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J. W. POWELL, DIRECTOR

ANALYSES OF WATERS
OF THE
YELLOWSTONE NATIONAL PARK

WITH AN ACCOUNT OF THE METHODS OF ANALYSIS EMPLOYED

BY

FRANK AUSTIN GOOCH
AND
JAMES EDWARD WHITFIELD

WASHINGTON
GOVERNMENT PRINTING OFFICE
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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY, DIVISION OF CHEMISTRY,
Washington, D. C., April 26, 1887.

SIR: I have the honor to transmit for publication as a bulletin of the Survey a paper entitled "Analyses of waters of the Yellowstone National Park, with an account of the methods of analysis employed," by Frank Austin Gooch and James Edward Whitfield. It represents work done in the Chemical Laboratory of the Survey and it is an exceedingly valuable contribution to science.

Very respectfully,

F. W. CLARKE,
Chief Chemist.

Maj. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

ANALYSES OF WATERS OF THE YELLOWSTONE NATIONAL PARK.

BY F. A. GOOCH AND J. E. WHITFIELD.

INTRODUCTION.

The series of waters—forty-three in all—of which it is the purpose of this paper to give some account comprises typical representatives of the geysers, hot springs, mud springs, cold springs, and surface waters found within the limits of the Yellowstone Park. It embraces collections made during the field seasons from 1883 to 1886 under the direction of Mr. Arnold Hague, geologist in charge of the Yellowstone Park Division, and submitted to us for analysis. In our account we have to deal simply with the results of analysis and with the analytical processes we have used—with the latter on the ground that some knowledge of the methods employed in the examination and of the quantities of material at our disposal is essential to a correct understanding of the meaning and value of the analyses themselves. Discussions of the broader chemical aspects of the problems which are involved in a thorough consideration of the relations of these waters, of correlative matters of geological interest, and of the physical phenomena belong properly to others.

The difficulties in the way of collecting and transporting large quantities of water in a region comparatively inaccessible were such that the number of large samples, for the more complete analyses, was restricted to a half-dozen; but, though at the beginning of the examination it was supposed that a partial analysis, such as might be made with smaller amounts of material, must suffice, it happened, fortunately, that the development of certain methods as the work progressed has so far extended the reach of the analyses of the smaller samples that from them it is possible to deduce results of fair accuracy, and, if such elements be left out of consideration as are shown by the more elaborate analysis to be present either not at all or only as traces in closely comparable waters, nearly as comprehensive results as those drawn from the examination of the larger samples.

OPERATIONS IN THE FIELD.

The examination of the waters was necessarily confined in the field to a very few points. Note was made of the *clearness* or *turbidity*, the *reaction* to litmus and turmeric, the *temperature*, and the presence or absence of *hydrogen sulphide.* The tests for the last were the sense of smell and the action of the water upon a polished silver blade.

The operations of collecting and preparing the samples for transportation were carried out as simply as possible. The water was bottled in boxed demijohns when it was possible, and otherwise in beer bottles, In every case great care was taken to clean the receptacle thoroughly and rinse before bottling with some of the water to be examined. In the greater number of cases the waters were so marvelously clear that filtration was entirely superfluous. When, however, the need and opportunity occurred the waters were filtered previous to bottling. All samples were corked tightly and sealed hermetically.

The size of the sample varied from a half liter to one hundred liters, according to the purpose for which it was taken; but the great bulk of the largest samples was, in every case excepting one, reduced greatly by the evaporation of the main portion of the sample previous to bottling. In the one exceptional case the sample was taken for the specific purpose of examining it as to its contents in the heavy metals, and was kept for subsequent reduction in porcelain in the laboratory, in order that the danger of contamination by the tin or copper of the tin-lined still which was employed to effect the reduction in the field might be precluded. No attempt was made to fix with more than a rough approximation the quantities of water evaporated. The concentrated waters, with the rinsings of the still in the natural water of the charge (such portions of the residue as adhered to the walls of the vessel having been dislodged as completely as possible by gentle friction with a rubber or the ball of the finger), were carefully bottled and sealed, and the determination of the degree of concentration was left to be effected in the laboratory in a manner to be described later. A portion of the water represented by the concentrated sample was always reserved in the natural condition for examination.

For the determination of hydrogen sulphide special samples of from 600 cm^3. to 700 cm^3. were generally taken, and to each, if the water did not carry free sulphur, was added before corking and sealing a small amount of lead acetate in crystals. Doubtless it might have been well to fix the hydrogen sulphide similarly in the case of waters carrying free sulphur, having first separated this by filtration; but on the few occasions when that need arose the means of removing the sulphur were not at hand. In these cases, therefore, the samples were simply bottled and sealed with care, and kept for examination in the laboratory.

Nearly all the waters examined were hot when the samples were taken and not surcharged with carbonic acid. It was considered unnecessary, therefore, under the circumstances, to take a special sample for the determination of the carbonic acid and treat it in the field so as to fix that gas in insoluble form, but for this estimation reliance was placed upon the general sample which, as has been said, was corked and sealed with great care.

OPERATIONS IN THE LABORATORY.

The operations in the laboratory comprised the determination of the specific gravity of the waters and, in the concentrated samples at hand, the estimation of the following substances:

* Silicic acid.
Titanic acid.
* Sulphuric acid.
Sulphurous acid.
* Carbonic acid.
Nitric acid.
Nitrous acid.
Phosphoric acid.
* Boric acid.
* Chlorine.
Bromine.
Iodine.
Fluorine.
* Sulphur.
* Hydrogen sulphide.
Copper.
Lead.
* Arsenic.
Antimony.
* Iron.
* Aluminum.
Manganese.
Barium.
Strontium.
* Calcium.
* Magnesium.
Cæsium.
Rubidium.
* Potassium.
* Sodium.
* Lithium.
* Ammonia.
* Albuminoid ammonia.

In analyses for which the natural water alone was available those substances only were sought which are marked in the table with an asterisk (*).

The determination of what is known as the *total residue*, the amount of solid matter left upon evaporating a known amount of water, is usually regarded as desirable, if for no other reason than to serve as a control of the summation of the determinations of the individual constituents; but the complexity of these waters and the relations of the combined salts are such that it is not possible to arrive at the same end in two successive treatments by evaporation and desiccation of the residue. The action of free silica, which is an abundant constituent of the waters, is to set free during the process carbonic acid from the carbonates and boric acid from the borates; to magnify the tendency of the chlorides of calcium, magnesium, and lithium to exchange chlorine for oxygen, and, if the temperatures be pushed sufficiently high, to dehydrate the silica and to volatilize sulphuric acid. Furthermore, the extent of such action is variable and indeterminate. There is obvious reason, therefore, for the difficulty which we experienced in obtaining residues of constant composition; and similar obstacles, as we found practically, oppose the attempt to reduce the residue to a definite condition by evaporation and ignition with sulphuric acid in excess. By means of no device which occurred to us (and several lines of experimentation which need not be mentioned here were followed) were we able to apply, in any form, this general method of control. The proof of the accuracy of our analytical work rests, therefore, upon the agreement of duplicate determinations.

For convenience in the matter of arrangement, we describe first those methods of analysis which were applied to waters in the natural condition; and the account of the treatment of concentrated waters follows. Methods for the determination of certain substances are described under both heads. For when the entire work was done upon the natural water the mode of examination was sometimes made, of necessity, by processes different from those which were applied in the examination of concentrated water; and under reversed conditions the converse was true. In some of the earlier analyses methods were employed which later experience taught us might be advantageously replaced by processes which were developed subsequently. In the account of the methods employed all of these are placed under the proper head; and in the statement of analyses mention is made, when there might be doubt of the particular method adopted.

TREATMENT OF NATURAL WATERS.

Specific gravity.—The figures which stand for the specific gravity of a water represent the weight of any volume of the water under consideration at 15.5° C. compared with the weight of the same volume of distilled water at the same temperature. The determinations were nearly all made with a Geissler bottle, fitted with a ground tubular stopper and cap, and a thermometer. In a few of the earlier determinations a bulb-apparatus similar in general principle, but wanting the immersed thermometer, was employed. The temperature of the water in the bottle was taken immediately after the final adjustment of volume, and the latter was effected instantly and without handling after the filled bottle had been permitted to stand a few moments to bring about an equal distribution of temperature. When the bulb-apparatus was employed the temperature of the water was taken before filling the bulb and after weighing, and the mean of the two readings was assumed to be the temperature of the water at the time when the volume was adjusted. The weight shown by the balance was taken as the weight of the water which would fill the apparatus at the temperature noted. The weight of the same volume of the water at 15.5° C. was calculated from the weight observed, upon the assumption that the co-efficient of expansion of the water under examination was the same as that of pure water. The rates of the value thus found to the value found by a similar treatment of pure water is the specific gravity at 15.5° C. It is obvious that, in order that the assumption of the identity of the co-efficients of expansion of the water under examination and of pure water may be the occasion of the least error, the observed temperature must be as near 15.5° C. as may be; and that the temperature of the balance-room should be not far from the same, in order that errors which may arise from changes of temperature in the water during the manipulation, and from the establishment of air-currents in the balance-case may be less liable to occur. So far as we were able these sources of inaccuracy were guarded against, but the conditions under which the work was performed necessitated the application of corrections rather greater than we should wish. The figures which represent the specific gravity in the statement of the analyses are probably not accurate beyond the fourth decimal place.

Hydrogen sulphide and free sulphur.—Hydrogen sulphide in waters which did not carry free sulphur was determined in the special sample to which lead acetate had been added in crystals at the time of bottling. Before breaking the seal of the bottle a scratch was made upon the neck on the line of the meniscus of the water within, and the volume of the sample—usually about 600 cm^3—was determined subsequently with sufficient accuracy (the amount of hydrogen sulphide present being always trifling) by finding the volume of water necessary to fill the bottle to the mark. The precipitate which had been formed in the bottle by the addition of lead acetate was left undisturbed at first, and the supernatant liquid decanted as completely as possible. Then the precipitate was easily removed, and for the most part dissolved by means of a little sodium hydrate in solution, and the solution and remaining precipitate were added to the water previously decanted. At this point the lead sulphide showed itself, if any was present, and was collected without difficulty by filtering the alkaline liquid in which it floated through a felt of asbestos in a perforated crucible, in the manner described by one of us previously.[1] The felt and the adherent precipitate were transferred to a beaker, treated with potassium chlorate and hydrochloric acid to oxidize the sulphide, and the sulphuric acid thus formed was determined by precipitation as barium sulphate. From waters carrying free sulphur that element was separated by filtration. The residue, after washing sufficiently to remove the sulphates, was treated with hydrochloric acid and potassium chlorate, and the resulting sulphuric acid was determined as barium sulphate. The filtrate from the sulphur contained the hydrogen sulphide, if it was present in the sample, and this was removed by lead acetate and estimated in the manner described above.

Sulphurous acid.—The test for sulphurous acid was made in the case of a few waters which did not carry more than a trace of hydric sulphide by titrating 200 cm^3 of the water, acidified with sulphuric acid, with a standardized solution of potassium permanganate. In none of these was a reducing action found greater than was attributable to the action of the hydrogen sulphide and arsenic (assumed to be in the condition of arsenious acid) known to be present.

Sulphuric acid.—The sulphuric acid was precipitated from a known weight of water, after acidifying distinctly with hydrochloric acid and heating to boiling by means of barium chloride. After cooling and

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[1] Am. Chem. Jour., vol. 1, 1879, p. 317.

settling, usually after twelve hours, the supernatant liquid was decanted as completely as possible from the precipitate and passed through an asbestos felt in a perforated crucible. The precipitate remaining in the beaker was boiled with a small portion of strong hydrochloric acid, and the latter was removed by evaporation on the water-bath. Treatment with hot acidulated water left the precipitate as pure as barium sulphate may be, and ready for collection upon the same felt through which the supernatant liquid had been poured. Thorough washing, ignition, and weighing completed the operation.

Nitric and nitrous acids.—In examining the waters as regards their contents in nitric and in nitrous acids a modification of the indigo method was followed. The action of these acids upon indigo is known not only to be variable with the conditions of dilution, temperature, and the proportion of sulphuric acid added, but also to be dependent upon the order in which the solution of indigo, the sulphuric acid, and the nitrous or nitric acid are intermixed. On this account great care was taken to secure uniformity of treatment of the standard solutions and the water under the test. For preliminary testing a portion of water was reduced by evaporation to a volume of 50 cm^3. cooled to the temperature of the air, introduced into an Erlenmeyer flask, and mixed with an equal volume of strong sulphuric acid. To the mixture the solution of indigo was added until a distinct tinge of green became visible. In this manner the amount of the solution of indigo from which a given amount of the water under test would discharge the color became known approximately. For the exact test the portion of water, after evaporation and cooling, was brought to a volume which was less than 50 cm^3. by an amount equivalent to the volume of the solution of indigo used in the preliminary test. To the portion thus prepared were added 50 cm^3. of strong sulphuric acid at once, and the solution of indigo as rapidly as the catching of the exact point at which the tinge of green appeared would permit. At the instant of coloration the flask with its contents was placed in a bath of paraffine heated to 140° C. The volume of the solution of indigo which had been added was noted and, if at the end of five minutes' heating in the bath the tinge of color was still visible, this volume was taken as the measure of the nitrates and nitrites in the water. If, on the other hand, the color vanished during the heating, it was reproduced by the addition of more indigo, and the digestion in the bath at 140° C. was prolonged during another interval of five minutes.

This mode of treatment was repeated until the coloration was permanent during the interval of digestion. The total volume of the solution of indigo employed was recorded, and its value in terms of nitric acid determined in the manner to be described.

As Warrington has shown,[1] the oxidizing power of nitric acid upon indigo decreases as the dilution of the solution in which the action takes

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[1] Jour. Chem. Soc. London, 1879, p. 578.

place increases. It is plain, therefore, that in order that the exact value of the volume of the indigo solution employed in the test may be known, the amount of nitric acid needed to discharge the color from an equal amount of the same solution under the conditions of the test must be determined. To effect this determination we made use of a solution of potassium nitrate of known strength, and found by experiment the amount of it which, mixed with 50 cm^3. of strong sulphuric acid, with water enough to bring the final volume to 100 cm^3., and with the amount of the solution of indigo employed in the test, was just adequate to discharge all color excepting the faint characteristic tinge which must remain unchanged after five minutes' heating. The oxidizing power of the nitrates and nitrites in the water is exactly measured by the amount of nitric acid in the quantity of the standard nitrate solution which is required to produce the end-reaction. The solution of potassium nitrate which we used contained 0.0001 g. to 1 cm^3. The mode of manipulation which we adopted keeps the proportion of strong sulphuric acid added to the mixture (excepting the preliminary tests) always the same, and consequently the heat generated in the reaction is the same always. The order in which the re-agents are brought together is the same in all cases, and sources of inaccuracy due to the variability of the action of nitric acid with the degree of dilution are eliminated.

Carbonic acid.—The greater number of the waters with which we have had to deal were hot when the sample was taken, and not surcharged with carbonic acid. In view of the circumstances under which the waters were collected it was thought that a portion of the general sample, which was carefully sealed, might be made to serve the purpose of determining the carbonic acid contained in the water, instead of portions taken specially for that end and treated in the field with a mixture of ammonia and calcium chloride to fix the carbonic acid gas. Accordingly dependence was placed upon the large general sample for this estimation. The presence of free silica in the waters and the complexity of composition place so great an obstacle in the way of determining the *free carbonic acid* that the attempt to make the estimation was not undertaken. The method which we adopted for the determination of the *total carbonic acid* is that well-known process which rests upon the boiling of the acidified liquid and the absorption and weighing of the gas evolved. The apparatus which we employed, differing somewhat from that in ordinary use for this purpose, is shown in Fig. 1. It consisted essentially of a flask in which to boil the water, a cooler to return the condensed steam to the flask, a U tube filled with anhydrous cupric sulphate to intercept traces of hydrochloric acid which might escape condensation in the cooler, a second U tube charged with calcium chloride to dry the gas, potash bulbs to retain the carbonic acid, and two tubes filled with calcium chloride, one of which was to retain moisture carried over from the potash bulbs and was weighed with them, the other serving to protect the weighed tube from the action of the external air. Through the rubber stopper of the flask passed the tube of a separating funnel, the end of the condensing tube, and a tube which connected the interior of the flask with the system of bottles and scrubbing tower, which furnished at will and under slight pressure a supply of dry air free from carbonic acid.

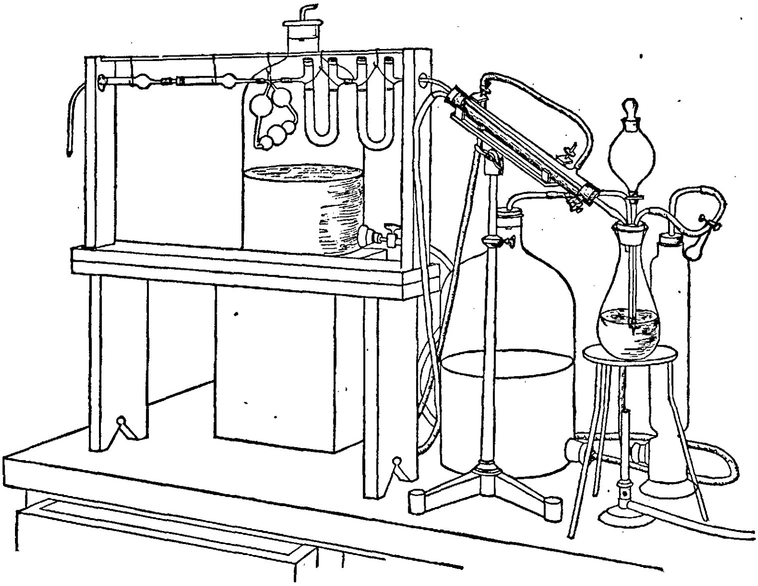

FIG. 1.—Apparatus for the estimation of carbonic acid.

