

The surface has already been found, being 452.3904 square centimeters. Evidently cubic centimeters divided by square centimeters will give thickness of the metal.

$$\frac{138.635}{452.3904} = 0.306 \text{ centimeters} = \text{thickness of the copper.}$$

Weight of the copper, being value of x , has already been found.

11. Water at maximum density (4° C.) has sp. gr. = 1. Ice has sp. gr. 0.92. A liter of water at 4° becomes what volume of ice? (Sp. gr. is inversely as volume, for same weight.)

Ans. 1.087 liters.

12. An iceberg (sp. gr. 0.92) floats in sea water (sp. gr. 1.027.) What proportion of it will be above sea level?

Ans. 10.42 per cent.

13. Taking the above data for ice and sea water, how many cubic feet does an iceberg contain which shows 6000 cubic feet above water?

Ans. 57,588.8 cu. ft.

14. Type metal contains: Lead, 70.00 per cent.; tin, 10.00 per cent.; antimony, 20.00 per cent. = 100.00 per cent. Take sp. gr. lead = 11.4. Sp. gr. tin = 7.3. Sp. gr. antimony = 6.7. Find the sp. gr. of the alloy, allowing neither expansion nor contraction.

Ans. 7.53 sp. gr.

15. A liter of POCl_3 whose sp. gr. is 1.7 is deoxidized to PCl_3 whose sp. gr. is 1.6. What volume will the latter occupy?

NOTE.—Get the relative weight of the two—that is, from the known weight of the first, deduce stoichiometrically the weight of the second.

Then proceed with $V = \frac{W}{G}$ as in all similar cases.

Ans. 0.95175 liters.

16. A sphere of wood has 0.8 sp. gr. and 0.6 meter radius. What is its weight?

Find $\frac{4}{3} \pi R^3$. Multiply by 0.8

Ans. 723.82464 kilos.

CALCULATION OF ANALYSES.

Analytical determinations are made in a variety of ways, of which only the more important need be epitomized.

1. By separation and weighing of the element itself, if solid or liquid, or, if gaseous, measuring its volume. (Cupellation of gold and silver. Copper by the battery, and other familiar cases.)

2. By the isolation, usually by precipitation, of a compound containing the element "sought." The compound being weighed, weight of the element is determined by its stoichiometric relation to the compound. This is the commonest of gravimetric methods. (*Example.*— AgCl , used for determination of either silver or chlorine.)

3. By weighing or otherwise estimating mass of some substance which, though not containing the "sought," has a definite relation to it. This is a mere variant of (2), principle being the same. (*Example.*—Having obtained ammonium chloroplatinate, $(\text{NH}_4)_2 \text{PtCl}_6$, ignite it and weigh residual platinum, whose relation to nitrogen in the now destroyed compound gives us required weight of the latter. Or again, we destroy the identity of the well known "yellow precipitate," and titrate for molybdenum, although phosphorus is our "objective.")

4. By expelling the element "sought" or a compound of it, and absorbing this in a previously weighed tube containing an appropriate absorbent. (Organic determination of carbon and hydrogen. For the former, as CO_2 , the "potash bulb." For the latter, as water, the "calcium chloride tube." Increase in weight of bulb or tube gives the desired datum.)

5. By loss. (a) The "sought" is expelled by ignition, and the residual matter gives its quantity by weighing and subtraction from original weight. (b) The "sought" is dissolved out of the portion taken for analysis, by either water or some proper solvent, and the residue weighed. (c) In gas analysis the whole volume of the mixed gases is passed through the solvent, and the loss of volume indicates volume (hence weight if desired) of one of the gases in the mixture.

6. By some one of the countless methods of volumetric analysis. These depend one and all on stoichiometric relations, but have the great advantage, besides rapidity, of being workable by persons who have not the remotest idea of the reactions involved, as may be seen in numberless cases in the technical laboratories of large establishments.

There are a very few special estimations which might be thought to fall outside of these, but they are included in principle.

