Potassium to carbonate. All of the calculated sodium to carbonate.

Silica	0.74	Potassium carbonate	4.87
Alumina	0.15	Calcium sulphate	27.90
Ferrous carbonate	0.14	Magnesium chloride	18.73
Calcium carbonate	19.80	Parts per 100,000	147.54
Magnesium carbonate	10.57	Loss	.40
Sodium carbonate	64.64		147.94

The above is an actual case. It is left as originally computed by atomic weights of 1907. Differences, if computed by 1911 factors, are exceedingly trivial.

Analysis of Mineral Waters.

Statements of mineral water analysis are not made on a strict "per cent." basis. A common method has been to give the "grains per gallon" of solid constituents. It is, however, becoming more usual to state "parts in 100,000" or "parts in 1,000,000."

Taking one liter of water for analysis each centigram is evidently "one part per 100,000" and each milligram is "one part per million."

United States gallon contains 58,318 grains of water. British Imperial gallon contains 70,000 grains (one lb. avdp.). Using metric weights and measures we may construct "assay gallons." If the estimation is to be made directly in "grains to gallon" take *as many centigrams* (by measure) *of the water as there are grains in the gallon.* This applies to either U. S. or British gallon. As the specific gravity of the water cuts no figure, we state *weight* of constituents per *volume* of water.

For statement in U. S. gallons take 0.58318 liter. For statement in Imperial gallons take 0.7 liter.

Then each centigram "found" of solid matter equals "one grain to gallon."

To calculate from one system of expression to another, use the following conversion factors:

Grains per U. S. gallon × 17.147 = parts per million.
Grains per Imperial gallon × 14.285 = parts per million.

Parts per million × .058318 = grains per U. S. gallon.
Parts per million × .07 = grains per Imperial gallon.

ASSAY WEIGHTS AND CALCULATIONS.

By an "assay" as distinguished from an "analysis" is usually understood the determination of a single constituent instead of the determination and summation of all the elements of an ore or other material.

We here confine the term to assays for the precious metals.

Assay reports in the United States are invariably made, so far as gold and silver are concerned, so as to return "ounces per ton."

The "Assay Ton," first devised by Dr. Chandler of the Columbia School of Mines, is now in use to the exclusion of all other units for "weighing in" of the assay charge. It is based upon the fact that a short ton (2,000 lbs.) contains $29{,}166\frac{2}{3}$ troy ounces. Ore being always weighed in short tons, and the precious metals as invariably in "Troy," the convenience of a weight whose use dispenses with most of the after calculations is evident at sight.

The device, then, is simply the adoption of a miniature ton in which, or in some multiple or sub-multiple of which, the ore is weighed. *In this miniature ton, the troy ounce is represented by the milligram.*

Hence the "ton" itself contains $29{,}166\frac{2}{3}$ milligrams.

If the "ton," as is usually the case, be considered too large a weight, some sub-multiple is taken. If a fifth of a "ton" is taken the results are multiplied by 5. If a tenth, by 10, etc.

Normally, however, with one "assay ton" as the ore-weight, it is obvious that *each milligram of metal found indicates one ounce to the ton.*

The "Ore and Scales" Problem.

It sometimes happens that an ore contains particles ("scales") of metal which cannot well be reduced to powder. If these "scales" are at all large, the difficulty of getting an average "pulp" for assay is serious.

Suppose, for an example, that we have a somewhat low-grade gold ore for assay, which nevertheless holds occasional particles of free gold. Say the bottled sample for assay contains one particle of free gold whose weight is *one milligram.* The assayer will probably take 0.1 assay ton for the assay. Then one milligram indicates *ten ounces* to the ton. In taking out his weight of ore he may or may not happen to include the "nugget," and the difference in result, being something over two hundred dollars to the ton, would be quite startling!

No device entirely obviates the uncertainty of assay results on very high grade ores, when free metal is present. Resampling and repetition of assays accompanied with more or less squabbling and recrimination, is a common experience.

The "ore and scales" method, sometimes called "pulp and scales," aims to avoid some of the uncertainty by screening out as much as possible of the metallic "scales." Then the ore and the scales are separately assayed.

No demonstration is needed to show that it is of primary importance that the ratio of the scales to the whole amount screened should be known.

It is also evident that only the ore which has passed through the screen should be assayed, then the two assays are combined as described below.

Valuation of an Ore by the "Ore and Scales" Method.

Let "A" be the assay value of the sample.

"a" = charge of ore *in assay tons.*

"b" = weight of the yield, *in milligrams.*

Then:

$$A = \frac{b}{a} \text{ (e.g., } a = 1,\ b = 6, \text{ then } A = 6 \text{ ounces to ton)}$$

But if the ore be weighed *in grams,* whose number = "c," then:

$$A = \frac{29166\,b}{c}$$

In an assay containing both ore and scales, separate by a fine screen, and weigh each portion. Then:

Let x = weight of pulp, and y = weight of scales (in grams).

z = assay of pulp (*oz. to ton*) for silver.

z' = assay of pulp for gold.

q = grams of silver in the scales, and q' ditto for gold in scales.