Before beginning the operation of determining the carbonic acid in a water the atmospheric air was expelled from the apparatus and replaced by pure air free from carbonic acid. The stop-cock in the funnel tube and the connection with the aspirator having been closed, the water started through the cooler, and the joint broken between the potash bulbs and the drying tube immediately preceding it, a few cubic centimeters of distilled water were put into the flask and boiled. The steam generated drove the air from the flask, and that remaining in the tubes was swept forward by pure air admitted from the aspirator. The outer opening of the tube at the end of the line was closed, the source of heat removed, and the flask allowed to fill with air from the aspirator. The whole apparatus having been filled thus with air free from carbonic acid, the water to be examined—we found 200 g. to be a convenient amount—was introduced into the flask through the funnel tube and followed by a little boiled water and a sufficiency of sulphuric acid, care being taken to exclude the outer air during the operation. The connection between the line of drying tubes and the absorption bulbs was re-established, the liquid in the flask was brought to the boiling point, and, to secure constant and quiet ebullition as well as to aid in transferring the carbonic acid from the flask to the absorption bulbs, a current of pure air was sent slowly through the boiling liquid which covered the end of the aspirating tube and that of the funnel tube. At the end of half an hour the burner was removed from under the flask and the apparatus was permitted to cool during another half hour, the current of air being kept in motion through it. The difference between the weights of the potash bulbs, with the drying tube which accompanies them, before and after the operation, was taken to be the weight of carbonic acid absorbed, and the *total carbonic acid* of the portion of water examined.

When the water under examination contained hydrogen sulphide, a little cupric sulphate was introduced before acidifying into the portion which was to serve for the determination of carbonic acid.

Arsenious acid and boric acid.—To the portion taken for analysis—usually 500 g.—hydrochloric acid was added in distinct excess, the temperature of the liquid was raised to 70° C., and the source of heat having been removed, hydrogen sulphide gas was introduced in a gentle current for several hours. The precipitation of the arsenious sulphide began at once, but the action of the precipitant was continued to insure completeness. The precipitate was collected upon an asbestos felt, washed, and dissolved in fuming nitric acid. The solution in nitric acid was evaporated to dryness, the residue was dissolved in hydrochloric acid, and from this solution, made strongly ammoniacal but kept small in volume, the arsenic was precipitated by the addition of the magnesium chloride mixture and brisk agitation. The precipitated ammonium-magnesium arsenate was allowed twelve hours in which to settle and was then transferred by means of the mother liquor, without the use of other liquid, to a perforated crucible carrying an asbestos felt, washed thoroughly with the mixture of one part of ammonia to three of water, usually employed for this purpose, but with the sparing use of the washing material which this mode of filtration permits, dried carefully, ignited gently at first, and at a low red heat afterward, in an atmosphere of oxygen. The great faults of this process, originally Levol's, have been the solubility of the precipitate in the mother liquor and, more especially, in the ammoniacal wash water, and the difficulty in drying or igniting the precipitate collected on paper. These sources of inaccuracy vanish, however, so completely with the use of the asbestos filter and due care in keeping the volume of mother liquor and the washings small, that the filtrate, freed from ammonia, acidified and charged with hydrogen sulphide, fails to yield arsenious sulphide. As a test for the presence of arsenic the method has enjoyed an excellent reputation, and in the form in which we have made use of it we believe it to be exact.

The filtrate from the precipitate of arsenious sulphide, containing all the boric acid, was nearly freed from hydrogen sulphide by the transmission of air, and the chlorine, with residual traces of hydrogen sulphide, was removed by treatment with silver nitrate and filtration. The filtrate from the precipitated sulphide and chloride was treated with sodium hydrate, in quantity a little more than sufficient to precipitate the excess of silver, as completely as may be. The whole was evaporated until the precipitate took on a compact and granular form, then filtered, and the filtrate was evaporated nearly to dryness. The residue was treated with nitric acid, first just to acidity, and then with a sufficient (measured) amount to make it certain that the boric acid was entirely free. The concentrated solution of the nitrates, nitric acid, and boric acid was drenched with methyl alcohol to precipitate the first and dissolve the last. The solution of boric acid was quickly separated from the precipitate by means of the vacuum filter, and the residue washed sufficiently with methyl alcohol. When much boric acid is present the precipitated nitrates should be dissolved in water and the process of precipitation with methyl alcohol repeated; but when small quantities are dealt with, as was the case in the most of our work upon these waters, a single treatment leaves no boric acid in the residue. From the solution in methyl alcohol, the boric acid was separated and its amount estimated by a method devised by one of us and described elsewhere in full.[1]

This process consists essentially in distilling to dryness the solution in methyl alcohol, containing free nitric acid and nitrates, and treating

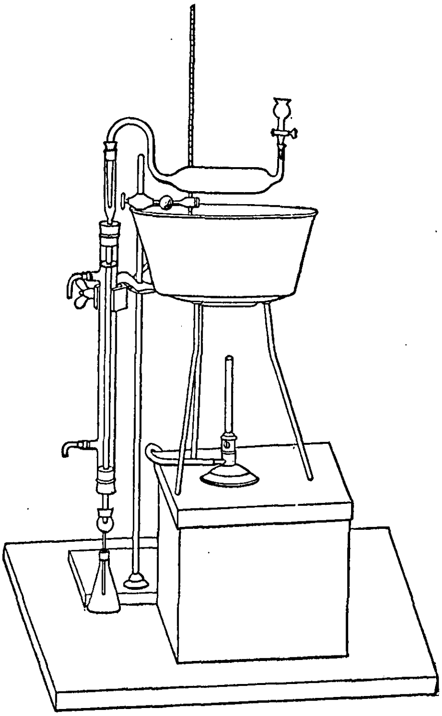

Fig. 2.—Apparatus for the estimation of boric acid.

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[1] Bulletin of the U. S. Geological Survey, No. 42. Am. Chem. Jour., vol. 9, p. 23.

the residue by successive drenchings with methyl alcohol and distillations. The distillate, carefully protected, contains at the end of the operation all the boric acid, and this is fixed as calcium borate by the evaporation of the distillate over lime. The difference between the weight of ignited lime and the weight of the same after having been submitted to the action of the alcoholic solution and ignition is the weight of boric anhydride in the solution.

The distillation was effected by means of an apparatus which consists of retort, condenser, and bath for heating (Fig. 2). For the last a bath of paraffine is on the whole most convenient. The condenser is set vertically to facilitate changing the level of the retort within the bath, and to secure at the same time continued and thorough washing of the tube by its own condensations. The retort, somewhat like the well-known drying tube of Liebig in general shape, is easily made of a pipette by bending the tube at one end to a right angle, at the other to a goose-neck, as shown. To the former end is fitted, by a rubber stopper or section of tubing, a glass funnel-tube provided with a stop-cock; the end of the goose-neck passes tightly through a rubber stopper in the upper end of the condensing tube. This is essentially the apparatus; but it is convenient to attach, to receive the distillate, a small Erlenmeyer flask, which moves with the condenser and is joined to it, in the manner indicated in the figure, by means of a thistle tube and a rubber stopper grooved to permit the free passage of air. In carrying out the distillation the liquid is introduced into the retort either by the funnel tube or previous to its insertion, the glass stop-cock is closed, the water started through the condenser, and the retort lowered into the hot paraffine, care being taken to begin the operation with the retort not more than half full and so inclined that only the rear dips below the surface of the bath. If the precaution to heat the retort at the start in this manner be overlooked it may sometimes happen that the sudden and violent expulsion of air through the liquid will carry portions of it bodily into the goose-neck and even into the condenser. With this point considered, the remainder of the operation presents no difficulty and requires little care. The size of the retort may be suited, of course, to the particular case in hand, but for most purposes a pipette of 200 cm^3. capacity makes a retort of convenient dimensions, neither too large for the distillation of small charges nor too small to permit the treatment of 100 cm^3. of liquid comfortably. The tube of the goose-neck should be wide enough to prevent the formation of bubbles in it; 0.7 cm. is a good measure for the interior diameter. It is of advantage to heat the bath to a point considerably above the temperature at which the liquid to be distilled boils—something between 130° C. and 140° C. does very well for water, and is not too high for methyl alcohol—and under such circumstances, and when the retort is entirely submerged, it often happens that evaporation takes place with extreme rapidity from the surface of the liquid in perfect quiet and without actual boiling.

Experiment showed that six successive treatments by drenching with 10 cm^3. of methyl alcohol and distillation to dryness were more than adequate to remove 0.2 g. of boric anhydride entirely from a residue containing 2 g. of sodium nitrate; but, in order to break up the crusted residue, which by its insolubility in the alcohol might effect to some extent the protection of the boric acid from the action of the alcohol, it was found best to introduce and evaporate 2 cm^3. of water between the second and third, and again between the fourth and fifth distillations. In most of the cases with which we were concerned in the work upon these waters four treatments by drenching and distilling, with one intermediate moistening with water, were entirely sufficient to volatilize the boric acid; but in every case the residue was examined for boric acid by the exceedingly delicate turmeric test, taking care to first oxidize nitrites by means of bromine, and to expel the last before applying the test.

When the solution of boric acid in methyl alcohol is put over lime and evaporated at once some volatilization of the boric acid is apt to take place; but a short period of digestion—from five to fifteen minutes—is sufficient to fix the boric acid completely.

To secure the proper exposure before evaporation, with the least delay, the lime which is to retain the boric acid, first ignited in the crucible in which the evaporation is to be made subsequently, is transferred to the receiving flask attached to the condenser before the distillation is begun, and so has opportunity to exert its action upon the boric acid as the distillation progresses. At the end of the distillation the distillate, containing the alcohol, boric acid, nitric acid, and lime, is transferred again to the crucible, evaporated to dryness at a very gentle heat, and ignited to a constant weight over the blast lamp. The greatest care is to be taken to secure similarity of conditions under which the crucible and lime are weighed before and after ignition, and definite periods of cooling before weighing—ten minutes is a suitable time—should be allowed to pass, in order to eliminate, as far as possible, the effect of atmospheric condensation upon the large surface of platinum.

The tendency of the process is to yield figures slightly larger than the truth, as was shown in the test analyses which are given in the full description of the process, to which reference has been made. In distilling 0.2 g. of boric anhydride and fixing it in 1.5 g. of calcium oxide, the mean error was shown to be about 0.0010+g. In the work upon the waters parallel determinations rarely differed by more than that amount.

Chlorine (with bromine and iodine).—The precipitation of chlorine, together with bromine and iodine, was usually effected without difficulty by treating the weighed portion of water—from 100 g. to 500 g., according to the circumstances—with nitric acid to a slightly acid reaction and silver nitrate in excess, directly and in the usual manner, excepting that the operation was effected in the cold and that the whole was allowed to stand quietly in the dark for several hours to secure perfect subsidence of the precipitate. In only one or two cases did the silica, which the waters carry abundantly, give rise to trouble in the precipitation. In such cases comparative tests were made as just described upon portions treated previously with an excess of pure sodium hydrate, it having been noticed that certain very siliceous waters, which of themselves very quickly filled the pores of the filter with an invisible coating of silica, could be made to filter with rapidity by first treating them with sodium hydrate in excess, and then with nitric acid to slight acidity. Treatment with acid alone did not bring about the desired condition of the silica. In the case of the water of the Coral Spring the proportion of silica is so great and its character such that to secure satisfactory results we were obliged to convert the silica to hydrofluosilicic acid, by the addition of hydrofluoric acid and nitric acid, before precipitating the silver salt. The silver chloride (including the bromide and iodide) was collected upon asbestos in a perforated crucible, dried directly over the free flame of a Bunsen burner turned very low and at a temperature below its melting point, and weighed. In the case of waters containing hydrogen sulphide in quantity precipitable by silver nitrate the portion for analysis was rendered ammoniacal before the addition of the silver salt, and the precipitated silver sulphide was filtered off. The silver salts of the halogens were then precipitated from the filtrate by nitric acid, and the process was completed as described.

Silica, iron and aluminum, calcium, and magnesium.—A single weighed portion of water served for the determination of the silica, iron and aluminum, calcium and magnesium. The water was acidified with hydrochloric acid, evaporated to dryness in platinum over the water-bath, again acidified and again evaporated. The residue was digested with hot water containing a little hydrochloric acid, and the solution was filtered from the residue of silica, which was ignited in platinum and tested as to its purity in the usual manner with hydrofluoric acid.

In the filtrate ammonia, in the slightest excess, precipitated ferric and aluminic hydrates from the boiling solution, and these were collected, ignited, and weighed as oxides in the usual manner. The lime was thrown out of the hot ammoniacal filtrate by ammonium oxalate, and the calcium oxalate filtered off after standing twelve hours in the cold. When the amount precipitated exceeded a few milligrams it was dissolved in hydrochloric acid, reprecipitated by ammonia and ammonium oxalate and collected upon a filter, the filtrate from the second precipitation being added to that from the first. The calcium oxalate was dried, ignited, and weighed as calcium oxide.

The filtrate (or the united filtrates) from the calcium oxalate was evaporated in platinum, and the residue was gently ignited to destroy the ammonium oxalate—which tends to delay the precipitation of the magnesia if permitted to remain in the solution—and dissolved in hydrochloric acid. From this solution the magnesia was precipitated in the usual manner by microcosmic salt and ammonia, and after standing twelve hours or more, the phosphate was collected upon asbestos in a perforated crucible, washed with the mixture of one part of ammonia to three of water, commonly used in the process, moistened at the end of the washing with a strong solution of ammonium nitrate in ammonia, ignited for a moment to redness, and weighed as the pyrophosphate.

Sodium, potassium, and lithium.—In some of the earlier work only sodium and potassium, of the alkalies, were determined in the natural water, and for the determination of the lithium portions of the concentrated water were treated by the method which will be referred to later. In the greater number of cases the same portion of the natural water served for the determination of lithium as well as sodium and potassium. The portion for analysis was acidified in platinum with hydrochloric acid and evaporated to dryness. The residue was extracted with hot water slightly acidulated with hydrochloric acid, the solution was separated from the precipitated silica by filtration, and to the filtrate was added, with care to secure a sufficiency and yet to avoid a great excess, barium hydrate made from the nitrate, itself purified by precipitation by nitric acid. Filtration separated the precipitated hydrates of aluminum, iron, and magnesium, with barium sulphate; and from the filtrate ammonium carbonate and ammonia precipitated, upon boiling, nearly the whole of the barium and calcium as carbonates. The filtrate from the precipitated carbonates was evaporated to dryness, and the residue was gently ignited to remove ammonium chloride, treated with hydrochloric acid, freed from the excess of acid by evaporation on the water-bath to dryness, dissolved in a very small amount of water, and treated again with a few drops of the solution of ammonium carbonate and ammonia. This treatment usually results in the precipitation of traces of barium carbonate which have previously escaped removal by the similar treatment of the larger volume of liquid. The filtrate from this last slight precipitate was again evaporated and treated as before; and, in case any further precipitation took place, the process was repeated until the purification was complete. Usually, however, the first precipitation in the larger volume of liquid and the second treatment in the solution reduced to small bulk are together sufficient to remove the barium carbonate completely. The filtrate from the last precipitate was evaporated in a weighed platinum dish, and the residue, consisting of the chlorides of sodium, potassium, and lithium, was dried, gently ignited, and weighed.

From the mixed chlorides the lithium salt was separated by a process which, devised by one of us during the progress of the work and described elsewhere in full,[1] needs but brief outlining in this place. To the concentrated solution of chlorides amyl alcohol is added and heat is applied, gently at first to avoid danger of bumping, until, the water

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[1] Bulletin of the U. S. Geological Survey, No. 42, p. 73; Am. Chem. Jour., vol. 9, p. 33.

disappearing from solution and the point of ebullition rising and becoming constant for some minutes at a temperature approximately that at which the alcohol boils by itself, the chlorides of sodium and potassium are deposited, and the lithium chloride is dehydrated and taken into solution. At this stage of the proceeding the liquid is cooled, a drop or two of strong hydrochloric acid being added to reconvert traces of lithium hydrate possibly in the deposit, and the boiling is continued until the alcohol is again free from water. If the amount of lithium chloride present in the mixture of salts is small it is now found in solution; the chlorides of sodium and potassium, excepting the traces for which correction will be made subsequently, are in the residue; and the separation may be effected by filtration and the washing of the residue with amyl alcohol previously dehydrated by boiling. If, on the other hand, the weight of lithium chloride present exceeds ten or twenty milligrams it is advisable, though not absolutely essential to the attainment of fairly correct results, to decant the liquid from the deposit, wash the latter with a little anhydrous amyl alcohol, dissolve in a few drops of water, and repeat the separation by boiling in amyl alcohol.

