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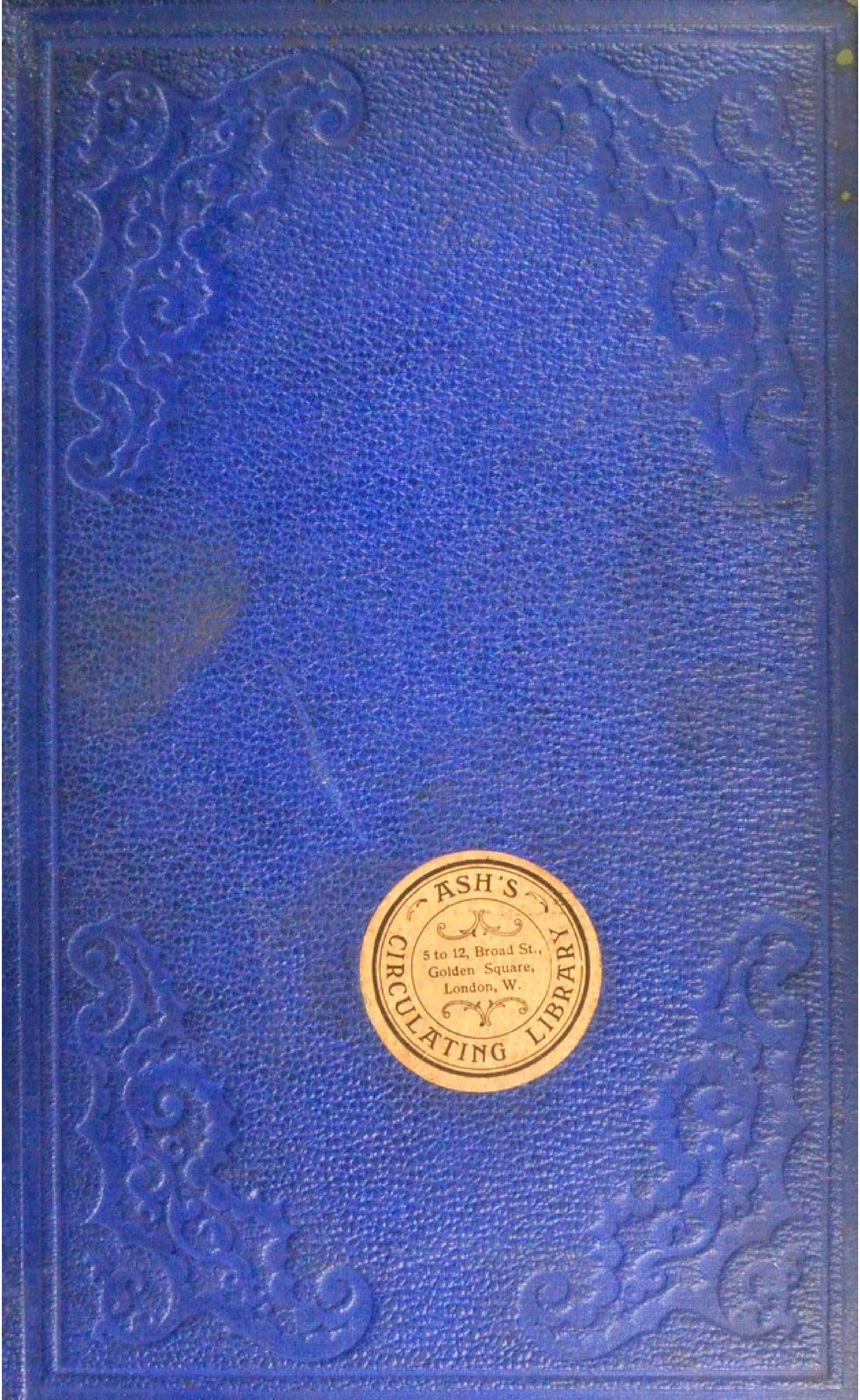

GALVANOPLASTIC MANIPULATIONS.

A PRACTICAL GUIDE

FOR THE

GOLD AND SILVER ELECTROPLATER

AND THE

GALVANOPLASTIC OPERATOR,

WITH

ONE HUNDRED AND TWENTY-SEVEN FIGURES IN THE TEXT.

TRANSLATED FROM THE FRENCH OF
ALFRED ROSELEUR, CHEMIST,
PROFESSOR OF THE GALVANOPLASTIC ART, MANUFACTURER OF CHEMICALS,
GOLD AND SILVER ELECTROPLATER.

BY

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PREFACE TO THE AMERICAN EDITION.

THE beautiful art so fully treated in M. Roseleur's Galvanoplastic Manipulations is one of great and steadily growing importance, especially in this country, and it has long needed and demanded a more thorough and truly artistic treatise than any hitherto existing in the English language. This pressing want is, as it is believed, satisfactorily filled by the volume herewith presented to the American public. That it is much the superior of any other of its kind ever issued here or in Great Britain there can be no question. In it will be found many details entirely wanting in all of the other books in the language on this subject, besides the freshest and most exact statements in regard to all of those points which have been treated by previous writers.

In the United States, under the benign and fructifying influences of a governmental policy which has existed during the past eleven years, and which gives some heed to the welfare of our diversified industries, the practice of this charming art has reached such proportions as place it in extent beyond that of any other country in the world. Our government having now fully recognized the principle, that, while exercising the *right* to levy taxes, it is also charged with the *duty* of extending protection to those—its producers—who finally bear the burden of all those taxes not borne by foreigners, the triumphs of this industry in the immediate future must be far greater than in the past. In this coming career the treatise of M. Roseleur will extend no inconsiderable aid to it, in causing many new and important applications of it, as well in the larger as in the smaller and more delicate kinds of work. Under such circumstances, it is believed that this volume can hardly fail to meet with that substantial appreciation, at the hands of the trade and of amateurs, to which its merits entitle it.

PHILADELPHIA, June 22, 1872.

AUTHOR'S INTRODUCTION TO THE FIRST EDITION.

If conscientious and persevering work be sufficient to make a good book, this one ought to be excellent.

Circumstances which it is not necessary to mention here induced me, several years ago, to relinquish the study of pure science, and to devote myself entirely to the new industry of metallic deposits by the wet way.

Being in constant relation with manufacturers, operators, and artists, I soon began to appreciate their wants, and to acknowledge with them how difficult it was to extract from too scientific and sometimes diffuse works, methods of operating which, being free from scientific theories, may present in a synoptical way all the series of operations conducting to a desired result.

Therefore, upon the advice of a great number of persons, I have undertaken this book, which I claim to be conscientious and true, since it does not contain any formula which I have not tried personally.

It may be said that, in the following practical chapters, I have too often sacrificed the form to the useful, and the style to the meaning, but I do not pretend to write for *savans*, and I address myself to artists and operators whose principal aim is to understand and execute well.

In order to assimilate the rapidity of description to that of the operations, I shall eliminate everything historical and all discoveries not yet applied; therefore every one will have the right to claim what is his own.

I shall generally indicate but a small number of methods, and often only one, when it is sure to give successful results.

After the description of modes of operation, the superiority of which has been proved by a practice of every day, I shall indicate to manufacturers the most simple processes for the preparation of the chemical products from which success or failure so often results. I shall also try to point out to them the means of prevention against the poisonous effects of the substances which they are obliged to use.

I shall be happy if my undertaking results in the advancement of an art already flourishing, and shall wait confidently for the verdict of those who shall put my lessons in practice.

A. R.

INTRODUCTION TO THE SECOND EDITION.

In this second edition I have nothing whatever to change in that I have said in the preceding introduction.

Greater care and industry in the revision of this book, in order to bring it up to the present state of knowledge, is, I think, the best means of deserving the too indulgent praise bestowed by the readers of the first edition.

A. R.

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PART I.

THIN ELECTRO-DEPOSITS.

CHAPTER I.

OBJECT OF THE ELECTROPLATING ART.

The art of depositing metals by the wet way comprises two orders of phenomena, which, although nearly identical in the appearance of their results, are widely different as regards the causes of their production. For instance, gilding by simply dipping into liquors prepared for the purpose is the result of chemical affinities alone; on the other hand, gilding by electro-deposits cannot take place without the simultaneous combination of chemical reactions, and *dynamic electricity*, which has already become of great practical importance, although so recently discovered.

The frequent application, in the same workshop, of metallic deposits by the wet way with or without the aid of electricity, renders it necessary that we should not separate the two processes, inasmuch as the manipulations and chemical preparations are nearly identical in either case, and the results are similar in appearance.

The operations "by simple immersion," by which dissolved metals are reduced to their primitive metallic state, are due to chemical affinities alone, and generally simply result in very thin layers of the reduced metal.

On the other hand, we may by electro-deposits arrive at two different results:—

It may be desired, for instance, to cover a common metal with a layer of another metal which is more precious, more resisting, less oxidizable, and with a more pleasing appearance; but this layer, generally, borrows its strength from the underlying metal, as is the case when we gild or silver copper, or when we cover zinc with copper, etc.

Or we may intend to reproduce with scrupulous exactness a given article by means of a metallic deposit which, after its separation from the mould, has sufficient firmness to be used for the same purpose, and such are the galvanoplastic reproductions of basso-relievos, medals, etc. We may also wish to impart a metallic hardness to substances without firmness, and retain at the same time nearly their primitive shapes and dimensions, as when we deposit metallic coats upon small statues, flowers, fruits, insects, etc.

We shall examine first the thin electro-deposits of gold and silver, as their applications present a great variety and are of general interest.

NOTE.—We call—

Electro-metallurgy, the art of extracting metals in a merchantable form (sheets, bars, or ingots), by the aid of electricity, from ores and natural products.

Electroplating, the art of covering, by the aid of electricity, one metal with a thin deposit or coat of another metal.

Electrotyping, the art of reproducing, by electro-deposits, the forms of printer's types.

Galvanoplastique or *galvanoplastic art*, the art of reproducing, by galvano- or electro-deposits, an object of art, especially when moulds are necessary.

The operations of electrotyping and of the galvanoplastic art are so similar that the difference is more in the name than otherwise. We regard galvanoplastique as more general in its meaning, and we shall therefore consider electrotyping printer's type as a branch of the galvanoplastic art.—*Trans.*

CHAPTER II.

CLEANSING.

CEANSING COPPER AND ITS ALLOYS—CLEANSING BY FIRE, OR BY ALKALIES—DIPPING—DIPPING IN OLD AQUA FORTIS—DIPPING IN AQUA FORTIS AND SOOT—AQUA FORTIS FOR A BRIGHT LUSTRE—DIPPING IN COMPOUND ACIDS FOR A BRIGHT LUSTRE—WHITENING BATH—COMPOUND ACIDS FOR A DEAD LUSTRE—DIPPING IN NITRATE OF BINOXIDE OF MERCURY.

Cleansing.

Before we undertake to lay a thin electro-deposit of one metal upon another, it is absolutely necessary that the latter should be perfectly clean, as the slightest impurity is sufficient to prevent the adherence of the two metals.

The operation or series of operations to arrive at this result is called *cleansing*.

The mode of cleansing varies with the metals operated upon, and that which is the most complicated.

and requires the greatest care and perfection is when we operate upon copper and its alloys. The cleansing of other metals, such as silver, iron, lead, tin, etc., is unhappily more mechanical than chemical, and this explains why the deposition of the precious metals upon them is generally more difficult and not so firm.

We shall nevertheless examine successively the preparation which metals or their alloys must receive before they are ready for a metallic deposit.

Cleansing Copper and its Alloys.

The mode of cleansing copper, brass, bronze, maillechort, oreide, similor, French gold, Manheim gold, British metal, German silver, and all those alloys where the proportion of copper predominates, is the same, and is divided into six operations:—

1. *Cleansing by fire or by alkalies.*
2. *Dipping.*
3. *Dipping in old aqua fortis.*
4. *Dipping in new aqua fortis and soot.*
5. *Dipping in compound acids for a bright or dead lustre.*
6. *Dipping in nitrate of binoxide of mercury.*[*]

Cleansing by Fire or by Alkalies.

The articles for electroplating are generally soiled by a coat of fatty matters coming from the operations of rolling, drawing, soldering, polishing with oil, etc., or from contact with the hands. The foreign substances, and especially those of organic nature, are

---

[*] Of these six operations, only four are indispensable; the third and sixth may be dispensed with in many cases, which we shall examine further on.

destroyed by heating the pieces in every direction over a gentle fire of charcoal, baker's breeze, or spent tan. A muffle furnace, heated up to a dull red heat, is to be preferred; but small articles may be cleansed in a hot revolving cylinder, like a coffee-burner.

This operation is not adapted to very delicate articles, such as filigree and spangled work, neither to table-forks and spoons, which must keep their sonorousness and toughness, or to those pieces the different parts of which are united by soft solders. In such cases, we boil the articles in alkaline solutions of potassa or soda, which saponify the fatty substances and render them soluble in water.

The operation is performed in a cast-iron kettle where there is a boiling and more or less concentrated solution of carbonate of potassa or soda, or of American potash; but I prefer caustic potassa or soda dissolved in ten times its weight of water. This solution lasts quite a long time, and, when it has lost part of its power, it may be reinvigorated by a few fragments of caustic alkali. At the boiling-point it will cleanse copper in a few seconds. If the articles to be scoured are joined with tin solder, they must not be allowed to remain too long in the caustic liquor, which may dissolve the solder and blacken the copper. The kettle of lye has a cover, so as to prevent the carbonatation of the caustic alkali, or its saturation by the acid vapors of the workshop.

Dipping.

The pieces are then dipped in a mixture of five to twenty parts (in weight) of sulphuric acid at 66° Baumé for one hundred parts of water. Most of the pieces to be cleansed may be dipped while hot in this mixture; but certain alloys, in which tin, or zinc, or antimony predominate, such as those called *potin*, or, very improperly, *cast bronze*, cannot be so treated, since the sudden cooling will occasion cracks and flaws.

Copper articles may remain any length of time in the dipping bath; but it is absolutely necessary that they should not be removed before the black coat of binoxide of copper, caused by the heating, is entirely dissolved. The remaining coat of red protoxide of copper is unacted upon by the sulphuric acid. We should remark that we must not submit to the action of diluted sulphuric acid articles having parts made of iron or zinc, which will be entirely dissolved; therefore, we must avoid the use of implements or wires of iron, zinc, or steel. A dipping bath which, from previous operations, contains copper in solution, will not suit for those articles which may contain iron, tin, tin solder, antimony, bismuth, or lead. In this particular case, we must use a newly made dipping bath with a small proportion of acid.

The articles cleansed by alkalies must be washed before being put into the dipping bath, or pickle, as it is sometimes called. We cannot insist too much on the necessity of thoroughly and rapidly rinsing in fresh water all the articles, before and after each of the following operations.

The various manipulations which we shall presently indicate, and which complete the cleansing, will succeed each other without interruption; and the articles will be stirred as well as possible in the acid baths (pickles) and in the rinsing water.

In order to prove the importance of these operations, I do not hesitate to state, that, even with very inferior electroplating solutions, good results may be arrived at if the cleansing is perfect, while the converse is not so.

After dipping and rinsing, the various pieces are fixed to a brass wire, or simply hooked upon brass or copper hooks represented by Figs. 1 and 2. Small articles of jewelry are simply suspended to a stout copper wire, as seen in Fig. 3.

Fig. 1.

Fig. 2.

Fig. 3.

These hooks had better be made of pure copper than of brass; and, with careful workers, it is still preferable to use glass hooks, which are cheap and not at all corroded by the acids. Every one can make such hooks or supports, by bending glass rods, by the heat of a charcoal fire or of a gas-burner, in the shape of Fig. 4, which is handy for the manipulation in the cleansing or dipping vessels.

Fig. 4.

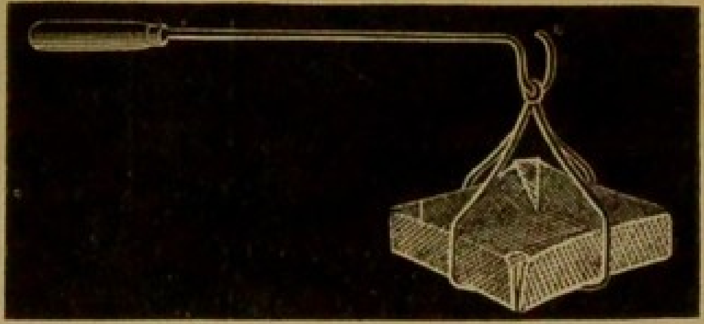
Those objects which cannot be suspended or attached to hooks, are put into perforated ladles of porcelain or stoneware (Figs. 5 and 6), or, what is

Fig. 5.

Fig. 6.

less economical, but sometimes absolutely necessary, into baskets of brass or copper wire cloth (Fig. 7) with the number of meshes to suit.

Fig. 7.



Persons who frequently have to cleanse very small articles, will find it advantageous to employ a basket of platinum wire cloth, which, although expensive in the first cost, will be found cheaper in the end, on account of its almost unalterable nature.

Dipping in old Aqua Fortis.

If we have on hand aqua fortis (nitric acid) already weakened by preceding dippings, we will plunge into it the articles which have passed through the sulphuric acid pickle bath and have been rinsed. They will remain there until the red coat of protoxide of copper has entirely disappeared, leaving after rinsing a uniform metallic lustre.

The dipping in old aqua fortis is not absolutely necessary, although we recommend it, for two reasons, the latter being the more important: First, it economizes the cost of fresh acids; second, as its action is slow, it prevents the too rapid corrosion of the cleansed copper during the time of the solution of the protoxide. If a few operators frequently complain of the burned, pitted, or pricked appearance of their pieces, it is due to the neglect of this operation and the direct dipping in stronger aqua fortis.

I shall indicate further on the processes for utilizing and extracting all that can be saved from old aqua fortis and other dipping baths.

Dipping in Aqua Fortis and Soot.

After rinsing in fresh water, the absolute necessity of which has already been pointed out, the articles, well shaken and drained, are plunged into a bath composed of—

Nitric acid at 36° Baumé (yellow aqua fortis)	100	parts	(volumes).
Chloride of sodium (common salt)	1	"	"
Calcined soot	1	"	"

This mixture attacks the metal with the greatest energy, and the pieces should therefore not remain in it more than a few seconds. The volume of acid should be about thirty times as great as that of the articles to be cleaned, in order to prevent too great an elevation of temperature due to the chemical reaction, and which would result in the rapid weakening of the acid.

After this bath, and rapid rinsing, in order to prevent the production of nitrous vapors, the pieces present a fine red lustre, sometimes gold-yellow or greenish-yellow, according to the alloy employed, and such as to make people believe that they are entirely deprived of foreign matter. It is not so, however; for, if we plunge the pieces in this state into a gilding or silvering bath, they become entirely black and without any metallic lustre.

If, on the other hand, we put aside without rinsing, the pieces removed from the dipping bath, there are produced on their surface a green froth and nitrous vapor, which indicate the decomposition of the acid with which they are contaminated. When the vapors have disappeared, the pieces, even after washing, remain of a dull black, on account of the formation of a basic copper salt which is not soluble in water.

This last mode of operating, called blacking by aqua fortis, is preferred by a few gilders, varnishers, and color fixers, who find it economical to allow the production of nitrous vapors while the pieces are draining on top of the vessel which contains the acids. At all events, any subsequent operation is to be prefaced by a rinsing in fresh water.

When small objects, such as pins, caps, eyelets, pearls, etc., are to be dipped, they are often put into a stoneware pot with a small quantity of aqua fortis, and then rapidly shaken and stirred. In this case, the acid is entirely used up with the production of abundant vapors, and the objects remain blackened and ready for a further cleansing.

In the above bath, soot, by its carbon and hydrogen, deoxidizes a small proportion of nitric acid, and the nitrous gas produced unites with the chlorine of the common salt to form a small quantity of aqua regia necessary to the operation.

I must urge upon the operator to be careful in the choice of the aqua fortis. Three kinds of nitric acid at 36° are to be found in the trade:—

One is perfectly white.

The other is colored straw-yellow.

The last is of a more or less dark-red color.

The white acid, without nitrous gas, does not cleanse well, especially when freshly used.

The red acid, which often contains chlorine, bromine, or iodine, acts too powerfully and pits the copper.

The straw-yellow acid, on the contrary, is a mixture in suitable proportions of nitric and hyponitric acids, and ought to be preferred to the others. Nitric acid at 40° is too energetic and costly; however, certain operators who have to cleanse large quantities of copper-wares, prefer it on account of the rapidity of the operation.

Aqua fortis is spent when its action on copper goods becomes too slow, and when the objects removed from the bath are covered with a kind of bluish-white film. Such acid is then preserved for the preceding operation, that is to say, dipping in old aqua fortis; or for dipping in the whitening bath.*

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* Very good aqua fortis may cleanse imperfectly when the temperature is too low or too high. This accounts for the difficulty in cleansing in frosty weather, or during the great heat of summer

Aqua Fortis for a Bright Lustre.

There is an excellent manner of obtaining a bright lustre for those pieces the surfaces of which have been dulled or slightly pitted by a defective cleansing, or by their passage through the acids for removing gold or silver. It is sufficient to allow them to remain for a few minutes in a bath composed of—

Old aqua fortis, nearly spent.	1 volume.
Hydrochloric acid	6 volumes.
Water	2 “

The pieces, when removed from it, are entirely black, and must be thoroughly rinsed in clear water to remove the kind of black mud which covers them. They are then cleansed and dipped anew.

This bath, which is in constant use by varnishers on metals, and scarcely known by electrogilders, will certainly be found useful by the latter. It is also very convenient for removing the sand adhering to the castings of copper alloys. Large pieces may remain in the bath during twenty or thirty minutes, and even longer, since this mixture acts very slowly on copper and its alloys.

Dipping in Compound Acids for a Bright Lustre.

These acids, which were rightly considered as indispensables by the first gilders by dipping, are of two kinds according to the object in view.

If the pieces must have a bright lustre, they are stirred for one or two seconds in a liquid (prepared the day previous, and cold) made of—

Nitric acid at 36° (yellow aqua fortis)	100 volumes.
Sulphuric acid at 66° (oil of vitriol)	100 “
Common salt (chloride of sodium)	1 volume.

It is absolutely necessary to rinse immediately and rapidly, in plenty of water, the pieces which have been dipped in these acids.

In preparing this bath, nitric acid is first put into the intended vessel, and then sulphuric acid, which is much denser and would not mix readily if it were put in first.

At the time of the mixing, and especially when the common salt is added, considerable heat is produced, with evolution of such a quantity of acid and deleterious fumes, that it is prudent to operate in the open air or under a good chimney-hood with a movable glass sash. As these acids must be employed cold, it is therefore necessary to prepare them in advance.

When in a hurry, these compound acids may be employed the same day that they have been prepared, provided the vessel is cooled off in ice or in cold water.

Copper articles, after this dipping, are lighter colored and much brighter than after the passage through aqua fortis. They may then be considered as completely cleansed.

The above acids are too energetic for small articles, such as pins, hooks, pearls, etc., which are generally cleansed in stoneware colanders, the holes of which are more or less obstructed and do not allow of the rapid draining of the acid, so that the articles become heated, and blacken before they are rinsed. In order to obviate this inconvenience, the above compound acids are diluted with one-eighth of their volume of water, and are sometimes called "bitter waters for a bright lustre."

Instead of dipping the objects in the whole of these bitter waters, they are put into a stoneware pot and rapidly stirred with a small quantity of "bitters," and then the whole plunged into a quantity of fresh water as soon as the acid has sufficiently acted. This method is not economical, since the acid is lost; but the advantage is that the dipping liquors do not become heated.

Whitening Bath.

Varnishers, and even most of the gold and silver platers, instead of frequently preparing new baths of compound acids for a bright lustre, use a mixture in indefinite proportions of—

Old aqua fortis,
Sulphuric acid,
Common salt,
And uncalcined soot, which is called "whitening bath, or white bath."

In a large stoneware vessel, a certain quantity of old aqua fortis from previous dippings is poured, and then is added twice the volume of sulphuric acid at 66°. The mixture becomes heated and is allowed to cool off until the next day. The nitrate of copper of the old aqua fortis has become converted into sulphate of copper, which is much less soluble, and which by cooling crystallizes against the sides of the vessel. The liquid portion is decanted into another vessel, and then about two or three per cent. (in volume) of common salt, and as much of calcined soot, are added. This mixture is much less energetic than the compound acids for a bright lustre, and often replaces them advantageously. The crystallized sulphate of copper is set apart, and sold.

This whitening bath is now and then strengthened, according to the need of the operator, by the addition of stronger aqua fortis and oil of vitriol. To replace the portion used up during the day, equal volumes of old aqua fortis and oil of vitriol are added at the end of the day. The next morning the liquors are decanted, and a new crop of sulphate of copper is gathered. Soot and common salt in sufficient proportions are also added. In this manner, a perpetual and cheap whitening bath is prepared.

A few operators heat this bath, and substitute hydrochloric acid for common salt.

Compound Acids for a Dead Lustre.

If, instead of a bright appearance, it is desired to impart to the objects a dead lustre, they are, after dipping in aqua fortis and rinsing, plunged into a bath prepared the day previous and composed of—

Nitric acid at 36° (yellow aqua fortis) . .	200 volumes.
Sulphuric acid at 66° (oil of vitriol) . . .	100 "
Common salt (chloride of sodium) . . .	1 volume.
Sulphate of zinc (white copperas) . . .	1 to 5 volumes.

We remark that in this mixture the proportion in volume of nitric acid is double that of sulphuric acid.

The copper articles may remain from five to twenty minutes in the cold bath, and the dead lustre will be the more apparent as the immersion has been more protracted.

From this bath, and after a long and thorough rinsing, the objects have an earthy appearance which is unpleasant to look at. This dulness is removed by a rapid passage of the pieces through the compound acids for a bright lustre and by an immediate rinsing. If they remain too long in the latter acids, the dead lustre will disappear, and the operation is to be begun anew.

If there be not at hand a bath for the bright lustre, the objects, after rinsing, may be rapidly passed through the same bath for dead lustre, which will remove the dulness of the lustre caused by a long immersion in the acid.

The compound acids for a bright lustre may, after a long use, be employed in a certain measure for a dead lustre bath. The mode of operation remains the same.

A few varnishers, especially those who cleanse the large embossings for furniture, or for clocks *Comté* fashion, employ a hot-bath for dead lustre, prepared as follows:—

Old aqua fortis	4 to 5 volumes.
Sulphuric acid	1 volume.
Sulphate of zinc	8 to 10 per cent.

The last substance being gradually added when needed for increasing the deadness of the lustre.

The lustre, thus obtained, appears dull, ochreous and yellowish; but after a thorough rinsing, a passage through the same bath for one or two seconds, and a last rinsing, it becomes clear enough.

The proportions which we have indicated for this bath are not immutable. They may be made to vary with the fancy and the habits of the operator, and also with the degree of energy of the old aqua fortis employed.

Dipping in Nitrate of Binoxide of Mercury.

In order to facilitate the adherence of the deposit with the subjacent metal, electroplaters have borrowed from the gilders by fire an operation which will be found important in practice.

This operation consists in plunging the cleansed ware, for one or two seconds, into the following solution:—

Water	10 kilogrammes or litres.
Nitrate of binoxide of mercury .	10 grammes.
Nitric acid or, preferably, sulphuric acid	20 "

When we pour nitrate of binoxide of mercury into water, there is formed a thick cloud of a yellowish-white color, which subsequently disappears by the action of the acid used. It is well to stir the mixture before using it.

Several authors recommend the nitrate of protoxide of mercury; but I have found in practice that it is inferior to that of binoxide.*

The proportion of mercury salt above indicated will be modified with the size of the pieces and the nature of the alloy. For instance, less mercury will be needed for light pieces of jewelry which need a very thin deposit. On the other hand, more mercury is advisable for heavy objects, such as spoons, forks, and table ornaments, which should receive a thick deposit of gold or silver. The latter must come from the mercurial solution with a perfectly white and bright appearance, looking like silver, while the color of the former is scarcely changed.

We may lay down as a principle that the solution of nitrate of binoxide of mercury is the touchstone of the cleansing operations. With a perfect cleansing, the piece will, after passing through a quite strong mercurial solution, be perfectly white and bright. On the contrary, there will be a damascene

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* Theory agrees with experience, since the exchange of bases takes place between oxides of the same degree HgO and CuO.

appearance, or various shades of color, if the cleansing has not been properly done.

When the amalgamating bath becomes spent by use, it may be reinvigorated by the addition of a few drops of nitrate of mercury; but it is more prudent to prepare a fresh one.

I cannot insist enough on the necessity, especially when gilding or silvering by dipping, of allowing no intervals between the various operations of cleansing, which, excepting the time necessary for cleansing by fire or by alkalies, ought to take place in less time than is needed to read the following *résumé*:—

1. Cleansing by fire or by alkalies.
2. Dipping and rinsing in water.
3. Dipping in old aqua fortis and rinsing.
4. Dipping in aqua fortis and soot, rinsing.
5. Dipping in compound acids for a bright lustre, or in the whitening bath, and rinsing.
6. Dipping in nitrate of binoxide of mercury, and rinsing.

And, lastly, plunging the articles into the electroplating bath.

This mode of operation, before any metal is deposited by the wet way, is equally good for copper, and all the alloys rich in this metal. However, maillechort, on account of the nickel it contains, will sometimes be a little difficult to manage, and may require freshly prepared dipping baths. But in this, as in many other cases, the operator will quickly learn by practice all the slight modifications which may be needed. As a rule, copper and its alloys must not be mechanically cleansed. But, if notwithstanding the proper care maillechort does not cleanse well, it is then cleaned with alkalies, carefully brushed with pumice-stone dust and a hard brush, then passed through quite a strong solution of binoxide of mercury, and lastly dried with a clean rag before it is put into the bath.

The dipping baths are ordinarily held in vessels of glass, stoneware, porcelain, or of any other ceramic compound which resists the corrosion of acids. Common earthenware and that with a lead varnish must be rigorously excluded. The best stoneware we use comes from Brittany; it is dark red, and entirely unacted upon by the acids. Next come the stonewares from Picardy, Nevers, and Alsace. The dipping pots must be rather high than wide, and be furnished with a cover, in order to prevent evaporation. Those with ground edges may be covered with a pane of glass. Wide and flaring earthen pans are very good for rinsing.

Electroplaters and varnishers ought to be provided with a considerable number of dipping pots of various sizes and shapes, in order to accommodate the work in hand, and not to be obliged to clean the same piece in two operations for the need of a suitable vessel.

A large hood, communicating with a chimney, and closed with a sliding glass sash, will contain the following apparatus for a complete cleansing operation:—

A furnace for cleansing by fire.
A pot for first dipping.
A pot for old aqua fortis.
A pot for aqua fortis and soot.
A pot for compound acids for dead lustre.
A pot for compound acids for bright lustre.
A pot for solution of nitrate of mercury.
A pot for acids to dissolve gold from old pieces.

A pot for acids to dissolve silver from old pieces.

Two large pans for rinsing with a constant flow of water.

Some electrogilders, who pay great attention to the rinsing process, dispose a series of three or four wide stoneware pans in such a manner that the contents of each flows into the next and lower one. The rinsing is begun in the lowest pan and finished in the highest, which receives its water from a stopcock.

If the draft of the chimney is not sufficient, a small fire may be kindled under the hood. A gas-burner is often sufficient.

It may be preferable to place the pot of nitrate of mercury, with two rinsing pans, near the electroplating bath.

CHAPTER III.

CLEANSING SILVER.

For cleansing the metals mentioned further on, science or practice does not furnish us as perfect methods as we possess for cleansing copper and its alloys. We shall be obliged to have recourse to mechanical agents which will not, like acids, act simultaneously on every part of the object, and therefore, we cannot entirely prevent the action of the air, steam, gases, and acid fumes. We shall, however, indicate the best processes for arriving at the most satisfactory results, within our power.

Cleansing Silver.

In order to prepare this metal for receiving a deposit of any other metal, it must be freed from any impurity. We begin by heating the object at a dull red heat upon a slow fire. If the silver is pure, which very seldom happens, it becomes covered with a thin bluish film resulting from the decomposition of animal or vegetable substances. If, on the other hand, and as is nearly always the case, the silver is alloyed with a variable proportion of copper, the latter becomes oxidized and covers the piece with a grayish-black coating. While the piece is still hot, it is plunged into a boiling pickle of water and sulphuric acid, which transforms the oxide into sulphate and dissolves it.

If the heat has been sufficiently protracted for oxidizing all the copper on the surface, the object, when removed from the pickle, is of a perfectly dead white. It is grayish, on the contrary, if the heating has been too short, and the operation must be repeated as many times as needed for a perfect lustre. This is especially necessary with silver alloys of a low degree of fineness.

A few gilders, instead of heating silver over a naked fire, place it in sheet-iron boxes filled with a mixture of powdered borax, lime, and charcoal dust. In this case the borax dissolves the oxide of copper as soon as formed; as for the chalk and charcoal dust, I do not understand their utility, unless they are intended to prevent the formation of a small quantity of oxide of silver, which would also have been dissolved in the pickle. It is possible that these substances aid in conveying the heat all over the piece. We derive this method from the gold and silver-smiths, who employ it for whitening and giving a dead lustre to their silverware.

If the objects to be cleansed are hollow, as certain medals formed of two shells soldered on their edges, it is absolutely necessary, before heating, to make a small hole which will allow of the escape of the air expanded by the fire. Without this precaution, the piece will certainly burst open, and possibly result in injury to the operator.

This aperture, necessary in one way, presents the inconvenience that when the piece is put into the pickle, the acid liquor takes the place of the air between the shells and is difficult to remove. In order to prevent the spotting of the piece by this liquor, it is dipped for a few minutes into a very dilute solution of ammonia or of soda crystals, which neutralizes the acid and prevents its action upon the silver. It is then sufficient to place the article between layers of dry and warm saw-dust (fir wood), which will absorb the saline solution.

A few persons use nitric instead of sulphuric acid for the pickle bath. In this case, the water must be distilled, and the acid free from chlorine or hydrochloric acid, otherwise the silverware will be covered with a bluish-white film of chloride of silver.

This method of cleansing silver will not suit those articles in which iron, zinc, etc., may be present. We must, in this case, employ alkalies, and polish afterwards with very fine sand or pumice-dust, with the aid of a stiff and short brush or with a scratch-brush alone.

Silver, perfectly cleansed by the above operations of heating and pickling, may directly receive a metallic deposit which will have the same dead lustre as the object itself. We may profit of this condition for producing agreeable contrasts between the different parts of the surface, since certain parts may be burnished with the burnishing tool. It is, however, customary, before introducing the articles into the electroplating bath, to scratch-brush them.

CHAPTER IV.

SCRATCH-BRUSHING—VARIOUS KINDS OF SCRATCH-BRUSHES—LATHE FOR SCRATCH-BRUSHES.

Scratch-Brushing.

This operation, very frequent in our art, since it often precedes, and nearly always follows, our manipulations, requires a special description.

Scratch-brushing consists in removing the dead lustre on an object, or cleansing its surface, by the frequently repeated friction of the points of many stiff and straight metallic wires.

The instrument used is called a scratch-brush or wire-brush, and its shape varies with the articles to be operated upon.

A hand scratch-brush is composed of numerous wires, stiff and straight, taken from a bundle, or coil of large diameter, so that the wires have less tendency to curve.*

For making a good hand scratch-brush, we choose a bundle or coil of brass wire of the proper degree of

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* For highly delicate objects, scratch-brushes are made of spun glass, the fibres of which are very thin and elastic.

fineness (Fig. 8), and we wrap tightly around it a good string for about two-thirds of the intended length of the instrument, usually 20 centimetres (about 8 inches). Then, with a cold chisel, we cut the bundle of wire close to the string at one end, and at 5 centimetres (about 2 inches) from the other end of the string wrapping. The end close to the string is dipped into a neutral solution of chloride of zinc, and plunged into melted tin, which solders all the wires, and prevents their separation and injury to the hand of the operator.

Fig. 8.

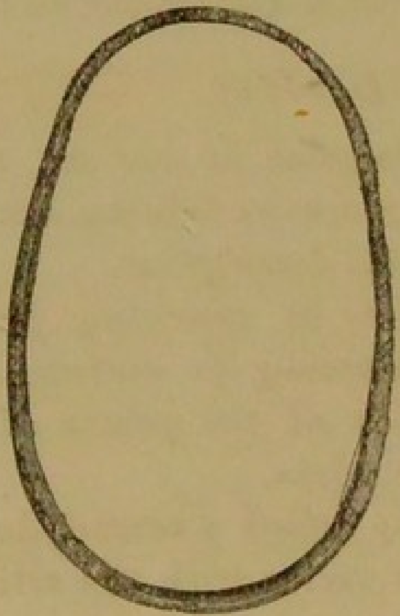


Fig. 9.

The tool thus made may be used as it is, but it is preferable to fix it, by means of another string, to a thin wooden handle which projects above the soldered end. (Fig. 9.)

Scratch-brushes are also made by cutting a coil of wire for a length of 30 to 40 centimetres (about 12 to 16 inches), binding it in the middle, and doubling it so as to unite the two ends. This process is less economical, and the wires have a tendency to become entangled.

Very small scratch-brushes are necessary for reaching small holes and corners.

An old scratch-brush, the wires of which have been bent in every direction, and fixed to a long handle, is useful for rubbing the insides of certain pieces, such as an Etruscan vase, a coffee-pot, etc.

The varnishers on metals use, for rapid work, a kind of brush (Figs. 10 and 11) with long and stiff brass wires. Such brushes will only suit large clock works, chimneys, fenders, etc.

Fig. 10.

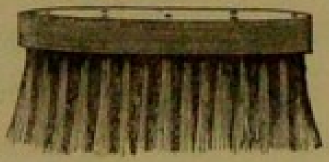


Fig. 11.

Scratch-brushing is scarcely ever done dry; the tool, as well as the pieces, must be constantly wet with a solution, which has sometimes a chemical effect, but most generally acts as a lubricant, which, at the same time, carries away the impurities.

The scratch-brush is the touchstone of the metallic deposits: when good they are only polished by the friction; bad ones scale off from the defective adhesion.

A good adjunct for scratch-brushing is a shallow wooden tub for the solution employed, with a board placed diametrally, nearly level with the edges, which, however, project a little above. This board serves as a rest for the pieces. The tub is raised by a support to about the height of the stomach of the operator sitting near by.

The liquid employed is water and vinegar, or sour wine, or solutions of cream of tartar or alum when we desire to brighten a gold deposit which is too dark. But, most generally, we use a decoction of liquorice root, horse-chestnut, marshmallow, Egyptian saponaire, or of the bark of Panama wood, all of which, being slightly mucilaginous, allow of a gentle rubbing with the scratch-brush, with the production of an abundant scum.

The resting board must not plunge into the liquid; the scratch-brush and the article are alone frequently wetted.

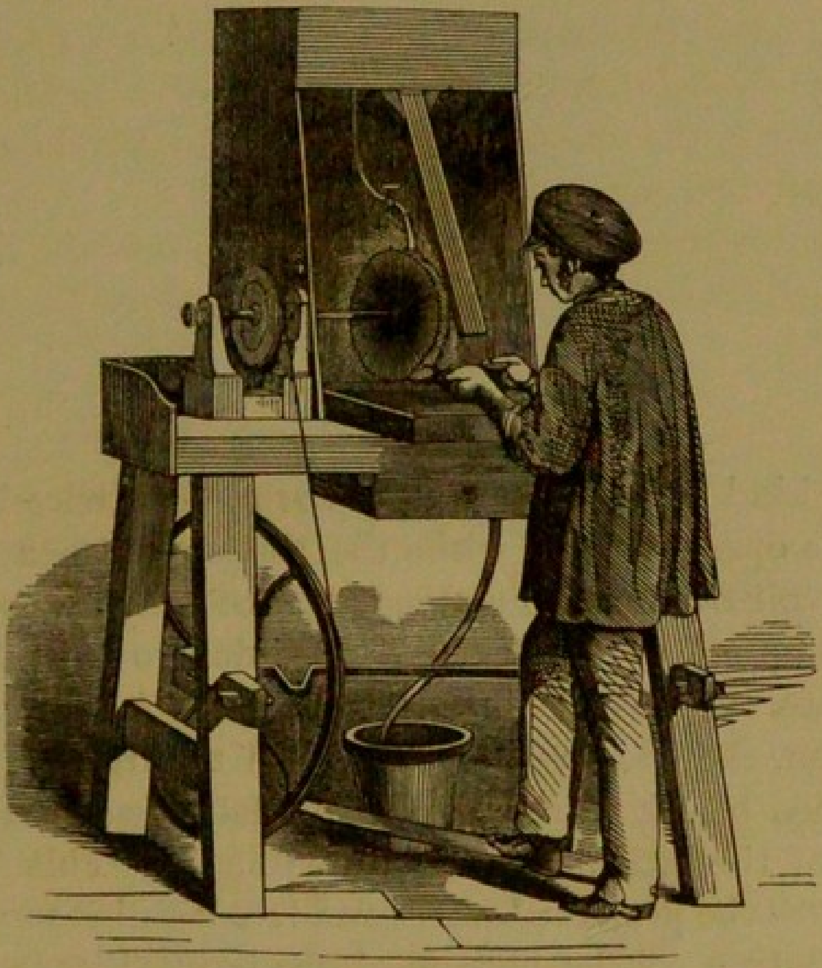
Every five or six days the old liquid is removed by careful decantation, so as not to carry away the deposits at the bottom, which always contain a certain proportion of the precious metals, and which are collected to be treated afterwards, as we shall explain further on.

With small objects and articles of jewelry, the operator holds the scratch-brush as a writing pen, and the motion back and forward is imparted by the wrist only, the forearm resting on the edge of the tub.

For larger articles of bronze, on the contrary, the operator holds his extended fingers close to the forepart of the scratch-brush, so as to maintain the wires, and, with raised elbow, strikes the piece repeatedly with a sliding motion at the same time. When a hollow is met which cannot be rubbed longitudinally, a twisting motion is imparted to the tool. These various motions are better understood when seen than when described.

This mode of hand scratch-brushing is long and tedious; besides, it is open to the inconvenience, on account of the irregular motion of the arm, of leaving on soft metals cross marks of a disagreeable appearance.

Fig. 12.

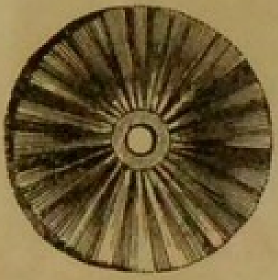


Circular wire-brushes, fixed on the spindle of a lathe, and the wires of which move all in the same direction, have been constructed for certain pieces of silversmith work, forks, and spoons, etc.

Lathe for Scratch-Brush.

The lathe for scratch-brushing (Fig. 12) is an ordinary lathe, upon the spindle of which is fixed, by mandrel or chuck, a circular brush of brass wires radiating from a wooden or metallic centre. The wires are from 6 to 7 centimetres long. (Fig. 13.) This brush receives its motion from the foot or from power, and revolves its top towards the operator, while the object to be scratch-brushed is present at the lower part.

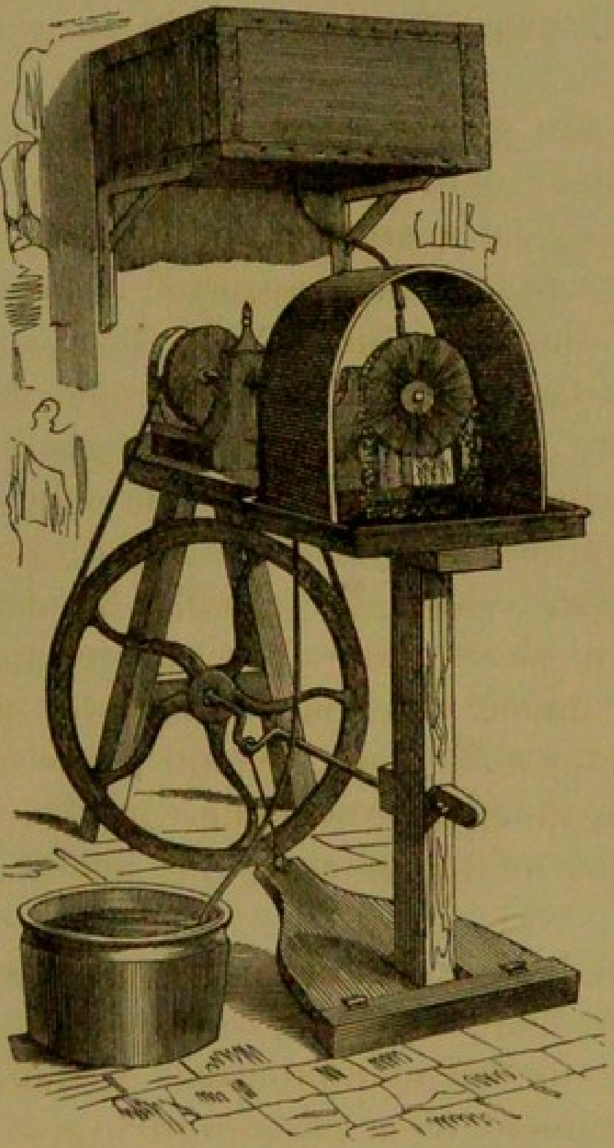
Fig. 13.



A kind of wooden frame covers the wire-brush, and is open in front, while the top supports a small reservoir from which a slender jet of water runs upon the summit of the brush. In order to protect the operator against the water projected by the rapid motion, there is fixed on the top of the frame a small inclined board, which reaches a little lower than the axis of the brush, without touching it. This board receives the projected water and lets it fall into a zinc pan resting on the bottom of the box. By means of a hole in a corner, and an India-rubber hose, all of the water runs into another vessel on the floor. Fig. 14 represents a lathe of another shape, which is well adapted for pieces of small dimensions, and without danger to the operator of getting wet.

The brass wire used for the manufacture of hand or circular scratch-brushes has a strength variable with its uses. Thick wires for bronzes are employed, from No. 12 to 24, and thinner wires down to No. 32 (French numbers) for lighter articles. Very delicate pieces, like watch-work, require much finer wire, and we shall return to this subject when speaking of the gilding of watch parts.

Fig. 14.



When a hand scratch-brush becomes too short, the twisted ends are cut with a cold chisel, and a new portion of wire is uncovered by removing part of the string wrapping. The best way to remove the twisted wire ends is by resting the scratch-brush upon a lead block, and cutting them with a sharp cold chisel, with one stroke of a hammer if possible.

We must be very careful of our scratch-brushes, and preserve the wires stiff and straight. When they begin to curl, they are now and then beaten with a mallet of boxwood, upon a small block kept between the knees, so as not to produce a dead stroke.

Scratch-brushes kept too long in water become hard.

If they are greasy, they are cleansed in caustic potassa; their oxide is removed by the compound acids. This last operation, and even the dipping in aqua fortis, are sometimes resorted to for diminishing the size of the wires, and making them smoother.

The circular brush is now and then turned over, that is to say, the left becomes the right hand face, in order to change the direction of the wires.

A few practical men have tried, by means of suitable gear, to keep the circular brush constantly immersed in the liquid. But the resistance offered requires so much more power that the method has been abandoned. There would have been more cleanliness, and a more complete protection against the oxidation of the wires by the acid fumes of the workshop.

Scratch-brushing is an important operation, the more so that many articles are delivered to the trade without any further manipulation. I would therefore advise beginners to be thoroughly practised in it before they undertake costly works.

Note.—Another apparatus employed for scratch-brushing and polishing consists of a quantity of disks of calico pressed together by side washers and nuts, and mounted upon a mandrel or arbor revolving with great velocity. These calico brushes are flexible, and follow the irregularities of shape of certain articles. They receive now and then a small quantity of rouge and water, or pumice-stone, or any other suitable polishing or abrading material.—*Trans.*

CHAPTER V.

BRIGHT LUSTRE BY MUTUAL FRICTION OF SMALL OBJECTS.

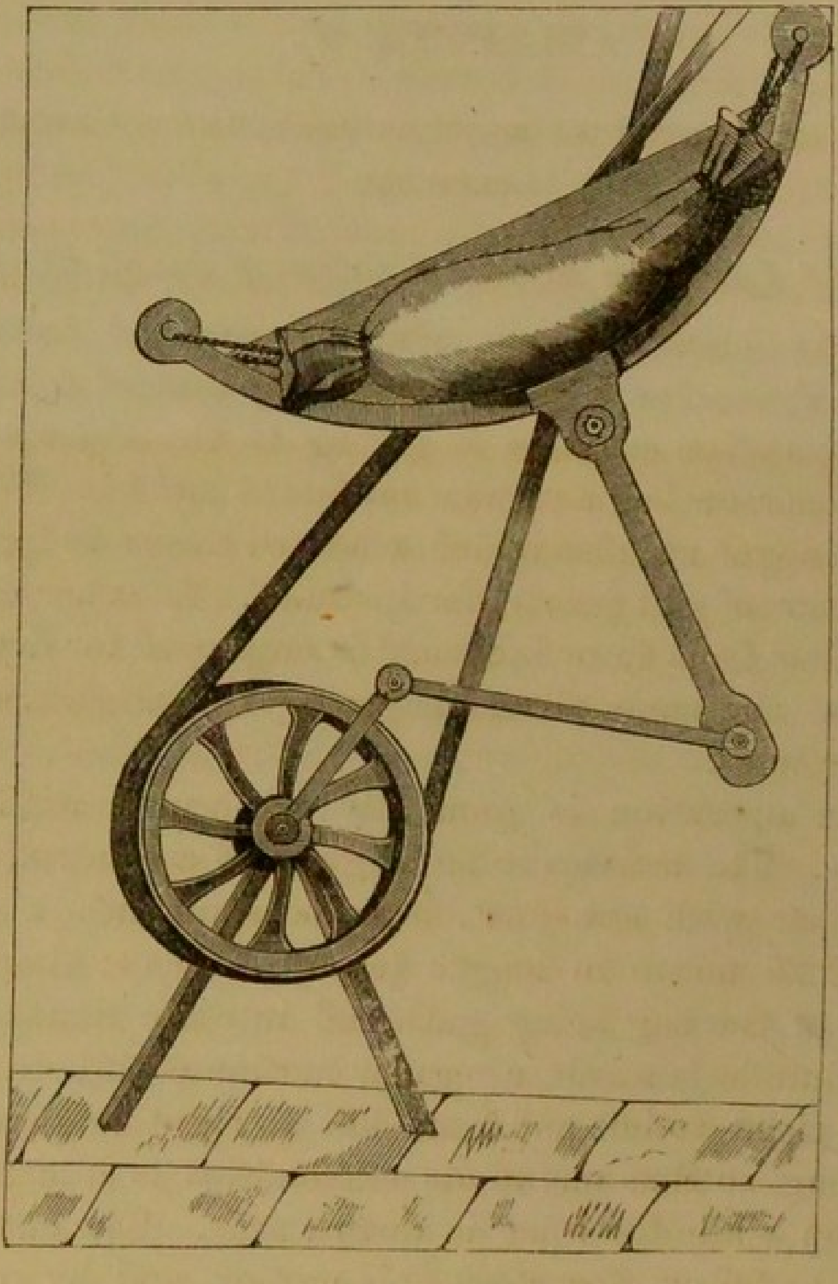
Bright Lustre by Mutual Friction of Small Objects.

VERY small objects, which cannot be scratch-brushed, receive a bright lustre by mutual friction. The operation consists in giving to the objects put into a narrow bag a regular motion to and fro. Water and vinegar are also added, when we desire to lighten the color of gilt pearls, for instance. In other cases, saw-dust from fir or boxwood is employed for drying, and, at the same time, increasing the brightness of the articles.

The operation is generally performed with the hands. The articles to be brightened are introduced, together with saw-dust, bran, or sand, into a cloth bag 1.25 metre in length (about 4 feet); then, the ends of the bag being gathered into the hands with the thumbs inwards, a regular motion with both arms from right to left and from left to right is given to the bag, so that one of its extremities is alternately on top while the other is downwards. The enclosed articles follow, therefore, this motion, and by rolling over each other become gradually polished.

Sometimes two men are employed, each one holding one of the ends of the bag. Another mode of operation consists in attaching one end of the bag to a hook fixed on the wall at about 1.25 metre (about 4 feet) from the floor, while the other end is alternately raised and lowered by hand.

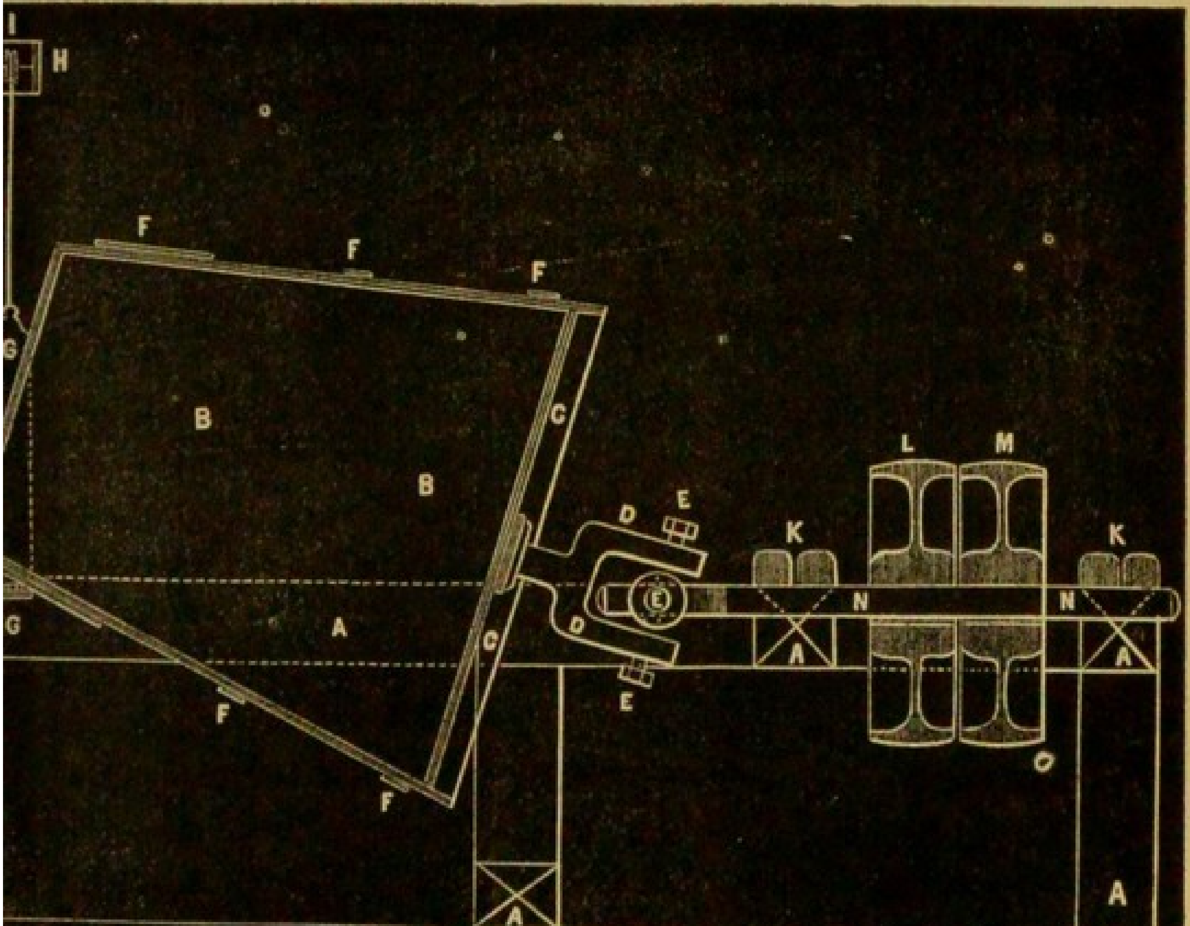
Fig. 15.



As this manual operation is very fatiguing, several machines have been devised for working by power. Among the more ingenious ones, I will indicate that of MM. Parent and Hamet, button manufacturers. As represented by Fig. 15, it resembles a big Y. The bag is attached to the two branches, and the to and fro motion is imparted by an excentric.

