

THE DISTRIBUTION OF THE PRECIOUS METALS AND IMPURITIES IN COPPER AND SUGGESTIONS FOR A RATIONAL MODE OF SAMPLING.

BY EDWARD KELLER.

Received January 8, 1897.

IN order to be able to conduct intelligently the sampling of copper, of various forms and grades, solid or in molten furnace charges, knowledge of this subject is essential. Yet figures and tests have been persistently withheld from publication, and the books at our command give us little or no information. This gap in our literature has led to a series of experiments, the results of which here follow :

Nearly all gold- and silver-bearing copper, destined for shipment, is cast into the form of bars or pigs. For the sampler the question arises: Does copper so cast remain homogeneous, or does it not? If so, no difficulty would occur; but experience teaches us that the cast metal is not homogeneous and this leads to the study of the behavior of the precious metals and impurities in copper, when the latter changes from the molten to the solid state.

For the purpose of the experiments, all available grades of copper were selected, and all of them subjected to the same conditions, which is important for the purpose of proper comparison.

The molten copper, directly obtained from reverberatory and blast furnaces, was cast in a cast iron mold, the sides and bottom of which were one inch thick, and would, therefore, give the copper a fair length of time to chill. The inside dimensions of the mold were: length, ten inches; width, nine inches; and depth five inches, which dimensions were the same for the blocks of copper obtained.

The accompanying figure (1) illustrates the method employed to obtain samples from these blocks. *A* was cut away, and the face thus produced on *B* was marked off over one-half of its surface into one inch squares (it being assumed that the other half would behave the same, or nearly so), and by drilling through the center of each square, three inches deep, the individual samples, as indicated by S_1, S_2, S_3, S_4, S_5 , etc., obtained.

In this way each block should have yielded twenty-five samples. But with the unrefined copper, the uppermost inch of the

block consisted mostly of blisters and some slag, while with the refined material the surface, on setting, had sunken nearly one inch. With all but one block, therefore, twenty samples of each only were considered.

In Fig. 2 are given the silver and gold determinations of a

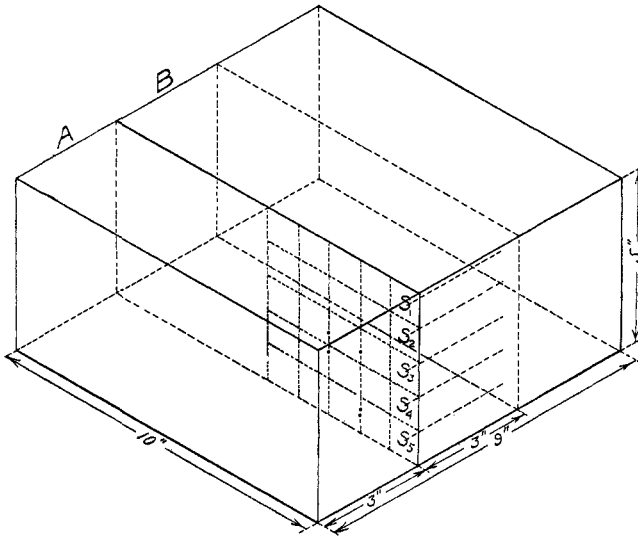


Fig. 1.

blister-copper for the twenty regular samples, as also of the uppermost crust, over the blisters. The amount of the precious

		132.3				
		.28				
179.9	201.1	111.6	100.7	36.6		
.34	.34	.24	.22	.22		
192.1	185.2	194.5	12.2	68.1		
.32	.34	.34	.26	.20		
114.5	117	122.3	105.1	67.2		
.22	.28	.30	.26	.20		
71.3	70.3	69.8	69.8	70.5		
.24	.22	.22	.22	.22		

Fig. 2.

metals is expressed in ounces per ton, in this, as well as all the following samples.