The filtrates, first measured apart, are united with the washings and evaporated to dryness, and the residue, treated with sulphuric acid in excess, ignited gently at first and finally to the fusing point, is weighed as the neutral lithium sulphate, containing traces of the neutral sulphates of sodium and potassium. From the weight thus found the subtraction of 0.00109 g. for every 10 cm^3. of filtrate exclusive of washings makes the proper correction for the amounts of the sodium and potassium salts present, and the residual weight represents the pure lithium sulphate. In cases where the precipitate consists solely of sodium chloride, the correction upon the weight of the sulphate is 0.00050 g.; when potassium chloride constitutes the residue the correction amounts to 0.00059 g. for every 10 cm^3. of filtrate. The alcohol used in washing has, within reasonable limits, no appreciable solvent effect upon the precipitate.

The precipitate, consisting entirely of sodium chloride and potassium chloride, is ready for the balance after drying a few minutes directly over a flame turned low, if the filtration is effected by means of asbestos in the perforated crucible; if paper is used as the filtering medium, after the solution of the precipitate, the evaporation of the solution and the gentle ignition of the residue. The weight of the insoluble chlorides actually obtained is corrected for the solubility of the salts in amyl alcohol by adding 0.00092 g. for every 10 cm^3. of amyl alcohol in the filtrates, exclusive of washings; 0.00041 g. of this representing the sodium chloride dissolved, and 0.00051 g. the potassium chloride. With due attention to the reduction of volume of the residual alcohol before filtering the correction may be held easily within narrow limits.

In applying this method to the analysis of the waters of the Yellowstone Park the practice of reducing the volume of amyl alcohol to about 15 cm^3. before filtering was followed uniformly. The corrections, therefore, were always the same, and amounted to an addition of 0.0007 g. to the apparent weight of sodium chloride, 0.0008 g. to that of potassium chloride, and a subtraction of 0.0017 g. from the weight of lithium sulphate indicated by the balance. In many cases the lithium present in the waters, though capable of detection by the spectroscope, amounted to so little in the portions devoted to its determination that the application of the correction left nothing to be called lithium sulphate. In such cases the lithium is counted as a "trace."

From the mixture of sodium chloride and potassium chloride the potassium salt was separated as potassio-platinic chloride. The chlorides were dissolved in a small amount of water, platinic chloride was added in solution, in quantity considerably in excess of the amount necessary to effect the conversion of all the potassium and sodium present to the double platinum salts, and the mixture evaporated on the water-bath to the point at which the residue becomes pasty if removed from the bath and allowed to cool. The crust thus formed was drenched with alcohol of 80 per cent., digested in the cold until thoroughly disintegrated, filtered off on an asbestos felt, washed with alcohol of 95 per cent., dried at a gentle heat, and weighed.

The lithium and potassium having been thus found directly, the sodium is given, in the form of the chloride, by the difference between the sum of the lithium and potassium chlorides and the total weight of the three chlorides; or, by the difference between the weight of potassium chloride found and the weight of the chlorides of potassium and sodium found (the proper correction having been applied) after the separation of the lithium. It may be urged against the former plan that to bring the three chlorides to a definite condition for weighing is a difficult undertaking in view of the great tendency of lithium chloride to exchange chlorine for oxygen in the presence of water. Our experiments indicated, however, that under repeated treatments by moistening and ignition the mixed chlorides did not change in weight materially, and we are disposed to attribute the result in part to the protective influence of the sodium and potassium salts upon the relatively small amount of lithium chloride, and in part to the care taken to secure thorough drying at a low temperature previous to the gentle ignition. In our work upon the waters we weighed the three chlorides together and found the sodium chloride by deducting from this weight the weights of potassium chloride and lithium chloride deduced by analysis.

A weak point in the process which we have employed in the determination of the alkalies would seem to be found in the separation of the magnesia by means of barium hydrate. In connection with this subject it is of interest to note that in the greater number of waters magnesia was present only in inconsiderable quantity, and further, that in the case of those in which it did appear in appreciable amounts the examination of the solution of the lithium sulphate, after the separation by amyl alcohol, failed to indicate the presence of magnesia in amount sufficient to be precipitable by microcosmic salt in an ammoniacal solution and under the usual conditions of the test, though this would be the place in which magnesia should appear if it had escaped removal from the chlorides. We are constrained to believe, therefore, that the process of separation which we adopted was exact within reasonable limits.

Ammonia and albuminoid ammonia.—The determination of ammonia was effected in the usual manner by distilling a measured portion of water with sodium hydrate, and nesslerizing the distillate. A second portion of water was distilled with sodium hydrate and potassium permanganate, and the distillate was nesslerized. The former process gives the combined ammonia present in the water; the latter the total ammonia, which includes, beside the ammonia existing as such in combination, that ammonia which is developed from other nitrogenous compounds by the action of the permanganate. The difference between the figures of the two processes is the albuminoid ammonia, so called. The composition of these waters renders them peculiarly liable to boil explosively, and some difficulty was experienced at first in the distillation; but the apparatus which is described in the paragraph on the determination of the boric acid proved to be of service in this case also, and made the determination practicable. The Nessler solution was very delicately adjusted, and the tests were made in small tubes and carried to the limit of 0.000001 g.

TREATMENT OF CONCENTRATED WATERS.

In the examination of the concentrated waters the whole sample was evaporated to dryness, and the residue thus left was extracted with hot water. It is usual in treating concentrated waters to add sodium carbonate during the evaporation, and to wash the residue until the washings cease to show an alkaline reaction. Four of the waters of which we had concentrated samples were, however, so alkaline of themselves that the addition of sodium carbonate was superfluous, and all were so siliceous that to wash the residue of evaporation until it was free from alkali was a matter of the greatest tediousness and difficulty. We found it best and sufficient to wash only to the vanishing point of the spectroscopic reaction for lithium in the washings. In this manner the separation of the greater part of the silica with the insoluble constituents of the water was effected without an entirely unreasonable expenditure of time and effort. The filtrate and washings were thoroughly mixed and made up to a definite weight. The residue was kept by itself for separate treatment.

The filtrate should contain the bromine, iodine, boron, arsenic, antimony; the copper, lead and tin, which can be present in the waters only in traces; the lithium, cæsium, rubidium, thallium, and part of the silicon and aluminum. The precipitate should contain the titanium, phosphorus, fluorine, iron, manganese, barium, strontium, calcium, magnesium, with the remainder of the aluminum and silicon.

STRENGTH OF THE CONCENTRATED WATERS.

The degree to which the concentration of the waters had been carried in the field was fixed by the determination of the total amount of halogens in a weighed portion of the extraction of the residue of evaporation. This portion was diluted, acidified with nitric acid, treated with silver nitrate until the precipitate ceased to form, and the last was collected on asbestos in a perforated crucible, dried (over the free flame of a Bunsen burner turned low) at a temperature considerably below its melting point, and weighed. Determinations of this sort were made in duplicate. Knowing the weight of the silver salt thus found and the weight of the same precipitable from a known weight of the natural water, the exact value of the concentrated water, in terms of the natural water which it represented, became known.

TREATMENT OF THE RESIDUE.

Fluorine.—The residue, dried by gentle heating, with the ash of the filter employed in separating and washing it, was placed in a retort of the pattern described in the section treating of the determination of boric acid in the natural water, drenched with strong sulphuric acid, and heated to 150° C., while a slow current of dry air was forced through the emulsion and thence directly into a U tube partly filled with dilute ammonia. The fluorine contained in the water should appear in the residue as calcium fluoride, should be volatilized as silicon fluoride by the action of the sulphuric acid, and, if present in more than very small amounts, should be indicated by the precipitation of silica in the U tube containing ammonia. Proceeding in this manner we found in the waters which we examined no fluorine; and on treating the ammoniacal liquid of the U tube according to the method of Berzelius, with zinc oxide dissolved in ammonia, evaporating until the solution ceased to evolve ammonia, filtering, adding to the filtrate calcium chloride followed by sodium carbonate, boiling, igniting the precipitate and extracting it with acetic acid, we were not able to detect a residue of calcium fluoride; nor in the zinc oxide precipitated by the expulsion of the ammonia dissolving it could we discover silica.

Barium and strontium.—The contents of the retort were transferred to platinum, treated with hydrofluoric acid (purified by redistillation) in sufficient amount to volatilize all silica, and evaporated to dryness with a little sulphuric acid. To insure thoroughness of action this process of treatment was repeated. The residue was fused with sodium carbonate and the melt was extracted with hot water containing a few drops of alcohol. The precipitate was separated from the solution by filtration and digested with hot dilute acetic acid, which should dissolve the barium, strontium, calcium, and magnesium carbonates. The solution in acetic acid, separated by filtration from the portion unacted upon, was nearly neutralized with ammonia, and to it was added in solution an amount of ammonium sulphate equal to fifty times the weight of the alkaline earths present, the whole being permitted to stand quietly twelve hours. By this treatment barium and strontium should be precipitated as sulphates, while calcium and magnesium should remain dissolved. The sulphates of barium and strontium may be separated afterward by digestion during twelve hours (at the ordinary temperature and with frequent stirring) in ammonium carbonate, the decantation of the supernatant liquid, the repetition of the treatment with ammonium carbonate, and, finally, the action of hydrochloric acid upon the residue—the strontium carbonate dissolving and the barium sulphate remaining insoluble in this acid. This mode of separating the barium and strontium was not actually applied in our work, inasmuch as we obtained from the quantities of water with which we had to deal no precipitate by ammonium sulphate, and it is mentioned only for the purpose of completing the scheme of analysis.

The solution which had been treated with ammonium sulphate to precipitate barium and strontium was preserved for subsequent examination for manganese.

Phosphoric acid.—The extract of the fusion in sodium carbonate was acidified with nitric acid, evaporated to small bulk, and from it the phosphoric acid was precipitated in the usual manner as a phosphomolybdate of ammonia. The precipitate, after standing twelve hours, was separated by filtration through a felt of asbestos in a perforated crucible, washed with the precipitant, and dissolved in ammonia. From this solution the phosphoric acid was precipitated by the magnesium and ammonium chloride mixture, and the ammonio-magnesium phosphate was filtered off on asbestos, washed with dilute ammonia (one part of ammonia to three of water), moistened with ammonium nitrate in ammonia, dried, ignited at a red heat, and weighed as magnesium pyrophosphate.

Manganese.—The residue left, after the extraction of the fusion in the sodium carbonate with water containing a little alcohol and the treatment with acetic acid, was fused again in a little sodium carbonate, the melt was dissolved in the crucible by heating with strong sulphuric acid, and this solution was poured into cold water. In this manner was obtained a solution containing the titanium and iron, and a part of the aluminum and manganese. From it all these elements, excepting the last, were precipitated by adding ammonia to an alkaline reaction followed by acetic acid to faint acidity, and boiling. The precipitate was kept for examination later. The solution was mixed with that which had been treated with ammonium sulphate in the test for barium and strontium, and to the mixture, heated on the water bath, were added ammonia in excess and bromine water. The precipitate thus obtained was ignited and weighed as Mn_3O_4, it being so trifling that solution and reprecipitation as the phosphate was unnecessary.

Iron.—The precipitate of ferric, titanic and aluminic hydrates was fused in a little sodium carbonate, the fusion was dissolved in strong sulphuric acid, this solution poured into cold water, and the dissolved iron, titanium, and aluminum were separated as follows, by a process devised by one of us and described fully elsewhere.[1] Tartaric acid, amounting to three times the weight of the oxides of iron, aluminum, and titanium present, was added to the solution, which was then made faintly ammoniacal and submitted to the action of a current of hydrogen sulphide. The precipitated ferrous sulphide was filtered off (care having been taken that the solution should still be alkaline before filtering), washed with hot water sufficiently but expeditiously, dissolved in hydrochloric acid, and the iron, first oxidized by bromine, was precipitated by ammonia and weighed as the oxide.

Titanic acid.—The filtrate from the ferrous sulphide was acidified strongly with sulphuric acid, heated to the boiling point, and treated with potassium permanganate until its characteristic color appeared. The final products of the action of the permanganate upon the tartaric acid are carbonic acid and water, but formic acid appears as an intermediary step in the oxidation. During the first action of the permanganate its conversion to manganous sulphate is rapid, but with the development of formic acid there takes place by its action upon the permanganate freshly added a precipitation of a brown hydrate of manganese which, redissolving readily so long as tartaric acid remains, yields only slowly to the further action of the formic acid. When, therefore, manganic hydrate appears abundantly in the boiling solution and does not dissolve perceptibly one may be reasonably certain that the conversion of the tartaric acid to at least the intermediary stage has been accomplished; but for the sake of greater security, the addition of the permanganate may be continued until the appearance of its color. When the amount of tartaric acid in the solution is known, as should be the case always, a simple mode of proceeding is, perhaps, to employ for the oxidation the amount of permanganate theoretically required. A weight of potassium permanganate amounting to two and a half times the weight of the tartaric acid to be destroyed is sufficient to carry the oxidation to the ultimate limit, providing there be no deposition of a manganic hydrate.

The residual permanganate and the insoluble hydrate were reduced and dissolved by the addition of a little ammonium bisulphite to the acid solution, and, the excess of sulphurous acid having been boiled off, acetic acid was added to the clear solution in quantity sufficient to make

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[1] Bulletin of the U. S. Geological Survey, No. 27, p. 16; Am. Chem. Jour., vol. 7, 1885-'86, p. 283.

the amount of the absolute acetic acid present from 7 to 11 per cent. by volume; enough sodium acetate was introduced to fix all the sulphuric acid as sodium sulphate, and the solution was boiled. If titanium is present it is precipitated under these conditions, while the aluminum remains dissolved. If the quantity of the precipitate thus obtained is considerable, it should be filtered from the liquid in which it floats and purified from the traces of manganese which it may carry, by fusion in a small quantity of sodium carbonate, the solution of the melt in sulphuric acid, and reprecipitation by ammonia.

In the waters which we examined we found no precipitate of titanic hydrate at the point in the process where it should appear were titanium present.

TREATMENT OF THE AQUEOUS SOLUTION.

The aqueous solution, its degree of concentration having been determined in the manner already described, was divided into five portions. Two of these were taken for the determination of bromine, iodine, lithium, cæsium, rubidium, and thallium, in duplicate; two for the determination in duplicate of arsenic, antimony, tin, copper, lead, and boron; and the remaining portion was reserved to be used in an emergency.

Iodine and bromine.—The portion for the determination of the elements of the former group was weighed and evaporated to a pasty condition. The residue was thoroughly extracted with strong alcohol, treated with water reduced again nearly to dryness, and again extracted with alcohol. The extract was evaporated after the addition of a drop or two of a strong solution of sodium hydrate, and this residue was extracted with alcohol like the former residue. The residues of the extractions with alcohol were kept for subsequent treatment. The alcoholic solution containing presumably all the iodine and bromine, with a small proportion of the chlorine originally in the water, was evaporated to dryness, and the solution of the residue in water was acidulated with sulphuric acid mixed with a solution of ferric sulphate introduced into a retort of the pattern previously described and figured in connection with the determination of boric acid in the natural waters, and distilled. The distillate was collected in a U tube attached to the condensing tube and sealed with carbon disulphide and water. If iodides are present in the retort to the minutest degree the iodine is set free as such, its characteristic color appears in the seal of carbon disulphide, and its amount may be determined by titration in the usual manner with sodium hyposulphite.

In the waters which we examined iodine was not present in sufficient quantity to appear in the test of the amounts at our disposal.

To the liquid remaining in the retort after the distillation had been prolonged sufficiently to insure the complete volatilization of the iodine a few crystals of potassium permanganate were added, and the distillation was continued. This distillate was collected as before in a **U** tube joined to the condenser, but the seal was made with chloroform and water. At the beginning of the operation the seal of the **U** tube showed in most cases the characteristic color of bromine, but this was discharged before the end of the operation by the excess of chlorine and replaced by the color of the latter. The contents of the **U** tube were transferred to a beaker and treated with pure sodium hydrate and zinc, and from the solution of sodium bromide and chloride thus obtained the silver salts were precipitated by silver nitrate, in the usual manner, after acidifying with nitric acid. The silver bromide and chloride thus precipitated were collected together upon asbestos in a perforated crucible, dried, weighed, and dissolved in potassium cyanide. From the cyanide solution the silver was deposited by electrolysis, according to the process described elsewhere by one of us for the indirect estimation of bromine in the presence of chlorine.[1] In this manner we obtained the weight of the mixture of silver chloride and silver bromide, and the weight of the silver contained in the mixture. The amounts of bromine and chlorine in the mixed salts were determined from these data by the solution of a simple algebraical equation.

Lithium.—The contents of the retort after the distillation of the bromine were united with the residues of the extractions by alcohol, the excess of sulphuric acid was volatilized, the residue dissolved in hydrochloric acid, the sulphates converted to chlorides by means of barium chloride, the baric sulphate thus formed separated by filtration, alumina, silica, and barium carbonate precipitated by ammonium carbonate and separated by filtration, and the solution evaporated to dryness. The residue was gently ignited to remove ammonium chloride, dissolved in water acidulated with hydrochloric acid, and this solution, concentrated until just ready to deposit, was drenched with strong alcohol. The sodium chloride precipitated was washed with alcohol until the spectroscope indicated entire freedom from lithium chloride. The alcoholic solution of lithium chloride was evaporated to dryness, and the residue was dissolved in a little water acidulated with hydrochloric acid. This solution was treated with a little pure barium hydrate (made from the nitrate precipitated from nitric acid) to remove traces of magnesia, and filtered, and from the filtrate the barium was removed by treatment with ammonium carbonate, repeated if necessary. From the solution of lithium chloride thus obtained the lithium was separated according to Mayer's method[2] by evaporation with hydro-disodic phosphate and sodium hydrate, the treatment of the residue with sufficient hot water to dissolve the salts, which should be soluble with the aid of gentle heat, the addition of an equal volume of ammonia, and digestion

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[1] Bulletin of the U. S. Geological Survey, No. 42, p. 89; Am. Chem. Jour., vol. 8, p. 421.