MM. Blanzy, Poure & Co., manufacturers of metallic pens at Boulogne-sur-mer, and licensed for the use of my patent for tinning, polish their products in square boxes with covers. These boxes rest by means of their axles upon a movable frame, the centre of rotation of which is near the floor, while the upper part receives the to and fro motion from an excentric gear. The boxes may be turned upside down when desired.

Fig. 16.



MM. Tailfer & Co., manufacturers of pins at Aigle, and also licensed for the use of my patent on tinning, employ a conical tub open at the small end, and inclined as seen in Fig. 16. The bottom receives from an excentric a peculiar motion by which it describes a circle of a certain radius, while the small end rotates with scarcely any deviation of its axis. This apparatus has the advantage of holding a large quantity of the substance, and of allowing us to see the progress of the operation by the open end. When the articles are sufficiently rubbed, the tub is made to swipe and empty itself downwards.

A A A A, Wooden frame of the apparatus (Fig. 16).

B, Tub, with iron hoops, F F F.

N N, Revolving shaft, upon which are fixed the fast and loose pulleys, L M.

D D, E E, Excentric universal gear.

G G, Stirrup, raised or lowered by the pulley H, and upon which the small, open end of the tub rests and revolves.

When the operation is to be effected in water, we often use a small tub suspended by two cords to a beam of the ceiling, and to which the operator imparts a to and fro motion by which the articles are made to roll one over the other.

Another polishing apparatus consists of a tumbler, that is, a cylindrical or polygonal drum, which is made to rotate by hand or power. In order to prevent certain objects, like hooks for ladies dresses, from catching each other and forming a kind of ball, numerous nails or wooden pegs are fixed in the interior of the drum.

CHAPTER VI.

GOLD COLORED VARNISH.

Gold Colored Varnish.

ALTHOUGH this work is especially intended for the art of depositing metals, our readers, we believe, will not object to a description of those processes by which are obtained the magnificent varnishes which imitate so completely the appearance, freshness, and rich tones of real gilding. In general, varnish is applied only upon copper and its yellow alloys.

Gold varnishers operate as follows: After the pieces have been perfectly cleansed, scratch-brushed and burnished if necessary, they are dried in the hot sawdust of fir wood, and wiped clean with a fine cloth. A light coat of varnish is then applied with a fitch pencil, and all excess of varnish removed or levelled with another flat brush of badger hair or bristles. The two brushes are kept together in the same hand, the one for varnish between the thumb, fore, and third finger, while the flat one (without a handle) is held between the other fingers and the palm of the hand. In this manner there is no interval in the use of the two brushes. The varnish is kept in a jelly pot or any other similar vessel, on the top of which a string has been stretched diametrically. This string is intended for removing, by pressure against it, the excess of varnish taken up by the brush or pencil. The varnish which covers the burnished parts of the piece may be removed with a clean rag wetted in alcohol and wrapped around the finger. Another dry cloth finishes the drying. Sometimes the burnished parts are also varnished, and the operation is difficult when their surface is considerable. Round wares, polished or burnished, may be varnished on a lathe.

After the varnish has been applied as equally as possible, the wares are put into a drying stove heated from 60° to 80° C., or supported upon wires on top of a small furnace heated with slow burning charcoal dust. The alcohol or essential oils of the varnish are rapidly volatilized, while the resins or gums melt and cover the objects with a glassy lustre. The heat must be sufficient to melt these gums, but low enough to avoid burning them. When the operation has been well performed, the pieces present a regular and fine golden appearance without red places, which latter indicate an unequal thickness of varnish.

Varnishers always use four varnishes of different shades,— *red gold, orange yellow gold, green gold, and colorless varnish for mixtures.* This last is employed for diluting the first three and diminishing the depth of their colors. These various varnishes give each to copper its proper color, and, when mixed, intermediary shades. It often happens that the various parts of a large piece are different in composition and color, and the varnisher is obliged to impart the same shade of gold all over, by skilful combinations of varnishes. He thus succeeds in giving the same gold color to half-red copper, and to alloys of yellow and green brass.

But a small quantity of varnish is poured into the varnish pot at one time, in order to prevent it from thickening by evaporation, and, after the operation, the residue is poured back into a well-closed vessel. The brushes and pencils must be often washed in alcohol, which may afterwards be used for diluting thick varnishes.

These varnishes are a solution in a mixture of alcohol with essence of lavender or of spikenard, of various resinous substances like sandarach, benzoin, dragon's blood, elemi, gamboge, etc., and of tinctorial matters such as turmeric, annotto, alkanet, etc. All qualities of varnishes are to be found, but the more expensive are often the more economical.

When we desire to take off the varnish from an imperfectly varnished piece, or from an old one, we may employ alcohol or concentrated sulphuric acid, or, better still, a boiling solution of caustic lye. The varnishing is then begun anew.

CHAPTER VII.

CLEANSING ZINC—LEAD—TIN—CAST IRON—WROUGHT IRON—STEEL—ETC.

Cleansing Zinc.

Zinc, next to copper and silver, is the most generally employed metal in the electroplating art. This substance, which ancient chemists had ranged among half-metals, *i.e.* those the brittleness of which is an impediment, has for some years past been so much modified in its preparation that, at the present day, there are few metals applied to more various uses than zinc. It is drawn out into quite tenacious medium sized wires which take the place of lead and brass wires for bindings, and of cords for clothes-lines; other wires are made so thin that it is possible to sew and embroider with them; it is laminated into sheets whose properties of resistance and lightness render them often preferable to other sheets of lead, iron, or copper; it is cast into all kinds of shapes and patterns, and the castings are sufficiently sharp and economical to allow us to obtain from them a great number of ornamental pieces such as were formerly made of copper, bronze, or brass. The clocks, cups, candelabras, chandeliers, statues, and ornaments of all kinds cheaply obtained with this metal have vulgarized useful artistic objects. It is sufficiently strong and sonorous for such uses, but its appearance is not prepossessing, and we cannot do better than to study the processes by which its surface is modified and rendered similar to that of more precious metals.

Zinc ornaments are often covered with a deposit of gold or silver; but, more generally, they receive a coat of pure copper or of brass which, after several chemical manipulations to be described further on, presents the various shades of bronze known as *vert antique*, *florentine*, *medal*, *artistic*, etc.

But before any of these operations are commenced, the zinc must have removed from its surface any foreign matter which may be there.

Zinc is cleansed as follows: It is passed through a boiling solution of caustic lye, without remaining too long in it, because it may be corroded, and even dissolved; after rinsing, it is plunged for a few minutes into water containing from one-tenth to one-twentieth of sulphuric acid, then rinsed in plenty of water (warm if possible), and, when necessary, brushed all over with a stiff brush and pumice-stone dust, or it is scratch-brushed. This last operation is especially useful when parts have been united with tin solder, which becomes black and dull by the alkaline and acid baths.

These processes never gave me perfectly satisfactory results, and I found out that the cleansing was much more thorough when the object was rapidly dipped into a cold mixture of—

Sulphuric acid	100 volumes.
Nitric acid	100 "
Common salt	1 per. cent.

and then still more rapidly rinsed in cold water perfectly free from copper salt which will blacken the zinc.

If, instead of quickly cleansing the zinc, we allow it to remain a little longer in the above mixture of acids, it acquires a fine dead lustre which, in some cases, may be utilized for producing agreeable contrasts between the various parts of the same ornament. The dead lustre will become a bright one, if we rapidly plunge the object in several times, and rinse it as often, in the same compound acids.

It happens quite often that the lines of tin or lead solder are black after being dipped into the acid bath; it is then sufficient to scratch-brush before placing the object in the electroplating solution.

Zinc may be slightly amalgamated with the solution of nitrate of binoxide of mercury, already indicated for copper, and which increases the adherence of the electro deposits.

It is often necessary, from some defect in cleansing, or in the electroplating operation, which impairs the adherence of the deposits, to do the work over again.

In such case it is prudent to remove the copper entirely, by plunging the object into aqua fortis and soot, until it appears entirely black. Another dipping into the compound acids will render it perfectly clean and white, and ready to receive a new deposit. But, if the defective deposit be thick, it becomes nearly impossible to save the piece, because the zinc becomes rapidly corroded at those places which are uncovered by the copper.

Cleansing Lead, Tin, &c.

Tin, lead, the alloy of these metals called solder, Algiers metal, Boulogne silver, Britannia metal, etc., are much more difficult to cleanse than zinc. We do not know any other process but a rapid scouring with potash lye and a rubbing with a hard substance. The objects are sometimes plunged into diluted hydrochloric acid; but the first operation is nearly always necessary. Notwithstanding the greatest care, the direct deposit of the precious metals is difficult and does not adhere well. The results are much better, if we interpose a coat of pure copper or brass, between the low metal and the gold or silver, when they adhere to each other perfectly well. Batteries and a hot electroplating bath are used for small objects, and cold baths for larger ones.

Cleansing Cast Iron.

Cast iron is cleansed by remaining immersed for two or three hours in water containing one-hundredth part of sulphuric acid. After this bath, the metal is rinsed in cold water, and scoured with sharp sand and a brush of dog's grass or a coarse rag, then put again in the acid pickle, rinsed, and plunged into the electro-bath. If more than one per cent. of sulphuric acid be added to the water, the length of the immersion must be shortened, otherwise the cast iron will be deeply corroded, and the carbon of the metal which is insoluble in the pickle will, with great difficulty, be removed by the friction of the sand. In fact, cast iron injured by too long an immersion, or by a too strong pickle, does not give good results in the subsequent operations of our art.

Cast iron does not become well gilt, and especially silvered, by a direct deposit of the precious metals. Copper or brass deposits are better, although far from perfect; but if cast iron be tinned by my process described further on, the coat is perfectly adherent, and will receive afterwards copper, brass, gold, or silver, if desired.

Some operators, when cleansing cast iron, prefer hydrochloric acid (muriatic acid) instead of sulphuric acid. In this case, five per cent. of acid is necessary, and the operation is more expensive and not so regular. I have ascertained that in our works, where several tons of cast iron are daily cleansed preparatory to tinning, one per cent. of sulphuric acid in water makes a pickle which will last a week, and that by then adding one per cent. of fresh acid to the old pickle it becomes as strong as before. Indeed, I prefer an acid bath already charged with sulphate of iron, because the cast iron is more uniformly corroded. Such is not the case with hydrochloric acid, a part of which is volatilized with the hydrogen gas produced.

If it be desired to keep for some time, before electroplating it, cast iron already cleansed, it is necessary to preserve it in a liquor rendered alkaline by caustic lime, potassa, or soda, or their carbonates; but caustic lime-water is the cheapest and most easy method, and cast iron which has remained in it for a few hours will not rust after quite a long exposure to a damp atmosphere.

Cleansing Wrought Iron.

The cleansing of wrought iron is effected in the same manner as cast iron, but may bear a stronger pickle and a longer immersion. We refer in this place to ordinary wrought iron covered with a film of black magnetic scale or of red rust. Whitened, filed, or polished irons must be treated like steel.

Cleansing Steel.

Polished articles of steel or iron must be first cleansed in a boiling solution of caustic lye (potassa or soda), and rubbed with pumice-stone dust, which scratches the polish slightly and thus produces a better hold for the metals deposited afterwards. They are then rapidly passed through a bath composed of—

Water	1000 grammes (1 litre)
Hydrochloric acid . . .	300 "
or Sulphuric acid	100 "

rinsed in cold water and plunged into the electro-plating solution. We must particularly avoid substituting nitric acid (aqua fortis) for the whole or a part of the hydrochloric or sulphuric acid of the above acid bath.

Iron and steel may be well gilt, without an intermediary coat, in hot gilding baths to be indicated further on. Silvering, on the other hand, is always imperfect and without adherence, notwithstanding the precautions and receipts recommended in certain books. I shall not describe them, because most of them are wrong, and because the success with the others is so problematical that they are not adapted to the arts.

On account of the difficulty of obtaining the adherence of silver directly upon steel or iron, it is customary to interpose a coat of copper or brass which renders the further operation of silver plating easy.

As we have just seen, the formation of deposits of tin, copper, or brass, may be, for a certain number of metals, considered as the complement of the cleansing operation. I would not hesitate to immediately describe these processes, were it not that we must have recourse to that marvellous instrument, the galvanic battery, which we must first know well before progressing further.

CHAPTER VIII.

GALVANIC BATTERIES: OF DANIELL—OF DANIELL WITH BALLOON—OF BUNSEN—OF BUNSEN MODIFIED BY ARCHEREAU—WITH BICHROMATE OF POTASSA—OF GROVE—WITH BISULPHATE OF MERCURY—OF SMEE—OF SMEE MODIFIED—ELECTRO-MAGNETIC APPARATUS—PULVERMACHER'S BATTERY.

Galvanic Batteries.

We thus call certain apparatus intended to furnish, with greater or less abundance, or with more or less constancy, the electric or voltaic fluid in its two different states, *positive* (vitreous) and *negative* (resinous), the former escaping at one end of the apparatus, and the latter at the other end. A *couple* or *element* of battery is composed of one electro-negative agent united to one electro-positive agent. The reunion of a greater or less number of such elements, joined as we shall see further on, constitutes the *battery*.

We call the *poles* the opposite points from which the two fluids escape, and they are designated by the name of the fluid transmitted. The *positive pole*, or vitreous, is indicated by the algebraic sign +; and the *negative pole*, or resinous, by the sign —.

The metallic bindings, ribbons, or wires, which conduct to a given place each of these fluids are called *conductors*, *electrodes*, or *reophores*.

When the two poles or their electrodes are brought into contact, the *circuit is closed*, that is to say, the two fluids separated by the battery combine anew, with the production of sparks or without any appearing phenomena, and the *neutral or natural fluid* is reconstituted.

When we plunge into a liquor the ends (not in contact) of the two electrodes, we say that this liquor is *electrolyzed*. It is nearly always to the wire connected with the negative pole (generally zinc) that we attach the object which is to receive the deposit, and the object takes the name of the *cathode*. The positive electrode is generally terminated by a foil or wire of platinum, or by a foil of the metal already contained in the solution, or by any other electricity conducting substance, like the graphite (carbon) of gas retorts for instance. This wire, foil, or conducting substance, is called the *anode*.

There are two kinds of batteries: Some operate under the action of physical agents, and, on account of their feeble intensity, are rarely used.

Others act under the influence of more or less violent chemical reactions, of decompositions and recompositions, or of greater or less affinities. These are the batteries which we shall to a certain extent describe.

The varieties of these instruments are, at the present time, very numerous. They have been modified in their shape and in the nature of their materials, by many persons. But, to sum up, the best battery is that which, under the smallest volume, is the most energetic, constant, regular, and economical.

We shall describe several of them, which any one may buy or construct himself.

Daniell's Battery.

This battery develops quite a constant and lasting current, it is, however, wanting in intensity. It is especially adapted to those slow deposits which must be thick and of uniform texture. A great advantage of this battery is that it will work without acids, and, therefore, without the production of gases or smell. In fact, it can be used in a private apartment without inconvenience.

One element of battery is made of a flat vessel of pure copper (Fig. 17), which is half filled with a saturated solution of sulphate of copper (blue vitriol), and into which is placed a diaphragm of sail cloth or a hog's bladder, or better still a cell of porous porcelain or earthenware (Fig. 18), which causes the solution of sulphate of copper to rise to about one inch from the top of the copper vessel. The diaphragm or cell is filled with a saturated solution of chloride of sodium (common salt), into which is plunged a well-cleansed zinc plate (Fig. 19).

Fig. 17.

Fig. 18.

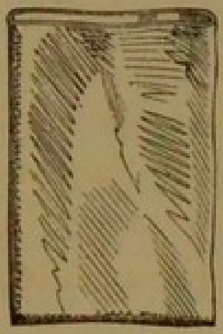
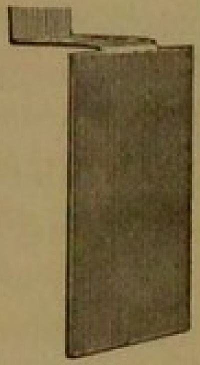


Fig. 19.



For the proper working of the apparatus, it is necessary that the levels of the two solutions should be nearly on the same plan. If there be any difference, the solution of chloride of sodium may be slightly above the other, because there is little inconvenience if a small quantity of salt becomes mixed with the sulphate of copper. On the contrary, if from a higher level the solution of sulphate of copper passes into the diaphragm or porous cell, the zinc is immediately corroded, and blackened, and the battery may cease to work.

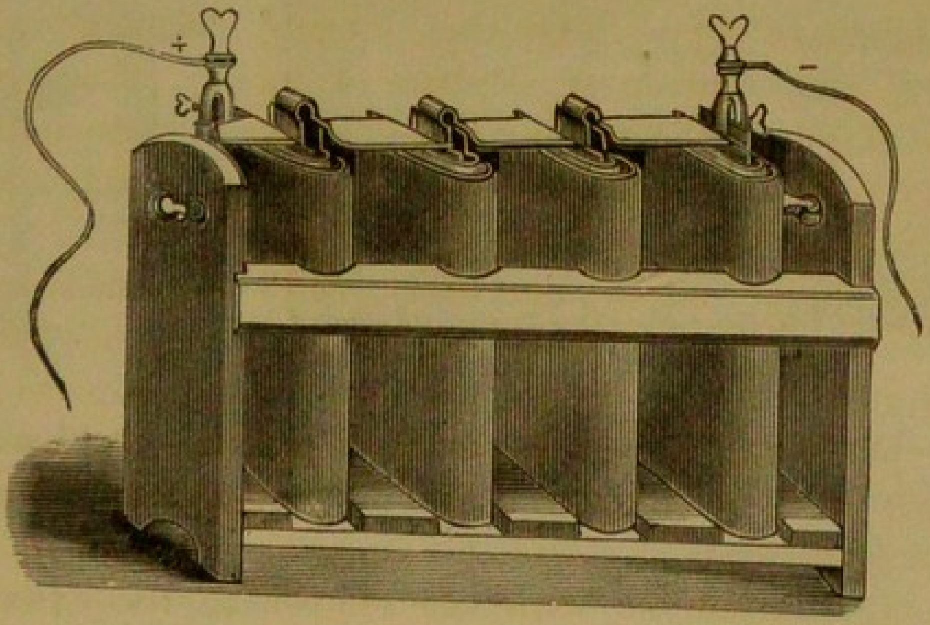
When we employ one of Daniell's elements only, which seldom happens on account of the feeble intensity of the current, the conducting wire which supports the article to be galvanized is connected with the zinc plate by a binding screw of brass, and the other wire or electrode supporting the anode is equally connected with the copper of the exterior vase.

The solution of sulphate of copper must be kept constantly saturated with crystals of this salt, plunging into the upper portion of the liquid, and inclosed in a small metallic perforated box or in a bag of linen or hair cloth. A similar process may be employed to keep the solution of common salt in a state of saturation. A battery thus disposed may be kept in operation for three weeks, or a month, and sometimes longer.

When this battery is working, the copper of the decomposed sulphate is deposited upon the copper of the vessel, which thus increases in weight and in value. The zinc is slowly dissolved in the solution of common salt, and forms a double chloride of sodium and zinc.

When two or a greater number of the elements of a Daniell's battery are to be joined together, the zinc of the first element is connected with the copper of the second element by means of a well-cleansed metallic ribbon, then the zinc of the second with the copper of the third, and so on, until the whole apparatus (Fig. 20), presents at one end a copper

Fig. 20.



vase, and at the other a zinc plate, unconnected. A metallic electrode, wire, or ribbon, connects the anode with the copper end, and a similar electrode is bound to the zinc end and supports the cathode or object to be electroplated.

There are numerous dispositions of Daniell's battery, among which that represented by Figs. 21 and 22. The engraving is sufficiently clear to need no other explanation, except that the copper rods with shelves for the support of the crystals of sulphate of copper are placed inside the porous cell, and a cylindrical zinc plate outside.

Fig. 21.

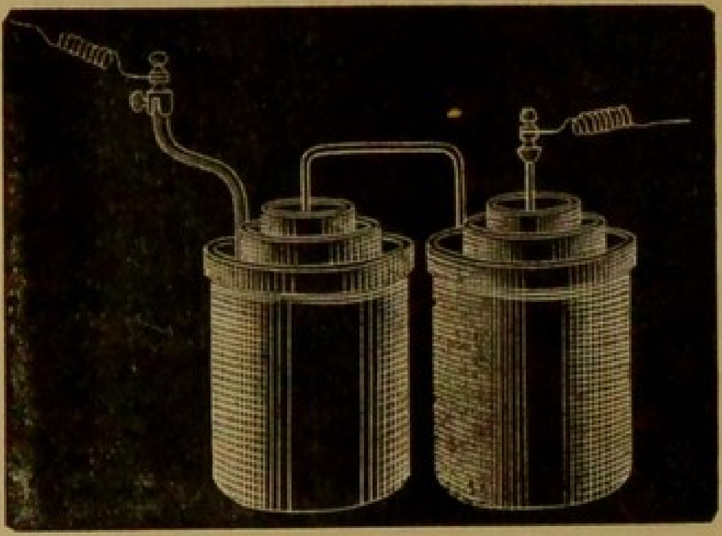
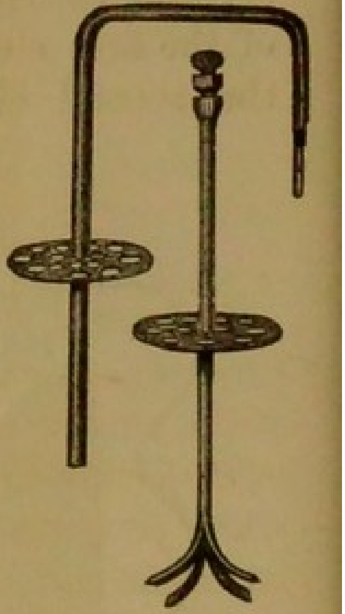


Fig. 22.



Another (Fig. 23), much in use by the electro-gilders of watch parts and by telegraphers, is composed of—

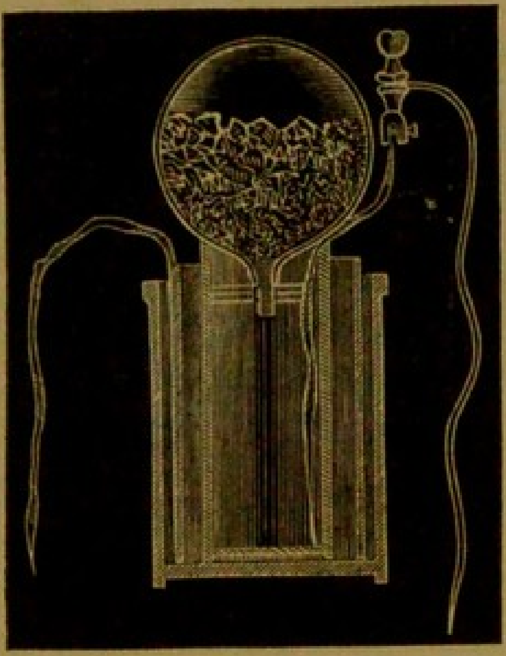
1. A cylindrical vase of stoneware, glass, or porcelain;

2. A cylinder of zinc to which is soldered or riveted a ribbon of pure copper;

3. A porous cell of baked clay;

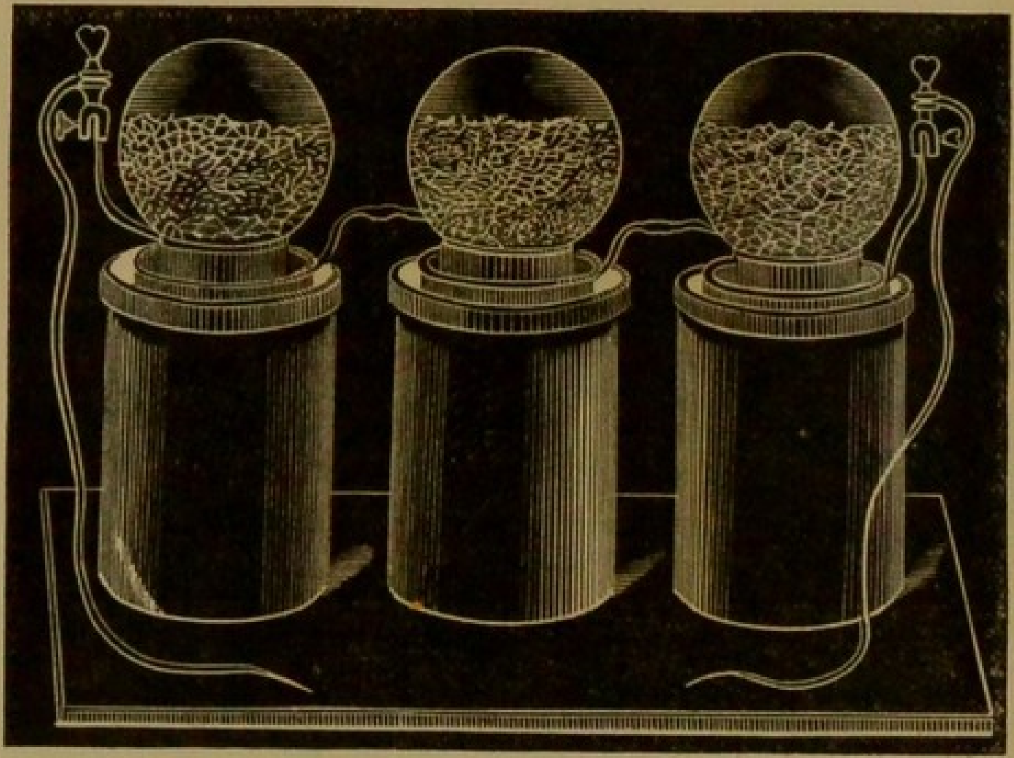
4. A glass balloon with a short neck, and filled with crystals of sulphate of copper. It is closed with a cork perforated with two holes, or having two notches cut on the surface along its length.

Fig. 23.



The rolled zinc plate is put into the stoneware pot concentrically to the porous cell. The copper ribbon of the zinc of the first element dips on to the bottom of the cell of the next element, in such a manner that, when several elements are connected together, there is at one end the ribbon of a zinc plate, and at the other end a copper ribbon put into the cell. Then, the porous cell and the stoneware pot are filled to the same level with water. The balloon containing the crystallized sulphate of copper receives as much water as it can hold, and the notched cork being put in place, the balloon is quickly inverted with its neck in the water of the porous cell. The battery is ready to work twenty-four hours after. The ribbon of the zinc end is connected with the objects to be electroplated, and that of the other cell end, with the soluble anode. Fig. 24 represents a battery of three of Daniell's elements with balloon.

Fig. 24.



This disposition of Daniell's battery operates as follows: The sulphate of copper contained in the balloon is dissolved in the water around it, and as this solution is denser than water it falls into the porous cell through one of the notches of the cork, while an equal quantity of purer and lighter water ascends through the other notch, and so on, producing a circuit of denser liquor falling by one notch, and of lighter liquor rising by the other. The solution of sulphate of copper is decomposed in the porous cell; the sulphuric acid passes through the cell by exosmose and acts upon the zinc, and at the same time, the copper becomes deposited upon the copper ribbon connected with the zinc of the former element. In order that this battery may work regularly for six or seven months, it is sufficient to replace the evaporated water. The balloon ought to contain at least one kilogramme of sulphate of copper, and the zinc be from 18 to 20 centimetres in height and from 10 to 12 in diameter. The zinc may be amalgamated, in which case the action is a little slow at the start, but more regular afterwards. The copper ribbon receives all the metal of the decomposed sulphate, and it sometimes happens that part of the copper becomes deposited upon the porous cell, which must then be cleaned in aqua fortis. When all the sulphate of copper is used up, the balloons are filled with a fresh quantity of crystals and new copper ribbons inserted to take the place of those rendered too voluminous. This sort of battery is in extensive use, and properly so, by telegraph operators. If gilders were willing to employ such batteries, with elements sufficiently large and numerous, they could dispense with acid batteries which require fresh food every day; but, whether right or wrong, they still prefer the Bunsen battery, or rather that modified by Archereau, which under a much smaller volume is more energetic in its action.

If it be desired to start immediately the Daniell battery with a balloon, it is sufficient to add a small quantity of sulphuric acid or of common salt to the water into which the zinc is plunged.

Bunsen's Battery.

Each element is composed of a glass vessel (Fig. 25) which is half filled with nitric acid at 36° or 40° Baumé, and which receives a hollow cylinder (Fig. 26) of pulverized coke, agglutinated at a high temperature by means of sugar, gum, tar, or any analogous substance. This cylinder carries at the upper part, which does not dip into the acid, a copper collar (Fig. 27) which may be tightened at will by means of a screw. A copper band or ribbon is fixed to the collar, and may be connected with the zinc of another element. A porous cell (Fig. 28) of baked porcelain is placed inside the coke cylinder, and contains a diluted solution of sulphuric acid (about $\frac{1}{10}$ acid) into which is put a bar or cylinder of zinc (Fig. 29) strongly amalgamated, that is to say, covered with mercury in the manner we shall indicate further on. Wrought or cast iron is sometimes substituted for zinc; but this process, although slightly cheaper, is open to the objection of causing the production of fœtid gases, and of rendering necessary a more frequent cleansing of the points of contact of the connections.

Fig. 25.

Fig. 26.

Fig. 27.

Fig. 28.

Fig. 29.

When a battery of several elements is to be formed (Fig. 30), the coke (carbon) of the first element is connected with the zinc of the second, and so forth, and the apparatus is ended, at one side, by a carbon communicating with the anode, and on the other, by a zinc connected with the cathode, or object to be electroplated.

The Grove battery, which we shall explain further on, has shown the way in which to modify the Bunsen battery in order to utilize all of its advantages. We

Fig. 30.

understand that in this apparatus, such as just described, the surface of the carbon is much greater than that of the zinc; it is a wrong disposition, since, generally, the intensity of the current is in direct ratio with the surface of the zinc corroded, provided that this surface be opposite and parallel to that of the carbon.

Bunsen's Battery Modified by Archereau.

This battery is preferred to all others by gold and silver electroplaters, and galvanoplastic operators. We shall describe it minutely, taking as a standard a battery composed of medium sized elements. Each operator will modify the proportions of the acids and amalgamating salts, according to the dimensions of his own apparatus.

Each element is composed of:—

1. An exterior vessel or pot of glass, porcelain, or most generally, stoneware;

2. A cylinder of amalgamated zinc,—*i.e.* covered with mercury,—provided with a binding screw (Fig. 32) or with a copper band (Fig. 31), whether we

employ a single element or it belongs to the end of a combination of them, or we have to connect the zinc with the carbon of another element;

Fig. 31.

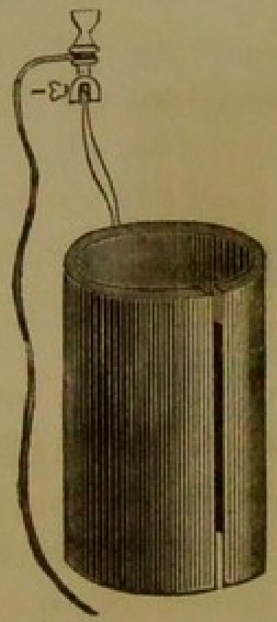
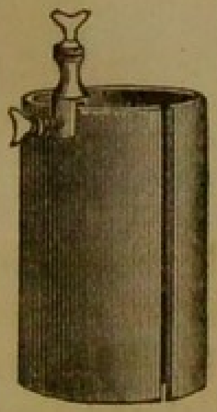


Fig. 32.



3. A porous cell (Fig. 33) of baked pipe or porcelain clay;

4. A prism or cylinder of graphite (Fig. 34) cut from the residue found in old gas retorts; Fig. 35 represents a prism of graphite (carbon) with a copper

Fig. 33.

Fig. 34.

Fig. 35.

band fixed to it by means of a wire of the same metal, all the binding being afterwards covered with a thick varnish intended to protect it against the acid fumes of the battery; this disposition is here indicated as a warning as to what should be avoided, since, notwithstanding the varnish, the acid rises by capillary attraction and corrodes the copper band between the carbon and the wire;

5. Binding screws of various shapes and sizes (Figs. 36 to 39) to connect the carbon or zinc by means of ribbons, or wires, or the two together;

Fig. 36.

Fig. 37.

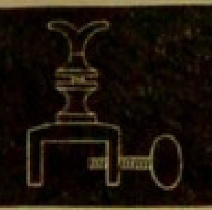


Fig. 38.

Fig. 39.

6. Conducting wires of pure copper, covered with cotton, silk, India-rubber or gutta-percha, and presenting the metal at their extremities in order to effect the connections.

Charge of the Battery.

Taking as a standard an element 25 centimetres in height, and 15 in diameter, operate as follows:—

1. Half fill with water the stoneware pot;

2. Add to this water 200 grammes of sulphuric acid at 66°;

3. Add also 30 grammes of amalgamating salt;*

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* Zinc may also be amalgamated with metallic mercury, after it has been cleansed in diluted sulphuric acid. It may be dipped into mercury, or rubbed over with this metal by means of a scratch-brush of brass wire. This method is much more tedious

4. Put the cylinder of zinc into the stoneware vessel;

5. Then introduce the cylinder or prism of carbon into the porous cell;

6. Fill the empty space between the carbon and the sides of the cell with nitric acid at from 36° to 40° Baumé;

7. Lastly, put the porous cell thus filled into the centre of the zinc cylinder.

The surfaces of the two liquids should be level.

Reunion of Several Elements.

When several elements are to be connected, they are placed near each other, without touching, however, and the first carbon or graphite is left free for the attachment of the anode. The ribbon or band of the first zinc is pinched between the jaws of the brass binding screw and the carbon of the second element, and so forth, until the last zinc is ready to be connected with the object to be electroplated.

Bringing Batteries into Action.

Batteries will furnish electricity as soon as the circuit is closed, that is to say, when the conducting wires starting, one from the carbon, and the other from the zinc, are put into communication whether by direct contact or by the intermediation of a conducting liquid.

It often happens that batteries, which appear to be in good order, do not work. This is certainly due to

and inferior to that of using amalgamating salt, which covers equally well all the portions under the liquid, and without rendering brittle the connecting copper bands, as is the case with metallic mercury.

some foreign substance preventing the conductibility at the points of contact, or to the copper band of one zinc resting upon another zinc. It is evident that by removing the cause of the inconvenience, the latter disappears.

Before using a battery, we must always try if the fluid escapes well from both extremities. For that purpose we present the point of the negative wire to the carbon of the other end, and, when everything is right, a spark will immediately ensue. The same experiment is made with the positive wire, against the last zinc, and another spark should be produced. It is still more easy to have the two ends of the wires made to rest at a short distance from each other upon a piece of carbon, or upon a file, and then rubbing with one wire while the other remains in contact. Numerous sparks will immediately appear.

When one element of a battery is wrongly put up, we discover the defect by successively presenting the end of one of the wires to the carbon of each element, and that which does not produce any spark belongs to the defective element.

Too much porosity in the cells is another cause of stoppage in the current, because the solution of zinc which penetrates, deposits upon the carbon a whitish coat preventing further action. We must then change the cell and scrape off the coat entirely from the carbon. This takes place generally when the battery has been working several days without the addition of fresh liquor, or when there is too much acid. It also happens that the battery will cease working from too great an accumulation of sulphate of zinc which, not having sufficient water to remain in solution, crystallizes upon the zinc, and prevents any further action. The acid solution is then removed, a fresh one substituted, and the zinc cleaned.

I prefer, for batteries, laminated zinc to that cast in a mould, because the latter is not so homogeneous and dense, and is more rapidly corroded, and even perforated.

Keeping Batteries in Order.

Every twenty-four hours, and sometimes oftener, the losses of batteries must be made good by adding, without taking the elements apart, about two teaspoonfuls of amalgamating salt and as much of sulphuric acid to the liquor of the zinc plates, and stirring with a glass rod. Nitric acid, to replace that evaporated, is put into the porous cell. This manner of operating may be sufficient for five or six days; but, after this lapse of time, all the old liquors must be removed, and fresh ones added, instead.

Although amalgamated zinc is scarcely corroded, even in a very acid solution, when the circuit is not closed, that is to say, when the two poles are not in connection by direct contact or through a conducting liquid, it is nevertheless preferable to take the batteries apart every evening and in the following manner:—

1. All the binding screws are let loose, and cleaned, if necessary;

2. The prisms or cylinders of carbon are removed, and, *without washing*, deposited in a vessel especially for their use;

3. The porous cells are removed, and their acid poured into a special vessel. The cells are *not washed;*

4. The zincs are removed from the acid liquor, and

simply placed in an inclined position upon the edges of the stoneware pots.

It is easily understood that the batteries are made ready to work by a converse manipulation.

Important Observations on Batteries.

It is prudent to have another set of instruments, or, at least, a supply of those parts which are easily broken.

Batteries must be kept in a place where the temperature does not greatly vary. A frost arrests their action, and extreme heat increases it too much.

A good place for them is a box or closet, and they are put at such a height that they may easily be manipulated. They must not, however, be placed on top of the metallic baths, because when stirred or moved about, drops of mercurial solution may run down the wires into these baths and spoil them. This box or closet should have means of ventilation, in such a way that the air coming in at the lower part, will escape at the top through a flue, and will carry away with it the acid fumes constantly disengaged.

It is well, when possible, to keep the batteries in a room different from that where the baths and the metals are to be operated upon, and which are so easily injured by acid vapors. The galvanic current is then conducted into the work-room by wires passing through holes in the wall, and covered with *gutta-percha.*

It is possible to branch several conducting wires upon main electrodes, and thus operate several baths, together or singly, with the same battery; but I prefer distinct batteries, one for each kind of metallic solution, because of several baths that which has the greatest conducting power will absorb nearly all of the electricity.

Grove's Battery.

This battery is analogous to the preceding one, and differs from it only by a platinum foil which plunges into the nitric acid, and replaces the prism of carbon. This foil is supported by a small brass stand (Fig. 40) fixed itself to a round band resting upon a rim on top of the exterior vase. A binding screw is soldered to the stand when connection is to be made with the copper ribbon (or band) of the preceding zinc. Fig. 41 shows at the same time another disposition of the brass stand for wire connections, and the ensemble of a mounted element. The several elements of batteries are united together in the manner already mentioned, the zinc to the platinum of the next element, and so on.

Fig. 40.

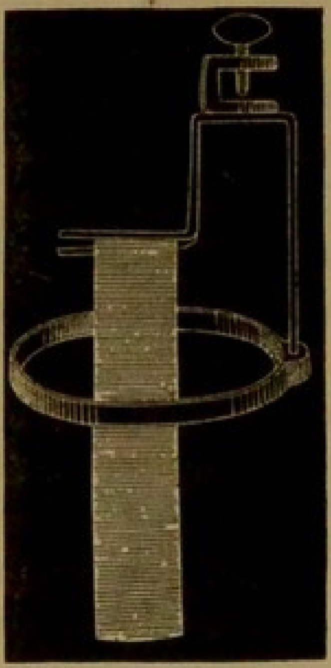
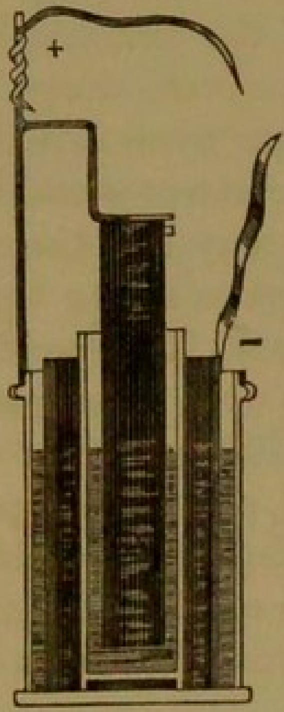


Fig. 41.



This battery has no other inconvenience than its great cost, due to the platinum employed. Mr. Hulot has proposed to substitute a foil of aluminium for that of platinum. Nevertheless, the price is too high, and prevents the extensive use of the battery, which, otherwise, gives satisfactory results.

We may mention, among batteries having some analogy with that of Bunsen modified by Archereau :—

1. The Grenet's battery, in which a solution of 100 parts of water, 10 of bichromate of potassa, and 10 of sulphuric acid in the porous cell, replaces the nitric acid employed by Grove and Bunsen. This battery does not emit acid fumes, but the carbon is rapidly incrustated with oxide of chromium, which arrests the galvanic current.

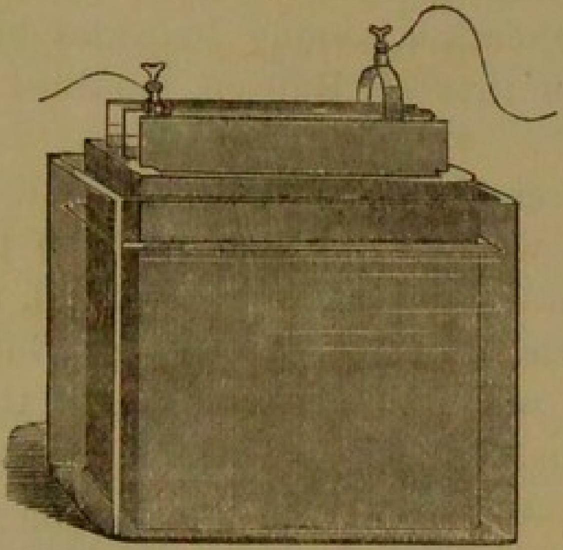
2. The Marié-Davy battery, in which sulphate of mercury, slightly damp, replaces the nitric acid in the porous cell. The working expenses of this battery are very high, and it is used only in the telegraphic service, where the Daniell battery with balloons is still preferred.

Smee's Battery.

This battery is very simple in construction, requires only one kind of liquid easily found everywhere, and does not emit any smell or acid fumes. All these advantages render it especially adapted to the use of provincial electroplaters and jewelers who often practice their operations in their sales-rooms.

It is composed (Fig. 42) of a thick wooden frame open at the top, with three internal parallel grooves which run the length of the two opposite sides. The middle groove receives a movable plate of silver, platinum, gold, or copper which has been strongly gilt, silvered, or platinized. The surfaces of this plate must be rough or with a dead lustre. Two plates of strongly amalgamated zinc run through the other two grooves. The plates of zinc are but a short distance apart, although without contact, from the central one, and are connected by a wire or a metallic band. The positive wire starts from the middle plate, and the negative from the zinc, and the whole apparatus is immersed in a solution containing common salt or one-tenth of sulphuric acid. Several of such elements may be united together by connecting the zinc of the first with the middle plate of the second, and so forth. We see therefore that this battery, with one liquid and without diaphragm or porous cell, acts like those of Volta, Wollaston, etc.

Fig. 42.



I have modified this battery in the following manner: The wooden frame is suppressed, and the entire cell is made of gutta-percha. The two narrow sides (Fig. 43) have three parallel grooves one centimetre deep, and seven to eight millimetres distant from each other. The central groove receives a plate of carbon (Fig. 44), which advantageously replaces the plate of silver or of *platinized* platinum. The two other grooves receive two plates of amalgamated zinc with one of the upper corners cut away, as seen in Fig. 45. A double binding screw, for the posi-

Fig. 43.

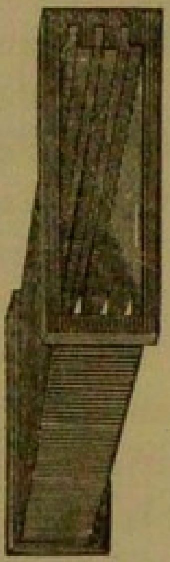


Fig. 44.

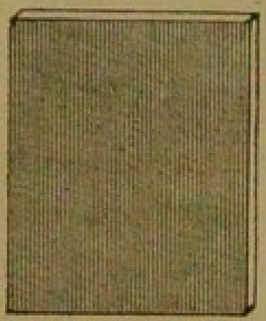


Fig. 45.

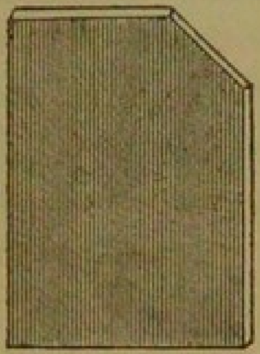
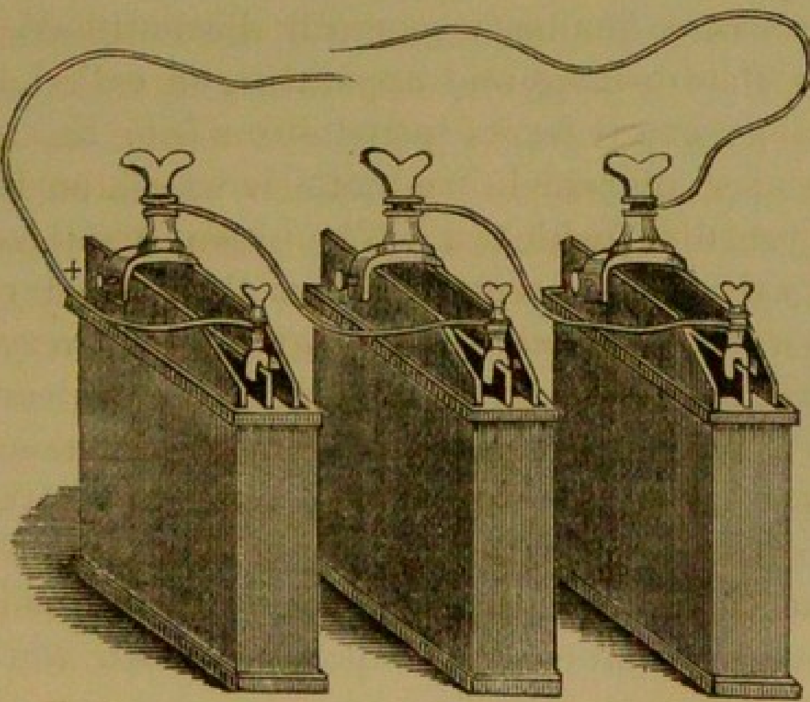


Fig. 46.



tive wire, is fixed upon the plate of carbon where the two zinc corners have been cut off, and another large binding screw unites the two zinc plates, and carries, at the same time, the negative wire.

This battery will work by filling the cell with water saturated with common salt, or acidulated with one-tenth of sulphuric acid. It is evident that batteries of several elements may be disposed (Fig. 46) by arranging them like the ordinary Smee batteries, from which they but slightly differ.

If we employ the diluted solution of sulphuric acid, the zinc will be kept bright and clean, and no hydrogen will be disengaged by the addition of a small quantity of amalgamating salt. With the solution of common salt, no amalgam is necessary.

Electro-magnetic Apparatus.

The trials made in large electroplating works, especially in those of Messrs. Charles Christofle & Co., induce me to give a short description of this apparatus, although its use, from some not well known cause, has been generally discontinued.

The electro-magnetic apparatus, so called by the company formed for its introduction into the arts, is essentially composed of a metallic wheel, on the circumference of which, and at given distances, are fixed metallic magnets. When this wheel rotates on its axis, each successive magnet comes very close but without contact, to a series of soft iron bars fixed at equal and given distances upon a metallic frame. The rapid and continuous passage of the magnets before the bars of soft iron, causes the decomposition of a great quantity of neutral fluid, and the magnets take up the positive fluid, while the negative one goes to the bars of soft iron. We easily understand that it is sufficient to connect conducting wires with the wheel of the magnets and with the frame of the soft iron bars, to have at our disposal the two kinds of electricity obtained by the preceding batteries. The cost of the apparatus, the power necessary to rotate it, and the difficulty of dividing, through many separated baths, the electricity produced by this method, appear to be the causes which have prevented the employment of this ingenious apparatus.

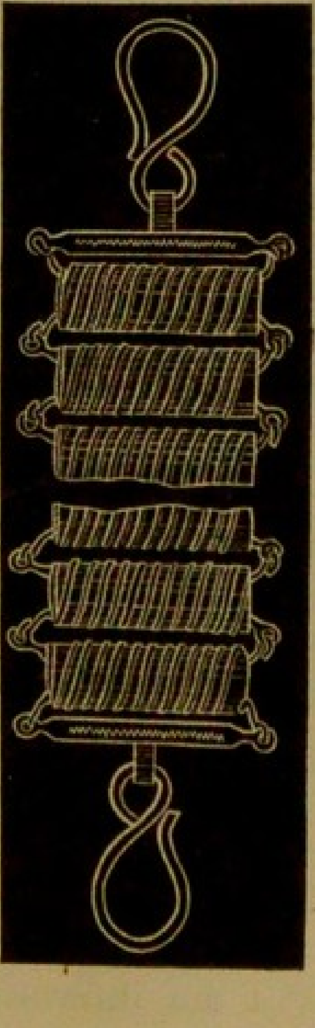
Pulvermacher's Chain or Battery.

I cannot conclude the description of the instruments intended for furnishing electricity to the galvanoplastic operator, without mentioning a marvellous little battery of a peculiar shape, and known by the name of Pulvermacher's electro-medical chain (Fig. 47).

This apparatus, as indicated by the name, is intended by the inventor more for therapeutic than industrial uses. However, it will be found very useful in many cases by gilders, jewellers, watchmakers, etc., who, for the gilding or silvering of small articles, hesitate before the trouble of fixing up a galvanic battery.

This apparatus is truly a chain, not like the useless one of Golde-

Fig. 47.



berger, made of rings alternately zinc and copper, but a chain, each link of which is really a voltaic element. Therefore, the chain or reunion of these links is nothing else than a true battery, the energy of which is proportional to the number of links, and the two extremities of which are the two poles.

Each link is made of a small cylinder of soft and porous wood, so as to imbibe and become charged with the acid liquors. Two spiral grooves are cut on the outside, and receive two parallel wires of zinc and copper, that is to say, the electro-positive and electro-negative agents.

On one side of the cylinder, a small loop ends the copper wire; the other side is terminated by a loop of zinc wire. For constructing the chain, the links are put together by connecting the loop of zinc with that of copper, and so on, and the chain or apparatus is ended on one side by a zinc loop, and on the other by a copper one.

In order that such a chain shall immediately disengage the two kinds of electricity by its extremities, it is sufficient to wet it with salt water, vinegar, or any other diluted acid. The power of this apparatus is surprising, considering its size.

When we wish to gild or silver with it, we begin by wetting it with some acid liquor, and then attach the object to be electroplated to the last loop of zinc, while a small anode of gold, silver, or platinum is fixed to the last copper loop. A chain of six links is more than sufficient for gilding or silvering small articles, such as watch-cases, snuff-boxes, etc.

After using it, we wash the chain in fresh water, and dry it in a cloth or in sawdust.

I am informed by Mr. Pulvermacher that he has made a great improvement in the construction of his *battery-chains*, by which any one can replace the zinc of the chain. Indeed, zinc is the only metal rapidly corroded, and it was formerly nearly impossible to replace it in the chain I have just described.

NOTE.—Alexander Watt recommends to electroplaters, from personal experience, the following battery: A stoneware jar holding about four gallons receives a cylinder of thin sheet copper, dipping into water acidulated with two pounds of sulphuric acid and one ounce of nitric acid. A solid zinc cylinder is put into the porous cell, which is filled with a concentrated solution of common salt, to which a few drops of hydrochloric acid have been added.

The same author gives a neat way of amalgamating the zincs. The mercury is put into a coarse flannel bag, dipped now and then into diluted hydrochloric acid, and rubbed against the surface of the zinc cylinder or plate.

Various kinds of metallic deposits require a variation in the quantity or intensity of electricity. An intense current, for brass and hard deposits for instance, will be obtained by joining alternately the zinc of one element to the copper or carbon of the next one. On the other hand, when, as for silver plating for instance, a smooth and not too hard deposit is desired, the current should be feeble in intensity, but considerable in quantity, and is obtained by connecting together all of the zincs on the one side, and all of the coppers or carbons on the other.

The porous cells are absolutely necessary in batteries working with two exciting solutions, like the Bunsen battery. But the trouble arising from the clogging of the pores of the cell, and from the difficulty of preventing the diffusion between the two liquids of the porous cell and of the jar, the specific gravity of which is constantly varying, makes it a great desideratum that the cell should be dispensed with in batteries worked with but one exciting fluid.

A good Wollaston battery is composed of a glass or stoneware jar, on top of which rests a wooden support having a slit in the middle, through which a zinc plate passes. Two copper plates, one on either side of the zinc, are fastened to the wooden support, and connected with a binding screw. This disposition utilizes the electricity of both faces of the zinc plate, but the latter should be thoroughly amalgamated. The exciting solution is composed of one part of sulphuric acid to fifteen of water.

The Callaud battery is a modification of that of Daniell, doing away with the porous cell. A jar is filled with water acidulated with sulphuric acid, only for starting the solution of the zinc, since the sulphuric acid will be furnished afterwards by the sulphate of copper. The zinc and copper plates are both placed horizontally in the jar; the zinc in the upper part, and the copper lying on the bottom. To start this battery, it is only necessary to throw into the jar a few crystals of sulphate of copper. These go to the bottom, dissolve and form a saturated solution around the negative plate of copper.

Several improvements have been made in this battery, as follows: The electrode or conducting wire from the copper plate is made to pass through a glass tube reaching down to the bottom of the jar, and large enough to contain a supply of crystals of sulphate of copper necessary to keep a saturated solution in the lower part of the cell. In this manner we avoid disturbing the upper part of the liquid in which the zinc dips, and its mixture with the solution of sulphate of copper. The deposits from the zinc and other impurities are prevented from falling upon the copper plate, and thus from interfering with the current, by covering the copper plate with a layer of clean quartz sand, which serves also as an obstacle to the diffusion upward of the sulphate of copper, because the interstices between the grains act as a series of narrow tubes. The thicker the layer of sand, the more completely is diffusion prevented, but the force of the current diminishes by reason of the increased resistance. Diffusion upward can be prevented without decreasing the power of the current, provided the battery be not kept too long without working. This is accomplished by projecting from the copper plate at the bottom, little pieces of copper, directed upward toward the zinc, but not touching it. As soon as the current passes, the portions of sulphate of copper nearest the zinc, which are those that have diffused upward the farthest, are reduced in preference to the portions lower down, and every attempt at rising is put down as soon as the current passes.

Mr. P. Casamayor, of New York, in a thorough examination of Callaud's battery and its modifications, has made the following tests with the galvanometer: With an element of Callaud, which gives a deflection of 77°, if a layer of beach sand of one inch and a half in thickness is placed over the copper plate, everything else remaining in the same condition, the deflection will be 68°. If the layer be three and a half inches thick, the deflection will be 57°. For comparison, a Daniell battery, with a cup and plate of the same size, gave a deflection of 87°.

The Callaud battery is therefore less powerful than one of Daniell, of the same size, and recently prepared. But, when the latter has been working for some time, when diffusion has taken place between the liquids of the cell and of the jar, etc., the superiority of Cállaud's battery becomes at once apparent.—*Trans.*

CHAPTER IX.

COPPER DEPOSITS—BY DIPPING—BY BATTERY.

Copper Deposits.

WE have said, in the articles on cleansing, that it was often useful, and sometimes absolutely necessary, to effect a primary deposit of copper, brass, and even tin upon common metals or alloys, such as wrought and cast iron, zinc, Algiers metal, etc., before they receive the precious metals. These various operations are often not only the complement of the cleansing process, but also give products ready for the trade without any further operation. We shall carefully describe the various formulæ, by the aid of which we arrive at these results.

Copper Deposits (by dipping).

Copper deposits are obtained, according to the metals employed or the object in view, either by simple dipping or by galvanic methods.

Copper deposits by dipping are seldom practised except upon iron, and are generally wanting in lasting qualities. They are intended to please the eye only, since, from the thinness of the deposit, the iron is not protected against atmospheric influences. It may even be rendered more liable to oxidation.

We employ a bath composed of—

Sulphate of copper (blue vitriol) . .	100 grammes.
Sulphuric acid (oil of vitriol) . .	100 "
Water	5 to 10 litres.

If the iron is steeped in this solution for a short time only, it immediately becomes covered with a bright pellicle of pure copper having a certain adherence; but should it remain there for a few minutes, the deposit of copper is thicker and muddy, and does not stand any rubbing. In this case, we are obliged to compress it by means of rollers or a draw plate, in order to impart a certain cohesion to the molecules of copper. Such is the process by which are obtained those coppered iron wires so much used for the manufacture of elastic beddings, etc.