A word should be said, however, upon estimation by "difference" or "deficit." This is sometimes a mere matter of subtraction, but it may also become necessary to calculate a little, *e.g.*, in apportioning oxygen (not susceptible of direct estimation) to various bases found in the analysis. This leads to the subject, to be illustrated by examples, of what is called "adjudication," by which is meant in this connection the proper adjustment of elements found to *one another*, so as to show rational or probable *compounds* as the outcome of the analytical work. Here comes in the rule for "excess and deficiency" whose application is simple enough in fact, though often tedious. A perfect "adjudication" is rarely possible in practice.

In the following examples method of procedure is indicated in some, especially those requiring "adjudication" and in cases of indirect analysis. Very full explanations have been omitted, as the student should have a grasp of the subject from the previous cases of computation given.

It is better practice to work out a method by the aid of already acquired principles, than to have every step explained. The answers will serve to check errors.

It is necessary for the student in analytical chemistry to discriminate between true accuracy and what may be termed "pseudo-accuracy." The latter term may be applied to certain cases of useless figuring, and also to many cases of attempted refinement in weighing.

Before taking up either in illustration, we may put the general case thus: "Refinement in operation or calculation is thrown away, if it has been preceded by careless work."

Thus, to go through the operations for the determination of phosphorus, where the expected total is not over one-tenth of one per cent., working so carelessly that there is a probable

error of not less than ten per cent. (*i.e.*, figuring percentage of error on the phosphorus obtained), that is, 0.01 per cent. of phosphorus; and then to weigh the resultant precipitate to the hundredth of a milligram, and gravely announce the result to the third decimal place, is "pseudo-accuracy" with a vengeance.

It is far from the intent of this paragraph to discourage careful weighing, or careful work at any point. But it is evident in the above case that any conclusion derived from the weighing, however careful, of the result, is not justified. Whatever value it has is derived from the actual operative work prior to the final weighing. The care taken in the latter cannot rectify the initial carelessness.

Useless refinement in "weighing in" is sometimes seen. The author remembers a striking instance, the chemist being a very skilful worker, who was making an analysis of refined lead, using the enormous quantity of one thousand grams. In order not to strain his balance, which was a small one, he weighed in ten portions of 100 grams each. In each portion he weighed with the utmost precision, trying to be certain that he did not miss total by the twentieth of a milligram, the limit of his balance.

The expected total impurity of the lead was less than two one-hundredths of one per cent.

Let us make the extreme supposition that the impurity was all in one element. Then suppose an error in weighing the original lead of *one-tenth of a gram*. This of course would be out of the question with the most ordinary care. But suppose it.

Then the error in determination of total impurity due to the misweighing will be $\frac{1}{100}$ of 1 per cent. of 0.2 gram. = 0.00002. Calculated in percentage of total weight taken it will be two millionths of one per cent.

But this very careful man weighed so carefully that he certainly did not miss the total by one milligram, or $\frac{1}{100}$ of our "supposition." His error on result then was under $\frac{2}{100,000,000}$ of one per cent., so that he unconsciously assumed that his balance was one thousand times more accurate than he knew it to be. "Accuracy" to this extent in this place is manifestly wasted.

Every number denoting a physical measurement is limited in its accuracy by the physical limitations of that measurement, that is, of the instrument used and the capacity of the operator to use it to its limit.

For example, take 0.8 gram of a substance for analysis. We find the weight of one constituent to be 0.2349 gram. The percentage of the "found" is then:

$$\frac{0.2349 \times 100}{0.8} = 29.3625 \text{ per cent.}$$

Suppose, as is probable, that the accuracy of the balance is limited to 0.0001 or one-tenth of a milligram. That weight indicates 0.01 per cent. on a gram portion taken.

But here, *on a less portion* we assume, if we use the figured result of 29.3625, that we can carry the result to the ten thousandth of 1 per cent. The fallacy is in carrying an arithmetical operation beyond the possibilities of our powers of observation. *The last two figures have no real significance.* It is, in short, *arithmetically* true that .2349 is 29.3625 per cent. of 0.8. But it is not true that we can, by figuring until we get no remainder, make our balance perform the impossible. In going, in the percentage figure, *beyond the smallest indication of the balance*, we do not even know whether the next figure is positive or negative, because we are now splitting (theoretically) the minimum possible indication of the instrument.

Such procedures, then, we designate as "pseudo-accuracy." In the figure 29.3625 even the "6" in the second decimal place is subject to some doubt. How futile, then, to carry the division further.