Note that we take the *whole quantity* of the scales for assay, be the same more or less, assuming that it is not possible to "sample" them fairly.

Of the ore we *take* whatever quantity is supposed to be requisite, in the usual manner for assaying, *i.e.,* in "ton" weights. But in applying the formula the *whole quantity* of ore screened must be reckoned with, of course, else the ratio of scales to screened ore is lost, and with it the entire calculation.

$$a = \frac{x + y}{29166} \qquad b = \frac{xz}{29166} + q \text{ (for silver).}$$

$$a = \frac{x + y}{29166} \qquad b = \frac{xz'}{29166} + q' \text{ (for gold).}$$

Substitute these values of a and b in the first equation, $A = \frac{b}{a}$, we have:

$$A = \frac{xz + 29166q}{x + y} \text{ silver.} \quad A' = \frac{xz' + 29166q'}{x + y} \text{ gold.}$$

We can use the formula for one metal only, or for two. Ordinarily, both silver and gold are sought in the same sample.

Example 1.—Weight of "pulp" 800 grams; of "scales" 40 grams. Assay of pulp: gold = 1.2, and silver = 108 oz. to ton. Scales, assayed "in toto" contain 0.05 gram gold, and 30.56 grams silver.

$x = 800.\ \ y = 40.\ \ z = 108.\ \ z' = 1.2.\ \ q = 30.56.\ \ q' = 0.05$

Then, $xz = 86{,}400$ and $x + y = 840.\ \ 29{,}166q = 891{,}312.96$

$$\text{Silver} = \frac{86{,}400 + 891{,}312.96}{840} = 1163.944 \text{ ounces to ton.}$$

Also, $xz' = 960$ and $29{,}166q' = 1458.30.$

$$\text{Gold} = \frac{960 + 1458.3}{840} = 2.8789 \text{ ounces to ton.}$$

Example 2.—Weight of pulp 987 grams. Of scales 1.41 grams. Assay of pulp: silver, 67 oz. to ton; gold, 0.2 oz. to ton. Scales contain: silver, 1.2 gram; gold, 0.1 gram.

$x = 987.\ \ y = 1.41.\ \ z = 67.\ \ z' = 0.2.\ \ q = 1.2.\ \ q' = 0.1$

Ans. Silver 102.3 oz. to ton; gold 3.15 oz. to ton.

Example 3 (one metal).—Pulp 1 kilogram. Scales 2.5 grams. Assay of pulp 150 oz. to ton. Metal in scales 2.4 grams.

$x = 1000.\ \ y = 2.5.\ \ z = 150.\ \ q = 2.4$

$xz = 150{,}000 \qquad x + y = 1002.5$

$29{,}166 \times 2.4 = 69{,}998.4$

Ans. 219.45 oz. to ton.

To Reduce Assays Giving Ounces to Ton, to Percentage Basis, or the Reverse.—Since there are 29,166 ounces troy in a ton, one-hundredth of that number, viz: 291.66, is one per cent. That is, an ore containing one per cent. of metal yields 291.66 oz. to ton by assay.

Hence the very simple rules:—Given the percentage, to find ounces to ton, multiply the percentage by 291.66. Given ounces per ton, to find percentage, divide number of ounces by 291.66.

If a multiple of the assay ton is taken for assay, *divide* result in milligrams by the number of tons taken, to obtain ounces to ton.

If a fraction of assay ton were taken, represented by a vulgar fraction, then *multiply* result in milligrams by the denominator of the fraction. If represented decimally, divide by the decimal fraction.

Examples in assay of irregular weights.

(4) 10 grams ore yield silver 0.05, and gold 0.001 gram. Find "assay." *Ans.* Silver, 145.83; gold, 2.916 oz. to ton.

(5) 13 grams ore. Silver, 0.045. Gold, 0.002. Find "assay." *Ans.* Silver, 100.91; gold, 4.48 oz. to ton.

Other examples will be found in the miscellaneous exercises.

Some Relations of Weight to Value in the Precious Metals.

One Troy ounce of gold, U. S. coinage value, is worth $20.6718.

One Troy ounce of silver, U. S. coinage value, is worth $1.2929.

One short ton* (2000 lbs. avdp.) of gold is worth $602,927.50 (six hundred and two thousand nine hundred and twenty-seven $\frac{50}{100}$ dollars).

One short ton* of silver is worth (coinage value) $37,709.58 (thirty-seven thousand seven hundred and nine $\frac{58}{100}$ dollars.)

One Troy pound of gold is worth $248.0616.

One Troy pound of silver is worth $15.5148.

One grain of gold is worth 4.306625 cents.

One grain of silver is worth 0.2693 cent.

One gram of gold is worth $0.66461.

* A ton of gold would make a cube of 14¼ inches edge. A ton of silver would make a cube of 17¼ inches edge.