Small articles, such as hooks, pins, nails, etc., are coppered by jerking them about for a certain length of time in sand, bran, or sawdust impregnated with the above solution, diluted with three or four times its volume of water.

Copper Deposits (by the battery).

Electro-deposits of copper are obtained by two different methods: First, by decomposing a simple salt of copper, the sulphate for instance, which is suitable for those metals only which are not decomposed by the acid solution; secondly, by decomposing a double salt of copper with another base, such as the double cyanide of potassium and copper. This latter process is equally well adapted to all metals and alloys.

The first process of copper deposits by a simple salt of copper will be treated *in extenso* in the second part of this work, *i. e.*, the GALVANOPLASTIC ART proper. Copper deposits by the galvanic decomposition of double salts is, on the other hand, the subject which occupies us in this place.

Copper deposits in baths holding the double salts are, as we have already said, well adapted to all metals and alloys; they are fine, lasting, and their thickness is entirely regulated by the will of the operator.

The most simple, although not the most economical, process consists in dissolving a soluble or insoluble salt of copper in water holding a sufficient quantity of the cyanide of potassium. We generally proceed as follows: Dissolve 500 grammes of sulphate of copper in ten litres of water, and add a solution of carbonate of soda until no more precipitate is formed; collect the green precipitate (carbonate of copper) thus obtained upon a cloth filter, and wash it several times with water; then stir the washed carbonate of copper in water, to which cyanide of potassium is added until the carbonate is entirely dissolved, and the solution is colorless. It is advantageous to add a small excess of cyanide, which will increase the conducting power of the liquor.

This bath may be indifferently employed hot or cold, and requires for its decomposition quite an intense electric current.

A copper plate or foil forms the anode, and becoming slowly dissolved, nearly makes up for the loss of the bath in copper which has deposited on the negative pole. This anode must be removed when the bath does not work, because it will be dissolved even without an electric current, and the bath, having been overcharged with copper, which is indicated by a blue or green color, will require a fresh addition of cyanide to be in good order.

This bath, we repeat, is not economical, and will, besides, act in a whimsical way. We have found by practice that either of the following formulæ is to be preferred in every respect:—

First Formula.

CONVENIENT FOR ALL METALS OR ALLOYS, AND INDIFFERENTLY EMPLOYED COLD OR WARM.

Water	10	litres.
Acetate of copper (crystallized)	200	grammes.
Carbonate of soda (crystals)	200	"
Bisulphite of soda	200	"
Cyanide of potassium pure per cent.*	200	"

For preparing this bath, the acetate of copper is put first into the vessel, and moistened with suffi-

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* We shall see, at the end of this work, in the chapter on Chemical Products, article *Cyanide of Potassium*, that there is very little uniformity in the composition of this salt, as found in the trade. Cyanides are sold which do not contain more than 30 per cent. of real cyanide, the remainder being carbonate of potassa. We, ourselves, manufacture three qualities of this product for different kinds of work. Our pure cyanide contains from 96 to 98 per cent. of real cyanide, and we designate it by the sign of per cent. or No. 1. The second quality, employed by galvanoplastic operators and copper or brass electroplaters, is a little more economical; it holds from 65 to 70 per cent. of real cyanide, and is called No. 2. We also manufacture a cyanide No. 3, which contains from 40 to 50 per cent. of real salt, and which we sell mostly to photographers, for working their papers and cleaning their hands when stained by nitrate of silver or chloride of gold.

cient water to make a homogenous paste. This salt, like flour, is wetted with difficulty, and will float on the surface of too great a body of water.

The carbonate of soda and two litres of water are added to this paste, and, after stirring, a light green precipitate is formed. Two litres more of water are then added with the bisulphite of soda, and the magma becomes of a dirty yellow color.

Lastly, the remainder of the ten litres of water, and the cyanide of potassium are introduced. The electro copper bath is then ready, and must be colorless. If, after the complete solution of the cyanide, the liquor is not entirely colorless, we must add more cyanide. But this does not happen unless the cyanide is not pure, or has begun to decompose.

If we desire a perfectly limpid bath, we may pass it through filtering paper, or decant it after settling.

This bath, for its decomposition, requires an electric current of middle intensity.

The copper anode should have a surface nearly equal to that of the immersed objects.

Large pieces are generally kept hanging and motionless in the bath; on the other hand, small articles are moved as much as possible, which is always to be preferred when practicable, especially with warm baths.

If it were always and everywhere possible to obtain a pure cyanide of potassium, we could confine ourselves to this formula, which is satisfactory in every case. But as it is very difficult to find everywhere a perfectly satisfactory cyanide of potassium, we shall reproduce here the various formulæ of our first edition, which require a cyanide containing from

70 to 75 per cent. of the real article. These formulæ are applied to various uses.

Second Formula.

COLD BATH FOR IRON AND STEEL.

Bisulphite of soda	500 grammes.
Cyanide of potassium	500 "
Carbonate of soda	1000 "
Acetate of copper	475 "
Ammonia (aqua ammonia)	350 "
Water	25 litres.

WARM BATH.

Bisulphite of soda	200 grammes.
Cyanide of potassium	700 "
Carbonate of soda	500 "
Acetate of copper	500 "
Ammonia (aqua ammonia)	300 "
Water	25 litres.

Third Formula.

HOT OR COLD BATH FOR TIN, CAST IRON, OR LARGE PIECES OF ZINC.

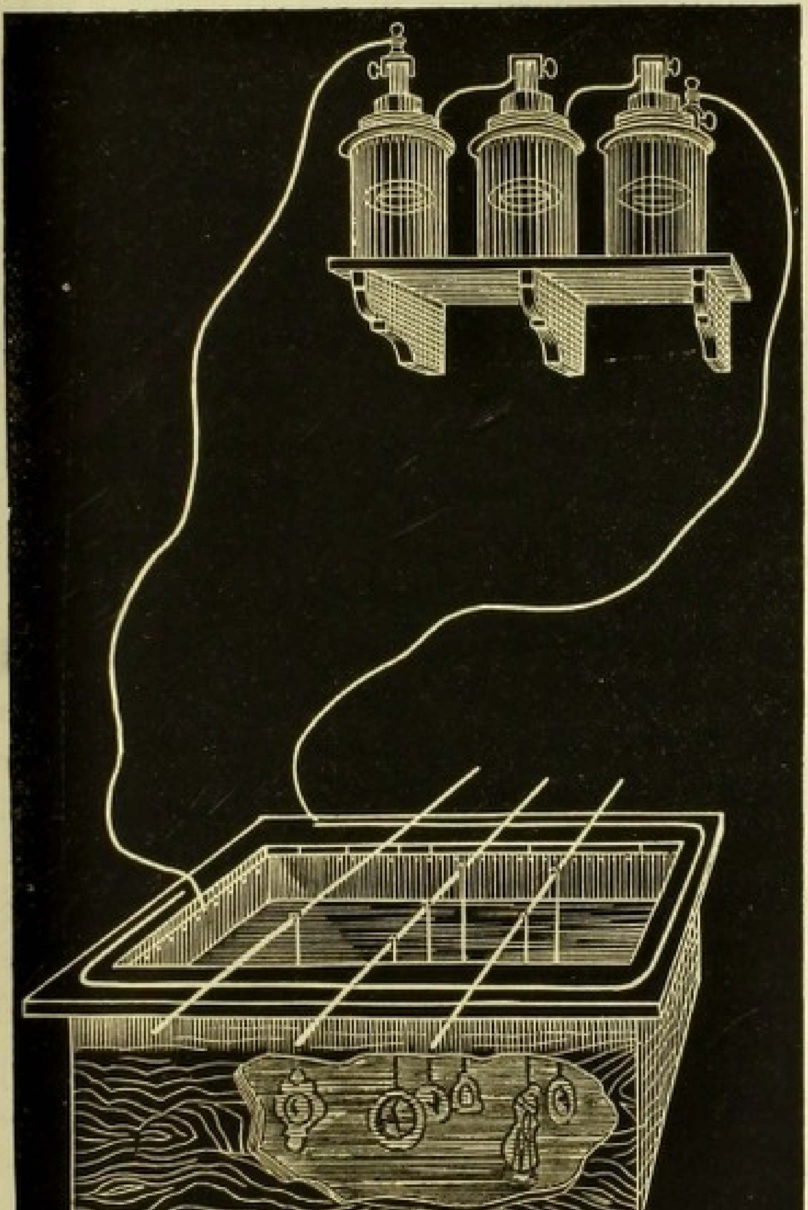
Bisulphite of soda	300 grammes.
Cyanide of potassium	500 "
Acetate of copper	350 "
Aqua ammonia	200 "
Water	25 litres.

Lastly, for those small articles of zinc which are coppered in a perforated ladle, and in nearly boiling baths:—

Cyanide of potassium	700 grammes.
Bisulphite of soda	100 "
Acetate of copper	450 "
Aqua ammonia	150 "
Water	20 to 25 litres.

In order to prepare these different baths, we dissolve in 20 litres of good water (preferably rain or distilled water) all of the salts, except the acetate of copper and the ammonia, which are dissolved in the remaining five litres. These two solutions are mixed, and that of copper and ammonia, which was

Fig. 48.



of a magnificent blue, must become entirely colorless.* The bath is ready to work when subjected to the action of the electric current.

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* It is well understood that, when the liquors are not colorless, there is a deficiency of cyanide of potassium, which must be added until entire decolorization takes place.

The baths intended for working in the cold are put into well-joined tanks of oak or fir wood (Fig. 48), lined inside with gutta-percha. The vertical sides are also covered with one or several sheets of copper, which act as the soluble anode, and the height of which is somewhat below the top edge of the tank. This anode is connected by the clean extremities of a conducting wire to the last copper or carbon (according to the kind of battery employed), that is to say, to the positive pole.

A stout brass wire is fixed upon the top of the tank, without any point of contact with the soluble anode, and is connected by a second wire with the last zinc or negative pole of the same battery.

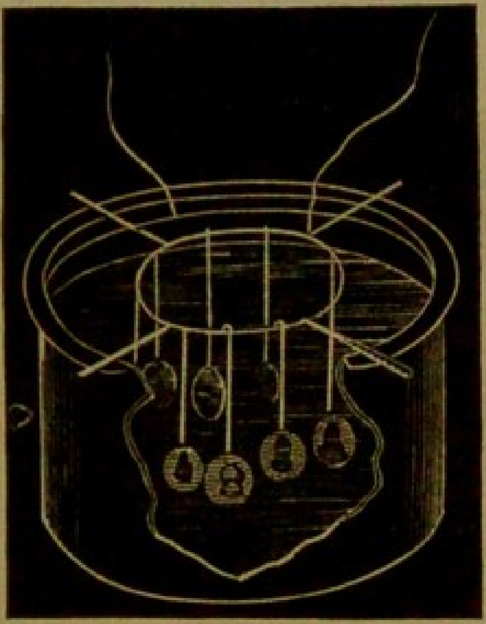
The objects to be coppered are suspended in the bath by means of copper wires, supported themselves upon a stout and clean brass rod, the two extremities of which rest upon the brass conducting wire fixed upon the tank. Several such rods are placed parallel to each other, and the greatest care must be had to prevent any contact with the anode, because the working of the bath would then be immediately stopped. It is needless to say that the objects must have been cleansed in the manner already described.

When the thickness of the deposited copper is very small, the coat is sufficiently bright to be considered finished after drying. But if the operation is more protracted, the deposit appears with a more or less dead lustre on account of its thickness, and, if a bright lustre is desired, we must use the scratch-brush.

The hot baths are put into stoneware vessels (Fig. 49) heated in a water or steam bath, or simply in an enameled cast-iron kettle placed directly over a fire.

The insides are also lined with an anode of copper connected with the positive pole of the battery, and

Fig. 49.



the edges of the vessels are varnished, or support a wooden ring upon which rests a brass circle communicating with the negative pole. The objects to be electroplated hang from this circle.

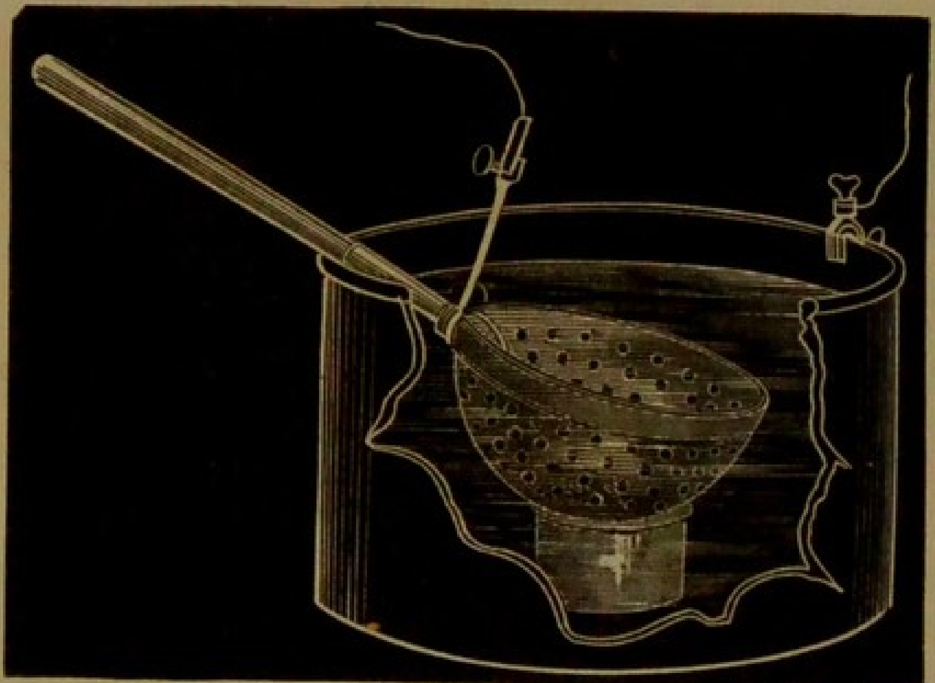
The hot process is much more rapid than the cold, and is especially adapted to those articles which are difficult to cleanse, because any remaining greasy substance is dissolved by the alkaline bath.

The squares of watch keys, the metal parts of portemonnaies, and other small articles, are coppered by this method if we desire a good adherence.

Packages of threaded articles, metallic pens for instance, are not suspended in the bath; they are simply connected with the negative wire in the hand of the operator, and stirred about in every direction in the bath. This agitation permits of the employment of quite an intense current, without danger to the beauty of the deposit.

Small articles of zinc, such a hooks, nails, etc., are disposed in a stoneware perforated ladle (Fig. 50), at the bottom of which is attached a zinc or copper wire, which is wound up around the handle, and is connected with the negative pole of the battery. It is sufficient that one of the small articles touches the wire for all of the others to be affected by the current, since they are in contact with each other. If the bottom of the vessel is metallic, and in order to prevent all contact with those objects which may pass through the holes, the ladle is made to rest upon a porcelain or stoneware ring. A jelly pot without a bottom will do very well.

Fig. 50.

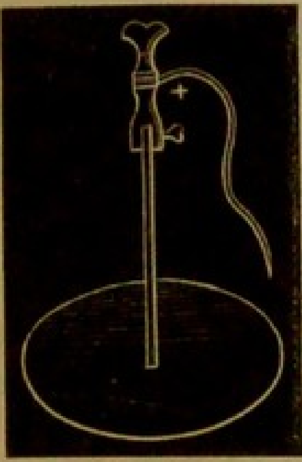


I have found by experience that this disposition is preferable to metallic sieves, especially those of copper or brass, which absorb nearly all the copper deposited.

During the operation, the articles are often stirred or jerked in the ladle, as we do with vegetables in a frying pan. This agitation changes the position and the points of contact of the objects.

It is to be strongly recommended for small articles, to place the anode on top of the ladle, but without any connection with the objects to be coppered. Fig. 51 represents a good disposition in this case of the soluble anode.

Fig. 51.



During the operation, the bath corrodes and slowly dissolves the copper anode; but here theory does not agree with practice, and this solution is not sufficient to compensate for the loss of metal, and to maintain the proper saturation of the liquor. When the deposit is being made too slowly, we must bring up the bath by the addition of a certain quantity of acetate of copper and cyanide of potassium (equal weights).

Some operators substitute the sulphate or the cyanide of copper for the acetate of this metal. The first should be rejected on account of its too great acidity, which uselessly destroys part of the salts of the bath. The second is too expensive, and does not give more satisfactory results than the acetate, which I prefer on account of its comparative cheapness and its perfect neutrality. Moreover, the acetates of potassa, or soda, or ammonia, formed by double decomposition, are without any bad effects during the operation.

Carbonate of copper, recently precipitated and dissolved in cyanide of potassium, may also be employed. This mixture is added to worn-out baths; but it is preferable not to wait until they are worn out, and to make up for the losses by adding, now and then, the double cyanide of potassium and copper already indicated.

When a bath is overloaded with salts, it becomes too dense, and the electricity passes through it with difficulty. The pieces plunged into it receive no deposit, or an imperfect one, although the relative quantities of copper salt and of dissolving agents are in suitable proportions. The working quality will be restored by the addition of water.

When the anode has too large a surface, or remains immersed in non-working baths, the liquor becomes overloaded with copper, turns blue or green, and requires the addition of cyanide of potassium.

It also happens that the anode becomes covered with a brown or white coat preventing its solution; the bath then becomes gradually poorer in metal, and ceases to give a deposit. In this case, we must add some of the solution of acetate of copper in ammonia, until the blue coloration is slow in disappearing. If we have put in too much of it, we correct the excess with cyanide of potassium. To sum up, an attentive and intelligent operator will always be able, with cyanide of potassium and salt of copper, to maintain the substances of his bath in a proper state of equilibrium.

We cannot conclude this article on copper deposits, without saying that some operators copper silver articles before gilding them. The adherence is greater, and the edges and corners do not become so rapidly white by friction.

Large pieces of silverware may be coppered in any of the baths we have mentioned. Very small articles, on the other hand, are simply threaded upon a zinc or iron wire, or placed in a perforated ladle with granules or cuttings of either of these metals. By plunging the whole for a few minutes in a very diluted but very acid solution of sulphate of copper, the zinc or the iron becomes dissolved, and the copper is deposited with adherence upon the silver, which acquires a magnificent pink color.

When the article thus coppered is intended to be gilded or silvered, it is immediately passed through the solution of nitrate of binoxide of mercury, rinsed in cold water, and plunged into the electro-baths, without drying or scratch-brushing.

CHAPTER X.

BRASS DEPOSITS.

Brass Deposits.

Brass deposits are much more frequently used in the arts than those of pure copper. Brass is preferred for those small articles of iron or zinc which are made in imitation of similar ones of brass, which are more expensive. Wood screws, hooks, and rings for furniture and curtains, hooks and eyes for dresses, wires of all sizes for chaplets, etc. etc., are made of iron or zinc plated with brass, so as to resemble those entirely of brass.

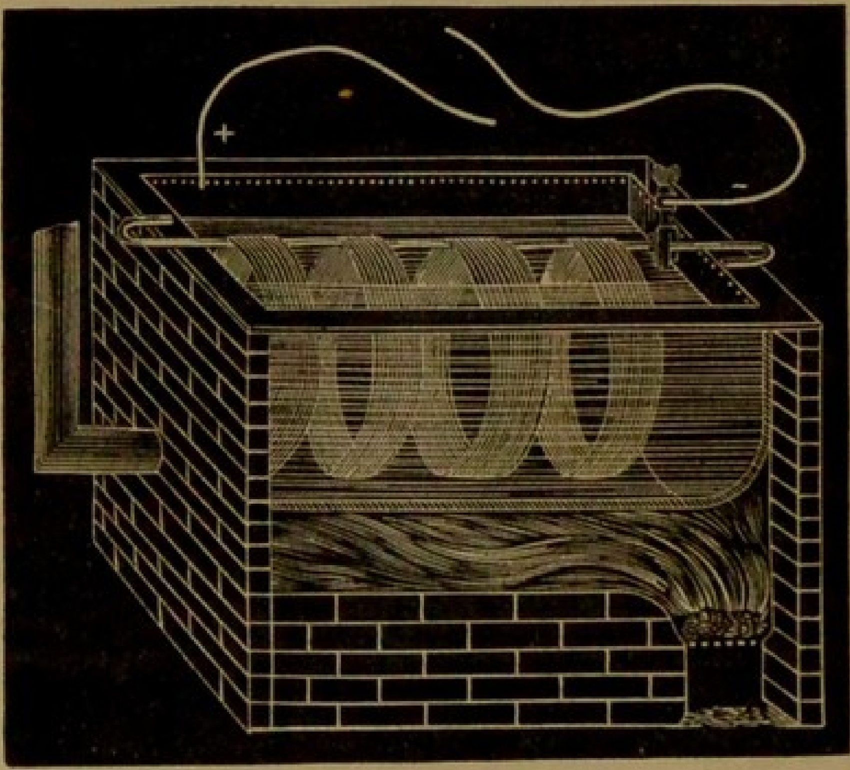
Moreover, all of the manufacturers of *bronze composition*, lamps, clocks, chandeliers, statues, and other articles made of zinc or cheap alloys, always begin by a brass deposit, before the bronze lustre is imparted.

Besides the fact that the bronzing operation is more easy and satisfactory upon brass deposits, there is also the advantage that, if, purposely or by constant use, the surface of the object becomes abraded, there appears the handsome yellow color of the underground, and the whole piece looks as if made of the more costly alloys of copper and zinc, or copper and tin.

The preliminary and finishing operations are the same for brass as for copper deposits. The disposition of the baths and apparatus is also similar, but the formulæ are different.

Heat is seldom employed for brass deposits, although it is preferred by those who electroplate, with this alloy, coils of iron or zinc wire. The proper temperature varies from 55° to 60° C., and the coils

Fig. 52.



dip into the bath one-half or two-thirds of their diameter only.

The bath is put into a sheet iron boiler (Fig. 52) heated by fire, steam, or hot water. The inside is lined with brass sheets connected with the positive pole of a battery. A stout copper or brass rod, in the direction of the length of the boiler, rests upon the edges, and the contact of the two metals is prevented by pieces of India-rubber tubing. The rod is connected with the negative pole by a binding screw.

The binding wire is removed from the coils, and the wires loosened (Fig. 53). The two extremities are bent together, and, with a stronger wire, a triangular handle is formed which contains the whole of a coil, and leaves a certain play necessary for the operation.

Fig. 53.

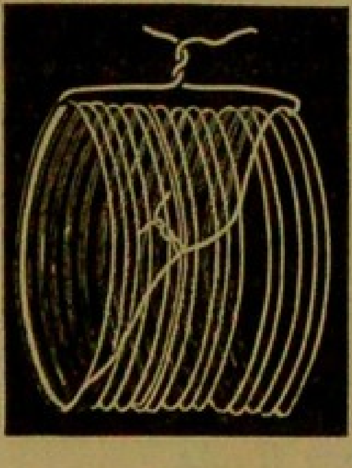
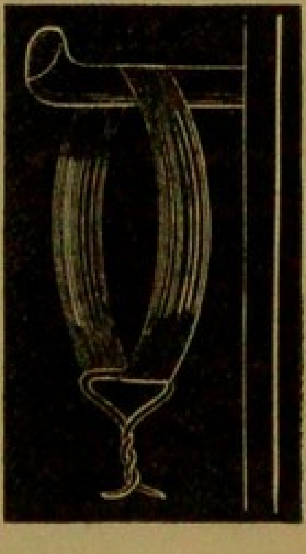


Fig. 54.



The iron wire, thus disposed, is dipped into a pickle of diluted sulphuric acid, and suspended to a strong and round peg held in the wall (Fig. 54), so that the coil may be made to rotate easily. After a scrubbing with wet, sharp sand and a hard brush, the coil receives a primary deposit of pure copper in an apparatus similar to that just described. It is then carried to the bath of brass, and suspended to the horizontal rod. In this position, only a part of the coil at a time dips into the solution and receives the deposit, which, to be continuous, requires that the coil be turned, now and then, one-half or one-fourth of its circumference. Experience has demonstrated that, by dipping the coil entirely into the liquid, which is easily done by giving the proper bends to the supporting rod, the operation is not so successful. With this latter disposition, it is not so easy to spread the wires upon the rod.

The wires are washed, dried in sawdust, and then in a stove, and lastly passed through a draw-plate in order to impart to them the fine polish of true brass wire.

Copper and brass wires are also covered with brass electro-deposits, in order to give them various shades. The brass wires of Lyons and Germany, used for trimmings and epaulets, are thus prepared, whether before gilding or silvering, or simply to arrive at special shades more pleasing than those of pure copper or pure brass. These wires, passed through the draw-plate, are sold under the name of *false gold*. It is evident that the composition of the brass bath must be such as to give a deposit resembling gold.

Formulæ of Brass Baths.

Most of the operators in brass electroplating prefer the ordinary cyanide of potassium to the pure article, on account of its lower price; but as nothing is more variable than the real value and dissolving property of ordinary cyanide, we cannot give exact weights for formulæ into which it enters. We are then obliged to give a general method by which a bath of brass may be prepared with any kind of cyanide. We operate thus:—

Dissolve *together*, in 10 litres of water, 250 grammes of sulphate of copper, and 250 to 300 grammes of sulphate of zinc;

Or, 125 grammes of acetate of copper, with 125 to 150 grammes of fused protochloride of zinc;

And add a solution of 1000 grammes of carbonate of soda, which immediately produces an abundant precipitate of the carbonates of copper and zinc, which is allowed to settle. Then decant the supernatant liquor, and replace it by fresh water two or three times, after as many settlings.

Lastly, pour upon the precipitate 10 litres of water containing in solution one kilogramme of carbonate of soda and 500 grammes of bisulphite of soda; and then, while stirring with a glass or wooden rod, add ordinary cyanide of potassium until the liquor is perfectly clear, or at least until nothing but the grayish-black iron, often found in the cyanide, or the brown-red oxide of iron in the sulphate of zinc, remains in suspension. An additional quantity of from 25 to 30 grammes of ordinary cyanide improves the conducting power of the liquor.

For those persons who employ the pure cyanide of potassium, or the ordinary cyanides with a constant and known composition, I here insert several formulæ which have proved satisfactory in regular everyday work.

First Formula.

COLD BRASS BATH FOR ALL METALS.

Carbonate of copper (recently prepared)	100	grammes.
Carbonate of zinc (recently prepared) .	100	"
Carbonate of soda (crystals)	200	"
Bisulphite of soda	200	"
Cyanide of potassium, pure	200	"
Arsenious acid (white arsenic)	2	"
Water	10	litres.

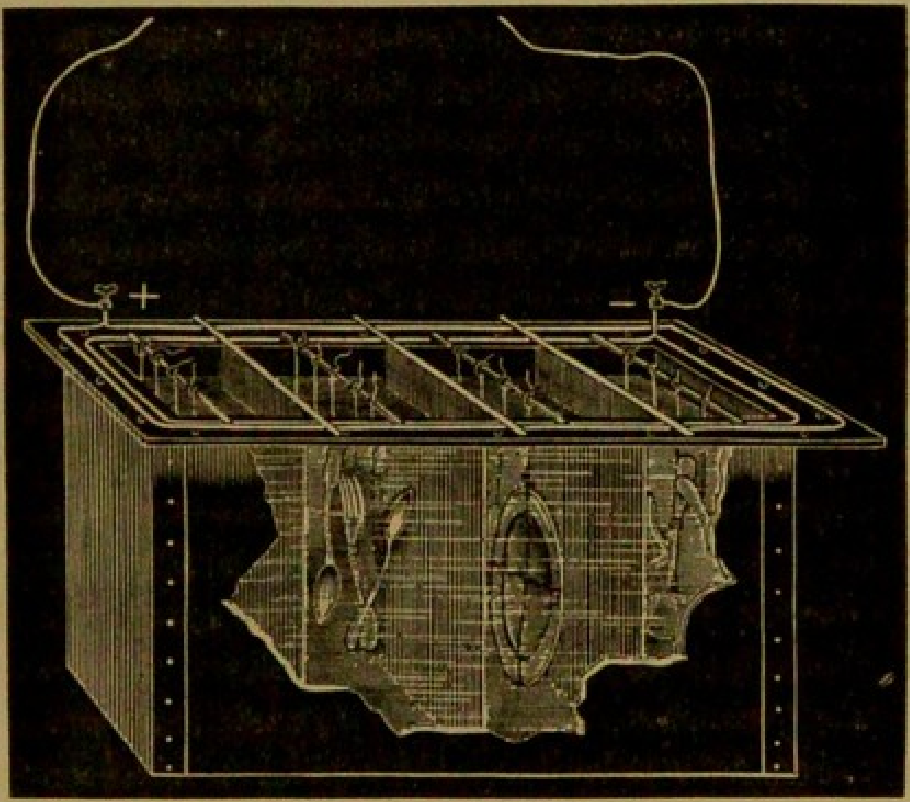
This bath is prepared as follows:—

Dissolve, in two litres of water, 150 grammes of sulphate of copper, and 150 grammes of crystallized sulphate of zinc, and add a solution of 400 grammes of carbonate of soda in one litre of water. A greenish precipitate of mixed carbonates of copper and zinc is immediately formed, which is well stirred and allowed to deposit for several hours. The supernatant liquid, holding the useless sulphate of soda, is thrown away, and replaced by 9 litres of water in which are dissolved the bisulphite and carbonate of soda of the formula. Lastly, dissolve together in the tenth litre of warm water the cyanide of potassium, and the arsenious acid, and pour this liquor into the former one, which is rapidly decolorized, and forms the brass-bath. Filter, if necessary.

Arsenious acid causes the deposit to be bright, but too great a proportion of it may give a white or steel-gray color to the metal: and it often happens that with new baths the first articles plunged into it receive a deposit having these shades. The inconvenience is slight, since the yellow color soon predominates. Brass electroplaters say that arsenious acid cleans the baths, because it prevents deposits of a dull color, or because, being transformed into arsenic acid, it prevents deposits from containing oxides of copper or zinc. The arsenious acid may be replaced by the soluble arsenites of potassa, soda, or ammonia, but then the proportion must be doubled.

The baths for electroplating in the cold are generally kept in wooden tanks lined inside with gutta-percha, which resists their action for a long time. The articles to be plated are suspended by copper or brass hooks to stout rods of the same metal, all connected with the last zinc of the battery (Fig. 55).

Fig. 55.



The sides of the tank are also lined with one or several brass sheets (united together) connected with the last carbon or copper of the same battery, the intensity of which is regulated by the surface of the articles to be electroplated.

Theoretically speaking, such a bath should be maintained at the proper metallic strength by the metal dissolved from the brass anodes, under the action of the electric current. But experience shows that it is not so, and that the losses are to be repaired by additions of copper and zinc salts, and arsenious acid, dissolved in cyanide of potassium. It is quite impossible to state the necessary proportions for maintaining the bath in proper working order; and the intelligent operator will determine the needed substances from the rapidity of the deposit, its color, etc.

If the deposit be too slow, he will try whether the bath will absorb the salts of copper and zinc, without the addition of cyanide.

If the coat of brass has an earthy and ochreous appearance, and especially if the liquor be blue or green, he will add cyanide of potassium until perfect decolorization takes place.

If the deposit be dull and unequal, a small quantity of arsenious acid, dissolved in cyanide, is needed.

If the deposit be too red, the operator will add the salt of zinc, alone, or dissolved in cyanide.

If the deposit be too white, or of a greenish-white color, he will add the salt of copper alone, or dissolved in cyanide.

Lastly, when, after long use, the bath has become overloaded with salts, the specific gravity is too great for the easy passage of the electric current, and the liquor must be diluted with water until it works satisfactorily. The specific gravity of a brass bath may vary, without inconvenience, from 5° to 12° of Baumé's hydrometer.

It is well understood that the pieces, before brass electroplating, must be perfectly cleansed in the manner indicated for zinc, iron, etc.; and if, notwithstanding the proper care, the brass deposit be irregular, the objects will be removed from the bath, rinsed, scratch-brushed, and put again into the bath until the color and the thickness of the deposit are satisfactory. They are then scratch-brushed anew, and, if necessary, rinsed in hot water, dried in warm sawdust of white wood, and put in the stove-room. The last three operations are indispensable for hollow-pieces.

We now give several formulæ based upon the employment of ordinary cyanide of potassium, which was alone to be found at the time of the first edition of this work. As many brass electroplaters have become accustomed to them, it is likely that they will be satisfied to find them here.

Second Formula.

BRASS BATH FOR STEEL, WROUGHT AND CAST IRON, AND TIN.

Dissolve together, in 8 litres of pure or rain water:—

Bisulphite of soda	200 grammes.
Cyanide of potassium No. 2	500 "
Carbonate of soda	1000 "

And to this solution add the following, made in 2 litres of water:—

Acetate of copper	125 grammes.
Protochloride of zinc (neutral) . .	100 "

The two liquors become colorless by their admixture. (Ammonia should be rigorously proscribed from brass electroplating baths for iron, at least for solutions worked in the cold.)

Third Formula.

BRASS BATH FOR ZINC.

Pure or rain water	20 kilog. or litres.
Bisulphite of soda	700 grammes.
Cyanide of potassium No. 2 . .	1000 "

To which add the following solution:—

Water	5 kilog. or litres.
Acetate of copper	350 grammes.
Protochloride of zinc . . .	350 "
Ammonia	400 "

The filtered bath is colorless, and gives, under the action of the battery, a brass deposit of a very fine shade, which may be made to vary from red to green, by increasing the proportion of copper, or that of zinc. The anode is of brass, of course.

The difficulty in brass electroplating, especially with small baths, lies in keeping the uniformity of the color of the deposit. We understand that the galvanic current, having simultaneously to decompose two salts offering each a different resistance, must, according to its intensity, vary *ad infinitum* the composition and the color of the deposited alloy. It will be found by practice that a feeble current decomposes principally the copper salt, and results in a red deposit; on the other hand, too great intensity in the current, decomposes the solution of zinc too rapidly, and the deposit is a white or bluish-white alloy.

We observe these phenomena especially with newly prepared baths, and it is not uncommon to see that the side of an object opposite the soluble anode is covered with a fine brass deposit, while the other has a reddish color. It is an indication that there is irregularity in the conducting power of the bath, which, however, becomes more regular after being used for some time.

The first inconvenience of a red deposit, due to a want of intensity in the current, may be remedied by increasing the number of the elements of the battery, or employing stronger acids, or decreasing the number and the surfaces of the objects to be plated. On the contrary, the other inconvenience of white deposits will disappear by diminishing the number of elements, or by increasing the surfaces to be covered.

The deposit may also be modified by substituting for the brass anode, either a sheet of pure copper, or one of zinc, or by simply hooking one of these sheets to the brass anode.

A bath of pure copper will be transformed into one of brass by the use of a zinc anode; and conversely, an electro-bath of brass will become one of copper by the aid of a copper anode.

The disposition of the baths for brass plating varies with the nature and the size of the objects to be plated; but it is always necessary to have all the articles suspended at about equal distances from the anodes. With small articles, the bath may be subdivided by several anodes forming partitions, as in Fig. 55, page 103, so that each loaded rod is between two anodes, or smaller separate baths employed. The anodes are removed when the bath does not work. Small articles which cannot be threaded upon a wire, like nails, wood screws, etc., are plated in a perforated stoneware ladle, as we have explained in Chapter IX.

In order that the brass electroplating of zinc and copper should be sufficiently lasting, the deposit must not be too thin, and must be scratch-brushed, rinsed in water rendered slightly alkaline by quicklime, and thoroughly dried in a stove. Its lustre and color are thus enhanced. But, generally, and especially when the bronze lustre is to be imparted afterwards, the articles are simply brass electroplated by remaining in the bath for 10 to 25 minutes.

We are not acquainted with satisfactory processes for brass plating by simple dipping. Nevertheless, a color resembling that of brass is given to small articles of iron or steel, by a long stirring in a suspended tub which contains the following solution :—

Water.	1 litre.
Sulphate of copper	4 to 5 grammes.
Protochloride of tin (crystallized) .	4 to 5 "

The shades are modified by varying the proportions of the two salts. It is by an analogous process that, at l'Aigle, are brass plated the iron pins called *Californiennes* and the large pins or *houseaux*, used in Brittany for cleaning butter.

NOTE.—Cast and wrought iron, lead and its alloys, require brass solutions richer in the metals than is the case when depositing brass upon zinc or its alloys. The battery power should also be greater.

Certain brassing baths are improved by a small proportion of chloride of tin dissolved in caustic potassa.

According to A. Watt, pewter is more easily coated with brass than lead, but the same bath may be used for either. Lead and pewter should be cleansed in a solution of about four ounces of nitric acid to the gallon of water, in which they remain for half an hour. They are then rinsed, scoured with sand, and rinsed again. A good battery power and a large surface of anode are necessary, especially at the beginning of the deposit.

The proper temperature of the bath for brassing lead, pewter, and tin is about 90° F.

Stirring articles in a brass bath has a tendency to cause the deposition of copper alone.—*Trans.*

CHAPTER XI.

TINNING—TINNING-BATH, BY EXCHANGE, FOR IRON —ELECTRO-TINNING—TINNING BY THE METHOD OF DOUBLE AFFINITY—TINNED CAST IRON.

Tinning.

WE have already said that, as with copper deposits, tinning is often the complement of the cleansing process for certain metals, like wrought and cast iron, upon which precious metals are to be deposited. We might, therefore, confine ourselves to the tinning of cast iron; but, as the tinning of a multitude of different articles is, at the present time, an important industry, we believe that a description of all the operations and processes will be found instructive and useful.

Tinning by the wet way is effected by three distinct methods:—*

1. BY EXCHANGE, that is to say, by the solution in a tin liquor of a small quantity of the metal immersed in it, and which takes the place of an equivalent proportion of tin deposited in the form of an adherent layer upon the other metal. This process does not give sufficiently lasting products, and is but a kind of whitening of the object, like that obtained with silver by simple dipping.

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* I have taken out, either in my own name or in connection with Mr. E. Boucher, several patents on the tinning processes described further on; but these patents have now expired.

2. BY THE GALVANIC WAY, that is to say, by the decomposition of certain tin solutions by means of separated batteries. This mode of operation is similar to that already described for copper and brass deposits.

3. BY THE METHOD OF SUBSTITUTION OR OF DOUBLE AFFINITY, which means that, by immersing at the same time in a tin solution two different metals kept in contact with each other, zinc and iron for instance, the zinc, instead of becoming tinned as by the first method, will dissolve and take the place of the tin, which, in its turn, will become deposited in uniform and adherent coats upon the iron.

Tinning Bath, by Exchange, for Iron.

This first process is of little importance as a protection for iron against oxidization, since the layer of tin is a mere film. However, it may be useful as a complement of the cleansing process, when thicker coats of tin are to be applied by the other two processes.

For the preparation of this bath, dissolve with the aid of heat, in an enamelled cast-iron kettle holding 20 litres of water:—

Ammoniacal alum	300 grammes.
Protochloride of tin (fused) . . .	10 "

And, as soon as the solution boils, the objects of iron, previously cleansed and rinsed in cold water, are steeped in it. They are immediately covered with a film of tin of a fine white dead lustre, which may be rendered bright by mutual friction in a bag or in a suspended tub.

The bath is maintained at the proper strength by small additions of fused protochloride of tin.

This bath is also very convenient for a preliminary tinning of zinc; but, as for iron, the pellicle is too thin to be resisting. The objects thus tinned or whitened present quite a crystalline appearance, and are brightened by the scratch-brush.

For tinning zinc by simple dipping, the ammoniacal alum may be replaced by any other kind of alum, and even by the sulphate of alumina; but experience proves that, for wrought and cast iron and steel, we cannot make this substitution.

If we desire, with the above solution, to tin other metals than zinc or iron, we must have recourse to the battery; but in this case I prefer using other special solutions, the description of which will follow.

Electro-Tinning.

Electro-deposits of tin may be obtained with many kinds of tin solutions; but the results are more or less satisfactory, and the methods more or less practical, as regards the facility of the operation, its cost, the strength and the beauty of the tinning.

The bath, which appears to me to possess all of the conditions desired by the operator, is composed of—

Rain or distilled water . . .	500 litres.
Pyrophosphate of soda or potassa .	5 kilogrammes.
Protochloride of tin, crystallized .	600 grammes.

Or, what is better, 500 grammes of the same salt fused, in order to have it free from an excess of acid.

The water is put into a tank entirely lined with anodes of tin sheets, united together and connected with the positive pole (carbon or copper) of the battery. The pyrophosphate of soda or potassa is next introduced and stirred in, and, when dissolved, the protochloride of tin is put into a sieve of copper half immersed in the solution. A milky-white precipitate is immediately produced, which disappears by continued agitation. When the liquid has become clear and colorless, or slightly yellow, the tinning bath is ready, and we have but to dispose upon transverse metallic rods, connected with the negative pole, the previously cleansed objects which we desire to tin.

The anodes are not sufficient to keep the bath saturated, and when the deposit takes place slowly, we add small portions of equal weights of tin salt and pyrophosphate. The solution of these salts should always be made with the aid of the sieve, since, if fragments of protochloride of tin were to fall on to the bottom of the bath, they would become covered with a slowly soluble crust preventing their solution.

The tinning thus obtained upon any kind of metal, and with equal facility, is quite resisting, and has a white and dead lustre resembling that of silver. A bright lustre will be obtained with the scratch-brush or the burnishing tool.

The reduction of these baths requires quite an intense current, and, as the first cost and the working of the batteries are expensive, we prefer, for small or large pieces, the third method, which we nearly always use in our own works.

Tinning by the Method of Double Affinity.

A bath for tinning may greatly vary in its composition; however, we here give two formulæ with which we arrive at rapid and sure results, with a preference for the second, which has no other inconvenience than to require the use of a salt not always found everywhere with a constant composition.

First Formula.

Distilled water	300 litres.
Cream tartar (bitartrate of potassa)	3 kilogrammes.
Protochloride of tin	300 grammes.

The powdered cream of tartar is dissolved in 200 litres of warm water, and the tin salt in 100 litres of cold water. The two mixed solutions become clear, and the resulting bath has an acid reaction.

Second Formula.

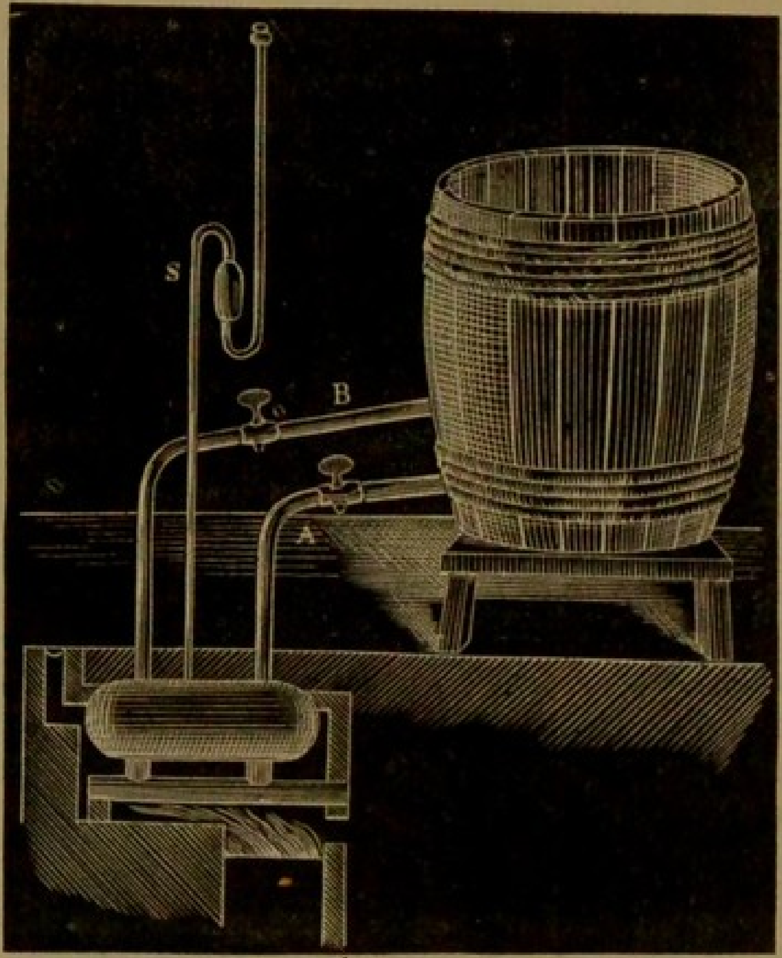
Distilled water	300 litres.
Pyrophosphate of potassa or soda	6 kilogrammes.
Protochloride of tin, crystallized (*i. e.*, acid)	600 grammes.
Or, the same fused (*i. e.*, neutral)	400 "

The whole is dissolved at the same time upon a metallic sieve, and, after stirring, the bath is clear.

Either of these solutions is kept in a hogshead with the top off. This hogshead or tank (Fig. 56) receives at its lower part two superposed tubes connected with a small boiler built below the level of the bottom of the tank. The tube A, starting from the bottom of the tank, reaches nearly to that of the boiler; on the other hand, the upper tube B, distant six or eight centimetres from the bottom of the tank, is connected with the top of the boiler; lastly, the safety tube S prevents any explosion, should there be an obstruction in the other tubes.

We readily understand that, with such a disposition, and with the boiler and tank filled with liquid, as soon as heat is applied the expanded and lighter

Fig. 56.

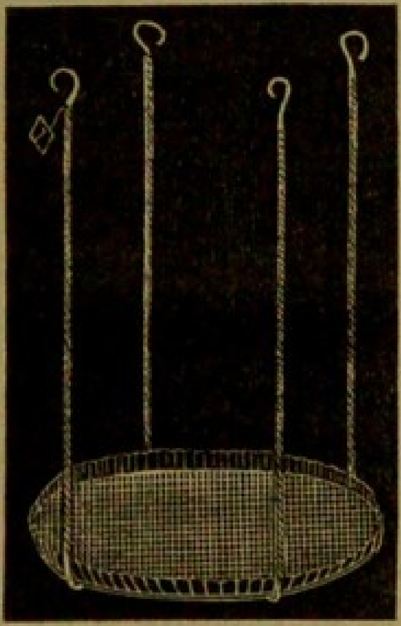


liquid will rise through the pipe B, while the colder and denser one will go into the boiler through the pipe A. A continual circulation is thus obtained, which is not only satisfactory as a means of heating, but also keeps up a constant agitation of the contents of the bath, and mixes the impoverished lighter portions with the richer and denser ones. A small quantity of water, or even mercury, is introduced into the upper branch of the tube S, to prevent the escape of the steam.

Large pieces, like cast-iron culinary vessels, are simply cleansed and rinsed, and piled in the bath with a few fragments of zinc. It is, however, preferable to use spirals of zinc, since, with less points of contact, there is less danger of staining the articles. On an average, the surface of the zinc should be the thirtieth of that of the tinned articles.

If, on the other hand, we have to tin very small objects, such as pins, nails, hooks, etc., we dispose them in layers two to three centimetres thick upon perforated plates of zinc, which allow of the circulation of the liquid, and have their edges turned up so as to prevent the objects from falling off. These plates (Fig. 57) are disposed upon numbered supports in order to remove them from the bath in the inverse order in which they have been put in.

Fig. 57.



These zinc plates must be scraped and cleaned when necessary, for presenting fresh surfaces of zinc instead of a white crust which prevents its contact with the articles to be tinned.

The length of the operation varies from one to three hours. Then all the objects are removed, and 250 grammes of pyrophosphate and as much of fused protochloride of tin are dissolved.

During the time the solution is taking place, the large articles are scratch-brushed, and the small ones stirred with a three-pronged iron fork in order to change the points of contact. The objects are then again steeped in the bath for at least two hours. These two immersions and that length of time are necessary for a good tinning. The large pieces are lastly scratch-brushed again, and the small ones rendered bright by one of the methods of mutual friction. The operation is ended by drying the whole in dry and warm sawdust of fir wood.

It is by this last process that we tin, inside and outside, those culinary cast-iron vessels sold under the name of *fonte argentine* (silver-like cast iron). These vessels, besides a bright and pleasing appearance, have the advantage of never communicating any taste, smell, or color to the food cooked in them, even when the tinning, by long use, has completely disappeared. This is due to the solution by the bath itself of the sulphides, phosphides, and other impurities of the raw cast iron.

If we observe that the tin deposit is gray and dull, although abundant, we prepare the bath, once or twice, with the acid crystallized protochloride of tin. With a very white deposit, but blistered and without adherence or thickness, we replace the acid salt by the fused one. In this latter case, we may also diminish the proportion of tin salt, and increase that of pyrophosphate.

As a great deal of the success of the operation depends upon the quality of the pyrophosphate, I shall indicate, in the brief treatise on chemistry at the end of this work, the process of obtaining it in a satisfactory way.

When a tinning bath has been worked for a long time, the liquor should be decanted to separate the pyrophosphate of zinc formed. And when, after several years, the bath is entirely used up from the alteration of the salts, it should be kept in preserving tubs where we put, after cleansing, the objects to be tinned.

Zinc is well tinned in a similar bath, but the proportions of the constituent part are modified as follows:—

Distilled water	300 litres.
Pyrophosphate of soda . . .	5 kilogrammes.
Protochloride of tin (fused) . .	1 "

A thin tinning is obtained by simple dipping, and one of any thickness by the aid of the battery.

We must not confound the tinning process, which we have just described, with the whitening by tin, practised from time immemorial by manufacturers for pins, copper nails, piano pin nails, etc., and which produces a "vapor of tin" only, so unweighable is the quantity deposited. This whitening by tin is effected by boiling for two or three hours, in long copper troughs, crude cream of tartar with tin plates supporting a layer of about two centimetres of brass or copper pins. The whole charge is composed of alternate layers of pins and tin plates, so that each layer of pins is between two tin plates.

This whitening process will not succeed with iron unless an intermediary coat of copper has been deposited.* Nevertheless, the iron will not be protected against oxidization, and we must have recourse to the above-described methods.

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* The processes of tinning iron previously coppered have been replaced with great advantage by those described in this chapter, at the works of Messrs. A. Tailfer & Co., at L'Aigle (Orne), where is manufactured the iron pin called *argentine* or *anoxyde*.

CHAPTER XII.

GILDING—GILDING BY DIPPING—PREPARATION OF THE GOLD BATHS FOR DIPPING—COLORING PROCESS.

Gilding.

GILDING, in the arts, is obtained by two very distinct methods: The wet and the dry way.

The first method appears to be the only one needed in this work, and, had these chapters been written a few months sooner, we should have confined ourselves solely to the processes by the wet way. But the recent demands of the trade, which often requires the two kinds of gilding upon the same piece, render it necessary for us to give some information upon what is called the "old processes."

Complete gilding works ought to be able to execute what is called the *demi mat* (half-dead lustre), that is to say, gilding the same object by the wet and the dry way.

Gilding by the wet way is effected either by simple affinities or chemical reactions, and receives then the name of *gilding by dipping;* or, by the combined aid of chemical reactions and electricity, which is called *gilding by the battery*, *electro* or *galvano-gilding*, and *gold electroplating*.

Gilding by dipping or simple immersion has a great analogy with the old processes of gilding by stirring, by the rag, by the cork, etc., all of which result in mere films of gold without firmness and lasting properties.

Electro-gilding, on the contrary, corresponds with the old process of gilding by fire or mercury. The thickness of the deposit is entirely within the will of the operator; but we must say that, notwithstanding certain advantages, electro-gilding is, even at the present day, far inferior to the gilding by fire in regard to firmness, the preservation of the under surfaces, and especially the power of resistance to the action of the noxious gases of the atmosphere. This criticism, however, should not prevent us from acknowledging the very great improvements made in the art of electro-gilding of late years, and to hope that soon the products by both processes will be equal in quality.

Gilding by Dipping.

This manner of gilding is practised upon small articles of false jewelry, made of copper, brass, bronze, or maillechort.

The baths employed contain the gold in the form of a double salt of protoxide, and should fulfil the following conditions:—

The solution must possess little stability, that is to say, be decomposed and abandon its gold under feeble influences, and it should dissolve the copper plunged into it in a quantity proportional (equivalent) to that of the deposited gold, thus forming a new double salt in which the copper is in the same degree of oxidization as the gold.

When, as is more ordinarily the case, the articles have been previously amalgamated, it is mercury and not copper which is substituted for gold in the solution.

In order to explain, we should say that, if, in a bath of double pyrophosphate of potassa and protoxide of gold, we dip a well-cleansed piece of copper, this metal will be coated with a pellicle of gold, and will restore to the liquor a proportional (equivalent) quantity of copper, so that the former salt will be transformed into a double pyrophosphate of potassa and protoxide of copper.

Preparation of the Gold Baths for Dipping.

The best of these baths is composed of—

Distilled water	. 10 litres.
Pyrophosphate of potassa* or soda	. 800 grammes.
Hydrocyanic acid of $\frac{1}{8}$ (prussic acid)	. 8 "
Perchloride of gold (crystallized) .	. 20 "

This quantity of chloride represents ten grammes of pure gold treated by aqua regia.

Put nine litres or kilogrammes of distilled water in a porcelain dish or capsule, or in an enamelled cast-iron kettle, and add, by small portions at a time, and stirring with a glass rod, the 800 grammes of pyrophosphate; heat afterwards to complete the solution, filter, and let it cool off.

Distilled or rain water is necessary, because the lime-salts contained in ordinary water decompose

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* As the pyrophosphate of potassa does not crystallize, its composition is often variable, and is too much or too little basic. The pyrophosphate of soda is most generally employed in the arts, and is obtained by melting, at a white heat, the ordinary crystallized phosphate of soda. The pyrophosphate of soda may be obtained in the form of crystals, which is a proof of a definite composition.

part of the pyrophosphate; and if this latter salt were all at once put into the liquor, it would form a thick mass requiring a very long time to dissolve.

On the other hand, the chloride of gold is prepared by introducing into a small glass flask or balloon—

Pure gold finely laminated	10 grammes.
Hydrochloric acid, pure	25 "
Nitric acid, pure	15 "

The flask is slightly heated, and, after a few seconds, effervescence and abundant nitrous vapors result. In a few minutes, the gold has entirely disappeared, and there remains a reddish-yellow liquor.

The flask is then put upon a sheet of iron pierced in its centre with a hole three centimetres in diameter, and supported by a tripod. The whole is heated by a gas or alcohol lamp until the excess of the acids is evaporated. Indeed, too much acidity may cause great irregularities in the working of the bath, and even prevent its action altogether.

An excess of nitric acid causes the "bumping" of the heated liquors, and may result in the overthrow of the whole; it is, therefore, preferable to have the hydrochloric acid predominating. Bumping may be stopped by the careful addition of a little hydrochloric acid.

The evaporation is finished when vapors escape slowly from the flask, and when the liquid has become of an oily consistency and of a deep hyacinth red color. The flask is then removed from the fire by means of wooden pincers, and set to cool upon a ring of plaited straw. If we desire a more rapid evaporation, we may seize the neck of the flask between the wooden pincers, and heat it upon ignited charcoal, or the alcohol lamp; but then we must often agitate the liquid to prevent part of the gold from returning to the metallic state.

The well-prepared chloride of gold, when cold, forms a saffron-yellow crystalline mass. If the color is red, it has been too much evaporated, and will do very well for electro-baths; but for dipping baths, it must be heated again after a small addition of the two acids.

It frequently happens that, by want of care, the preparation is burned off; that is to say, the perchloride of gold, by too protracted a heat, has passed to the state of insoluble protochloride, or even of metallic gold. The treatment must then be begun again with aqua regia, *i. e.* the indicated mixture of pure nitric and hydrochloric acids.

The perforated sheet of iron, upon which the flask rests, is intended to prevent the action of heat upon the sides of the vessel, and which will decompose the films of chloride of gold wetting the flask at these places.

I do not like the employment of wide and shallow vessels, like capsules and porcelain dishes, for the preparation of the chloride of gold, because, during the effervescence due to the action of the acids upon the metal, a sensible proportion of the liquor is projected over and lost. And, unless large glass vessels are employed, I do not think that the sand-bath is useful. With sufficient care, we may heat good flasks directly upon a fire, and for many years, I have every day thus prepared 30 grammes of gold without any accident.