For the purpose of a general analysis of this block, samples were taken from the bottom, center, and top of *B* (Fig. 1). They gave the following results :

	Bottom. Per cent.	Center. Per cent.	Top. Per cent.
Ag.....	0.248	0.641	0.454
Au.....	0.00068	0.00109	0.00089
Pb.....	0.002	0.058	0.019
Bi.....	0.005	0.055	0.024
Sb.....	0.048	0.157	0.099
As.....	0.034	0.108	0.074
Te.....	0.004	0.027	0.019
S.....	0.040	0.112	0.047
	<hr style="width: 50%; margin: 0 auto;"/> 0.382	<hr style="width: 50%; margin: 0 auto;"/> 1.159	<hr style="width: 50%; margin: 0 auto;"/> 0.737

A glance at these figures convinces us that in this case a concentration, or segregation, of precious metals and impurities has taken place in a high degree towards the center; not the geometrical center but the center of solidification, which latter naturally lies above the former, more heat being given off at the bottom to the metallic mold than to the air on top, for which reason solidification proceeds more rapidly from the bottom.

Of the degree of concentration we best receive an idea by comparing each element of the bottom sample with the corresponding element of the center sample. Dividing the value for the latter by the value for the former, gives us the degree of concentration from bottom to center. We have accordingly :

Element.	Concentration.
Ag.....	2.59
Au.....	1.60
Pb.....	29.00
Bi.....	11.00
Sb.....	3.27
As.....	3.18
Te.....	6.75
S.....	2.80

The difference of behavior of the various elements is surprising.

That a sample, which is not a correct average from a bar, or pig, of such copper, might lead to great errors regarding its silver and gold contents, needs no further illustration. But also the copper determinations would be far from being correct should they be made of a sample from any one part of such bar

or pig. This will at once become evident if we take the copper by difference (100 — amount of impurities) in the three analyzed samples :

	Bottom. Per cent.	Center. Per cent.	Top. Per cent.
Copper by difference	99.618	98.841	99.263

Fig. 3 represents a block of refined converter-copper, with

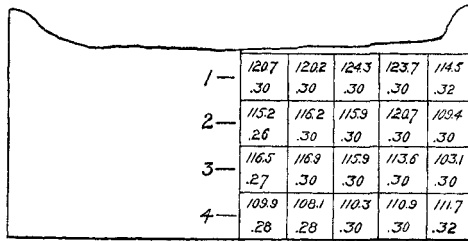


Fig. 3.—Block of Refined Converter-Copper with Determinations.

silver and gold as found in the respective samples.

General analyses were made of Sample 1, Samples 2 and 3 combined, and Sample 4, with the following results :

	1.	2 and 3.	4.
	oz.		oz.
Ag.....	120.7		109.9
Au.....	0.30		0.28
	Per cent.	Per cent.	Per cent.
Bi	0.0026	0.0017	0.0013
Sb	0.057	0.060	0.051
As	0.022	0.021	0.014
Te	0.008	0.0056
O	0.293	0.200
(Cu ₂ O.....)	2.687	1.800)

Among copper metallurgists it is customary to give the amount of cuprous oxide instead of the oxygen. Both figures are, therefore, here inserted.

It will be noticed that the concentration of the precious metals and impurities in this second sample is analogous to the first ; they have moved from the sides and bottom towards the center and top ; but the degree of concentration is very much reduced. This may easily be explained by the fact that the refined copper contains a much smaller amount of impurities than the blister copper, thereby giving it a higher melting-point and a higher conductivity for heat, both properties favoring a more rapid solidification, and consequently shortening the time for the molecules to move towards the center.

Fig. 4 represents an original converter pig, from which

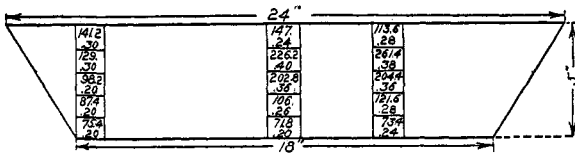


Fig. 4.—Converter Pig Copper.

kind of copper the previous sample was derived. The pig was drilled vertically, through the center. The values found for silver and gold show no variation, as to distribution, from the two other samples already illustrated.

