XXII.—*Some Results of the Analysis of Commercial Coppers.*

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THE influence undoubtedly exerted by such metals as antimony, arsenic, and bismuth, in modifying the physical properties of copper, renders their detection, with certainty, when present in minute quantities, and their correct estimation, of considerable importance. Although many processes have been suggested for the determination of these metals, and especially of the two first named, chemists of considerable experience and ability are frequently found to differ widely in the results of their analyses of commercial copper from the same source, one chemist insisting, perhaps, on the presence of arsenic in very appreciable quantities, while another denies its existence in the same sample.

The causes of these discrepancies are well illustrated by the circumstance that one of the methods for the separation of arsenic from copper, most generally recommended in all works upon analytical chemistry, even in the very latest editions,—namely, the digestion of their sulphides in the sulphides of ammonium, sodium, or potassium, has been shown, by the experiments of Mr. Bloxam, to be altogether fallacious, when the arsenic does not exist in greater proportion than one per cent.; and that even one part of that metal, in conjunction with ninety of copper, cannot be detected by that method.

When it is remembered that, in the superior classes of refined copper, arsenic is seldom found in larger quantities than 0.10 per cent., and frequently only in proportions of from 0.02 to 0.05 per cent., it is very evident that, by pursuing the course above alluded to, no arsenic would be dissolved by the alkaline sulphides, and, consequently, the absence of that metal would be presumed.

The separation of *antimony* from copper, by means of sulphide of ammonium, does not appear, from Mr. Bloxam's experiments, to be attended by the same difficulties as in the case of arsenic. Mr. Bloxam's researches upon this portion of the subject merely show that when 1 per cent. of antimony is present in copper the metal may be detected in the sulphide of ammonium-solution; but, with regard to smaller quantities than this, we have no information.* From many experiments which we have instituted, it would seem that the detection of less than three-hundredths of a grain in one hundred grains of copper cannot be relied upon with any degree of certainty.

It also appears, from the experiments of the same chemist, that 20 or 30 per cent. of *tin*, when alloyed with copper, may be overlooked when the separation is based upon the solubility of sulphide of tin in sulphide of ammonium.†

In the case of arsenic, when in combination with copper, far smaller quantities may, however, be detected than those stated by Mr. Bloxam, if hydrosulphuric acid is passed through the solution, to which ammonia has previously been added, in excess. By

* Quarterly Journal of the Chemical Society, Vol. v. p. 104.

† In a note (p. 37c) appended to the last edition of Fresenius's Quantitative Analysis, the author says that M. Lucius, one of the students in his laboratory, has succeeded in effecting the complete separation of copper from tin, by means of yellowish sulphide of sodium, but it is indispensable to digest them three or four times with sufficiently large quantities of the solvent.

adopting this method of operating, the arsenic is never precipitated, and consequently the separation is nearly, if not quite, complete. It is only necessary to saturate thoroughly with hydrosulphuric acid, in order to prevent traces of copper from entering into the ammoniacal liquid. For example :—

In a mixture of 10·00 grains of copper
and 0·10 grain of arsenic,

the latter was immediately detected, on the addition of hydrochloric acid to the filtered liquid.

In 10·00 grains of copper
mixed with 0·01 grain of arsenic,

the latter was discernible when the filtrate, mixed with excess of acid, had been kept in a warm place for half an hour.

Arsenic may, moreover, be detected in copper, in quantities not less than 0·20 to 100·00 of the latter, when the mixed sulphides are digested in strong sulphide of ammonium for many hours.