When the chloride of gold is cold and crystallized, we dissolve it in the flask with a little distilled water, and throw the solution upon a paper filter placed in a glass funnel supported by the neck of a clean bottle. The object of this filtration is to separate a small quantity of silver always found in the gold of the trade. The chloride of gold is very soluble, while that of silver is perfectly insoluble. The flask and filter are thoroughly rinsed with the unemployed tenth litre of water, so as to introduce all the gold into the bath.

The filtered solution of chloride of gold is poured into the cooled one of pyrophosphate, and the whole is stirred with a glass rod. Lastly, the 8 grammes of hydrocyanic acid are added, and the bath is brought up nearly to the point of ebullition for use.

If the solution of pyrophosphate be still tepid, it is preferable to add the prussic acid before the chloride of gold, and I think that it is better to do so always.

Hydrocyanic or prussic acid is not absolutely necessary for the success of the gilding, and many operators do not use it at all; but, then, the bath is too easily decomposed, and the gold is precipitated too rapidly upon the objects steeped in it.

At the time when the solutions are mixed in the cold, the liquor is yellow or greenish-yellow; but it must become colorless by the increase of temperature. Nevertheless, it sometimes happens that the liquor becomes currant red, or wine-lees violet, which is an indication that there is too little hydrocyanic acid, and that we must add it, drop by drop, until the liquor becomes colorless. An excess of this acid is objectionable because the deposit of gold is rendered too thin, and may cease entirely, in which case the bath cannot be decomposed except by electricity. At all events, there is a very simple method of keeping the baths in good working order, and which consists in adding prussic acid gradually to those too rich in gold; and, conversely, correcting the excess of prussic acid with a small proportion of chloride of gold, until the gilding is produced without difficulty and of the proper shade.

Prepared in the above-mentioned manner, the bath will produce a very fine gilding upon well-cleansed articles, which must also have been passed through a very diluted solution of nitrate of binoxide of mercury, without which the deposit of gold is red and irregular, and will not cover the soldered portions.

The articles to be gilded must be constantly agitated in the bath, and are supported by a hook or in a stoneware ladle perforated with holes, or in baskets of brass gauze, according to their shape or size.

All the minutiæ in the preparation, which we have indicated, are far from being observed by gilders well conversant with this kind of work. For the preparation of their baths, they are satisfied with dissolving their pyrophosphate in ordinary water, and adding at the same time the prussic acid. Their gold is dissolved in the aforementioned manner, and its solution, without previous filtering, is added to that, more or less cold, of pyrophosphate.

Gilders by dipping usually employ three baths, disposed in close proximity one to the other, and heated upon the same furnace by charcoal or gas.*

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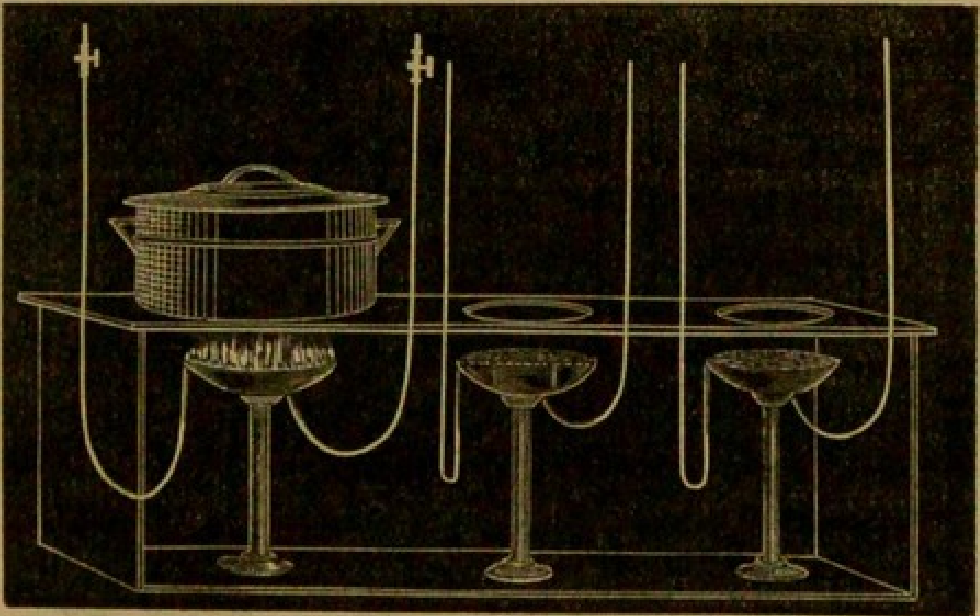
* The gas furnace, which is the easiest and cleanest of all (Fig. 58), is made of a sheet-iron box perforated on top by three holes intended to support the bottoms of three kettles. Inside, and under each kettle is a gas apparatus composed of five or six jets burning with a blue flame, that is to say, by an arrangement which allows of the admixture of 1 part of gas with 5 or 6 of air.

The first bath is nearly deprived of gold by a previous operation, and is used for removing all excess of acid which may remain upon the articles to be gilded. The second bath still retains some gold, but not enough to give a sufficiently rich and dark gilding. The pieces passed through it absorb the remaining gold at the same time that they begin to receive the precious deposit, which will be finished in thickness and shade in the third bath.

The fresh bath of to-day becomes the second of to-morrow, and the second takes the place of the first, and so forth.

Fig. 58.



These jets are often replaced by a kind of rose perforated burner, inside of which the mixture of gas and air takes place. This apparatus has two separate stopcocks, one connected with a small central jet, and the other with the rose burner. When the two cocks are opened; the gas is lighted at all the apertures, and the baths are rapidly heated up to the point of ebullition. The cock of the rose burner is then turned off, and the central jet is sufficient to keep up the proper temperature.

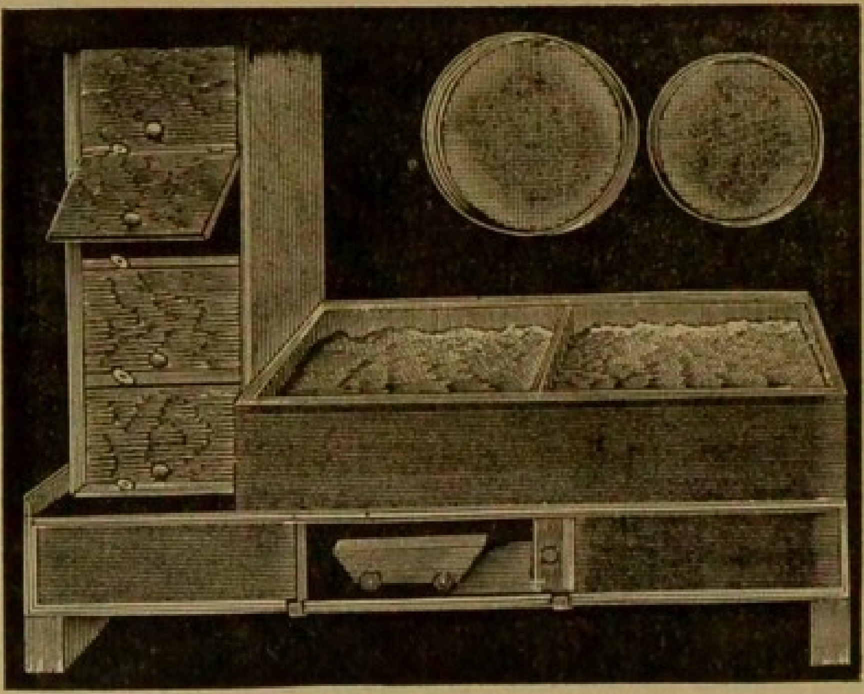
This method of operating allows of much more gilding with a given quantity of gold, than with one bath alone. It explains the possibility for well-organized works, to produce a cheaper and finer gilding than can be arrived at with inferior dispositions.

The gilding is made in a few seconds, and the finishing operations consist in rinsing in fresh water, drying in dry and warm sawdust, and burnishing, if desired.

A good sawdust should be free from impurities and resin, and come from white woods, especially from fir, poplar, and linden. That of oak and walnut blackens the gilding; and that of boxwood, although often employed, is not sufficiently absorbing, and clogs the wet pieces.

Sawdust should be neither too fine nor too coarse. It is generally kept in a box (Fig. 59) with two partitions, and the bottom of which is of zinc. This box is supported upon a frame of sheet iron or brickwork,

Fig. 59.



which admits, at its lower part, of the rolling of a large foot-stove filled with baker's charcoal (braize), which gives a regular and gentle heat, and keeps the sawdust always dry. The same apparatus is also employed for heating a small stoveroom, the partitions of which are of wire gauze, and where the hot air circulates freely. The doors of this stoveroom are hinged at the top, so that they will always close down without being attended to. It is there that we finish the drying of those pieces having hollow parts which the sawdust cannot reach. We also dry there the resist varnishes, the articles silvered with the brush, etc.

After drying very small articles in sawdust, the latter substance is removed by sieves of various numbers or by winnowing.

Coloring process.

It happens sometimes that, from forgetting some of the precautions indicated, the gilding is dull and irregular in color. We must then have recourse to the coloring process, conducted as follows:—

Melt together in their water of crystallization, and at about 100° C., equal parts of—

Sulphate of iron (green copperas).
Sulphate of zinc (white vitriol or copperas).
Sulphate of alumina and potassa (potash alum).
Nitrate of potassa (saltpetre).

Smear the imperfectly gilt articles with the mixture, so as to have them entirely covered, and put them in the centre of a furnace (Fig. 60) where the charcoal burns between the sides and a cylindrical and vertical grate. The hollow central portion, where the heat radiates, receives the objects. Fig. 61 represents a

Fig. 60.

vertical, and Fig. 62 a horizontal, section of the apparatus.

Fig. 61.

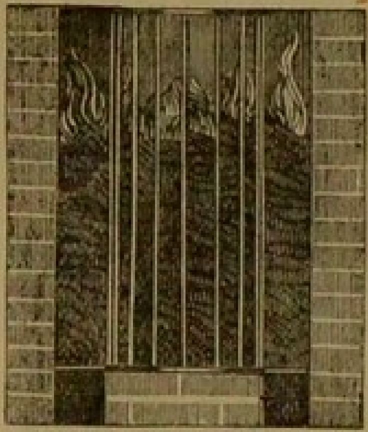
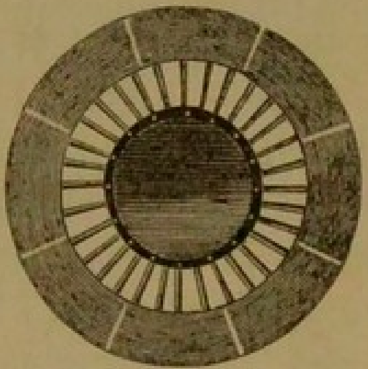


Fig. 62.



The salts begin to dry, fuse afterwards, and all the mass acquires the dull appearance of yellowish clay. When the moistened finger is presented to one piece, and a slight hissing sound is heard, the heat has then been sufficiently raised, and all the articles are rapidly thrown into a very diluted solution of sulphuric acid, where the external coating of salts is soon dissolved. The jewelry then presents a warm and uniform shade of color.

This process will evidently only suit when all the parts of the copper articles are entirely gilt by the first operation. If they are not, the ungilt portions will show themselves by a red coloration, and the articles must then be deprived of their gold, cleansed, and gilt anew. We shall soon indicate the processes by which we arrive at these results without injury to the copper or its alloys.

At the present time, most of the gilders by dipping gild also with the battery; and, when the first gilding is imperfect, instead of coloring by the process just described, they put the articles for a few moments into the electro-bath, which is preferably worked hot, and the composition of which shall be given further on, at the beginning of Chapter XX.

CHAPTER XIII.

SEQUEL TO GILDING BY DIPPING.

OR MOULU—COLORED GOLDS—GREEN AND WHITE GILDING—GILDING SILVER BY DIPPING.

Sequel to Gilding by Dipping.

WE have said that, generally, gilding by dipping is especially resorted to for false jewelry. There is, however, an easy method of obtaining by this process as good results as by the battery, and which consists in gilding several times, by dipping, those objects which require a good plating. The secret is, that before each dipping, the article is passed through the solution of nitrate of binoxide of mercury. By thus doing, a coat of mercury is deposited at each operation, and becomes dissolved in the bath of pyrophosphate, to be replaced by a new coat of gold.

This method is applied every day to the plating of large pieces, such as clocks, chandeliers, ornamental bronzes, etc., which generally require the use of the battery. There is the great advantage that gilding by dipping is superior to that by electricity in depth of shade, brightness, lustre, and especially in not raising or scaling off, because the deposit is of pure gold only, whereas, by the galvanic process, a subsalt of this metal is often deposited.

It is easy to ascertain that the coat of gold increases in depth with each successive immersion by watching the various degrees of intensity with which nitric acid attacks the objects after each operation. I have succeeded in gilding copper strongly enough to have it resist the action of concentrated acids for several hours.

A strong gilding by dipping may, like that by the battery, be scratch-brushed and or moulued; but the latter operation is made in the cold.

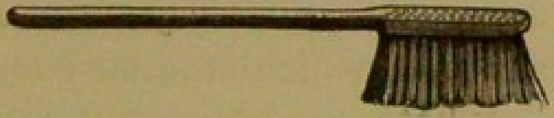
Or Moulu.

This operation consists in smearing, by means of a brush or pencil, the objects gilt and scratch-brushed with a thin magma of nitrate of potassa, alum, and sanguine (a kind of oxide of iron, red chalk), which have been intimately mixed and ground under the muller, and to which has been added a solution of saffron, or annotto, or other coloring substance, according to the depth of yellow or red desired.

If the gilding is strong and thick, the objects are heated until the coat of the previous magma curls over at the approach of a wet finger. On the other hand, if the gilding is a mere film of gold, the mixture is simply allowed to stand upon the articles for a few minutes. In either case, the whole is rapidly washed in warm water holding in suspension a certain quantity of the materials for or moulu.

Without using any other water, the articles are rapidly dried, when they appear of a darker shade. We must then equalize the color, that is to say, remove the portions too much colored by striking them vertically with the long bristles of a brush with a handle (Fig. 63).

Fig. 63.



The operation of or moulu is practised only after burnishing, if the whole or a part of the article requires it.

If the tint of or moulu does not appear satisfactory from too great or too small a proportion of the substances employed, it is easy to begin the operation anew, after washing off the or moulu in a diluted solution of sulphuric acid.

We shall give, in the chapter on CHEMICAL PRODUCTS, the manner of preparing various shades of or moulu.

Colored Golds.

Nothing is more various than the differences of shades, tints, and colors presented by the gilt articles found in the trade. They vary from the red of rose copper to a pale white similar to that of silver. Hence, all those denominations employed in the arts, of yellow gold, virgin gold, red gold, pink gold, new gold, blossom gold, green gold, and white gold.

The last two shades, very much sought for, are easily obtained by simple dipping.

Green and White Gilding.

These shades, which may be graduated at will, are obtained by adding drop by drop, and until the desired shade is arrived at, a solution of nitrate of silver to the bath of double pyrophosphate of soda and gold, of which we have given the formula.

The solution of nitrate of silver is prepared by dissolving, in 100 grammes of distilled water, ten grammes of nitrate of silver crystallized, or, better still, fused and white, which is lunar caustic.

The pyrophosphate dissolves silver but slightly, nevertheless, it absorbs it in sufficient quantity for whitening the gilding to the point of making it appear like silver.

It is always to be recommended, before gilding green or white, to gild yellow the objects in the ordinary bath, then to pass them rapidly through the mercurial solution, and, lastly, to dip them into the gold bath holding the nitrate of silver.

The bath, to which the silver solution has been added, parts quite rapidly with its silver upon the first articles steeped in it. It is, therefore, necessary to maintain the constancy of the shade by the addition of a few drops of the silver solution when required.

Gilding Silver by Dipping.

Although copper and its alloys are mostly used when gilding by dipping, it is not impossible to gild silver in the following manner:—

The silver articles, previously cleansed and scratch-brushed, are boiled for about half an hour in the gold bath of pyrophosphate, to which have been added a few drops of sulphurous acid, or, preferably, hydrocyanic acid in excess of the quantity needed by the primitive bath. The latter of these acids dissolves a small proportion of silver, and allows an *equivalent* of gold to deposit. The former, *i. e.*, sulphurous acid, acts like a reducing agent of the gold solution, and causes the metal to deposit upon the silver, from the affinity between metals, especially when one of them is in the nascent state, *i. e.*, just disengaged from a combination. This gilding is very fine, but without firmness. The deposit is rendered more rapid and thicker when the articles of silver are continually stirred with a rod of copper, zinc, or brass; but then we have the galvanic action by contact of two heterogeneous metals in a saline solution.

CHAPTER XIV.

SEQUEL TO GILDING BY DIPPING.

GILDING ON PORCELAIN, GLASS, OR CRYSTAL.

Gilding on Porcelain, Glass, or Crystal.

DURING the last few years, baths of pyrophosphates have been successfully employed for gilding glass, crystal, stoneware, earthenware, and porcelain.

The operation is conducted as follows:—

Mix intimately, first in a crystal mortar and then between a muller and a ground plate glass, neutral chloride of platinum with rectified essence of lavender, so as to form a thin syrup, which is applied with a brush in very thin layers upon the glass, porcelain, or other ceramic object which we desire to decorate. After drying, heat in a muffle up to a dark red. At this temperature, the essence is partly volatilized, and the hydrogen of the remainder reduces the platinum to the metallic state, which then appears with a perfect polish. After cooling, pass the whole object through aqua fortis, which is without action upon the platinum, but destroys the impurities which may tarnish its surface. Rinse in plenty of water, and dip into the gold bath the object which has been wrapped with a few turns of fine brass wire, having numerous points of contact with the platinized places.

After a few minutes, the platinum is entirely covered with a fine pellicle of gold which has the same adherence and polish. A rubbing of the gold with a chamois skin finishes the operation. This method, as we readily see, dispenses with any burnishing, which is always costly, and often impracticable in the deeply indented parts.

If the gilding be too red, add to the bath a few drops of a solution of double cyanide of potassium and silver (liquor for silver electroplating).

This method is preferable to that of baths with separate battery; the gilding has a bright instead of a dead lustre, and its adherence is greater.

At the present time, the bright gold gilding by Dutertre's process has been generally substituted for that which we have described, and consists in applying with a brush or pencil an intimate mixture of sulphide of gold and various essences to the objects, which are then submitted to an incipient red heat. The resulting gilding looks like burnished gold, is more or less firm and lasting, and is applied to a multitude of small porcelain articles, the indented surfaces of which render impossible the employment of the burnishing or any other polishing tools.

CHAPTER XV.

SEQUEL TO GILDING BY DIPPING.

GOLD DIPPING BATH WITH BICARBONATES.

Gold Dipping Bath with Bicarbonates.

We have described with great care the gold baths with pyrophosphates, because they appear to us preferable to all others. Nevertheless, it is possible to gild, by dipping, with other substances, and especially with the bicarbonates of potassa or soda, which, a few years since, were extolled by a few rule-of-thumb practical men. This simply proves that they were not acquainted with, or did not know how to use, the pyrophosphates.

The bath with bicarbonates is prepared by mixing in a cast-iron kettle, turned clean and smooth inside on the lathe, and gilt by the protracted ebullition of nearly spent gold baths—

Water	16 kilogrammes.
Bicarbonate of potassa or soda (preferably, of potassa)	9 "
Pure gold (transformed into chloride)	120 grammes.*

The whole is boiled for at least two hours, and fresh water added to replace that evaporated. A part of the gold, in the form of a violet black powder, has become precipitated, and requires the cooling and decanting of the liquor. This is boiled again, and the gilding proceeded with, in the same manner as before indicated, except that the mercurial solution should be more diluted than is necessary with the baths of pyrophosphates.

The operation is terminated when about half of the gold in the liquor has become deposited. The remainder goes to the saved waste.

If we now compare the formulæ of the two baths, and consider the dilution of the one and the concentration of the other, the rapidity of operation in the first and the loss of time occasioned by the second, the facility of using all the gold dissolved by the pyrophosphate and the impossibility of utilizing a great proportion of that in the bicarbonate, we must acknowledge that there is no possible doubt as to which to choose, especially when the quality and the fineness of the products are at least equal. We will add that, at the present time, we do not know any gilder employing the above formula, which we have simply recorded as an historical remembrance.

Gilding by Dipping.—Diluted Bath.

We finish the series of formulæ for gold baths by dipping with one, which on account of the facility of

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* This weight is that of the metallic gold, and not that of its chloride resulting from the treatment by aqua regia.

working, and the great quantity of articles which may be gilt, is often employed, notwithstanding the slight durability of the results.

This bath should be employed only as a complement to the cleansing process, before a more resisting gilding, and is composed of—

Water	10	litres.
Bicarbonate of potassa	200	grammes.
Caustic potassa	1800	"
Cyanide of potassium	90	"
Gold (to be transformed into chloride)	10	"

The whole is brought up to the point of ebullition, and a pale gilding, a mere blush, is obtained even upon imperfectly cleansed articles, and without employing nitrate of binoxide of mercury.

It is possible, at four or five different times, to add chloride of gold (5 grammes each time) to this bath without any other substances. Afterwards it is maintained at the proper strength by additions of gold and salts in the above proportions, and it lasts for quite an indefinite period.

Such a bath may gild about 4 kilogrammes of small jewelry with 1 gramme of gold, whereas a bath with pyrophosphates gilds only about 1 kilogramme of small articles with the 1 gramme of gold extracted from the liquor.

The gilders of large bronze pieces use this bath for cleansing them before they are put into the electro-bath, and on this account it is called the *cleansing* or *preparing* bath.

CHAPTER XVI.

GILDING BY STIRRING AND GOLD AMALGAM.

Gilding by Stirring and Gold Amalgam.

THE old processes admit of the gilding of small copper articles with a thin and adherent layer. The method of ancient gilders, by stirring and gold amalgam, gives results very analogous to those obtained by the process by dipping, just explained.

The operation of gilding by stirring and gold amalgam is performed as follows:—

In the centre of a charcoal stove put a crucible holding a given quantity of pure and dry mercury, and when the temperature has reached about 100° C., add one-half of the weight of gold. Stir with an iron rod, and when the amalgam has acquired the consistency of butter, throw it into cold water, and keep it there for use.

After the cleansing in aqua fortis of the articles to be gilded, put them in a stoneware pan, and water them with a diluted solution of nitrate of binoxide of mercury, taking care to stir or jerk the articles all the while, in order to change the positions of their surfaces and cover them with a regular white coating of mercury.

At this point, add to the mass the desired proportion of amalgam, which, on stirring the articles, is spread all over them. Then rinse in cold water, and transfer the contents of the stoneware pan into a large and deep copper ladle, perforated with numerous small holes, and having a long handle which allows of the jerking motion such as that given to a frying-pan.

The ladle and its contents are then kept over a live charcoal fire, and the articles are constantly stirred in order to have the heat equal everywhere. The mercury of the amalgam is soon volatilized, and the gold remains adherent to the articles.

If, instead of a yellow gilding, a red one be desired, we then proceed to the *waxing*, which operation consists in pouring upon the pieces, kept in the ladle and upon the fire, an intimate and fluid mixture of—

Oil	25 parts.
Yellow wax	25 "
Acetate of copper	10 "
Fine sanguine or red ochre . . .	40 "

The articles are constantly agitated, and the mixture is allowed to burn out, when the whole is thrown into a very diluted solution of sulphuric acid. The waxing is, of course, done only after the complete volatilization of the mercury.

After the pickle, the gilding has the dull appearance of ochreous clay, and must be scratch-brushed. The small articles are brightened in a narrow and long bag, where they are put with copper pearls or the waste from these pearls, and wet with water holding vinegar. One end of the bag is attached to a strong nail or peg on the wall, higher than the operator, and the other end being taken in the hand, a to-and-fro motion is imparted to the bag. The gilt articles and the copper granules roll over each other, and become mutually polished. Lastly, rinsing, and drying in sawdust, and sometimes burnishing, are attended to.

Gilding by stirring and amalgam may give good results; but most generally the proportion of gold is so slight that it not seldom happens than the pellicle of gold remains in the acid solution used for cooling, and that the finished articles have nothing to enhance their value but the red from the waxing, and the bright lustre from the polishing operation. These coppers, however, are with difficulty oxidized, as if they had been penetrated by the fatty substances of the waxing composition. I have analyzed jewelry, claimed to have been gilt by stirring and gold amalgam, and the gilding of which had been found very fine; not a trace of gold could be found. The entire quantity of the gold employed must therefore have been left in the acid pickle, which was thrown away. I have also seen a very fine batch of gilt articles, the gold of the amalgam of which had fallen into the charcoal of the stove, where it was found entire afterwards.

Each operator has his own method of waxing, and varies its composition. That given above succeeds well, and I have seen it often practised, and I use it myself.

CHAPTER XVII.

COLD GILDING WITH THE RAG.

Cold Gilding with the Rag.

We shall not conclude the methods of thin gilding, without mentioning a very simple, and often very useful, process of gilding silver. It was formerly, and is even at the present time, used for gilding the insides of snuff-boxes, and similar articles.

This process is known under the name of *cold gilding with the rag, with the thumb, with the cork.*

Dissolve pure gold, finely laminated, in aqua regia made of—

Nitric acid	5 parts.
Hydrochlorate of ammonia (sal ammoniac)	2 "
Nitrate of potassa (saltpetre)	½ part.

Heat carefully upon a gentle fire; the nitric acid decomposes the hydrochlorate of ammonia, and the hydrochloric acid combines with the nitric, thus forming the aqua regia which dissolves the gold. The nitrate of potassa remains mixed with the chloride of gold, and we shall soon see what its use is for.

When all the gold has disappeared, pour the cooled contents of the flask into a flat-bottomed stoneware pan. Into this liquor, dispose one upon the other, and in sufficient quantity, squares of pure linen cloth, and strike them with a glass rod, in order that they become equally impregnated with the chloride of gold. Each square of cloth is then taken with wooden pincers, well drained, and spread for drying in a dark closet. When the desiccation is nearly complete, each piece of cloth, supported upon glass rods, is placed on top of a charcoal fire, and soon takes fire. The combustion is accelerated by the presence of the nitrate of potassa, and is finished upon a marble slab. Grind the ashes under a muller, collect, and keep them between the folds of a parchment leaf, around which a wet cloth has been folded. The ashes remain there for a week, but every day they are stirred in order to have an equal wetting by the dampness which penetrates through the parchment.

The powder is then ready to use, and it is sufficient to mix it upon a slab with a few drops of water, and to rub with this paste the well-cleaned surfaces of the silver to be gilt. The smooth surfaces are rubbed with the thumb, the fillets or grooves with a fine cork cut to the proper shape, and the corners or angles with a stick of soft wood, like linden or poplar. Lastly, the articles are burnished. This gilding is very thin, but quite resisting, especially after the action of the burnishing tool, which has incrustated the gold into the pores of the silver. If a red shade be desired instead of a yellow one, a small proportion of pure copper is added to the gold to be dissolved in aqua regia.

By the action of the fire during the combustion of the cloth, a part of the perchloride of gold has been reduced to metallic gold, and the remainder has been transformed into protochloride. The presence of the latter salt in the mixture seems to us to cause the adherence of the deposit, since the protochloride of gold, in contact with silver, decomposes this metal and transforms it into chloride, whereas the gold is deposited in the nascent state, *i. e.*, in the best condition for the combination to take place.

We are perfectly satisfied that gilding with the rag will succeed just as well by using the ashes immediately after the burning of the cloth impregnated with perchloride of gold; but we have preferred to describe the operation such as we have seen it performed, with all its quasi-mystical accompaniments.

CHAPTER XVIII.

GILDING WITH THE BRUSH OR WITH SHELL GOLD.

Gilding with the Brush or with Shell Gold.

The durability of this gilding is that of the glue or cement employed, and it is applied only on very small surfaces for slight repairs which do not require the gilding anew of finished articles.

The gold powder is simply mixed with gum-water, applied with a brush upon the parts to be mended, and allowed to dry.

The gold powder is prepared by the attrition under the muller of the cuttings of gold beater's foil, and in order to prevent them from being blown away, a certain quantity of white honey is added. When it is considered that the powder is fine enough, the paste is put into water, by which the honey is dissolved. After several washings, settlings, and decantings, the powder is allowed to dry. In case of hurry, the washing may be performed upon a paper filter. The dry powder is again ground with a little gummy or mucilaginous water, and the paste produced spread over a small porcelain cup, or more generally over the inside of a mussel shell.

If a powder of green gold be desired, silver foil is mixed with the gold cuttings. An addition of rose copper foil produces a red gold. It is, however, preferable to use foils laminated from alloys made for the purpose.

We may say, in advance, that the preparation is the same for silver powder employed for mending slight defects in silver articles not exposed to friction.

Every gilder should have at hand a complete stock of these various powders, which will save him a great deal of tedious work.

CHAPTER XIX.

GALVANO-GILDING OR GOLD ELECTROPLATING.

Gold Electroplating.

GILDING by the battery presents the advantage of being easily applied to all the usual metals, and of producing deposits, the thickness of which is entirely regulated at the will of the operator.

It is not always necessary in electro-gilding to use a battery, for we must remember that the contact of two heterogeneous metals, especially within an acid or saline liquor, is sufficient to produce electricity. Electro-gilding, therefore, will take place each time, that, in a proper gold solution, there is contact between an electro-negative metal and an electro-positive one.

We have already stated that, in gilding silver by dipping, the same phenomenon takes place by the contact of copper or zinc rods which act like the positive element of a feeble battery, the negative element of which is represented by the silver. We shall see, further on, that it is sufficient to plunge the articles, attached by zinc wires, into gold baths prepared for the use of batteries, to have the operation taking place in the same manner as with a separate battery.

It is, therefore, well understood that what we call electro-gilding, or, in a more general way, electro-deposit, is the deposit obtained by an electric current, whatever be its mode of production. But we shall describe more particularly, as being more general, the methods and formulæ which require generators of electricity separated from the baths.

Electro-gilding is done with the aid of heat, or in the cold. This latter method is especially employed for those large pieces, like clocks, chandeliers, etc., which will otherwise require the heating of great volumes of liquid.

Electro-gilding by heat, on the other hand, is perfectly well adapted to the great majority of cases, when small articles, such as forks, spoons, knives, snuff-boxes, etc., are to be gilt.

Let us here say that hot gilding offers several advantages over the method in the cold. The deposits are more smooth and clean, the color is deeper, and the articles, removed from the bath, may not require coloring. We may, therefore, correct the mistaken idea, so often to be met in the arts, and due to the facility of obtaining pleasing but not durable deposits with very little gold by hot baths, that *gildings made by the hot method resist less than those obtained in the cold way.*

We say, on the contrary, that *with the same quantity of gold, gilding by heat is much more durable than that obtained from cold baths.* Everybody knows that all electro-deposits, including those of gold, are nothing else than cobwebs, the meshes of which are more or less close. Is it not evident that, with a cold bath and upon a cold article, the network will remain what it was at the time of the deposit; whereas, if into a hot bath we plunge a cold surface, this will expand by the heat and present to the deposit a larger surface, which, contracting by cooling, will condense at the same time the meshes of the network of the gold deposit?

Another proof of the superiority of hot over cold gilding is that we cannot gild by the latter method steel, tin, or lead, which may be gilt in hot baths. These also dissolve easily the fatty bodies or the oxides which may remain on the surface of the articles, and thus aid the success of the operation.

To sum up, the want of durability is not due to the use of hot baths, but to the thinness and beauty of the deposit which it is possible to obtain by the hot method, and with which, unhappily, too many gilders content themselves.

Cold Electro-gilding Baths.

The proportions and the nature of the salts employed may vary ad infinitum; but here are three formulæ which are in general use and give satisfactory results.

First Formula.

BATH WITH GOLD AMMONIUM.

Water (better distilled) . . .	10 litres.
Cyanide of potassium (ordinary 70 per cent)	300 grammes.
Pure gold	100 "
Ammonia (aqua ammonia) . . .	500 "

This bath is prepared as follows:—

1. Heat in a glass balloon or flask the 100 grammes of gold with 250 grammes of pure hydrochloric acid, and 125 grammes of pure nitric acid. When the gold is dissolved, continue the heat in order to expel

the excess of acid fumes, and until the color of the syrupy liquid is dark red, nearly black. Remove then from the fire, and dissolve the brown-yellow crystalline mass formed by cooling, in one or two litres of water, and pour into a large porcelain dish.

Add to this liquid the 500 grammes of ammonia, which immediately produce an abundant yellowish precipitate of gold ammonium, or ammoniuret of gold. Throw the whole upon filtering paper, and the filtered liquid, which is slightly yellow and still contains traces of gold, is kept with the saved waste. Wash several times with cold water the precipitate remaining upon the filter, until it no longer smells of ammonia.

The ammoniuret of gold should not be dried, because it is fulminating, *i. e.*, detonates by a slight shock or friction.

2. Dissolve in the vessel used as a bath, and in the ten litres of water, the 300 grammes of ordinary cyanide of potassium. Filter, if necessary, and add the wet gold ammonium, which is rapidly dissolved by stirring, and forms a clear gold bath. But before using it cold, the ammonia should be expelled by boiling it for about one hour.

For a newly prepared cold electro-gilding bath, I prefer the ordinary cyanide of potassium, which, on account of the potassa it contains, renders the liquor a better conductor of the electricity. On the other hand, I prefer, for the preservation of the strength, the pure cyanide, which possesses the advantage of a constant composition, and does not load the solution with foreign salts.

The gold solution for maintaining the metallic strength of the bath is prepared as follows: Transform the gold into ammoniuret, as indicated above, and suspend the product in water (1 litre for 100 grammes of gold), then add cyanide of potassium until the liquor is colorless. If there were not a sufficiency of water with the gold ammonium, the liquor would be dark red, and could not be decolorized by an excess of cyanide; nevertheless, there is no inconvenience in introducing this liquor into the impoverished bath.

Second Formula.

BATH WITH THE DOUBLE CYANIDE OF GOLD AND POTASSIUM.

Water (preferably distilled) . . .	10	litres.
Cyanide of potassium, pure . . .	200	grammes.
or ordinary cyanide, according to strength,	300 to 400	"
Pure gold	100	"

For the preparation of the bath, proceed as follows:—

1. Make a neutral chloride of gold, as in the preceding formula, and, when cold and crystallized, dissolve it in 2 litres of water. Filter if needed.

2. Dissolve the cyanide in 8 litres of water, filter if needed, and mix the two solutions, which become colorless.

When, before using it, it is possible to boil this bath for half an hour, it becomes a better conductor of electricity, and the gilding is more uniform.

Its strength is maintained by additions of neutral chloride of gold and pure cyanide of potassium (from 1 to 1.5 gramme of pure cyanide to 1 gramme of gold used).

These two formulæ of baths may be diluted with once or twice their volume of water; the gilding will remain fine, but the proportion of gold deposited is less in a given length of time.

Third Formula.

BATH WITH PRUSSIATE OF GOLD.

Cyanoferride of potassium (yellow prussiate of potassa)	200 grammes.
Carbonate of potassa, pure	150 "
Chloride of ammonium (sal ammoniac)	30 "
Gold (transformed into chloride)	15 "
Water	10 litres.

Boil together all the salts, less the chloride of gold, separate by filtration the precipitate of carbonate of iron, add then the chloride of gold dissolved in a little water, and allow the bath to cool off.

It is useless to say that any kind of gold salt, and the oxide or even the finely comminuted metal, may take the place of the chloride of gold; but this latter should be preferred on account of the facility of its preparation, and of its solubility.*

A few operators prefer the ammoniuret of gold (gold ammonium) prepared as in the first formula.

The addition of a little hydrocyanic (prussic) acid produces a brighter, but thinner, gilding.

The indicated cyanides may be replaced by cyanides or prussiates with other earthy or alkaline bases, provided they are soluble; such are the cyanides of sodium, calcium, and ammonium.

Cold gilding baths are generally kept in vessels of

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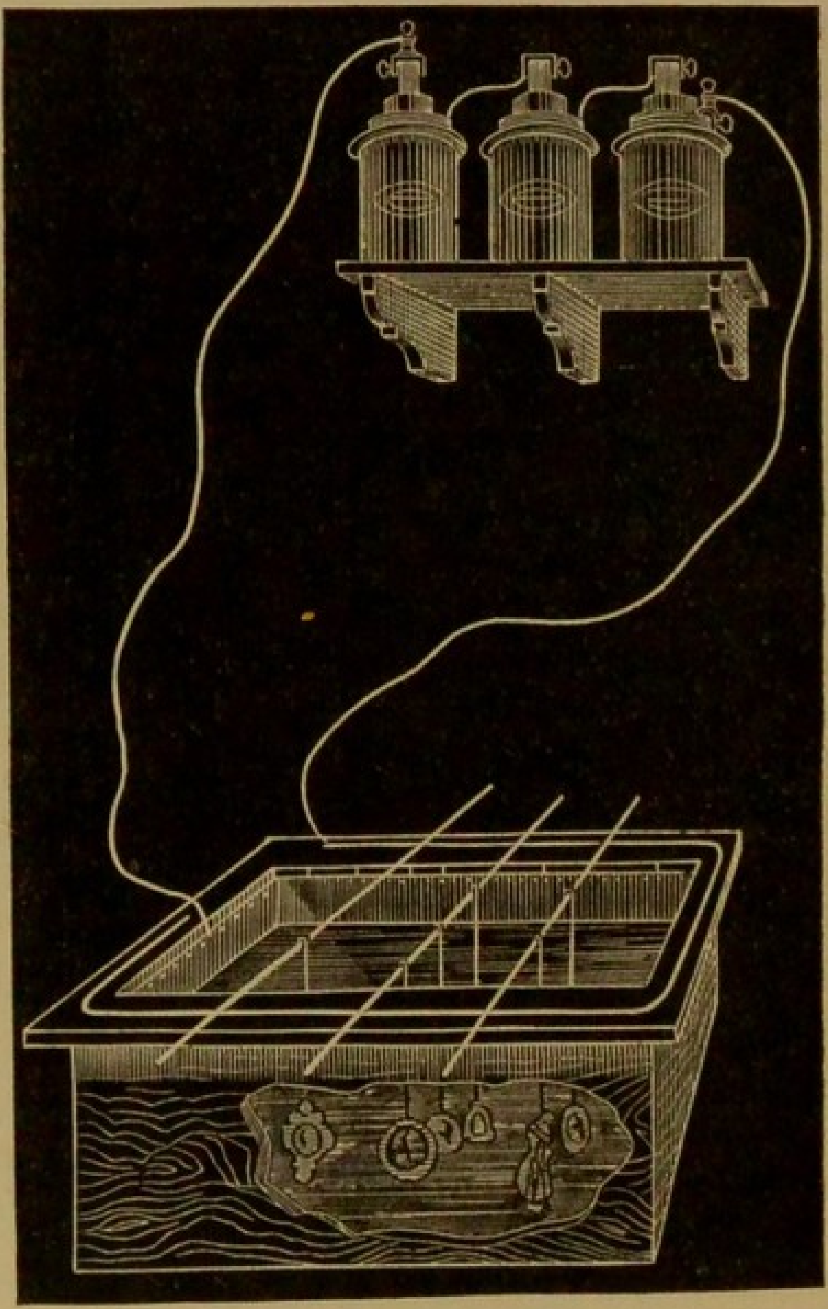
* The use of the cyanide of gold, extolled by certain merchants of chemical products, results in their selling very dear a product which contains but a small proportion of metal. Any kind of gold salt will be transformed into cyanide by the cyanide of potassium, and it is entirely useless to pay $6 for a product which contains but $2 or $3 worth of metal. The small proportion of chloride of potassium resulting from the transformation of the chloride of gold into cyanide does not prevent the good working of the baths.

stoneware, earthenware, or porcelain; but for large volumes of liquor we use wooden troughs lined with gutta percha plates.

The sides of the trough support anodes of laminated gold (Fig. 64), which dip entirely into the liquor,

Fig. 64.



and are held by small platinum wires. They are connected with the positive pole of the battery.

The articles to be gilt are suspended, by means of metallic slinging wires, to a movable frame of clean brass rods connected with the negative pole.

The deposit of gold is often pure yellow, but it has sometimes a dull and earthy gray color. In the latter case we are obliged to scratch-brush it a long time and with the greatest care, and then to pass it through the or moulu coloring.

The gold anode not only conducts the electricity, but also maintains the metallic strength of the bath up to a certain point. Theoretically, as much gold should be dissolved from the anode, as there is gold deposited upon the other pole; but in practice, we are obliged to add now and then, either the oxide or the chloride of gold, and a certain proportion of cyanide of potassium to make up for that transformed into carbonate of potassa and cyanate of ammonia.

The proportion of cyanide is about double that of the chloride of gold added. We ascertain, however, by the color of the bath and the shade of the deposit, if the proportion of the chloride of gold is too great, in which case we add more cyanide.

If gold predominates, the deposit is quite black or dark red; on the other hand, when the cyanide is in excess, the gilding is very slow and gray, and it will often happen that pieces already gilt will lose their gold.

Some gilders, in order not to increase the specific gravity of their liquors by the addition of new salts, add a little hydrocyanic acid, which, displacing the carbonic acid of the carbonates, forms with them new cyanides. This process is costly, and propagates the employment of the most poisonous substances. It will be preferable to add some water with the new salts, or to substitute for the cyanide of potassium the cyanide of calcium, which, reacting upon the carbonate of potassa in the bath, forms a soluble cyanide of potassium and an insoluble precipitate of carbonate of lime. The cyanide of ammonium may also be employed, and will, by double decomposition, give rise to carbonate of ammonia which is volatile.

Notwithstanding these inconveniences, the cyanide of potassium is nearly always employed, because its preparation is more easy and cheap.

When the bath does not act, the gold anode must be removed from it, otherwise it will be dissolved, and the bath will contain too much metal.

If the anode were partly immersed in the bath, it would be rapidly cut at the level of the liquid; and for this reason we have recommended the employment of platinum wires which are not acted upon.*

Cold electro-gilding, in opposition to the hot method, should be done slowly; and the operator will have to look often at the pieces in the bath in order to scratch-brush those with an irregular deposit, or with dark spots.

As it is not possible to constantly modify the surface of the anode, to correspond with that of the articles, the intensity of the current should be often changed by increasing or diminishing the number of the elements, or the strength or the volume of the liquors in the battery. With too much intensity in the current, the deposit is black or red; it is yellow with the

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* We should notice as a remarkable phenomenon, that the solutions of cyanides, even without the action of the electric current, rapidly dissolve in the cold or at a moderate temperature all the metals except platinum; and that at the boiling point, they have scarcely any action upon the metals.

proper amount of electricity. With a weak current those portions only opposite the anode become covered with gold; it is therefore recommended to change the position of the objects often, in order that the deposit be regular. With freshly prepared baths, it often happens that surfaces already gilt will lose their gold by changing their positions; thus, for instance, if the inside of a snuff-box is gilt when opposite the gold anode, it may be ungilt by presenting the outside to the soluble anode. When this phenomenon takes place, it is a sure sign that the bath contains too much cyanide of potassium, and too little gold, or that the electric current is too weak.

When the deposit obtained in cold baths is unsatisfactory in appearance, although the quantity is sufficient, the proper shade or tone may be imparted by the following methods:—

1. The gilt article is steeped in a solution of nitrate of binoxide of mercury, until its color has become white. It is heated afterwards to volatilize the mercury, and lastly scratch-brushed.

2. Plunge the article into concentrated sulphuric acid, then heat it until abundant white fumes are disengaged, and throw it, still hot, into a weak pickle of sulphuric acid. In this case, the acid has destroyed the organic impurities which may exist in the deposit, and reduces to the metallic state the subsalts of gold.

3. Smear the gilt article with a thick magma of water and powdered borax, or with biphosphate of lime of the consistency of honey, and heat until igneous fusion takes place. Then put the article into diluted sulphuric acid, which dissolves the borax

or the biphosphate, and leaves the gold with its natural bright lustre.

NOTE.—When, after scratch-brushing small gilt articles, their color is not entirely satisfactory, it may be improved by plunging the articles again into the bath but for one instant, and then immediately into boiling water.

In gilding German silver, A. Watt recommends that the solution should be worked at rather a low temperature, and with a less surface of anode. The solution should be just so weak in precious metal, that the German silver will not precipitate the gold without the aid of the battery; otherwise the deposit will take place so rapidly that the gold will peel off when being burnished, or even scratch-brushed.—*Trans.*

CHAPTER XX.

GOLD ELECTROPLATING IN HOT BATHS—GREEN GOLD —WHITE GOLD—RED GOLD—PINK, OR NEW GOLD.

Gold Electroplating in hot baths.

WE have already stated that this sort of gilding is more regular, more rapidly obtained, and possesses a deeper shade, than that by cold baths.

The composition of the liquors may be varied greatly; but we shall indicate only four formulæ which we use every day, and which we can warrant.

These formulæ are set down in the order of their value, the first one being the best.

First Formula.

Phosphate of soda (crystallized)	600 grammes.
Bisulphite of soda	100 "
Cyanide of potassium, pure	10 "
Pure gold (to be transformed into chloride) .	10 "
Rain or distilled water	10 litres.

This formula is equally satisfactory for the rapid electro-gilding of silver, bronze, copper, maillechort, and other alloys rich in copper. On the other hand, for gilding wrought and cast iron and steel directly, that is to say, without a previous coat of copper, the formula is modified as follows :—

Distilled water	10 litres.
Phosphate of soda	500 grammes.
Bisulphite of soda	125 "
Cyanide of potassium (pure)	5 "
Gold (for a perfectly neutral chloride*) .	10 "

If, on the contrary, we have to gild zinc, tin, lead, antimony, or the alloys of these metals, it is then always preferable to give them a previous coat of copper, or at least to begin the gilding in a hot gold electro-bath, nearly worn out, and to scratch-brush the articles carefully. The gilding is completed in a new hot bath, with quite an energetic current.

PREPARATION OF THE HOT ELECTRO-GILDING BATH BY THE PRECEDING FORMULA.

We proceed as follows :—

1. Into a porcelain dish, or into an enamelled cast-iron kettle heated over a charcoal stove, put 8 litres of rain or distilled water, and dissolve in it, by the aid of stirring, the 600 grammes of crystallized phos-

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* It should be well understood, once for all, that the proportion of gold indicated is that of the metal employed and not that of the resulting salt. Therefore, it is not necessary to mind the weight of the chloride, if we have dissolved 10 grammes of gold in aqua regia. Those persons who buy the chloride of gold already prepared, will remember that 10 parts of metallic gold correspond to about 18 parts of neutral chloride, or to 20 or 22 parts of acid chloride such as is sold in chemical stores.

phate of soda. When this salt is entirely dissolved, remove the liquor from the fire, filter it if necessary, and allow it to cool off.

2. Introduce into a glass flask 10 grammes of finely laminated gold, with 15 grammes of pure nitric acid and 25 grammes of pure hydrochloric acid. Heat slowly until all the gold has dissolved, and then more rapidly to expel the excess of acid. There should remain in the balloon only a thick liquid of a blackish-red color. Remove then the flask from the fire, and by cooling the contents form a brown-red crystalline mass.

3. Dissolve in a porcelain dish, and in 1 litre of water, 100 grammes of bisulphite of soda and 5 to 10 grammes (according to the case) of pure cyanide of potassium.

4. Dissolve then the neutral chloride of gold in the tenth litre of water, and pour it slowly (stirring all the while with a glass rod), into the *cold* solution of phosphate of soda. This mixture acquires a greenish-yellow tinge; and without losing time, pour into the mixture the solution of bisulphite and of cyanide. The whole liquor soon becomes colorless, and the gilding bath is ready.

If, instead of allowing the solution of phosphate of soda to cool off, the chloride of gold were thrown into it while hot, there would be danger of a partial reduction of the gold in the form of a metallic red or yellow powder.

To sum up, a good preparation of the bath requires:—

1. The solution of 600 grammes of phosphate of soda in 8 litres of water, which is allowed to *cool off;*

2. The solution, in the ninth litre of water, of the

chloride resulting from the 10 grammes of water, and its gradual mixing with the former solution;

3. The solution in the tenth litre of water, of 100 grammes of bisulphite of soda, and 10 grammes of pure cyanide, and the mixing of this last solution with the preceding ones.

We cannot approve of the practice of many gilders who substitute ordinary for distilled water, dissolve all the salts together, except the chloride of gold, and add the last to the hot liquid. This method is certainly more rapid, but always produces turbid baths, the working of which is uncertain.

The hot electro-gilding baths are kept in porcelain dishes for small quantities of liquor, but with large volumes, enamelled cast-iron kettles are employed. They are kept at a temperature which may vary from 50° to 80° C.

Small articles, like brooches, bracelets, and jewelry ware in general, are kept in the right hand with the conducting wire, and plunged and constantly agitated in the bath. The left hand holds the anode of platinum wire, which is steeped more or less in the liquor, according to the surface of the articles to be gilt.

Large pieces are suspended to one or more brass rods, and as with the platinum anode, are not moved about.

The gilding is very rapid, and a sufficient thickness is obtained after a few minutes.

The shade of the gold deposit is modified by dipping the platinum anode more or less into the liquor. If it dips but a little, relatively to the surface of the articles, the gilding is pale; by immersing it more and more, the shade will become deeper and deeper, until it is red.

It is useless to say that the platinum anode is connected by a conducting wire to the positive pole of the battery, and that the conducting wire starting from the negative pole touches or supports the articles to be gilt.

Generally, gilders of small jewelry nearly exhaust their baths; and as soon as they cease to give satisfactory results, make a new one, and keep the old bath for colored golds, as shall be explained further on, or for beginning the gilding of articles which are scratch-brushed and then finished in a fresh bath. On the contrary, those who gild large pieces maintain the strength of their baths by successive additions of chloride of gold, or, what is better, of equal parts of gold ammonium and pure cyanide of potassium. In this manner baths may be made to last a long time, but they are open to the inconvenience of furnishing a red or green gilding, if many articles of copper or of silver have been gilt in them.

As a general rule, it is preferable to replace the impoverished baths by fresh ones, instead of keeping up their strength by additions of metal.

The articles of copper or its alloys should be perfectly cleansed, and, according to the judgment of the operator, will be passed or not, through a *very diluted* solution of nitrate of binoxide of mercury. Silver requires to be heated, dipped, and perfectly scratch-brushed. For this latter metal, the gilding should be strong, in order to prevent the corners and raised parts from soon becoming white and bare; and, when practicable, a good precaution will be to give it a coat of copper or brass, or at least a first gilding in an old bath.

Second Formula.

Phosphate of soda	400	grammes.
Bisulphite of soda	100	"
Bicarbonate of potassa	50	"
Caustic potassa	50	"
Cyanide of potassium	15	"
Pure gold for neutral chloride	15	"
Rain or distilled water	10	litres.

All the substances except the chloride of gold may be dissolved together, and filtered if necessary; then the solution of the chloride of gold is added. This bath is heated at from 50° to 60° C., and produces a very fine gilding, but it requires quite an intense electric current. It does not suit for the direct gilding of iron or steel.

Third Formula.

Yellow prussiate of potassa	150	grammes.
Carbonate of potassa, pure	50	"
Hydrochlorate of ammonia	20	"
Pure gold for neutral chloride	10	"
Water	5	litres.

The first three salts are dissolved in hot water, and the solution filtered; after cooling, the gold solution is added, and the whole brought again to a boil for half an hour, taking care to replace the evaporated water.

Fourth Formula.

Cyanide of potassium, pure	50	grammes.
Gold, for neutral chloride	10	"
Water	3	litres.

Dissolve the chloride of gold in the whole of the water, and add the cyanide which becomes dissolved and makes the liquor colorless. This bath may be employed almost without regard to temperature, and its simple formula should render it preferable to all others, were it not that it is not uniform in its working. This bath is especially open to the objection of ungilding one face of the object while the other face becomes gilt, or of producing a red gilding at the bottom and a yellow one at the top. This inconvenience, and several others, will partly disappear by a long ebullition.

The first formula alone suits for the direct gilding of wrought iron, polished cast iron, and steel. The gilding obtained with the other receipts upon these metals does not adhere well, and sometimes not at all.

For gilding polished steel without the interposition of copper, it will be well, as we have already said, to diminish by one-half the proportion of cyanide indicated in the first formula; we will therefore employ 5 grammes of cyanide for 10 of gold.

The articles of steel, after cleansing by alkalies, are rapidly passed through a very diluted solution of hydrochloric acid, wiped off when practicable, and dipped into a very hot bath with an intense galvanic current at the beginning, which is gradually diminished afterwards by partly withdrawing the platinum anode.

Small articles of steel, such as pens, watch hands, etc., are threaded upon a thin brass wire, and separated one from the other by glass beads. After cleansing, they are put into the boiling bath, rinsed, and dried and polished in hot and dry sawdust.

GENERAL OBSERVATIONS UPON HOT ELECTRO-GILDING.

Hot, like cold, baths may be more concentrated, that is to say, the quantity of water may be diminished without changing the proportions of the salts and of the gold. But I have always found it preferable, in practice, to use diluted solutions, which deliver the metal in smaller quantity, in a given time, but with a better aggregation of its molecules.

Instead of suspending the articles in a state of immobility in the hot baths, they should, as far as practicable, be kept in constant agitation. In this manner there is no difference of specific gravity among the layers of the liquor, and the gilding possesses an uniform color.

A soluble anode of gold is rarely employed when electro-gilding by the aid of heat; a foil or a wire of platinum is preferred, and rightly so, since it is not dissolved, and is more handy for regulating the intensity of the current, by immersing it more or less into the liquid. This anode allows, with the same bath and battery, the deposit of gold with three different shades: a pale color, with the anode dipping but slightly; a yellow color, when the immersion is greater; and a red gold, if the whole anode is in the liquor. These various shades are simply due to different modes of aggregation of the gold molecules, and this phenomenon is the more striking as we operate with baths holding alloys. Thus, for instance, in a bath of pink gold, composed of gold, copper, and silver, we may at will, and by increasing or diminishing the length of the platinum anode in the liquor, impart to the deposit a white, yellow, or red shade, since the various metals require for their reduction different degrees of intensity in the galvanic current.

Therefore, with hot electro-gilding baths, and especially with small articles, a skillful operator will keep them with his right hand constantly moving in the liquid, while the left hand is employed in changing the position of the platinum anode, so as to suit the surface and the nature of the articles, and obtain the desired shade.

All the hot electro-gilding baths may have their strength maintained by successive additions of chloride of gold with a proper proportion of the other salts; but we soon ascertain that with the increasing density of the liquid, the results become inferior, and that it is preferable to wear out the bath entirely and to prepare a new one.

When a bath becomes exhausted, the gilding is red if much copper has been gilt in it, and green in the case of silver articles. It may be used then for a first coat upon objects which are finished in a new bath.

Electro-gilding, either by the cold or hot method, may present many different colorations due sometimes, as already said, to different modes of molecular aggregation, but oftener to the alloy of other metals with gold. Thus green or white golds result from the simultaneous deposit of gold and silver in various proportions; red gold from the alloy of copper and gold; and pink gold from the combination of gold, silver, and copper.

Green and White Golds.

It is sufficient, until the desired shade is obtained, to add to one of the above baths a solution of the double cyanide of silver and potassium or a diluted solution of nitrate of silver. The tints will vary from a leek green to a very pale whitish-yellow. This kind of gilding mixed upon the same articles with red, yellow, or pink gold, will produce splendid effects of contrast, especially upon chased parts, where the green gold has a velvety lustre.

Red Gold

Is obtained by mixing in suitable proportions the electro-copper bath already described with one of the baths for electro-gilding. We may also use an old bath in which a great many copper articles have been gilt, and use a quite intense current of electricity. Yellow gilding may be made to pass to red, by heating it after it has been covered with a paste of acetate of copper, cream of tartar, and common salt, called *green for red* by old gilders (see this term in the chapter on CHEMICAL PRODUCTS at the end of this work). The heated piece is plunged into a weak solution of sulphuric acid, and carefully scratch-brushed afterwards.