One milligram of gold is worth $0.00066461 or 0.066461 of one cent.

One gram of silver is worth $0.041567.

One milligram of silver is worth $0.000041567 or 0.0041567 of one cent.

One dollar's worth of gold weighs 23.22 grains.

One dollar's worth of silver weighs 371.258 grains.

One gold dollar, 900 fine, weighs 25.8 grains.

One silver dollar, 900 fine, weighs 412.5 grains.

By "fine" gold is meant simply gold chemically pure. The figures above all refer to "fine" gold.

By "parts fine" is meant the number of parts in one thousand which a given coin or bar may contain of "fine" gold.

Thus a gold bar which is said to be 820 fine contains $\frac{820}{1000}$ of gold and $\frac{180}{1000}$ of some other metal. United States gold coin is always "900 fine."

To find the value per ounce of a bar whose fineness has been determined by assay we multiply $20.6718 by the fineness, the latter being taken as a fraction,*e.g.*, if we have found "920 fine," we multiply by .920.

Then the weight of the bar, in ounces and decimals, is multiplied by the value per ounce.

A "carat" is merely another division of the fineness of a mass of gold. A "carat" in gold valuation is not a weight, but a fraction—one twenty-fourth of the total, whatever that may be.

Eighteen carat gold is simply gold of which $\frac{18}{24}$ *is* gold. Translated into mint language, it would be stated as "750 fine."

Carats, with corresponding fineness and value per ounce. 1—24.

Carats.	Fine.	Value.	Carats.	Fine.	Value.
1	41.66	$0.86	13	541.66	$11.19
2	83.33	1.72	14	583.33	12.05
3	125.00	2.58	15	625.00	12.92
4	166.66	3.45	16	666.66	13.78
5	208.33	4.31	17	708.33	14.64
6	250.00	5.17	18	750.00	15.50
7	291.66	6.03	19	791.66	16.36
8	333.33	6.89	20	833.33	17.22
9	375.00	7.74	21	875.00	18.08
10	416.66	8.60	22	916.66	18.94
11	458.33	9.46	23	958.33	19.80
12	500.00	10.33	24	1000.00	20.67

MEXICAN ASSAY RETURNS.

Mexico uses the metric system, and assays of ores for the precious metals are reported in grams to the metric ton (tonne).

As there are one million grams in a metric ton, one gram to the "tonne" is one millionth, or one ten-thousandth of one per cent.

Since one hundred per cent. in the Mexican system equals 1,000,000 grams, and one hundred per cent. in the United States system equals 29,167 ounces, we have:

$$\frac{1,000,000}{29,167} = 34.285$$

That is, any number of grams to tonne is 34.285 times corresponding "ounces to ton."

Hence, *given grams to tonne* in a Mexican report, *to find ounces to ton* in the United States system:

"Divide number of grams by 34.285."

We may also multiply by the reciprocal:

$$\frac{1}{34.285} = 0.029167$$

The latter has the advantage of presenting the same significant figures as the familiar number denoting ounces Troy in a ton, or milligrams in an assay ton.

To pass from ounces to grams it is only necessary to reverse the rule, using 34.285 as multiplier or 0.029167 as divisor.

Example.—Grams of metal to "tonne," 3679; how many "ounces to ton"? *Ans.* 107.3.

VOLUMETRIC ANALYSIS

By "Volumetric" analysis is meant analysis by means of solutions of certain reagents, whose exact chemical equivalence *per liter* (or other definite volume) is known.

The analytical operation is known as "titration."

The reagent is dropped from a graduated vessel (usually a burette) into a solution of the substance which is being estimated.*

It is necessary that some visible "end point" should mark the completion of the reaction. This "end point" may be the appearance of a color, or the vanishing of a color. It may be the cessation of the formation of a precipitate, or (as in acid-alkaline interaction) a change of color instead of appearance or disappearance. Finally, there may be no sufficient change visible in the solution under examination to warrant the designation of "end point" but the solution may be tested by the withdrawal of a small portion (on the end of a rod), which drop is then tested by another reagent, usually on a "spot plate" made for the express purpose of such tests.

Example.—In the titration of a ferrous solution by potassium bichromate, the true "end point," *i.e.*, the entire transition of the ferrous salt into the ferric form, cannot be recognized in the solution itself. When it is suspected that the "end" is near, a drop of the solution is withdrawn and touched to a drop of testing solution—"ferricyanide." Since ferrous salts give a blue color with potassium ferricyanide and ferric salts do not, the gradual lessening of the blue color in successive tests indicates the approach of the "end," and the failure to produce any color marks the true "end point."

Other changes may be exemplified in the disappearance of the rich purple of "permanganate" in the iron and many other tests. The change of litmus from red to blue or vice

* In a few cases this may be reversed, the solution under examination being dropped into a previously measured amount of the reagent. The chemical principle is not affected. A few examples will be given of this procedure.