[2] Fresenius's Quant. Anal., 6th Aufl., Band II. p. 215.

in the cold during twelve hours. The precipitate was filtered upon asbestos in a perforated crucible, washed with a mixture of equal parts of ammonia and water, ignited, and weighed. The filtrate from this precipitate was evaporated, and the residue of evaporation was again treated as before to recover traces of lithium; and a similar process of treatment was applied to the filtrate from the second precipitate. The three precipitates thus obtained contained presumably all the lithium as the tribasic phosphate.

This is the method of determining lithium which was employed previous to the development of the process which has been described in connection with the account of the determination of lithium in the natural waters (p. 22). Were the work to be repeated we should unquestionably employ the amyl alcohol process exclusively, although it may be said for the determinations by Mayer's method that their actual error was very much diminished by the use of comparatively larger portions of material for the analysis, and we are confident that the results are, on that account, fairly trustworthy.

Cæsium, rubidium, and thallium.—The filtrate from lithium phosphate was freed from ammonia by boiling; the phosphoric acid was precipitated by ferric chloride and ammonia, with the usual precautions to secure a suitable proportion of the iron salt and to keep the excess of ammonia at the lowest possible limit, and removed by filtration; the filtrate from ferric phosphate and ferric hydrate was evaporated to dryness and gently ignited to remove ammonium salts; the residue thus left was dissolved in water and treated with platinic chloride in excess of the amount necessary to convert all the alkaline chlorides present to platinum salts.

The precipitate by platinic chloride was extracted by boiling repeatedly with small portions of water, and the residues of this treatment were tested from time to time spectroscopically. The characteristic lines of cæsium and rubidium appeared more distinctly toward the end of the process of extraction when they were visible at all. Thallium, which should appear, if present, in the intermediate extracts, failed to show itself in any of the waters.

Arsenic, antimony, tin, copper, and lead.—The weighed portion of the concentrated solution was acidified with hydrochloric acid, heated to 70° C., and submitted to the action of a current of hydrogen sulphide during several hours. The precipitated sulphide was filtered off upon anthracene in a perforated crucible, following the method described by one of us.[1] The crucible with the adherent filter of anthracene and the precipitate were placed in a small beaker, drenched with benzol, and gently warmed until the anthracene dissolved. Water containing sodium hydrate was added and, after sufficient digestion on the water-bath, the liquid and precipitate were transferred to a paper filter, pre-

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[1] Bulletin of the U. S. Geological Survey, No. 42, p. 86; Am. Chem. Jour., vol. 7, 1885-'86, p. 87.

viously moistened with water. In this manner the aqueous solution, carrying the arsenic, antimony, and tin, if present, was permitted to traverse the filter, while the sulphides of copper and lead, with possibly free sulphur, remained with the benzol upon the filter. After thorough washing with water the receptacle for the filtrate was changed, the filter was moistened with alcohol, and thus the benzol, with the anthracene in solution, was induced to pass through the paper, which, with the residue upon it was washed with benzol followed by alcohol and then by water. The filter was carefully incinerated, and the ash was digested with a few drops of nitric acid. The solution thus obtained was evaporated to dryness, the residue was moistened with hydrochloric acid, and, after the volatilization of the most of the acid, dissolved in hot water. From this solution hydrogen sulphide should precipitate copper and lead as sulphides. In the single case of that water which had been concentrated in porcelain no black sulphide was obtained at this point in the operation; in other cases, a trifling black precipitate fell, which subsequent examination proved to be copper sulphide exclusively, doubtless originating in the concentrating vessel.

The second precipitation with hydrogen sulphide was introduced to test the presence of copper and lead, in the process just outlined, because the residue left upon the filter when the benzol is washed from it is apt to be dark in color, even in the absence of black sulphides.

The alkaline filtrate from the benzol and the insoluble residue were acidified with hydrochloric acid, after the addition of a drop or two of ammonium sulphide; the precipitate was filtered off on asbestos in a perforated crucible; the filter and precipitate were dried and treated in a small beaker with fuming nitric acid; the solution in nitric acid was evaporated to dryness, the residue was dissolved in hydrochloric acid, and from this solution, made strongly alkaline with ammonia containing some ammonium sulphide (the last to keep tin, if present, in solution), but kept small in volume, the arsenic was precipitated by the magnesium chloride mixture. The liquid was briskly stirred and then allowed to stand quietly for twelve hours at least. The precipitate was transferred by means of the mother liquor, without the use of other liquid, to a perforated crucible carrying an asbestos felt, washed with a mixture of one part of ammonia to three of water, dried carefully, ignited in an atmosphere of oxygen, and weighed as magnesium pyroarsenate.

The filtrate from the ammonio-magnesium arsenate, which should contain the antimony and tin of the water, was evaporated to remove the great excess of the ammonia, and acidified with hydrochloric acid. The sulphur thus precipitated should carry with it the antimony and tin as sulphides. In no case were we able to detect antimony in this precipitate. In one or two cases there were evidences of the presence of tin, but this doubtless came from the lining of the vessel in which concentration was effected; in the water which was concentrated in porcelain no tin was found.

Boric acid.—The filtrate from the original precipitate by hydrogen sulphide in the acid solution was warmed gently, submitted to the action of a current of air to blow out the excess of hydrogen sulphide, brought nearly to neutrality by the addition of sodium carbonate, made faintly alkaline with ammonia, filtered from the precipitate thus thrown down, and evaporated nearly to dryness after the addition of enough sodium hydrate to expel the ammonia and yet preserve strong alkalinity. The residue was acidified with hydrochloric acid and extracted thoroughly with alcohol, and the alcoholic solution was made alkaline with sodium hydrate and evaporated to dryness. This residue was dissolved in water, just acidified with hydrochloric acid, and from the solution the last traces of silica, alumina, lime, and phosphoric acid were removed by the action of ammonia and ammonium carbonate, and filtration. In the filtrate the boric acid was determined according to Marignac's process, by treatment with magnesium chloride, ammonium chloride, and ammonia, evaporation to dryness, ignition at a red heat, extraction with boiling water, and the repetition upon the extract of the process of evaporation, ignition, and extraction. The residues left after extraction were together ignited and weighed, and the magnesia in the weighed material was determined by precipitation as the ammonio-magnesium phosphate and weighing as the pyrophosphate. The difference between the weight of the residue and its contents in magnesia is boric acid.

This was the process which we employed in the earlier determinations. The process which was developed later, and applied to the determination of boric acid in the natural waters, is preferable.

STATEMENT OF THE RESULTS OF ANALYSIS.

In stating the facts deduced from the analysis of the waters, it has seemed best to adopt the plan of recording the oxygen acids as anhydrides, the basic elements as such, and the oxygen which must exist in combination with the bases by itself; thus avoiding an arbitrary division of the basic elements among the oxygen acids and halogens. The basic oxygen, so-called, of the alkaline waters was found by computing the amount of oxygen which would exist in the oxides of the basic elements and deducting from this amount the weight of oxygen equivalent to the halogen discovered by analysis. In the case of waters which carried such an excess of acid that the halogens may be supposed to be uncombined with bases, the basic oxygen is the amount of oxygen which would exist in the oxides of the basic elements. In waters of such acidity that a portion only of the halogen may be supposed to be in combination with basic elements the equivalent in oxygen of the amount of halogen which is regarded as in combination was deducted from the total amount of oxygen of the oxides in computing the basic oxygen. The halogen which remains uncombined with the basic elements was, as a matter of course, assumed to be in association with hydrogen.

The hypothetical combination of the elements found in the waters must necessarily be largely imaginary, for nothing is more plainly evident than the impossibility of stating authoritatively, in the present condition of knowledge, the actual division of a number of acids among a number of bases in solution. This we do know, that the combination is determined not only by the relative proportions of all the constituents, but by the absolute quantities of all associated in a definite amount of liquid. It is with no purpose, therefore, of attempting to represent actual conditions of combination, but only for the sake of securing a common ground of comparison among themselves and with other waters, that we have assumed arbitrarily the existence in these waters of the definite and simple combinations of the following scheme:

In alkaline waters, bromine has been combined as KBr; B_2O_3 as $Na_2B_4O_7$; As_2O_3 as $NaAsO_2$; P_2O_5 as Na_2HPO_4; chlorine has been assigned to the bases in the order NH_4, Li, K, Na; SO_3 has been linked with such bases as remain in the order NH_4, Li, K, Na, Mg, Ca; residual bases have been classed as neutral carbonates in the order Mg, Ca, Na; residual sodium has been represented as $NaSiO_3$; aluminum and iron have been put down as Al_2O_3 and Fe_2O_3; and residual CO_2 and SiO_2 have been shown as such.

In making up the hypothetical composition of acid waters the same general arrangement has been kept as far as possible in order to secure ready comparison with the alkaline waters. Though the relative avidity of hydrochloric acid is greater at ordinary temperatures than that of sulphuric acid, we have nevertheless represented hydrochloric acid as the free acid whenever it became necessary to represent one of them as free.

The sulphuric acid indicated by the analysis has been combined with the bases in the order Ca, Mg, Al_2, Fe_2, Na, K, Li, NH_4; the residual bases have been combined with chlorine in the same order; the anhydrides B_2O_3, As_2O_3, P_2O_5, SiO_2, CO_2, and residual SO_3, have been stated as such; residual chlorine has been represented as HCl, and H_2S as such.

It is apparent that in some instances combinations have been imagined which might exist under some of the circumstances encountered, but which are improbable under other conditions met with in waters of a generally similar character; thus, for the sake of uniformity, we have represented the boric acid of the alkaline waters invariably as $Na_2B_4O_7$, and the phosphoric acid as Na_2HPO_4, regardless of the variable action of an excess of alkaline carbonate upon these salts in hot solutions and under prolonged digestion. So, also SiO_2 has been stated as free, when, if so, it must have been in solution in the presence of the carbonates of sodium, magnesium, and calcium; the neutral carbonates have been represented as such in the presence of free carbonic acid, both in hot and in cold waters; and potassium has been arbitrarily associated with bromine; and ammonium, lithium, and potassium have been preferred to other bases in combining the chlorine.

In the following tables are given the direct results of analysis in grams per kilogram of water, and the percentage composition of the material shown by the analysis; the hypothetical combination in grams per kilogram of water, and the percentage composition of the material of the hypothetical combination; the quantity of water used in each determination, and the number of determinations of each constituent. In the final table all the direct results of analysis are summarized.

ANALYSES.

CLEOPATRA SPRING.

(Locality, Mammoth Hot Springs; date of collection, July 28, 1884; temperature, 67° C.; reaction, alkaline; specific gravity, 1.00205.)

Sample No. 1 was taken from the center of the spring.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.0517	2.48	2	200
SO_3	0.4395	21.08	2	200
CO_2	0.6287	30.15	2	200
B_2O_3	0.0226	1.08	2	500
As_2O_3	0.0031	0.15	2	500
Cl	0.1749	8.39	2	200
Br	Trace	......	1	100
H_2S	Trace	......	1	600
O (basic)	0.1954	9.37	..	....
Fe } Al }	0.0049	0.23	2	200
Ca	0.3076	14.75	2	200
Mg	0.0729	3.50	2	200
K	0.0511	2.45	2	200
Na	0.1299	6.23	2	200
Li	0.0023	0.11	2	200
NH_4	0.00063	0.03	1	50
	2.08523	100.00		

Albuminoid ammonia (not in summation) 0.00020 grams per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0019	0.09
LiCl	0.0140	0.67
NaCl	0.1903	9.13
KCl	0.0976	4.68
KBr	Trace	......
Na_2SO_4	0.1448	6.94
$MgSO_4$	0.3645	17.48
$CaSO_4$	0.1953	9.37
$Na_2B_4O_7$	0.0326	1.56
$NaAsO_2$	0.0041	0.20
$CaCO_3$	0.6254	29.99
Al_2O_3	0.0093	0.45
SiO_2	0.0517	2.48
CO_2	0.3537	16.96
H_2S	Trace	......
	2.0852	100.00

Sample No. 2 was taken at a point in the overflow about 85 feet (25 vertically and 60 horizontally) from the margin of the basin, for the purpose of getting some idea of the rate at which the water near the source was depositing travertine. The sample was collected at the same time with No. 1. The temperature of the water had fallen at the place where the sample was taken to 44° C. The determinations were not duplicated, and a portion of 150 g. was devoted to each determination. The deposit of calcium carbonate, which was found in the sample on cooling and standing—though the water was clear when it was bottled—was analyzed separately.

Constituents.	Grams per kilo of water.		
	In the water.	In the deposit.	Total.
SO_3	0.4573	......	0.4573
CO_2	0.3433	0.0433	0.3866
Ca	0.1926	0.0578	0.2504
Mg	0.0786	0.0011	0.0797

If it be assumed that at the point at which the sample was taken, the water still carries the sulphates with which it left the source—and this assumption is consonant with the fact that the travertine deposits of these springs carry only trifling amounts of sulphuric acid—the comparison of the analyses of Nos. 1 and 2 indicates that during the flow of the water, hot, thinly spread, and thoroughly churned, 4 per cent. of it was lost by evaporation; and that every kilogram of water which left the source and made this passage deposited something like 0.1675 g. of calcium carbonate.

Sample No. 3 was taken as a preliminary specimen October 11, 1883. The sulphuric acid, carbonic acid, and calcium were alone determined:

	Grams per kilo.
SO_3	0.4254
CO_2	0.5071
Ca	0.3006

It will be noted that the small sample of 1883 carried about the same amount of lime, a little less sulphuric acid, and very much less carbonic acid than the sample of the year following. The deficiency in carbonic acid may have resulted from imperfect sealing of the bottle in which the water was preserved, and the lapse of time before the analysis was made.

ORANGE SPRING.

(Locality, Mammoth Hot Springs; date of collection, October 11, 1883; temperature, 63° C.; reaction, alkaline.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.0502	2.94	1	500
SO_3	0.4407	25.84	1	250
CO_2	0.3378	19.81	1	500
B_2O_3	Present	......	1	....
As_2O_3	......	......	1	....
Cl	0.1623	9.51	1	250
Br	Trace	......	1	....
H_2S	None *a*	......	1	....
O (basic)	0.1796	10.53	1	....
Fe Al	0.0012	0.07	1	500
Ca	0.2821	16.54	1	500
Mg	0.0659	3.86	1	500
K	0.0610	3.58	1	500
Na	0.1233	7.23	1	500
Li *b*	0.0016	0.09	1	500
NH_4	......	......	--	....
	1.7057	100.00		

a As received in the laboratory. *b* By Mayer's method.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
LiCl	0.0097	0.57
NaCl	0.1636	9.59
KCl	0.1165	6.83
KBr	Trace	......
Na_2SO_4	0.1834	10.75
$MgSO_4$	0.3295	19.32
$CaSO_4$	0.2002	11.74
$CaCO_3$	0.5580	32.71
Al_2O_3	0.0022	0.13
SiO_2	0.0502	2.94
CO_2	0.0924	5.42
	1.7057	100 00

HOT RIVER.

(Locality, Mammoth Hot Springs; date of collection, October 5, 1884; temperature, 58° C.; reaction, alkaline; specific gravity, 1.00157.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.0500	2.87	2	200
SO_3	0.4230	24.26	2	200
CO_2	0.4270	24.49	2	200
B_2O_3	0.0128	0.73	2	500
As_2O_3	0.0004	0.02	2	500
Cl	0.1604	9.20	2	100
Br	None	......	1	100
H_2S	None	......	1	600
O (basic)	0.1682	9.64	..	....
Fe Al	0.0051	0.29	2	200
Ca	0.2360	13.53	2	200
Mg	0.0631	3.62	2	200
K	0.0462	2.65	2	100
Na	0.1506	8.63	2	100
Li	0.0011	0.06	2	100
NH_4	0.00011	0.01	1	50
	1.74401	100.00		

Albuminoid ammonia, trace.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0003	0.02
LiCl	0.0068	0.39
NaCl	0.1855	10.64
KCl	0.0882	5.06
Na_2SO_4	0.2265	12.98
$MgSO_4$	0.3155	18.09
$CaSO_4$	0.1450	8.31
$Na_2B_4O_7$	0.0185	1.06
$NaAsO_2$	0.0004	0.02
$CaCO_3$	0.4833	27.71
Al_2O_3	0.0097	0.56
SiO_2	0.0500	2.87
CO_2	0.2143	12.29
	1.7440	100.00

GARDINER RIVER.

(Locality, above Hot River; date of collection, October 12, 1883; temperature, 8° C.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.0469	21.95	2	100
SO_3	0.0117	5.47	2	100
CO_2	0.0710	33.23	2	200
Cl	0.0049	2.29	2	100
O (basic)	0.0216	10.11	..	....
Fe Al }	0.0042	1.96	2	100
Ca	0.0250	11.70	2	100
Mg	0.0005	0.23	2	100
K	0.0079	3.70	2	100
Na	0.0200	9.36	2	100
Li	Trace	......	..	....
	0.2137	100.00		

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
LiCl	Trace	......
KCl	0.0103	4.82
K_2SO_4	0.0056	2.62
Na_2SO_4	0.0161	7.53
Na_2CO_3	0.0340	15.91
$MgCO_3$	0.0018	0.84
$CaCO_3$	0.0625	29.25
Al_2O_3	0.0079	3.70
SiO_2	0.0469	21.95
CO_2	0.0286	13.38
	0.2137	100.00

GARDINER RIVER.