Pink Gold or New Gold.

This kind of gilding requires many precautions, and is the most difficult to obtain, not only on account of the different tendency of the various metals to galvanic decomposition, but also because the jewellers disagree as to the proper shade. The gilder should expect trouble on that account, since he will have to vary the shade for each customer, some preferring a gilding slightly yellower, and others redder or whiter. In our opinion, pink gilding, to be perfect, should present at the same time the red, yellow, and white shades, in such a manner that a practised eye will distinguish them. It is impossible to describe the effect produced by these mixed tints, which can be remembered only after having been seen.

Some time ago, the various shades of pink were obtained by gilding in the following bath at different temperatures, and under currents of variable intensity, the articles already yellow gilt by battery or by dipping. This bath was composed of—

New silver bath	1 part
New gold bath (hot gilding)	25 parts
New copper bath	15 "

This formula, contained in the first edition of this work, possesses no regularity in the working, and may give to a first batch of articles a white color, to the second a red gilding, and to the third a dull, dark shade.

At the present time we use the following methods:—

The articles are first gilt yellow by the formula of the pyrophosphate bath for dipping, or by that of the hot electro-bath. Then, without drying, but keeping them in fresh water, small lots or packages are made weighing from 30 to 50 grammes each, which are lightly passed through the mercurial solution, and then red gilt in an old and hot bath (where a great deal of copper has already been gilt), or in a new bath composed of ten parts of hot electro-gilding bath (first formula, Chapter XX.), and three to four parts of the coppering solution (first formula, with battery, Chapter IX.).

According as the electric current is more or less intense, so is the gilding more or less red. For imparting to it the whitish tint of many articles gilt by stirring and of the gold alloy for jewelry controlled by law, the red gilding is passed through a boiling and nearly exhausted bath of pyrophosphate, to which has been added one-tenth, or a twentieth, or a thirtieth of its volume of a silver bath, or simply a few drops of a concentrated solution of nitrate of silver. A few gilders simply pass their red gilding through a cold silver bath by dipping. In whatever manner we operate, a blush of silver is deposited upon, and whitens more or less, the red gilding.

This gilding should be scratch-brushed, or, preferably, burnished, and it then imitates the gilding by mercury or alloyed gold. It may be chased, but then the lustre soon disappears, on account of the proportion of copper.

When we miss the proper pink gilding, which often happens, it is sufficient to plunge the articles for a few seconds into a mixture of five parts of sulphuric acid to one of nitric acid. The copper and silver are dissolved, and the yellow gilding reappears, upon which the operation may be begun anew.

NOTE.—Besides the variations of color in gilding due to the dipping of the anodes more or less into the bath, and to the strength of the electric current, A. Watt says that "moving the articles about in the bath will at all times enable the operator to vary the color of the deposit from pale straw yellow to a very dark red. The temperature of the solution likewise influences the color of the deposit, the color being lightest when the solution is cold, and gradually becoming darker as the temperature increases."
—*Trans.*

CHAPTER XXI.

GILDING WATCH PARTS, AND OTHER SMALL ARTICLES FOR WATCHMAKERS.

Gilding Watch Parts, and other small Articles for Watchmakers.

THIS kind of gilding, which was for a long time a monopoly in Switzerland, is applied on a large scale in France only in the departments of Doubs and Jura, and especially at Besançon and at Morez in Jura. As several gilders of Paris begin to employ it quite successfully, I think that it is proper to devote a special chapter to the subject, and to thank at the same time M. Pinaire, gilder at Besançon, who, with a rare disinterestedness and liberality, not only imparted to me all of the processes, secrets, etc., employed in his own works, but also allowed me to publish them.

In the gilding of watch parts, and other small articles for watchmakers, gold is seldom directly applied upon the copper. In the majority of cases, there is a preliminary operation, called *graining*, by which a very agreeable grained, and slightly dead, appearance is given to the articles. If we examine carefully the inside of a watch, we will see the peculiar pointed dead lustre of the parts.

This peculiar bright dead lustre, if I may so express myself, is totally different from what we have already mentioned. For instance, it does not resemble the dead lustre obtained by slow and thick electro-deposits of gold, silver, or copper, which is coarser and duller than that of watch parts. Neither does it resemble the dead lustre obtained with the compound acids, which is the result of a multitude of small holes formed by the action of the acids; whereas the grained dead lustre is formed by the juxtaposition, upon a previously even surface, of a quantity of more or less large grains, *always in relief.*

The graining may be produced by different methods, and upon gold, platinum, and silver; and since the latter metal is that preferred, we shall describe the process applied to it.

This kind of gilding requires the following successive operations:—

1. *Preparation of the Watch Parts.*—Coming from the hands of the watchmaker, they preserve the marks of the file, which are obliterated by a rubbing upon a wet stone, and lastly upon an oilstone.

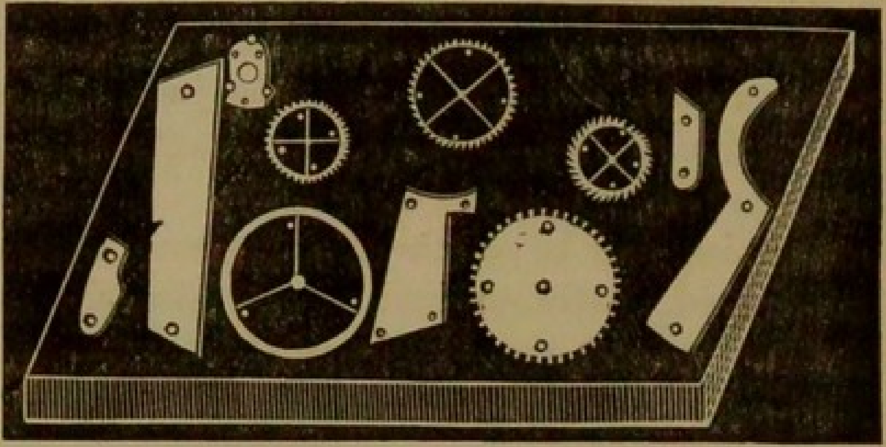
2. The oil or grease which soils them is removed by boiling the watch parts, for a few minutes, in an alkaline solution made of one hundred parts of water and ten of caustic soda or potassa, and rinsing them in clean water, which should wet them entirely if all the oil has been removed. The articles are threaded upon a brass wire.

3. A few gilders then cleanse them rapidly in the compound acids for a bright lustre; others simply dry them carefully in sawdust from white wood.

4. *Holding the Parts.*—The parts thus prepared are fastened, by means of brass pins with flat heads, upon the even side of a block of cork (Fig. 65). A few operators have lately substituted gutta-percha for cork, but this method does not appear to have given good results, since it has not become popular.

5. The parts thus held upon the cork are thoroughly rubbed over with a brush, entirely free from fatty matters, and charged with a paste of water and of the finest pumice-stone powder. The brush is made to move in circles, in order not to abrade one side more than the other. The whole is thoroughly rinsed in clean water, and no particle of pumice dust should remain upon the pieces or the cork.

Fig. 65.



6. Afterwards, we plunge cork and all into a weak mercurial solution, which very slightly whitens the copper, and is composed of—

Water	10 litres.
Nitrate of binoxide of mercury	2 grammes.
Sulphuric acid	4 "

The pieces are simply passed through the solution, and then rinsed. This operation, which too many gilders neglect, gives strength to the graining which, without it, possesses no adherence, especially when the watch parts are made of white maillechort dignified by the name of nickel by watchmakers, or when the cuvettes contain tin in their composition.

7. *Graining.*—In this state, the parts are ready for the graining, that is to say, a silvering made in a particular manner.

Nothing is more variable than the composition of the graining powders; and it may be said that each gilder has his own formula, according to the desired fineness of the grain.

Here are the formulæ which I have seen used in the works of M. Pinaire:—

Silver in impalpable powder[*] . .	30 grammes.
Bitartrate of potassa (cream of tartar) finely pulverized and passed through a silk sieve	300 "
Chloride of sodium (common salt) pulverized and sifted as above . .	1 kilogramme.

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[*] The silver powder is obtained by immersing cleansed copper plates in a *very diluted* solution of nitrate of silver made with distilled water. The more diluted the solution is, the finer is the kind of moss of silver precipitated upon the copper, and the more easily it is removed. The operation is generally conducted as follows: In a suitable vessel of glass or porcelain, 20 grammes of crystallized nitrate of silver are dissolved in 10 litres of distilled water, and five or six bands of cleansed copper 2 centimetres wide are plunged into it. These bands should be long enough to allow of a portion being above the liquid.

The whole is kept for twenty-four hours in a dark place, and the liquid is now and then stirred with the copper bands. This motion is sufficient to loosen the deposited silver, and present fresh copper surfaces to the action of the liquor.

When no more silver becomes attached to the copper, the operation is completed, and there remains a blue solution of nitrate of copper.

The silver powder is washed either by decantation, or upon a filter, until there remains nothing of the copper solution. Lastly, another washing is had with distilled water, and the silver powder is carefully dried, that is to say, by avoiding contact with hard bodies, which may render the powder compact and produce a sort of cohesion of the molecules which is injurious for the further graining.

At the present time, the majority of operators, instead of preparing their graining silver, prefer buying the Nuremberg powder

Another.

Silver powder	30 grammes.
Cream of tartar	120 to 150 "
Common salt (white and clean)	400 "

Another.

Silver powder	30 grammes.
Cream of tartar	100 "
Common salt (clean and white)	1 kilogramme.

All of these substances should be as pure as possible, and perfectly dry. Cream of tartar is generally dry; but common salt often needs, before or after it has been pulverized, a thorough desiccation in a porcelain or silver dish in which it is kept stirred with a glass rod or a silver spoon.

The mixture of the three substances must be thorough, and effected at a moderate and protracted heat.

The graining is the coarser as there is more common salt in the mixture; and conversely, it is the finer and more condensed as the proportion of cream of tartar is greater, but it is then more difficult to scratch-brush.

8. *The Graining proper.*—This operation is effected as follows: A thin paste of one of the above mixtures with water is spread by means of a spatula upon the watch parts held upon the cork. The cork itself is

which is produced by grinding a mixture of honey and silver foil with a muller upon a ground glass plate until the proper fineness is obtained. The silver is separated by dissolving the honey in boiling water, and washing the deposited metal in a filter, until there is no remaining trace of honey. The silver is then carefully dried at a gentle heat.

This silver, like bronze powders, is sold in small packages weighing a German ounce, that is to say, about 29 grammes.

fixed upon an earthenware dish, to which a movement of rotation is imparted by the left hand. An oval brush (Fig. 66), with close bristles, is held in the right hand, and rubs the watch parts in every direction, but always with a rotary motion. A new quantity of the paste is added two or three times, and rubbed in the manner indicated. The more we turn the brush and the cork, the rounder becomes the grain, which is a good quality; and the more paste we add, the larger the grain.

Fig. 66.

The watchmakers generally require a fine grain, circular at its base, pointed at its apex, and close, that is to say, a multitude of juxtaposed small cones. A larger grain may, however, have a better appearance; but this depends on the nature and the size of the articles to be grained.

9. When the desired grain is obtained, the watch parts are washed and then scratch-brushed. The wire brushes employed also come from Nuremberg, and are made of brass wires as fine as hair (Fig. 67). As these wires are very stiff and springy, they will, when cut, bind and turn in every direction, and no work can be done with them. It is therefore absolutely necessary to anneal them more or less upon an even fire. An intelligent worker has always three scratch-brushes, annealed to different degrees: one which is *half soft*, or half annealed, for the first operation of uncovering the grain; one *harder*, or little annealed, for bringing up the lustre; and one *very soft*, or fully annealed, used

Fig. 67.

before gilding for removing the erasures which may have been made by the preceding tool, and for scratch-brushing after the gilding. Of course, the scratch-brushing operation, like the graining proper, must be done by striking circles, and giving a rotary motion between the fingers to the tool. The cork is also, now and then, made to revolve. After a good scratch-brushing, the grain, seen through a magnifier, should be regular, homogeneous, and with an equal lustre all over. Decoctions of liquorice, saponaire, or Panama wood are employed in this operation.

It frequently happens that the same watch part is composed of copper and steel, and this latter metal requires to be preserved against the action of the cleansing acids and of the graining mixture, by a composition which we call *resist*, by analogy with the same term employed by dyers and calico-printers for similar purposes.

This preparation consists in covering the pinions and other steel parts with a fatty composition, which is sufficiently hard to resist the tearing action of the bristle and wire brushes, and sufficiently insoluble in the alkalies of the gilding bath.

Here is the formula of this composition or resist:—

Yellow wax	60	grammes
Translucent colophony	100	"
Red sealing-wax (extra fine) . . .	40	"
Impalpable peroxide of iron (English polishing rouge)	30	"

The colophony and sealing-wax are melted in a porcelain dish upon a water-bath, and the yellow wax added afterwards. When the whole is thoroughly fluid, the English rouge is gradually added and stirred in the mass with a wooden or glass rod. The fire is withdrawn, but the stirring should be continued until the mixture becomes solid, otherwise all the oxide of iron will fall on to the bottom of the dish.

The flat parts which will receive this resist are slightly heated, and then covered with the above mixture, which melts and is easily spread. For covering steel pinions, which generally form a raised cylinder upon the gear, we employ a small gouge of copper or brass fixed to a wooden handle (Fig. 68), and which resembles a pen-holder. The metallic part of the gouge is heated upon an alcohol lamp, and a small quantity of resist is taken with it. The composition soon melts, and, by turning the tool around the steel pinion, this becomes coated. Before fastening the pinion upon the cork, a small cavity has been dug in the latter, and where the pinion rests. The remainder of the operation is conducted as with the other watch parts. Nevertheless it is prudent to use a scratch-brush with long wires, as their flexibility prevents the removal of the composition. When, after gilding, the resist is to be removed, we plunge the parts into warm oil, or into tepid benzine or turpentine, then into a very hot soap water or alkaline solution, and lastly into fresh water. Scratch-brushing and drying in warm sawdust of white wood terminates the operation.

Fig. 68.

The holes of the pinions are cleaned and polished with small pieces of very soft white wood, the friction of which is sufficient to restore the primitive lustre.

The gilding of those parts composed of copper and steel requires the greatest care, since the slightest rust destroys their future usefulness. Should some gold have become deposited upon the steel, it should be removed by rubbing with a piece of wood and impalpable pumice dust, tin putty, or English rouge.

10. *Gilding.*—After the series of preparations which we have described, we come at last to the gilding, which may be effected by some of the processes already indicated. Hot baths, of course, should not be employed for those pieces covered with the resist. I shall, nevertheless, indicate and recommend the formula which I have seen employed at Besançon, and which gives good results.

Four grammes of finely laminated and pure gold are heated in order to destroy all organic substance, and then dissolved in a glass flask with six grammes of pure nitric acid, and twelve grammes of pure hydrochloric acid. When the gold is dissolved, and the excess of acids is evaporated, leaving in the flask a nearly syrupy dark-red liquid, the whole is removed from the fire and allowed to cool. Then dissolve the chloride of gold in fifty or sixty grammes of distilled water, and pour into a large glass vessel. Dilute with about a half litre of distilled water, and pour into the liquor a certain excess of pure ammonia, which precipitates the gold in the state of a yellow powder of ammoniuret of gold, or fulminate of gold, which is highly detonating when dry. We ascertain that the proportion of ammonia is sufficient, when a new quantity of this reagent, being added to the clear liquid above the settled powder, does not produce any new turbidity or precipitate. The clear liquor is decanted and kept among the saved waste. The settled powder is then collected upon a small filter, previously wetted with distilled water, and there washed with distilled water until all ammoniacal smell has disappeared. The filter and its contents are afterwards put into a glass or porcelain vessel with one litre of distilled water and twelve grammes of pure cyanide of potassium, which rapidly dissolves the gold and leaves the filter. The whole is filtered anew, boiled for fifteen to twenty minutes, filtered again, and left to cool. The bath obtained is excellent for gilding the most delicate watch parts, under the influence of an electric current regulated to suit the surfaces to be gilt.

This bath, or these baths, since every gilder possesses several of them of various degrees of exhaustion, are generally kept in glass or porcelain vessels with a flat bottom, and holding from four to five litres within a depth of ten to twelve centimetres. The articles to be gilt are suspended to metallic holders, connected with the zinc pole of a battery, and of a shape appropriate to the nature and form of the watch parts. One or several platinum wires are used for anodes, and are disposed in the centre or at the circumference of the bath.

The battery most generally employed by gilders of watch parts is composed of three, four, five, or six small Daniell's elements. Those with balloons, on account of their constancy, should be preferred. The batteries of Smee, and especially those of Bunsen, Grove, and Archereau, should be discarded, on account of their intensity, which may result in too rapid deposits. Moreover, they are wanting in constancy, and their production of acid fumes is objectionable in work-rooms where there are many articles of steel.

The slower the gold deposit, the finer and more adherent it is. When the operator judges that the coating is sufficient, the articles are washed in clean water, and fixed again upon the cork plate in order to proceed to the last scratch-brushing with a decoction of liquorice, of the bark of Panama wood, of horse chestnut, or of Egyptian saponaria.

CHAPTER XXII.

GILDING THIN WIRES.

Gilding Thin Wires.

Trait is the French name of a thin wire of gold, or silver, or of gilt or silvered copper, which is used for the manufacture of metallic fringes and lace for epaulets, and other purposes.

The articles manufactured of pure gold or silver are called *fine;* those made of gilt silver are *half* fine; and those composed of gilt or silvered copper are *false.**

There is also the *truly false*, which is nothing but brass wire, the color of which imitates gold.

Formerly, at Lyons and in certain towns of Germany, the copper or silver wires were gilt with an amalgam, that is to say, with the aid of fire and mercury. A cylindrical rod of copper or silver, of variable dimensions, was well cleansed, and then covered with mercury and gold foil, or with gold amalgam. The whole was heated upon a clear charcoal fire, in order to evaporate the mercury; and

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* At the present time, gilt silver is *fine;* gilt copper is *half fine;* and copper or brass alone is *false.*

then passed through draw plates of steel, for the large numbers, and of ruby, corundum, or diamond for the smaller numbers. This process was open to the disadvantage of having parts of the wire uncovered with gold, because the coat of the latter metal was not regular.

At the present time, nearly all the gilt wire manufactured in Paris and Lyons is gilt by electricity, thanks to the aid of intelligent manufacturers who have spared neither time, money, nor study.

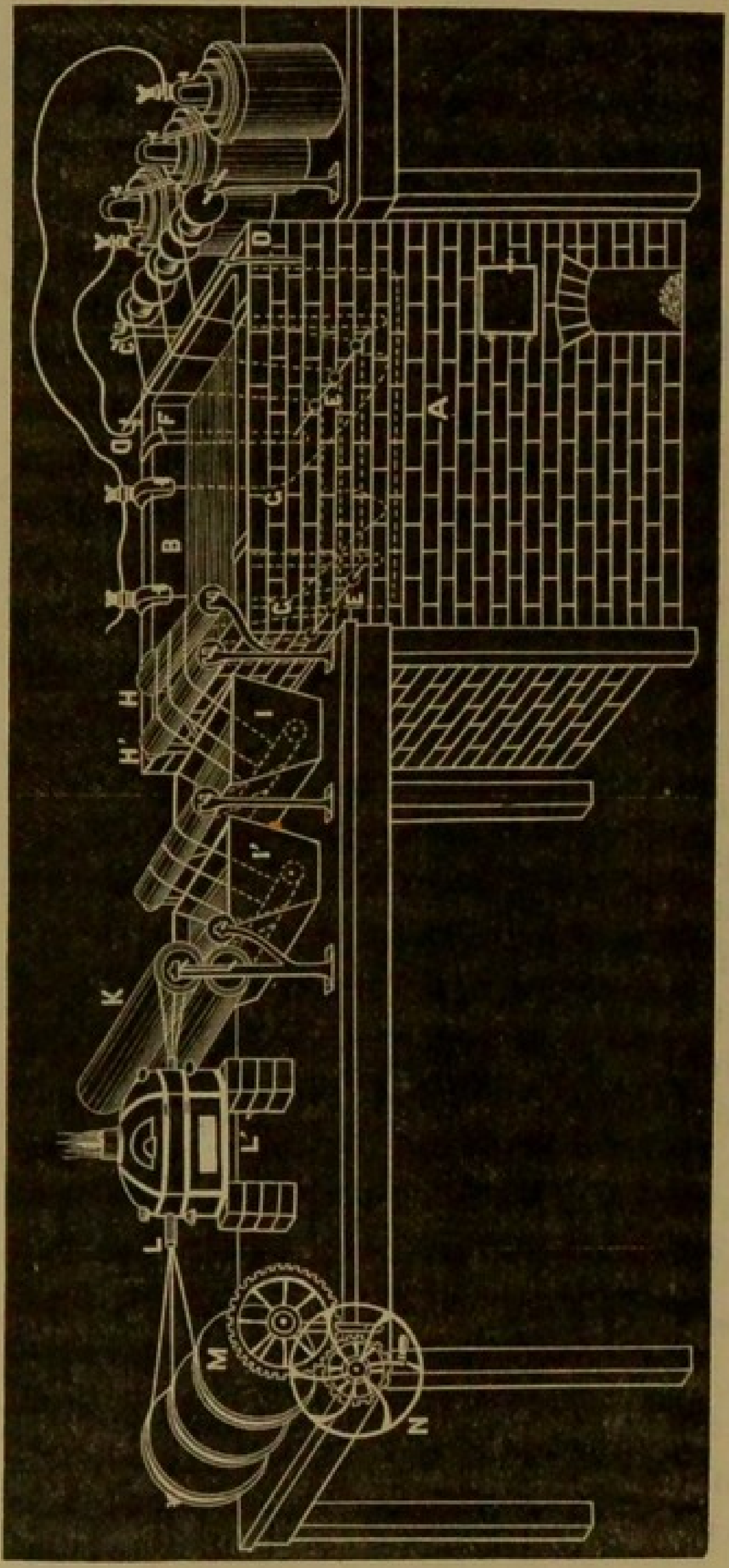
The baths and the batteries are the same as those already mentioned, and if we make a special chapter of this subject, it is because we have found out, by experience, that the success of the operation is due to a certain disposition of the apparatus.

We shall endeavor clearly to explain the arrangement of a bath for gilding thin wires, and we also rely, upon being well understood, upon a careful examination of the plates.

Upon a brick furnace A (Fig. 69), which may be heated either with solid fuel or gas, is a cast-iron enamelled kettle B, for holding the gold bath. This kettle may be 1 metre in length, 0.50 metre wide, and 15 to 18 centimetres deep. As the fireplace may be lighted or not, it is not necessary to change the kettle, when we desire the bath cold or warm. If we employ gas as fuel, the burner is made of an elliptic ring with numerous jets (twenty-five or thirty) attached to it.

At one extremity of the apparatus, near the battery, are two wooden trestles C supporting an iron rod which passes through a certain number of wooden spools carrying the wire to be gilt. These spools may turn freely upon the rod, and the unwound wires, before

Fig. 69.



plunging into the bath, are pressed against a copper or brass rod D connected with the negative (zinc) pole of the battery. The wires are therefore connected with this same pole.

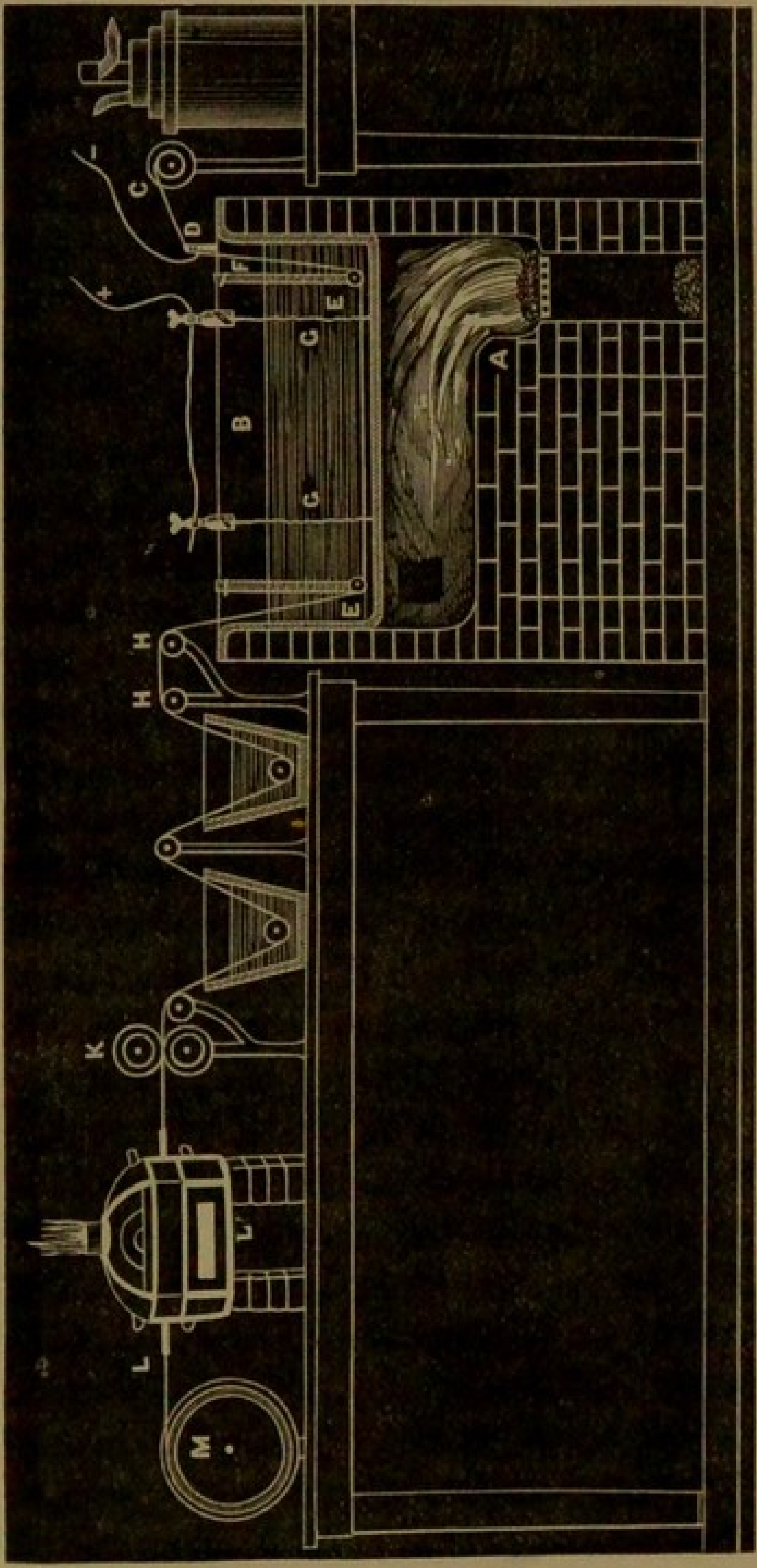
The wires penetrate the bath to about two-thirds of its depth, and are kept stretched by a system of small grooved pulleys E, E of glass, porcelain, or ivory, rolling freely upon glass or ivory axes, themselves maintained near the bottom by supports screwed on the top edges of the kettle.

At the bottom of the bath, and crossing the wires to be gilt, are two or more platinum wires G, G, the vertical branches of which communicate with the positive (carbon) pole. These platinum anodes must, of course, have no point of contact with the wires to be gilt. Therefore, these two kinds of wire represent, in the bath, the two poles of the battery.

At the other end of the apparatus we see another series of wooden spools M, upon which the gilt wire is wound up. But these spools are fast to the square iron axis which traverses them, and which communicates by gearing with a crank moved slowly enough to insure a good gilding to the wire, during its passage through the bath.

After being gilt, the wires are rinsed and dried in a suitable manner; thus, as seen in Fig. 70, they reach two wooden bobbins or rollers H, H revolving freely upon their axes, and plunge by means of grooved rollers into the first trough filled with a weak solution of cyanide of potassium, which cleans and brightens the gilding. By a similar disposition, they pass into the second trough filled with fresh water frequently renovated, which removes the salts they have carried with them. The drying rollers K are covered with several layers of calico, and move by gear in opposite directions. As a last precaution,

Fig. 70.



the wires are completely dried in a flat tube L, maintained at a dull red heat in the furnace L′.

In a kettle of the size indicated above, twenty wires may be gilt at the same time. The copper wires to be gilt are generally silvered previously and passed once through a draw plate, in order to avoid the cleansing process before gilding.

The more intense the battery, or the slower the passage of the wires through the bath, so will the deposit of gold be increased; and in order not to make mistakes, it will be well to weigh the bobbins before and after the operation. In such case, the extreme spools for winding up and winding out should be of the same weight.

This kind of gilding requires a constant supervision, either for uniting the broken wires, the severed parts of which may touch the anodes and stop the operation; or for regulating the intensity of the battery, which being too powerful or too weak, will correspondingly produce a red or green gilding.

The baths of double cyanide of gold and potassium are employed cold or slightly tepid (Chapter XIX.).

On the other hand, the baths with phosphate and bisulphite of soda are used for hot electro-gilding, and their concentration is double, *i. e.*, the proportion of water is one-half of that indicated (Chapter XX.).

As the platinum anodes do not make up for the metallic loss of the bath, it is necessary frequently to add new portions of metal and salts, in the manner already indicated.

Pure gold wire is often gilt, in order to impart to it a more uniform and a deeper shade.

After being gilt, the wire is passed through the draw plate or the rollers, whether we desire to keep it round or make it flat. With the draw plate it is diminished by about one-fourth or one-half of a number, simply to remove the dulness of the deposit, and bring up the lustre. When the gilt wire is flattened between the rollers, its surface is bright or dull, according to the state of the surface of the rollers.

It is evident that silvering, or any other metallic electro-deposit upon thin wires, will be effected in a similar manner.

CHAPTER XXIII.

RESISTS.

Resists.

WHEN we desire to obtain upon the same object gildings of several colors, we employ *resists*, generally made of some kind of varnish. Thus, after having gilt an article of an uniform color, red or green for instance, it is covered with a fat varnish (made drying by the addition of chromate of lead), at those places which we desire to preserve from, or resist the action of, the new bath. By means of resists and successive baths, we are enabled to obtain five or six different shades upon the same object.

The resist varnishes are applied with a brush or pencil, and should be thoroughly dried in a stove before we plunge the object into another solution. These varnishes may be colored with various oxides or colored salts, in order to facilitate their use upon those places which should be sharply delineated; chromate of lead and artificial ultramarine blue are well suited for the purpose. The resist varnishes are also employed for preserving the reverse parts of articles which receive the gilding only on the front surface. When the operation is finished, the resist is easily removed by a washing, first with essence of turpentine, and then with alcohol ; and these liquids may be advantageously replaced by gasoline, benzine, or benzole. The latter substance results from the distillation of coal tar, and dissolves, even in the cold, nearly all the fatty and resinous bodies. It is sufficient, when we have used benzole, to wash the article in boiling water, and then to dry it in warm sawdust of fir wood. It comes out perfectly clean. Such is not always the case with rectified turpentine, and it is prudent to plunge the object into a hot alkaline lye, then to rinse and dry it in warm sawdust.

CHAPTER XXIV.

GILDING WITH A DEAD LUSTRE—GILDING BY FIRE OR MERCURY—GILDING WITH A PARTLY DEAD, PARTLY BRIGHT LUSTRE.

Gilding with a Dead Lustre.

ALL that we have said relates to gilding with a bright lustre; but the trade often requires a dead lustre, and sometimes the two kinds of lustre upon the same piece.

Gilding with a dead lustre may be obtained by five different methods :—

1. By the slow deposit of a large proportion of gold. This gilding is very durable, but is dull and earthy in appearance. Moreover it is too costly for the arts.

2. By acids; that is to say, by giving a dead lustre to the metallic surface, before gilding, and by the processes indicated in the cleansing operations. This method is employed only for small articles, or when gilding by dipping. Varnishers, however, use it for bronze articles, or large embossed work.

3. With frosted silver, *i. e.* by depositing upon the object to be gilt a coat of frosted silver (by processes soon to be described), and then gilding in a good bath. Unhappily this method is somewhat expensive, and the burnished parts are greenish. Moreover the intermediary coat of silver is more easily blackened by sulphur fumes than gold.

4. By copper, *i. e.* by depositing in a solution of sulphate of copper decomposed by a battery a galvanoplastic coat of this metal which possesses a pink dead lustre. The whole is rapidly passed through the compound acids for a bright lustre, and the mercurial solution, and then gilt in a good bath. When the dead lustre obtained in the galvanoplastic bath is perfect, the compound acids may be dispensed with, and the article is simply plunged into the mercurial solution before it is gilt. This last mode of operation is generally preferred by gilders. This gilding is very handsome in lustre and color. The burnished parts will be red, if vinegar or soap-water be employed; and of a fine yellow color, if the burnishing tool be wetted with saliva, a decoction of flaxseed, of Egyptian saponaire, or of marshmallow root. We shall soon indicate (Chapter XXV.), the best conditions for obtaining a fine dead lustre with copper.

If the deposit of gold be of insufficient thickness, it will blacken sooner or later, by the oxidization of the intermediary coat of copper.

5. Lastly, the dead lustre by mercury. It is the old process of gilding by fire, and we shall describe it presently, since it furnishes the most durable products, although costly.

Gilding by Fire or Mercury.

Although we have chosen this chapter on dead lustre gilding for describing the method with mercury, we should not forget that we may also produce a bright lustre with mercury. Before the introduction of the galvanic processes into the arts, there were nearly as many sorts of gildings as at the present time; but their cost was greater, the operation was more difficult, and the worker was constantly exposed to the deleterious fumes of mercury. We must also acknowledge that the products were, and still are, superior as regards durability, if not in appearance.

Mercury gilding may furnish gold with a bright or a dead lustre, scratch-brushed, or-moulued, and with different shades. Therefore, the reader will not consider it out of place that we should indicate the different modes of operation.

The amalgam of gold is prepared in the manner described in the process of gilding by stirring (Chapter XVI.), only a little less mercury is used, in order to have an amalgam about as hard as wax. This amalgam is crystalline, and a certain crakling sound is heard when we crush the crystals between the fingers. A certain stock of amalgam is generally prepared in advance, and it is divided into small balls of nearly equal size, the value of which is ascertained from their number, and from the total weight of gold employed. Thus, if ten small balls contain altogether 5 grammes of gold, each ball will hold 0.5 gramme of precious metal. These balls are kept in water, but they should not remain too long without being used, because the phenomenon of *liquation* takes place, and the different parts do not present the same composition.

When using the amalgam, it is spread with the finger upon a flat, hard stone, called the *gilding stone*, and having dipped a scratch-brush of stout brass wire into a solution of nitrate of binoxide of mercury until it becomes completely white, it is then passed upon the amalgam, a portion of which is carried away. The object, previously well cleansed, is scratch-brushed in every direction, and the tool is often dipped into the mercurial solution in order to facilitate the regular and even spreading of the amalgam.

This operation requires great care for giving an uniform coat upon the hollow and raised parts.

When the back part of a piece does not require gilding, the flat outline, and also the back edge, should be gilt, in order that the naked copper shall cause no injury in the subsequent operations.

When the article is uniformly covered with the amalgam, it is heated upon a charcoal fire without draft, and which rests upon a cast-iron plate.* The entire attention of the operator is now required for

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* We are indebted to M. Darcet for a gilding forge which allows the workman to watch the operation from behind a glass frame, and is thus saved from the mercurial vapors. But such are routine and carelessness, that this apparatus has not become popular; and in most workshops, with a simple hood, the workmen remain constantly exposed to the deleterious fumes of mercury.

watching the process. With his left hand covered with a thick glove of buckskin, he turns the piece in every direction upon the fire, and, as the mercury disappears, with his right hand he strikes the article in every direction with a brush, the handle and the bristles of which are long, in order to equalize the gilding, and to push the remaining amalgam upon those parts which appear less charged with it.

When the whole of the mercury has become volatilized, the gilding has a dull greenish-yellow color, resembling that of boxwood, and the operator then examines whether the coat of gold is continuous. Should a few empty places appear, a new quantity of amalgam is added, and the whole heated again.

The next operation is scratch-brushing, which furnishes a pale-green color, and also requires another heating for arriving at the desired shade. The reheating should be sufficient for expelling any remaining mercury, and producing a fine orange-yellow color.

We may now proceed to one of two distinct operations, accordingly as we desire a bright or a dead lustre. In the first case, we submit the object, with the aid of heat, to the or-moulu process already described. In the second, the object is firmly fixed to an iron rod, with wire of the same metal (Fig. 71), and smeared with a hot paste for dead gilding, composed of nitrate of potassa (saltpetre), chloride of sodium (common salt), and the double sulphate of alumina and potassa (potassa alum). The whole is heated upon a brisk charcoal fire, without draft, and moved about until the mixture becomes dry and begins to fuse, when the article is

Fig. 71.

immediately plunged into a barrel or cask half filled with water.

The covering of salts is immediately dissolved, and the dead lustre appears in all its beauty. This operation, without being very difficult, requires a certain amount of practice, and a skillful workman is sought for.

The gilding must be strong to stand the dead lustre process, especially (as is often the case) when the first trial is not successful.

An object may possess the right kind of dead lustre and still be covered with red lines left by the iron wire. These disappear by plunging the object into a not too diluted solution of nitric acid. Pure hydrochloric acid is preferable.

The gilders with mercury do not employ pure gold; that which they use is previously alloyed with a certain proportion of copper or silver. With the latter metal the gilding is green. Red gilding is either obtained with a dark or-moulu or with the *green for red,* already mentioned. (See this name in the chapter on CHEMICAL PRODUCTS.)

Gilding with a partly Dead, partly Bright Lustre.

During the past twenty years we have met with many mixtures of bright gilding by the wet way, and dead gilding by fire, upon the same article.

In order to arrive at these results, operate as follows:—

Gild with the amalgam those parts which are intended for a dead lustre, and heat, scratch-brush, and reheat to the orange-yellow color. Then, with the battery, give a sufficiently strong gold deposit to the whole, without regard to the parts already mercury-gilt, scratch-brush all the surfaces carefully, and smear the electro-gilt portions first with a thin mixture of water, glue, and Spanish white, and afterwards with a thick paste of yellow clay. After drying, cover the mercury-gilt portions with the paste for dead gilding, and proceed as has already been explained. The Spanish white, &c., are dissolved in a dilute solution of hydrochloric acid. The glued paste is intended to preserve from the heat the electro-gilt portions, which are again wire-brushed with all the care necessary for not scratching the dead lustre. Brushing comes next.

This method, which is generally followed, is open to several objections, among which is the production of red spots on those places which have been heated too much, or where the coat of gold was not thick enough. It is easier and more sure to proceed as follows:—

Gild with the amalgam, and bring up the dead lustre upon those portions which are to receive it, and preserve them entirely with the resist varnish. After thorough drying, cleanse the object by dipping it into acids, in the usual manner, and gild in the electro-bath. The resist varnish stands all these acids and solutions. When the desired shade is obtained, dissolve the varnish with gasoline or benzine, which, unless there has been friction applied, does not injure in any way either the shade or the velvety appearance of the dead lustre. Wash in a hot solution of cyanide of potassium, then in boiling water, and allow to dry naturally.

The resist varnish may also be removed by allowing the object to remain for a variable length of time in concentrated sulphuric acid marking 66° Baumé, which has no action whatever upon the gilding. In this case, the washing with cyanide is unnecessary, and pure water is sufficient.

Gilding with a dead lustre, whatever be the process employed, suits only those objects which will never be subjected to friction. Even the contact of the fingers injures it.

A new freshness is imparted to old dead gildings by a washing in caustic lye, and then in a dilute solution of nitric or sulphuric acid. This process is sufficient to remove the dirt of grease, dust, and smoke, but, evidently, will not remedy scratches. In the latter case, the objects must be scratch-brushed, and then heated with the composition for a dead lustre.

CHAPTER XXV.

GILDING ZINC WITH A DEAD LUSTRE.

Gilding Zinc with a Dead Lustre.

THERE is, at the present time, no artistic bronze, whatever be the finish, elegance, and delicacy of its shape, which may not be reproduced in zinc (decorated with the name of *Bronze composition*) with an accuracy which often deceives a practised eye. Most of our stores are filled with clocks, chandeliers, cups, and other articles of luxury made of zinc only. A great many of such articles have a simple coating of brass, bronzed afterwards to imitate similar objects of real copper, brass, or bronze; but others rival in their gilding the finest products of the gilding by mercury, either with a dead lustre, scratch-brushed, or burnished.

Gilt zinc, especially with a dead lustre, is, at the present day, manufactured in France on such a large scale, that we feel ourselves obliged to devote to it an entire chapter.

The first operation consists in filling with tin solder all the holes and the smallest defects which may exist in the object of zinc, and, at the same time, removing with appropriate tools the seams, burrs, rough spots, &c.

Afterwards, the piece is scoured by passing it, for a few seconds only, through a boiling solution of 100 parts of water and 5 or 6 parts of caustic potassa or soda. Too long a presence in this caustic lye will spoil the polish of the zinc, which becomes dissolved. After this scouring or cleasing, the object is rinsed in fresh water.

It is then steeped for half a minute in a pickle composed of 10 parts of sulphuric acid, and 100 parts of water, and lastly rinsed in fresh, or preferably boiling, water.

Thus prepared, the object is immersed in a cold or warm electro-bath of copper or brass, for a few moments, and until it has been covered with a thin metallic pellicle, which is deposited very uniformly if the object has in it no tin solder and is perfectly cleansed. On the contrary, the deposit is black and dull on those parts which have been soldered, or imperfectly cleansed. In the latter case, the article is thoroughly scratch-brushed, and dipped again into the electro-bath for a half hour or an hour, until the deposit is sufficiently thick. Most gilders use a warm bath for the first pellicle, scratch-brush, and complete the deposit in a cold bath.

If a bright gilding or-moulu fashion be desired, the article may be rinsed in fresh water, and then dipped into an electro-gilding bath.

On the other hand, if we desire a dead lustre gilding, equal in appearance to the best mercury gilding, we proceed by either of the two following methods:—

First Method.—With Silver.

An electro-silvering bath is prepared by dissolving in 10 litres of water, 150 grammes of fused nitrate of silver, and adding 250 grammes of pure cyanide of potassium, which, at first, produces an abundant precipitate, which soon becomes dissolved. The filtered liquid is the silver bath, into which is steeped the zinc article previously coated with copper or brass. Under the influence of a proper electric current, the silver deposited is of a very handsome frosted (dead lustre) appearance, and perfectly white. The object is then rapidly and thoroughly rinsed, and dipped into an electro-gilding bath, of which we shall give the formula.

The dead gilding obtained by this process is very fine and silky, but is soon altered and darkened by the sulphuretted hydrogen of the atmosphere and of the gas-light, which sulphurizes the silver through the thin film of gold.

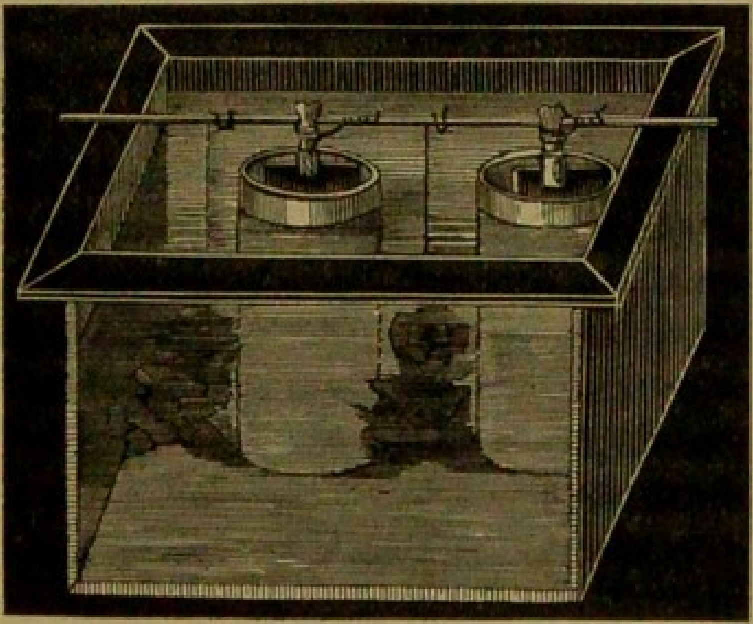
This first process is seldom employed at the present day, and the following one is preferred, and rightly so, since it is more durable and more economical:—

Second Method.—By Galvanoplastic Processes.

Add to the necessary quantity of water, one-tenth of its volume of sulphuric acid, and dissolve in this acid liquor as much sulphate of copper (blue vitriol) as it will hold at the ordinary temperature. This solution will then mark from 20° to 24° Baumé, and then add enough water to reduce its specific gravity to 16° or 18°.

This galvanoplastic bath is generally held in large vessels of stoneware, slate, wood, or gutta-percha; and porous cells are immersed in it which are filled with a weak solution of sulphuric acid and of amalgamating salts. Plates or cylinders of zinc are put into these cells, and are connected with one, or several brass rods, which rest upon the sides of the trough, and support the articles which are to receive a dead lustre in this bath. (Fig. 72.) The articles of zinc, previously coated with copper or brass, are therefore suspended to the rods, and remain in the so-

Fig. 72.



lution of sulphate of copper until they have acquired a satisfactory dead lustre.

It is prudent, a few seconds after the articles have been immersed in the bath, to withdraw them from it, and to examine them carefully. Indeed, should the previous coat of copper or brass be insufficient to resist the corroding action of the acid solution of sulphate of copper, there is produced a muddy and dark deposit, which is easily removed with the finger. And should this occur, the object must be scratch-brushed and placed again in the former alkaline baths of copper or brass, in order to increase the deposit which protects the zinc in the galvanoplastic bath.

The beginner, before undertaking this operation, will do well to consult and become conversant with the second part of this work on the *galvanoplastic art.*

When the galvanoplastic dead lustre has been successfully obtained, the deposit is perfectly regular, and of a pink shade which possesses great freshness. When, on the contrary, it is irregular, marbled, crystalline, of a vinous or fire-red color, and dull or earthy in appearance, these defects are due to the following causes: either the bath is in a bad state of conductibility or of saturation; or the surface of the zincs is too considerable in proportion to that of the objects, and therefore too much electricity is given out; or, lastly, the previous electro-deposits of copper or brass were insufficient or inferior in quality. The remedy for either of these inconveniences is easily found out, and simply requires a little care and attention.

The galvanoplastic dead lustre being once obtained in a satisfactory manner, two preliminary operations are needed to insure the success of the gilding.

They consist in rapidly passing the object (with dead lustre), after rinsing, through a solution made of—

Water	10 litres
Nitrate of binoxide of mercury	10 grammes
Sulphuric acid	20 "

then, after rinsing, plunging it into another solution composed of—

Water	10 litres
Cyanide of potassium	400 grammes
Nitrate of silver	100 "

The object acquires a slightly white tinge in this liquor, and is again rinsed in fresh water, before being put into the following gilding bath:—

Distilled water	10 litres
Phosphate of soda	600 grammes
Bisulphite of soda	100 "
Cyanide of potassium, pure	10 to 12 "
Chloride of gold, neutral	20 "

The mode of preparation of this bath is given at the beginning of Chapter XX.

This bath should be nearly boiling, and worked with quite an intense galvanic current. The anode is a platinum wire, which being more or less immersed in the liquor, allows of the regulation of the amount of electricity according to the volume, weight, and surface of the object to be gilt.

This kind of gilding requires at the beginning an energetic electric action, obtained by steeping the platinum wire deeply in the liquid, in order to have the entire surface of the piece covered quite instantaneously; then, as the thickness of the deposit increases, so is the anode gradually removed from the bath until it dips very little. The gilding obtained by this method has a remarkable freshness of tone.

A few gilders, before using the bath with battery, pass the zinc articles through another bath by dipping, which they call *preparing bath*, and which is nothing but a gold bath by dipping, such as that described at page 120, Chapter XII.

Others gild in two operations, that is, after having deposited about half of the gold intended for the object, this is removed from the bath, washed, passed again through the mercurial solution, and replaced in the gold bath for finishing up the gilding.

After gilding, the articles are rinsed in clear boiling water for a few seconds, and dried in the stove, or in warm sawdust of fir wood. All friction should be carefully avoided, otherwise the dead lustre will become scratched. These washings are necessary, because, if saline matters are left, they will react upon the zinc and the copper, and the gilding will be covered with verdigris.

When certain parts of this gilding are burnished, their color is green if the frosted surface has been obtained in the silver bath, and red if the galvanoplastic bath has been employed. These inconveniences are remedied by dipping the burnished article again, for a short time, into the gold bath. It is evident that this last deposit of gold must be thin enough not sensibly to impair the brightness of the burnished parts.

Dead lustre electro-gilding upon zinc, like that obtained by the old process, will suit those objects only which have no friction to bear, and which are not often handled. This kind of gilding is especially applied to clocks and similar articles, which remain under glass.

The dead lustre obtained by a thick deposit of gold is always dull, earthy, and of a disagreeable appearance.

The process of dead lustre gilding, described in this chapter, may be applied to all metals and alloys, provided that those corroded by the solution of sulphate of copper be previously coated with copper or brass. Indeed, these previous coatings of copper or brass are always desirable, because they prevent crystalline and irregular deposits often formed upon metals which are not corroded by the bath of sulphate of copper. I have discovered by experience, that the galvanoplastic dead lustre upon cast or laminated copper, is much finer when the pieces have been previously covered with copper or brass in the alkaline baths.

We thus sum up the operations necessary for gilding zinc with a dead lustre:—

1. Mending the pieces, that is, closing up all the holes with the soldering iron, etc.;
2. Scouring or cleansing in a caustic solution of soda or potassa;
3. Cleansing in water acidulated with sulphuric acid;
4. Effecting electro-deposits of copper or brass, for a few minutes in hot alkaline baths;
5. Scratch-brushing;
6. Finishing the electro-deposits of copper or brass in cold alkaline baths;
7. Washing and imparting a dead lustre either in the silver bath, or in that of sulphate of copper;

8. Rinsing, and passing through a weak mercurial solution;

9. Washing, and steeping in a silvering bath by dipping (many gilders omit this operation);

10. Rinsing, and gilding in the nearly boiling gold bath, in one or two operations;

11. Washing in pure boiling water;

12. Drying in sawdust or in a stove, or in both;

13. Burnishing certain parts, then slightly regilding, washing, and drying.

Faded gildings may be renovated by dipping them, for a greater or less length of time, into a weak and tepid solution of cyanide of potassium, and afterwards into very dilute nitric or sulphuric acid. We may add that imperfect gildings may be removed by inverting the poles in a solution of cyanides, that is, by connecting the gilt articles with the positive pole (carbon or copper), and the negative pole (zinc) with the anode which becomes gilt. This process is especially employed for removing the gold from articles of iron, steel, and even silver, which cannot be submitted to the *ungilding* (*stripping*) *bath* which we are about to describe. Silver, copper, and brass may also be removed by similar processes.

CHAPTER XXVI.

DISSOLVING GOLD FROM GILT ARTICLES.

Dissolving Gold from Gilt Articles.

We cannot take leave of the gilding processes without giving the means of ungilding those articles which need this operation.

Artists or manufacturers are often required to ungild objects, either for doing anew an imperfect gilding, or extracting the gold from worn-out articles intended for remelting. The method varies considerably, according to the metal upon which gold has been deposited.

Iron and steel are ungilt, without any injury to themselves, by dipping them into a bath of 10 parts of cyanide of potassium and 100 parts of water, and connecting them with the positive pole of a battery. A wire or foil of platinum is fixed to the negative pole. This is nothing but inverting the position of the poles; and in this case the gold applied upon the iron or steel is dissolved in the solution of cyanide, and partly deposited upon the platinum anode, from which it is removed in a regular gold bath. When there is only a mere film of gold upon iron or steel, it may be removed by the cyanide alone, without the aid of electricity, but this method is slow.

Silver, copper, and their alloys may also be ungilt by this process; but, as the cyanide dissolves at the same time the gold and part of the other metals, it is preferable to operate as follows:—

For ungilding silver, it is heated to a cherry-red heat, and immediately thrown into a pickle of more or less diluted sulphuric acid. The gold scales off, and falls on to the bottom in the shape of spangles. The operation is repeated until gold no longer appears upon the surface of the silver, which is then white and frosty.

This process is imperfect, and is not adapted to light and hollow articles, for which the preceding process is preferable.

For copper and its alloys, such as bronze, maillechort, brass, etc., we proceed by two different methods, according to the nature and volume of the objects.

Small jewelry ware, thinly gilt, either by battery or by dipping, is dipped into the following bath:—

Sulphuric acid (oil of vitriol) . . .	10 volumes.
Nitric acid (aqua fortis)	1 volume.
Hydrochloric acid (muriatic acid) . .	2 volumes.

Which is simply aqua regia in a large quantity of sulphuric acid. It is precisely this great excess of sulphuric acid which allows of the solution of gold, without sensibly attacking copper or its alloys.

Ordinarily, the sulphuric acid is put alone into a stoneware jar, and the mixture of hydrochloric and nitric acids (aqua regia), kept in a stoppered bottle, is gradually added to it as the operation of ungilding proceeds. The same sulphuric acid may last a long time, provided it is kept well covered, and its dissolving action promoted by successive additions of nitric and hydrochloric acids.

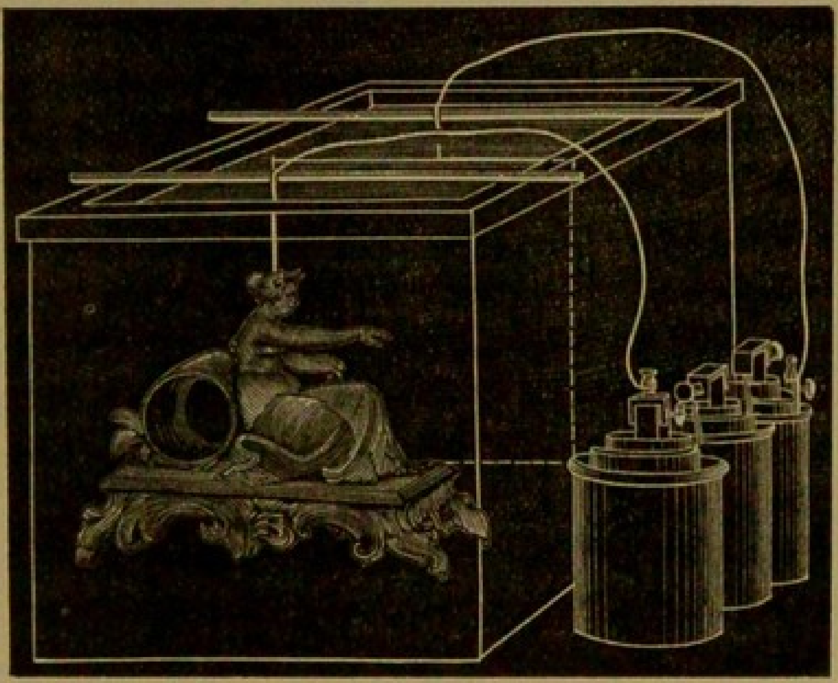
The articles should be withdrawn often, in order to watch the operation, which is terminated when no gold is seen, and when the copper has acquired a uniform blackish-gray coat. We may also ascertain that all the gold has been dissolved, by plunging the objects into the compound acids, in which they are perfectly cleansed when the gold has disappeared.

Nitrate of potassa (saltpetre) and chloride of sodium (common salt) may be substituted for nitric acid and hydrochloric acid. The result is identical; but in this case the salts must be finely powdered, and stirred with a glass rod, in order to be dissolved, decomposed, and transformed into aqua regia.

A few operators ungild small jewelry by a more or less protracted immersion in the compound acids for a bright or dead lustre; but they spoil their acids and lose the gold.

For large objects, such as clocks, chimney ornaments, chandeliers, etc. (and also for smaller articles), we operate as follows (Fig. 73):—

Fig. 73.



Concentrated sulphuric acid (66° Baumé) is put into a glass or stoneware vessel supporting two brass rods.

