates and Bicarbonates generally.*

(B) *Bicarbonate of Lime.*

(C) *Carbonates and Bicarbonates of Magnesia and the Alkalies.*

(D) *Free Carbonic Acid.*

Test No. 26.—*To test for Carbonates and Bicarbonates generally.*

Take 300 grains measure of the water in a test tube and add to it a few drops of clear Lime Water. A white cloudiness, followed soon by a white precipitate in the water, proves the presence of Bicarbonate of Lime or of other carbonates or bicarbonates in the water.

Test No. 27.—*To test for Carbonates and Bicarbonates generally.*

Take 300 grains measure of the water in a test tube which is well fitted with a cork. Through this cork a small funnel penetrates which dips below the surface of the water, a piece of glass tubing also penetrates the cork but does not enter the water. The outer end of this glass tubing is bent over so as to reach nearly to the bottom of the second test tube containing Lime Water. Now pour a little dilute Hydrochloric Acid through the funnel into the first test tube. If any gas which may now pass over through the tubing into the test tube containing the Lime Water makes the latter appear cloudy and eventually produces therein a white precipitate, whilst at the same time an effervescence is noticed in the first test tube, then the original water contains Carbonates or Bicarbonates.

Test No. 28.—*To test for Bicarbonate of Lime in Water.*

(1) Take quarter of a pint of the water in a glass beaker and gently heat it over a smokeless flame, and let the water boil for five minutes. Then let the water cool and rest. This done, gently pour away the clear water, or nearly all of it, leaving any precipitate behind. If this is white, and if on adding a drop or two of dilute Hydrochloric Acid to it an effervescence occurs, then the original water contains Bicarbonate of Lime. Again the deposit alluded to should dissolve when a few drops of Acetic Acid are added to it, but a deposit will again occur when to this solution a few drops of Ammonic Oxalate solution are added.

(2) The number of grains of Bicarbonate of Lime per gallon, calculated as carbonates, may be known by testing the water for Temporary Hardness. In this case the number of grains per gallon and the number of degrees of temporary hardness per gallon are the same. *See* Test No. 46 (c).

Test No. 29.—*To test for Magnesic and for Alkaline (Sodic, Potassic and Ammonic) Carbonates and Bicarbonates in Water.*

(1) Take half a pint of the water and evaporate it down in an open vessel, and over a smokeless flame, to one-fourth its bulk, stir up any deposit there may be and filter through a filter paper. Take 300 grains measure of the filtrate in a test tube, which tube is fitted with a cork and its appendages as described in Test No. 27. The dilute Hydrochloric is added as directed in that test. Any cloudiness which is now formed in the Lime Water proves the presence in the original water of Magnesic or Alkaline Carbonates or Bicarbonates. The effervescence should also occur in the tube containing the 300 grains of water.

(2) Proceed exactly as in the above sub-test (1) until the 300 grains of the filtrate are taken, and then, instead of adding acid through a funnel in a cork, merely add a few drops of clear Lime Water to the water in the test tube. A white cloudiness followed by a precipitate proves the presence of Magnesic or of Alkaline Carbonates or Bicarbonates in the water. The precipitate or deposit should behave like the deposit described at the end of Test No. 28, sub-test (1).

(3) In the absence of Magnesic Salts from the water (*See* Test No. 39, for Magnesic Salts) both the above sub-tests (1) and (2) prove the presence of Alkaline Carbonates or Bicarbonates in the water.

Test No. 30.—*To test for Free Carbonic Acid in Water.*

(1) As Carbonic Acid has an acid reaction, Test No. 4, for Free Acids, should first be applied.

(2) Take about half a pint of the water in a glass beaker and add to it two or three drops—not more—of clear Lime Water. If a cloudiness is formed at first, but on gently stirring the water this cloudiness disappears and no precipitate takes place, then Free Carbonic Acid is present. Try the water with a little more Lime Water, until the cloudiness no longer disappears on stirring.

Significance and Value of the Tests for Carbonates, Bicarbonates and Free Carbonic Acid.

The most esteemed brewing waters are not only rich in Sulphate of

Lime but usually a considerable amount of Bicarbonate of Lime is also present. Temporary hardness in water is due exclusively to the presence of Bicarbonate of Lime. Water of this kind, rich in Bicarbonate of Lime, is usually derived from deep chalk wells, or it runs over limestone. Though rich also in nitrates, perhaps, the water is usually very pure, very free from organic matter and from ammonia.

Shallow well water and river water, especially when impure, usually contains a considerable amount of Carbonates, aud sometimes they contain free Carbonic Acid. Organic impurity and ammonia, with other indications of pollution, usually accompany the Carbonates in these waters.

Tests Nos. 31 to 33.—*To test for Phosphates in Water.*

Test No. 31.—Take a pint of the water in a glass beaker or in a porcelain basin, make it slightly acid with a few drops of Nitric Acid, and then evaporate it down over a smokeless flame to at least one-fifth its bulk. Then remove the containing vessel, stir up any deposit there may be, and then take 300 grains measure of the water in a test tube, and make it distinctly acid with Nitric Acid. Now add to this acidified water a few drops of a clear solution of Ammonic or Potassic Molybdate, shake up together the contents of the tube, and gently heat the same over a flame or in some hot water for five minutes. If any Phosphates are present, the water will soon turn a yellow colour, and eventually a beautiful canary-colour deposit will settle.

Test No. 32.—*Tests for Phosphates in Water* (continued).

Take a pint of the water in a glass beaker or in a porcelain vessel, dissolve in it a little Carbonate of Soda or of Potash till the water is distinctly alkaline, then commence evaporating the water down over a smokeless flame. When boiling has lasted for ten minutes, remove the vessel, let the water cool a little, and then filter it through a filter paper placed in a glass funnel. Collect the filtrate and continue the boiling, after having added a little more of the Carbonate, until the water is evaporated down to one-fifth its original bulk. Let the water cool again, stir up any deposit there may be in it, and then filter as before. Take about 300 grains measure of the filtrate in a test tube, make it slightly alkaline with Ammonia, and then add a few drops of a clear solution of Sulphate of Magnesia. If a white cloudiness or deposit occurs, then Phosphates are present in the water. The deposit should redissolve on the addition of a little Acetic Acid, but fall again on the addition of some more Ammonia.

Test No. 33.—*Tests for Phosphates in Water* (continued).

The Sugar Test. Take a pint of the water in a clean white glass bottle, and dissolve in it a very small piece of pure loaf sugar. The bottle may remain corked or uncorked, but it should be exposed to light and placed in a warm south aspect, or else kept fairly constantly at a temperature of 65° to 70° F. on a mantelpiece or elsewhere. It should be thus left at least two or three days. At the time this experiment is begun a similar bottle should be filled with some pure distilled water, treated with a little sugar, and placed side by side with the first bottle. After a day or two make a comparison of the water in the two bottles. The water in the second bottle should be perfectly clear, whilst the other, if it contains Phosphates, will be found turbid, and if examined by the microscope will show cells with bright nuclei in them, vibrios, living threads and other organisms. Some of these are even visible to the naked eye. The better the water is the longer it will remain clear, but a foul water will soon swarm with the signs of minute life.

Significance and Value of the Tests for Phosphates.

The presence of these salts in a natural water is generally a suspicious sign, especially so if the water is from a river or from a shallow well. Phosphates indicate the previous or the actual existence of animal or vegetable life in water. The absence of Phosphates is so far a good point in the water's favour, but in any case where Phosphates are present, the co-existence in the water of organic impurities and of ammonia should be determined before condemning the water. Water previously bad, but well filtered through sand, gravel, or through poor soils, will often lose all traces of Phosphates and will be greatly purified in other respects. Like Nitrates in drinking water so Phosphates in drinking or brewing water, they do not themselves do any harm but are regarded merely as the necessary accompaniments of pollution. Bad filters, especially filters not cleaned out and containing used-up animal charcoal, often render the filtered water worse than it originally was, for the Phosphates in the charcoal gradually encourage life, and at moderately warm temperatures develop it rapidly.

Tests No. 34 and 35.—*To test for Chlorides in Water.*

Test No. 34.—Take half a pint of the water and evaporate it down in a glass beaker or in a porcelain basin, and over a smokeless flame, to one-fifth of its bulk. Then stir up any deposit there may be, and, when cool, filter the water through a filter paper placed in a glass funnel. Take about 300 grains measure of the filtrate in a test tube, add to it a few drops of Nitric Acid till it is well acid, and then a few drops of a clear solution of Silver Nitrate. The formation of a white cloudiness, followed soon by a white deposit, indicates the presence of Chlorides in the water. A little Ammonia added gradually to the deposit will dissolve it.

Test No. 35.—*Tests for Chlorides in Water* (continued).