(Locality, Mammoth Hot Springs, below Hot River; date of collection, September 26, 1884; temperature, 13° C.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.0272	5.51	2	500
SO_3	0.0802	16.24	2	500
CO_2	0.1725	34.94	2	500
Cl	0.0301	6.10	2	500
O (basic)	0.0487	9.86	..	....
Fe Al	0.0010	0.20	2	500
Ca	0.0749	15.17	2	500
Mg	0.0175	3.55	2	500
K	0.0105	2.13	2	500
Na	0.0311	6.30	2	500
Li	Trace	......	..	....
	0.4937	100.00		

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
LiCl	Trace	....
KCl	0.0200	4.05
NaCl	0.0339	6.87
Na_2SO_4	0.0549	11.12
$MgSO_4$	0.0739	14.97
$MgCO_3$	0.0094	1.90
$CaCO_3$	0.1873	37.94
Al_2O_3	0.0019	0.38
SiO_2	0.0272	5.51
CO_2	0.0852	17.26
	0.4937	100.00

WATER SUPPLY AT MAMMOTH HOT SPRINGS.

(Locality, faucet in hotel; date of collection, July 28, 1884.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.0355	12.88	2	1000
SO_3	0.0310	11.24	2	1000
CO_2	0.1230	44.61	2	200
Cl	0.0022	0.80	2	500
O (basic)	0.0248	9.00	...	....
Al Fe	0.0011	0.40	2	1000
Ca	0.0316	11.46	2	1000
Mg	0.0089	3.23	2	1000
K	0.0031	1.12	2	1000
Na	0.0145	5.26	2	1000
Li	None	......	..	....
	0.2757	100.00		

Ammonia, 0.000022 gram; albuminoid ammonia, 0.000028 gram; nitric acid, 0.000115 gram per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Grains per U. S. gallon.
KCl	0.0046	1.67	0.2685
K_2SO_4	0.0015	0.54	0.0875
Na_2SO_4	0.0448	16.25	2.6151
$MgSO_4$	0.0076	2.76	0.4436
$MgCO_3$	0.0258	9.36	1.5060
$CaCO_3$	0.0790	28.65	4.6114
Al_2O_3	0.0021	0.76	0.1225
SiO_2	0.0355	12.88	2.0722
CO_2	0.0748	27.13	4.3662
	0.2757	100.00	16.0930

SODA SPRING.

(Locality, Mammoth Hot Springs; date of collection, ——, 1887; temperature, 6° C.; reaction, acid; specific gravity, 1.00041.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.0184	2.08	2	500
SO_3	0.0390	4.42	2	200
CO_2	0.6735	76.30	2	200
B_2O_3	None	......	2	1,000
As_2O_3	None	......	2	1,000
Cl	0.0044	0.50	2	200
H_2S	None	......	..	200
O(basic)	0.0432	4.89	..	....
Fe	0.0053	0.60	2	500
Al	0.0004	0.06	2	500
Ca	0.0808	9.15	2	500
Mg	0.0106	1.20	2	500
K	0.0027	0.31	2	200
Na	0.0039	0.44	2	200
Li	None	......	2	200
NH_4	0.0005	.05	2	50
	0.8827	100.00		

Albuminoid ammonia: Trace.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0015	0.17
LiCl	None	......
KCl	0.0051	0.58
NaCl	0.0015	0.17
Na_2SO_4	0.0102	1.16
$MgSO_4$	0.0500	5.67
$MgCO_3$	0.0021	.24
$CaCO_3$	0.2020	22.88
Fe_2O_3	0.0076	.86
Al_2O_3	0.0008	.09
SiO_2	0.0184	2.08
CO_2	0.5835	66.10
	0.8827	100.00

FEARLESS GEYSER.

(Locality, Norris Geyser Basin; date of collection, August 18, 1884; temperature, 88° C.; reaction, neutral; specific gravity, 1.00110.)

Constituents	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0. 4180	25. 60	2	500
TiO_2	None	......	1	39, 500
SO_3	0. 0367	2. 25	2	1000
CO_2	0. 0046	0. 28	2	500
N_2O_5	None	......	1	400
P_2O_5	None	......	1	39, 500
B_2O_3	0. 0223 *a*	1. 36	2	7, 900
As_2O_3	0. 0022	0. 14	2	7, 900
Cl	0. 6705	41. 06	2	200
B_2	0. 0026	0. 16	2	7, 900
I	None	......	2	7, 900
Fl	None	......	1	39, 500
H_2S	Trace	......	1	600
O(basic)	0. 0113	0. 70	..	......
Fe	0. 0006	0. 04	2	39, 500
Al	0. 0002	0. 01	2	500
Mn	None	......	1	39, 500
Ba	None	......	1	39, 500
Sr	None	......	1	39, 500
Ca	0. 0092	0. 56	2	500
Mg	0. 0001	0. 01	2	500
Cs	Trace	......	1	7, 900
Rb	Trace	......	1	7, 900
K	0. 0415	2. 54	2	200
Na	0. 4046	24. 77	2	200
Li	0. 0081 *b*	0. 50	2	7, 900
NH_4	0. 00025	0. 02	1	500
	1. 63275	100. 00		

a Found by Marignac's method. *b* Found by Mayer's method.

Albuminoid ammonia (not in summation) 0.00001 grams per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0007	0.04
LiCl	0.0492	3.02
KCl	0.0768	4.71
KBr	0.0039	0.24
CsCl	Trace	......
RbCl.........	Trace	......
NaCl	0.9760	59.78
Na_2SO_4	0.0404	2.47
$MgSO_4$.......	0.0005	0.03
$CaSO_4$	0.0230	1.41
$Na_2B_4O_7$	0.0319	1.96
$NaAsO_2$......	0.0029	0.18
$CaCO_3$	0.0061	0.37
$FeCo_3$........	0.0011	0.06
Al_2O_3	0.0004	0.02
SiO_2	0.4180	25.60
Co_2	0.0019	0.11
H_2S..........	Trace	Trace
	1.6328	100.00

The analysis of a preliminary sample of 1,350 cm^3., taken September 27, 1883, yielded the following figures, which signify grams of material per kilogram of water: SiO_2 0.3463; SO_3 0.0501; Cl 0.6476; Fe, Al 0.0021; Ca 0.0098; Mg trace; K 0.0443; Na 0.3931; Li 0.0042.

PEARL GEYSER.

(Locality, Norris Geyser Basin; date of collection, August 20, 1884; temperature, 84° C.; reaction, neutral; specific gravity, 1.00110.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0. 4636	27. 89	2	500
TiO_2	None	....	1	54, 000
SO_3	0. 0228	1. 38	2	1, 000
CO_2	0. 0075	0. 45	2	200
N_2O_5	....	....	1	......
P_2O_5	None	....	1	54, 000
B_2O_3	[0. 0273]	[1. 65]	..	......
As_2O_3	0. 0038	0. 23	2	3, 200
Cl	0. 6520	39. 22	2	200
Br	....	....	..	......
I	....	....	..	......
Fl	None	....	1	54, 000
H_2S	Trace	....	1	600
O(basic)	0. 0134	0. 81	..	......
Fe	Trace	....	1	54000
Al	0. 0031	0. 18	2	500
Mn	Trace *a*	....	1	54, 000
Ba	None	....	1	54, 000
Sr	None	....	1	54, 000
Ca	0. 0064	0. 38	2	500
Mg	0. 0009	0. 05	2	500
Cs	....	....	..	......
Rb	....	....	..	......
K	0. 0544	3. 27	2	200
Na	0. 4046	24. 34	2	200
Li	0. 0022 *b*	0. 14	2	10, 800
NH_4	0. 00021	0. 01	1	1, 000
	[1. 66221]	[100. 00]		

a 0.000038 gram. *b* By Mayer's method.

Albuminoid ammonia (not included in summation) 0.00001 g.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0006	0.03
$LiCl$	0.0133	0.80
KCl	0.1039	6.26
$NaCl$	0.9738	58.59
Na_2SO_4	0.0366	2.21
$CaSO_4$	0.0037	0.22
$NaAsO_2$	0.0050	0.30
$Na_2B_4O_7$	[0.0394]	[2.37]
$MgCO_3$	0.0031	0.18
$CaCO_3$	0.0133	0.80
Al_2O_3	0.0059	0.35
SiO_2	0.4636	27.89
H_2S	Trace	......
	[1.6622]	[100.00]

An accidental loss of the material for analysis prevented the determinations of the boric acid, bromine, iodine, calcium, and rubidium. In the figures given above it has been assumed, in order that the analysis may be utilized as far as may be for comparison with the others, that the boric acid was present in amount just sufficient to neutralize the excess of base over all acid in the dissolved material. This supposition is probably not very far wrong, if we may draw any conclusion in this matter from the composition of adjacent waters, but it is nevertheless purely an assumption.

CONSTANT GEYSER.

(Locality, Norris Basin; date of collection, September 13, 1885; temperature, 92° C.; reaction, acid; specific gravity, 1.00115.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.4685	28.88	2	200
SO_3	0.0923	5.69	2	200
CO_2	0.0155	0.95	2	200
B_2O_3	0.0317	1.95	2	500
As_2O_3	0.0018	0.11	2	500
Cl	0.5740	35.39	2	200
Br	Trace	......	2	100
H_2S	None [a]	......	1	600
O(basic)	0.0185	1.14	..	....
Fe	Trace	......	2	200
Al	0.0048	0.29	2	200
Ca	0.0146	0.90	2	200
Mg	0.0018	0.11	2	200
K	0.0745	4.60	2	200
Na	0.3190	19.67	2	200
Li	0.0030	0.19	2	200
NH_4	0.00127	0.08	1	50
H (in HCl)	0.0008	.05	..	....
	1.62207	100.00		

[a] As received in the laboratory.

Albuminoid ammonia, none.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0038	0.23
LiCl	0.0182	1.14
KCl	0.1423	8.77
KBr	Trace	......
NaCl	0.7590	46.79
Na_2SO_4	0.0635	3.91
$MgSO_4$	0.0090	0.55
$CaSO_4$	0.0496	3.07
$Al_2(SO_4)_3$	0.0304	1.88
$Fe_2(SO_4)_3$	Trace	......
SiO_2	0.4685	28.88
B_2O_3	0.0317	1.95
As_2O_3	0.0018	0.11
CO_2	0.0155	0.95
HCl	0.0287	1.77
	1.6220	100.00

CORAL SPRING.

(Locality, Norris Geyser Basin; date of collection, August 20, 1884; temperature, 73° C.; reaction, acid; specific gravity, 1.00130.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.6070	31.77	2	200
SO_3	0.0264	1.38	2	200
CO_2	0.0425	2.22	2	200
B_2O_3	0.0328	1.71	2	1,000
As_2O_3	0.0007	0.04	2	1,000
Cl	0.7087	37.09	2	100
H_2S	None	......	1	600
O (basic)	0.0053	0.28	..	.....
Fe	Trace	......	..	200
Al	0.0029	0.15	2	200
Ca	0.0102	0.54	2	200
Mg	0.0022	0.11	2	200
K	0.0729	3.81	2	100
Na	0.3936	20.60	2	100
Li	0.0020	0.11	2	100
NH_4	0.00042	0.02	1	50
H (in HCl)	0.0032	0.17		.....
	1.91082	100.00		

Albuminoid ammonia (not in summation), 0.00010 grams per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0012	0.06
LiCl	0.0121	0.64
KCl	0.1393	7.29
NaCl	1.0011	52.39
$MgCl_2$	0.0016	0.08
Al_2Cl_6	0.0143	0.75
Fe_2Cl_6	Trace	......
$MgSO_4$	0.0090	0.46
$CaSO_4$	0.0347	1.82
B_2O_3	0.0328	1.72
As_2O_3	0.0007	0.04
SiO_2	0.6070	31.77
CO_2	0.0425	2.22
HCl	0.0145	0.76
	1.9108	100.00

CORAL SPRING.

(Locality, Norris Geyser Basin; date of collection, October 11, 1886; temperature, 72° C.; reaction, faintly acid; specific gravity, 1.00124.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.5805	31.30	2	200
SO_3	0.0280	1.51	2	200
CO_2	0.0262	1.41	2	200
B_2O_3	0.0368	1.98	2	500
As_2O_3	0.0009	0.05	2	500
Cl	0.0701	36.14	2	200
H_2S	None	......	1	600
O(basic)	0.0175	0.94	..	....
Fe	Trace	......	2	200
Al	0.0077	0.42	2	200
Ca	0.0071	0.39	2	200
Mg	0.0014	0.07	2	200
K	0.0815	4.40	2	200
Na	0.3925	21.16	2	200
Li	0.0040	0.21	2	200
NH_4	0.0003	0.02	1	50
	1.8545	100.00		

Albuminoid ammonia (not in summation) 0.00060 gram per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0009	0.05
LiCl	0.0243	1.31
KCl	0.1557	8.39
NaCl	0.9483	51.13
Na_2SO_4	0.0228	1.23
$MgSO_4$	0.0070	0.39
$CaSO_4$	0.0179	0.96
$Na_2B_4O_7$	0.0531	2.86
$NaAsO_2$	0.0012	0.07
$CaCO_3$	0.0048	0.26
Al_2O_3	0.0139	0.75
Fe_2O_3	Trace	......
SiO_2	0.5805	31.30
CO_2	0.0241	1.30
	1.8545	100.00

ECHINUS SPRING.

(Locality, Norris Geyser Basin; date of collection, August 20, 1884; temperature, 91° C.; reaction, acid; specific gravity, 1.00071.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0. 2532	30. 46	2	200
SO_3	0. 1929	23. 21	2	200
CO_2	0. 0250	3. 01	2	200
B_2O_3	0. 0173	2. 08	2	500
As_2O_3	0. 0016	0. 19	2	500
Cl	0. 1207	14. 52	2	200
Br	Trace	......	2	100
H_2S	Trace	......	1	600
O(basic)	0. 0386	4. 64	..	....
Fe	None	......	2	200
Al	0. 0027	0. 33	2	200
Ca	0. 0115	1. 38	2	200
Mg	None	......	2	200
K	0. 0395	4. 75	2	200
Na	0. 1265	15. 22	2	200
Li	Trace	......	2	200
NH_4	0. 00106	0. 13	1	50
H(in HCl)	0. 0007	0. 08	..	....
	0. 83126	100. 00		

Albuminoid ammonia: None.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0. 0040	0. 48
LiCl	Trace	......
KCl	0. 0754	9. 07
KBr	Trace	......
NaCl	0. 0908	10. 92
Na_2SO_4	0. 2803	33. 72
$CaSO_4$	0. 0391	4. 70
$Al_2(SO_3)_4$	0. 0171	2. 06
SiO_2	0. 2532	30. 46
B_2O_3	0. 0173	2. 08
As_2O_3	0. 0016	0. 19
CO_2	0. 0250	3. 01
HCl	0. 0275	3. 31
H_2S	Trace	......
	0. 8313	100. 00

SCHLAMMKESSEL.

(Locality, Norris Geyser Basin; date of collection, August 20, 1884; temperature, 91° C.; reaction, acid; specific gravity, 1.00130.)

The water was filtered from material in suspension.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.4577	27.04	2	200
SO_3	0.1012	5.98	2	100
CO_2	0.0175	1.04	2	100
B_2O_3	0.0390	2.30	2	200
AS_2O_3	None	....	1	200
Cl	0.6391	37.75	2	100
Br	Trace	....	1	100
H_2S	Trace [a]	....	..	....
O (basic)	0.0202	1.19	..	....
Fe. Al	0.0081	0.48	2	200
Ca	0.0078	0.46	2	200
Mg	0.0003	0.02	2	200
K	0.0254	1.50	2	200
Na	0.3654	21.58	2	200
Li	0.0029	0.17	2	200
NH_4	0.00633	0.37	1	50
H (in HCl)	0.0019	0.12	..	....
	1.69283	100.00		

[a] As received in the laboratory.

Albuminoid ammonia (not in summation) 0.00040 grams per kilo.

Hypothetical Combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0188	1.11
LiCl	0.0176	1.03
KCl	0.0485	2.86
KBr	Trace	......
NaCl	0.8585	50.72
Na_2SO_4	0.0862	5.09
$MgSO_4$	0.0015	0.09
$CaSO_4$	0.0265	1.57
$Al_2(SO_4)_3$ $Fe_2(SO_4)_3$	0.0513	3.03
SiO_2	0.4577	27.04
B_2O_3	0.0390	2.30
CO_2	0.0175	1.04
HCl	0.0697	4.12
H_2S	Trace	....
	1.6928	100.00

FOUNTAIN GEYSER.