It is not thought worth while to further illustrate this principle. What has been said will be quite enough for any student whose arithmetical sense has been developed.

No general discussion of the subject, "Calculation of Analyses," is necessary, for there is nothing in it which demands any new principle or method. The learner will soon perceive that, possibly with some trivial exceptions, every point has been already treated under some other head. We make a heading of it to indicate how previously given rules find here some practical applications.

Examples.—(a) One gram of coal yields 0.07 BaSO₄, what per cent. of sulphur does it contain?

$$0.1373 \times 0.07 = 0.0096. \quad \text{Ans. } 0.96 \text{ per cent.}$$

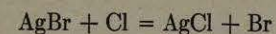
If the student is not already used to "translating" weights (*i.e.*, fractions of a gram) into percentages he will do well to start at this problem. The portion taken being one gram, 100 per cent. is represented by one gram, *i.e.*, by 1.0. Analyses, however, are always written with *percentages in whole numbers and decimal fractions of same*. Having taken 1 gram for analysis, one per cent. appears in the figures (*weights*) as 0.01. Twelve and a half per cent. would be 0.1250. Half of one per cent. would be 0.0050.

Having the Weight, Expressed in Grams, Move the Decimal Point Two Places to the Right to Express Percentage Direct, *i.e.*, Parts in 100.

Many a student has learned this in five minutes. Few laboratory instructors but can bear me out in the assertion that there are others who are liable to stumble over it for weeks. It is not a "function" of the learner's natural power of apprehension, but of the way (usually exceedingly bad) in which he has been taught arithmetic. Most high-school graduates are hazy on the two most used of all principles after the elements, *i.e.*, decimals and proportion.

(b) We expel from a substance (1 gram) 284 c.c. (0.284 liter) of carbon dioxide (CO₂). What per cent. by weight of it in the substance (0° and 760 mm.)? *Ans.* 44 per cent.

(c) A mixture of the chloride and bromide of silver weighs 1 gram.



We convert it all into chloride by the reaction shown in the equation. The chloride now weighs 0.92 gram. *Find weights of chlorine and bromine. Do not use the atomic weight of silver in the calculation. (Use approximate weights 35.5 and 80.)*

Solution.—The loss of weight is due to the substitution of chlorine for bromine. Hence it is proportional to the difference of these two in atomic weights. Loss = 0.08 gram. Diff. in at. wts., 80 - 35.5 = 44.5.

Then:

$$\begin{array}{l} \text{Diff. in at. wts. : At. wt. Br} = \text{Loss in wt. : Wt. of Br} \\ 44.5 \quad \quad \quad : 80 \quad \quad \quad = 0.08 \quad \quad : 0.1438 \end{array}$$

We may now cupel the chloride and weigh the silver, whence the chlorine by subtraction, fulfilling the requirement not to use the at. wt. of silver.

(d) A mineral (1 gram) yields a mixture of the chlorides of potassium and sodium which weighs 0.3687 gram. From this is afterward precipitated potassium salt K_2PtCl_6 0.4240 gram. What are the percentages of potassium and sodium? (Method indicated without operations.)

1. Compute potassium from the platinum salt.* 2. Compute weight of potassium chloride from the element. 3. Subtract this weight from the original mixture. 4. Calculate sodium from its chloride.

Ans. Potassium 6.83 per cent. Sodium 9.36 per cent.

(e) A crucible containing copper weighs 12.234, but when the copper is converted into cupric oxide (CuO) it weighs 12.348. What was weight of copper? *Ans.* 0.4517 gram.

(f) Five (5) grams of hematite yield the following precipitates:

For sulphur— $BaSO_4$, 0.0700; for P_2O_5 , $Mg_2P_2O_7$, 0.0400; for Fe_2O_3 , iron (volumet.), 3.15; for SiO_2 , 0.4648.

Find percentages of sulphur, ferric oxide, phosphoric anhydride, silica. Multiply by factors from table, divide by 5 and move decimal point. (Iron = 56)

Answers. S. = 0.192. P_2O_5 = 0.5103 per cent.

Fe_2O_3 = 90.00. SiO_2 = 9.296 per cent.