Quantitative Test.—To estimate the Chlorine present in all the Chlorides. Take a pint of the water in a glass beaker or in a porcelain basin, and evaporate it down, over a smokeless flame, to one-tenth of its bulk, that is to 2 ounces measure. Then remove the vessel, let the water cool, stir up any deposit there may be, and then filter through a filter paper placed in a glass funnel. Wash the filter paper by pouring a little warm distilled water on to it, and let the washings collect with the main filtrate. Place this filtrate in a clear white glass cylinder 7 or 8 inches high. The filtrate measures about 2 ounces, and it should be quite clear. Now make this water distinctly acid by a few drops of strong Nitric Acid, and shake up the mixture, then add from a burette, and a few drops at a time, some of a clear but weak solution of Nitrate of Silver in pure water. This solution holds say 30 grains of pure dry Silver Nitrate in a pint of pure water. If any Chlorides are present in the water being tested, a white cloudiness will form when the Silver Nitrate solution is added to it. Stir up with a glass rod the Silver Nitrate solution with the water, and then let the cloudiness settle. When the water is clear again—placing the cylinder in hot water hastens this—add a few drops more of the Silver Nitrate solution, let the cloudiness again settle after a stirring up, and repeat this process once more or until no cloudiness forms, when some more Silver Nitrate solution is added to the water. Let all the cloudiness settle to the bottom of the cylinder, a gentle heat hastens this. Then filter off the water gradually through a filter paper, leaving most of the deposit behind in the glass. Collect the filtrate, see that it is strongly acid, and add a little more of the Nitrate of Silver solution to it. If no cloudiness occurs it may be thrown away, but if a cloudiness does occur, let it settle as before and then filter the water once more through a filter paper. Now wash with some pure water all the deposit in the cylinder on to the filter paper, let these washings filter through, then remove the whole of the deposit of Silver Chloride which is on the filter paper into a small weighed porcelain basin. Dry this deposit gently over a smokeless flame, when dry let it cool, then weigh, deduct the weight of the basin and thus get that of the Silver Chloride. This weight of Silver Chloride divided by 4 gives the weight of Chlorine in the pint of water taken. Though 4·04 is the correct divisor, 4 is near enough. The weight of Chlorine per pint multiplied by 8 gives the weight of it existing as Chlorides in a gallon of the water. Practically then the weight of Chlorine existing as Chlorides in a gallon of water is obtained by multiplying the weight of the Silver Chloride from a pint by 2.

Significance and Value of the Tests for Chlorine or Chlorides.

When the grains of Chlorine per gallon are found by analysis, it is usual to multiply the weight by 1·65, and thus to get the equivalent in Common Salt (Sodic Chloride) per gallon. This habit, however, is absurd, it is apt to mislead a brewer entirely, for it by no means follows that all nor half the Chlorine in a gallon exists as Common Salt, nor is such a thing likely, though it is just possible. A water containing say 10 grains of Chlorine per gallon as Chlorides is represented as containing 16·5 grains of Common Salt, when very likely it only contains one-fourth that quantity, for the Chlorides of Calcium, of Magnesia, of Potash, and of Ammonia are all possibly present. All these salts are commonly found in water, and will be found of course increased in quantity per gallon in the beer, by reason of the concentration in the copper and the extra quantities dissolved from the brewing materials. A great many grains of Chlorine may be found in a gallon of beer. If this Chlorine is all reckoned as if it formed part of Common Salt an unfounded charge may be made against the brewer.

It would almost be impossible to find a natural water when it is delivered for consumption entirely free from Chlorides. Their existence in either large or small quantities does not in itself condemn nor recommend a water, but, taken with the other points of the analysis, the water's quality can be judged. A water free from organic impurities but rich in mineral matters, including Chlorides, would be pronounced a good brewing water; on the other hand, one rich in organic matter and also containing Chlorides would be regarded with suspicion.

Tests Nos. 36 to 38.—*To test for Salts of Lime in Water.*

(A) *Bicarbonate of Lime.*

(B) *Lime Salts generally.*

(C) *Permanently Soluble Lime Salts.*

Test No. 36.—*To test for Bicarbonate of Lime in Water.*

(1) *See* Test No. 28, sub-tests (1) and (2), also the Test for Temporary Hardness, No. 46 (C).

In addition to these, the presence of this Salt may be further proved by taking a little of the precipitate given in Test No. 28, sub-test (1), at the end of a clean platinum wire, this end is formed into a small hook, the other end is fixed in a piece of glass rod. On applying the hooked end which holds the precipitate to a colourless Bunsen flame or to a blowpipe flame, occasional red-brick colour flashes will be distinctly seen as the lime burns. They will be best observed by holding the wire towards the top of the flame and just as the wire containing some fresh lime is placed in the flame.

(2) To estimate the amount of Bicarbonate of Lime. Take half a pint of the water in a glass beaker or in a porcelain basin and heat it gradually over a smokeless flame, and let boiling continue for ten minutes. Now remove the vessel, let the water cool, stir up any deposit there may be, and filter the water through a filter paper placed in a glass funnel. Wash all the deposit in the vessel on to the filter paper with a little pure water, and let these washings filter through. Then replace the whole of the deposit on the filter paper into the glass beaker or other vessel used, which vessel should be quite clean inside. Add a little water to this and then a little dilute Hydrochloric Acid. The lime will dissolve amid considerable effervescence. Stir up the mixture, see that it is distinctly acid, and then after a time filter it through a filter paper. Collect the filtrate and wash any deposit there may be on the filter paper with pure water, letting these washings collect with the main filtrate. Place the whole of this in a small weighed porcelain basin, evaporate the liquid down to dryness over a smokeless flame. When dry and cool, weigh the whole, deduct the weight of the basin, and so obtain the weight of the Chloride of Calcium obtained from the Bicarbonate of Lime in the half-pint of water taken. This weight multiplied by 1·11, that is 1⅛ practically, will give the corresponding weight of Carbonate of Lime which existed of course in the soluble form of Bicarbonate in the half-pint of water. This weight of Carbonate multiplied by 16 gives the weight per gallon.

Test No. 37.—*To estimate the total amount of Lime Salts per gallon.*

Take half a pint of the water in a glass beaker or in a porcelain basin and heat it over a smokeless flame. Let boiling continue for ten minutes, then remove the vessel, let the water cool, stir up any deposit there may be, and then filter the water through a filter paper placed in a glass funnel. Collect any deposit that may have formed during the heating on to the filter paper, and leave it there. Meanwhile collect all the filtrate and continue to boil it again, and until it only occupies one-fourth of the bulk of the half-pint originally taken. Then remove the vessel, let the water cool a little, place the whole of it and any deposit there may be in it into a glass beaker, and add a very little Ammonia till the water is just weakly alkaline to red litmus paper. Stir up a little, then add to the water a little, say 250 grains measure of a strong solution of Ammonic Chloride, stir up again and leave for five minutes. Now add some Ammonic Carbonate solution and stir up gently, heat the liquid, and if there is a cloudiness in it this will gradually settle, then add a little more Ammonic Carbonate solution, let any cloudiness settle, and then filter the liquid through the filter paper already used. Collect the filtrate, leaving all the deposit upon the filter paper. To the filtrate add yet a little more Ammonic Carbonate solution, stir up, and if a cloudiness again appears the liquid must be gently warmed, and then filtered through the filter paper again. If, on now adding a little more Ammonic Carbonate to the filtrate, it remains clear, then it can be thrown away. Now turn to the deposit on the filter paper, wash this deposit several times with a little warm distilled water, letting the washings filter away. Then place the whole of the deposit into a small porcelain basin, add a little water to it and then gradually some weak Hydrochloric Acid, stir up, and add a little more acid till there is no effervescence and until the water is just acid. Nearly the whole of the deposit will now dissolve. Filter this solution through a filter paper and collect it in a small weighed porcelain basin, place it over a flame and evaporate down, with occasional stirrings, to dryness, let cool and then weigh. Deduct the weight of the basin, the remainder weight is that of the Lime Salts in the half-pint of water taken and weighed as Chloride. This weight multiplied by 16 gives the weight per gallon.

Test No. 38.—*To test for Permanently Soluble Salts of Lime. These include the Sulphate, the Nitrate and the Chloride.*

(1) Qualitative. Proceed exactly as in the foregoing, (Test No. 37) except that the filter paper after the first filtering must be thrown away. Continue the evaporation of the filtrate to one-fourth the original bulk, then add as directed, first, a little Ammonia till the liquid is just faintly alkaline; second, the 250 grains of the strong Ammonic Chloride solution, stirring up after this; and third, the Ammonic Carbonate solution. If now any cloudiness appears, then some of these Permanently Soluble Lime Salts are present. Collect a little of the deposit which will fall on heating the liquid, and test it for the Lime flame as shown at the end of Test No. 36 (1).

(2) Quantitative. Proceed exactly as in Test No. 37, except that the first filter paper after being washed and the washings collected with the filtrate must be thrown away. Then continue the process till the end of the experiment No. 37. The weight obtained on weighing will be that of the Permanently Soluble Lime Salts in the half-pint of water and reckoned as Chlorides. This weight multiplied by 16 gives the weight per gallon.

Significance and Value of the Tests for Lime Salts.

The two tests, one for the Bicarbonates or the Temporarily Soluble Lime Salts, and the other for the Permanently Soluble Salts, are both very useful ones, giving a good idea of the character of a water for brewing. The Permanently Soluble Lime Salts are the most esteemed, so much so, that many devices exist for artifically treating brewing waters so as to give them Permanent Hardness. The Bicarbonates are mostly precipitated either in the boiler or in the mash liquor tank. In moderate quantities these latter salts are probably useful in improving the quality of wort, especially if a bad malt has been used. The two classes of Lime Salts are usually found together and in waters of good quality derived from deep wells or from springs. Lime Salts give to waters what is known as Hardness, though Salts of Magnesia also contribute to this.