Fig. 5 represents a refined copper, in which the amounts of

1—	270.4	3.22	3.28	341.4	362.8
	280	3.08	3.16	324	332
2—	303.4	3.384	3.602	357	368.6
	3.08	3.24	3.32	3.28	3.36
3—	350	3.518	3.58	353.4	364.6
	3.36	3.32	3.36	3.32	3.28
4—	353	3.634	3.662	365.2	360.
	3.32	3.40	3.40	3.40	3.36

Fig. 5.—Refined Copper.

silver and gold, as well as the impurities, are considerably higher than in those represented by Figs. 2 and 3.

Samples 1, 2, 3, and 4 were analyzed as follows :

	1.	2.	3.	4.
	Ounces.	Ounces.	Ounces.	Ounces.
Ag	270.4	309.4	350.0	353.0
Au	2.80	3.08	3.36	3.32
	Per cent.	Per cent.	Per cent.	Per cent.
Pb	0.204	0.248	0.351	0.392
Sb	0.163	0.185	0.211	0.217
As	0.134	0.151	0.197	0.212
Te	0.0125	...	0.015	0.0195

Here, again, we see differences in the quantities of the elements in each sample ; that is, concentration. But if we compare these with the former samples we observe the astonishing fact, that now we have the maxima in the position, where before were the maxima, and vice versa. In other words, we find a copper in which the conditions have been reversed. Instead of the precious metals and impurities concentrating towards the

center, it is now the copper which takes that place, and leaves the former concentrated towards the outside.

Fig. 6 represents a black copper from a blast furnace, but

1	379.0	387.6	378	427.2	507.8
	1.04	1.00	1.00	.92	1.00
2	337.8	362.2	384	399.8	489.4
	1.00	.92	.92	1.04	1.04
3	350.2	355.8	361	392.6	474.6
	.88	.88	.92	1.04	1.04
4	364.4	374.4	381.2	402.8	488.8
	1.00	1.00	1.00	1.08	1.04
5	425.6	424	432.8	458	505.6
	1.04	1.04	1.04	1.00	1.00

Fig. 6.—Black Copper Showing all Characteristics of Blister Copper.

showing all the characteristics of a blister copper. It is, in its relations to our subject, an analogon to the preceding sample.

Five samples were subjected to general analysis :

	1.	2.	3.	4.	5.
	Ounces.	Ounces.	Ounces.	Ounces.	Ounces.
Ag	379.0	337.8	350.2	364.4	425.6
Au	1.04	1.00	0.88	1.00	1.04
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Pb.....	2.487	2.445	2.366	2.531	2.851
Bi.....	0.400	0.360	0.360	0.310	0.420
Sb.....	3.438	3.073	2.820	2.789	3.929
As.....	0.705	0.716	0.630	0.627	0.706
Te.....	0.892	0.768	0.814	0.856	0.882
S.....	0.538	0.467	0.462	0.487	0.469
Fe.....	4.220	5.050	4.430	5.460	3.500

Scrutinizing the values for the various elements, it will be seen that sulphur and iron have behaved differently from the rest. Sulphur shows irregularities, while iron has concentrated towards the center ; it has gone with the copper.

It will further be observed that the minimum amount of each element is not found in the same sample for all. In sample No. 2 we have the minimum for silver and tellurium ; in No. 3 for gold and lead ; and in No. 4 for bismuth, antimony, and arsenic.