Although the rules laid down in analytical works, for the detection and separation of nearly every metal with which we are acquainted, appear, generally speaking, to be sufficiently plain and conclusive, every chemist must have experienced the difficulty of separating, or even distinguishing, very small quantities of metals, when associated with another in very much larger proportion. To take for example, the examination for tin, antimony, arsenic, and bismuth, of a specimen of refined copper which is supposed to be nearly pure, having passed through the various stages of its metallurgy, until the completion of the final operation. The copper would be dissolved in nitric acid, and water added; when, in the majority of cases, a turbidity in the liquid would be thereby produced. This might consist of antimonious or antimonie acid; arsenic, as arseniate of antimony; bismuth, thrown down from its solution as basic nitrate; lead, as sulphate (for if a trace of sulphur is present, sulphuric acid will be formed, and sulphate of lead consequently produced); and the whole of these compounds may weigh collectively only two- or three-tenths of a grain. Should either the nitric acid or water employed contain a trace of chlorine, silver, which is almost invariably found in copper, would also be separated, and add to the complexity of the precipitate.

Having ourselves individually experienced numerous difficulties such as those glanced at above, in the constantly recurring exa-

mination of specimens of commercial copper, we have devoted considerable attention to the improvement of the existing methods for the detection and correct estimation of its metallic impurities, and especially of antimony, arsenic, and bismuth; and in our researches on this subject we have, with the valuable co-operation of Mr. E. O. Brown, arrived at results which we believe are sufficiently important to analytical chemists, to warrant their publication.

The following is a method which, after various modifications, we have now employed for some time, with considerable success, both for the quantitative and qualitative examination of copper, when antimony, arsenic, bismuth, and lead, have to be detected and estimated.

About 200 grains of the metal are dissolved in nitric acid, a small quantity of solution of nitrate of lead is added, equal to about 10 grains of the salt, and subsequently an excess of ammonia and carbonate of ammonia. A precipitate is formed, which may consist of oxide and carbonate of lead, arseniate and antimoniate of lead, and oxide of bismuth, the whole of the copper remaining in solution. The precipitate is separated by filtration, thoroughly washed and digested in a strong solution of oxalic acid, whereby the antimony and arsenic are dissolved.

To the filtered liquid, sulphide of ammonium is added, or, what is preferable, it is rendered alkaline by ammonia, and hydrosulphuric acid is passed through to saturation. Traces of sulphide of copper generally impart a brownish tinge to the liquid, and are deposited after some time, as it is nearly impossible to wash away the last traces of that metal from the nitrate of lead-precipitate. This sulphide is filtered off, and a slight excess of hydrochloric acid is then added to the filtrate, which is diluted to about 8 ounces. If any large amount of either antimony or arsenic be present, there will be an immediate precipitate. If smaller quantities exist (one- or two-hundredths of a grain) the flask should be placed on the sand-bath for a few hours, and the temperature maintained at from 140° to 200° Fahr., when the metals, if present, will make their appearance as sulphides. If the precipitate be orange or orange-red, the presence of antimony is certain, but if of a pure canary-yellow, its absence may be presumed.

The precipitated sulphides are oxidized by means of concentrated nitro-hydrochloric acid, the clear solution is mixed with chloride

of ammonium and excess of ammonia, and the arsenic is separated as the ammonio-magnesian arseniate ($2\text{MgO}, \text{NH}_4\text{O}, \text{AsO}_5, \text{HO}$). The filtrate from this is slightly acidified with dilute hydrochloric acid, and the antimony is precipitated by hydrosulphuric acid, and ultimately determined as antimoniate of teroxide of antimony (SbO_4). Should the presence of antimony and arsenic have been previously ascertained, it is, of course, unnecessary, in the quantitative process, to precipitate them both as sulphides from their solution in oxalic acid, as the arsenic may be at once precipitated by the addition of sulphate of magnesia and excess of ammonia, and the antimony determined in the filtrate.

In the determination of the *bismuth* and *lead* contained in copper, uniformly successful results have been obtained by employing the following method, which, as far as regards the separation of these metals from the copper and from any tin, antimony, or arsenic that it may contain, is founded upon the plan for detecting the arsenic and antimony just now described.