Tests Nos. 39 and 40.—*To test for Salts of Magnesia in Water.*

Test No. 39.—Take half a pint of the water in a glass beaker or in a porcelain basin, and heat it over a smokeless flame. Let boiling continue for ten minutes. Then let the water cool a little and filter it through a filter paper placed in a glass funnel. Collect the filtrate, throwing away the filter paper and anything upon it. Continue the evaporation till the water is reduced to one-fourth its original bulk, then add a very little Ammonia till the water is just alkaline, then add 250 grains of a strong solution of Ammonic Chloride. Stir up after this, let stand five minutes, then add some Ammonic Carbonate solution and stir up again. Let any cloudiness settle by gently heating the liquid, then filter it and add a little more Ammonic Carbonate solution, and, if necessary, heat gently, then filter again from any cloudiness or deposit, and if after this filtering a little more Ammonic Carbonate still produces a cloudiness, the process must be repeated again. Now concentrate the filtrate down again to about 3 ounces, filtering again after this if any deposit occurs. Now make the filtrate slightly alkaline with Ammonia, and then add a few drops of a solution of Disodic Phosphate. If any Magnesia Salts are present a white precipitate will soon form; the precipitate will dissolve when a little Acetic Acid is added, but will fall again on the addition of Ammonia.

Test No. 40.—*To estimate the amount of Magnesic Salts in Water.*

Quantitative Test. Proceed as in the foregoing (Test No. 39) till the liquid is concentrated to one-fourth its bulk. Then add a few drops of Ammonic Carbonate solution, stir up, then let any precipitate fall, and then filter the liquid through a filter paper. Collect the filtrate, wash the deposit on the paper with a little pure water, and let these washings collect with the main filtrate. Then add a little more of the Ammonic Carbonate solution, together with 250 grains measure of strong Ammonic Chloride solution, stir up, and if any cloudiness or precipitate occurs, filter again, washing the deposit as before. Now make the filtrate alkaline with Ammonia, and add a little of a solution of Disodic Phosphate. Heat the liquid slightly to hasten the precipitate, and as the water clarifies itself add a few drops more of the

Phosphate solution. Continue the heating, and after a time filter through a clean filter paper, collect the filtrate and treat it with a little more of the Phosphate, filtering again, if any deposit occurs, through the same filter paper. Wash the deposit on the filter paper with some pure water, let the washings filter through, then place the whole of the deposit into a small weighed porcelain basin, and dry gradually over a smokeless flame. When quite dry, weigh the residue as a phosphate, and multiply this weight by 16 to get the quantity in a gallon of water. As the Magnesia was present in other forms than the phosphate, the actual weight present would be less than is proved by weighing the phosphate by probably one-third.

Significance and Value of the Tests for Salts of Magnesia.

The presence of these salts in a brewing water is so far a point in its favour, unless they are present in excessive quantities as sulphates.

Nearly all Magnesic Salts are permanently soluble, they give permanent hardness to water. They exist in large quantities, occasionally in rather too large quantities, in the best ale-brewing waters. The Sulphate, if present in too large quantities, will cause the beer to act as a mild aperient.

Tests Nos. 41 and 42.—*To test for Salts of Soda in Water.*

Test No. 41.—Take half a pint of the water in a glass beaker or in a porcelain basin, and heat it over a smokeless flame. When boiling has continued for fifteen minutes, remove the vessel, let the water cool, and then filter it through a filter paper placed in a glass funnel. Collect the whole of the filtrate in a similar vessel to the first used, add a little Ammonia to it, and then a little—about 200 grains measure—of a solution of Ammonic Carbonate. Stir the mixture up, continue the heating for five minutes, then let any deposit settle down and add a little more both of Ammonia and of the Carbonate solution. If any cloudiness occurs yet, continue the heating for another five minutes, let cool and then filter again. Collect the filtrate, and if on once more adding a little Ammonia and Ammonic Carbonate a cloudiness appears, the heating and filtering must be once more repeated. Now continue the evaporation until the solution does not measure more than one-fifth of the original half-pint taken, then let the liquid cool, stir up any deposit there may be, and then filter again. Then add to the filtrate, drop by drop, some dilute Hydrochloric Acid until, on stirring up, the whole mixture is quite acid and no effervescence occurs. The evaporation may now be carried even a little further. Now take a clean platinum wire, hooked at the free end and fixed in a glass rod at the other, dip the wire in the concentrated liquid, and then apply it to the colourless flame of a Bunsen burner or of a blowpipe. A permanent bright yellow colour will be imparted to the flame if any Soda Salts are in the liquid. If there is any doubt about the colour, continue the evaporation to dryness, and then dip the wire into the dry residue; the wire should be held towards the top of the flame.

Test No. 42.—*Tests for Soda Salts* (continued).

Quantitative Test. Proceed exactly as in the above, (Test No. 41) taking care each time the liquid is filtered to pour a little water on to the filter paper to wash the deposit thereon, and let these washings collect with the filtrate. When eventually the water has been evaporated down to one-fifth its original volume and filtered, place it in a small weighed porcelain basin, and evaporate to dryness, after being sure that the weak Hydrochloric Acid added had made the water distinctly acid. When quite dry, heat the residue strongly for ten minutes, then let cool and weigh, deduct the weight of the basin, the remaining weight is that of the Soda Salts including those of Potash. This residue will include chlorides, nitrates, sulphates and phosphates of Soda and Potash, if any were present in the original water; the carbonates will have been changed into chlorides. The brewer will get a very good idea of the weight of alkaline salts in the water. The weight found multiplied by 16 gives the weight per gallon.

Significance and Value of the Tests for Soda Salts (including Potash Salts).

As both these alkalies form numerous salts, and as of these all the common ones are very soluble in water and plentiful in nature, it is not remarkable that most natural waters should contain more or less of them. It would be a rare specimen of water that did not contain both Soda and Potash Salts. These salts are of course found in still larger quantities in the beer produced, for they are augmented by concentration in the copper and by the large quantities extracted during brewing from all the mashing materials, and from the hops and yeast.

The purest waters both for drinking and for brewing, derived from deep wells and springs, contain Soda and Potash Salts. The worst waters, from rivers and shallow wells, are also rich in these salts.

Test No. 43.—*To test for Salts of Potash in Water.*

(1) Proceed exactly as in the test for Soda Salts (No. 41) until the testing at the Bunsen or the blowpipe flame is resorted to. Salts of Potash give a violet or a purple tinge to these colourless flames, but as the Soda—yellow—flame is usually very bright, the tinge from Potash Salts is often lost when looked for by the naked eye. To discover the Potash tinge when the Soda yellow flame predominates, take a piece of blue glass or a bottle filled with a weak Indigo solution, and then, having dipped the platinum wire into the liquid or into the residue under examination, observe the colour given to the flame thereby, and through the medium of the coloured glass or bottle. By this means, in spite of the brightness of the yellow flame from Soda, the violet Potash one will be distinctly seen, especially during the first few seconds after the wire is placed in the flame. Care must be taken in this experiment not to confuse the ordinary flame as seen through a blue medium with the proper Potash tinge. A little nitrate or chloride of Potash placed at the hooked end of the wire and tested at the flame will give the observer an idea of what to look for in any future case.

(2) Quantitative. The Potash Salts may for the brewer's purpose be reckoned along with the Soda Salts, as directed in the test for Soda Salts (No. 42).

Significance and Value of the Tests or Potash Salts. See Soda Salts.

Test No. 44.—*To test for Iron in Water.*

There are several beautiful tests easily applied.

(1) Take half a pint of the water in a glass beaker or in a porcelain basin, render it distinctly acid by a few drops first of Hydrochloric then of Nitric Acid, and then evaporate the water down over a smokeless flame to one-fifth its original bulk. Let cool, stir up any deposit there may be, and then filter through a filter paper placed in a glass funnel. Divide the filtrate into three portions of about 300 grains each. Take one portion in a test tube, keep it acid with a drop of Hydrochloric and of Nitric Acid, heat it gently for a minute, and then add a few drops of a clear solution of Potassic Ferricyanide (K_6. Fe_2. Cy_{12}.) The formation of a Prussian Blue precipitate or of a dark blue colouring proves the presence of Iron in the water.

(2) The second portion of 300 grains of the filtrate just alluded to above is taken now, a few drops of Nitric Acid are added to it, and then the liquid is gently heated. Now add a few drops of a solution of Ammonic Sulphocyanide (S. Am. Cy.); the formation of a blood-red colour proves the presence of Iron.

(3) The third portion of 300 grains of the filtrate alluded to above (1) is itself divided into two portions. To the first of these add very gradually, till it is alkaline, some Ammonia; a faint white precipitate proves the probable presence of Iron. The second of these portions is kept acid with Nitric Acid, and then some, about its own bulk—say 150 grains—of a solution of Sulphuretted Hydrogen is added to it. If no change occurs now, but on subsequently gently adding Ammonia till the liquid is alkaline a black precipitate or black colour forms, then Iron is present in the original water.

Significance and Value of the Tests for Iron.

A little Iron is frequently present in brewing waters; it may get there naturally during the water's course, or it may get there from the brewery heating vessels and pipes. If the water comes from a river, some foundry or works on its banks may account for the presence of Iron, or if from a well, the Iron may come from the drainage from neighbouring mines. In a brewing water Iron is considered obnoxious, it is said to darken the colour of the worts and beers.