(g) Mixture of KCl and NaCl weighs "a." Mixture of K_2SO_4 and Na_2SO_4 wt. "b." Find percentages of potassium and sodium. Let $x = K$, and $y = Na$.

$$x + \frac{35.5}{39}x + y + \frac{35.5}{23}y = a. \quad (K = 39. \quad Na = 23).$$

$$x + \frac{48}{39}x + y + \frac{48}{23}y = b. \quad (\text{Fractions } \div 2, \text{ num. and den.})$$

In these fractions, the ratios between the atomic weights of the metals and the anions are shown. Let the student figure out the detail. Numerical example is annexed.

(g) Numerical example. Let "a" = 0.1328 and "b" = 0.1580.

* It is quite as easy, however, if only KCl is sought, to use factor which gives it directly from Pt. See table of "Chemical factors."

As before, let $x =$ potassium and $y =$ sodium. We shall then find: Potassium = 0.039 and sodium = 0.023.

If we should put $x = KCl$, and $y = NaCl$, we have:

$$x + y = 0.1328, \text{ and } \frac{87}{74.4}x + \frac{71}{58.4}y = 0.158$$

(h) We take four portions of pig iron for analysis, viz: 5 grams for sulphur, 5 for phosphorus, 3 for carbon and 1 for silicon. (Use factors.)

Weights of the various precipitates with answers opposite.

$Mg_2P_2O_7$	0.0400.....	P = 0.223 per cent.
$BaSO_4$	0.02335.....	S = 0.065 per cent.
SiO_2	0.0380.....	Si = 1.783 per cent.
CO_2	0.2200.....	C = 2.000 per cent.

(i) An ore contains the following constituents only, viz: silica, pyrite (FeS_2), zinc sulphide and lead sulphide. Its analysis by elements gave the following, (portion taken for analysis 1.5 gram in each determination):

For silica.....	SiO_2 = 0.5892 gram.
For iron.....	Fe_2O_3 = 0.1599 gram.
For lead.....	$PbSO_4$ = 0.6039 gram.
For zinc.....	ZnO = 0.1620 gram.
For sulphur.....	$BaSO_4$ = 1.8639 gram.

Calculate this analysis and sum (1) by elements (except silica which goes in as SiO_2); (2) by compounds as given in the statement.

BY ELEMENTS.		BY COMPOUNDS.	
Silica.....	39.28 per cent.	Silica.....	39.28 per cent.
Iron.....	7.46 per cent.	Iron di-sulphide...	16.03 per cent.
Lead.....	27.50 per cent.	Lead sulphide....	31.76 per cent.
Zinc.....	8.69 per cent.	Zinc sulphide	12.93 per cent.
Sulphur.....	17.07 per cent.		
Total.....	100.00 per cent.	Total.....	100.00 per cent.

Requirements similar to this are very common, though such perfect summations are not usual. This is a mere "set up" case.

Methods of procedure (not operations) are here given. They are much the same in all cases of mineral, matte or slag analysis, where there is any "adjudication" to arrange.

Calculate how much sulphur is required for all of the zinc. Subtract from total sulphur and add to zinc, making zinc sulphide (ZnS).

Find sulphur needed for all of the lead. Subtract it from the sulphur left after allowing for zinc. Add to lead, making PbS.

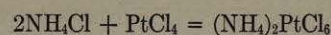
Find sulphur needed for all of the iron. In this particular case it "balances" exactly. If, however, the sulphur left after allowing for zinc and lead had been too small for the iron, we should put it all into pyrite (FeS₂) and then, taking *the iron left over*, calculate that to oxide.

Other cases of adjudication, residual quantities and excess will be found in the following examples.

(j) One gram of organic matter has its nitrogen determined as gas, by measurement of volume at 0° and 760 mm. Volume, 100 c.c. (0.100 liter). What per cent. of nitrogen?

Ans. 12.5 per cent.

(k) In 1 gram of organic matter, we convert nitrogen into ammonia which is absorbed into HCl, forming NH₄Cl. Addition of PtCl₄ reacts thus:



This precipitate is ignited, which destroys it, leaving only the platinum behind.

Weight of the metallic platinum = 0.64 gram. What per cent. of nitrogen? *Ans.* 9.20 per cent.