The blocks of copper represented by Figs. 2 and 3 were comparatively low in their contents of precious metals and impurities, while those in Figs. 5 and 6 were comparatively high. The sample represented in Fig. 7 is low in precious metals, and high in impurities ; yet we find that the silver has concentrated in accordance with the latter class. A general

<i>Slag and Matte</i>					
	59.6	59.2	60.3	60.4	61.3
	60.7	60.3	60.8	60.9	61.8
	60.5	60.8	61.2	61.3	61.6
	61.7	61.3	61.9	61.7	61.2

Fig. 7.—Black Copper.

furnace sample of this copper showed the following composition:

	Ounces.
Ag	62.2
Au	0.14
	Per cent.
Pb	0.78
Bi.....	0.0035
Sb	0.238
As	0.052
Te	0.0095
S.....	0.796
Fe	0.17

Fig. 8 is a photographic reproduction¹ of the face of *B* (Fig. 1) of the block of black copper represented in Fig. 6. It shows with the distinctness of a drawing each successive zone of solidification, by curved lines, or cavities, as well as the direction of solidification and concentration by straight linear cavities, which are perpendicular to the tangents of the curves, and which converge toward the center of solidification, the latter also being clearly indicated, much above the geometrical center, for reasons already given. The curved linear cavities were not readily discernible on the fresh cut, but were brought out plainly by rubbing with damp charcoal powder.

Reviewing the results obtained, they clearly prove the existence of two classes of copper-alloys. As already pointed out, in one class the foreign elements concentrate towards the center of solidification; in the other the copper concentrates to the center, while the foreign elements appear to have concentrated towards the outside.

Not a single element tested for has remained homogeneously

¹ For the photograph the writer is indebted to Mr. William Keyser, Jr., of Baltimore.

throughout, but the degree of uneven distribution varies with each one.

From data given in Hofman's *Metallurgy of Lead*, pp. 244 and 245, I conclude that this metal shows the same characteristics, in this respect, as copper. Also from an article by A. Raht in the *Mineral Industry*, 1894, p. 414. This writer gives a few instances in which he shows that silver and gold in base bullion bars are highest at the bottom and sides and lowest towards the top. He quotes Rosenlecher (from the *Berg- und Hüttenmännische Ztg.*, Oct. 5, 1894) as having found exactly the reverse, and accuses the latter of strained figures, pet theories, etc. There seems no substantial reason for this inference, and undoubtedly Rosenlecher is as correct as Raht, and Raht as correct as Rosenlecher. The experiments of either covered but a narrow field, and neither discovered the other's side.

Very likely many of the alloys behave similarly, and homogeneity cannot be found with any of them.

Edward Mathey, in a publication in *Nature*, No. 1394, Vol. 54, calls attention to the fact that bars of gold, alloyed with zinc and lead, show very uneven distribution, gold having concentrated to the center and bottom, gravity being one cause.

To overcome difficulties in sampling such material, Mr. Mathey looks for a solvent and finds silver to be the medium. His figures cannot be pronounced as entirely conclusive, and the method proposed to obtain reliable samples is very circuitous, to say the least, although the trouble to be overcome is thereby minimized.

To come to the practical question of sampling, we must, from the stated and indubitable facts, draw the conclusion that it is almost impossible to obtain, from bars and pigs with irregular dimensions, by drilling, punching, or chipping, samples of satisfactory accuracy. As we have seen, concentration takes place from or towards every surface, and that in such bodies of metal a core, as it might appropriately be called, is formed, which is enriched or impoverished, as the case may be, and which in its shape does not conform to the outer surface. It is for this reason so difficult to obtain aliquot parts of the different portions of a bar or pig.

The root, then, of the difficulties of sampling, so often com-



Fig. 8.

plained of, lies in the irrational shape into which various metals are cast.

Another conclusion, which we must draw from observed facts, is the following : When we take from a molten mass of copper a sample by means of a ladle, the latter must be so hot as not to allow the forming of any solidified metal (sculling) ; for should this happen, the remaining liquid portion, which is to constitute the sample, would for one class of copper be too high in its contents of precious metals ; for the other class it would be too low. If we pour from a ladle, in which the whole metal is liquid, a so-called shot sample, there is no reason assignable that it is not a correct sample. When large samples of shot are taken from charges, which are supposed not to be homogeneous, they must, of course, be remelted, and a smaller sample taken in the same way ; or a sample plate must be cast, for which the rule below described must be observed, otherwise the final sample may become erroneous.