One of these rods is connected by a conducting wire with the last carbon of a battery of two or three Bunsen's inverted elements, and supports by means of hooks the objects to be ungilt, and which are entirely covered by the sulphuric acid. The other rod supports, also by means of a hook, a copper plate facing the object, and is connected with the last zinc of the battery. The electric fluid traverses the sulphuric acid, and carries the gold from the positive to the negative pole; and as the copper plate is not prepared for retaining the gold, this latter metal falls on to the bottom of the bath in the state of a black powder, which is easily recovered afterwards.

As long as the sulphuric acid is concentrated, and even under the action of the galvanic current, it does not sensibly corrode the copper. But it is not so when it becomes mixed with water; and as it rapidly absorbs the dampness of the atmosphere, the vessel in which it is contained should be kept perfectly closed, when the ungilding process is not in active operation. It is evident that the pieces for ungilding should be put into it in a state of dryness.

When we intend to sacrifice the gilt articles of copper or silver, it is sufficient to let them remain in pure nitric acid, which dissolves all the metals except gold, which either floats at the surface of the liquid as a metallic foil, or falls to the bottom as a blackish powder. If then the liquor be diluted with distilled water, and filtered, all the gold will remain on the filter, and the solution will contain the other metals.

We shall give, at the end of this book, the most simple and practical processes for revivifying, for future use, the gold saved by these different methods of ungilding.

CHAPTER XXVII.

SILVERING.

Silvering.

BEFORE the discovery of the hydroplastic methods, there were in the arts two processes for silvering metals, and these two processes formed two separate industries. Artistic and useful objects of all kinds were manufactured from *plated silver*, that is to say, copper plates covered with silver. On the other hand, articles entirely finished as regards dimensions and shape, were *silvered with silver foils.* There was, it is true, a method of silvering by the wet way; but the products were, and still are, so deficient in durability, that the process was known under the modest title of *Whitening with silver in a pot.* We shall nevertheless examine this operation, which is still employed for whitening certain small wares for which durability is of secondary importance, and which simply borrow of silver its whiteness; such are hooks and eyes, buttons, buckles for suspenders, articles for umbrella-makers, etc., which sooner or later return to the primitive color of their material—copper or brass.

CHAPTER XXVIII.

PLATED SILVER.

Plated Silver.

PLATED silver is obtained by rolling together a plate of copper of the first quality, and one of silver, either welded, or simply united by juxtapositing their hot and clean surfaces wetted with a concentrated solution of nitrate of silver. The two metals are reduced and drawn out about equally by the pressure of the rolls, and long sheets or bands of silvered metal are thus obtained, with which a great many articles may be manufactured.

We soon understand the inconveniences of this mode of operation, and we shall point out four principal ones: In the first place, a great quantity of material is lost, since we have to cut out the objects from a sheet entirely silvered, and the waste retains a large proportion of the precious metal; in the second place, the cut sections present many parts without silver, which must be hidden either by ledges, or by silvering by another method.

The third inconvenience is the absolute necessity of employing pure copper, which is more costly, less sonorous, and not so tough as its alloys.

The fourth defect, which is capital, lies in the difference of thickness of the silver, according to the shape of the object. It is evident that, in the embossed parts, the bottom of a vase for instance, the silver has increased in surface, and therefore that its thickness is less than that of the flat surfaces. Moreover, these raised surfaces are the more exposed to friction, and it is just there that the coat of silver is the thinner. We shall see further on that the conditions are reversed with electro-silvering, and that the parts in relief receive a more abundant deposit of silver, which is a satisfactory result.

The best plated silver has one-tenth of silver, and is manufactured by applying upon an ingot of pure copper weighing 9 kilogrammes, another ingot of pure silver weighing 1 kilogramme. The two are rolled together until the desired thickness is obtained. It is even possible to produce a bad plated silver, with one-tenth of the precious metal; for, should we roll the two metals until the foil of silvered copper becomes $\frac{1}{10}$ of a millimetre thick, the thickness of the silver will be only $\frac{1}{100}$ of a millimetre. Articles manufactured with such foil will possess no other strength than that imparted by the lead, mastic, or cement with which they are filled; and it is by analogous processes that are obtained embossed candlesticks, filled with plaster of Paris, and which become red after very little use.

The silver of the plated metal will be bright if the rollers are well polished, and dull with rough rollers.

A sheet of copper, rolled between two sheets of silver, will, of course, be plated on both sides.

The only solder practicable which does not injure plated silver is tin solder; and when the objects manufactured are required to resist a certain temperature, like chafing dishes, nuts and screws are employed.

When the silver of the plated article was worn out in certain places, there was no satisfactory method of remedying it before the invention of the hydroplastic process.

NOTE.—The electroplating of old wares made from copper laminated with a covering of silver, is often difficult; and we find in A. Watt's *Electro-metallurgy* good directions, which we transcribe here:—

"Supposing that we have to electroplate an old cruet or liquor frame, the bottom is separated from the wire, either by unsoldering or unscrewing, as the case may be. Smoothness is imparted by emery cloth, or by pumice-stone and water, or by powdered bath-brick brushed over with a hard brush. Spots of verdigris are removed with a few drops of hydrochloric acid. The great difficulty consists in giving a good electro-deposit upon the edges or mounts where there is some lead or lead solder. It will be necessary to apply to such parts, with a rather soft brush, a solution made by dissolving four ounces of mercury in nitric acid, and adding about half a pint of cold water. This solution is to be lightly brushed over the lead mounts only; the article and brush are then to be well rinsed, and the brush and plain water applied in the same way. The solution of mercury will turn the edges black, or dark gray, but the subsequent brushing will render them bright again. The frame is now to be well rinsed and is ready for the depositing bath. If, on its first immersion, any black spots exhibit themselves, the frame may be removed, again brushed over, and finally returned to the bath. If the edges do not receive the coating of silver as readily as the other parts, the solution may require a little more cyanide, or a greater battery power, or an increase in the surface of the anode.

"These lead edges may be prepared for receiving the silver deposit by a previous coat of copper applied as follows: The edges are plunged into a solution of sulphate of copper, with a little free sulphuric acid in it; then, by touching the lead edge with an iron wire, it becomes immediately coated with a bright deposit of copper, which is rinsed and becomes a good conductor for the further electro-deposit of silver.

"The coating of tin underneath the bottom of cruet frames is very difficult to plate, unless in a solution made expressly for it. Therefore it may be preferable to remove it either with abrading materials, or with nitric acid employed with care."

Not only for old plated ware, but also for many articles on which are found unruly spots of tin solder, this rapid process of depositing copper will be found useful.—*Trans.*

CHAPTER XXIX.

SILVERING WITH SILVER FOIL.

Silvering with Silver Foil.

This method, in opposition to plated silver, is never practised except upon objects already manufactured, and with their definite shape; and is adapted to all kinds of copper, bronze, maillechort, or brass. It is, therefore, in certain respects, superior to plated silver; but it is very difficult of execution, and is less adhering to the metal underneath.

The operation is conducted as follows:—

After annealing the articles, they are thrown still hot into a bath of sulphuric acid with a small proportion of hydrochloric and nitric acids. Their appearance is then a dull and dead lustre, owing to a multitude of small holes, which are so many points of attachment for the silver foil.

The objects, thus prepared, are tightly fixed upon an iron rod, which is held in a vise. Their temperature is raised to about 150° C. by means of incandescent charcoal put at the proper place, so as to open the pores of the metal, which, by cooling afterwards, will imprison the silver applied. The silver foils are taken from the book with small tweezers, and are cut to the proper dimension upon a cushion with an ivory or steel knife. After each foil is deposited upon the object, it is made to adhere by a light pressure of a rag pad, and afterwards by the friction of a steel burnishing tool. The parts of silver foil which do not adhere are removed with a soft brush. It is possible to superpose a certain number of foils upon the same object, but the adherence will be in an inverse ratio to the quantity.

Gold beaters prepare silver foil either with a bright, or a dead, lustre. The latter is made adhering only by the pressure of the pad, and not by that of the burnishing tool. This dead lustre cannot compare in fineness with that obtained by the battery; it is true, however, that it resists the handling better, and the sulphur gases of the atmosphere.

Articles thus silvered are burnished only after all the silver foils have been applied; round or cylindrical objects are burnished upon the lathe, and the other forms by the hand.

A practised eye will readily ascertain whether an object has been silvered with foils, because, in this case, there are always places and lines showing the vibrations of the burnishing tool.

This method of silvering by silver foils is, at the present time, employed only for very large objects, such as high chandeliers, crosses, holy water pots, and other church ornaments.

During the time when MM. Charles Christofle & Co. had the monopoly of the patents for electroplating, another firm tried the use of silver foils for silvering spoons and forks, but the attempt was soon abandoned. We do not intend to judge the value of the process employed, but we shall simply state that the operation was as follows: The articles were first slightly silvered with a dead lustre in a silver bath by dipping, heated, and then covered with silver foil. The adherence of the latter was due to the pressure of an iron scratch-brush striking vertically, and forcing like the silver foils into the pores of the metal underneath. Burnishing by the usual method finished the operation. It was, therefore, impossible to obtain a dead lustre by this method.

CHAPTER XXX.

WHITENING WITH SILVER IN A POT.

Whitening with Silver in a Pot.

We have already said that it is not possible, by this process, to coat copper articles with more than a blush weight of silver. Indeed, let us imagine what may be the thickness of the silver coat, when the cleansing, labor, silvering, discounts, and profits included, are paid at the rate of ten cents per kilogramme (2.20 pounds) of hooks and eyes and eyelets. The price is reduced to four and six cents for the same weight of suspender's buckles and pins. The value of one gramme (about fifteen grains) of pure silver is about five cents.

This whitening is made as follows:—

A certain quantity of pure granulated silver is dissolved in double its weight of pure nitric acid. The solution is largely diluted with water, and the metal precipitated in the shape of heavy white clods by means of common salt or hydrochloric acid. All of the nitrate of silver has been decomposed when a further addition of hydrochloric acid or common salt to the clear supernatant liquid does not produce any turbidity. The clear liquors are then thrown away, and the chloride of silver obtained is washed several times, in order to deprive it of all free acid. If this precipitate is to be kept some time before use, it should be removed from the action of the solar rays, which blacken it rapidly.

The chloride of silver, with a little water, is thoroughly mixed with at least eighty times its weight of finely powdered bitartrate of potassa (cream tartar), and kept in a stoneware pot.

Nothing is more variable than the composition of the paste used in this process, and we see each operator adding to the cream tartar some other substance, such as common salt (chloride of sodium), sulphate of soda (Glauber's salt), bichloride of mercury (corrosive sublimate), caustic lime, calcined magnesia, etc., the greater part of which are useless, if not hurtful. Here is a formula which succeeds very well, and which is often preferred to the simple mixture of chloride of silver and bitartrate of potassa.

Pure silver (for making the chloride) .	30	grammes
Powdered cream tartar	2500	"
Salt which has been used for curing codfish*	2500	"

One or several spoonfuls of the paste prepared as above are thrown in, and entirely or partly dissolved in the boiling water contained in a kettle of pure copper. Such is the bath into which we dip the articles, either with the aid of a hook, or with a basket of wire gauze, such as we have indicated in the chapter on gilding by dipping. However it is more usual to have another basin of copper, shallow and perforated with holes, which rests against the upper

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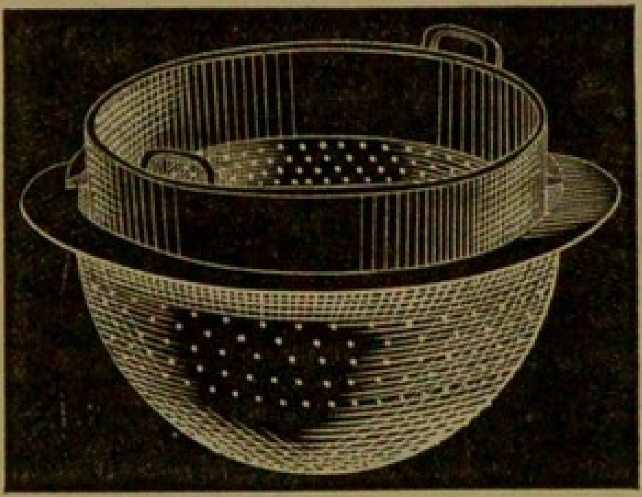
* This salt has no other advantage over common salt than its greater cheapness. Certain operators employ chloride of silver and common salt only, but the shade obtained is bluish.

sides of the kettle (Fig. 74). By means of the handles of this basin, it can be removed at once with its contents.

Fig. 74.



The articles are stirred with a wooden spatula; and at each operation a quantity of paste, proportioned to the surfaces to be whitened, is added.

These baths do not work well when freshly made, and they become the better as they are more used. They acquire a dark green tint, due to the copper which is dissolved and which takes the place of the deposited silver.

The operators by this process do also the varnishing, coloring, and cleansing in aqua fortis; but their cleansing methods are inferior to those employed for gilding. In general, they use the worn-out acids of gilders, as we have already said when speaking of the cleansing of copper.

The articles are brightened by friction with sawdust, and scarcely ever by scratch-brushing.

The smallest particle of iron, zinc, or tin introduced into the whitening bath is sufficient to impart a red coloration to the articles of brass or copper which may be in the liquor.

The iron is separated by a magnet; and the zinc is dissolved in pickles of hydrochloric or sulphuric acid, which, when cold, do not sensibly corrode the copper articles. As for tin or lead, they must be picked by hand.

If, from some cause, the operation has not succeeded, the articles are plunged for a few seconds into a boiling solution of—

Water	10 litres
Nitrate of silver	100 grammes
Ordinary cyanide of potassium . .	600 "

This bath, which retains its strength for a long time, considerably increases the brightness and whiteness of the deposit.

We shall soon give, *in extenso*, the new processes of whitening or silvering by dipping, which have nearly everywhere, and with advantage, replaced the old process just examined.

CHAPTER XXXI.

COLD SILVERING BY RUBBING.

Cold Silvering by Rubbing.

We cannot terminate the description of the old methods of silvering metals, without mentioning the quasi-intermediate process of *cold silvering by rubbing*, with the thumb, a cork, or a brush. The results obtained are better than those by the whitening process, although not very durable; and we are enabled to repair slight defects upon more durable silverings, and to produce mixtures of gold and silver, or gold and *oxydé*, upon *slightly* gilt objects. We thus avoid, for small works, the use of resist varnishes.

The paste employed in this process is prepared by thoroughly grinding in a porcelain mortar or with a muller, and, as far as practicable, not in the light, the following substances:—

Water	100 to 150	grammes
White fused nitrate of silver, or, preferably, the chloride. . . .	200	"
Binoxalate of potassa (sorrel's salt) .	300	"
Bitartrate of potassa (cream tartar) .	300	"
Chloride of sodium (common salt) .	420	"
Chloride of ammonium (sal ammoniac)	80	"

Or a more simple mixture of—

Chloride of silver	100	grammes
Bitartrate of potassa . . .	200	"
Common salt	300	"

When the mixture has been finely pulverized in a porcelain mortar, it is triturated under the muller and upon a plate of ground glass until there is no granular feeling. The paste is kept in a porcelain pot, or in a black glass vessel, so as to preserve it from the solar rays, which decompose it rapidly.

When we desire to use it, we add a little water to it so as to form a thin paste, which is applied with a brush or pencil upon the cleansed articles of copper, or upon those gilt by dipping, or even upon those gilt by the battery, provided that the coating be thin enough to allow the copper, through the coat of gold, to decompose the silver paste. The paste is allowed to dry naturally, or with the aid of a gentle heat.

According to the thickness of the gold deposit, the chemical reaction is more or less complete, and the dry paste is of a pink shade, or entirely green. In the latter case, a large proportion of the copper has been decomposed, and an equivalent quantity of silver has become reduced to the metallic state.

The remaining salts are removed by a thorough rinsing in cold water, and the silver appears with quite a fine frosted appearance, the brightness of which may be increased by an immersion of a few seconds into a very diluted solution of sulphuric acid, or, preferably, of cyanide of potassium.

This silvering bears the action of the wire brush and of the burnishing tool very well; it may also receive the *oxydé*, which proves its superiority over the previous whitening process.

Should a first silvering not be found sufficiently durable, it is possible, after scratch-brushing, to apply a second or a third coat.

The deposit, we have said, is fast enough upon pure copper, but the silvering is not so adhering or white as upon a gilt surface.

This process is advantageous for keeping in good order the reflectors of lanterns: in which case, the paste is rubbed with a fine linen pad upon the reflector, which acquires a dull and leaden appearance; then, with another rag, a thin magma of Spanish white, or other similar substance, is spread over the reflector and allowed to dry. Lastly, a rubbing with a fine and clean linen rag will restore the lustre and whiteness of the plated silver.

For keeping in order the reflectors of plated silver used in railways, we prefer the following method :—

To a silvering bath made of water .	1 litre
Nitrate or chloride of silver . .	50 grammes
Cyanide of potassium . . .	300 "

Add sufficient Spanish white (levigated chalk), in fine powder, to produce a thin magma, which is kept in a well-closed pot. This paste, by means of a brush or of a pad of old linen, is spread all over the surface of the reflector, and allowed to dry almost entirely, when it is briskly rubbed over by means of another clean and dry rag of old linen. The produced silvering is the brighter as the operation is more frequently repeated. It is evident that this process is equally suited to all articles of plated silver, such as carriage and saddlery ware, &c.

The various powders or liquids sold under the names of *silvering liquid*, *conservator of plated silver*, *California liquor*, *&c.*, and which are used in coffee-houses for hiding for a few days the worn-out parts of their spoons and forks, are nothing else than a greater or less proportion of the above paste in ordinary, or salted, water.

We must not confound these compounds with other liquors bearing the names of *aurophile* and *argentophile*, and which are intended for cleaning old gildings and silverings. They are simple solutions of cyanide of potassium, and correspond to the method which we have indicated for reviving old gildings.

CHAPTER XXXII.

SEQUEL TO SILVERING: SILVERING BY DIPPING IN A WARM BATH—IN A COLD BATH.

Silvering by Dipping in a Warm Bath.

THERE are two processes of silvering by the wet way and without the battery, which are as different in their operation as in their composition and results. One of them, indeed, is especially intended for silvering hooks and eyes, buttons, buckles, &c., and is practised at the temperature of ebullition in a bath of the double cyanide of potassium and silver.

This bath is made by dissolving in a kettle of enamelled cast-iron, and in 9 litres of water, 500 grammes of ordinary cyanide of potassium (it is our cyanide No. 2, the preparation of which is described in the chapter on CHEMICAL PRODUCTS).

On the other hand, we dissolve 150 grammes of fused nitrate of silver in 1 litre of water contained in a glass vessel or a porcelain dish.

This second solution is gradually poured into the first one, and the whole is stirred with a glass rod. The white or grayish-white precipitate produced at first is soon dissolved, and the remaining liquor is filtered if we desire a perfectly clear bath, which it is sufficient to bring to the boiling-point for immediately silvering the cleansed copper articles plunged in it.

The objects should be simply dipped in, and quite as soon withdrawn; a more protracted sojourn will result in a less white and bright silvering.

The silvering should immediately follow the cleansing, although the rinsings after each operation should be thorough and complete.

This bath, by the bright and light silvering it produces, is perfectly adapted for set jewelry, which cannot be scratch-brushed without flattening the clasps, and to which a bright lustre is absolutely necessary as a substitute for the foil of burnished silver placed under the precious stones of real jewelry. The employment of the solution of nitrate of binoxide of mercury is useless, and even injurious, for this bath.

It has been demonstrated by experience that it is useless to keep up the strength of the solution by new additions of cyanide and of silver salt; a bath thus reinvigorated gives results far inferior to those of the former solution. The bath should, therefore, be worked out as long as the silvering is satisfactory, and when exhausted, put away with the waste. Many manufacturers who follow this process use a battery and a soluble anode in order to obtain a more durable deposit; but their mode of operation is no longer a simple dipping, and properly belongs to the electro-silvering by heat, which shall soon be examined.

A few silverers by dipping formerly used a solution which, when boiling, produced a very fine silver coat, with a dead, or partly dead, lustre, upon coppers cleansed according to the methods indicated at the beginning of this work.

They prepared their bath by dissolving with the aid of heat, and in a well-scoured kettle of pure copper:—

Distilled, or rain water . . .	5 litres
Ferrocyanide of potassium (yellow prussiate of potassa)	600 grammes
Carbonate of potassa (pearlash) . .	400 "

And, when the liquid was boiling, they added the well-washed chloride obtained from 30 grammes of pure silver (*chloride of silver* and its preparation are indicated at the end of the book). This bath should be made to boil for about half an hour, and be filtered, before using. By this method, part of the silver becomes deposited upon the copper kettle, and should be removed when a new bath is prepared. This inconvenience is probably the cause of the abandonment of this process, although the products are remarkably fine.

All the silvering baths by dipping, which contain a great excess of cyanide of potassium comparatively to the proportion of the silver salt, will silver well, even in the cold, copper articles perfectly cleansed; whereas this property diminishes in proportion to the increase of the amount of silver in the bath. In other words, any silver bath with a great proportion of cyanide silvers well by simple dipping, and this property diminishes with the decrease of the amount of cyanide.

The manufacturers of small articles, partly copper and partly iron, such as those used for saddlery and carriage wares, employ a particular process of silvering, and their bath is composed of—

Water (pure)	5 litres
Caustic potassa	160 grammes
Bicarbonate of potassa	100 "
Cyanide of potassium	60 "
Nitrate of silver, fused .	20 "

The cyanide, caustic potassa, and bicarbonate are dissolved in 4 litres of water in a cast-iron enamelled kettle, and then the fifth litre of water, into which the nitrate of silver has been separately dissolved, is added to the former solution.

For the silvering operation proper, a certain quantity of articles are cleansed, thoroughly rinsed, and put into a small enamelled kettle. Enough of the silver bath is poured in, to cover the articles entirely, and the whole is brought to a boil for a few seconds, and stirred with a wooden spatula. When the silvering appears satisfactory, the liquor employed is put with the saved waste; and in this manner, the same liquid is never used for two batches of articles. This process furnishes a somewhat durable silvering with a dead lustre, and of a more or less grayish-white, which is increased in whiteness and brightness by soap and burnishing. It is in this manner that are silvered small buckles, buttons, materials for window shades, and carriage nails, which are always composed of iron and copper.

Silvering by Dipping in a Cold Bath.

This process, although more easy, and furnishing a better and more durable silvering than the other processes by simple dipping, is very little used. But we trust that our readers will try it, and we will guarantee them perfect success.

This process is more easy, because the bath is cold and therefore always ready for use, and does not require weighing in preparing and maintaining it.

The deposit is finer and more unalterable, because only chemically pure silver is deposited, without any mixture of subsalts, as is the case with the other baths, the products of which sooner or latter become yellow. It is also the more durable, because the deposit, without the aid of electricity, may become nearly as thick as desired, and in direct ratio to the length of the immersion.*

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* This last assertion is in direct contradiction to the general theory of deposition by simple dipping, which holds that the metal deposited is replaced in the solution by an *equivalent* of the immersed metal, which becomes dissolved as long as it is not entirely covered by the deposited metal.

Although we have avoided any scientific theory in this practical book, we feel obliged rapidly to explain this phenomenon, which we meet for the first time. We have said in the Chapter on *copper deposits*, for instance, that when an article of iron is plunged into a solution of sulphate of copper, part of the iron is dissolved as sulphate of iron, while an equivalent proportion of copper is separated from the solution and coats the iron. So it is when we plunge an object of copper into a bath of double cyanide of silver and potassium; part of the copper is dissolved and forms a double cyanide of copper and potassium, whereas an equivalent proportion of silver is deposited upon the remaining copper. In either case, the exchange is arrested as soon as the copper, for instance, is coated with a continuous layer of silver, which prevents the solution of the metal underneath.

The same phenomenon takes place at first, during the operation of silvering in the cold by the double sulphite of soda and silver, and an equivalent proportion of double sulphite of soda and copper is formed. But, afterwards, another and a different reaction takes place, by which the silver deposit continues to increase in thickness, without any further solution of copper, and it is due to the chemical nature itself of the component parts of the bath.

We may, indeed, represent the bath as formed of sulphite of soda holding in solution a sulphite of oxide of silver,—that is to say, for the last compound—sulphurous acid, oxygen, and silver.

It is sufficient to know that silver has very little affinity for either sulphurous acid or oxygen, and, on the other hand, that sulphurous acid possesses a great tendency to become sulphuric acid by absorbing oxygen, and we shall then understand that in

This bath is formed of bisulphite of soda, to which is added a salt of silver, the nitrate preferably, until it begins to be dissolved with difficulty. It is therefore with a *double sulphite of soda and silver* that the cold silvering by dipping is effected. It is evident that the bisulphites of potassa, ammonia, and other alkalies may be substituted for the bisulphite of soda, but the latter is to be preferred, because its preparation is cheaper, more easy, and better known.

Before giving the composition of the bath, and the manner of preparing it, we shall indicate a sure process for obtaining a good bisulphite of soda, because it is rarely found in the trade sufficiently pure for silvering.

PREPARATION OF BISULPHITE OF SODA FOR COLD SILVERING.

Into a tall vessel of glass or porcelain (Fig. 75) put—

Water	5 litres
Crystallized carbonate of soda .	4 kilogrammes

and pour mercury, a few centimetres deep, into the bottom of the vessel, so that the glass tube carrying the sulphurous acid gas plunges into it, and may not be stopped by the crystals formed during the opera-

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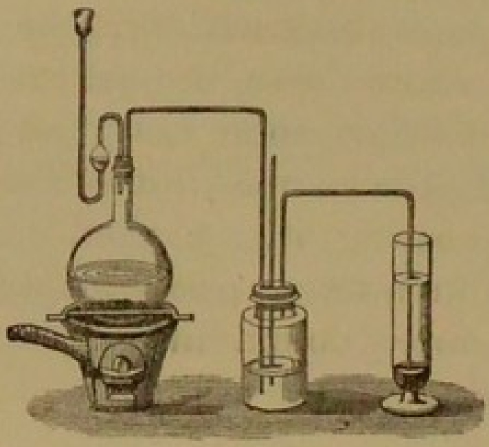
such a bath, silver will continue to become deposited, without the solution of any more copper to take its place in the bath. This is so true, that, if a bath of this kind be allowed to remain in a glass vessel, it will be slowly and spontaneously decomposed, and will silver the glass itself. The sulphuric acid formed reacts upon a portion of the undecomposed sulphite of soda, sets free an equivalent of sulphurous acid which maintains the bath in the state of bisulphite, and forms itself with soda a sulphate of soda without action on the silvering process.

tion. Then dispose an apparatus for the production of sulphurous acid, as indicated in the Chapter on CHEMICAL PRODUCTS, and pass the washed gas through the vessel holding the carbonate of soda.

Fig. 75.



A part of this salt becomes transformed into sulphite of soda, which dissolves, and a part falls on to the bottom as bicarbonate. The latter, however, is transformed into sulphite of soda by a continuous production of sulphurous acid, and the carbonic acid escapes.

When all has become dissolved, continue the passage of sulphurous acid until the liquid slightly reddens blue litmus paper, and then put the whole aside for twenty-four hours. After that time, a certain quantity of crystals are found upon the mercury, and the liquid above, more or less colored, is the bisulphite of soda for silvering. The crystals are separated from the mercury, drained, and kept for gilding baths. They are not suitable for silvering.

The liquid bisulphite of soda thus prepared, should be stirred with a glass rod, in order to eliminate the carbonic acid which may still remain.

The liquor should then be again tried with litmus paper; and if the blue color turns a deep red, a little carbonate of soda is added for neutralizing the excess of sulphurous acid. On the other hand, if the red litmus paper becomes blue, there is too much alkali, and more sulphurous acid gas should be passed through the liquid, which is in the best conditions when litmus paper becomes violet or slightly red. This solution marks from 22° to 26° Baumé, and should not come in contact with iron, zinc, tin, or lead.

PREPARATION OF THE COLD SILVERING BATH BY DIPPING.

A vessel of stoneware, glass, or porcelain is about three-fourths filled with the liquid bisulphite of soda, and a solution of nitrate of silver in distilled water, of a middling degree of concentration, is gradually added while the bath is continually stirred with a glass rod.

By the contact of the two liquors, a flocculent and white precipitate of sulphite of silver is produced, which, with the aid of stirring, is dissolved by the bisulphite of soda. The bath is, therefore, formed of a solution of a double sulphite of soda and silver. The silver solution is added as long as the precipitate readily disappears, and stopped when it becomes slow to dissolve.

In this state, the bath is always ready to work, and produces quite instantaneously a magnificent silvering upon copper, bronze, or brass articles which have been thoroughly cleansed, and passed through a weak solution of nitrate of binoxide of mercury, although this last operation is not absolutely necessary.

We may obtain with this bath, and according to the length of time of the immersion :—

1. A very fine whitening by silver, which is as cheap as any of the other described processes ;

2. A bright silvering sufficiently durable, and especially adapted for setting jewelry;

3. A silvering with a dead lustre, still more durable, for a quantity of objects, without electricity, and in the cold.

The loss of silver by the bath is made good by additions of nitrate of silver; but as there comes a time when the proportion of bisulphite is not sufficient to dissolve the metallic salt, it is necessary to add some bisulphite of soda to restore the bath to its primitive state. For five consecutive years, when I was silvering jewelry ware, I always used the same bath, now and then reinvigorated by additions of bisulphite of soda or nitrate of silver, as needed. And in this same bath, as many articles were daily silvered as a man could conveniently carry, and at prices varying from ten cents to two dollars per kilogramme.

The silver, which is slowly deposited upon the sides of the vessel, may be easily dissolved in nitric acid for future uses.

If I have carefully described this process of silvering in the cold, it is because I do not doubt that it will eventually replace all the other known methods.

NOTE.—A. Watt gives the following useful solution of silver or gold for silvering or gilding without the aid of a battery :—

One ounce of nitrate of silver is dissolved in one quart of rain or distilled water, and a few crystals of hyposulphite of soda are added, which form a brown precipitate soluble in a slight excess of hyposulphite. Small articles of steel, brass, or German silver may be silvered by simply dipping a sponge in the solution and rubbing it over the surface of the article to be coated. A solution of chloride of gold may be treated in the same manner, and applied as described. A more concentrated solution of either gold or silver thus made may be used for coating parts of articles which have stripped or blistered, by applying it with a camel's hair pencil to the part, and touching the spot at the same time with a thin clean strip of zinc.—*Trans.*

CHAPTER XXXIII.

SILVER ELECTROPLATING.

Silver Electroplating.

WE have now arrived at the most important part of our manipulations, that which has created such a revolution in the working of artistic and useful metals. It is our intention to describe it with the greatest care, and the operator will have reason to thank us for many details which, at first, may appear of secondary importance.

It is by electrodeposits of silver that we plate our tablespoons, forks, etc.: therefore are these methods of importance to our health; by them, comfort and even luxury, at modest rates and with artistic appearance, penetrate to the various classes of society; and lastly, the fear of material loss is partly alleviated, since we replace by objects of small intrinsic value, those previously made of solid silver.

Without tarrying among the various formulæ given by certain persons, so called inventors, for electro-silvering baths, we shall describe one which, for a long time has held the place of acknowledged superiority. It is composed of—

Water	10 litres or kilogrammes
Cyanide of potassium, pure*	500 grammes
Pure silver for cyanide .	250 "

This bath is prepared as follows:—

1. A porcelain dish or capsule, of 1 litre capacity receives—

Pure granulated silver . . .	250 grammes.
Pure nitric acid at 40° Baumé . .	500 "

The whole is heated by charcoal or gas, but the dish should be supported by an iron triangle, and not be in direct contact with the fire.

The acid rapidly attacks and dissolves the silver with an abundant production of nitrous vapors, which should not be inhaled. When the yellow vapors have

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* The chemical composition of commercial cyanide of potassium is exceedingly irregular. The facility with which many foreign substances may be incorporated with it during its preparation, and a desire to make large profits, are the reasons why many commercial cyanides do not contain more than 25 and 30 per cent. of the real article. We shall give in the chapter on Chemical Products, at the end of this work, the best method of preparing it for our purposes.

We manufacture three qualities of cyanide of potassium, each of which has its particular uses:—

Our cyanide No. 1 or 100°, contains from 90 to 100 per cent. of real cyanide, and is especially employed for gilding and silvering baths. When we simply say *cyanide of potassium*, we mean this quality.

Our cyanide No. 2 contains from 60 to 70 per cent. of real cyanide; it is the article prepared by Liebig's method, and is used for electrobaths of copper, brass, etc.

Lastly, our cyanide No. 3, which marks from 55° to 60°, is for scouring and preparing baths, and for photographic operations.

disappeared, there remains in the dish a liquid more or less greenish, bluish, or colorless, according to the proportion of copper held by the commercial silver, which is seldom entirely pure.

The heat is then increased in order to evaporate the excess of acid, which escapes in the form of white fumes. The material in the dish swells up and dries, and, with a further increase of heat, fuses like wax.

The dish is then removed from the fire, and being held with a cloth, the molten mass is made to flow upon the sides, where it soon solidifies.

We have thus obtained the fused nitrate of silver (lunar caustic), which is more or less white, or gray, according to the purity of the silver employed.

When the whole is perfectly cooled, the dish is turned upside down, and by a gentle tap on the sides, the mass is detached.

2. The nitrate of silver is dissolved in ten or fifteen times its weight of distilled water, and hydrocyanic acid (prussic acid) poured into this solution, where it immediately produces an abundant white precipitate of *cyanide of silver*. We ascertain that a sufficiency of prussic acid has been employed, when, by adding a few drops of it to the clear liquid, no precipitate or turbidity appears.

The whole is then thrown upon a filter of calico stretched upon a wooden frame, and the cyanide of silver remains on the cloth, whereas the solution with the nitric acid and excess of prussic acid passes through. The precipitate left upon the filter is washed two or three times with pure water.

3. The cyanide of silver thus prepared is put into the vessel intended for the bath, and stirred with the ten litres of water. The cyanide of potassium is then

added, which becomes dissolved itself, and also dissolves the cyanide of silver. The silvering bath is therefore a solution of a *double cyanide of potassium and silver.*

Those persons who operate on a small scale, in order to render the operation more rapid, substitute the nitrate or the chloride of silver for the cyanide. This mode of operation is not economical in the long run, since, after having maintained the strength of their baths with such materials, the liquors will become loaded with chloride of potassium or nitrate of potassa, and, being too dense, will not be easily traversed by the electric current. Moreover, in cold weather, the above salts will crystallize upon the immersed articles, and, as silver will not be deposited upon these crystals, the silver coat will be full of holes, without possibility of burnishing it, and the operation will have to be begun anew.

We should say, nevertheless, that amateurs or operators who employ small baths often renovated, may substitute for the cyanide of silver, the chloride, or, better still, the nitrate of this metal. But, in the latter case, the quantity of cyanide of potassium should be increased. Such baths will be prepared as follows:—

1. The nitrate of silver is prepared in the manner indicated above, and 150 grammes of it (nearly equal to 100 grammes of pure silver) are dissolved in 10 litres of water.

2. The cyanide of potassium No. 1, about 250 grammes, are then added to the above solution.

After stirring to facilitate the complete solution, the liquor is filtered, in order to separate the iron contained in the cyanide. This operation, however, is not absolutely necessary, because the iron rapidly falls to the bottom of the bath, and the solution becomes limpid.

We see that, in this case, we have only 10 grammes of silver per litre of water; but it is enough for ordinary operations. On the other hand, many silver electroplaters employ much richer baths, holding up to 100 grammes of metal per litre; but I personally prefer an average of from 20 to 25 grammes, which furnishes very good and regular results.

The proportion of cyanide of potassium employed is much more than is required for dissolving the silver, since 1½ part of good cyanide is sufficient for 1 part of silver; but experience demonstrates that, unless there be a great excess of cyanide of potassium, the liquors do not conduct electricity well, and the deposit of silver is granulated, striated, and irregular.

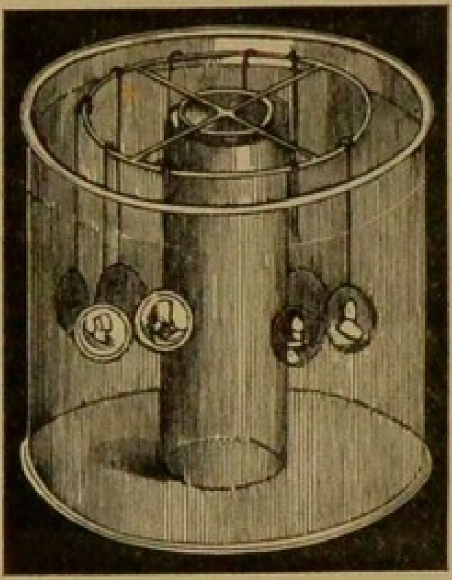
The operation is effected with a battery, and with baths either warm or cold. The latter method is generally adopted for articles which require great solidity. The hot process is employed for small articles, although it is preferable for steel, iron, zinc, lead, and tin which have been previously electro-coppered.

The hot electro-silvering baths are generally kept in enamelled cast-iron kettles, and the articles are either suspended, or moved constantly about in them. The preliminary operations of cleansing in acids and passing through the mercurial solution, are necessary. A somewhat energetic current is needed, especially when the articles are moved about, in order to operate rapidly. There is too much electricity, when the articles connected with the negative pole of the battery become gray or black, and produce many bubbles of gas. A platinum anode (large wire or thin foil) is generally preferred to the soluble anode of silver employed in cold baths, but the solution is rapidly impoverished.

In the hot silvering baths, the separate battery is often replaced by a zinc wire wrapped around the articles. The points of contact of the two metals are often black or gray; but the stain rapidly disappears by plunging the object into the liquor for a few moments, after it has been separated from the zinc, and carefully scratch-brushed.

A few gold and silver electroplaters employ, instead of separate batteries, the *simple apparatus* (Fig. 76), which consists of a glass, porcelain, or stoneware vessel holding the bath, and in the centre of which is a porous cell filled with a solution of 10 per cent. of cyanide of potassium or of common salt. The cylinder of zinc, immersed in this exciting liquid, carries a circle of brass wire, the cross diameters of which are soldered to the zinc. It is then sufficient

Fig. 76.



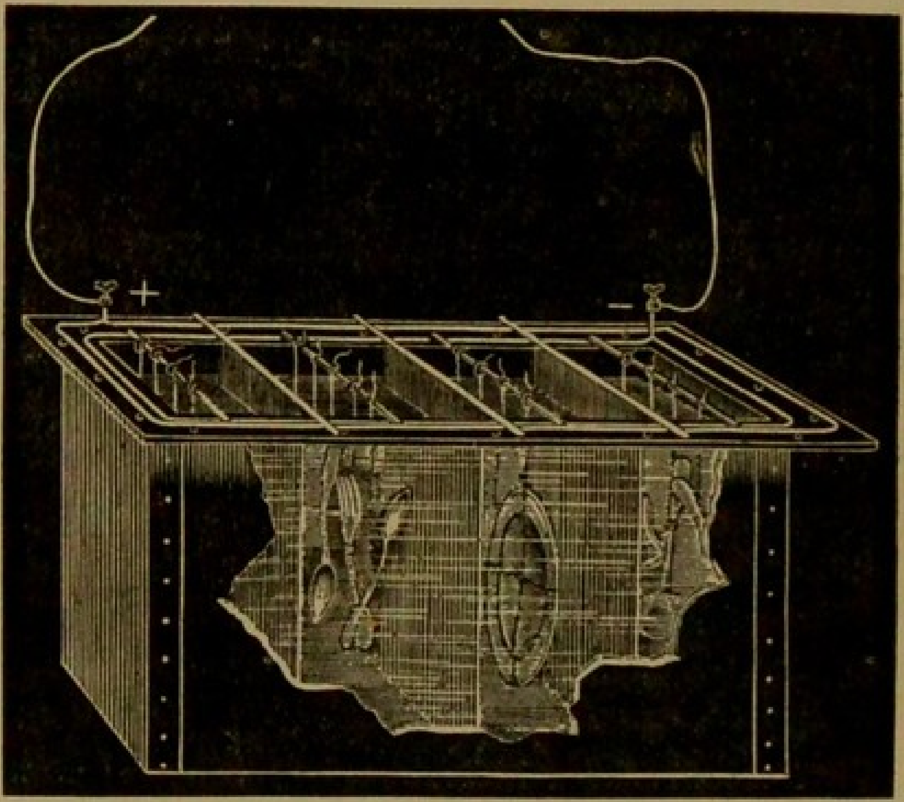
to suspend the well cleansed articles to the brass circle by means of slinging wires. At the beginning, the operation goes on rapidly, and the deposit is good; but, after a certain length of time, the solution of zinc traverses the porous cell by exosmose, and the purity of the bath is impaired.

An impoverished hot bath is reinvigorated by additions of equal parts of cyanide of potassium and of silver salt. It is also necessary to replace the water in proportion as it is evaporated.

When the silver baths rapidly deposit their metal without the aid of electricity, it is a proof that they are too rich in cyanide, or too poor in silver. A deposit effected under such conditions is rarely adhering, especially when we operate upon articles previously coppered, because then the excess of cyanide dissolves the pellicle of deposited copper, and the silver which takes its place may be removed with the finger. This phenomenon will be particularly observed with articles of steel, tin, lead, etc., which of necessity have been coated with copper. The remedy consists in adding to the bath only enough of silver salt and no more, so that a piece of copper will not become sensibly silvered in it, without the aid of electricity.

The cold electro-silvering baths are disposed differently, according to the articles to be operated upon. Those generally employed for silver electroplating tablespoons and forks, etc., are contained in large and rectangular wooden troughs (Fig. 77), lined with gutta percha, or made of riveted wrought iron. They are sufficiently high to allow of about 10 centimetres of liquid being above the immersed objects, and the distances from the bottom and sides are nearly the same. This condition will permit a regular deposit of metal at both extremities of the object. The upper ledge of the trough carries two

Fig. 77.



brass rods all round, which do not touch one another, and one of which is higher, in order that other metallic rods, being put across, will rest upon the higher or the lower rods, but not upon both at the same time. Each of these rods is connected with one of the poles of the battery, by means of conducting wires, the points of contact of which should be perfectly clean. The rod which supports the articles to be silvered is connected with the negative pole represented by zinc in most batteries; and the other, supporting the anodes, is attached to the positive pole, which is carbon with Bunsen's elements, copper for Daniell's, and platinum with Grove's cells.

A certain number of spoons and forks fixed to one rod (Fig. 78), by means of copper wires, are cleansed at the same time, and the rod is placed upon the negative conducting rod of the trough. Then, facing each other, we dispose upon the positive conducting wire of the trough another metallic rod to which the soluble silver anode is attached like a flag (Fig. 79).

Fig. 78.

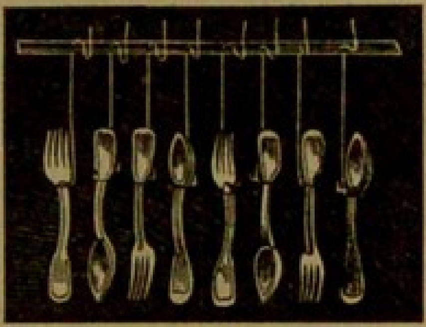
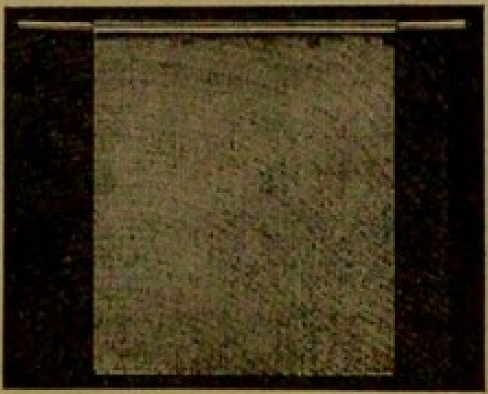


Fig. 79.

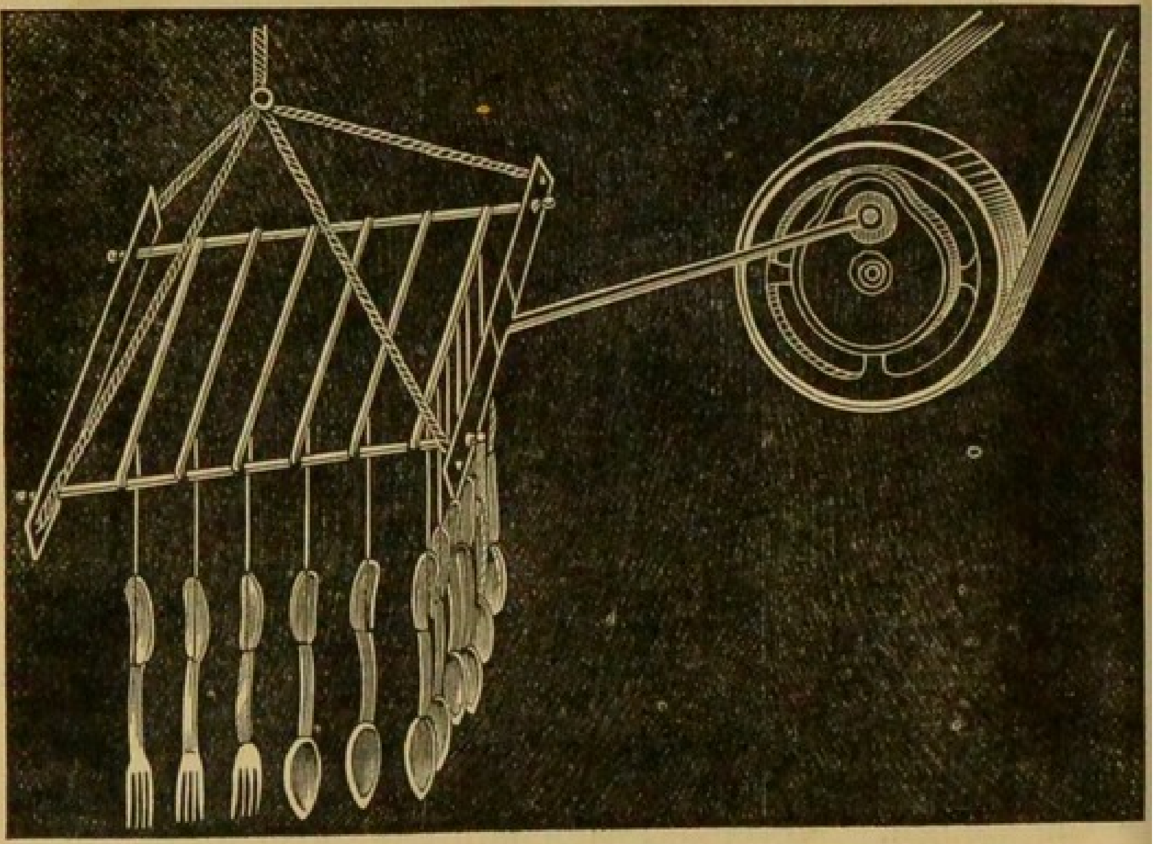


Next comes another series of spoons and forks, faced by another soluble anode, and so on, and in such a manner that each series of spoons and forks is between two anodes. The articles to be silvered all rest upon the negative conducting rod, and the soluble anodes upon the positive one.

This disposition is evidently the best for obtaining a sensibly equal deposit upon all the pieces; nevertheless it still requires the turning upside down of the objects during the operation, in order to prevent a thicker deposit on the lower parts. Indeed, we should not forget that the richest part of the solution is the densest, and therefore lies near the bottom of the trough. Moreover, the change of position of the articles prevents the formation of longitudinal striæ, which are often seen upon smooth articles left unmoved in the solution for a long time.

These striæ are generally due to the existence of a multitude of small ascending and descending currents, formed by the successive displacements of denser and lighter liquid layers. They do not take place in liquors kept in a state of constant agitation. The denser layers, being richer in metal, deposit it more abundantly upon the direction which they follow, and form grooves which cannot be filled by the lighter and poorer currents. It is, therefore, advantageous either to keep the bath or the objects in constant motion; and in large silvering works, where there is a motive power available, a small portion of it may be used for imparting a motion to the objects to be silvered. In this case, the frame supporting the articles does not rest upon the trough,

Fig. 80.



but is suspended above the bath, and receives its motion from a small eccentric. (Fig. 80.)

Any other system, producing the same results, may be employed.

Tablespoons and forks of ordinary dimensions, in order to acquire sufficient durability, should receive a silver deposit weighing from 70 to 100 grammes per dozen. The coat will adhere strongly, if the well-cleansed articles have been fully amalgamated in the solution of nitrate of binoxide of mercury. Their sojourn in the silver bath varies from twelve to fifteen hours, according to the intensity of the current. The silvering will be the better and finer as the intensity of the current is weaker, provided that we remain within certain limits determined by the surfaces to be silver-plated.*

Electro-silvering baths do not generally work so well when freshly prepared, as when they have been used for a certain time, and have become *electrolized;* the deposit is not always uniform, and is often granulated, bluish, or yellowish. It is therefore desirable to mix a portion of old liquors with those recently pre-

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* A sufficient quantity of silver may be deposited within three or four hours, but then the aggregation of the metallic molecules is not satisfactory, and the burnishing is very difficult. When the articles, spoons and forks for instance, have acquired a film of silver, they are sometimes removed from the bath and thoroughly scratch-brushed; but, as the contact with the fingers may have left upon them some greasy spots, they should be cleansed in alcohol, or, preferably, in a hot silvering bath, thence again passed through the mercurial solution, and finished in the former cold electro-bath. This first scratch-brushing, which is not always necessary, obviates the tendency of certain cleansed alloys to assume a crystalline appearance, and corrects certain imperfections of the cleansing process.

pared. New baths may acquire an artificial age by boiling them for a few hours, or adding to them one or two thousandths of aqua ammonia.

The greatest reproach to electro-silver-plating is that the deposit does not remain white, but becomes yellowish by contact with the air. This phenomenon is due to the simultaneous deposit, by galvanic action, of pure silver and of a subsalt, the *subcyanide of silver*, which is rapidly decomposed and darkened by light. It is therefore sufficient to eliminate the latter compound, and the inconvenience will disappear. This may be arrived at by the following methods:—

1. The articles are left immersed in the bath for some time after the electric current has been interrupted, when the subcyanide of silver is dissolved by the cyanide of potassium.

2. After having smeared the objects with a paste of borax, they are heated in a muffle until the salt fuses and dissolves the subcyanide. This process anneals and softens the metal.

3. The poles of the battery are inverted for a few seconds, that is to say, the articles become soluble anodes, and the electric current carries away the subcyanide of silver in preference to the metal. It is evident that this operation should be very short, otherwise the silver will entirely abandon the objects and will coat the silver sheets; and should the operation last still longer, the copper itself will follow the same direction.

NOTE.—We condense from A. Watt's *Electro-Metallurgy*, certain precautions for the silver-plating of Britannia metal, pewter, and all combinations of lead and tin. They are best placed in a solution containing a good deal of free cyanide, and the deposit should be rapid at first. The surface of the anode should be about three times that required for German silver, and the battery power strong, but not too intense.

It is better not to disturb these articles in the solution, especially at the beginning of the deposit. Afterwards they may be shifted for obtaining a uniform coat.

If the articles, when they have been placed in the plating bath for a few moments, present an unequal surface, it is advisable to remove them, and have them brushed over again as before; then, after well rinsing, they should be quickly returned to the bath and allowed, if possible, to remain without further disturbance. —*Trans.*

CHAPTER XXXIV.

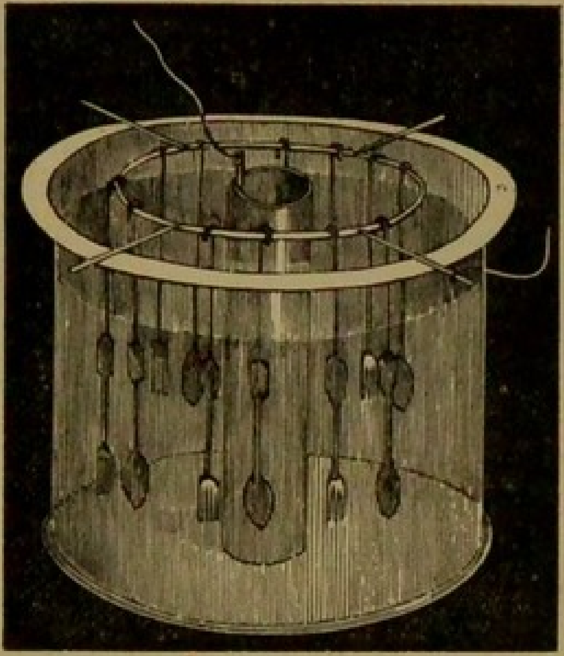
SILVER BATH FOR AMATEURS.

Silver Bath for Amateurs.

Amateurs, or those who simply wish to make a few experiments in electro-silvering, will find the following disposition very satisfactory, since the expenses are small, and the results certain.

The bath is kept in a cylindrical vessel (Fig. 81) of stoneware, glass, or porcelain, and of appropriate size. The spoons and forks, for instance, after a thorough cleansing and amalgamation, are attached by clean copper wires to the circumference of a brass ring, supported upon the top of the apparatus by three or four soldered wires. The ring is connected with the negative pole of the battery, and the positive pole with a platinum anode which dips into the middle of the apparatus. A silver sheet rolled as a cylinder is preferable to the platinum wire. It results from this disposition that all the objects suspended from the brass ring are equally distant from the anode, and receive the same amount of deposited silver. Nevertheless, the articles to be silvered should be now and then turned upside down, and also sideways, so that each face of the object will be, in turn, directly opposite the silver anode. These changes moreover, present the advantage that the points of contact with the suspending wires receive their quota of metallic deposit. When this precaution is not followed, the place where the wire was attached appears as a furrow without silver, and defaces the general appearance.

Fig. 81.



Points, edges, corners, and all raised parts, offer a more easy passage to the electric current, and therefore become more coated with metal. It is, in this case, an excellent condition, which can be obtained only by electro-silvering.

As the wearing out of tablespoons and forks is greater on their convexity, this part should face the silver anode longer than the concave portions.

NOTE.—Bisulphide of carbon, in small proportion, imparts, for some unknown reason, a bright lustre to electroplated articles. We find the mode of operation thus described in A. Watt's *Electro-Metallurgy*: "Put an ounce of bisulphide of carbon into a pint bottle containing a strong silver solution with cyanide in excess. The bottle should be repeatedly shaken, and the mixture is ready for use in a few days. A few drops of this solution may be poured into the plating bath occasionally, until the work appears sufficiently bright. The bisulphide solution, however, must be added with care, for an excess is apt to spoil the solution. In plating surfaces which cannot easily be scratch-brushed, this brightening process is very serviceable. The operator, however, must never add too much at a time."

We have already seen the difficulty of obtaining regular deposits of gold or silver over articles which have parts soldered with soft, or even hard, solder. This difficulty may be greatly obviated by scratch-brushing these parts dry, that is, without the usual liquid employed. The scratch-brush leaves minute particles of metal which render these refractory parts better conducting, provided, however, that during the operation no grease or other impurities are left on these spots.—*Trans.*

CHAPTER XXXV.

ARGYROMETRY, OR METHOD BY WHICH THE WEIGHT OF DEPOSITED SILVER IS DIRECTLY ASCERTAINED.

Argyrometry, or Method by which the Weight of Deposited Silver is directly ascertained.

To ascertain with exactness the quantity of deposited silver upon a determined surface and in a given time, such is the important problem for the silver electroplater to solve. With the different dispositions previously described, we cannot arrive at very correct results, and, although a long practice may facilitate the operation, there is always more or less guesswork and reckoning.

Here are some of the methods employed by operators who do not possess the precise apparatus which we shall soon describe: For instance, let us suppose that twelve tablespoons are to be coated with 72 grammes of silver. The articles are cleansed by the processes already described, then dried in sawdust or otherwise, and weighed in a scale. However rapid this manipulation may be, the surface of the copper will be slightly oxidized and tarnished by the contact of the fingers or sawdust; and, in order to recover their former cleanliness, the articles will have to be plunged into a strong pickle of sulphuric acid, and then into the mercurial solution. After rinsing, and a more or less protracted immersion in the bath, the operator will judge by practical experience that it is nearly time to withdraw the spoons from the solution, and he will have to weigh them several times before the intended weight of silver has been deposited.