Test No. 45.—*To test for Copper or for Lead in Water.*

Take a pint of the water in a glass beaker or in a porcelain basin, make it distinctly acid with Nitric Acid, and then evaporate it down over a smokeless flame. When the water is reduced to about half its original bulk remove the vessel, let the water cool, stir up any deposit, and then filter through a filter paper placed in a glass funnel. Collect the filtrate, keep it acid with Nitric Acid, and continue the evaporation until the water does not measure more than one-tenth of its original bulk, that is till it is reduced to about 2 ounces. Then remove the vessel, let the water cool, and stir up any deposit there may be. Now, as a preliminary test, take about 150 grains measure of the water and add to it a few drops of a solution of Ammonic Sulphide or of Ammonic Hydric Sulphide. If no blackness occurs now it is no use going any further. If a blackness does appear then proceed as follows:—Take about 200 grains measure of the concentrated water, which is distinctly acid, and add to it at least its own bulk of a solution of Sulphuretted Hydrogen in water. If a blackness occurs after a short time, then either Lead or Copper or else perhaps both are present. To prove which divide what remains of the water into two equal portions.

The first portion is placed in a test tube, and a few drops of dilute Sulphuric Acid are added; a white precipitate slowly falling proves the presence of Lead. Let the deposit collect, then pour off the liquid leaving the deposit behind, pour a little pure water on to this to wash it, and then pour this water off also. Now add a little of a solution of Acetate of Ammonia, the Lead will dissolve, but if a few drops of a solution of Potassic Bicarbonate are added a heavy yellow deposit will occur, which is soluble in Acetic Acid.

The second portion is placed in another test tube, some Ammonia is very gradually added to it; if now a blue colour forms then Copper exists in the water.

Significance and Value of the Tests for Copper and Lead.

The presence of these metals in a water, even in such quantities as to be discoverable by the above tests, renders the water dangerous for use. The presence in a brewing water of such metals would probably be owing to contamination from neighbouring works or to the drainage from mines, or this presence may be due to some fault in the service pipes, the pumps, or the heating tanks and coppers.

Test No. 46.—*To test for Hardness in Water.*

(A) *Total Hardness.*
(B) *Permanent Hardness.*
(C) *Temporary Hardness.*

The Soap test when carefully performed will, with some experience, allow the hardness of water to be accurately determined. It will not, however, except in special waters, show the number of grains per gallon of Lime and Magnesia Salts, it will merely as a rule show the hardness that these salts give to the water. This is all that is claimed for it, though some have tried to strain the test to show grains per gallon instead of degrees of hardness per gallon, and have failed, and therefore denounce the Soap Test as illusory.

Temporary Hardness can be determined with the greatest accuracy. It includes only that hardness due to the presence of the Bicarbonates of Lime in the water. Grains per gallon of this salt and degrees of temporary hardness per gallon are practically the same.

Permanent Hardness includes the hardness given to water by anything else than Bicarbonate of Lime, and includes therefore that from the Nitrate, Chloride and Sulphate of Lime, and that from the Magnesia Salts, and from any other metallic salts.

Total Hardness is the sum of the Temporary and the Permanent Hardness.

(A) *To test for Total Hardness.*

Every work on Water Analysis and many other works describe this test, but for a simple, brief and correct description I refer the operator to Miller's "Elements of Chemistry," Part II, Inorganic Chemistry, pages 519 and 520, under the heading of "Clark's Soap Test." Methylated spirit will be found cheaper than proof spirit for preparing the soap solution. *See* Note below.

(B) *To test for Permanent Hardness.*

Take a pint of the water to be tested and boil it thoroughly for ten minutes, filter it when a little cool through a filter paper placed in a glass funnel. Collect the filtrate and make it up to exactly the original pint by adding distilled water. Then proceed exactly as in the test for Total Hardness.

(C) *To test for Temporary Hardness.*

This is found by deducting the degrees of Permanent Hardness from those of Total Hardness, the remainder are the degrees of Temporary Hardness.

Significance and Value of the Test for Hardness.

By the Soap Test the comparative though not the absolute amount of Lime and Magnesia Salts in water can be ascertained, as grains per gallon of these salts and degrees of hardness per gallon are approximately represented by the same number. Hardness is a good quality in a brewing water, Permanent Hardness being the most esteemed. Some of the best brewing waters are very hard, and they are at the same time nearly free from organic matter. The test for Hardness does not alone allow an opinion to be formed about a water's purity, though a hard water from a spring or from a deep well is pretty sure to be a good brewing one. On the other hand, river water, shallow well and other polluted waters are frequently very hard.

INTERPRETATION OF CHEMICAL ANALYSES OF WATER.

Analytical reports on brewing waters are frequently so framed that they perplex and even mislead a brewer. In the foregoing tests some of the difficulties of water analysis are laid bare. It is most essential that a report should be thoroughly understood in all its details, and in the relation of each detail to every other one, and a report ought to be so framed as to show this. The most important details should have the greatest prominence, whilst accidental and unimportant ones should be kept in the background.

Dealing with reports in general, the following subjects want particular attention:—

1st.—The method of calculating and expressing the analytical results.

2nd and 3rd.—The method of analysis adopted and the determinations required in a full analysis of water for brewing purposes.

NOTE.—The trouble of preparing the standard soap and lime solutions may be saved by buying them ready-made from the chemical vendors. The chemist must be directed to prepare the solutions agreeably to directions given in Miller, page 519.

1st.—*The method of calculating and expressing the analytical results*

There are many ways of doing this, but of these the choice usually lies between the following three:—

No. (1) Results expressed in parts per 70,000 or in grains per gallon.
No. (2) Results expressed in parts per 100,000.
No. (3) Results expressed in parts per 1,000,000.

Of these three the first method (1) is decidedly the best for the brewer's purpose, and, as the results found by the other two methods can be so easily translated into terms of this one, it is a pity that it is not oftener done. Many reports are so carelessly set up that some of the details are expressed in grains per gallon, No. (1), and others in parts per 100,000 or in parts per 1,000,000, as per Nos. (2) and (3). This fact too often escapes the brewer's notice.

As a standard gallon of water contains 70,000 grains, an analysis showing parts per 70,000 shows at the same time grains per gallon. When the analysis is expressed in parts per 100,000, all that is necessary to be done to let it show grains per gallon is to take $\frac{7}{10}$ of each, or to multiply each constituent by ·7. If the analysis shows parts per 1,000,000, then to express this in grains per gallon take $\frac{7}{100}$ of each, or multiply each constituent by ·07. Thus the following analysis by Dr. Frankland can be expressed in two other ways:—

Deep Chalk-Well Water at Harrow.

Results of Analysis expressed in parts—(1) per 70,000; (2) per 100,000; (3) per 1,000,000.

	Total Solids.	Carbon from Organic Matter.	Nitrogen from Organic Matter.	Ammonia.	Nitrogen from Nitrates and Nitrites.	Total Nitrogen from all sources.	Previous Sewage Contamination.	Chlorine.	Hardness.		
									Total.	Permanent.	Temporary.
(1)	70·62	·041	·021	·082	None	·088	650	11·4	31·0	17·79	13·28
(2)	100·88	·059	·030	·118	None	·127		16·3	44·4	25·42	18·98
(3)	1008·8	·590	·300	1·180	None	1 270		163·0	444 0	254·20	189·80
	a.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*	*h.*	*i.*	*j.*	*k.*

NOTE.—The Nitrogen in column (F) is the total of that in columns (C), (D) and (E). As the Nitrogen in Ammonia is only $\frac{14}{17}$ of the weight of the Ammonia, the total in column (F) is thus the sum of columns (C) and (E) plus $\frac{14}{17}$ of column (D).

Previous sewage contamination is the same in all three cases. *See* the heading "Previous Sewage Contamination," page 45.

2nd and 3rd.—*The method of analysis adopted and the determinations required in a full analysis of water for brewing purposes*

Though in so large and so extremely difficult a subject as Water Analysis there must necessarily be several different methods applicable to certain parts of the process, yet it is fortunate that in many respects the different schools of analysts follow now practically the same methods, both in experiment and in expression. Thus the same method for estimating the Total Solids is followed universally, though the old-fashion division of this determination into Organic and Mineral Solids is very properly falling out of use. In estimating the amount of Chlorine, the degrees of Hardness (Temporary and Permanent), the amount of the various Mineral Salts and to a great extent the amount of Ammonia, in all these cases the same methods—or at least methods giving between themselves similar results—are used. It is, however, in estimating the Organic Matter and the various kinds of this, that rival, not to say antagonistic, processes are in vogue, and the same antagonism necessarily extends itself to the methods of expressing the results and to the significance attached to the determinations.

Dr. Frankland does not estimate directly the amount of Organic Matter, but by a most costly and difficult, yet most accurate process, he determines the respective amounts such matter contains of (A) Organic Carbon, (B) Organic Nitrogen. He also estimates the amount of Nitrogen contained in the Nitrates, and further, of course he estimates the amount of Ammonia and of its salts. From the amount of Nitrogen existing in the Nitrates and in the Ammonia he builds up the determination Previous Sewage Contamination, for an account of which *see* that heading on page 45.

Professor Wanklyn estimates the amount of Organic Nitrogenous Matter by a method known as the "Albuminoid Ammonia Process," fully explained with the Tests for Organic Nitrogenous Matter, Nos. 16 and 17.