The nitric acid-solution of about 200 grains of the copper, is mixed with a small quantity of solution of phosphate of soda; ammonia in excess is then added; and the resulting precipitate is collected and purified from copper by washing with ammoniacal water. This precipitate is afterwards dissolved in hydrochloric acid, its solution is rendered alkaline with ammonia, and submitted to a current of hydrosulphuric acid. The precipitated sulphides of lead and bismuth are thoroughly washed, and dissolved in dilute nitric acid; the solution is nearly neutralized with ammonia, and then digested with a little hydrated oxide, or basic nitrate, of copper, which precipitates the oxide of bismuth, while lead remains in solution. The precipitate is thoroughly washed, dissolved in dilute nitric acid, and the bismuth separated from the copper by the addition of excess of ammonia; the oxide of bismuth thus obtained is purified by washing, and its weight determined in the usual manner. The solution containing the nitrates of lead and copper is mixed with solution of carbonate of soda; excess of acetic acid, and a small quantity of bichromate of potassa are added, and the chromate of lead is collected.

It should be observed that, in the event of the copper containing iron, that metal would be obtained as oxide together with the bismuth. When this is the case, which may readily be known by the brownish tinge imparted to the oxide of bismuth, they have to be separated. The mode of operation does not need description here.

The analytical methods just described are available not only for the determination of appreciable quantities of the metals antimony, arsenic, bismuth, and lead, but also for the detection of very minute proportions of those metals, and especially of the first two, when existing in copper.

In order to test the delicacy of the method described for the detection of minute traces of either arsenic or antimony, the following experiments were instituted :—

100 grains of electrotype-copper were dissolved in nitric acid, nitrate of lead was added, and afterwards a mixture of ammonia and carbonate of ammonia; the precipitate was boiled with solution of oxalic acid for half an hour, the dissolved portion filtered, and sulphide of ammonium added in excess. The few black flakes of sulphide of copper were separated by filtration, and hydrochloric acid was added to the filtrate. An opalescence was produced, which did not increase upon the application of gentle and long-continued heat, and did not assume any tinge of yellow: arsenic and antimony were therefore presumed to be absent.

Another 100 grains of the same copper were dissolved in a similar manner, and 0.1 grain of arsenic acid was added to the solution. The precipitate with nitrate of lead and carbonate of ammonia, treated as described above, gave an instantaneous indication of arsenic, which increased very much upon applying heat, the sulphide falling down in clear yellow flocks. Another similar quantity of the copper was tested with the addition of 0.05 grain of arsenic acid. The result was not so instantaneous, but, eventually, equally conclusive. 0.02 grain was then tried, with a similar confirmation; and even 0.01 grain of metallic arsenic, when dissolved in nitric acid, and added to the solution of the 100 grains of metallic copper, became, after some time, abundantly evident.

From these experiments, it appears that there is no difficulty whatever in detecting minute traces of arsenic in the presence of copper, the latter existing, in proportion to the former, as ten thousand to one.

A similar series of experiments was made upon the detection of antimony by this method. 0.10, 0.05, 0.02, and 0.01 grain were each added to four solutions of 100 grains of copper in nitric acid, and the results were quite as satisfactory as in the case of arsenic.

The presence of arsenic, even in a very small quantity of commercial hydrochloric acid, can be easily detected by this method. If a few drops of the acid be added to an ounce of water, nitrate of lead and excess of ammonia introduced, and the precipitate digested in sulphide of ammonium, the filtrate, on addition of hydrochloric acid and application of heat, shows abundant indications of arsenic.

Minute traces of this metal may also be satisfactorily recognized by the magnesia-test, as is shown by the following experiments; 100 grains of electrotype-copper and 0.10 grain of arsenic acid were dissolved in nitric acid. Ammonia was added in excess, and subsequently a small quantity of solution of sulphate of magnesia. In a few hours, a distinct crystalline precipitate was observed upon the sides of the glass, which proved to be the arseniate of magnesia and ammonia. 0.02 grain of arsenic was added to 100.00 grains of copper, and treated in the same way. The liquid was allowed to remain for a few days, and the slight sediment, containing a basic salt of copper, was digested in sulphide of ammonium. Hydrochloric acid, added to the filtrate, caused a precipitate, which, on heating, assumed a pure yellow tint.