In most smelting and refining works sample-bars or cakes are desired, and to have these in the proper shape should be the duty of the sampler.

To eliminate all the difficulties inherent to pigs and bars, as above described, we only need reduce one dimension ; or to state it more plainly, we cast a plate, whose thickness is small, compared to the other two dimensions. Of course concentration in this plate is governed by the same law as in any other body ; it takes place from or towards the center, but the concentration in the horizontal direction, from the sides, can extend no farther than the distance equal to the thickness of the plate, for, when the solidification has proceeded that distance horizontally, the plate has entirely solidified vertically. We then have all around this plate a zone not wider than its thickness, where concentration has taken place just as in a bar or block ; that is, horizontally and vertically, and consequently, we have one enriched and one impoverished band around the four sides. In the part of the plate enclosed by this zone we have had concentration in the vertical direction only, and the plate here, therefore, consists of what we may term layers of metal of different concentration. If we drill or punch through all of these layers we obtain a correct sample of the whole plate. This then seems the simplest solu-

tion of the sampling of any metal or bullion, and it is difficult to see any reasonable objection to the casting into plates of appropriate size of such material destined for shipment, of which subsequent sampling is required, and for which the remelting and taking of samples from furnace charges is impracticable. Uncertainty in sampling would be eliminated, and giving the plates beveled edges the handling thereof would not be more difficult than with bars.

Fig. 9 represents a plate of refined converter copper, fifteen

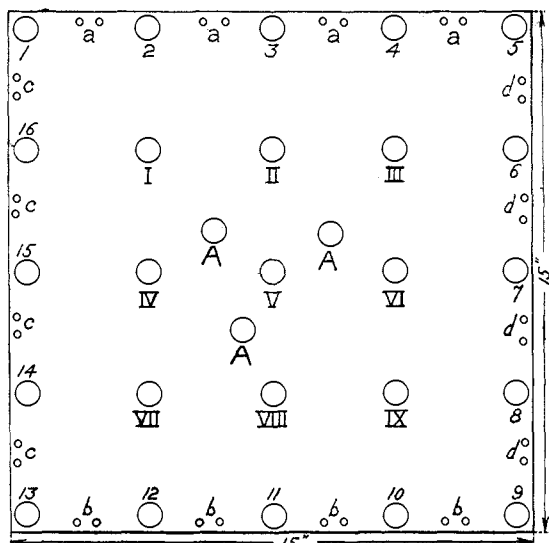


Fig. 9.

inches square by one inch in thickness. The holes designated by small letters were drilled with a one-quarter inch drill, one-fourth to one-eighth inch from the edge of the plate. The drillings from each side were collected in one sample, making the four samples, *a*, *b*, *c*, and *d*. The other holes were drilled with a three-quarter inch drill. Those designated by Arabic figures are from one-eighth to one-fourth inch from the edge. Those with Roman figures and the preceding ones were drilled through the plate. The three marked *A* were drilled about one-half inch deep, and the drillings collected for the top sample, then drilled through the plate, and the drillings taken for the bottom sample. The assays, in ounces per ton, were as follows :

$a = 105$, $b = 100.7$, $c = 101.7$, $d = 100.1$. Average = 101.9.
 (1) = 99.2, (2) = 103.2, (3) = 104.2, (4) = 99.8, (5) = 98.6,
 (6) = 97.8, (7) = 98.5, (8) = 99.3, (9) = 98.7, (10) = 98.9,
 (11) = 99.4, (12) = 99.4, (13) = 98.9, (14) = 103.7, (15) =
 98.5, (16) = 99.5. Average = 99.85.

I = 98.4, II = 98.8, III = 98.9, IV = 97.6, V = 99.6, VI =
 99, VII = 98.2, VIII = 99.4, IX = 99.5. Average = 98.7.