Dr. Tidy compares the amount of Organic Matter in any water with that in another by means of a process known as the "Oxygen Process."

A brewer, therefore, anxious to know the quality of his brewing water, and who accordingly gets it analised by three different analysts, may probably, so far as the most important detail is concerned—and this is the amount of Organic Matter—get on this point three different reports, which of course permit of no comparison being made between them, except from the hands of a first-rate water analyst. I have accordingly given below a complete scheme of Water Analysis as applicable to Brewing Waters. Where alternative processes exist these have been placed in their proper relative places, and in the analyses under "Standards of Purity of Water for Brewing," given further on, the results as obtained from different processes have been to a certain extent arranged side by side.

Complete Scheme of the determinations required in a Water Analysis for Brewing Purposes.

Note.—Results in all possible cases to be expressed in Grains per Gallon.

1.—Total Solids.

2.—Organic Carbon, Dr. Frankland's Method;
    or (A) Any other Combustion Process;
        (B) Dr. Tidy's Oxygen Process, showing the amount of freshly-liberated Oxygen absorbed per gallon of water.

3.—Organic Nitrogen, Dr. Frankland's Method;
    or (A) Any other Combustion Process;
        (B) Professor Wanklyn's Albuminoid Ammonia Process.

4.—Ammonia. Free or as salts.

5.—Nitrogen existing as Nitrates and Nitrites, Dr. Frankland's Method;
    or (A) The Indigo Process.

6.—Total combined Nitrogen from all sources, namely, (1) Organic Nitrogenous Matter, (2) Ammonia, (3) Nitrates, &c.

7.—Total Nitrogen existing in the two forms, (1) Ammonia, and (2) Nitrates and Nitrites.
This determination is derived from those numbered 4 and 5.

8.—Previous Sewage Contamination. *See* page 45.
This determination is deduced from No. 7.

9.—Chlorine.

10.—Sulphates. The amount of Sulphuric Acid present in these. (1) Lime and Magnesia Sulphates, (2) Alkaline Sulphates.

11.—Phosphates. The amount of Phosphoric Acid present in these.

12.—Sulphides and Sulphuretted Hydrogen.

13.—Carbonates and Bircarbonates. (1) Lime Salts, (2) Magnesia and Alkaline Salts.

14.—Hardness. (1) Total, (2) Permanent, (3) Temporary.

15.—Stability of the Water in reference to its keeping qualities. *See* Test No. 5, page 16.
Also Smell, Taste and Appearance of the Water.

16.—Iron or any higher metal.

17.—Specific Gravity.

18.—Acidity or Alkalinity.

Note.—An analysis showing the above items and taken with—never without—the known or the probable history of the water would be most serviceable.

Under the headings of the respective tests in the previous pages will be found all hat need be said about them.

Previous Sewage Contamination.

This expression is often heard of in connection with water analysis. The usefulness of its indications as well as the author of the expression itself are frequently the subjects of bitter attacks from interested and from irresponsible persons.

The determination is based upon the quantity of Nitrates and the quantity of Ammonia in water, for these indicate generally the previous animal contamination. The "Previous Sewage Contamination" can be calculated from any analysis which gives the quantities of Ammonia and of Nitrates. The quantity of Organic Matter present is not reckoned, for this indicates really something worse, namely, "actual," not previous contamination. The quantity of Nitrogen existing in Ammonia and in Nitrates being found, a small deduction is made for the Nitrogen that is derived from the air and which exists in these forms, the remaining weight multiplied by 10,000 represents the "Previous Sewage Contamination." As the average weight of Nitrogen existing in these two forms in ordinary filtered sewage is 10 parts in every 100,000 parts, this number 10 multiplied by 10,000 gives 100,000 as the previous sewage contamination, that is, shows the liquid to be really what it is. The nearer then that the quantity of Nitrogen in water existing in the two forms approaches 10 in every 100,000 parts, or, what is the same thing, the nearer the "Previous Sewage Contamination" deduced therefrom approaches the standard 100,000, the nearer does such water approach the quality of sewage.

Most natural waters, even the impure ones, fall a long way below this standard, in fact a water is considered a very bad one when it contains in 100,000 parts only 2 parts of Nitrogen in the forms of Ammonia and Nitrates, for, if it contains this amount of Nitrogen, then the "Previous Sewage Contamination" is practically 2 multiplied by 10,000, that is 20,000, or one-fifth the strength of actual sewage. Natural water as it is found in some mountains, lakes or in deep wells, has so little Nitrogen in it in the two forms mentioned, that after the deduction for that derived from the air is made there is nothing left to multiply by 10,000, so that the "Previous Sewage Contamination" is nothing. Shallow well waters and river waters, on the other hand, contain frequently so much Nitrogen in their Ammonia and Nitrates, that they give indications of considerable sewage pollution. A water showing "Previous Sewage Contamination" must not, however, be condemned as unfit for use nor even be regarded as impure, for if such a rule were carried out, very few waters as supplied by the Companies or as derived even from deep wells would escape condemnation. Several other tests, especially those for Organic Matter, must be equally taken into account along with this one. Thus a water showing as much as 20,000 degrees of "Previous Sewage Contamination," that is to say, containing in 100,000 parts 2 parts of Nitrogen in the two forms of Ammonia and Nitrates, need not be regarded suspiciously if the water is derived from a deep well, and if there has been no chance of impure water leaking into the well. In such a case of deep well water the Organic Matter would probably be very small. But a shallow well or a river water containing half those quantities, namely 1 part of Nitrogen in the forms mentioned in 100,000 parts, and showing therefore only 10,000 degrees of previous contamination, would be regarded with the greatest suspicion, for such water would probably contain Organic Matter to some considerable extent, and would show also all the other usual indications of sewage pollution.

Simplification of the expression "Previous Sewage Contamination," so that the test can be applied more easily to Brewing Waters.

Nitrogen existing in water in the forms of (1) Ammonia and (2) Nitrates and Nitrites is the basis of the expression "Previous Sewage Contamination." The weight of such Nitrogen in 100,000 parts of water, when multiplied by 10,000, gives practically the degrees of previous contamination. In 100,000 parts of filtered sewage there are on the average 10 parts of such Nitrogen, in 70,000 parts therefore, or in one gallon of sewage, there would be 7 parts or 7 grains of the Nitrogen. The nearer then that the amount of Nitrogen in the two forms approaches 7 grains in a gallon of water, the nearer is the quality of such water to that of sewage. A water containing 1 grain of Nitrogen in the forms of Ammonia and Nitrates in a gallon, is thus one-seventh as impure as sewage is. Usually a water will contain very much less Nitrogen than this in those two forms. It would then be well for all the purposes of the test for "Previous Sewage Contamination" if the standard 7 were adopted as the number of grains per gallon of water for the Nitrogen existing in Ammonia and Nitrates. Waters could then be compared directly with this standard. Every analyst of brewing waters determines the amount of Ammonia and its salts, and the amount, by one process or another, of the Nitrogen existing as Nitrates, and he could at once say how many grains and parts of grains of Nitrogen exist in such forms in a gallon of water. The brewer, knowing that 7 grains is the highest standard per gallon, could then at once determine for himself the "Previous Sewage Contamination."

The following facts must, however, be always borne in mind:—

1st.—That "Previous Sewage Contamination" does not of itself condemn a water. The tests for Organic Matter, for Phosphates and Chlorine must be considered also.

2nd.—From the actual amount in grains of the Nitrogen existing in the two forms, the constant quantity, ·022 grain per gallon, should be deducted for the usual impurities from the air and rain. The remaining weight can then be compared with the standard 7 grains.

3rd.—If water contain only Nitrogen as Nitrates, and none or practically none as Ammonia, the test for "Previous Sewage Contamination" loses its worst significance. Most good waters will thus be excluded from any suspicion.

Standards of Purity of Water for Brewing Purposes.

A quantitative analysis or the qualitative tests have shown the brewer what kind of water he has to deal with. He wants to know now whether such water is fit for brewing, and if not, whether any practicable system of filtration or whether any other treatment will render it fit.

The whole analysis must be carefully gone over; it is seldom that one or two items of it allow a sound opinion to be formed. And it must here be repeated once more that the chemical analysis, however complete it may be, however damaging or however favourable to the water, must always be compared with, nay, even subordinated to, those local observations and enquiries as to the water's origin and history, which can as a rule be so readily made. It can usually be ascertained whether animal or vegetable pollution has a chance of contaminating the water, whether leakings or tricklings of polluted water into the pure supply take place. The immediate source of the water is of course considered, whether it is from a deep or a shallow well, from a river or from elsewhere, and whether any filtration takes place before the brewer has to deal with the water. This having been done, the value or otherwise of the chemical analysis becomes far more apparent.

Shallow well and river waters must always be regarded more suspiciously than deep well waters. Different standards of purity are in fact applied to these various kinds of water, the surface waters being judged far more severely than the deep well waters.

A good water for brewing purposes and from a deep well might contain a little Organic Matter and traces of Ammonia, it might be rich in Mineral Matter, especially in Lime and Magnesia Salts and in Common Salt. These solids might amount to 50 or more grains per gallon. Nitrates might be present to such an extent that the Nitrogen in these and in the Ammonia would reach 1 grain per gallon. These Nitrates would as a rule prove that the water had at some time been contaminated, but during its passage through the earth the objectionable Organic Matter had been removed from the water. The effect of Nitrates on the fermentation must not however be overlooked.