(Locality, Lower Geyser Basin; date of collection, August 24, 1884; temperature, 82° C.; reaction, alkaline; specific gravity, 1.00100.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water in each determination.
SiO_2	0.3315	23.69	2	200
TiO_2	None	......	1	31,000
SO_3	0.0195	1.39	2	200
CO_2	0.2307	16.48	2	200
N_2O_5	None	......	1	500
P_2O_5	0.00004	......	1	31,000
B_2O_3	0.0138[a]	0.99	2	6,200
As_2O_3	0.0027	0.19	2	6,200
Cl	0.3337	23.84	2	100
Br	0.0004	0.03	2	6,200
I	None	......	2	6,200
Fl	None	......	1	31,000
H_2S	Trace	......	1	600
O (basic)	0.0654	4.67	..	......
Fe	0.0002	0.01	2	31,000
Al	0.0057	0.41	2	200
Mn	Trace[b]	......	1	31,000
Ba	None	......	1	31,000
Sr	None	......	1	31,000
Ca	0.0014	0.10	2	200
Mg	0.0010	0.07	2	200
Cs	None	......	2	6,200
Rb	None	......	2	6,200
K	0.0379	2.71	2	100
Na	0.3522	25.16	2	100
Li[c]	0.0035	0.25	2	6,200
NH_4	0.00015	0.01	1	500
	1.39979	100.00		

[a] By Marignac's method. [b] 0.000003 grams. [c] By Mayer's method.

Albuminoid ammonia (not in summation) 0.00038 grams per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0004	0.02
LiCl	0.0213	1.52
KCl	0.0720	5.15
KBr	0.0006	0.04
NaCl	0.4636	33.12
Na_2SO_4	0.0346	2.47
$Na_2B_4O_7$	0.0198	1.42
$NaAsO_2$	0.0035	0.25
Na_2CO_3	0.3541	25.30
$MgCO_3$	0.0035	0.25
$CaCO_3$	0.0035	0.25
$FeCO_3$	0.0004	0.02
$MnCO_3$	Trace	......
Al_2O_3	0.0108	0.77
SiO_2	0.3315	23.69
CO_2	0.0801	5.73
H_2S	Trace	......
	1.3997	100.00

GREAT FOUNTAIN GEYSER.

(Locality, Lower Geyser Basin; date of collection, August 24, 1884; temperature, 82°–93° C.(*a*); reaction, alkaline; specific gravity, 1.00104.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.3182	24.19	2	200
SO_3	0.0187	1.42	2	100
CO_2	0.2107	16.02	2	200
B_2O_3	0.0100[b]	0.76	1	50
As_2O_3	0.0017	0.13	2	500
Cl	0.3508	26.67	2	100
H_2S	None	......	1	600
O (basic)	0.0472	3.59	..	....
Fe	Trace	......	2	200
Al	0.0021	0.16	2	200
Ca	0.0017	0.13	2	200
Mg	0.0023	0.17	2	200
K	0.0145	1.10	2	100
Na	0.3351	25.47	2	100
Li	0.0025	0.19	2	100
	1.3155	100.00		

[a] The usual range of temperature during the interval between eruptions.

[b] Rests on one determination, and that made with an insufficient amount of water, the remainder having been lost accidentally.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
LiCl	0.0152	1.15
KCl	0.0277	2.11
NaCl	0.5354	40.70
Na_2SO_4	0.0332	2.52
$Na_2B_4O_7$	0.0144	1.09
$NaAsO_2$	0.0022	0.17
Na_2CO_3	0.2536	19.28
$MgCO_3$	0.0080	0.61
$CaCO_3$	0.0043	0.33
Al_2O_3	0.0040	0.30
Fe_2O_3	Trace	......
SiO_2	0.3182	24.19
CO_2	0.0993	7.55
	1.3155	100.00

HYGEIA SPRING.

(Locality, Lower Geyser Basin; date of collection, September 11, 1885; temperature, 43° C.; reaction, alkaline; specific gravity, 1.00107.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.2477	20.98	2	200
SO_3	0.0196	1.65	2	200
CO_2	0.2907	24.62	2	200
B_2O_3	0.0239	2.02	2	500
As_2O_3	0.0034	0.29	2	500
Cl	0.2487	21.06	2	200
Br	Trace	......	1	100
H_2S	None[a]	......	..	....
O (basic)	0.0504	4.27	..	....
Fe	None	......	2	200
Al	0.0036	0.31	2	200
Ca	0.0064	0.54	2	200
Mg	0.0022	0.19	2	200
K	0.0154	1.30	2	200
Na	0.2654	22.48	2	200
Li	0.0032	0.27	2	200
NH_4	0.00021	0.02	1	50
	1.18081	100.00		

[a] As received in the laboratory.

Albuminoid ammonia, none.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Percent. of total material in solution.
NH_4Cl	0.0006	0.06
LiCl	0.0194	1.64
KCl	0.3594	30.44
KBr	Trace	......
NaCl	0.0294	2.49
Na_2SO_4	0.0348	2.95
$Na_2B_4O_7$	0.0345	2.92
$NaAsO_2$	0.0049	0.41
Na_2CO_3	0.2393	20.26
$MgCO_3$	0.0077	0.65
$CaCO_3$	0.0160	1.35
Al_2O_3	0.0068	0.58
SiO_2	0.2477	20.98
CO_2	0.1803	15.27
	1.1808	100.00

MADISON SPRING.

(Locality, Terrace Springs, near junction of Gibbon and Firehole Rivers; date of collection, September 11, 1885; temperature, 60° C.; reaction, alkaline; specific gravity, 1.00100.)

Constituents.	Grams per kilo of water.	Percent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.1507	11.37	2	200
SO_3	0.0123	0.93	2	200
CO_2	0.6140	46.31	2	200
B_2O_3	0.0130	0.98	1	500
As_2O_3	Trace	......	1	500
Cl	0.0698	5.26	2	200
Br	None	......	1	100
H_2S	None[a]	......	..	....
O (basic)	0.1062	8.01	..	....
Fe	None	......	2	200
Al	None[a]	......	2	200
Ca	0.0255	1.92	2	200
Mg	0.0017	0.13	2	200
K	0.0385	2.90	2	200
Na	0.2930	22.10	2	200
Li	0.0004	0.03	2	200
NH_4	0.0008	0.06	1	50
	1.3259	100.00		

[a] As received in the laboratory.

Albuminoid ammonia (not in summation), 0.00020 grams per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0024	0.18
LiCl	0.0024	0.18
KCl	0.0735	5.54
NaCl	0.0513	3.87
Na_2SO_4	0.0218	1.65
$Na_2B_4O_7$	0.0187	1.41
$NaAsO_2$	Trace	......
Na_2CO_3	0.6025	45.44
$MgCO_3$	0.0060	0.45
$CaCO_3$	0.0638	4.81
SiO_2	0.1507	11.37
CO_2	0.3328	25.10
	1.3259	100.00

FIREHOLE RIVER.

(Locality, above the junction of Nez Percé Creek; date of collection, August 24, 1884; temperature, 8° C.; reaction, alkaline; specific gravity, 1.00031.)

The water was filtered before bottling.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determination.	Grams of water employed in each determination.
SiO_2	0.0965	22.10	2	200
SO_3	0.0084	1.92	2	100
CO_2	0.1010	23.83	2	200
B_2O_3	0.0060	1.37	1	340
As_2O_3	None	......	1	500
Cl	0.0737	16.89	2	100
H_2S	None	......	..	....
O (basic)	0.0265	6.07	..	....
Fe	Trace	......	2	200
Al	0.0031	0.71	2	200
Ca	0.0066	1.51	2	200
Mg	0.0007	0.16	2	200
K	0.0170	3.89	2	100
Na	0.0930	21.30	2	100
Li	0.0011	0.25	2	100
	0.4366	100.00		

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
LiCl	0.0067	1.53
KCl	0.0325	7.44
NaCl	0.0867	19.86
Na_2SO_4	0.0149	3.42
$Na_2B_4O_7$	0.0087	1.99
Na_2CO_3	0.1201	27.51
$MgCO_3$	0.0024	0.55
$CaCO_3$	0.0165	3.78
Al_2O_3	0.0059	1.35
Fe_2O_3	Trace	......
SiO_2	0.0965	22.10
CO_2	0.0457	10.47
	0.4366	100.00

EXCELSIOR GEYSER.

(Locality, Midway Basin; date of collection, August 25, 1884; temperature, 92° C.; reaction, alkaline; specific gravity, 1.00110.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determination.	Grams of water employed in each determination.
SiO_2	0.2214	15.04	2	200
TiO_2	None	......	1	24,000
SO_3	0.0146	0.99	2	200
CO_2	0.3825	25.97	2	200
N_2O_5	None	......	2	120
P_2O_5	Trace	......	1	24,000
B_2O_3	0.0161[a]	1.09	2	2,400
As_2O_3	0.0026	0.18	2	2,400
Cl	0.2793	18.96	2	100
Br	Trace	......	2	2,400
I.............	None	......	2	2,400
Fl	None	......	1	24,000
H_2S..........	Trace	......	1	600
O (basic).....	0.0955	6.49	..	......
Fe	0.0018	0.12	2	24,000
Al	0.0012	0.08	2	200
Mn	Trace	......	1	24,000
Ba	None	......	1	24,000
Sr	None	......	1	24,000
Ca	0.0022	0.15	2	200
Mg	0.0022	0.15	2	200
Cs	None	......	2	2,400
Rb	None	......	2	2,400
K.............	0.0325	2.21	2	100
Na	0.4186	28.43	2	100
Li	0.0020[b]	0.14	2	2,400
NH_4	0.00001	......	1	50
	1.47251	100.00		

[a] By Marignac's method.

[b] By Mayer's method.

Albuminoid ammonia (not in summation), 0.00002 gram per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	Trace	Trace
$LiCl$	0.0121	0.82
KCl	0.0621	4.22
KBr	Trace	Trace
$NaCl$	0.3948	26.81
Na_2SO_4	0.0259	1.76
$Na_2B_4O_7$	0.0232	1.58
$NaAsO_2$	0.0034	0.23
Na_2HPO_4	Trace	.....
Na_2CO_3	0.5739	38.97
$MgCO_3$	0.0077	0.52
$CaCO_3$	0.0055	0.37
$FeCO_3$	0.0037	0.25
Al_2O_3	0.0023	0.15
SiO_2	0.2214	15.04
CO_2	0.1365	9.28
H_2S	Trace	Trace
	1.4725	100.00

A preliminary sample of 600 cm³., taken August 29, 1883, yielded as analysis the following figures, which signify grams of material per kilogram of water: SiO_2, 0.2727; SO_3, 0.0107; B_2O_3, present; Cl, 0.2765; Fe and Al, 0.0009; Ca, 0.0055; Li, present.

OLD FAITHFUL GEYSER.

(Locality, Upper Geyser Basin; date of collection, September 1, 1884; temperature, 84°–88° C. (*a*); reaction, alkaline; specific gravity, 1.00096.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.3828	27.52	2	500
TiO_2	None	......	1	84,000
SO_3	0.0152	1.09	2	1,000
CO_2	0.0894	6.43	2	200
N_2O_5	None	......	2	1,500
P_2O_5	None	......	1	84,000
B_2O_3	0.0148*b*	1.07	2	13,500
As_2O_3	0.0021	0.15	2	13,500
Cl	0.4391	31.57	2	200
Br	0.0034	0.25	2	13,500
I	None	......	2	13,500
Fl	None	......	1	84,000
H_2S	0.0002	0.01	1	600
O (basic)	0.0419	3.02	.	......
Fe	Trace	......	2	84,000
Al	0.0009	0.06	2	500
Mn	Trace *c*	......	1	84,000
Ba	None	......	1	84,000
Sr	None	......	1	84,000
Ca	0.0015	0.11	2	500
Mg	0.0006	0.04	2	500
Cs	Trace	......	2	27,000
Rb	Trace	......	2	27,000
K	0.0267	1.92	2	200
Na	0.3666	26.36	2	200
Li	0.0056*d*	.40	2	13,500
NH_4	0.00001	......	1	50
	1.39081	100.00		

a The usual range of temperature in the pools about the crater, from which the sample was taken immediately after eruption.

b By Marignac's method.

c 0.000005 grams.

d By Mayer's method.

Albuminoid ammonia (not in summation), 0.00002 grams per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	Trace	Trace
LiCl	0.0340	2.44
KCl..........	0.6393	45.97
KBr	0.0478	3.44
CsCl.........	Trace	......
RbCl	Trace	......
NaCl.........	0.0051	0.37
Na_2SO_4......	0.0270	1.94
$N_2aB_4O_7$	0.0213	1.53
$NaAsO_2$......	0.0027	0.19
Na_2CO_3	0.2088	15.02
Na_2SiO_3......	0.0279	2.01
$MgCO_3$.......	0.0021	0.15
$CaCO_3$	0.0038	0.27
$FeCO_3$	Trace	......
$MnCO_3$	Trace	......
Al_2O_3	0.0017	0.12
SiO_2	0.3691	26.54
H_2S.........	0.0002	0.01
	1.3908	100.00

ERRATA.

OLD FAITHFUL GEYSER—HYPOTHETICAL COMBINATION.

Corrections in above table.

For KCl read NaCl
" KBr " KCl
" NaCl " KBr

SPLENDID GEYSER.

(Locality, Upper Geyser Basin; date of collection, September 10, 1885; temperature, 93° C.; reaction, alkaline; specific gravity, 1.00132.)

The concentration of the water was effected in porcelain.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.2964	18.14	2	500
TiO_2	None	....	1	22,000
SO_3	0.0158	0.97	2	500
CO_2	0.4225	25.86	2	200
N_2O_5	None	....	2	400
P_2O_5	0.00012	0.01	1	22,000
B_2O_3	0.0234	1.43	2	500
As_2O_3	0.0019	0.12	2	4,500
Cl	0.3227	19.75	2	200
Br	None	....	2	4,500
I	None	....	2	4,500
Fl	None	....	1	22,000
H_2S	None	....	1	600
O (basic)	0.0897	5.49		......
Fe	0.00008	0.005	2	22,000
Al	0.0027	0.16	2	500
Mn	None	....	1	22,000
Ba	None	....	1	22,000
Sr	None	....	1	22,000
Ca	0.0030	0.18	2	500
Mg	0.0005	0.03	2	500
Cs	None	....	2	9,000
Rb	None	....	2	9,000
K	0.0121	0.74	2	200
Na	0.4407	26.97	2	200
Li	0.0023	0.14	2	200
NH_4	0.00008	0.005	1	50
	1.63398	100.000		

Albuminoid ammonia (not in summation), 0.00002 grams per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0002	0.01
$LiCl$	0.0140	0.86
KCl	0.0231	1.41
$NaCl$	0.4940	30.23
Na_2SO_4	0.0281	1.72
$Na_2B_4O_7$	0.0335	2.05
$NaAsO_2$	0.0025	0.15
Na_2HPO_4	0.0002	0.01
Na_2CO_3	0.5286	32.36
$MgCO_3$	0.0018	0.11
$CaCO_3$	0.0075	0.46
$FeCO_3$	0.0001	0.01
Al_2O_3	0.0051	0.31
SiO_2	0.2964	18.14
CO_2	0.1989	12.17
	1.6340	100.00

SPLENDID GEYSER.

(Locality, Upper Geyser Basin; date of collection, August 28, 1884; temperature, 93° C.; reaction, alkaline; specific gravity, 1.00127.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.3000	18.81	2	200
SO_3	0.0158	0.99	2	100
CO_2	0.4042	25.34	2	200
B_2O_3	0.0240	1.51	2	500
As_2O_3	0.0010	0.06	2	500
Cl	0.3181	19.94	2	100
Br	None	......	2	100
H_2S	None	......	1	600
O (basic)	0.0866	5.43	..	....
Fe	Trace	......	2	200
Al	0.0034	0.21	2	200
Ca	0.0034	0.21	2	200
Mg	0.0015	0.09	2	200
K	0.0152	0.95	2	100
Na	0.4179	26.20	2	100
Li	0.0037	0.23	2	100
NH_4	0.00042	0.03	2	50
	1.59522	100.00		

Albuminoid ammonia (not in summation) 0.00020 grams per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0012	0.08
LiCl	0.0225	1.41
KCl	0.0290	1.82
NaCl	0.4692	29.41
Na_2SO_4	0.0280	1.76
$Na_2B_4O_7$	0.0346	2.17
$NaAsO_2$	0.0016	0.10
Na_2CO_3	0.4977	31.20
$MgCO_3$	0.0053	0.32
$CaCO_3$	0.0085	0.53
Al_2O_3	0.0064	0.40
SiO_2	0.3000	18.81
CO_2	0.1912	11.99
	1.5952	100.00

GIANTESS GEYSER.

(Locality, Upper Geyser Basin; date of collection, August 29, 1884; temperature, 93° C.; reaction, alkaline; specific gravity, 1.00100.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.3917	27.62	2	200
SO_3	0.0167	1.18	2	200
CO_2	0.1055	7.44	2	200
B_2O_3	0.0233	1.64	2	200
As_2O_3	0.0006	0.04	2	200
Cl	0.4408	31.08	2	100
Br	Trace	......	2	100
H_2S	Trace	......	1	600
O (basic)	0.0411	2,90	..	...
Fe	Trace	......	2	200
Al	0.0049	0.34	2	200
Ca	0.0007	0.05	2	200
Mg	0.0012	0.08	2	200
K	0.0410	2.90	2	100
Na	0.3451	24.33	2	100
Li	0.0057	0.40	2	100
NH_4	......	......	..	....
	1.4183	100.00		

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
LiCl	0.0346	2.44
KCl	0.0783	5.52
KBr	Trace	......
NaCl	0.6173	43.52
Na_2SO_4	0.0296	2.09
$Na_2B_4O_7$	0.0336	2.37
$NaAsO_2$	0.0008	0.06
Na_2CO_3	0.1959	13.81
$MgCO_3$	0.0042	0.30
$CaCO_3$	0.0017	0.12
Al_2O_3	0.0093	0.65
SiO_2	0.3917	27.62
CO_2	0.0213	1.50
H_2S	Trace	......
	1.4183	100.00

The analysis of a preliminary sample of 1,300 cm^3., taken August 28, 1883, yield the following results, which are given in grams of material per kilogram of water: SiO_2, 0.3843; SO_3, 0.0144; Cl, 0.4384; Fe and Al, 0.0030; Ca, 0.0058; Mg, 0.0002; Li, 0.0043; Na and K, weighed together as chlorides, 0.9559. The chlorides of the sodium and potassium found in the preceding analysis amount to 0.9564 gram.