A method, published by one of us, in the *Chemical Gazette* for 1857 (vol. xv., p. 113), seems also to be advantageous in the quantitative estimation of arsenic and copper. Oxalic acid, added to a slightly acid solution of the two metals, precipitates nearly the whole of the copper, leaving the arsenic dissolved. The great practical difficulty, is the tendency which oxalate of copper possesses, of passing through filtering paper, even when double or treble filters are employed. This difficulty, however, may be overcome by adopting the following mode of operation. Ammonia is added to the solution of the metals in sufficient quantity to throw down the oxide of copper, without redissolving it. Oxalate of ammonia, poured in excess upon this precipitate, effects its solution, forming a double oxalate of copper and ammonia. The introduction of nitric acid causes a precipitate of oxalate of copper, which can be filtered with great readiness. Sulphide of ammonium, added in excess to the filtrate, throws down the small quantity of copper which has escaped precipitation by oxalic acid, at the same time holding the arsenic in solution, which may be estimated in the usual manner. The following experiments were instituted at the time of publication:—

A mixture of 50 grains copper and 0·5 arsenious acid = 0·378 arsenic, gave 0·365 grains of arsenic.

With a mixture of 40 grs. copper and 0·10 grain of arsenic, decided indications of the latter were obtained.

It appears, from the above results on the comparative merits of the three methods detailed for the detection of arsenic in copper, that the plan of precipitation by means of nitrate of lead exhibits very decided superiority over the other methods, not only in point of delicacy, but also as regards facility and rapidity of execution. Thus, less than 0·01 grain of arsenic in 100 grains of copper is readily discovered by means of the nitrate of lead-process within two hours, while, for the detection of more than double that proportion of arsenic by the method of Levöl (*i. e.*, by its precipitate as the ammonio-magnesian salt), at least forty-eight hours must elapse before any conclusion can be arrived at.

When compared with the very delicate process of testing copper for traces of arsenic recommended by Dr. Odling, the nitrate of lead-method also offers considerable advantages, being quite equal to it in point of delicacy, and susceptible of far more rapid application. Dr. Odling suggests, that the finely divided copper to be tested should be exposed for a few days to the joint action of pure cold hydrochloric acid and of air. The resulting liquid, and any copper that remains undissolved are to be transferred to a retort and carefully distilled, the mouth of the retort dipping into water. Special tests for arsenic are then to be applied to the product of distillation. The addition of a small quantity of chlorate of potassa to the hydrochloric acid is recommended, to accelerate the solution of the copper, care being taken to keep the metal in excess, so as to ensure the complete decomposition of the chlorate before distillation. Dr. Taylor directs, that any copper remaining undissolved, after two or three days' exposure to hydrochloric acid and air, should be removed before distillation, its weight being deducted from that of the copper originally employed.

If, instead of allowing the copper to remain in prolonged contact with hydrochloric acid and air, at ordinary temperatures, it is introduced, together with a little hydrochloric acid, into a capacious vessel, and exposed to a gentle heat, the results of the experiment are considerably modified. A specimen of copper, containing only a very minute trace of arsenic, and in which that impurity had been distinctly detected, both by the