A—top = 99.9, A—bottom = 98. Average, 98.9.

In the discussion of the theory of a thin plate it was pointed out that there must exist around the edge a zone of higher and one of lower concentration than in any other part of the plate, due to the horizontal and vertical movement of the molecules in this zone. The assays have demonstrated the correctness of that statement, although the zone does not appear to be strictly defined. This undoubtedly is due to temperature conditions of the mold and currents in pouring the metal.

The vertical concentration in the plate, inside the edge zone, is also clearly demonstrated by the top and bottom samples. These assays were repeated several times, while the rest were all made singly.

The samples and assays of the edge zone are, of course, incorrect representatives of the true contents of the plate and the furnace charge which it represents. The correct figure should be the average of I, II, III, IV, V, VI, VII, VIII, and IX = 98.7, as also the average of A-top and A-bottom = 98.9, the two figures being indeed very close together.

The plate, from which the above figures are derived, was cast

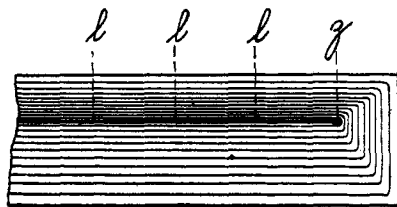


Fig. 10.—Vertical Section through the Edge and Part of Plate.

in a mold with very heavy bottom and thin sides. The solidification, therefore, took place much more rapidly from the bottom than from the sides and top. In Fig. 10 is illustrated this

process, it representing a vertical section through the edge and part of the plate. At z would be the highest or lowest point of concentration, according to the class of copper, the molecules meeting there from top, side, and bottom. At l would be the highest or lowest concentration of the layers, the molecules meeting from top and bottom.

For practical sampling, plates from eight to ten inches square are of ample size, but should not be more than one inch thick, and the drillings to be taken at least one inch from the edge through the entire plate.

After having seen how a correct shot sample or a reliable sample plate is obtained, let us now see how copper in its molten state is constituted.

The table below gives the results of tests, made for about three weeks, with furnace charges of from 90,000 to 110,000

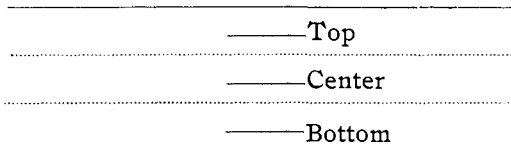


Fig. 11.—Position of Samples in Charge.

pounds of refined converter copper. The copper having been poled was, therefore, well mixed.

Sample plates were taken from the middle of every third of the charge, a practice adopted at these works. Fig. 11 illustrates the position of the samples in the charge.

	Ounces of sil- ver. Average.	Ounces of sil- ver. Average.	Ounces of sil- ver. Average.	Ounces of sil- ver. Average.
Top	106.7	115.4	113.0	110.5
Center ..	106.5	113.9	111.8	109.7
Bottom..	104.3	115.7	110.1	109.8
	} 105.8	} 115.0	} 111.6	} 110.0
Top	110.3	109.1	109.3	108.2
Center ..	110.2	108.9	108.4	108.1
Bottom..	109.1	108.1	108.7	108.1
	} 109.9	} 108.7	} 108.8	} 108.1
Top	107.8	107.9	107.4	107.8
Center ..	107.9	108.6	107.9	108.2
Bottom..	107.9	106.6	106.8	108.0
	} 107.9	} 107.7	} 107.7	} 108.0
Top	108.1	108.5	106.8	105.8
Center ..	108.1	108.8	106.9	106.8
Bottom..	108.2	108.1	107.4	106.5
	} 108.1	} 108.5	} 107.0	} 106.4
Top	106.9	105.6	101.2	103.4
Center ..	106.0	106.2	101.4	101.8
Bottom..	105.7	105.8	101.4	101.4
	} 106.2	} 105.9	} 101.3	} 102.2

The greatest irregularities occurred during the first few days, and were due to the furnace being new and the bottom seasoned with non-silver-bearing copper.