Others do differently; they cleanse the spoons or forks and put them immediately into the bath, except one, which is treated as above and is used as a *witness.* This piece is now and then removed from the bath to ascertain its increase of weight, and when it has acquired its proportion of silver, it is supposed that the operation is regular and complete.

It is easily understood how defective and erroneous such methods are. In the first place, for instance, the operation is tedious, and it will be one chance out of a thousand if the correct result is arrived at.

In the second, it is sufficient that the piece serving as the witness be attached to a more or less clean wire, which is then more or less conducting, or be at unequal distance from the soluble anode, to arrive at most erroneous results if the quantity of silver supposed to be deposited upon the other articles be calculated from the increase of weight of the witness piece.*

This inconvenience is obviated, and we know the precise moment when the given proportion of silver has been deposited, by a very simple and easy process.

After having removed one dish of an ordinary pair of scales we substitute for it a metallic frame which supports the articles to be silvered, and communicates through the beam, the knives, and the column with the negative electrode of a battery. The soluble anode is connected with the positive pole (Fig. 82).

When the articles, spoons and forks, for instance, are suspended to the frame, and are in the bath, the equilibrium of the scale is established by means of weights upon the remaining dish. This equilibrium is then broken by increasing the previous tare with a weight equal to the silver which we desire to deposit. It is evident that the operation will be

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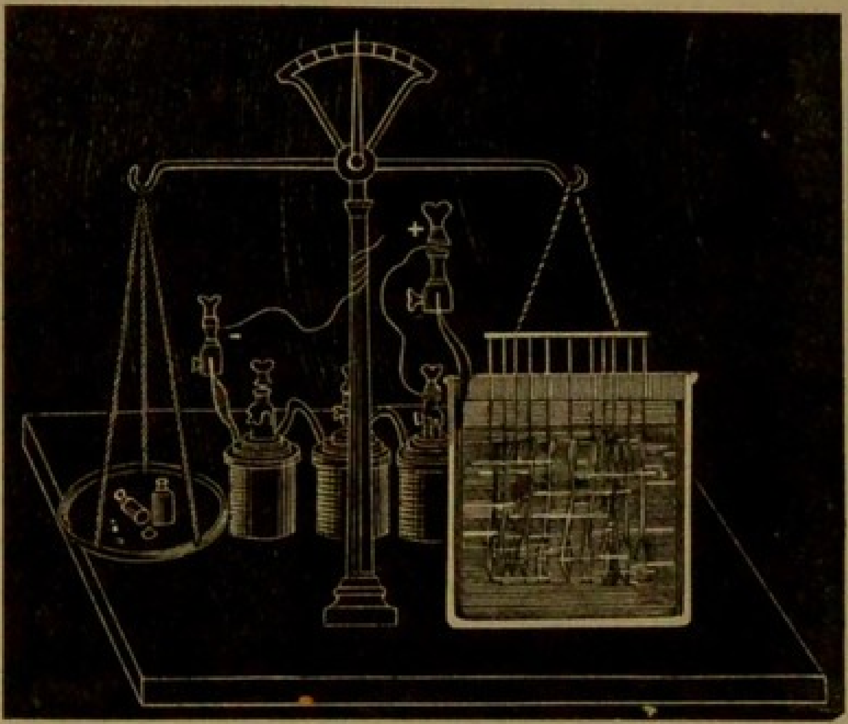
* Strongly amalgamated articles will not become sensibly oxidized during the drying which precedes their weighing.

When, during the operation, the objects have been dried in order to ascertain the proportion of deposited silver, they should not be returned to the bath without having been cleaned in a hot solution of cyanide of potassium, which dissolves the grease from the handling, and passed again through the solution of nitrate of binoxide of mercury, and rinsed. Alcohol may be substituted for the hot solution of cyanide, but the results are not so sure, and the expense is greater.

finished when the equilibrium of the beam is re-established.

Fig. 82.

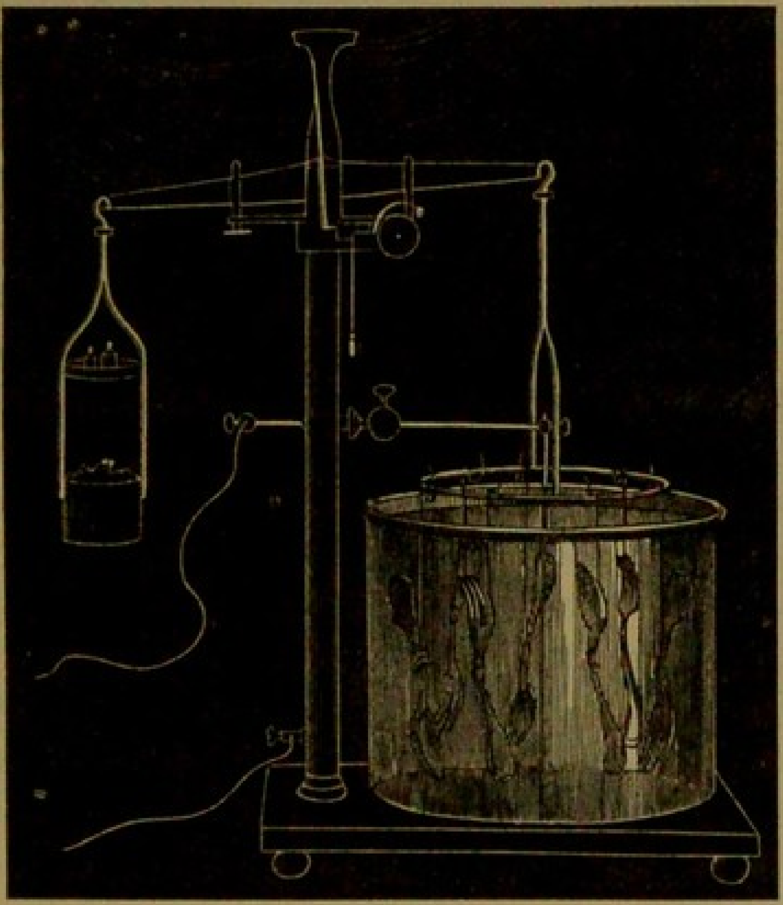


This method is not mathematically accurate, since the articles are more bulky after than before the silvering process (according to the Archimedian principle: *Solids plunged into a liquid lose a weight equal to that of the volume of the displaced fluid*); nevertheless it is sufficiently exact for all practical purposes.

We cannot too strongly advise conscientious manufacturers to employ analogous processes, not only for their own interests, but also with a view to public morals.

A skilful operator will employ scales for each bath, especially when silvering spoons and forks. The supporting frames may be circular, in order to have the soluble anode in the centre of the bath and at equal distances from the articles. The central anode does not prevent the employment at the same time of another anode laid on the sides of the vessel, so that the articles receive the action of the current in front and behind them. Lastly, there is no difficulty in so disposing a sounding bell that it will indicate the precise moment when the equilibrium of the scale takes place (Fig. 83).

Fig. 83.



We see that, in this pattern, the negative electricity communicates with the articles to be silvered through the column itself, the knives, and the beam. The positive fluid passes through a conducting wire isolated from the column by a glass tube. Such an apparatus may be modified in many ways.

These dispositions will result in great exactness as to the weight of deposited silver, less labor, smaller batteries (since the surface of the anode is much larger than that of the articles), and lastly, with several baths there is no danger of a complete stoppage, from a defect in the solution, as is often the case when one trough only is employed.

Each of these baths will be reinvigorated after two or three operations, by the addition of equal quantities of silver salt and cyanide of potassium.

After many operations, the specific gravity of the bath becomes too great. Indeed, if the silver is deposited, the cyanide remains behind and is partly decomposed into carbonate of potassa, which is without action on the silvering process, but prevents the free passage of the electric current. We may then substitute for the cyanide, hydrocyanic acid, which combines with the potassa of the carbonate, while the carbonic acid escapes in a gaseous form. We have thus reconstituted the cyanide with its dissolving properties for metals, oxides, and metallic salts.

The bath may also be regenerated by the cyanides of calcium or barium, the bases of which form insoluble carbonates, whereas the cyanogen combines with the potassa of the carbonate.

CHAPTER XXXVI.

ARGYROMETRIC SCALE.

AUTOMATIC APPARATUS WHICH DEPOSITS WITHOUT SUPERVISION AND WITH CONSTANT ACCURACY A DETERMINED QUANTITY OF SILVER, AND WHICH SPONTANEOUSLY BREAKS THE ELECTRIC CURRENT WHEN THE OPERATION IS TERMINATED.

It does not require a great deal of thought to understand that the preceding kinds of apparatus are still quite imperfect, because the operator must be present when the operation is finished, in order to withdraw the objects from the bath, or arrest the galvanic action. It is a condition which is not always possible, especially with those baths working day and night, and which will often deposit a great excess of silver, if they are not watched.

We believe that we have succeeded in avoiding all the inconveniences pointed out, by means of the argyrometric, or rather metallometric, scale patented by us in 1856, and which we shall describe minutely.

We manufacture four sizes of this apparatus:—

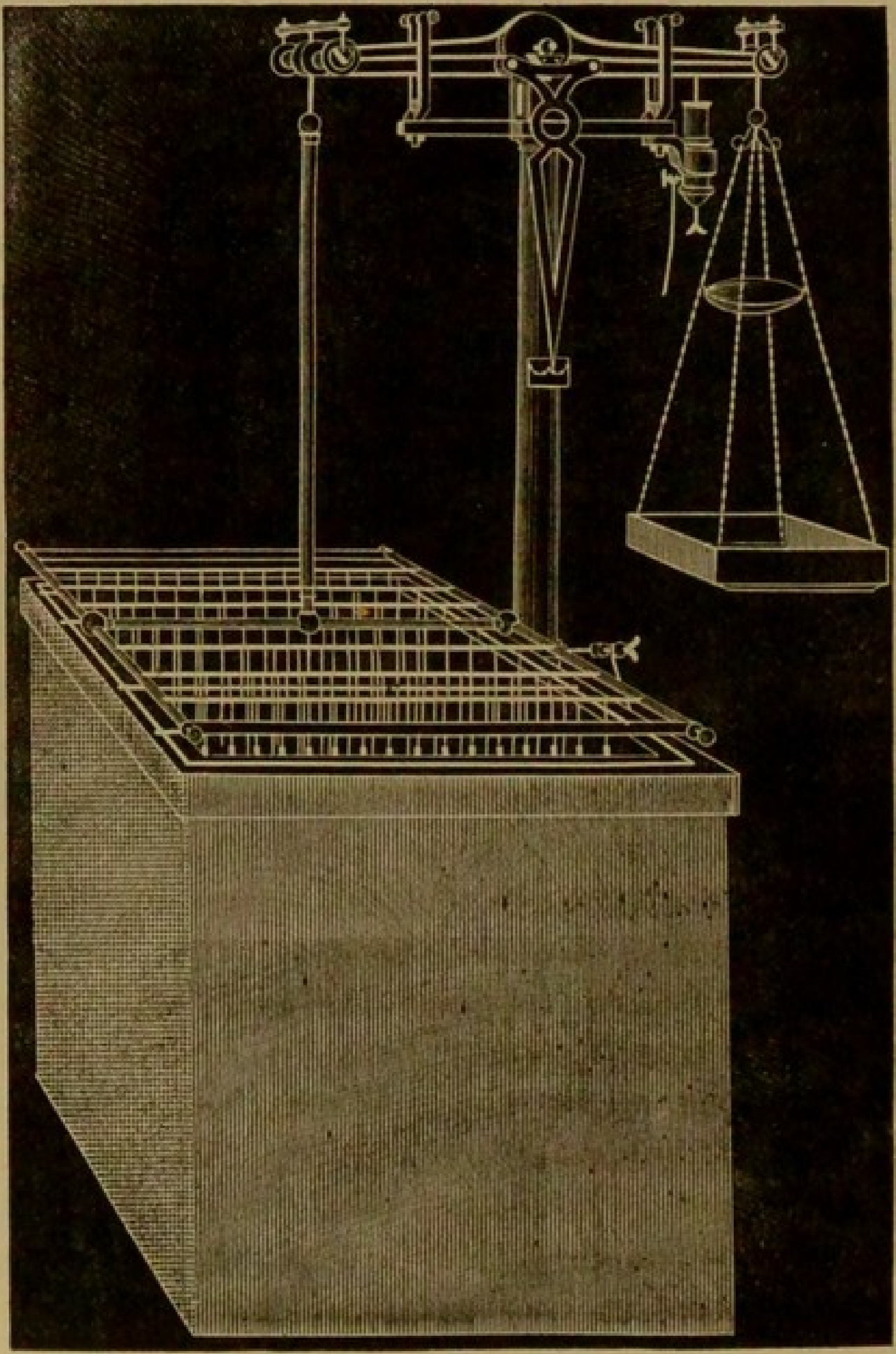
The smallest, or first size, is sufficient for a dozen of forks or spoons, and is intended for amateurs, chemical laboratories, physical cabinets, etc.

The three other sizes are for manufacturers, and will carry four, six, or twelve dozens of forks and spoons, or a proportional quantity of other articles.

COMPOSITION OF THE APPARATUS.

Each manufacturing apparatus is composed of (Fig. 84):—

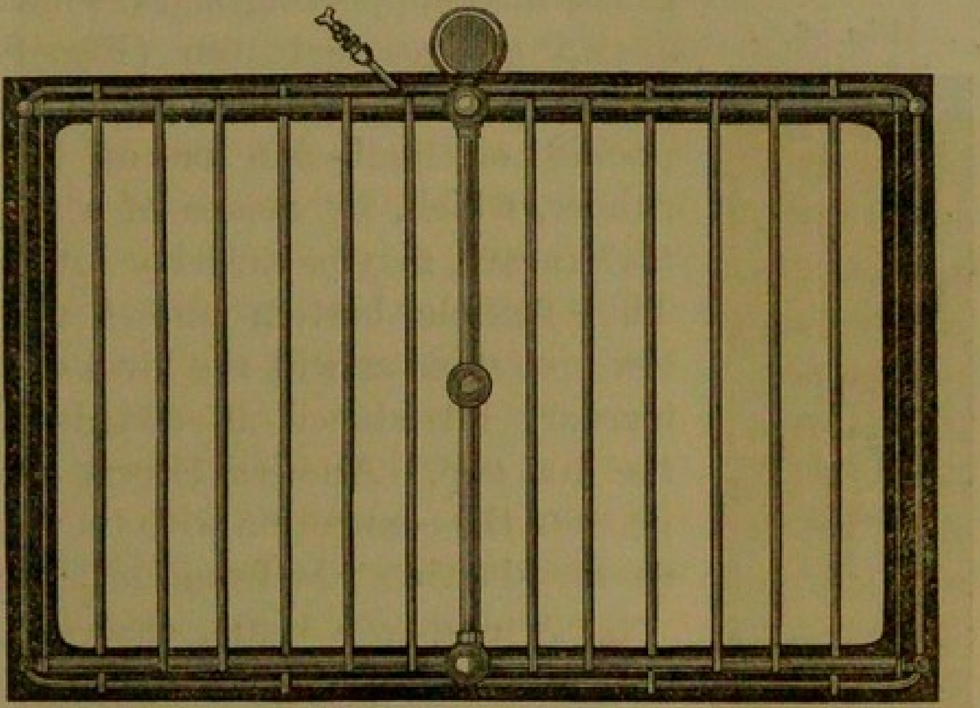
Fig. 84.



1. A wooden trough lined with gutta percha, which is perfectly impervious, and unacted upon by the silver-bath.

The upper ledge of this trough carries a brass rod fixed by small nails penetrating the wood through the gutta percha. This winding rod (Fig. 85), has a screw connection at one extremity for attaching

Fig. 85.



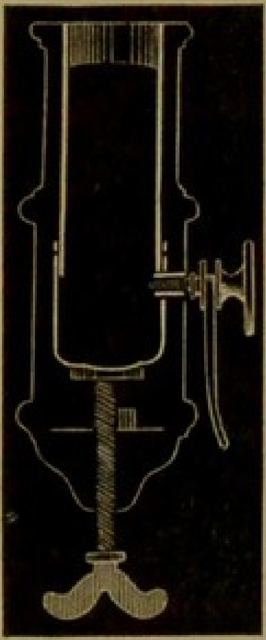
the conducting wire from the positive pole of the battery, and supports the various anodes which dip entirely into the liquid, and communicate with cross brass rods by means of hooks of platinum wire. These cross rods have their extremities filed flat, so as not to roll, and to have a better contact with the fixed winding rod.

2. A cast-iron column screwed at its base to one of the sides of the trough, and which carries near the top two projecting arms of cast-iron, the extremities of which are vertical and forked, and may be opened or closed by iron clamps. These forks are intended for maintaining the beam, and preventing the knives from leaving their bowls under the influence of too great oscillations.

In the middle of the two arms, there are two bowls of polished steel, hollowed out wedge shape, and intended to receive the knives of the beam.

One of the arms of the column carries at its end a horizontal ring of iron, in which is fixed a heavy glass tube supporting and insulating a cup of polished iron (Fig. 86). This cup has at its lower part a small pocket of lamb-skin or of India-rubber, which, by means of a screw underneath, may be raised or lowered. This flexible bottom allows us to lower or raise at will the level of the mercury introduced afterwards into the iron cup. Another lateral screw permits the connection with the negative conducting wire from the battery.

Fig. 86.



3. A cast-iron beam, carrying in the middle two sharp knives of the best steel, hardened and polished. At each extremity there are two parallel bowls of steel separated by a notch, and intended for the knives of the dish for weights, and of the frame supporting the articles. One of the arms of the beam is provided with a stout platinum wire, standing immediately above and in the centre of the cup of mercury. According as the beam inclines one way or the other, this wire goes in or out of the cup.

4. A dish for weights, with two knives of cast-steel fixed to the same metallic bar, which is attached to four chains supporting the lower wooden box for the tare. The smaller pan, for the weight corresponding to the silver to be deposited, is midway.

5. The supporting frame, which is also suspended

by two steel knives, and the vertical rod of which is formed of a stout brass tube fixed below to the brass frame proper, which is equal in dimensions to the opening of the trough, and supports the various rods bearing the articles.

6. Lastly, a certain number of suspension rods (Fig. 87), made of brass, and flattened at their extremities so as not to roll and to have a better contact. The slinging wires are of pure copper, and are soldered with tin in holes drilled in advance. These wires are bent at their extremity in such a manner that the fork or spoon may easily be put in, or removed, and Fig. 88 represents this disposition in full size.

Fig. 87.

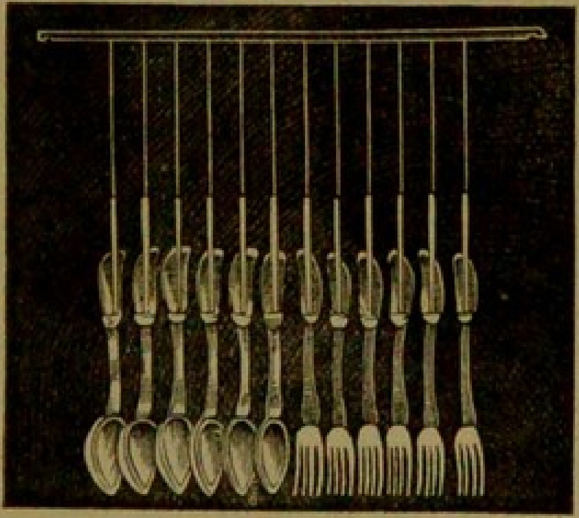
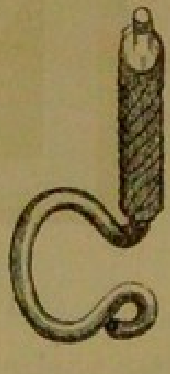


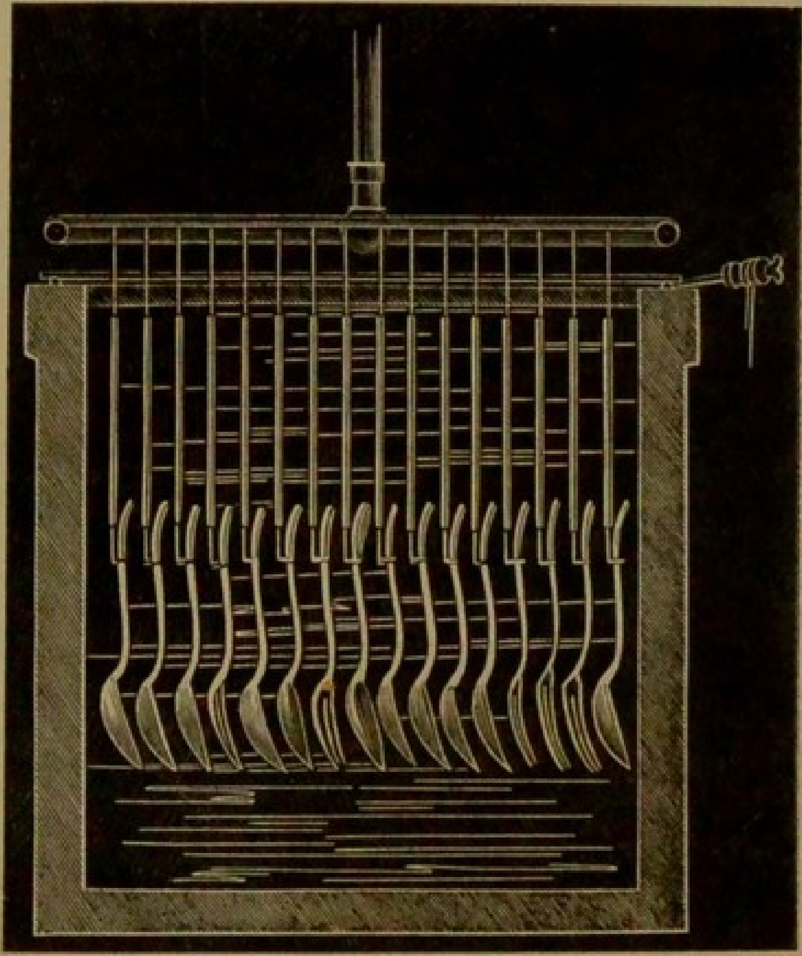
Fig. 88.



The straight portion of these wires which dips into the liquid is covered with a small tube of India-rubber, which prevents the useless deposit of silver upon them. The hooks, however, become coated with silver, which is removed by acids after having raised the India-rubber tube.

Fig. 89 represents a vertical and transverse section of the trough, when in operation.

Fig. 89.



DISPOSITION OF THE APPARATUS.

The various parts of the apparatus being described, we now have to indicate the precautions necessary for their disposition, upon which the exactness of the operation depends.

The trough is set upon four bricks, one at each corner, so that having a free circulation of air under it the bottom will not rot, and the whole is, by the aid of a spirit level, made perfectly horizontal.

The column is then screwed on, and made vertical by the aid of the plumb bob. After having withdrawn the iron clamps from the forks, the beam is put in place with great precaution, so as not to hurt the knives which rest in the bowls of the centre of the column. The clamps are again put on, and the beam should now oscillate freely upon the knives without friction.

The two knives of the supporting frame are put in their places, as are also those of the pan for weights.

Mercury is then poured into the six bowls where the knives rest, until all the polished parts of the latter are covered. Mercury presents the following advantages:—

1. It prevents the corrosive action of the acid vapors of the work-room upon the polished parts of the knives and bowls.

2. The friction is lessened, and the weighings are more correct.

3. It considerably increases the surfaces of contact for the passage of the electricity, which, otherwise, would be obliged to circulate through the edges of the knives.

4. It prevents the softening, by the heat produced by the electricity, of the edges of the knives.

Lastly, the insulated steel cup is filled with mercury, so that the point of the platinum wire attached to the beam merely touches it when the equilibrium is established, that is to say, when the index marks zero. The surface of the mercury should be, now and then, cleaned of any dust which may prevent the passage of the current. The small flexible pocket is used for raising or lowering the level of the mercury, and therefore fixing it at the proper height.

WORKING OF THE APPARATUS.

1. The trough is filled up with the silver bath to within a few centimetres of the upper edge.

2. All of the anodes are hooked upon their rods, every one of which rests upon the winding rod nailed upon the trough, and communicating by means of the binding screw with the positive pole of the battery.

The silver anodes should be dipped entirely into the liquid, otherwise they will be rapidly cut at the line of the level, while the platinum supporting wires are unacted upon.* The anodes are placed parallel to each other, one at each end of the trough, and the intermediary ones are from about 20 to 25 centimetres distant, in order to leave a sufficient space for two rods supporting the spoons and forks.

3. Two transverse wooden rods are put under the suspending frame, which is thus insulated from the winding rod for anodes, and the rods supporting the objects are placed upon it in such a manner that there are two rods for each space between two silver anodes. We must be careful to preserve the same distance between the anodes and the spoons or forks, and, in order to avoid all uncertainty, the places for the rods of anodes and for those supporting the articles, are marked with a file. It is evident that if

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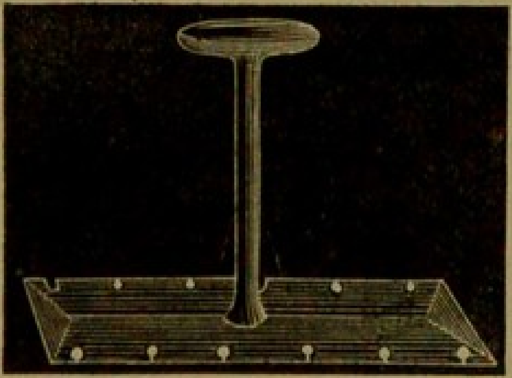
* These anodes are plates of pure laminated silver, and should be at least as high as the articles to be silvered. Their width is from 3 to 4 centimetres less than that of the trough. As it often happens that the laminating rollers have left upon the silver traces of grease and of oxide of iron, the plates should be heated at a dull red heat and cleansed. A simple scouring in a boiling caustic lye is often sufficient.

these equal distances be not preserved, the articles nearer the anodes will be charged more rapidly, and the total amount of silver will not be equally divided. We also understand that, since we put two rows of objects between two anodes, the surfaces opposite to the anodes will be covered more rapidly; therefore it is necessary, during the operation, to invert the supporting rods, *i. e.*, that their extremities on the side of the trough towards the scale go to the other side. This manipulation is unnecessary if we put only one row of articles between, and at equal distances from, two silver anodes.

Before being plunged into the bath, the articles are thoroughly cleansed, and amalgamated. For the rapid and easy handling of forks and spoons during these operations, I have invented a support (Fig. 90) made of gutta percha, and composed of a handle fixed to a plate carrying twelve notches sufficiently narrow at their entrance to allow of the introduction of the forks and spoons by their edges only (sideway). From the entrance, the notches are gradually widened, so that the forks and spoons will stand by their own weight. The edges of the notches are also bevelled, in order to diminish the points of contact with the metal.

Fig. 90.



When twelve spoons or forks have been scoured in boiling caustic lye, and passed through the acid pickle, they are suspended to this support and successively dipped into aqua fortis, the compound acids, and the solution of nitrate of binoxide of mercury. Then by plunging the whole into a large tub of water, and giving a jerk upwards, all the pieces fall from the notches.

This gutta percha support is scarcely attacked by the cleansing acids, and presents the advantage of more rapidity in the operation, great cleanliness, and a sensible economy in slinging wires and in acids. Two of these supports are necessary; one is filled while the other is passed through the cleansing acids.

When all the articles for the same bath are prepared, they are suspended to the rods. This labor is made easy by supporting each rod at its extremities upon two long hooks fixed to the wall, and then introducing each piece into the hook of the slinging wire. The work is begun by the left hook, the opening of which is towards the right side.

When a rod is thus charged, it is seized by its extremities, and the suspended articles are entirely plunged, first into a very diluted solution of nitrate of binoxide of mercury, or simply of sulphuric acid, then into a trough of fresh water, and lastly into the silvering bath. The operation is the same with the other rods.

As soon as the bath is filled with the articles, the tare is made in the wooden box with any kind of materials, weights, or lead shot, added until the equilibrium of the beam is found, that is, when the index marks 0. We then remove the wooden rods which prevented the supporting frame from resting directly upon the trough.

The equilibrium is afterwards broken, by placing upon the intermediary pan a weight equal to that of the silver which we desire to deposit. Following the inclination of the beam, the platinum wire attached to it penetrates the mercury held in the iron or steel cup; and it is then sufficient to connect the conducting wires with the battery, to begin the electro-silvering operation.

It is readily understood that, when the articles will have been coated with a proportion of silver equal to the weight in the pan on the other side of the beam, the equilibrium will be re-established, and the platinum wire will leave the mercury, thus severing the electric circuit, and stopping the deposit of silver, just as if one of the conducting wires had been cut off.

The operation will therefore be completed without any watching; and, what is more, the results will not be modified, whatever be the length of time the articles remain in the solution. Indeed, an excess of silver cannot be deposited, since there is no electric circuit; on the other hand, should the bath dissolve a certain proportion of the deposited silver, the articles become lighter, and the equilibrium is again broken, resulting in the platinum wire re-entering the mercury, and closing the circuit anew. We have therefore a series of oscillations due on the one hand to a slight excess of the electro-deposit, and on the other to its partial solution in the cyanide, and the result is that the deposited silver remains within the proportions determined in advance.

GENERAL OBSERVATIONS FOR KEEPING IN ORDER THE ARGYROMETRIC APPARATUS.

When a silvering operation is complete, we should carefully withdraw the tare from its box, in order to rest the supporting frame squarely upon the trough, without jerks, which may endanger the edges of the knives. The rods and articles may then be removed easily.

The parts of the apparatus which require the greatest cleanliness are the two binding screws through which the current passes, the points of contact of the rods carrying the articles with the supporting frame, and lastly those of the anode rods with the winding brass rod fixed to the trough.

Acids should never be used for cleansing any part of the apparatus, and the best substances for the purpose are sand and emery paper, or, preferably, a rag with finely powdered pumice-stone or ashes.

We should also avoid any rough motion which is injurious to the sharpness of the edges of the knives; and lastly, the apparatus should not carry a greater weight than that for which it is intended.

OBSERVATIONS UPON ANODES.

By watching attentively the behavior of the anodes under the galvanic action, the operator will acquire valuable indications in regard to the composition of the bath, the proper proportion of its component parts, and the results which he may expect.

Thus, should the anodes become *black* during the passage of the electric current, it is a sure proof that the solution contains too little cyanide of potassium and too much silver. In this case, the deposit is adherent, but entirely too slow, and the bath loses more silver than it can gain from the anodes. We must then add, with precaution, cyanide of potassium.

If, on the other hand, the anodes remain *white* during the current, the proportion of cyanide of potassium is too great, the deposited silver is often without adherence, and the anodes lose more metal than is deposited. The remedy consists in adding the silver salt until it dissolves with difficulty.

To sum up, everything is in good working order when the soluble anodes become *gray* during the passage of the electricity, and *white* when the circuit is broken.

The specific gravity of the bath may vary from 5° to 15° of the Baumé hydrometer for salts, and still furnish good results.

Beside the examination of the anodes, there is another simple and rapid process for ascertaining the state of the bath, and establishing the proper ratio between the silver and the cyanide. About one-fourth of a litre of the liquor is put into a tall glass; and a solution of 10 grammes of nitrate of silver in 100 grammes of distilled water is poured into the former, drop by drop. If the white precipitate produced be rapidly dissolved by stirring, the liquor is too rich in cyanide, or too poor in silver; should the precipitate remain undissolved, notwithstanding a long stirring, the liquor is too rich in silver and too poor in cyanide of potassium. Lastly, when the precipitate is dissolved but slowly, the liquor is in the best condition. The remedy for the first two cases is obvious.

A durable electro-silvering, that is to say, with a thick, continuous and adherent metallic deposit, is of such importance at the present day, that we do not hesitate to repeat again in a synoptic form, the ten operations necessary for obtaining good results. We revert once more to the silver-electroplating of spoons and forks.

FIRST OPERATION.

Boil the articles a few minutes in a solution made of—

Water	10 litres
Caustic potassa	1 kilogramme

and wash in fresh water.

SECOND OPERATION.

Dip into a cleansing pickle composed of—

Water	10 litres
Sulphuric acid	1 kilogramme

and rinse.

THIRD OPERATION.

Plunge for a few seconds into the following mixture:—

Nitric acid at 36° Baumé, yellow . .	10 kilogrammes
Common salt	200 grammes
Calcined soot	200 "

and wash rapidly in running water.

FOURTH OPERATION.

Dip rapidly into the following mixture, prepared the day before:—

Yellow nitric acid at 36° Baumé . . .	10 litres
Sulphuric acid at 66° Baumé	10 "
Common salt	400 grammes

and wash very rapidly in clean water.*

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* Some operators substitute for these two cleansings in acids, a scouring with pumice-stone dust. This method may suit certain kinds of maillechort and German silver, which are difficult to cleanse in acids, but it is not desirable for the metals easily cleansed by dipping. When certain coppers are spotted in aqua fortis, the defect is generally due to an imperfect cleansing in alkalies.

FIFTH OPERATION.

Immerse the articles for a few seconds or until they are entirely whitened, in a solution of—

Water	10 litres
Nitrate of binoxide of mercury	100 grammes

with sufficient sulphuric acid and stirring for rendering the liquor clear, and wash in fresh water.

SIXTH OPERATION.

Immerse the articles in the bath, under the influence of a weak current, and after waiting for a quarter of an hour, examine carefully each supporting rod. If the articles be covered regularly and without stains, the operation is continued; on the contrary, should the silver-deposit be crystalline and stained, the pieces are withdrawn, scratch-brushed, passed through a hot solution of cyanide of potassium, rinsed in fresh water, plunged into the mercurial solution, rinsed again, and then replaced in the silver bath.

SEVENTH OPERATION.

If the scale apparatus is not employed, the current is arrested for a few minutes before the articles are withdrawn from the bath, in order that the solution may redissolve the subsalts of silver deposited at the same time as the pure metal.

EIGHTH OPERATION.

Remove from the bath, wash in fresh water, and then in a very weak solution of sulphuric acid.

NINTH OPERATION.

Scratch-brush.

TENTH OPERATION.

Burnish if desired.

The baths for electro-silvering very large pieces, or those of variable patterns, will evidently be held in appropriate troughs, with soluble or insoluble anodes placed sometimes in the middle, sometimes against all the sides.

The articles removed from the bath have a dead lustre, which is crystalline and micaceous when the liquors are new, and dull and earthy looking with old solutions. This dead lustre is easily scratched, and becomes yellow by contact with the air. In order to preserve its freshness, it should be covered with a thin coat of colorless alcohol varnish. We have already seen that an article, rendered yellow by the alteration of the subcyanide of silver, may be restored to its primitive whiteness by the combined action of heat, borax, and a diluted solution of either nitric or sulphuric acid; or, more simply, by an immersion, without electricity and for a few minutes, into a tepid solution of cyanide of potassium.

CHAPTER XXXVII.

BURNISHING.

Burnishing.

WE have given *in extenso* a description of the scratch-brushing operation, and we have now to do the same in regard to burnishing.

We call *burnishing* the operation by which the asperities and roughness of an object are rubbed and flattened down by a burnishing tool, so that all the molecules of the surface are, as far as practicable, levelled to the same plane which then reflects the light as does a looking-glass or a well-polished mirror.

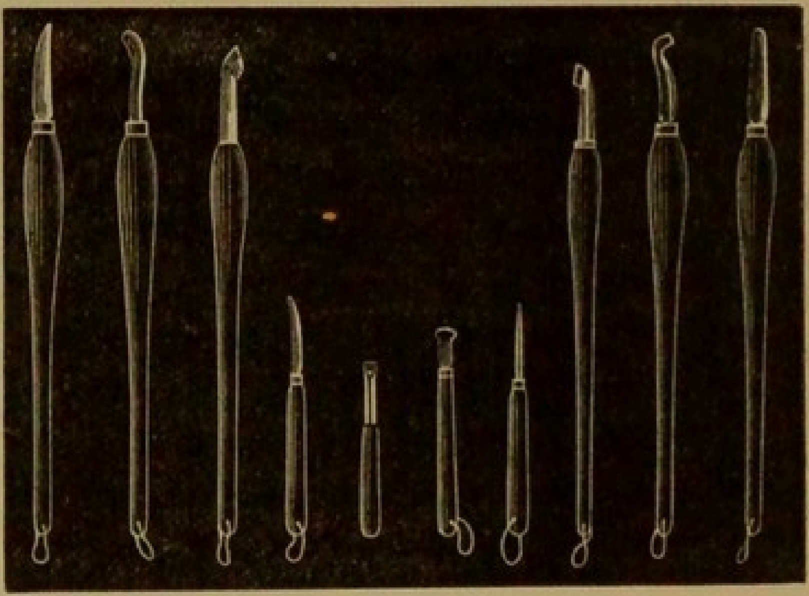
Burnishing is therefore an important operation for electro-deposits, which are constituted by the juxtaposition of a multitude of small crystals with hollows, intervals between them, and with facets reflecting the light in every direction. There is, moreover, a great advantage in laying down these crystals, and thus closing the meshes of the net presented by every deposit by the wet way. The deposited metal is at the same time hardened, and if we be allowed to say so, forced to penetrate into the pores of the underlying metal. The resistance or durability is thus increased to such an extent, that there is no exaggeration in affirming that, with the same amount of silver, a burnished article will last twice as long as one which has not been so treated.

The instruments employed for burnishing are made of different materials, and all of them must fulfil the requisite conditions of great hardness and a perfect polish.

Hardened cast-steel, agate, flint, and sanguine (blood-stone, a kind of peroxide of iron or anhydrous hematite) answer the purpose. For burnishing metallic electro-deposits, steel and blood-stones are especially employed. There are several qualities of blood-stone, those of the East, and those of the West; its grain should be close, hard, and without seams or veins; it should leave no white lines on the burnished parts, nor take off any metal, and its color should be of an intense black red. As for steel, it must have fine and close grains, and be perfectly polished. Should the polish of any kind of burnishing tool become altered by use, it is restored by friction upon a skin or leather attached to a wooden block, which is itself fixed to the bench by four protruding points of iron. The leather is covered with English polishing rouge (colcothar, sesquioxide of iron), in impalpable powder, or, preferably, with pure alumina obtained by the calcination of ammonia alum in a forge fire. Venetian tripoli, rotten-stone, tin putty, emery, or many other hard substances in minute powder may also be employed.

Nothing is more variable than the shapes given to burnishing tools (Fig. 91). Some represent a lance, a tooth, a knife; others imitate a hind's foot, the olive, a half sphere, a dog's tongue, etc. etc. At all events a considerable stock is necessary.

Fig. 91.



The burnishing operation is divided into two distinct parts: the first consists in roughing, and the second in finishing. The tools are also of two kinds: the first present quite a sharp edge, whereas the latter have a rounded surface. An intelligent worker will not part at any price with a good burnishing tool, since he is so fully cognizant of its importance for rapid and successful work.

The operation is conducted in three different modes: by hand, on the lathe, and by the arm. The tools for the hand or the lathe are fixed, by means of copper ferrules, to wooden handles, cylindrical and short, in order that the hand be not influenced by their weight. On the contrary, the tools for the arm or the vice are fastened to wooden handles sufficiently long to rest their slender part upon the arm or the shoulder, whereas the stouter portion is grasped by the hand.

The burnishing tools and the objects are frequently wet by certain solutions, some of which simply facilitate the sliding of the instrument, while the others have a chemical action upon the shade of the burnished articles. The first category comprises pure water, solutions of soap, decoctions of linseed, and infusions of the roots of marshmallow or liquorice; the second includes wine-lees, cream tartar, vinegar, alum in water, etc.

When we burnish the gold applied upon electro-deposits of copper (as is the case in gilding with a dead lustre by that method), we should simply wet with saliva, for fear of producing a disagreeable red shade. A solution of green soap is generally preferred by operators, although when old it imparts an unpleasant tinge, due to the sulphides of the liquor.

When the burnishing is completed, the surface is wiped off longitudinally with a soft and old calico rag; sawdust, hard cloth, and tissue paper produce streaks.

It is said that the polish obtained by burnishing is *black*, when it reflects the luminous rays like a mirror; and, should the presence of mercury, or a bad deposit, or any other cause prevent the tool from producing a bright surface, it is said that the object is *greasy*.

Articles which have been previously polished, such as steel mountings of carpet and lady's hand bags, and which generally receive a mere pellicle of electro-deposit, are not burnished, but simply rubbed with a chamois skin and the best quality of English polishing rouge.

On the other hand, too thick or too rapid electro-deposits cannot be burnished, but are polished by rubbing with a skin impregnated with a mixture of oil and some hard powder, like pumice-stone, tripoli, tin putty, sanguine, etc. Coarse powders are used at the beginning, and impalpable ones at the end of the operation.

There is, therefore, a great difference between polishing and burnishing, since the former levels the surface by removing the asperities, whereas the latter crushes and flattens them.

Polished silver deposits are more agreeable to the eye than burnished ones; but the hardening of the latter renders them more durable.

CHAPTER XXXVIII.

DISSOLVING SILVER FROM SILVERED ARTICLES.

Dissolving Silver from Silvered Articles.

When a silvering operation has failed from want of adherence of the deposit, or from a granular surface, or when we desire to silver anew old articles, it is absolutely necessary to dissolve the silver in order to restore the surface of the copper to its primitive state, and to permit of its thorough cleansing.

The operation is conducted in the cold or with the aid of heat.

For dissolving silver in the cold the objects are suspended in a large vessel filled with the following mixture: Sulphuric acid at 66° Baumé (concentrated oil of vitriol), 10 litres; nitric acid at 40° Baumé (concentrated aqua fortis), 1 litre; and they remain there for a greater or less length of time, according to the thickness of the coat of silver to be dissolved.

This liquid presents the remarkable property, when it does not contain water, of dissolving the silver without sensibly corroding copper and its alloys, such as bronze, brass, maillechort, German silver, packfong, similor, etc. We should, therefore, avoid introducing into it wet articles, and should keep the liquid perfectly covered when not in use.

As far as practicable, the articles will be placed in the liquid without touching each other, and in a vertical position, so that the silver salt will fall on to the bottom.

In proportion as the action of the liquor diminishes, small and gradual additions of nitric acid are poured in.

While the process of dissolving silver in the cold is the more regular and certain, its action is considered too slow by some operators, especially when the proportion of silver is great. The other more rapid process is then resorted to.

A flat pan of enamelled cast-iron is nearly filled with concentrated sulphuric acid, and the whole brought up to a temperature of from 150° to 200° C.

Then, at the moment of using it, pinches of dry and pulverized nitrate of potassa (saltpetre) are thrown into it, and the article, held with copper tongs, is plunged into the liquid. The silver is rapidly dissolved, and the copper or its alloys is but slightly corroded.

According to the rapidity of the solution more or less pinches of saltpetre are added. We ascertain that all the silver has been dissolved, when, after rinsing in water and dipping the articles into the cleansing acids, they present no brown or black spots, or, in other words, when they appear like new metals.

These two methods are not suitable for removing the silver from wrought and cast-iron, zinc, or lead; it is preferable to invert the electric current in a cyanide bath, or to use mechanical processes.

Old desilvering (stripping) liquors become green after a certain length of use, and, in order to recover the silver, they are diluted with four or five times their volume of water before we add to them hydrochloric acid or common salt. We ascertain that the precipitation is complete when the settled liquid does not become turbid by a new addition of common salt or hydrochloric acid.

The resulting chloride of silver is separated from the liquid either by decantation or filtration, and is afterwards reduced to the metallic state by one of the methods to be hereafter indicated.

CHAPTER XXXIX.

RESISTS AND RESERVES.

Resists and Reserves.

WE call *reserves* or reserving the manipulation by which certain parts of a metallic article (which may be already covered with an electro-deposit on its whole surface), is coated with another metal. For instance, if we gild the parts in relief of an object the body of which is silvered, we make a *gold reserve;* and conversely, a *silver reserve* will be the silvering of certain parts of a body already gilt. This operation is very easy, and simply requires a little practice and care, and especially a firm hand to make thin lines with the hair pencil.

After having thoroughly scratch-brushed and wiped off the object, the parts which are intended to remain with the primitive color are covered by means of a brush with a *resist* varnish,* which is dried in the air, or in a stove, or upon a gentle fire

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* Resist or reserve varnishes are generally solutions, in boiled linseed oil or essence of turpentine, of certain resins, like copal, elemi, gallipot, etc.; and, as these varnishes are not sufficiently colored to distinguish the places where they have been laid on, they are mixed with a certain proportion of red lead, orange mineral, or, preferably, chrome yellow (chromate of lead), which at the same time enhances their drying properties. The coloration of the resist varnish may also be produced with artificial ultramarine or Prussian blue.

until it no longer sticks to the fingers. The object is then ready to be put into the bath.

It is evident that the galvanic deposit will coat only those parts unprotected by the varnish. As far as practicable, the temperature of the bath should be low, and the current weak, for fear of having frayed lines where the deposit touches the varnish, from the latter becoming softened or from gaseous bubbles which are disengaged at the negative pole under the action of a strong electric current. When the deposit is completed, the resist varnish is removed with warm essence of turpentine, and afterwards with tepid alcohol; but it is preferable to use gaseine or benzole, which dissolve rapidly, and in the cold, nearly all resinous and fatty bodies, and which volatilize readily. The varnish may also be destroyed by a brief immersion in concentrated sulphuric acid when cold.

It quite often happens that several colors and metals are associated upon the same object, such as silver with both a bright and a dead lustre, and yellow, green, red, white, or pink golds, and platinum, etc. To the artist will belong the choice of the dispositions which will appear the most pleasing. We have already stated in the chapter on resists, which follows the gilding processes, that such varnishes were employed for avoiding the deposit of the precious metals upon those parts which do not need them.

CHAPTER XL.

OLD SILVERING—OXIDIZED SILVER (*oxydé*)—DEEP BLACK.

The articles silvered by the wet way may acquire a *patine* or antique appearance by various methods, and among them the *old silver* and *oxydé.*

Old Silvering.

It is an operation which consists in imparting to silvered articles, certain tinges resembling those of old artistic productions made of solid silver. For instance, the groundwork and hollow portions which are not subject to friction, are covered with a blackish red and earthy coat, whereas the parts in relief remain with a bright lead lustre.

This operation is very simple. A thin magma of finely powdered plumbago (black lead) with essence of turpentine (to which a small proportion of sanguine or red ochre is sometimes added, for imitating the copper tinge of certain old silverware) is smeared all over the articles. After drying, a gentle rubbing with a soft brush removes the parts without adherence; and the reliefs are set off (discharged) by means of a rag dipped into alcohol. *Old silver* is of a pleasing appearance upon objects imitating old cups, chandeliers, vases, statues, etc.

Old silver is easily removed, and the primitive brightness of the metal restored, by a hot solution of caustic potassa or cyanide of potassium. Benzole may also be employed.

In order to impart the old silver tinge to small articles, such as buttons, rings, etc., they are jerked in the above magma, and rubbed in a bag with a large quantity of dry sawdust from fir-wood, until the desired shade is obtained.

A great many operators, at the present day, produce the old silver by beginning with the *oxydé* and setting off the reliefs by means of a hard brush and pumice-stone or Spanish white. This last process is nearly exclusively used for metallic mountings of albums.

Oxidized Silver (Oxydé).

This term is entirely incorrect, since it is not an oxidization, but a combination with sulphur or chlorine. If we have retained the word, it is because it is the popular one.

Every one knows that sulphur, soluble sulphides, and hydrosulphuric acid (sulphuretted hydrogen) blacken silver. This phenomenon is seen every day by the action upon this metal of old eggs, rank gases, etc. It is also known (and photography is based upon this phenomenon) that insoluble silver salts, and particularly the chloride of this metal, rapidly blacken by solar light.

It is thus easy to blacken silver, and consequently to obtain the *oxydé*, by its contact with one of the indicated reägents. We may use vapors of sulphur, hydrosulphuric acid free or combined, liver of sulphur or other polysulphides, hypochlorite of lime (bleaching powder), or Javel water. In the majority of cases, heat will be required to render more rapid the action of these substances.

The operation is generally conducted as follows:—

Four or five thousandths, that is to say, 4 or 5 grammes per litre, of hydrosulphate of ammonia, or, preferably, of quintisulphide of potassium (liver of sulphur) are added to ordinary water brought up to a temperature of 70° to 80° C. As soon as the articles are dipped into this solution, they become covered with an iridescent pellicle of silver sulphide, which, after a few seconds more in the liquid, becomes blue black. The article is there removed from the water, rinsed, scratch-brushed, and burnished when so desired.

We should, as far as practicable, immediately use the freshly prepared liquors, otherwise the prolonged heat will precipitate too much sulphur, and the deposit will be wanting in adherence to such an extent that it may be removed with the finger, leaving after it a red tinge resembling copper, although the material may be brass or German silver. Moreover, an oxydé obtained in freshly prepared liquors is always brighter and blacker than that produced in old solutions, which is always dull and gray.

If the coat of silver be too thin, and the liquor too strong, the alkaline sulphide dissolves the silver, and the underlying metal (copper, etc.) appears. In this case, we are obliged to cleanse and silver again, and to use a weaker blackening solution.

The silvering obtained by cold rubbing and with the paste already described, takes the oxydé color well.

Oxidized parts and gilding are often put upon the same article by the following method: After the whole surface has been gilt, certain portions are reserved by covering with the resist varnish in order to silver the remainder. Should the process of silvering by paste and cold rubbing be employed, the gilding should be very pale, because it is not preserved, and is deeply reddened by the sulphur liquor. When this inconvenience occurs from a too concentrated liquor, it is partly remedied by rapidly washing the article in a tepid solution of cyanide of potassium.

The oxydé by sulphur, we have said, is blue black. For the past six years another coloring called *deep black*, has been substituted for it, and is directly obtained upon cleansed copper. The manipulation is very simple, and is as follows: from 100 to 150 grammes of blue ashes (hydrocarbonate of copper) are dissolved in a sufficient quantity of aqua ammonia, and the cleansed coppers are rapidly plunged into this solution, cold or tepid, where they become instantaneously covered with a fine black deposit. This coat is so thin that burnished articles look like varnished black.

The oxydé is intended, in many cases, as a substitute for the *niel*, and since we have named this kind of work, we shall have to indicate briefly the process of obtaining it.

CHAPTER XLI.

NIEL, OR NIELLED SILVER.

Niel, or Nielled Silver.

THIS product, which still bears the name of the inventor, is truly a kind of inlaid enamel work, and is obtained by the sulphuration of certain parts of a silver object. But this sulphuration, instead of being direct as the previous one, is made by inlaying the silver surface with a sulphide of the same metal prepared beforehand.

After having prepared the *niel*, an operation which consists in forming a triple sulphide of silver, lead, and copper,* and reducing it to a fine powder, which is mixed with a small proportion of a solution of sal ammoniac, the artist hollows out the engraving upon a silver surface, and covers the whole, hollows and reliefs, with the niel composition. The article is then heated in a muffle until the composition melts, and becomes soldered to the metal. The pattern is uncovered by a level polish, when the silver will appear as over a black ground.

This method is costly, since each article must be engraved. The arts have called to their aid another

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* For preparing the niel, a certain proportion of sulphur is introduced into a stoneware retort or a deep crucible. On the other hand, a certain quantity of silver, copper, and lead is heated in another crucible, and when melted is poured into the fused sulphur, which transforms these metals into sulphides. A small portion of sal ammoniac is then added, and, after being removed from the balloon, crucible, or retort, the product is pulverized and ready for use.

Here are, however, the proportions indicated by Mr. Mackenzie, who has paid much attention to the subject:—

First crucible,	Flowers of sulphur	750 grammes
	Sal ammoniac	75 "

Second crucible, which, after fusion, is poured into the first:—

Silver	15 grammes
Copper	40 "
Lead	80 "

We consider that it would be preferable to diminish the proportion of lead, the sulphide of which impairs the blue shade of the niel, and corrodes too deeply.

and a cheaper process, which consists in engraving in relief a steel plate, and compressing it against a silver plate between two hard bodies. The copy is therefore hollow, and is ready to receive the niel. A great many copies may be obtained from the same matrix.

Such is the method by which a quantity of nielled articles are manufactured, such as so-called Russian snuff-boxes, cases for spectacles, sugar-plum boxes, etc.

Nielled silver is generally sold at about 10 cents per gramme, and at such a price, the weight of the article must be sufficiently great to pay for the labor.

Would it not be possible to obtain the niel by the following process: a drawing or pattern cut upon thin paper, like lace paper, is dipped into a thin paste of niel composition, or into a concentrated solution of some sulphide, and then applied upon a plate of silver which is afterwards heated in a muffle. The heat will destroy the organic substance, and a pattern will remain formed by the composition absorbed by the paper. Artists and manufacturers may try the process, if they think it sufficiently valuable.

CHAPTER XLII.

PLATINUM DEPOSITS.

Platinum Deposits.

In the year 1846, I had discovered and patented the first platinum bath capable of furnishing deposits of any desired thickness. The former attempts had simply resulted in a mere film of platinum upon copper and its alloys. In 1847, I presented to the king, Louis Philippe, a ewer and its basin, upon which I had deposited about 400 grammes of pure platinum, certain parts of which remained with a dead lustre, while the others were burnished. The basin had in the centre a large medal, around which was written: *First vase with thick platinum electro-deposit, by Roseleur and Lanaux* (the latter was my partner, and school fellow at the laboratory of the school of medicine).

Notwithstanding the early date of our discovery, the publicity given to our patent which was offered without royalty to the public, and the complete description of the process in our first edition, it is only seven or eight years since platinum deposits have found favor, and taken rank, in the arts.

Platinum Deposits by Dipping.

Copper and its alloys will alone receive a satisfactory platinum deposit; iron, zinc, lead, and tin, coated with this metal, and even after a previous coppering, give but defective results.

The platinum deposits are obtained either by simple dipping, or by galvanic action. In the former case, satisfactory results are obtained by immersing thoroughly cleansed copper articles in the following solution, kept boiling:—

Distilled water	1000	grammes
Caustic soda	120	"
Platinum for neutral chloride . .	10	"

The deposit is bright, quite durable, but of a dark color resembling *oxydé*, or sulphuretted silver.

Thin Platinum Electro-deposits.

The platinum baths suitable for electro-deposits are very numerous; indeed, they will succeed when the chloride of platinum is dissolved in a solution of a salt with alkaline, neutral, or acid reaction. Nevertheless, the sulphites and cyanides, even those having soda for base, should be excepted. Thus, the following formulæ will give, by the aid of heat and electricity, platinum deposits quite pleasing in appearance:—

First Formula.

Distilled water	1000	grammes
Carbonate of soda	400	"
Platinum for neutral chloride . .	10	"

Temperature of the bath, from 70° to 80° C.

Second Formula.

Distilled water	1000	grammes
Phosphate or borate of soda . .	600	"
Platinum for neutral chloride . .	10	"

Third Formula.

Distilled water	1000	grammes
Pyrophosphate of soda, or chloride or iodide of sodium	300	"
Platinum for dry chloride . .	10	"

These various formulæ are open to the inconvenience of allowing of only exceedingly thin deposits, since if the coating were permitted to go on increasing most of it would be without adherence, and often in the form of scales. The deposit is black or steel gray.

On the other hand, here is a bath which, when properly operated upon, will permit of the deposit of any quantity of platinum upon the same surface, and with a color and lustre exactly the same as those of the platinum articles found in the arts.

Thick Platinum Electro-deposits.

A glass flask is filled with 10 grammes of finely laminated platinum (spongy or black platinum is preferable), and a mixture of 150 grammes of hydrochloric acid and 100 grammes of nitric acid at 40° Baumé. It is then put upon a piece of sheet-iron perforated in the centre, so that the bottom of the flask alone receives the heat. After an abundant production of orange-yellow fumes, the platinum disappears, and there is left a red liquid which should be heated until it becomes viscous enough to stick against the sides of the flask. This latter part of the operation may be effected in a porcelain dish, the shallow form of which aids in the evaporation of the acids in excess. After cooling, the residuum is dissolved in 500 grammes of distilled water, and filtered if necessary.