distillation-process, as just described, and by the nitrate of lead-method, was submitted to treatment with a small quantity of warm hydrochloric acid, in a Woulfe's bottle immersed in a water-bath. To this bottle were attached two others, the first containing water, into which the exit-tube of the heated bottle dipped, the second being partly filled with solution of acetate of lead. To the last bottle was attached a delivery-tube, which passed into a vessel containing a neutral solution of nitrate of silver. After continuing the application of heat for several hours, and examining the contents of the bottle containing water, in which any products of distillation had condensed, not a trace of arsenic could be detected, but in the nitrate of silver-solution was observed a very small black precipitate, resulting from the escape of hydride of arsenic from the apparatus. A similar experiment was made with a specimen of copper which contained about 0.3 per cent. of arsenic. After exposure of this to heat, in contact with the acid, for a short time, it became coated with the grey film produced in applying Reinsch's test.* At the conclusion of the operation, which was continued for about four hours, no trace of arsenic was discovered in the condensed product, but an abundant precipitate was produced in the solution of silver. A specimen of copper, containing 1.1 per cent. of arsenic, was submitted to the same treatment for two successive periods of about two hours each. After both operations, the water in the condensing vessel contained only a very minute trace of arsenic, while the hydride of arsenic evolved was very considerable.†

It appears from these results that if, in exposing copper which contains arsenic to the action of hydrochloric acid, heat be applied,

* This grey deposit, which consists, according to Lippert (*J. f. prakt. Chem.* v. 81, p. 168), of an arsenide of copper having the composition Cu_3As , makes its appearance only slowly when a slightly arsenical copper is exposed to the joint action of hydrochloric acid and air. But if the acid be mixed with about half its volume of the ordinary test-solution of pure sesquichloride of iron, a grey film is very speedily produced, if the copper contain only a trace of arsenic, in consequence of the comparative rapidity with which the solution of the copper is then effected. For the same reason, the contact, for an instant, of a fragment of chlorate of potassa, with the copper immersed in hydrochloric acid, will produce a grey stain upon the metal, even if the proportion of arsenic present be very small indeed. It need scarcely be stated that, under ordinary circumstances, these tests are only useful as affording a preliminary indication of the extent to which a specimen of copper is contaminated with such metals as arsenic, antimony, lead, or bismuth.

† Sublimates of arsenious acid were obtained by heating a portion of the delivery-tube through which the gas passed from the lead- to the silver-solution. The experiments were expedited by passing a slow current of air through the apparatus.

the arsenic will continue for a considerable period to pass off only in the form of hydride of arsenic, even if it be present in the copper in very considerable proportion; and that it might, therefore, readily escape detection in the distillation process, if heat were at once applied, to aid in the solution of the copper, for the purpose of shortening the time required for the application of the test, as directed by Drs. Tay or and Odling. If the process of heating be continued for a long period, the disengagement of hydride of arsenic gradually diminishes, and eventually ceases almost entirely, as the amount of copper in solution becomes considerable, and as the fragments of metal become perfectly coated with the grey arsenide.

As a qualitative method of testing copper for arsenic and antimony, the plan of heating the metal with hydrochloric acid and carrying the evolved gas, purified as described, through nitrate of silver-solution, with the assistance of a slow current of air, can be recommended as comparatively very expeditious and exceedingly delicate; but, to identify each metal, when present in minute quantities, and to arrive at a knowledge of the proportion existing in the copper, by treatment with hydrochloric acid, it is unquestionably necessary to effect the solution of the copper at ordinary temperatures, before distilling, and hence this method of examination is very tedious when compared with the process of separation by means of nitrate of lead and oxalic acid.

As regards the qualitative examination for *bismuth* in copper, considerable advantages, in point of delicacy and rapidity of execution over the quantitative method described in a former part of the paper, are possessed by a mode of testing for that metal, which is based upon a curious reaction exhibited by iodide of potassium in the joint presence of bismuth and lead, and which, we believe, has not hitherto been noticed. When iodide of potassium is added to a solution of a lead-salt, it is well known that yellow iodide of lead is precipitated, which dissolves on heating the liquid, and is re-precipitated, on cooling, in brilliant golden-coloured scales. (The solution of the amorphous iodide may be greatly facilitated by the addition of a small quantity of hydrochloric acid.) If the least trace of bismuth is present in the lead-salt, the re-precipitated scales are no longer yellow, but assume a dark orange or crimson tint, varying in intensity of colour according to the amount of bismuth present. This test is of such extraordinary delicacy, that 0.00025 of a grain of bismuth

may be detected in copper with the greatest ease, the iodide of lead becoming dark orange, while 0·001 grain imparts a reddish-brown tinge, and 0·01 grain a bright crimson, the scales resembling chromate of silver in appearance.