(l) A fertilizer contains the three forms of calcium phosphate, known as "soluble," "reverted," and "insoluble." (These are taken out by proper solvents and phosphoric acid determined separately in each portion.)

Results in actual P₂O₅ percentages are here given as derived from each form. Calculate the analysis, *i.e.*, state what is the percentage of *each form of calcium phosphate*. (The percentages are on the total of the fertilizer in every case.) Find also per cent. of total CaO with P₂O₅.

From CaH₄(PO₄)₂ 10.0 per cent. of P₂O₅.
 From CaHPO₄ 3.0 per cent. of P₂O₅.
 From Ca₃(PO₄)₂ 8.0 per cent. of P₂O₅.

Look sharp in calculating the middle substance, CaHPO₄.

Under what form of error does this fall, as a danger which has been warned against? Use Ca = 40.0 at. wt.

Answers. CaH₄(PO₄)₂ .16.48 per cent.
 CaHPO₄ 5.75 per cent.
 Ca₃(PO₄)₂ . . . 17.46 per cent. Total CaO, 16.56 per cent.

(m) In analysis of a mixture of KCl and NaCl we find (1 gram taken):

Impurities 0.069 gram.
 (K, Na) Cl 0.931 gram. Total, 1.000 gram.

From the precipitate AgCl the *total chlorine* is found to weigh 0.497.

Find weights of the potassium and sodium—also of their chlorides separately. (Note that 0.931 - 0.497 = 0.434). Let $x = \text{Na}$, and $y = \text{K}$.

$$x + y = 0.434. \quad \text{Also, } x + \frac{35.5}{23}x + y + \frac{35.5}{39}y = 0.931$$

Whence:

$x = \text{Na} = 0.161$ NaCl = 0.4095
 $y = \text{K} = 0.273$ KCl = 0.5215 Total, 0.9310.

(n) Analysis of common salt. One gram taken, which contains, beside NaCl, calcium sulphate, magnesium chloride and water. Weights as follows:

CaO = 0.0062. BaSO₄ = 0.0258. Mg₂P₂O₇ = 0.0111. AgCl = 2.3938

CaO needs no calculation except adjustment to SO₃.

BaSO₄ calculated to SO₃, .0258 × .3429 = 0.0088 = wt. of SO₃
 0.0062 : 0.088 = 56 : 80. That is, the CaO and SO₃ just "match."

The magnesium similarly calculated gives MgCl₂ as follows:

Mg₂P₂O₇ : 2MgCl₂ (Why 2MgCl₂ instead of MgCl₂?)
 222.72 : 190.52 = 0.0111 : 0.0095 = wt. of MgCl₂

Note that it is not necessary to figure Mg or MgO first. We compute to MgCl₂ directly.

It is necessary, however, to figure the chlorine out from this MgCl₂ so that little is saved by the direct computation. We find 0.0070 as the weight of its chlorine. From weight of AgCl we find total of 0.5918 chlorine, from which we subtract that called for by magnesium.

$0.5918 - 0.0070 = 0.5848 =$ wt. of chlorine combined with sodium.

From this we get the NaCl simply enough:

$$\frac{.5848}{.606} = 0.965 \text{ gram, or } 96.50 \text{ per cent.}$$

(Since NaCl has 60.60 per cent. of chlorine.)

Ignition at gentle heat causes the salt to lose 0.0090 on 1 gram taken.

Summation:

$$(0.62 \text{ CaO} + 0.88 \text{ SO}_3 = 1.50 \text{ per cent. CaSO}_4)$$

Sodium chloride (NaCl).....	96.50 per cent.
Calcium sulphate (CaSO ₄).....	1.50 per cent.
Magnesium chloride (MgCl ₂).....	0.95 per cent.
Water.....	0.90 per cent.
Summation.....	99.85 per cent.
Loss or deficit.....	0.15 per cent.
	100.00 per cent.

(o) A slightly oxidized ore contains silica, iron di-sulphide (pyrite) zinc sulphide and some iron oxide (ferric oxide). Weights from 1 gram: Silica 0.4958. For total iron, Fe₂O₃ = 0.2224. For zinc, ZnO = 0.1456. For sulphur, BaSO₄ = 1.6630.