The risk of recent contamination is, however, much greater in the case of local companies' or other supplies from shallow wells or from rivers. A little filtration through sand or gravel may have removed the coarser parts of pollution, but filtration on the very large scale is seldom sufficient for the brewer's purpose when a doubtful water is being considered.

Most important to a brewer are the subjects of filtration, softening and hardening of water. Filtration efficiently conducted greatly improves the quality of a bad water, and it is strongly recommended. Filtration will as a rule soften the water, but the water can, if necessary, be easily hardened again. Mr. Faulkner gives an excellent illustration, in his latest work, of a method which filters and then hardens water. Softening by Clarke's process greatly improves a bad water's quality; it reduces the amount of Organic Matter; it does not interfere with the valuable Permanent Hardness, but removes the less desirable Temporary Hardness. One thing, however, is most essential for success, and that is complete rest for at least six hours in a subsidence tank after the Lime solution has been mixed with the water to be softened. *See* Note below.

Note.—Softening of Water. Say it is a water of 20 degrees of Temporary Hardness, then about 1 oz. of Lime is required for each barrel. Take then the weight required, break it up into small pieces, and stir it up in a pail or vessel containing a few gallons of the water. Stir up repeatedly, and then let the whole settle. After a time pour this lime solution into the tank containing the water to be softened, mix the solution well up with the water, and then let the whole be at rest for six hours. Then draw off the water without disturbing the bottom layer of one or two inches; reject this residuum. Too much lime should not be added or the water will turn alkaline. To prevent this, test the water by taking a pint of it, boiling it thoroughly, and then applying a red litmus paper to it; if alkaline the paper will be turned blue. A little more of the hard water can in such a case be added to that being softened in the tank.

Downward filtration of water through 9 or 10 feet of gravel or sand, and either previous to or subsequent to the softening process, will greatly improve the water's quality. Upward filtration is useless, so too is downward filtration if in the latter case the process is forced, or if the filtering material is not renewed or thoroughly cleansed occasionally.

At to the amounts of any particular kind of matter, organic or mineral, which may be in a water and yet not unfit it for brewing purposes. It is almost impossible in respect of any one constituent to fix a limit, moreover any limit must, as has been said, vary according to the kind of water and whether it is surface water or otherwise. The following analyses of good, medium quality, and foul waters from all sources will serve as standards for comparison, and will perhaps give a better idea of what a water is than any amount explanation. Though many of the waters were analised with a view to discover their fitness for drinking, the analyses will serve admirably when the water is regarded from a brewing point of view. Two points, however, though of less importance for drinking purposes are of great importance for brewing purposes, they are the Hardness and the Nitrogen as Nitrates.

Analyses of Waters by Dr. Frankland, and altered so as to show Grains per Gallon.

Description of Sample.	Total Solids.	Carbon from Organic Matter.	Nitrogen from Organic Matter.	Ammonia.	Nitrogen from the Nitrates and Nitrites.	Nitrogen from the Nitrates and Nitrites together with that from the Ammonia.	Previous Sewage Contamination.	Chlorine.	Hardness.			Remarks as to Character.
									Total.	Permanent.	Temporary.	
Thirlmere Lake	1·86	·135	·003	·003	None	·002	None	Not determined.	·5	—	—	Soft. Good.
Lock Katrine	2·29	·179	·005	·002	·021	·023	do.	do.	·2	—	—	Soft. Good.
Derbyshire Hills	4·76	·169	·018	·001	·001	·002	do.	do.	1·9	—	—	Soft. Good.
Spring Water	2·45	·035	·013	None	None	None	do.	·91	1·5	1·5	None	Soft. Good.
Spring Water	25·50	·031	·006	do.	do.	do.	do.	4·41	17·1	3·8	13·4	Hard. Good.
Deep Well	19·76	·019	·002	·035	do.	·029	90	1·33	2·5	1·7	·8	Soft. Good.
Deep Well	20·63	·030	·002	·001	·009	·010	None	2·90	15·2	3·5	11·7	Hard. Good.
Deep Well	20·44	·036	·016	None	·041	·041	270	·82	17·8	2·5	15·3	Hard. Good.
Deep Well	16·31	·035	·011	·001	·073	·074	740	·70	13·4	1·9	11·5	Hard. Good.
Deep Well, Chalk	31·36	·044	·009	·001	·285	·286	3,770	Not determined.	18·3	Not determined.	Not determined.	Hard. Good.
Deep Well, Chalk	26·58	·114	·000	·004	·593	·597	8,205	do.	15·1	do.	do.	Hard. Good.
Thames Water, as delivered	22·00	·228	·027	·002	·126	·128	1,510	1·33	16·5	3·5	13·0	Hard. Indifferent.
Lea Water, as delivered ...	21·10	·080	·009	·001	·252	·253	3,300	Not determined.	14·0	Not determined.	Not determined.	Hard. Indifferent.
Shallow Well	132·18	·654	·074	·112	3·068	3·160	44,853	16·59	22·2	16·8	5·4	Hard. Foul.
Dilute Sewage average of 37 samples... ...	57·7	2·927	1·382	3·806	Not determined.	Not determined.	Not determined.	8·01	Not determined.	Not determined.	Not determined.	Hard. Foul.
	a.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*	*h.*	*i.*	*j.*	*k.*	

NOTE.—It will be seen from the above analyses that some deep well waters richer in Nitrates than the river waters are yet considered better than the latter waters, but the latter excel the former in their amounts of Organic Carbon and Nitrogen.

Column (F) is made up from column (E) plus $\frac{14}{17}$ of column (D), for Ammonia contains $\frac{14}{17}$ of its weight of Nitrogen.

Column (G) is made up from column (F). *See* Heading "Previous Sewage Contamination," page 45.

Analyses of Waters by Dr. Hassall, but showing Grains per Gallon. *(Professor Wanklyn's Method).*

Description of Sample.	Total Solids.	Free Ammonia.	Albuminoid Ammonia.	Nitrogen from the Nitrates.	Chlorine.	Hardness.
Bad Water ...	47·6	·006	·009	1·4	8·64	24·6
do. ..	65·7	·005	·015	·8	10·66	24·5
do. ...	76·4	·032	·004	1·3	·54	37·4

Dr. Tidy's Classification of Waters.

Class 1.—Very pure. Waters absorbing not more than ·05 grain of liberated Oxygen per gallon.

„ 2.—Medium purity. Waters absorbing from ·05 to ·15 grain of liberated Oxygen per gallon.

„ 3.—Doubtful purity. Waters absorbing from ·15 to ·2 grain of liberated Oxygen per gallon.

„ 4.—Impure water. Water absorbing more than ·2 grain of liberated Oxygen per gallon.

PART II.

BREWING MATERIALS.

TESTS APPLICABLE TO BARLEY, MALT, SUGAR, HOPS AND YEAST.

BARLEY.

Test No. 47. *Growth during Malting.*

A good British Barley steeped in the malting cistern for two or three days will swell about 23 per cent. therein, so that 100 bushels will produce about 123 by this operation. Certain foreign dry varieties of barley, which are usually very light and thin, will swell up enormously during two days' steep, namely, from 40 to 50 per cent. of their original bulk.

Again, a good British Barley which has passed through the ordinary germinating process of steeping and flooring, will be found, when placed raw upon the kiln, to have swelled up from 80 to 90 per cent. of its original bulk when dry barley. The other dry varieties alluded to will probably have swollen over 100 per cent.

Good screened malt will measure from 5 to 8 per cent. more than the original barley from which it was produced. Light varieties of barley will, under the same conditions, measure from 10 to 12 per cent. more as screened malt than they did as dry barley.

Test No. 48.—*Indications of Spoiled Barley.*

A black or brown colour at the germinating end of the barley grain—visible also in the resulting malt—is usually indicative of the barley having been over heated in the stack or of its having partially rotted.

Test No. 49.—*Mouldiness in Barley.*

This usually accompanies dampness and acidity. The mouldiness can often be seen by the naked eye, and can frequently be smelt. A microscope is valuable in looking for mouldiness.

Test No. 50.—*To test for Acidity in Barley.*

Acidity usually accompanies dampness and mouldiness, and is found in barley which has been damp at one time but dried since. Its amount can be estimated comparatively or quantitatively. The following comparative test is easily performed:—

Take exactly a quarter of a pound of the barley, place it in a glass beaker, treat it with a little warm distilled water at 100° F., about a quarter of a pint, and for ten minutes. Stir the whole up together frequently. At the end of this time filter the liquid through a filter paper placed in a glass funnel, wash the barley with a little more of the water and let these washings filter through, and make up the whole filtrate to a quarter of a pint. Stir the liquid up a little and then apply a blue litmus paper, if this turns red proceed to test the comparative amount of the acid. For this purpose, take in a glass graduated tube of 1,000 grains capacity, and with divisions for each 10 grains, some Ammonia solution of exactly 998 6 specific gravity. Let some of this solution, a few drops at a time, into the liquid as prepared, stirring up thoroughly with a glass rod after each addition. A blue and a red litmus paper held side by side are dipped into the liquid after each stirring, and the process is continued till the liquid is neutral. This is known by the fact that neither litmus paper is changed in colour on being dipped into the liquid. If too much Ammonia solution has been added, then the red paper turns blue. When neutrality is reached, read off the number of grains of the Ammonia solution used, and compare this number with the number used when a quarter-pound sample of barley of known first-rate quality is treated in exactly the same way as the sample under actual treatment. The relative amounts of Acidity are thus known.