The mode of operation in applying this test is as follows:—About 100 grains of the copper to be examined are dissolved in nitric acid, a solution of nitrate of lead, equal to about 5 grains of the salt, is added, and subsequently ammonia and carbonate of ammonia. The precipitate is washed with ammoniacal water, to free it from copper, and dissolved in warm acetic acid. Considerable excess of iodide of potassium is introduced, and the liquid is warmed until the precipitate disappears. On cooling, the crystalline scales will shew, by their colour, the presence or absence of bismuth.* If in the same specimen of copper it is desired to test for arsenic and antimony, the nitrate of lead-precipitate is digested with oxalic acid. The oxalates of lead and bismuth are insoluble in acetic acid, and must therefore be dissolved in as small a quantity as possible of hydrochloric acid.

By the employment of the test just described, bismuth has been detected in many specimens of very pure copper. Nearly all the modern copper-coinage, more especially that of the reigns of George III. and IV., contains very considerable traces, and in the new bronze-currency it is abundantly evident. It is found also in the silver money of England, as well as of other countries, owing, probably, to the copper with which it is alloyed. Copper which has been rolled out to a ribbon, has been found to contain it to the extent of at least 0·02 per cent., while in some specimens of commercial sheet copper, as much as between 0·10 and 0·20 per cent. has been discovered. It may also be traced in nearly all copper gauzes, wires, and foil.

It might be presumed, from the nature of the methods described at the commencement of this paper, that bismuth would be separated from antimony and arsenic by means of oxalic acid. Numerous experiments have proved this to be the case. The precipitate occasioned by nitrate of lead, after digestion in oxalic acid,

* Iodide of lead is very soluble in the acetates of soda, potassa, and ammonia, even in the cold, forming colourless solutions, from which iodide of potassium, added in excess, precipitates iodide of lead in the crystalline state, although no heat has been applied. Gmelin, in mentioning many solvents of this compound, does not allude to the acetates of the alkalies, which dissolve it with infinitely greater ease than any of the others which are mentioned.

is entirely deprived of any antimony or arsenic with which it might have been previously associated, while the whole of the bismuth remains undissolved.

We append to this paper a tabular statement of the results obtained by an application of the methods of analysis, specially recommended in this paper, to the qualitative and quantitative examination of a large number of varieties of copper, which includes specimens of blister, bar, and refined copper from Chile, Mexico, Australia, North America, Buenos Ayres, Manilla, Spain, Russia, Sweden, Norway, Italy, and Hungary; numerous specimens of English "*best-select*" copper, of sheet and bolt-copper, and also several English and foreign coins.

The results of these examinations lead us to the following conclusions regarding the principal metals associated with copper:

1°. Arsenic and silver are almost invariable impurities in copper;

2°. The occurrence of bismuth in copper is very general; this metal seems to be absent only in those cases in which carbonates of copper have been alone employed in the production of the metal, as in the majority of Australian and Russian coppers;

3°. Antimony is not nearly so general an impurity of copper as has been supposed. There appears little doubt that, in analyses for practical purposes, the bismuth existing in copper has been mistaken for antimony, inasmuch as the rough qualitative method of testing, by the addition of a large quantity of water to the strong solution of copper in nitric acid, commonly employed, furnishes a white precipitate which has been regarded as an indication of antimony;

4°. Lead is of very rare occurrence in cake-copper, both unrefined and refined, as sent into the market; but appears to be an almost invariable constituent of copper which has been manufactured into sheet or rod.