Each assay was made singly only and some of the differences may be attributed, therefore, to possible experimental errors, although nearly all are within the usual allowable limits in this kind of work.

The following are the values for silver and gold of three successive charges from a furnace of 30,000 pounds.

	Ounces of sil- ver.	Aver- age.	Ounces of gold.	Aver- age.
Top	163.6	} 163.1	0.24	} 0.24
Center	163.2		0.24	
Bottom	162.6		0.24	
Top	363.9	} 363.2	2.92	} 2.95
Center	363.3		2.96	
Bottom	362.5		2.96	
Top	319.9	} 320.0	2.32	} 2.35
Center	320.1		2.36	
Bottom	320.1		2.36	

On the strength of these results, it is safe to say, that any charge of molten copper, once thoroughly agitated and mixed, is, and remains, uniform, and a sample taken from any part correctly represents the whole charge.

The subject treated is not only of practical importance, but has also a very interesting scientific side.

It is of course nothing new to find uneven distribution of the elements in an alloy, but that this distribution should follow within very narrow limits the quantities of these elements present in two diametrically opposite ways, as shown by the preceding experiments, is a subject which has not been discussed, and which is decidedly perplexing to explain. No law known to the writer would apply to this remarkable phenomenon.

As shown by the analytical figures, the impurities, in the cases where they have concentrated at the center, have a far higher degree of concentration than in the cases where they have gone towards the outside. This is readily explained. In the first case, the molecules move in the same direction as solidification takes place. They are, therefore, able to move and concentrate until the last particle of the metal is solid.

By the increase of impurities towards the center, the melting-

point of the alloy in that region is undoubtedly lowered, and thereby the solidification retarded, thus giving the elements more time to pursue their course.

In the case of concentration towards the outside, the elements move in the opposite direction in which solidification takes place, and by encountering the already solidified metal, their course is ended. The center being drained of impurities, its melting-point undoubtedly rises, accelerating the process of solidification, and reducing the time of motion and concentration.

That each element shows a different degree of concentration has already been pointed out. In explanation of this fact it might simply be said that it is due to the differences of affinity, which, of course, is true. But for the term "affinity" between metals we have as yet no expression in values or figures. We shall, therefore, attempt to find whether there is any relation between this and other physical properties of the atom of the respective elements, and shall, for that purpose, first consider the case of the copper as represented by Fig. 2, the differences here being best defined.

In the following table the elements are arranged in the order of their degree of concentration. T = melting-point in $^{\circ}\text{C}$; A = atomic weight; D = density, or specific gravity; $V = \frac{A}{D}$ = atomic volume.

Element.	Concentration.	T .	A .	D .	V .
Pb	29.00	332	206.4	11.38	18.1
Bi.....	11.00	265	210.0	9.82	21.4
Fe	6.75	500	126.0	6.25	20.2
Sb	3.27	437	122.0	6.70	18.2
As	3.18	500	74.9	4.70 ¹	15.9
S.....	2.80	115	31.98	2.04	15.7
Ag	2.59	969	107.66	10.50	10.2
Au	1.60	1037	197.0	19.30	10.2
Cu	0.992	1057	63.3	8.80	7.2

Comparing the degree of concentration with the melting-point we find a correspondence in a general way, the elements of low melting-point showing a higher degree of concentration than those of high melting-point. The sulphur forms a very marked exception to this rule.

¹ This is the density given for amorphous arsenic; for the crystalline form it is 5.67; consequently $V = 13.2$.

Between degree of concentration and either atomic weight or specific gravity there seems to exist absolutely no direct relation. Gravity in this case, therefore, can be no factor governing the distribution of the elements.