Test No. 51.—*To test for Moisture in Barley.*

Moisture increases the weight of barley, and a barley having an unusually high weight may very possibly be very damp.

Take exactly a quarter of a pound of the barley, place it in a wide and shallow vessel, such as a porcelain basin, or lay it on a flat slab. Now gently heat it over a moderate and a smokeless flame, letting all moisture escape, and continue this process till the barley is quite dry. A fixed time should be always adhered to, say two hours. A water oven is a most convenient thing for this experiment. Then remove the barley, let it cool, and weigh it again. Some grain weights will be required, a quarter of a pound is exactly 1,750 grains. The loss in weight is due to moisture driven off, and this loss can either be compared at once with the loss experienced under similar circumstances by the same weight of first-rate barley, or the percentage moisture can be estimated by simply dividing the loss in weight by 17½, the 1,750 grains being of course 17½ hundred. This percentage can then be compared to that similarly obtained from known good barley of average dryness.

MALT.

Test No. 52.—*Average Weight per Bushel measure.*

A good malt, after screening, weighs from 40 to 41 pounds per bushel measure. Excess weight over this may be due to:—

(1) The unusual dampness of the malt, with its accompanying mouldiness and acidity.

(2) To the presence of a quantity of ungrown or of partially-grown grains.

(3) To the admixture of barley with the malt.

On the other hand, malt weighing less than the average, may do so from its having been made from a thin, light barley, or from a barley which had commenced to germinate in the stack, through moisture and heat.

Test No. 53.—*Practical Tests for Good Malt.*

(1) Select indiscriminately 200 malt grains from a quantity taken from a part of a malt parcel which has not been merely accidentally damaged by tramping or accidentally mixed with barley. Throw these into a basin of water at the ordinary temperature. Any barley grains present and any only partially-grown grains will soon sink to the bottom, but the good malt grains will float. Repeat the experiment with another 200 grains. The more sinkers there are the worse the malt is, or the more there are of barley grains. Examine the sinkers for barley. A good sample of malt would only have one or two sinkers in a hundred grains, and very often would have none at all.

(2) Select indiscriminately 200 malt grains, and with a sharp thin-bladed knife cut off the husk at the back of each grain, beginning at the end whence the plumule starts. The plumule is thus laid bare. Arrange the grains so treated in three lots—the first lot being the grains in which the plumule has grown up two-thirds or three-fourths the length of the grain, the second lot being those in which the plumule has only grown up one-fourth or one-half the length of the grain, and the third lot being those in which the plumule has only just commenced to grow, or in which it has not grown at all. Examine this third lot for barley. A good malt should contain at least 90 grains in every 100 in the first lot, that is of grains in which the plumule has grown three-fourths the length of the grain.

(3) Any blackening seen at the germinating end of the grain—the end whence the plumule commences to push its way upward—is usually considered a sign that the barley had commenced to germinate in the stack or had begun to rot.

Test No. 54.—*To test for Moisture in Malt.*

Take accurately a quarter of a pound of the malt (1,750 grains weight) and proceed exactly as in the test for Moisture in Barley (Test No. 51). Compare the total loss in drying, which is due of course to moisture expelled, with that given when a sample of known good malt of average dryness is similarly treated; or compare the percentage moisture as obtained from the same test (No. 51) with the percentage moisture in a good average dry malt.

Test No. 55.—*To test for Acidity in Malt.*

Acidity is usually found along with mouldiness in a damp malt, or in one which has been damp and has been since dried. Take some of the malt, gently crush it up, then weigh out exactly a quarter of a pound (1,750 grains weight) and proceed exactly as in the test for Acidity in Barley (Test No. 50). Compare the number of grains of the Ammonia solution used with the number used when a similar weight of known good malt is treated in the same way.

SUGAR AND SYRUPS.

Test No. 56.—*To test for Acidity in Sugar and Syrups.*

All sugars, but especially cane sugar, and syrups should be tested for acidity. In the case of these latter, the acidity test is a valuable indication of the sugar's fitness for brewing. In the case of prepared glucoses the test is not usually of equal value, these sugars are generally neutral, care being taken in the manufacture to secure this.

Take a quarter of a pound of any sample, weighing it accurately. If necessary break the sugar up into small pieces. Dissolve it, or as much of it as is soluble, in a pint of distilled water at 100° F. Let stand for ten minutes, then stir up again and make the bulk up to a pint exactly. Now test the solution for acidity by dipping a blue litmus paper into it, and if this turns red proceed to ascertain the degree of acidity. Take the Ammonia solution of 998·6 gravity and apply the test to this sugar solution in exactly the same way as to the quarter of a pint of the barley solution in Test No. 50. Note the number of grains of the Ammonia solution used, and compare this number with that used on other occasions in dealing in the same way with the same weight of sugar.

Test No. 57.—*To test for Moisture in Sugar and Syrups.*

Weigh accurately a quarter of a pound of the sugar or the syrup; if the sugar is in lumps it must be previously broken up into small pieces. Place the weighed quantity in a wide and shallow porcelain basin, and proceed to dry it exactly as directed in the test for Moisture in Barley (Test No. 51). The same treatment must be exactly followed in all its details in any other case. The total loss by moisture in the quarter of a pound, or the percentage moisture by dividing the total loss by 17½ as usual, can then be ascertained; and these can be compared with the percentage moisture guaranteed on purchasing, or with the percentage in a known good sample similarly treated of the particular kind of sugar or syrup being dealt with.

Test No. 58.—*To test for Starch in Glucoses or in other prepared Brewing Sugars.*

This is a simple but an important test, for if any starch were left unconverted in these sugars it will of course get into the wort and remain there as such.

Prepare a very small portion, and at the time required, of an Iodine solution by taking a crystal or two of dry Iodine, placing this in a test tube, and adding about 250 grains measure of Methylated Spirit. A rich brown solution is thus obtained.

Take an ounce of the sugar to be tested, powder it up and treat it with a quarter of a pint of boiling water. Let the sugar solution cool down to 60° F., then stir up and take about 300 grains of it in a test tube. Add now a few drops of the Iodine solution and stir up; the formation of a blue colour proves the presence of Starch.

Test No. 59.—*To estimate the amount of Mineral Matter in Sugar.*

Take a little of the sugar, powder it up finely, and then place exactly 100 grains weight of it in a porcelain or a platinum dish, the weight of the dish being known. Dry the sugar by placing the containing vessel over a gentle flame as, for instance, an Argand burner. When dry the sugar can be weighed again, and thus the percentage moisture read off at once. Continue the heating, turning the flame gradually higher—a Bunsen burner can be used here. Continue the burning until only a grey-white mass is left. When cool, weigh again, deduct the weight of the dish; the weight of the ash is thus obtained, and this too is the percentage ash or mineral matter. The ash can be dissolved in hot water, and the tests for each kind of mineral matter can be applied as in the tests for them in water.

Hops.

Test No. 60.—*To test for Moisture in Hops.*

Excess of moisture in hops usually accompanies mouldiness and acidity. The most exposed parts of the hop packet of course suffer most. In taking a sample to represent the whole it should be taken from an unexposed part of the packet.

Weigh accurately a quarter of a pound of the hops, place them on a piece of paper and lay them out flat in a water oven, and leave them there for two hours, or until quite dry. Or place the hops in a wide but shallow porcelain dish, and dry them slowly over a gentle and smokeless flame. When cool weigh again; the loss through escaped moisture is thus known, and the loss divided by 17½ gives the percentage moisture.

Test No. 61.—*To test for Acidity due to exposure in Hops.*

Weigh accurately one ounce of the hops taken from the most exposed portion of the package. Place them in a wide shallow basin or in a glass beaker, and pour over them a quarter of a pint of distilled water at 100° F., stirring up well together the water and the hops. Leave for ten minutes, during which time the stirring is continued. Then filter through a filter paper, wash the hops with a little more water, add these washings to the filtrate, which should now be made up to exactly a quarter of a pint. With a blue and a red litmus paper together test this filtrate, and, if the blue paper is turned red, proceed to estimate the acidity by using the test Ammonia solution exactly as directed in the test for Acidity in Barley (Test No. 50). Compare the number of grains of this Ammonia solution used with the number used when the same weight, one ounce, of known good hops is similarly treated.

YEAST.

Test No. 62.—*To test its Purity and Activity.*

Take a small portion of the yeast and stir it up in a wine-glassful of a very weak sugar solution at a temperature of 70° F. Leave for ten minutes, then stir up again, and then spread out on a clean glass slide two or three drops of the liquid and examine the same under a microscope—a ⅛-inch or ⅙-inch power will be found very useful. Repeat the examination with a few more drops of the yeast solution, comparing the microscopic fields with the illustrations of this kind given in

(1) Pasteur's Studies on Fermentation, Faulkner's translation; or

(2) Faulkner's Modern Brewing; or

(3) Hooper's Manual of Brewing.

Watch also the development of the yeast.

PART III.

WORT AND BEER.

Wort.

Test No. 63.—*To test for Starch in Wort.*

(1) *Ale Wort.*

(2) *Stout and Porter Wort.*

Prepare the Iodine solution as directed in Test No. 58.