BEEHIVE GEYSER.

(Locality, Upper Geyser Basin; date of collection, September 1, 1884; temperature, 93° C.; reaction, alkaline; specific gravity, 1.00095.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.3042	25.12	2	200
SO_3	0.0271	2.24	2	100
CO_2	0.0920	7.60	2	200
B_2O_3	0.0145	1.20	2	500
As_2O_3	0.0011	0.09	2	500
Cl	0.3894	32.15	2	100
Br	Trace	......	2	100
H_2S	None	......	1	600
O (basic)	0.0364	3.00	..	....
Fe	Trace	......	2	200
Al	0.0029	0.24	2	200
Ca	0.0039	0.32	2	200
Mg	0.0002	0.02	2	200
K	0.0213	1.76	2	100
Na	0.3118	25.74	2	100
Li	0.0061	0.50	2	100
NH_4	0.00021	0.02	1	50
	1.21111	100.00		

Albuminoid ammonia, none.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0006	0.05
LiCl	0.0370	3.05
KCl	0.0407	3.36
KBr	Trace	......
NaCl	0.5582	46.09
Na_2SO_4	0.0481	3.97
$Na_2B_4O_7$	0.0209	1.73
$NaAsO_2$	0.0014	0.12
Na_2CO_3	0.1754	14.48
$MgCO_3$	0.0007	0.06
$CaCO_3$	0.0098	0.81
Al_2O_3	0.0055	0.45
SiO_2	0.3042	25.12
CO_2	0.0086	0.71
	1.2111	100.00

GROTTO GEYSER.

(Locality, Upper Geyser Basin; date of collection, August 28, 1884; temperature, 93° C.; reaction, alkaline; specific gravity, 1.00120.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.2590	18.15	2	200
SO_3	0.0148	1.04	2	100
CO_2	0.3155	22.11	2	200
B_2O_3	0.0290	2.03	2	500
As_2O_3	0.0003	0.02	2	500
Cl	0.3045	21.34	2	100
Br	Trace	......	2	100
H_2S	None	......	1	600
O (basic)	0.0807	5.66	..	....
Fe	Trace	......	2	200
Al	0.0036	0.25	2	200
Ca	0.0039	0.28	2	200
Mg	0.0010	0.07	2	200
K	0.0249	1.74	2	100
Na	0.3853	27.00	2	100
Li	0.0041	0.29	2	100
NH_4	0.00023	0.02	1	50
	1.42683	100.00		

Albuminoid ammonia (not in summation) 0.00010 gram per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent of total material in solution.
NH_4Cl	0.0007	0.05
LiCl	0.0249	1.75
KCl	0.0476	3.34
KBr	Trace	......
NaCl	0.4293	30.09
Na_2SO_4	0.0263	1.84
$Na_2B_4O_7$	0.0418	2.93
$NaAsO_2$	0.0004	0.03
Na_2CO_3	0.4573	32.05
$MgCO_3$	0.0035	0.25
$CaCO_3$	0.0097	0.68
Al_2O_3	0.0068	0.47
SiO_2	0.2590	18.15
CO_2	0.1195	8.37
	1.4268	100.00

TURBAN AND GRAND GEYSERS.

(Locality, Upper Geyser Basin; date of collection, September 1, 1884; temperature, 91° C.; reaction, alkaline; specific gravity, 1.00108.)

The vents of these geysers connect with one another.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.3035	21.83	2	200
SO_3	0.0218	1.57	2	100
CO_2	0.1950	14.02	2	200
B_2O_3	0.0243	1.75	2	500
As_2O_3	0.0011	0.07	2	500
Cl	0.3767	27.09	2	100
Br	Trace	......	2	100
H_2S	Trace	......	1	600
O(basic)	0.0596	4.28	..	....
Fe	Trace	......	2	200
Al	0.0032	0.25	2	200
Ca	0.0028	0.20	2	200
Mg	None	......	2	200
K	0.0167	1.20	2	100
Na	0.3818	27.46	2	100
Li	0.0036	0.25	2	100
NH_4	0.00042	0.03	1	50
	1.39052	100.00		

Albuminoid ammonia (not in summation) 0.00020 gram per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0012	0.08
LiCl	0.0218	1.57
KCl	0.0319	2.29
KBr	Trace	......
NaCl	0.5643	40.59
Na_2SO_4	0.0387	2.79
$Na_2B_4O_7$	0.0350	2.52
$NaAsO_2$	0.0014	0.10
Na_2CO_3	0.3209	23.08
$MgCO_3$	None	......
$CaCO_3$	0.0070	0.50
Al_2O_3	0.0061	0.43
SiO_2	0.3035	21.83
CO_2	0.0587	4.22
H_2S	Trace	......
	1.3905	100.00

ARTEMISIA GEYSER.

(Locality, Upper Geyser Basin; date of collection, September 1, 1884; temperature, 89° C.; reaction, alkaline; specific gravity, 1.00121.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.2737	18.39	2	200
SO_3	0.0127	0.85	2	100
CO_2	0.3607	24.24	2	200
B_2O_3	0.0177	1.19	2	500
As_2O_3	0.0014	0.09	2	500
Cl	0.2996	20.13	2	100
Br	Trace	......	2	100
H_2S	None	......	1	600
O(basic)	0.0903	6.06	..	....
Fe	Trace	......	2	200
Al	0.0079	0.59	2	200
Ca	0.0014	0.09	2	200
Mg	None	......	2	200
K	0.0163	1.09	2	100
Na	0.3988	26.80	2	100
Li	0.0070	0.47	2	100
NH_4	0.00021	0.01	1	50
	1.48771	100.00		

Albuminoid ammonia, trace.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0006	0.04
LiCl	0.0425	2.86
KCl	0.0311	2.09
KBr	Trace	.....
NaCl	0.4101	27.56
Na_2SO_4	0.0226	1.52
$Na_2B_4O_7$	0.0202	1.36
$NaAsO_2$	0.0018	0.12
Na_2CO_3	0.5245	35.26
$MgCO_3$	None	none.
$CaCO_3$	0.0035	0.23
Al_2O_3	0.0150	1.01
SiO_2	0.2737	18.40
CO_2	0.1421	9.55
	1.4877	100.00

TAURUS GEYSER.

(Locality, Shoshone Basin; date of collection, July 20, 1887; temperature, 92° C.; reaction, alkaline; specific gravity, 1.00105.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.2926	22.69	2	500
SO_3	0.0385	2.98	2	200
CO_2	0.3210	24.89	2	200
B_2O_3	0.0149	1.16	2	1,000
As_2O_3	0.0007	0.05	2	1,000
Cl	0.1935	15.00	2	200
Br	None	......	2	100
H_2S	None	......	..	......
O (basic)	0.0781	6.05	..	......
Fe	Trace	......	2	500
Al	0.0040	0.31	2	500
Ca	Trace	......	2	500
Mg	0.0009	0.07	2	500
K	0.0235	1.82	2	200
Na	0.3202	24.83	2	200
Li	0.0009	0.07	2	200
NH_4	0.0010	0.08	2	50
	1.2898	100.00		

Albuminoid ammonia, 0.0002 grams per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0030	.24
LiCl	0.0055	.43
KCl	0.0449	3.48
NaCl	0.2729	21.15
Na_2SO_4	0.0630	4.88
$MgSO_4$	0.0045	.35
$Na_2B_4O_7$	0.0215	1.67
$NaAsO_2$	0.0009	.07
Na_2SiO_3	0.4971	38.54
SiO_2	0.0480	3.72
CO_2	0.3210	24.89
Al_2O_3	0.0075	.58
Fe_2O_3	Trace	Trace
	1.2898	100.00

ASTA SPRING.

(Locality, Hillside Springs; date of collection, September 16, 1884; temperature, 84°C.; reaction, alkaline.)

Constituents.	Grams per kilo of water	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.1650	24.40	1	200
SO_3	0.0324	4.79	1	200
CO_2	0.1800	26.61	1	200
B_2O_3	Trace	......	..	100
As_2O_3	......	......	..	....
Cl	0.0947	14.00	1	200
Br	None	......	1	100
H_2S	None	......	..	....
O (basic)	0.0392	5.79	..	....
Fe A }	0.0059	0.87	1	200
Ca	0.0118	1.75	1	200
Mg	0.0010	0.15	1	200
K	0.0116	1.72	1	200
Na	0.1340	19.80	1	200
Li	0.0008	0.12	1	200
	0.6764	100.00		

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
LiCl	0.0048	0.71
KCl	0.0221	3.27
NaCl	0.1320	19.51
Na_2SO_4	0.0575	8.50
$Na_2B_4O_7$	Trace	......
$NaAsO_2$	......	......
Na_2CO_3	0.1463	21.63
$MgCO_3$	0.0035	0.52
$CaCO_3$	0.0295	4.36
Al_2O_3	0.0112	1.65
SiO_2	0.1650	24.40
CO_2	0.1045	15.45
	0.6764	100.00

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BENCH SPRING.

(Locality, Upper Geyser Basin; date of collection, September 2, 1884; temperature, 88° C.; reaction, slightly acid.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.2400	50.88	1	40
SO_3	0.1151	24.40	1	100
CO_2	......	......	1	....
B_2O_3	None	......	1	....
Cl	Trace	......	1	100
H_2S	None	......	..	....
O (basic)	0.0350	7.42	..	....
Fe Al	0.0145	3.07	1	40
Ca	Trace	......	1	40
Mg	Trace	......	1	40
K	0.0097	2.06	1	100
Na	0.0574	12.17	1	100
Li	Trace	......	1	100
	0.4717	100.00		

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
K_2SO_4	0.0216	4.58
Na_2SO_4	0.1772	37.57
$MgSO_4$	Trace	......
$CaSO_4$	Trace	......
$Al_2(SO_4)_3$	0.0066	1.40
Al_2O_3	0.0263	5.57
SiO_2	0.2400	50.88
HCl	Trace	......
CO_2	......	......
	0.4717	100.00

FIREHOLE RIVER.

(Locality, above Upper Geyser Basin ; date of collection, August 27, 1884 ; temperature, 12° C. ; reaction, slightly alkaline ; specific gravity, 1.00015.)

The water was filtered before bottling.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.0407	30.86	2	200
SO_3	0.0062	4.70	2	100
CO_2	0.0305	23.11	2	200
B_2O_3	Trace	......	2	500
As_2O_3	None	......	2	500
Cl	0.0105	7.96	2	100
H_2S	None	......	..	....
O(basic)	0.0103	7.81	..	....
Fe	Trace	......	2	200
Al	0.0029	2.20	2	200
Ca	0.0052	3.94	2	200
Mg	0.0011	0.83	2	200
K	0.0094	7.13	2	100
Na	0.0151	11.45	2	100
Li	Trace	......	2	100
NH_4	0.00002	0.01	2	50
	0.13192	100.00		

Albuminoid ammonia (not in summation), 0.00010 grams per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	Trace	Trace
LiCl	Trace	Trace
KCl	0.0181	13.72
NaCl	0.0030	2.27
Na_2SO_4	0.0110	8.34
$Na_2B_4O_7$	Trace	Trace
Na_2CO_3	0.0210	15.92
$MgCO_3$	0.0038	2.88
$CaCO_3$	0.0130	9.86
Al_2O_3	0.0055	4.17
Fe_2O_3	Trace	......
SiO_2	0.0407	30.86
CO_2	0.0158	11.98
	0.1319	100.00

YELLOWSTONE LAKE.

(Locality, near outlet; date of collection, September 18, 1884; specific gravity, 1.00014.)

The water was filtered through linen.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.0420	24.32	2	200
SO_3	0.0070	4.04	2	100
CO_2	0.0725	42.00	2	200
B_2O_3	None	......	2	500
As_2O_3	None	......	2	500
Cl	0.0094	5.43	2	100
H_2S	None	......	..	...
O (basic)	0.0100	5.78	..	...
Fe	None	.....	2	200
Al	0.0021	1.21	2	200
Ca	0.0086	4.97	2	200
Mg	0.0003	0.16	2	200
K	0.0047	2.71	2	100
Na	0.0156	9.36	2	100
Li	Trace	......	..	100
NH_4	0.00042	0.02	1	50
	0.17262	100.00		

Albuminoid ammonia (not in summation), 0.00022 grams per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0012	0.69
LiCl	Trace	......
KCl	0.0090	5.21
NaCl	0.0071	4.11
Na_2SO_4	0.0124	7.18
Na_2CO_3	0.0202	11.73
$MgCO_3$	0.0010	0.58
$CaCO_3$	0.0215	12.45
Al_2O_3	0.0040	2.32
SiO_2	0.0420	24.33
CO_2	0.0542	31.40
	0.1726	100.00

ALUM CREEK.

(Locality, at the crossing of the road; date of collection, September 19, 1884; reaction, acid; specific gravity, 1.00105.)

The water was filtered through linen before bottling.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.2180	17.83	2	200
SO_3	0.4202	34.38	2	200
CO_2	0.0075	0.61	2	200
B_2O_3	0.0057	0.47	2	500
As_2O_3	None	......	2	500
Cl	0.2028	16.59	2	200
Br	Trace	......	1	100
H_2S	None	......	..	....
O (basic)	0.0840	6.87	..	....
Fe	0.0250[a]	2.04	2	200
Al	0.0025	0.20	2	200
Ca	0.0127	1.04	2	200
Mg	0.0038	0.31	2	200
K	0.0741	6.06	2	200
Na	0.1595	13.05	2	200
Li	0.0009	0.08	2	200
NH_4	0.00106	0.09	1	50
H (in HCl)	0.0046	0.38	..	....
	1.22236	100.00		

Albuminoid ammonia (not in summation), 0.00010 gram per kilo.

[a] All in ferric condition.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0031	0.26
LiCl	0.0055	0.45
KCl	0.0669	5.47
KBr	Trace	......
K_2SO_4	0.0872	7.13
Na_2SO_4	0.4924	40.29
$MgSO_4$	0.0190	1.55
$CaSO_4$	0.0432	3.53
$Al_2(SO_4)_3$	0.0158	1.29
$Fe_2(SO_4)_3$	0.0893	7.31
SiO_2	0.2180	17.83
B_2O_3	0.0057	0.47
CO_2	0.0075	0.61
HCl	0.1688	13.81
	1.2224	100.00

CHROME SPRING.

(Locality, Crater Hill; date of collection, September 19, 1884; temperature, 92° C.; reaction, neutral; specific gravity, 1.00231.)

The water was filtered from suspended matter before analyzing and the latter was examined by itself.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.3750	13.04	2	200
SO_3	0.3618	12.59	2	100
CO_2	0.0147	0.51	2	200
B_2O_3	0.0842	2.93	2	250
As_2O_3	0.0072	0.25	2	250
Cl	1.0207	35.52	2	200
Br	......	......	..	....
H_2S	None *a*	......	..	....
O (basic)	0.0801	2.78	..	....
Fe Al	0.0043	0.14	2	200
Ca	0.0140	0.48	2	200
Mg	0.0020	0.06	2	200
K	0.1603	5.66	2	100
Na	0.7320	25.47	2	100
Li	0.0064	0.21	2	100
NH_4	0.0106	0.36	2	40
	2.8733	100.00		

a As received in the laboratory.

Albuminoid ammonia (not in summation), 0.00107 grams per kilo.

Material in suspension in a kilo of water	SiO_2	0.4791 gram.
	S	0.0757 gram.
	Other insoluble matter	0.0503 gram.
		0.6051 gram.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0.0315	1.10
LiCl	0.0388	1.35
KCl..........	0.3062	10.66
KBr	......	......
NaCl	1.3536	47.11
Na_2SO_4	0.5804	21.46
$MgSO_4$.......	0.0100	0.34
$CaSO_4$	0.0476	0.45
$Na_2B_4O_7$	0.0516	1.74
Al_2O_3	0.0082	0.29
SiO_2	0.3750	13.05
B_2O_3	0.0485	1.69
As_2O_3........	0.0072	0.25
CO_2	0.0147	0.51
	2.8733	100.00

A preliminary sample of 600 cm³., taken September 18, 1883, yielded, when filtered from suspended material, the following figures signifying grams of material per kilogram of water:

SiO_2, 0.2380; SO_3, 0.3516; Cl, 1.0442; Fe and Al, 0.0080;
Ca, 0.0185; Mg, 0.0024; K, 0.1438; Na, 0.6269; Li, 0.0041.

The reaction was acid.

MUSH POT SPRING.

(Locality, Pelican Creek; date of collection, October 1, 1886; temperature, 85° C.; reaction, acid; specific gravity, 1.00088.)