It may be observed, in conclusion, that iron, which, like sulphur, exists, as might be supposed, in considerable proportions in what is technically termed bar copper, is almost perfectly removed by the refining process.

RESULTS of the Examination for Metallic Impurities, of different varieties of Copper.

Description of Copper.	Silver.	Arsenic.	Anti- mony.	Bismuth.	Lead.	Tin.	Iron.
BAR AND BLISTER COPPER.							
Chile, No. 1 Bar	Silver was detected in all these specimens, but not determined.	traces	..	traces	..	..	0·62
" 2 "		traces	..	..	..	..	0·71
" 3 "		traces	..	traces	..	..	0·85
" 4 "		0·10	..	traces	..	..	0·91
" 5 "		traces	traces	traces	..	..	0·62
" 6 "		traces	..	traces	..	..	0·46
" 7 "		traces	..	traces	..	..	0·52
" 8 "		traces	..	traces	..	..	0·67
" 9 "		traces	..	traces	..	..	0·64
" 10 "		traces	traces	traces	..	..	0·52
" 11 "		traces	..	..	..	..	0·62
" 12 "		0·02	traces	..	..	..	0·50
" 13 "		0·04	traces	..	..	..	0·43
" 14 "		0·07	0·50	traces	..	..	0·51
" 15 "		..	..	..	..	..	0·84
" 16 "		0·40	traces	traces	..	..	1·64
" 17 "		0·45	..	..	..	..	1·52
" 18 "		traces	..	..	..	..	0·70
" 19 "		0·50	0·20	..	..	..	0·08
" 20 "		..	..	..	..	..	1·20
" 21 "		..	traces	traces	..	..	0·98
" 22 "		..	traces	traces	..	..	1·00
" 23 "		traces	..	traces	..	..	1·20
" 24 "		traces	..	traces	..	..	1·04
" 25 "		traces	..	traces	..	..	1·12
" 26 "		traces	..	traces	..	..	1·02
" 27 "		traces	..	traces	..	..	0·84
" 28 "		0·03	traces	traces	..	..	1·10
" 29 "		..	..	..	..	..	0·75
" Blister Copper	0·10	traces	traces	..	..	0·32	
Matzatlan Copper	traces	..	traces	..	..	1·32	
New Mexican	..	..	..	..	..	0·42	
Spanish, No. 1	Silver was detected in all these specimens, but the quantities were not determined.	3·31	0·70	..	..	..	traces
" 2		2·49	..	trace	..	..	"
" 3		2·15	..	0·04	trace	..	"
" 4		1·18	..	..	trace	..	"
" 5		1·20	..	trace	..	..	"
" 6		0·90	..	..	..	..	"
" 7		0·30	..	..	..	..	0·21
" 8		0·25	..	traces	..	..	0·35
Swedish, No. 1		0·25	0·20	..	..	..	0·31
" 2		..	traces	..	..	..	0·20
Manilla Slab		1·24	0·65	0·05	..	..	traces
Buenos Ayres Slab		0·31	0·17	0·10	..	..	traces
Australian (Sydney)		..	..	..	..	..	1·01
" (Sydney)		..	..	..	..	..	0·76
REFINED COPPERS.							
Chile, (Société Italienne)	Silver was detected in all these specimens, but the quantities were not determined.	..	..	..	..	..	0·01
Chile, No. 2		0·04	..	..	..	..	0·03
" 3		0·03	..	..	..	..	..
Spanish		traces	..	..	..	..	0·06
" No. 2		0·63	..	..	..	..	..
Italian, No. 1		..	..	trace	..	..	..
" 2		..	..	..	..	..	trace
Tuscan Rosette		..	..	trace	..	..	trace

OF COMMERCIAL COPPERS.