Compute by assuming all of the zinc present as ZnS. Then "adjudicate" by letting all remaining sulphur go to iron as FeS₂; finally compute any iron left over as Fe₂O₃. Begin by computing per cents. in toto:

The BaSO ₄ gives as per cent. of total sulphur.....	22.83
The Fe ₂ O ₃ gives as per cent. of total iron.....	15.56
The ZnO gives as per cent. of total zinc.....	11.70

Now adjust according to the scheme given above:

11.7 zinc requires 5.74 sulphur. This gives 17.44 per cent. ZnS.
22.83 sulphur - 5.74 sulphur = 17.09 sulphur remaining for iron.
According to the formula FeS₂, 17.09 S₂ requires 14.9 Fe. 31.99 per cent. FeS₂.

15.56 Fe - 14.9 Fe = 0.66 Fe. ("Residual" iron.) 0.66 Fe corresponds to 0.94 per cent. Fe₂O₃.

The silica requires no computation except moving the decimal. Described in ordinary language the process is this:

"Take out all the zinc as zinc sulphide. Subtract the required sulphur from total sulphur, then take out as much pyrite (FeS₂) as the sulphur allows you. Finding some iron left over, adjust this to as much oxygen as it will carry as Fe₂O₃. Add in the silica as weighed."

Summation:

Silica.....	49.58 per cent.
ZnS.....	17.44 per cent.
FeS ₂	31.99 per cent.
Fe ₂ O ₃	0.94 per cent.
	99.95 per cent.
Loss.....	0.05 per cent.

(p) In the analysis of a fertilizer compound, we get from 1 gram portions: For NH₃; Pt = 0.4200. For K₂O; KCl = 0.0220. For P₂O₅; Mg₃P₂O₇ = 0.6560. For SO; BaS₂O₄ = 0.0466. Find percentages of the required constituents.

Answers: NH ₃	7.346 per cent.	P ₂ O ₅	41.96 per cent.
K ₂ O.....	1.390 per cent.	SO ₃	1.600 per cent.

(q) In an iron ore, which contains both FeO and Fe₂O₃ all the elements are determined, iron being estimated as all Fe₂O₃. Metallic iron = 65.10 and summation is 100.7 per cent. Assuming that this is absolutely correct as to operations, find percentages of FeO and Fe₂O₃. Also what per cent. of iron in the FeO and what in the Fe₂O₃? (Take iron as 56. This makes factor to pass from Fe₂O₃ to Fe = 0.7.)

Solution.—All we have to "go on" is the excess of 0.7 which arises from estimating all the iron as existing in the form of Fe₂O₃, whereas some of it is present as FeO (magnetite, which is written Fe₃O₄, i.e., Fe₂O₃ + FeO). Results, not operations, are given. The student should remember that in the comparison of FeO and Fe₂O₃ we must consider FeO as Fe₂O₃ or 2FeO.

Answers: FeO =	6.30.	Its iron =	4.90 per cent.
Fe ₂ O ₃ =	86.00.	Its iron =	60.20 per cent.

(r) One gram of anthracene is analyzed. Its carbon weighed as CO₂ gives 3.4591 grams. Its hydrogen weighed as water gives 0.5058 gram.

Ans. Carbon 94.34 per cent. Hydrogen 5.66 per cent.

Deduce formula from this analysis. *Ans.* C_7H_5 . But as molecular weight is about 178 the trial formula must be doubled, *i.e.*, $C_{14}H_{10}$.

(s) A sample of sodium bicarbonate contains both Na_2CO_3 and $NaHCO_3$. Its total carbon dioxide (CO_2) is determined as 45 per cent. and its total sodium as $Na_2O = 32$ per cent. *Required*, percentages of the two forms as above, of sodium carbonate. It is of course necessary to assume that no other forms or compounds of sodium are present. Let $x = Na_2CO_3$ and $y = NaHCO_3$. (Use $Na = 23$ and $H = 1$.)

$$\frac{CO_2}{Na_2CO_3} x + \frac{CO_2}{NaHCO_3} y = 45$$

$$\frac{Na_2O}{Na_2CO_3} x + \frac{Na_2O}{2NaHCO_3} y = 32$$

Substitute values in the formulæ, *i.e.*, molecular weights. The remainder of the process is omitted, except as to the suggestion that it will be found rather easier to solve for "y" and then proceed with the other deductions. Get per cent. of Na_2O in the carbonate first determined, etc.