(1) Ale Wort. Take a sample of the wort in a clear glass sampling jar, cool the wort to 60° F., and then add a drop or two of the Iodine solution to it. Mix the whole up. Any blue colouration which may now appear proves the presence of starch. The blue colour can best be seen on the wort's surface, or else down the sides of the sampling vessel when the wort is moved to one side.

If the ale wort is very strong and of a dark colour the blue reaction cannot be seen so distinctly. In such a case dilute the wort, after cooling, with its own bulk of water, then add the Iodine solution.

(2) Porter and Stout Wort. Take a sample of the wort in a clear glass sampling jar, cool it down to 60° F., then dilute it with at least its own bulk of water. The dark colour is thus lessened. Now add a few drops of the Iodine solution and watch for a blue colouration, best seen at the wort's surface or down the sides of the vessel when this is moved to one side.

Remarks upon the presence of Starch in Wort.

Starch may get into wort in any of the following ways:—

(A) In Mashing. By too high an initial mashing heat, the diastatic power is thus destroyed, and the starch gets little chance of conversion into sugar.

By incomplete mixing in the mash tun. Some of the starch is left unaffected, but gets washed out in the sparging. If the mixture of the water with the materials is not made gradually a large quantity of hot water may come in contact with a small portion of the materials, and thus, in that portion of the mash, may kill the diastase. Some of the starch may in this and the other cases get eventually into solution, but the temperature is then too high for converting it to sugar.

By too short a mashing at a rather high temperature.

(B) In Sparging. By employing very hot liquor in sparging some additional starch may be dissolved, but it is run off into the copper and no opportunity is afforded for its conversion.

When the test, as described, shows the presence of starch in the wort, the wort could in some cases be used as part of the mashing liquor in a fresh brew, and thus the starch would have every opportunity for its conversion to sugar. In other cases, if the results were serious and practical means were at hand, the wort could be cooled down, say to 155° to 160° F., and then a quantity of malt mashed into it. This would effect the conversion of much of the starch.

Test No. 64.—*To test for Acidity in Wort.*

Take a small quantity of the wort, and, if fermentation has commenced, pour it violently five or six times from one small beaker or other vessel into another, the Carbonic Acid gas is thus to a great extent expelled. When the froth has subsided, measure off exactly 1,000 grains of the wort by means of a graduated glass tube. Place this wort in a tumbler or in a beaker, and add a little water to it. Have ready a small glass rod for stirring, a piece of India rubber being over one end of this rod, so as not to break the glass whilst stirring. Have ready also some test Ammonia solution of exactly 998·6 gravity, and place this in another graduated grain tube. Take a blue and a red litmus paper, and now let into the wort, a few drops at a time, some of the Ammonia solution, about 90 or 100 grains may be let in to start with. Stir up the wort and the Ammonia solution thoroughly, then let the froth subside and dip the two test papers into the mixture; if the blue paper still turns red, add a little more of the Ammonia solution and stir as before. If too much Ammonia has been added the red paper will turn blue, and a fresh experiment must be begun. When, however, neither paper is changed in colour on dipping into the mixture, then neutrality is reached, and the exact number of grains of the Ammonia solution used is read off. If this number is divided by 1,000, then the wort's percentage acidity is at once known. Say 90 grains were used, then $\frac{90}{1000}$, that is ·090 is the percentage acidity; if 110 were used, the $\frac{110}{1000}$, that is ·110 is the percentage acidity. As a rule, in wort of ordinary strength and thoroughly fermented, the percentage acidity would be about ·1, that is $\frac{1}{10}$th per cent. But the percentage acidity varies in ordinary cases with the strength of the wort and its degree of fermentation from about ·090 to ·15, or to a little above this.

In this test the whole of the permanent acidity (for the volatile Carbonic Acid has been expelled) is reckoned as if it were Acetic Acid. Although all the acidity is not in fact due to this acid, yet its being reckoned as if it were does not affect the value of this test. This is fully explained in my work on "Original Gravity," page 29.

NOTE.—Be sure the Ammonia solution is kept at the proper strength, namely, sp. gr. 998·6. This Solution can always be bought ready-made. If a solution is too weak, a drop or two of strong Ammonia will bring it up to the strength; and if too strong, a little pure water will bring it down to the right strength. Its weight, 998·6, is the best test for its correctness.

The Test for Acidity is meant to be applied to the wort's natural acidity—the acidity extracted from the ordinary brewing materials and that created during fermentation. In such a case the test is most useful in indicating the quality of the wort, for an abnormal acidity, due of course to natural causes, is an unhealthy sign, reflecting upon the quality of the materials used or upon the fermentation. If, however, during the malting, mashing or fermentation processes any chemicals have been used, or if they have been used for cleaning out the collecting vessels, then the natural acidity may be either considerably increased or diminished by these artificial causes. It is impossible to make any average allowance for these cases.

Test No. 65.—*To test the Wort's Purity in reference to Disease Ferments.*

Take a few small samples from various parts of the wort. Stir each one up before examining it, and then spread in each case a few drops of the wort upon a glass slide and examine under the microscope with a ⅙th or a ⅛th inch power. Decide as directed in the Test for Purity of Yeast (Test No. 62).

BEER.

Test No. 66.—*To estimate the Acidity in Beer*

Take half a pint of the beer and pour it violently several times from one small vessel into another, in order to expel the Carbonic Acid gas. Let the froth subside, and then measure off exactly 1,000 grains of the beer, and place it in a tumbler or in a glass beaker. Add a little water to this. Then proceed exactly as in the Test for Acidity in Wort (Test No. 64). Read off the number of grains of the Ammonia solution used; this number divided by 1,000 gives at once the percentage acidity of the beer. Say 220 grains were used, then the percentage acidity is $\frac{220}{1000}$, that is ·220. The usual percentage acidity in a sound beer varies from ·1 to ·3 according to the strength of and the age of the beer. Any excess over ·3 per cent. is considered a bad indication.

Test No. 67.—*To test the Purity of the Beer in respect to Disease Ferments and Disease Organisms.*

(1) Take various small portions of the beer, and in each case stir up well, and then spread a drop or two on a glass slide and examine with a ⅙th or a ⅛th power.

(2) In the case of old beer. Take a little of the deposit on the bottom of the cask or the bottle and spread on a glass slide.

In each case compare carefully the microscopic field as is directed in the Test for the Purity of Yeast (Test No. 62). Illustrations of Beer Residues will be found with the other illustrations.

Tests for (1) ***Starch in Beer. See*** **Test No. 63—Starch in Wort. (2)** ***Alcohol in Beer and Wort. See*** **Distillation Process of finding Original Gravities—pages 54 and 55 in Author's book on "Original Gravity."**

EXTRA TESTS. GAUGING.

Test No. 68.—*To find the exact capacity of any cask or other movable vessel.*

For the brewer's purpose this is best done by using a cylinder filled with water and with a gauge tube attached. Each inch in the cylinder holds exactly so many gallons, and the number of gallons and parts of the same emptied from the cylinder in filling a cask is read off at once by referring to the gauge tube. But in the absence of one of these appliances the following methods are recommended. Precise accuracy is not required for beer casks, yet the following rough methods will give the capacity to within a quarter of a gallon.

(1) Weigh the empty cask or vessel to the nearest half-pound. Then completely fill it with water and weigh again. Deduct the weight of the vessel, bring the remaining weight—that of the water contained—to pounds, and divide by 10; the capacity of the vessel in gallons is thus known.

NOTE.—The nearer the temperature of the water used is to 62° F. the more correct the answer will be, but if the temperature is within 5 or 6 degrees above or below 62° F., the capacity obtained, will with the ordinary brewing water, be within a quarter of a gallon of exactness.

(2) Take any liquid, water, beer or wort, at any temperature and fill a gallon measure with it exactly. Weigh this to the nearest ounce, deduct the weight of the gallon measure, the remainder is that of the gallon of liquid as taken. Now weigh the empty cask or vessel to the nearest half-pound, fill it completely with the liquid, weigh again, and then deduct the weight of the vessel; the remainder is the weight of the liquid in the vessel. Bring this weight to pounds and divide it by the weight of the gallon of the liquid; the capacity of the vessel in gallons is thus found.

(3) Take any liquid, water, beer or wort, at any temperature, and by means of a gravity saccharometer read off the gravity of the liquid at that temperature. Say beer is used and the gravity read off is 1010. Put the decimal point after the second figure, and thus get practically the weight of a gallon of the liquid in pounds, in this case 10·10 pounds. Now weigh the empty vessel to the nearest half-pound, fill it completely with the liquid and weigh again, deduct the weight of the vessel, and thus get the weight of the contained liquid. Bring this to pounds and divide it by the weight per gallon, in this case by 10·1 pounds. The capacity of the vessel in gallons is thus known.

Test No. 69.—*To find the exact quantity of any liquid in any cask or other movable vessel.*

If the weight of the empty cask or vessel is not known, the vessel must be emptied and weighed to the nearest half-pound. Then, when the liquid has been replaced, Test No. 68 (1) can be applied if the liquid is water; or whatever liquid it is and at whatever temperature, Test No. 68 (2) and (3) can be applied. Weigh the vessel or cask again when the liquid is in it, deduct the weight of the vessel, and the remainder, treated by any of these three methods, will give the exact quantity of gallons and parts of the same—to a quarter of a gallon—in the vessel.