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RESULTS of the Examination for Metallic Impurities, of different varieties of Copper

Description of Copper.	Silver.	Arsenic.	Antimony.	Bismuth.	Lead.	Tin.	Iron.
Russian (C.C.N.D.)	Present but not determined.	0·11	.. {	minute traces	} ..	..	..
" No. 2		..	..	..	..	..	0·30
Hungarian		0·36	0·22	traces	..	..	trace
" Rosette		0·06	0·12	..	..	..	..
Australian (Burra Burra) ..		0·02	..	..	..	..	trace
" (Kapunda)		0·01	..	..	..	..	trace
Lake Superior		0·07	0·01	..	..	..	trace
Norwegian (Alten)		trace	..	..	..	..	trace
North American		0·22	..	..	..	..	trace
" No. 2		0·06	..	..	..	..	trace
" No. 3	trace	..	..	..	..	..	trace
English Tile	traces	0·07	traces	0·02	..	..	trace
English Best Select, No. 1	0·03	0·03	..	0·05	..	..	trace
" " No. 2	0·02	0·04	..	0·04	..	..	trace
" " No. 3	0·02	0·01	..	0·05	..	..	trace
" " No. 4	0·03	0·04	..	0·04	..	..	trace
" " No. 5	0·02	0·12	0·02	0·05	..	..	trace
" " No. 6	0·04	0·15	0·05	0·05	..	..	trace
" " No. 7	0·03	0·14	0·02	0·04	..	..	trace
" " No. 8	trace	0·13	0·07	trace	..	..	trace
" " No. 9	trace	trace	trace	trace	..	..	trace
" " No. 10	0·03	0·14	0·05	0·05	..	..	trace
" " No. 11	0·07	0·31	trace	0·17	..	..	trace
" " No. 12	0·05	0·15	trace	0·12	..	..	trace
" " No. 13	0·05	0·12	trace	0·13	..	..	trace
" " No. 14	0·05	0·14	trace	0·12	..	..	trace
" " No. 15	0·06	0·10	..	0·12	..	..	trace
" " No. 16	0·02	0·04	0·02	trace	..	..	trace
" " No. 17	0·03	0·06	..	0·04	..	..	trace
SHEET AND BOLT COPPER.							
Sheet, No. 1	0·07	trace	trace	0·13	0·07	..	trace
" No. 2	0·05	0·08	0·02	0·09	0·15	..	trace
" No. 3	0·07	0·12	trace	0·06	0·08	..	trace
" No. 4	0·02	0·14	..	0·04	0·05	..	trace
" No. 5	0·05	0·09	..	0·13	0·25	..	trace
" No. 6	0·06	0·10	0·01	0·18	0·18	..	trace
" No. 7	0·03	0·10	trace	0·10	0·40	..	trace
" No. 8	0·05	0·06	trace	trace	0·15	..	trace
" No. 9	0·03	0·12	trace	0·05	0·38	..	..
Bolt, No. 1	trace	0·07	..	0·02	0·13	trace	trace
" No. 2	trace	0·01	..	0·02	0·22	trace	trace
COINS.							
Copper Coin, George III. ..	All these specimens contained silver, the proportions were not determined.	0·12	trace	trace	..	..	trace
" " George IV. ..		0·09	trace	trace	..	trace	trace
" " William IV. ..		0·04	..	trace	..	trace	trace
New Bronze Coin		trace	..	trace	.. {	not estimated	{ trace
Spanish Coin, 1856		0·30	..	trace	..	trace	0·03
Chile Coin, 1858		trace	..	trace	..	trace	0·04
United States Coin, 1849 ..		trace	..	trace	..	trace	trace
Chinese Coin		trace	..	0·04	..	trace	0·12
Old Italian Coin		trace	..	..	..	trace	0·21
*Bactrian Coin (181 B.C.) ..		..	..	trace	..	..	trace
Dutch Coin	..	..	..	trace	..	0·17	..
Copper rolled into thin ribbon	..	..	..	0·03	..	..	..

* This coin was kindly given to us by Walter Hawkins, Esq., from his valuable collection.