The water was filtered from suspended material before the analysis.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.2270		2	200
SO_3	0.5375		2	200
CO_3	0.0045		2	200
B_2O_3	0.0056		2	500
As_2O_3	None		2	500
Cl	0.0047		2	100
H_2S	None *a*		..	....
O (basic)	0.0929		..	....
Fe	Trace		2	200
Al	0.0045		2	200
Ca	0.0632		2	200
Mg	0.0214		2	200
K	0.0195		2	200
Na	0.1175		2	200
Li	None		2	200
NH_4	0.0100		2	50
H (in HCl)	0.0001		..	....
	1.1084			

a As received in the laboratory.

Albuminoid ammonia (not in summation), 0.00060 gram per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
$(NH_4)_2SO_4$	0.0366	3.30
Na_2SO_4	0.3627	32.72
K_2SO_4	0.0435	3.93
$MgSO_4$	0.1070	9.66
$CaSO_4$	0.2149	19.39
$Al_2(SO_4)_3$	0.0285	2.57
$Fe_2(SO_4)_3$	Trace	......
SiO_2	0.2270	20.48
B_2O_3	0.0056	0.50
SO_3	0.0733	6.61
CO_2	0.0045	0.41
HCl	0.0048	0.43
	1.1084	100.00

The water carried in suspension 0.5551 gram of insoluble matter per kilogram of water. This material dried at 104°; lost 7.33 per cent. of its weight on ignition. The partial analysis of 3.4972 grams of the ignited material resulted as follows:

	Per cent.
SiO_2	61.30
SO_3	0.63
Al_2O_3	24.24
Fe_2O_3	6.53
MnO	Trace
CaO	1.74
MgO	2.18
K_2O	0.57
Na_2O	0.84
	98.03

DEVIL'S INK POT.

(Locality, Mount Washburn; date of collection, July, 8, 1886; temperature, 92° C.; reaction, acid; specific gravity, 1.00221.)

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0.0897	2.65	2	200
SO_3	1.9330	57.07	2	200
CO_2	0.0647	1.91	2	200
B_2O_3	0.0518	1.53	2	500
As_2O_3	None	......	2	500
Cl	0.0058	0.17	2	200
H_2S	0.0051	0.15	2	200
O (basic)	0.3795	11.20	-	....
Fe	Trace	......	2	200
Al	0.0037	0.11	2	200
Ca	0.0396	1.17	2	200
Mg	0.0121	0.36	2	200
K	0.0083	0.25	2	200
Na	0.0245	0.72	2	200
Li	0.0004	0.01	2	200
NH_4	0.7687	22.69	2	100
H (in HCl)	0.0002	0.01	-	....
	3.3871	100.00		

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
$(NH_4)_2SO_4$	2.8185	83.21
Li_2SO_4	0.0031	0.11
Na_2SO_4	0.0756	2.23
K_2SO_4	0.0185	0.54
$MgSO_4$	0.0605	1.78
$CaSO_4$	0.1346	3.97
$Al_2(SO_4)_3$	0.0234	0.69
SiO_2	0.0897	2.65
B_2O_3	0.0518	1.53
SO_3	0.0356	1.05
CO_2	0.0647	1.91
HCl	0.0060	0.18
H_2S	0.0051	0.15
	3.3871	100.00

SODA BUTTE SPRING.

(Locality, Soda Butte; date of collection, September 17, 1885; temperature, 18° C.; reaction, alkaline; specific gravity, 1. 00138.)

The water was filtered before bottling.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.	Determinations.	Grams of water employed in each determination.
SiO_2	0. 0335	1. 72	2	200
SO_3	0. 0614	3. 15	2	200
CO_2	1. 2490 *a*	64. 18	2	200
B_2O_3	0. 0150	0. 77	2	500
As_2O_3	None	......	2	500
Cl	0. 0315	1. 62	2	200
Br	None	......	2	100
H_2S	0. 0042 *b*	0. 22	2	200
O (basic)	0. 1618	8. 32	.	....
Fe Al	0. 0069	0. 36	2	200
Ca	0. 2325	11. 95	2	200
Mg	0. 0632	3. 25	2	200
K	0. 0238	1. 22	2	200
Na	0. 0575	2. 95	2	200
Li	Trace	......	2	200
NH_4	0. 0057	0. 29	1	50
	1. 9460	100. 00		

a Cupric sulphate was used to hold back H_2S in the determination of CO_2.
b As received in the laboratory.

Albuminoid ammonia (not in summation), 0. 00140 gram per kilo.

Hypothetical combination.

Constituents.	Grams per kilo of water.	Per cent. of total material in solution.
NH_4Cl	0. 0169	0. 87
LiCl	Trace	......
KCl	0. 0425	2. 19
K_2SO_4	0. 0034	0. 17
Na_2SO_4	0. 1062	5. 46
$Na_2B_4O_7$	0. 0216	1. 11
Na_2CO_3	0. 0419	2. 15
$MgCO_3$	0. 2212	11. 37
$CaCO_3$	0. 5813	29. 87
Al_2O_3	0. 0131	0. 67
SiO_2	0. 0335	1. 72
CO_2	0. 8602	44. 20
H_2S	0. 0042	0. 22
	1. 9460	100. 00

Summary of Analyses.

[The amounts of substances are stated in grams per kilogram.]

	Date of collection.	Temperature.	Reaction.	Specific gravity.	SiO_2	TiO_2	SO_3	CO_2	N_2O_5	P_2O_5	B_2O_3	As_2O_3	Cl	Br	I	Fl	H_2S	Basic O	Fe	Al	Mn	Ba	Sr	Ca	Mg	Cs	Rb	K	Na	Li	NH_4	In $\frac{HCl}{H}$	Total.	Albuminoid ammonia.
		Degrees C.																																
Cleopatra Spring	Oct. 11, 1883	71	Alkaline				0.4254	0.5071																0.3006										
Cleopatra Spring	July 28, 1884	67	do	1.00205	0.0517		0.4395	0.6287			0.0226	0.0031	0.1749	trace.			trace.	0.1954	0.0049					0.3076	0.0729			0.0511	0.1299	0.0023	0.00063		2.08523	0.00020
Overflow of Cleopatra Spring	July 28, 1884	44	do				0.4573	0.3866																0.2504	0.0797									
Orange Spring	Oct. 11, 1883	63	do		0.0502		0.4407	0.3378			present.		0.1623	trace.			none.	0.1796	0.0012					0.2821	0.0659			0.0610	0.1233	0.0016			1.7057	
Hot River	Oct. 5, 1884	58	do	1.00157	0.0500		0.4230	0.4270			0.0128	0.0004	0.1604	none.			none.	0.1682	0.0051					0.2360	0.0631			0.0462	0.1506	0.0011	0.00011		1.74401	trace.
Soda Butte Spring	Sept. 17, 1885	18	do	1.00138	0.0335		0.0614	1.2490			0.0150	none.	0.0315	none.			0.0042	0.1618	0.0069					0.2325	0.0632			0.0238	0.0575	trace.	0.00570		1.9460	0.00140
Fearless Geyser	Aug. 18, 1884	88	Neutral	1.00110	0.4180	none.	0.0367	0.0046	none.	none.	0.0223	0.0022	0.6705	0.0026	none.	none.	trace.	0.0113	0.0006	0.0002	none.	none.	none.	0.0092	0.0001	trace.	trace.	0.0415	0.4046	0.0081	0.00025		1.63275	0.00001
Fearless Geyser	Sept. 27, 1883	92	do		0.3463		0.6501						0.6476						0.0021					0.0098	trace.			0.0443	0.3931	0.0042				
Pearl Geyser	Aug. 20, 1884	84	do	1.00110	0 4636	none.	0.0228	0.0075		none.		0.0038	0.6520			none.	trace.		trace.	0.0031	trace. *h*	none.	none.	0.0064	0.0009			0.0544	0.4046	0.0022	0.00021			0.00001
Constant Geyser	Sept. 13, 1885	92	Acid	1.00115	0.4685		0.0923	0.0155			0.0317	0.0018	0.5740	trace.			none. *a*	0.0185	traee.	0.0048				0.0146	0.0018			0.0745	0.3190	0.0030	0.00127	0.0008	1.62207	none.
Coral Spring	Aug. 20, 1881	73	do	1.00130	0.6070		0.0264	0.0425			0.0328	0.0007	0.7087				none.	0.0053	trace.	0.0029				0.0102	0.0022			0.0729	0.3936	0.0020	0.00042	0.0032	1.91082	0.00010
Coral Spring	Oct. 11, 1886	72	Faintly acid	1.00124	0.5805		0.0280	0.0262			0.0368	0.0009	0.6701				none.	0.0175	trace.	0.0077				0.0071	0.0014			0.0815	0.3925	0.0040	0.00030		1.8545	0.00060
Echinus Spring	Aug. 20, 1884	91	Acid	1.00071	0.2532		0.1929	0.0250			0.0173	0.0016	0.1207	trace.			trace.	0.0386	none.	0.0027				0.0115	none.			0.0395	0.1265	trace.	0.00106	0.0007	0.83126	none.
Schlammkessel	Aug. 20, 1884	91	do	1.00130	0.4577		0.1012	0.0175			0.0390	none.	0.6391	trace.			trace.	0.0202	0.0081					0.0078	0.0003			0.0254	0.3654	0.0029	0.00633	0.0019	1.69283	0.00040
Fountain Geyser	Aug. 24, 1884	82	Alkaline	1.00100	0.3315	none.	0.0195	0.2307	none.	0.00004	0.0138	0.0027	0.3337	0.0004	none.	none.	trace.	0.0654	0.0002	0.0057	trace. *b*	none.	none.	0.0014	0.0010	none.	none.	0.0379	0.3522	0.0035	0.00015		1.39979	0.00038
Great Fountain Geyser	do	82–93 *c*	do	1.00104	0.3182		0.0187	0.2107			0.0100	0.0017	0.3508				none.	0.0472	trace.	0.0021				0.0017	0.0023			0.0145	0.3351	0.0025			1.3155	
Hygeia Spring	Sept. 11, 1885	43	do	1.00107	0.2477		0.0196	0.2907			0.0239	0.0034	0.2487	trace.			none *a*	0.0504	none.	0.0036				0.0064	0.0022			0.0154	0.2654	0.0032	0.00021		1.18081	
Madison Spring	do	60	do	1.00100	0.1507		0.0123	0.6140			0.0130	trace.	0.0698	none.			none *a*	0.1062	none.	none.				0.0255	0.0017			0.0385	0.2930	0.0004	0.00080		1.32590	0.00020
Excelsior Geyser	Aug. 25, 1884	92	do	1.00110	0.2214	none.	0.0146	0.3825	none.	trace.	0.0161	0.0026	0.2793	trace.	none.	none.	trace.	0.0955	0.0018	0.0012	trace.	none.	none.	0.0022	0.0022	none.	none.	0.0225	0.4186	0.0020	0.00001		1.47251	0.00002
Excelsior Geyser	Aug. 29, 1883	92	do		0.2727		0.0107				present.		0.2765						0.0009					0.0955						present.				
Old Faithful Geyser	Sept. 1, 1884	84–88 *d*	do	1.00096	0.3828	none.	0.0152	0.0894	none.	none.	0.0148	0.0021	0.4391	0.0034	none.	none.	0.0002	0.0419	trace.	0.0009	trace. *e*	none.	none.	0.0015	0.0006	trace.	trace.	0.0267	0.3666	0.0056	0.00001		1.39081	0.00002
Splendid Geyser	Sept. 10, 1885	93	do	1.00132	0.2964	none.	0.0158	0.4225	none.	0.00012	0.0234	0.0019	0.3227	none.	none.	none.	none *a*	0.0897	0.00008	0.0027	none.	none.	none.	0.0030	0.0005	none.	none.	0.0121	0.4407	0.0023	0.00008		1.63398	0.00002
Splendid Geyser	Aug. 28, 1884	93	do	1.00127	0.3000		0.0158	0.4042			0.0240	0.0010	0.3181	none.			none.	0.0866	trace.	0.0034				0.0034	0.0015			0.0152	0.4179	0.0037	0.00042		1.59522	0.00020
Giantess Geyser	Aug. 29, 1884	93	do	1.00100	0.3917		0.0167	0.1055			0.0233	0.0006	0.4408	trace.			trace.	0.0411	trace.	0.0049				0.0007	0.0012			0.0410	0.3451	0.0057			1.4183	
Giantess Geyser	Aug. 28, 1883	93	do		0.3843		0.0144						0.4384						0.0030					0.0058	0.0002			*f*	*f*	0.0043				
Beehive Geyser	Sept. 1, 1884	93	do	1.00095	0.3042		0.0271	0.0920			0.0145	0.0011	0.3894	trace.			none.	0.0364	trace.	0.0029				0.0039	0.0002			0.0213	0.3118	0.0061	0.00021		1.21111	none.
Grotto Geyser	Aug. 28, 1884	93	do	1.00120	0.2590		0.0148	0.3155			0.0290	0.0003	0.3045	trace.			none.	0.0807	trace.	0.0036				0.0039	0.0010			0.0249	0.3853	0.0041	0.00023		1.42683	0.00010
Turban and Grand Geysers	Sept. 1, 1887	91	do	1.00108	0.3035		0.0218	0.1950			0.0243	0.0011	0.3767	trace.			trace.	0.0596	trace.	0.0032				0.0028	none.			0.0167	0.3818	0.0036	0.00042		1.39052	0.00020
Artemisia Spring	do	89	do	1.00121	0.2737		0.0127	0.3607			0.0177	0.0014	0.2996	trace.			none.	0.0903	trace.	0.0079				0.0014	none.			0.0163	0.3988	0.0070	0.00021		1.48771	trace.
Taurus Geyser	July 20, 1884	92	do	1.00105	0.2926		0.0385	0.3210			0.0149	0.0007	0.1935	none.			none.	0.0781	trace.	0.0040				trace.	0.0009			0.0235	0.3202	0.0009	0.0010		1.2898	0.0002
Asta Spring	Sept. 16, 1884	84	do		0.1650		0.0324	0.1800			trace.	undet.	0.0947	none.			none.	0.0392	0.0059					0.0118	0.0010			0.0116	0.1340	0.0008			0.6764	
Bench Spring	Sept. 2, 1884	88	Slightly acid		0.2400		0.1151				none.		trace.				none.	0.0350	0.0145					trace.	trace.			0.0097	0.0574	trace.			0.4717	
Chrome Spring	Sept. 19, 1884	92	Neutral	1.00231	0.3750		0.3618	0.0147			0.0842	0.0072	1.0207				none. *g*	0.0801	0.0043					0.0140	0.0020			0.1603	0.7320	0.0064	0.0106		2.8733	0.00107
Chrome Spring	Sept. 18, 1883	92	Acid		0.2380		0.3516						1.0442						0.0080					0.0185	0.0024			0.1438	0.6269	0.0041				
Alum Creek	Sept. 19, 1884		do	1.00105	0.2180		0.4202	0.0075			0.0057	none.	0.2028	trace.			none.	0.0840	0.0250	0.0025				0.0127	0.0038			0.0741	0.1595	0.0009	0.00106	0.0046	1.22236	0.00010
Mush Pot Spring	Oct. 1, 1886	85	do	1.00088	0.2270		0.5375	0.0045			0.0056	none.	0.0047				none. *a*	0.0929	trace.	0.0045				0.0632	0.0214			0.0195	0.1175	none.	0.0100	0.0001	1.1084	0.00060
Devil's Ink Pot	July 8, 1886	92	do	1.00221	0.0897		1.9330	0.0647			0.0518	none.	0.0058				0.0051	0.3795	trace.	0.0037				0.0396	0.0121			0.0083	0.0245	0.0004	0.7687	0.0002	3.3871	
Firehole River at Marshall's	Aug. 24, 1884	8	Alkaline	1.00031	0.0965		0.0084	0.1040			0.0060	none.	0.0737				none.	0.0265	trace.	0.0031				0.0066	0.0007			0.0170	0.0930	0.0011			0.4366	
Firehole River above Upper Basin	Aug. 27, 1884	12	Slightly alk.	1.00015	0.0407		0.0062	0.0305			trace.	none.	0.0105				none.	0.0103	trace.	0.0029				0.0052	0.0011			0.0094	0.0151	trace.	0.00002		0.13192	0.00015
Gardiner River above Hot River	Oct. 12, 1883	8			0.0469		0.0117	0.0710					0.0049					0.0216	0.0042					0.0250	0.0005			0.0079	0.0200	trace.			0.2137	
Gardiner River below Hot River	Sept. 26, 1884	13			0.0272		0.0802	0.1725					0.0301					0.0487	0.0010					0.0749	0.0175			0.0105	0.0311	trace.			0.4937	
Water Supply at Mam. Hot Springs	July 28, 1884				0.0355		0.0310	0.1230	trace.				0.0022					0.0248	0.0011					0.0316	0.0089			0.0031	0.0145	none.	0.000022		0.2757	.000028
Soda Spring	—— 1887	6	Acid	1.00041	0.0184		0.0390	0.6735			none.	none.	0.0044				none.	0.0432	0.0053	0.0004				0.0808	0.0106			0.0027	0.0039	none.	0.0005		0.8827	trace.
Yellowstone Lake	Sept. 18, 1884			1.00014	0.0420		0.0070	0.0725			none.	none.	0.0094				none.	0.0100	none.	0.0021				0.0086	0.0003			0.0047	0.0156	trace.	0.00042		0.17262	0.00022

a As received in laboratory. *b* 0.000003. *c* Usual temperature between eruptions. *d* Temperature in pools about crater after eruption. *e* 0.000005. Total Na and K as chlorides, 0.9559. *g* As received in the laboratory; sulphur in suspension, 0.0757. *h* 0.000038

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