Finally, in the last column, the values for the atomic volume unmistakably show a similar arrangement to those for concentration. From this fact a law can be formulated (in the way of suggestion) reading as follows: "When, on the solidification of a metal (copper) the small amounts of impurities segregate, or liquefy, and consequently concentrate towards the center, the degree of concentration is greatest for those whose atomic volume, compared with the atomic volume of that metal, show the greatest difference." Influence of other properties (melting point, etc.) would modify the law accordingly.

If the law expressed be true, we should then have for that class of alloys an alloy series of the metals, in which the latter are arranged according to their atomic volume:

Element.	V.	Element.	V.	Element.	V.	Element.	V.
Ni.....	6.7	Rh.....	8.6	Au.....	10.2	Sn.....	16.1
Co.....	6.9	Ir.....	8.6	Al.....	10.7	Tl.....	17.1
Fe.....	7.2	Os.....	8.8	Cd.....	12.9	Pb.....	18.1
Cu.....	7.2	Pt.....	9.1	Mg....	13.8	Sb.....	18.2
Pd.....	8.2	Zn.....	9.1	In.....	15.3	Bi.....	21.4
Ru....	8.4	Ag.....	10.2				

The theory thus deduced from an alloy of copper is, in the main, corroborated by an analysis of lead bullion by Schertel.¹ Elements (Cu, Fe, Zn), whose atomic volume differ most from that of lead, have concentrated in a higher degree than those which stand closer to the latter. Antimony, which is almost identical with lead in this property, has concentrated with that metal. Silver and bismuth do not appear to fall exactly in line.

In the class of copper, in which the impurities are found concentrated towards the outside, the above rule does not seem to apply, but owing to the small differences in the degree of concentration and consequent large influence of possible experimental errors, it would be too venturesome to attempt the establishment of another rule or law.

One fact observed in the copper represented by Fig. 6 seems also confirmatory of the theory expressed; namely, the concen-

¹ Hofman's Metallurgy of Lead, p. 244.

tration of the iron with the copper, both metals having the same atomic volume.

The following table gives the elements and their degree of concentration, as found in the above-mentioned copper, compared with the other physical properties.

The degree of concentration was obtained by dividing the values of the fifth sample by those of the third.

Element.	Concentration.	T.	A.	D.	V.
Sb	1.39	437	122.0	6.70	18.2
Pb	1.21	332	206.4	11.38	18.1
Ag	1.21	967	107.66	10.50	10.2
Au	1.18	1037	197.0	19.30	10.2
Bi.....	1.17	265	210.0	9.82	21.4
As	1.12	500	74.9	4.71	15.9
Te	1.08	500	126.0	6.25	20.2
S	1.02	115	31.98	2.04	15.7
Cu	0.987	1057	63.3	8.80	7.2
Fe	0.79	2080	55.9	7.80	7.2

The material on the subject discussed is, as yet, too scant to allow the drawing of positive conclusions. It should always be remembered by investigators that to give their work full scientific value, not only one or two elements in a combination of many, should be studied, but the interrelations of all must be observed.

BALTIMORE COPPER WORKS, DEC. 1896.

[CONTRIBUTIONS FROM THE CHEMICAL DIVISION, U. S. DEPARTMENT OF AGRICULTURE. NO. 24.]

RECOVERY OF WASTE PLATINUM CHLORIDE.

CONTRIBUTED BY H. W. WILEY.

Received January 26, 1897.

ALUMINUM turnings, freed of oil, have been used in this laboratory for some time for many purposes. Immediately after the publication of the paper of Wislicenus and Kaufmann¹ on the various applications of aluminum amalgam in the laboratory, a large quantity of these turnings was procured from the Pittsburg Reduction Co. Considerable difficulty was encountered in attempting to use these turnings in the manner described in the paper cited above. Mr. McElroy prepared the amalgam by washing aluminum clippings with ether to remove oil, treating with dilute caustic soda till free evolution of gas took place,

¹ *Ber. d. chem. Ges.*, 28, 1323.