Answers. $NaHCO_3 = 85.11$ per cent. $Na_2CO_3 = 1.01$ per cent.

(t) A mixture of $CaSO_4$ and $CaCO_3$ gives: CaO , 11.2 grams. SO_3 , 8.0 grams. Find weights of $CaSO_4$, $CaCO_3$, and CO_2 .

Answers. $CaSO_4 = 13.60$ grams; $CaCO_3 = 10.00$ grams; $CO_2 = 4.40$ grams.

(u) Being about to determine calcium as CaO , I ignite it in a platinum crucible, and then find I have forgotten to weigh the latter. However, I weigh the whole, then add sulphuric acid and ignite again, converting the CaO into $CaSO_4$. The gain is 0.4 gram. What was weight of the CaO ? (Use approximate weights, Ca , 40; S , 32.) *Ans.* 0.28 gram.

(v) A mixture of the chloride and bromide of silver weighs 0.75 gram. The silver in same weighs 0.50 gram. Find the percentages of bromine and chlorine. Take silver 108, chlorine 35.5, bromine 80, atomic weights.

$$\begin{aligned} Ag : AgCl &= Ag : AgCl \\ 108 : 143.5 &= .50 : .6643 \end{aligned}$$

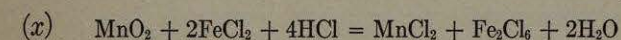
That is, if all were $AgCl$ the total would weigh only .6643 instead of .7500. The excess, which equals .0857, is due to the replacement of part of the (assumed) chlorine by bromine.

Difference between atomic wts. ($Br - Cl$) is 44.5. Hence:

$$\begin{aligned} 44.5 : 80 &= .0857 : 0.154. \text{ Weight of bromine } 0.154 \\ \text{Also, } 0.75 - (.5 + .154) &= 0.096 = \text{chlorine} \end{aligned}$$

(w) From one gram of iron we expel the sulphur as H_2S and with the latter we precipitate 24 milligrams of lead sulphide (PbS). What per cent. of sulphur in the iron?

Ans. 0.321 per cent.



0.5 metallic iron dissolved in the acid, also 1 gram of the manganese ore. We now find 0.285 iron by titration. What was percentage of MnO_2 in the ore. (We assume that the titration was upon the ferrous salt remaining.)

Ans.—The .215 remaining indicates the Fe_2Cl_6 of the equation. Final calculation left to the student.

Ans. 16.7 per cent. MnO_2 in the ore.

(y) Sulphur from 1 gram of substance is evolved as H_2S , which measures 20 c.c., normal conditions. Find per cent. of sulphur. (Part of operation omitted.)

$$22.4 : 34 = 0.02 : 0.03036. \quad \text{Ans. } 2.857 \text{ per cent. sulphur.}$$

(z) Spring water analysis. One liter gave 147.94 parts per 100,000, or 1.4794 grams, of solid matter. Silica weighed 0.0074. Al_2O_3 , 0.0015, $FeCO_3$, 0.0014, the latter calculated from titration for iron.

Other elements gave precipitates weighing as follows:

For SO_3	$BaSO_4$	0.4768
For CaO	$CaSO_4$	0.5497
For MgO	$Mg_3P_2O_7$	0.3568
For K_2O	K_2PtCl_6	0.1708
Alkalies as chlorides weighed.....		0.7644
Chlorine determined by silver, weight..		0.1400(Cl not $AgCl$)

All other salts are carbonates. Calculate sodium by difference, and sum up the analysis.

First assign all the SO_3 to CaO . Excess of CaO to carbonate.

All the chlorine to magnesium. Excess of the latter to carbonate.

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:

$$\text{Grains per U. S. gallon} \times 17.147 = \text{parts per million.}$$

$$\text{Grains per Imperial gallon} \times 14.285 = \text{parts per million.}$$

$$\text{Parts per million} \times .058318 = \text{grains per U. S. gallon.}$$

$$\text{Parts per million} \times .07 = \text{grains per Imperial gallon.}$$

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 milli-