On the other hand, 100 grammes of phosphate of ammonia are dissolved in 500 grammes ($\frac{1}{2}$ litre) of distilled water, and the two solutions are mixed. There is produced an abundant precipitate of phosphate of ammonia and platinum in a liquid of orange color, which should not be separated, and into which we pour, stirring all the while, another solution of 500 grammes of phosphate of soda in 1 litre of distilled water.

The mixture is made to boil, and the evaporated water replaced, until no more ammonia is disengaged, which is ascertained by the smell; and until the liquor, which was previously alkaline, begins to redden blue litmus paper. By the reactions which take place, the yellow liquor becomes colorless, which indicates the formation of a double platinum salt.

The bath is then ready to deposit platinum upon articles of copper or its alloys, by the aid of heat and of a quite intense electric current.

Copper dishes which I coated with platinum resisted twenty evaporations of nitric and sulphuric acids alternately employed, but at last they were corroded.

Any contact of iron, zinc, lead, or tin with the bath will decompose it, and the deposited metal will be black and pulverulent.

The dead lustre of platinum is pearl-gray; it is very hard, and cannot be made bright by scratch-brushes of brass, which render its surface yellow. Iron wires or, preferably, powdered pumice-stone should be employed.

Platinum deposits may be burnished by an energetic friction, and the lustre obtained is very durable.

As most of the platinized articles, such as chandeliers, fire grates, lamps, etc., have a thin platinum deposit, they are generally burnished before the coating. After the operation, they are rubbed with English polishing rouge and chamois, and the difficulty of burnishing platinum itself is avoided.

We should not forget, even with platinum, that all the electro-deposits are but nets, the meshes of which are made smaller by the superposition of coats, but which can never be made entirely impervious. Therefore, and notwithstanding the above-stated experiment, we cannot hope to obtain by electro-deposits instruments as durable as those made of forged platinum.

Platinum deposits may be removed from copper by a very long immersion in the liquors indicated for ungilding, but the success is not certain.

CHAPTER XLIII.

DEPOSITS OF NICKEL—ZINC—IRON—STEEL—ANTIMONY—BISMUTH AND LEAD—COLORED (ELECTRO-CHROMIC) RINGS.

We have now completed the list of electro-deposits of those metals which are more generally employed in the arts. We shall finish the first part of this work with the most simple and certain methods of depositing other metals of secondary importance, which may, nevertheless, be serviceable for artistic or useful applications.

We shall now rapidly describe the various operations, which we have performed ourselves, for obtaining electro-deposits of nickel, lead, zinc, iron, and antimony.

Deposits of Nickel.

Nickel deposited by the wet way is whitish with a slightly yellow tinge, resembling the alloy for cymbals. Its dead lustre is dull and pearl-gray, and is easily obtained by dissolving the nitrate of nickel in its own weight of ammonia, and diluting the whole with 20 or 30 times its volume of liquid bisulphite of soda, marking about 24° Baumé.

This application is without industrial uses,* since

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* Since the above was written, nickel plating has taken a place in the arts, and is found useful whenever articles require to be protected against the oxidizing action of damp or salt air, sulphurous

nickel costs about five times as much as copper, and presents the same disadvantages, including poisonous properties.

Deposits of Zinc.

Zinc is easily deposited by the wet way and by the battery. The color of its dead lustre is gray bluish-white.

When a soluble zinc salt is precipitated by ammonia, and the precipitate redissolved in an excess of alkali, we obtain a bath which gives quite satisfactory results.

It is also possible to dissolve any kind of zinc salt in cyanide of potassium or a soluble sulphite.

gases, and weak acids. Dental forceps, fire grates, lanterns, stair-rods, spoons and forks, mountings for guns and pistols, door plates, sewing machine parts, etc. etc., are now nickel plated. Electrotypes of this metal are said to stand the wear and tear caused by ink and press much better than the ordinary copper ones.

The Star Nickel Plating Works, No. 428 Walnut Street, Philadelphia, which we have had occasion to visit, work under the patent of Dr. Isaac Adams, that is, with double salts of nickel, such as the double sulphates or hydrochlorates of nickel and ammonia. It is considered necessary for the success of the operation to have neutral baths, and salts of a perfectly constant composition.

The baths are like ordinary electro-plating baths, with separate batteries, and soluble anodes of nickel plates. The operation for medium sized articles lasts about twelve hours.

The cleansing methods vary with the nature and composition of the objects; but grinding-wheels, pumice-stone, etc., are often employed, since a great many articles to be nickel plated are of iron or steel, which do not stand the acids well, and often require to be polished beforehand.

The polished nickel plated wares have a bright lustre intermediary between that of silver and that of steel.—*Trans.*

These zinc deposits by the wet way are entirely different, as regards the operation and the durability, from the methods of so-called *galvanization*, by which cleansed iron is plunged into a bath of molten zinc, and becomes protected against oxidization for a long time, which is not the case with electro-deposited zinc. A few gilders employ this deposited metal, the dead lustre of which imitates chased aluminium; but it becomes tarnished entirely too soon.

Deposits of Iron and Steel.

Iron may also be deposited by the wet way; but the product is very easily oxidized. It is obtained by decomposing by the battery a perfectly neutral protochloride of iron. This bath is rapidly altered by contact with the air, and is transformed into sesquichloride, which is unsuited to our purpose. A few operators have tried the double chloride of iron and ammonium remaining in the liquor after an imperfect precipitation of the iron by ammonia. This solution did not appear to me better than that previously described. The double chloride of iron and ammonium, obtained by the protracted ebullition of a solution of chloride of ammonium (sal ammoniac) upon iron filings, produces a very thin deposit of iron, very difficult to oxidize, and so hard that the improper name of steel was given to it. It is employed for hardening the surface of engraved plates or of ordinary electrotypes.*

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* Double sulphates of iron and ammonia, or of iron and potassa, and double chlorides of the same bases, appear to have been successfully used for electro-deposits of iron.—*Trans.*

Deposits of Antimony.

Electro-deposited antimony possesses all the brightness of polished cast-iron. Its dead lustre is a slate gray, and it may be easily scratch-brushed and polished; however, during the last operation, the tool slides as upon a slightly greasy substance. It resembles black platinum and the oxydé, and may advantageously take the place of either in many cases.

Such deposits are obtained by boiling for about one hour, and in a porcelain dish or in an enamelled cast-iron vessel, the following substances:—

Water	10 litres
Carbonate of soda	2000 grammes
Sulphide of antimony, finely powdered	500 "

The boiling solution is filtered through paper or a fine cloth, and by cooling, deposits a reddish-yellow powder of *kermes* or *oxysulphide of antimony*. This powder is again boiled in the same liquor, and the new solution is the antimony bath. It is, therefore, necessary to use the bath constantly boiling. For the anode we use either a plate of antimony or a platinum wire.

Deposits of Bismuth.

I have vainly tried many reagents for keeping the bismuth in the state of a soluble double salt, which could be reduced by galvanic action. I call the attention of savans and operators to this point.

Deposits of Lead.

They are obtained by means of the plumbite of potassa or soda, which is prepared by the protracted ebullition of 10 grammes of protoxide of lead (litharge, massicot) in 100 grammes of caustic potassa or soda, dissolved in 2 litres of distilled water.

The lead deposits may be compared to those of zinc, as regards their results and uses.

The same bath may be used for the demonstration of a very remarkable application of electricity to metallic deposits. Indeed, we may produce with it those magnificent iridescent colorations upon metals called the *colored rings* of Nobili, and from which has sprung the *electro-chromic* art.

Colored (Electro-Chromic) Rings.

With a solution of plumbite of soda and a battery we may, at will, paint a given metallic surface with the richest colors of the prism and of the rainbow, and successively transform the colors already obtained into those of the solar spectrum. We simply need to invert the electric current, that is to say, attach the articles to the positive pole, and connect the pole zinc with a platinum anode.

The mode of operating is as follows:—

After the bath of plumbite of soda has cooled off, the metallic or metallized article, connected with the positive pole, is dipped into it. Then the platinum wire, communicating with the negative pole, is gradually introduced into the liquor without touching the article. We immediately see the latter colored with various shades; the yellow is the first, but all of them become dark or are entirely transformed, accordingly as we dip the platinum wire more or less. We may thus vary *ad infinitum* these plays of light, which are due to the variability in thickness of the deposits of plumbic acid or oxidized lead. Too much intensity in the current will hide all the various tinges under a uniform dark brown coat.

These colorations, which resist friction quite well, have been at first called *colored rings*, although they rarely present a concentric form.

When an article is unsatisfactory in its coloration, it is rapidly dipped into aqua fortis, which dissolves the oxide of lead, and restores the metallic surface to its primitive state.

A few years ago I applied the electro-chromic processes to the decoration of stonewares and porcelains previously coated with platinum, as indicated in the chapter on GILDING BY DIPPING. The results were sufficiently satisfactory to find their application in many ceramic wares.

Watch-dials and hands are thus colored in Switzerland, and bells, etc. in France. A skilful person might, by the same processes, impart to certain productions of bronze the natural colorations of the represented objects, for instance, scarabei, and other insects with glaring colors.

While the article is colored by the oxide, a part of the metallic lead is deposited upon the anode in the shape of small cubic crystals, which have no adherence either with themselves or with the platinum wire. This want of adherence is explained by the very small volume of the anode compared with the colored surfaces.

NOTE.—*Other baths for nickel* have been employed, and are prepared as follows:—

A solution of nitrate of nickel, without excess of acid, is precipitated by cyanide of potassium, and the precipitate redissolved by more cyanide.

An acid solution of nickel may be precipitated by alkalies, such as potassa, soda, or ammonia; and after washing the precipitate, it is dissolved in cyanide of potassium.

A moderate battery power and nickel anodes are employed.

Mr. Nagel uses 400 parts by weight of crystallized sulphate of nickel, and 200 parts of ammonia dissolved in 6000 parts of distilled water, and 1200 parts of ammonia water of 0.909 sp. gr. added.

Temperature of the bath about 100° F., medium current, and platinum anode.

For *depositing zinc* upon copper or brass, in the wet way, Dr. R. Bottger first prepares finely divided zinc, by pouring the molten metal into a previously strongly heated iron mortar, and stirring until nearly cold. The pulverulent zinc thus obtained is placed in a porcelain vessel, and to it is added a concentrated solution of sal ammoniac. This mixture is heated to boiling; and the copper or brass objects to be coated with zinc (but previously well cleansed, and best even with an acid) are then placed in the liquid, wherein they become coated with a brilliantly white adhering layer of zinc.

A New Method of Nickel Plating.—Dr. Wolcott Gibbs gives in the January number of the *American Journal of Science*, a brief description of a new process for plating various metals with nickel without the use of a battery, which process was devised by Prof. Stolba. Into the plating vessel—which may be of porcelain, though the author prefers copper—is placed a concentrated solution of zinc chloride, which is then diluted with from one to two volumes of water, and heated to boiling. (If any precipitate separates, it is to be redissolved by adding a few drops of hydrochloric acid.) As much powdered zinc as can be taken on the point of a knife is thrown in, by which the vessel becomes covered internally with a coating of zinc. The nickel salt—for which purpose either the chloride or sulphate may be used—is then added until the liquid is distinctly green; and the articles to be plated, previously thoroughly cleaned, are introduced, together with some zinc fragments. The boiling is continued for fifteen minutes, when the coating of nickel is completed, and the process is finished. The articles are well washed with water and cleaned with chalk. If a thicker coating be desired, the operation may be repeated. Professor Stolba found that copper vessels thus plated were scarcely tarnished after several months' use in the laboratory.

Wrought and cast-iron, steel, copper, brass, zinc, and lead have been successfully coated by this process. It is only necessary that the size of the objects should permit them to be covered entirely by the plating liquid, and that their surfaces should be thoroughly cleaned.

Salts of cobalt, treated in the same manner, afford a cobalt plating, which is steel-gray in color, not so lustrous as the nickel, and more liable to tarnish.

CHAPTER XLIV.

REDUCTION OF OLD BATHS—EXTRACTION OF GOLD, SILVER, PLATINUM, AND COPPER—ASHES.

Reduction of Old Baths.

Before passing to the study of the galvanoplastic art proper, we shall indicate the most economical and practical processes for separating from worn-out baths or liquors spoiled in any way, the precious metals they contain, and in such a state of purity that they may be used for the preparation of new baths.

We shall also explain the treatment of old acids, and other substances generally considered as waste, and which require great attention, since in many works they represent a value equal to one-fourth or one-fifth of that of the precious metals employed.

Extraction of Gold.

All the liquids which contain gold (excepting those in which there is a cyanide, and which shall be examined further on) are strongly acidulated by sulphuric or hydrochloric acids, unless they are already acid, and then largely diluted with water. The precious metal is precipitated by a solution of sulphate of protoxide of iron (green vitriol, copperas), and, after a few hours' waiting, we ascertain that the liquor does not contain any more gold when a new addition of sulphate of iron fails to produce any turbidity.

The precipitated gold, which is in the form of a red or black powder, is collected upon a filter, washed, and strongly dried in an iron pan with weights equal to its own of *borax*, *saltpetre*, and *carbonate of potassa*.

The fritted mass is then gradually introduced into a refractory crucible heated to a white heat in a good air furnace. When all of the substance is introduced, the heat is increased and the furnace closed, in order that all the metal may fall on to the bottom of the crucible. After cooling, we shall obtain a button of pure gold, which, being dissolved in aqua regia, will reconstitute the pure chloride of gold. (See this name in the chapter on CHEMICAL PRODUCTS.)

Should we desire immediately to dissolve in aqua regia the pulverulent gold left on the filter, it will be necessary to wash it several times with a diluted solution of sulphuric acid, in order to remove the sulphate of iron with which it is impregnated.

This mode of reduction is well adapted to an impure chloride of gold, to the baths by dipping with the bicarbonate or pyrophosphate of soda, and also to the ungilding acids; but it is imperfect with baths holding a *cyanide*, which never completely part by this process with all the gold they contain.

The best manner of treating the latter liquors consists in evaporating them to dryness in a cast-iron kettle, and calcining the residue to a white heat in a good crucible. A small proportion of borax or saltpetre may be added to aid the fusion, but generally it is unnecessary.

The button of gold separated at the bottom of the crucible is red when saltpetre has been employed, and green with borax; but these differences of coloration have nothing to do with the purity of the metal, and are due to peculiar molecular states.

Gold may also be separated from liquors which contain no cyanide, by an excess of protochloride of tin, which produces a precipitate of *Cassius purple* (stannate of protoxide of gold), easily reduced by heat. Sulphurous acid will also reduce the gold. But in this case, the liquor should be heated.

Granulated gold is obtained by running the molten metal, in a small stream, and from a certain height, into a large quantity of cold water.

Extraction of Silver.

The liquors which contain silver in the form of a *simple salt*, that is, in solution by an acid, are very easily treated; it is sufficient to add to them an excess of common salt, or hydrochloric acid, and all the silver will be precipitated in the state of chloride of silver, which, after washing, may be employed for the preparation of new baths, or reduced to the metallic form by one of the processes which we shall soon describe. Solutions of nitrate of silver, desilverizing acids, etc., belong to this case.

Common salt, on the other hand, is without action upon the liquids which hold silver in the state of a *double salt*, and will rather aid the solution than the precipitation. The double tartrate of silver and potassa (whitening bath), the double sulphite of soda and silver (bath for dipping), etc., belong to this category. Before employing common salt, the liquors should be rendered acid by sulphuric acid, which, displacing the other acids, combines with the base and restores the silver to the state of a simple salt, easily precipitated by common salt. Hydrochloric acid alone precipitates silver well from these solutions.

The liquors which contain silver, as *cyanide*, form another exception; and, in order to extract all the metal, we should again have recourse to the process employed for similar combinations of gold, that is to say, evaporation to dryness, and reduction of the mass in a crucible, with an addition of carbonate of soda and powdered charcoal. The silver is then obtained as a melted button at the bottom of the crucible.

When it has been possible to obtain the chloride of silver, the metal is reduced by many processes, the principal of which are:—

1. The well-washed chloride of silver is put into an iron ladle, with a few millimetres of pure water above the chloride. The greater affinity of iron for chlorine determines its departure from the silver; and, after twenty-four to thirty hours, if we throw the contents of the ladle upon a filter, and wash thoroughly with pure water, in order to remove the soluble chloride of iron, we shall obtain pure silver in a minute state of division. This method is rarely employed on account of the length of time required.

2. Well-washed chloride of silver (water does not dissolve a trace of it) is put into a stoneware pan with two or three times its weight of zinc, and the whole is covered with water rendered acid by sulphuric acid. As soon as they are in contact these substances react upon each other: the sulphuric acid and the zinc decompose the water into its elements, the oxygen of which oxidizes the zinc, which then combines with the acid, and becomes sulphate of zinc (white vitriol or white copperas), a very soluble salt.

On the other hand, the hydrogen transforms the chlorine of the silver into hydrochloric acid, also very soluble in water. The remaining silver is in impalpable powder, and cannot pass through the filters. It is well understood that before filtering we should wait until all the zinc has become dissolved. The obtained silver will be thoroughly washed with pure water, and may then be dissolved in pure nitric acid to form a pure nitrate of silver.

This process, although easy and rapid, is seldom employed, because it is very difficult to find zinc without lead, which will unite with and follow the silver in subsequent manipulations.

3. The chloride of silver, freed from foreign metallic salts by washing, is mixed with four times its own weight of crystallized carbonate of soda, and half of its weight of pulverized charcoal. The whole is made into a homogeneous paste, which is thoroughly dried in an iron pan, and then introduced into a red hot crucible. After the igneous fusion the heat is raised, in order to increase the fusibility, and to allow of the smallest globules reaching the bottom of the crucible. After cooling, we have a button of pure silver. Should the crucible be moved at the time of the solidification, the button will be of a very irregular shape.

If we desire granulated silver, we should, as for gold, pour it in a small stream, and from a certain height, into a large volume of water. The melted metal should not be allowed to fall on to the same spot.

This third method is nearly exclusively employed in electro-gilding and silvering works.

We understand that, during this operation, the carbonic acid of the carbonate of soda having disappeared, the oxygen of the soda unites with the carbon of the charcoal, and escapes in the gaseous form. In its turn, the sodium combines with the chlorine of the chloride of silver, and becomes chloride of sodium, whereas the metallic silver is set free. We shall here notice the fact that the chloride of sodium which was decomposed by the silver salt in the *wet way*, is now reconstructed by the *dry way*.

4. Lastly, we may in many cases employ a plate or band of copper for separating silver from its salts; but it is quite difficult to free it entirely from traces of copper. Nevertheless, as we have already said, this process is employed for the preparation of the graining silver, before gilding watch parts.

Extraction of Platinum.

This process is very simple, and consists in first rendering acid by hydrochloric acid any kind of platinum bath, unless it is already so, and then plunging cleansed iron into it. The platinum is reduced to the form of a black powder, which is washed, and then calcined to a white heat. By dissolving it in aqua regia we reconstitute the chloride of platinum necessary for the preparation of the baths.

I do not know whether it be due to a peculiar state of the metal, or to some unknown chemical combination of the black powder precipitated by iron, but this black powder will not dissolve in aqua regia unless it has been previously strongly heated. This phenomenon leads me to suspect, according to the salt employed for dissolving the platinum, the presence of a sulphide, phosphide, or carbide of this metal, upon which the acids have no action.

Platinum baths may also be reduced by evaporating them to dryness, and strongly calcining the residue, which is then washed upon a filter in order to remove the soluble salts, and again submitted to a white heat. The platinum thus obtained is soluble in aqua regia.

Extraction of Copper Salts.

In those works where great quantities of copper are operated upon, it is advantageous to extract the metal dissolved in the cleansing baths, which are generally allowed to go to waste with the rinsing water, by the majority of gilders, silver electroplaters, and galvanoplastic operators. Nothing is more easy and less expensive than the recovery of such copper. All the liquids holding copper are collected in a large cask filled with wrought or cast iron scraps. By the contact of the copper solution and of the iron, a chemical reaction immediately takes place, by which the iron is substituted for the copper to make a soluble salt, whereas the *cement copper* falls to the bottom of the cask in the shape of a brown powder.

The cask should be sufficiently large to hold all the liquids employed in a day's work. The liquors are decanted every morning.

The old iron scrap is generally suspended in willow baskets on top of the liquor, and, by stirring now and then the liquid with them, the metallic powder of copper alone falls to the bottom of the cask.

The same method is employed for recovering the copper from old cleansing acids, or from worn out galvanoplastic baths. The copper thus obtained is quite pure, and, by calcining it in contact with the air, we obtain a black binoxide of copper for neutralizing too acid galvanoplastic baths.

Ashes.

Nothing whatever should be lost in well conducted works. Sweepings, sawdust, residues from the bottoms of scratch-brushing tubs, filters, papers, rags, etc., should be carefully collected, mixed, and burned in a furnace constructed for the purpose. The ashes are finely pulverized, sifted, and sold to certain operators called *ash washers*, who extract the precious metals from them.

At the time of selling the purchaser is called, and, after having thoroughly mixed the heaps of ashes, several samples are taken with a sampling-gauge, which is a rod hollowed out laterally. The various samples are then mixed, and divided into two parts, one for the buyer and the other for the seller, each of whom has one assayed for gold and silver. From the comparison of the two assay certificates, the buyer takes the lot at its value, after having deducted a certain sum for the expense of the operation and his profit.

The ash washer, in his turn, pulverizes and sifts the ashes again, and sells them to persons having mercury mills. In these mills the ash is thoroughly mixed with a great quantity of mercury, which soon combines with the gold and silver. The amalgams are separated by washing, and then distilled in cast-iron retorts of a peculiar shape.

The mercury is volatilized, and the fixed metals, such as gold and silver, remain in the retort. For separating these metals the solid mass is granulated, and treated by pure nitric acid, which dissolves the silver, and is without action upon the gold. The latter metal, in the shape of a black or violet powder, collects at the bottom of the vessel, and is pure, after having been washed with distilled water, which removes the nitrate of silver with which it is impregnated.

When an ingot contains little silver and much gold, it is previously melted with a certain proportion of the former metal, in order to be more easily dissolved in nitric acid.

The ingots of silver and copper are treated in cast-iron kettles by boiling and concentrated sulphuric acid, which transforms the copper into soluble sulphate of copper, and silver into sulphate of silver, but slightly soluble. The separation of the two may be partly effected by washing, but, generally, the silver is precipitated by plates of copper. The alloy, previous to its solution, is finely laminated or granulated.

We do not claim, in this place, to give a complete description of the arts of assaying, refining, and ash washing; we simply present to our readers a general view of the methods, which are of secondary importance in our art, except so far as they allow us to save our waste.

PART II.

GALVANOPLASTIC OPERATIONS PROPER.

THICK DEPOSITS.

CHAPTER XLV.

OBJECT OF THE GALVANOPLASTIC ART.

ANY one who has already practised the operations described in the first part of this work, will find no difficulty whatever in the manipulations which shall follow. The GALVANOPLASTIC ART proper requires baths less complex in their composition; the causes of failure from too much or too little intensity in the electric current are less frequent; and, in the majority of cases, there is not the drawback of very expensive substances.

Although electro-gilding, silver electroplating, and other metallic deposits obtained by the aid of electricity, are branches of the *galvanoplastic art*, it is customary to apply this term to *those deposits with sufficient thickness to form a resisting body, which may be separated from the objects serving as moulds, and which, at the same time, will preserve the shape and dimensions of the model.* In order to be more explicit, let us give a few examples:—

We make upon one of the faces of a bronze medal an electro-deposit which, being separated from the mould, reproduces with mathematical accuracy all the parts of the model, except that the hollow portions become in relief, and conversely.

A statue of plaster of Paris, a sculpture in wood, an impress in wax or in gutta percha, a fruit, etc., may, after certain preparations, be covered with an electro-deposit of copper, for instance, and it will be possible to destroy the model, and to have a deposit representing its shape and its dimensions.

The galvanoplastic art may even impart a certain degree of resistance and unalterability to brittle and alterable substances. Thus, ornaments and utensils of crystal, porcelain, clay, or wax, may be preserved against rapid destruction by a metallic coating which will respect all the minutiæ of their forms. It will also be easy to keep destructible articles, like small animals, plants, insects, and flowers, indefinitely, which will leave their exact imprint on the durable deposit of metal with which they have been covered.

Is there a more striking proof of the accuracy of galvanoplastic imprints, than to say that the electro-deposit of copper upon a daguerreotype will reproduce it with all its shadows, tints, half tints, etc.? The copper itself will appear superior to the model, since the image will be in the right position, and less exposed to atmospheric and photodynamic influences.

In the galvanoplastic operations copper is almost exclusively employed. Indeed, this metal is easily separated from its saline combinations, is very malleable, and not very oxidizable; and, being perfectly cleansed by the wet way, there will be no difficulty in gilding, silvering, and platinizing it.

We must not confuse the galvanoplastic deposits with the thin ones already described in the first part of this work, and which are but adhering pellicles. The copper galvanoplastic deposits are generally obtained from simple salts (the sulphate of copper). The thin electro-deposits, on the other hand, are produced from double salts (double cyanide or sulphite of soda and copper).

It is also possible to have galvanoplastic deposits entirely of silver and gold; but these are mere exceptions, on account of the cost of the materials and of the difficulties of the operation. We shall, nevertheless, mention them after we shall have passed entirely over the ground of copper galvanoplastic deposits, which have been, and are still, so useful to the arts.

The galvanoplastic operator will have presented to him the following cases:—

1. He will have simply to apply upon a metallic surface conductor of electricity, a deposit of copper adhering to the metal underneath.

2. Or, the operation being completed, the two metals will have to be separated in such a manner that they will furnish two identical productions, one of which will be in relief, and the other hollow. (Casts of medals, basso relievos, irons for artificial flowers, etc. etc.)

3. Or he will have to apply the electro-deposits upon substances not naturally conductors of electricity, but rendered so by the process of metallization. The object will be entirely or partly covered with the metallic deposits. (Copper deposits upon ornaments of plaster of Paris, wax, glass, porcelain, etc., or upon leaves, fruits, insects, etc.)

4. Or, after the deposit, he will have to separate

the non-metallic model in order to have a perfect copper copy of it. (Reproduction of *type* in stearine, gutta percha, gelatin, etc. etc., typographic clichés, electrotypes.)

5. Or, if he cannot apply the electro-deposit of copper directly upon the model, he will have to make moulds upon which a greater or less number of copies may be obtained. (It is the general case: the imprint of the model is taken with a plastic substance, which is rendered a conductor of electricity, and upon which the galvanoplastic deposit is effected.)

The above five cases represent all the possible applications of the galvanoplastic art, and all require the same bath, the composition of which is very simple.

CHAPTER XLVI.

THE BATHS.

The Baths.

1. Put into a vessel, unacted upon by sulphuric acid, and made of glass, stoneware, porcelain, gutta percha, or lead, a certain quantity of water, to which is added about 8 to 10 per cent. of sulphuric acid, that is to say, 8 to 10 volumes of acid for 100 volumes of water. If we operate in a glass vessel or in one lined with gutta percha, we must pour in the acid slowly and stir the water all the while, otherwise the acid, which is much denser than water, falls to the bottom, and, slowly combining with the surrounding water, may cause an increase of temperature suffi-

cient to break the glass or melt the gutta percha. Whatever be the nature of the vase, it is always wise to add the acid by small quantities at a time, and to stir the liquid with a glass or wooden rod.

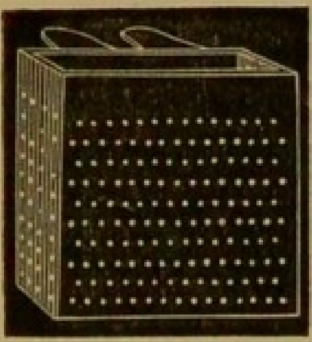
2. Dissolve in this acidulated liquor as much sulphate of copper as it will absorb at the ordinary temperature. If the crystals of sulphate of copper have been put directly into the liquid, they fall on to the bottom, where they are slowly dissolved, because the layer of water in contact is soon saturated, and, being more dense than the liquid on top, does not mix with it. In this case, it is, therefore, necessary to agitate the liquor frequently with a glass or wooden rod, in order to mix the dense and saturated layers with the lighter ones which have dissolved little or no sulphate. But it is preferable to operate in a different manner; for instance, the crystals of sulphate of copper may be put into a perforated ladle of copper or stoneware, or even into a bag of cloth, and to fix the whole near the surface of the liquid. In this way, as soon as a portion of liquor has become saturated with sulphate of copper, it becomes denser and flows downward, whereas a lighter portion takes its place, and becomes saturated in its turn. When the liquid refuses to absorb any more crystals, it is said to be saturated, and marks about 25° of Baumé's hydrometer for salts, or liquids heavier than water.

Water, without the addition of sulphuric acid, will dissolve equally well the sulphate of copper, and may form a galvanoplastic bath. But, if the water is not pure, and contains, as is often the case, bicarbonate of lime, the solution is rendered turbid by a precipitate of carbonate of copper.

The baths of water and sulphate of copper only, are rarely employed, because they are bad conductors of electricity, and because the deposits of copper are irregular, granular, and brittle. It is possible to replace the sulphuric acid by other acids or salts which increase the specific gravity of the liquor, and increase its conductive power; such are the acetic, tartaric, citric, etc., acids, or the bisulphates of potassa and soda, alum, and sulphate of alumina. But, in the arts, sulphuric acid is nearly always employed.

To sum up, a galvanoplastic bath is made of water, more or less acidulated with sulphuric acid, and saturated with sulphate of copper at the ordinary temperature.

Fig. 92.



Baths of sulphate of copper, while they are working, must always be kept saturated; that is to say, new crystals of sulphate of copper must replace those decomposed and forming the metallic deposit. We shall arrive at this result by suspending to the top of the vessel, and steeping in the upper portion of the liquid, bags of cloth or hair, or baskets of gutta percha (Fig. 92), always filled with crystals of sulphate of copper.

We cannot be too particular about the choice of the sulphate of copper; indeed, we find in the trade three very distinct varieties of this salt. The first, which is the best, results from the refining of coin, or from the treatment of copper or its oxide by sulphuric acid, more or less concentrated. The sulphate is in the shape of rhombic crystals, semi-transparent, and of a fine blue color. Its solution is also a pure blue.

The second variety has been produced by the spontaneous oxidization and acidification of natural copper sulphides, or pyrites. As these ores contain a great proportion of arsenic and other metals, the resulting sulphates are very impure, and often present white and green veins.

The third comes from the treatment by sulphuric acid of the dipping liquors employed for cleansing copper and its alloys. These sulphates are mixed with those of zinc and of other metals entering into the composition of bronzes, brasses, or other alloys. Besides they still retain a certain proportion of nitric acid, which is injurious to the operation.

We shall give in the third part of this work (CHEMICAL PRODUCTS), the best and easiest methods for ascertaining the purity of the sulphate of copper.

The galvanoplastic baths are always employed in the cold, and are kept in vessels of shapes adapted to the wants of the operator. Stoneware, porcelain, and glass are the best materials for the purpose; but as it is quite difficult to find in the trade such vessels sufficiently large, we also employ wooden troughs covered inside with coats of gutta percha, marine glue, or other resinous substances, or with a sheet of lead, which may be painted with resist varnish.

Zinc, iron, and tin cannot evidently be used on account of the chemical reactions taking place between these metals and the sulphate of copper.

The working of galvanoplastic baths remains satisfactory, when their specific gravity is retained between 20° and 25° Baumé.

CHAPTER XLVII.

MODES OF OPERATING—DEPOSITS BY SEPARATE BATTERIES—SIMPLE APPARATUS—THE SAME FOR THE "AMATEUR"—LARGE APPARATUS.

Modes of Operating.

We have said that copper can be reduced by two distinct methods: by the aid of electric batteries, separate from the bath, or by the *simple apparatus*, that is to say, by constructing a battery in which the object to be covered constitutes the positive *element.* We shall describe these two processes.

Deposits by Separate Batteries.

When the solution of sulphate of copper has been prepared and disposed as we have described, the object,* which is to receive the deposit, is connected with the conducting wire attached to the negative pole of the battery, zinc generally, and immersed in the solution. On the other hand, the conducting wire starting from the positive pole (carbon or copper) is attached to a foil or plate of copper, and this anode is placed in the liquor parallel to the object connected with the other pole. This plate should have a surface at least equal to that of the article to be covered. The deposit begins immediately, and

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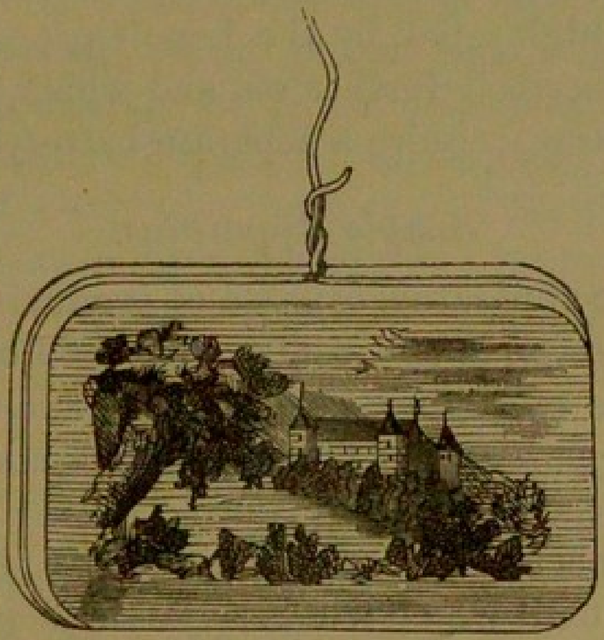
* There are certain preliminary preparations of the article which we shall describe further on, and which vary with the materials employed and the object in view.

its progress may be watched by removing now and then the object from the solution.

If we operate upon a clean metallic substance, the deposit of copper will be quite instantaneous on every part of it; on the contrary, if the surface but moderately conducts the electricity (as plumbago or graphite), the deposit begins at the points touched by the conducting wire, and then proceeds forward from one molecule to the other. Thus, for instance, a medal of wax covered with plumbago (Fig. 93) and wrapped at the rim alone with the conducting wire, will receive a deposit beginning at the periphery, and radiating towards the centre. After a variable length of time, the whole surface will be covered; but, evidently, the thickness of the deposit will be greater on the sides than on the middle.

Fig. 93.



With a little practice it is easy to ascertain whether the intensity of the current corresponds to the surfaces to be covered. The operation is slow with a weak current, but there is no other inconvenience, unless the substance of the mould is alterable, like gelatine. Too intense a current results in a granular deposit, the particles of which have little cohesion between themselves, and no adherence with the mould.

Batteries separated from the liquors are no longer employed for galvanoplastic operations, in the arts especially. The amateur alone sometimes uses this method, which is more slow, more expensive, and less easy than that with the simple apparatus. We must except, however, the galvanoplastic operations on articles in high relief, by the Lenoir processes, which shall be described further on, and which, in the majority of cases, require a separate battery.

Simple Apparatus.

A simple apparatus, capable of producing galvanoplastic deposits, is essentially composed of a solution of sulphate of copper, in which is immersed a diaphragm or porous cell filled with a liquor capable of dissolving the iron or zinc placed in it. The iron or zinc is connected by a conducting wire with the object in the bath which will receive the deposit.

It is, therefore, easily understood that the nature, shape, volume, and disposition of the simple apparatus may vary *ad infinitum*, to suit the purpose of the operator and the shape of the moulds.

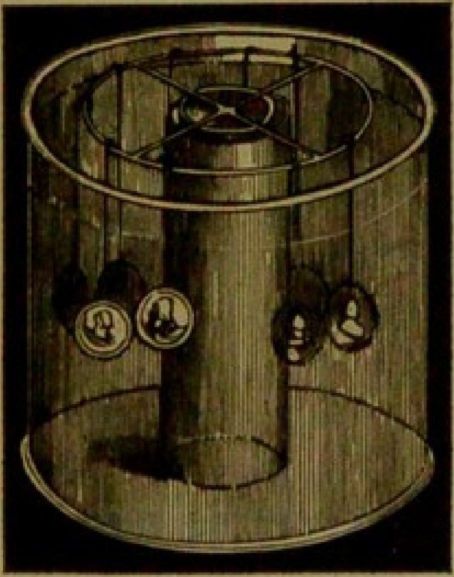
The most convenient apparatus will ever be that where the surfaces of the zinc are nearly equivalent, and, as far as practicable, parallel to those of the mould. This latter condition is, in most cases, very difficult to fulfil; indeed, a small statue would then require zincs and porous cells all around it, and following all the irregularities of its contour.

At all events, we shall describe those apparatuses which seem to us the most convenient by their dispositions, and the most economical in their nature.

Simple Apparatus for Amateurs.

Beginners will have no difficulty in arranging an inexpensive "simple apparatus," which will suit perfectly for depositing copper upon small flat surfaces, or upon medals or small articles in basso-relievo. The solution of sulphate of copper may be kept in a stoneware, earthenware, or porcelain vessel, in the centre of which stands a porous cell filled with water acidified with 2 or 3 per cent. of sulphuric acid, and 1 per cent of amalgamating salts. This liquid surrounds a cylinder of zinc (Fig. 94), which supports a circle of brass wire, the two crossed diameters of which are soldered, or simply fixed, in four notches on the top of the zinc cylinder.

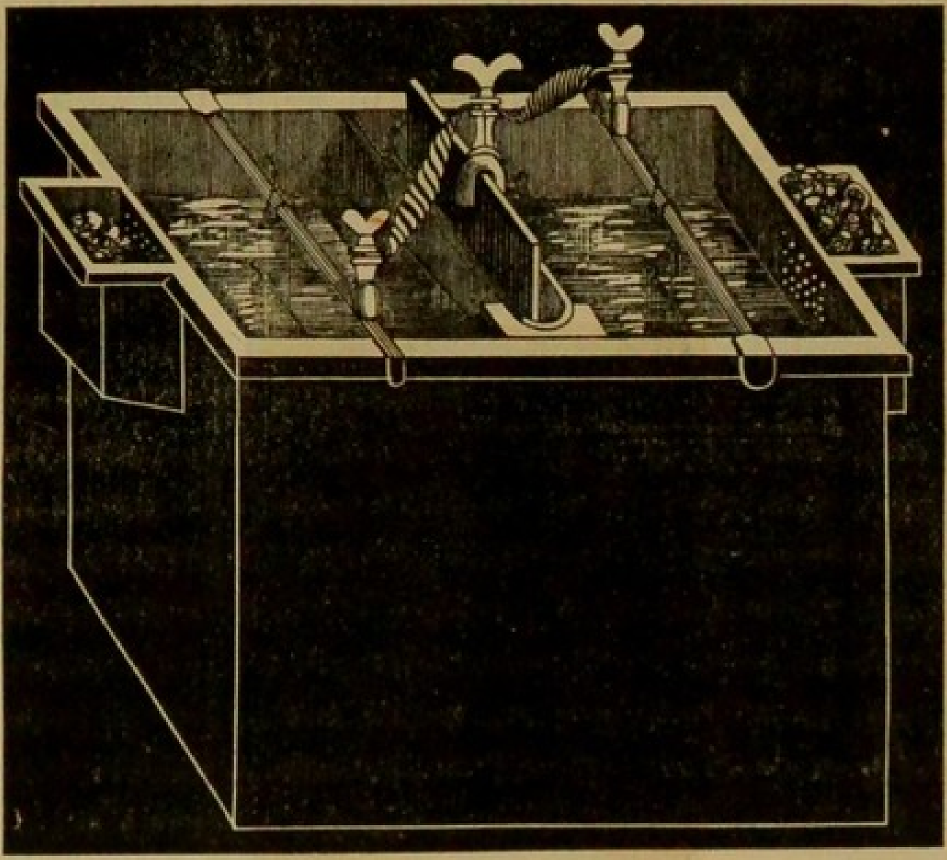
Fig. 94.



In this manner it will be easy to suspend from this circular framework a certain number of objects or moulds, which will be immersed in the liquid in such a way, as to have their faces to be covered, near and opposite to the cell. Two small bags of hair, filled with sulphate of copper, are attached to the upper edge of the vessel.

We have also built, of two different sizes, a simple apparatus for amateurs, which is very convenient. Fig. 95 represents one of these, which is easily moved about, and is not brittle. It is a rectangular trough of gutta percha, in the centre of which are two grooves for the passage of a flat cell. At the two extremities, and on top, two small compartments have been applied, which may

Fig. 95.



serve for handling the apparatus, and communicate with the inside of the trough by numerous small holes. They are filled with crystals of sulphate of copper. The porous cell contains acidulated water and a plate of amalgamated zinc. The connections are made by means of double binding screws, placed upon the zinc plate and the supporting rods. The metallic wires are twisted in spirals, so as to allow of the moving about of the rods.

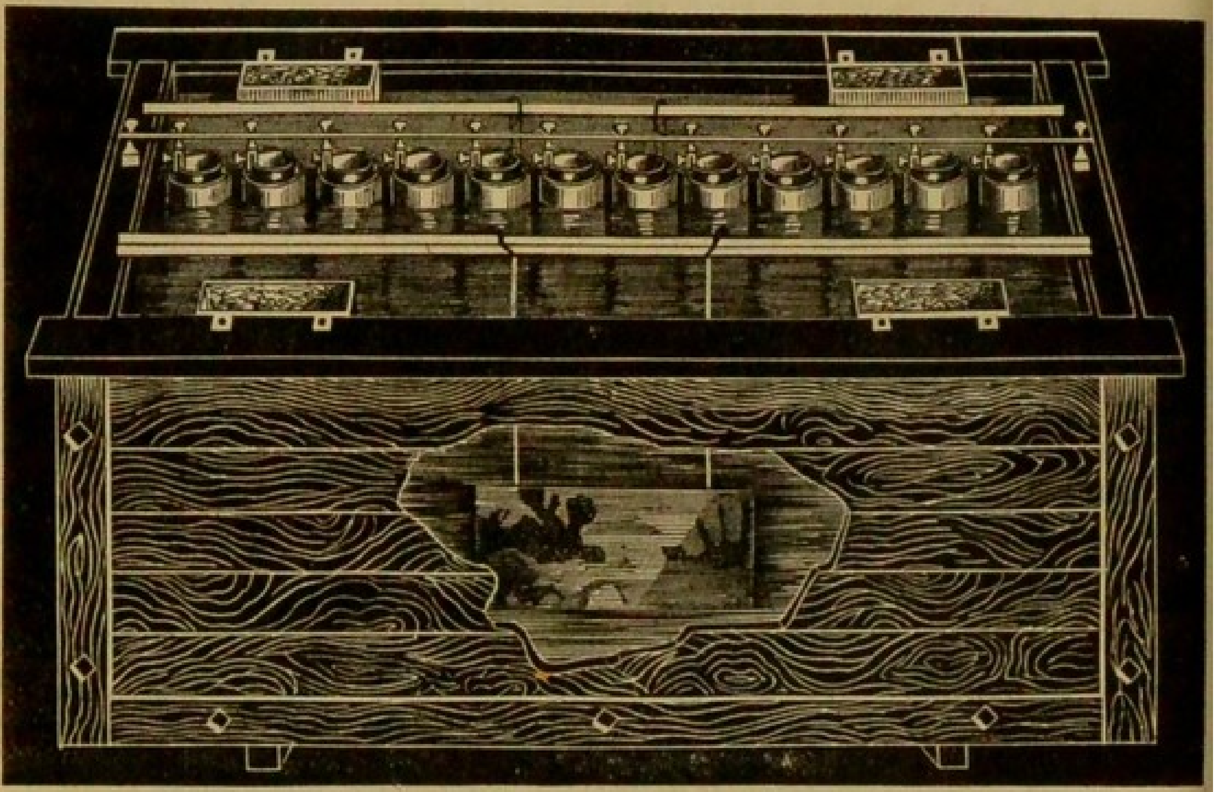
We easily understand that with this apparatus we operate on each side of the cell upon two medals or basso-relievos; but, if we use two cells, one at each end of the apparatus, and with the supporting rod in the middle, we may effect the deposit on objects in high relief,—a small statue, for instance.

Large Apparatus.

If we have to cover large surfaces, the bath will be contained in a large wooden trough (Fig. 96), lined inside with gutta percha, or lead, or any other substance unacted upon by the bath. In the middle of the trough we will dispose a row of cells close to each other, and each with its zinc cylinder. A thin metallic ribbon is connected with all the binding screws of the cylinders, and is in contact at its extremities with two metallic bands on the ledges of the trough. The metallic rods supporting the moulds are in contact with the metallic bands of the ledges, and therefore in connection with the zincs.

With such a disposition of the supporting rods on each side of the trough, the entire surface of the zincs is utilized. It will also be easy to double the effect, by employing two rows of cells instead of one; thus, a surface will be covered on each side of the trough, and two other surfaces, back to back, in the interval between the two rows of cells.

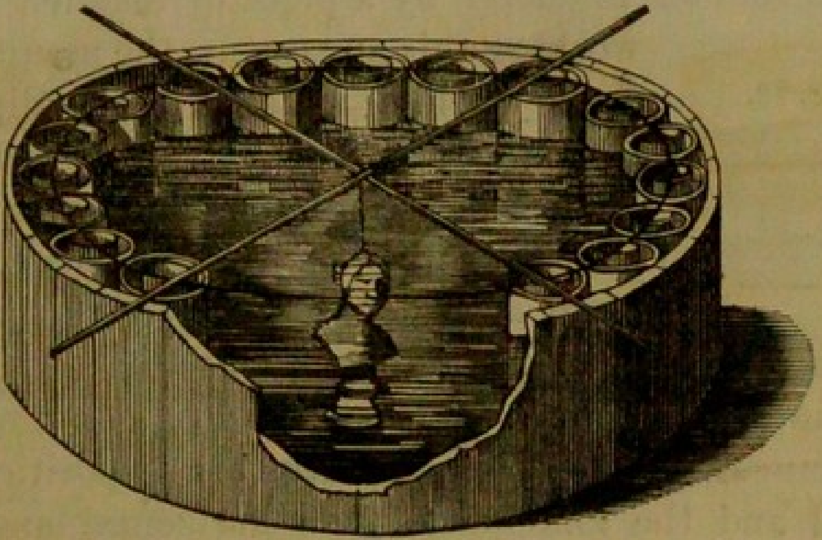
Fig. 96.



If, instead of nearly plane surfaces, we have to operate upon objects in high relief, we have recourse to the circular trough (Fig. 97), where the cells form a circle, and the mould to be covered is in the centre.

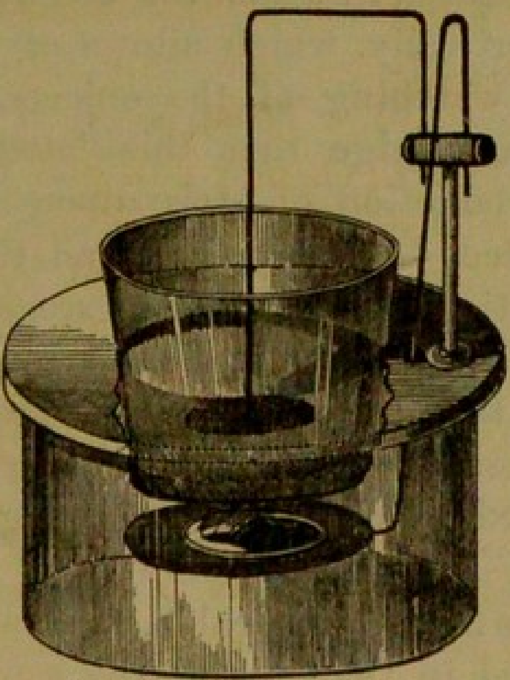
Whatever the shape of the mould be, its position should now and then be changed, that is to say, the upper portions should become the lower ones, and conversely. This is necessary, because the lower layers of the bath give the more abundant deposits, which is explained by the difference of specific gravity of the layers more or less charged with sulphate. Indeed, a solution may contain very little sulphate at the surface, and be saturated with it at the bottom. This accounts for the practice of keeping the bag of sulphate on top of the liquor, instead of having the crystals at the bottom.

Fig. 97.



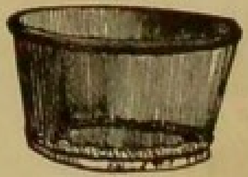
Formerly, a certain apparatus, quite inconvenient, and called an *electrotype*, was used for the reproduction of medals. It was composed of a cylindrical glass vase, with a wooden cover (Fig. 98), to which was fixed a support in the shape of a T, with two holes

Fig. 98.



and their binding screws. The wooden cover had a circular opening through which passed a truncated cone of glass (Fig. 99), open on the top and closed on the smaller diameter by a piece of bladder. For working this apparatus, the mould was fixed upon a metallic disk, dipping into the solution of sulphate of copper, and connected by a bent wire with the top support. Another wire, bent twice at right angles, passed through the second hole of the support, and carried a disk of zinc dipping into acidulated water contained in the truncated cone of glass. By this disposition the mould and the zinc plate were horizontal and opposite each other, although separated by the bladder.

Fig. 99.



This apparatus, the manipulation of which was tedious and difficult, has been simply mentioned, because it was the first in use. It has been superseded by apparatus in which the cell and the moulds are placed vertically, which allows of the rapid removing and watching of the objects. We must, however, acknowledge that this latter disposition favors the production of striæ upon the deposits, when we neglect to change now and then the position of the articles. These striæ are mainly due to the up and down currents formed by liquids more saturated one than the other, and are the more numerous as the intensity of the current is greater. They may be avoided by frequently agitating the bath or the objects.

We must, as far as practicable, maintain the liquids in the bath and in the cells at the same level; and it is even more prudent to have that of the bath slightly above that of the cell, in order to prevent the solution of zinc from becoming mixed by exosmose with the copper bath. The converse is preferable, although the zincs are blackened by a pulverulent deposit of copper.

CHAPTER XLVIII.

DIAPHRAGMS OR POROUS CELLS—KEEPING THE BATTERIES IN ORDER—AMALGAMATING SALT—ACID BATHS.

Diaphragms or Porous Cells.

WE thus call vessels made of materials capable of containing liquids, and, at the same time, allowing them to ooze out slowly through their pores, especially under the influence of electricity. Pipe clay, pasteboard, bladder, gold-beater's skin, and parchment, condensed tissues, especially sail cloth, and certain kinds of woods may be employed for diaphragms. But none is so good as porcelain clay, or kaolin, submitted to a certain heat (biscuit baking), which hardens the paste without destroying its porosity. Vases made with this material are just porous enough, and resist the action of concentrated acids. It is this latter quality which renders kaolin cells so much superior to all the substances indicated above.

It is often quite difficult to obtain cells of dimensions and shape suitable to our wants.* The largest

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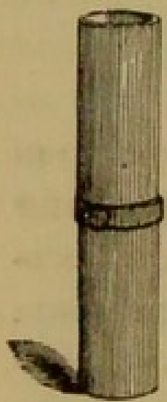
* Our trade facilities, established since the publication of the first edition of this work, allow us to sell diaphragms of every shape and size, up to 1.20 metre in height. We think, however, that it is better not to suppress in this book the manner of utilizing utensils already in hand.

generally found in the trade do not exceed 10 centimetres in diameter, and 36 centimetres in height. And, as it often happens that we have to effect deposists upon surfaces, the height of which is at least double that stated, we shall indicate the manner of remedying this inconvenience. Diaphragms of about 0.70 metre in length may be made as follows: Saw off carefully the bottom of a large cell, and grind well to match the top of another. Then heat the two ground ends, superpose them, and wrap the joint with a ribbon of gutta percha, which is kept firm in place by a screwed collar of copper. Heat the collar again slightly, and screw on, in order to soften the gutta percha and to make the joint tighter. Lastly, cover the copper collar entirely with varnish or, preferably, melted gutta percha (Fig. 100).

Fig. 100.



When the dimensions of the diaphragms are too great to allow of the employment of kaolin, we must have recourse to sail cloth, fixed with copper nails upon a frame of oak. The seams are covered with coal tar, and the cloth lasts longer than is generally thought. Diaphragms are also made of well-joined boxes of thin and porous woods. But, we repeat it, there is nothing like kaolin cells.

Keeping the Batteries in order.

We have already said that the electric current was produced by the action of certain liquids which dissolve zinc slowly, and that the ordinary liquor was water with two or three per cent. of sulphuric or hydrochloric acid, or simply a solution of common salt. It is evident that, after a greater or less length of time, the action will be arrested by the saturation of the acid or of the salt; we must therefore maintain or revive the action by additions of the exciting liquid, and we generally proceed as follows:—

The battery, charged as has been described, will work well for twenty-four hours; and, for four consecutive days, it will be sufficient to add small quantities of acid and amalgamating salt, in proportion to the volume of the cells. The mixture is stirred each time with a glass rod.

The fifth day, all the exciting liquors are thrown away, and fresh ones substituted, because, without this precaution, the zinc salt will be so abundant as to crystallize upon the zincs and the cells. The endosmose cannot take place and the current is stopped.*

It is useless to allow the corrosion of the surface of the zinc which is not opposite the article to be covered; therefore, we will carefully varnish the insides of zinc cylinders. This method, however, will succeed only with the employment of the amalgamating salt.

Cast-zinc will work, but it is far inferior, as regards durability and economy, to laminated zinc, which is more homogeneous and condensed, and which will be uniformly corroded instead of being perforated.

It sometimes happens that zinc is scarcely attacked,

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* A diaphragm or cell may be clogged in two different ways,—By the sulphate of zinc which, having an insufficiency of water, crystallizes in the pores. In this case it is sufficient to boil the cells in water acidulated by sulphuric acid, and all will be right again.—Or by deposits of copper caused by bad working. It is then necessary to dip the cells in aqua fortis until all of the copper is dissolved, and to rinse in plenty of water afterwards.

It is also possible to clean cells by keeping them filled with water, which, escaping through the pores, pushes out the salts and the acids with which they are clogged.

even by concentrated liquors, and that a multitude of small cavities are engraved on its surface. It also becomes covered with a blackish-gray crust, and no electricity is disengaged. These phenomena take place when the zinc is rich in lead.

All commercial zincs contain lead, more or less; but when the proportion of lead is too great, the above trouble takes place. In zinc rolling mills, a great quantity of zinc is melted at once, and then the phenomenon of *liquation* takes place, by which nearly all of the lead goes to the bottom. It results that when the upper portions of the molten metal are ladled out to form the slabs for rolling, the zinc obtained is quite pure; whereas that taken from the bottom parts is rich in lead. The latter is very good for roofing and many other purposes, but it should be avoided by galvanoplastic operators.

Amalgamating Salt.

The great majority of operators, in order to avoid the solution of the zinc when the apparatus does not work, cleanse it in diluted hydrochloric acid, and then amalgamate it by rolling the cylinders in a trough filled with mercury. This method necessitates the employment of a large quantity of mercury, which, however, does not form a uniform coating, and renders brittle the copper connections. Instead of metallic mercury, I use a compound of this metal, made for the purpose, and introduced into the cell itself in a liquid state. In this manner, that part only of the zinc which dips into the liquor receives the mercury deposit, and the amalgamation is continued during the solution of the zinc.

This product, of which I have a monopoly, is a triple salt of binoxide of mercury (sulpho-chloro-nitrate). Nitrate of binoxide of mercury may be employed, but the excess of nitric acid it contains corrodes the zincs rapidly.

Acid Baths.

We have said that when a bath is impoverished, that is to say, contains too weak a solution of sulphate of copper, the electro-deposit is pulverulent, black, and irregular. The same inconvenience occurs when the liquors become too acid, because then they do not dissolve enough of sulphate of copper.

While it is true that, in baths working with separate batteries, the copper anode is dissolved and combines with the sulphuric acid set free at the other pole, and thus maintains the solution without a great excess of free acid, it is not so with the simple apparatus. There the acid set free by the deposited metal will soon be sufficient to render the bath too acid, and to this cause of acidity we should add the contingency of the liquors oozing out from the cells. It is therefore necessary that this inconvenience should be now and then corrected, otherwise the electro-deposits will be worthless, or at least very brittle.

I recommend the following remedies: When the bath is too acid, add carbonate of copper to it until effervescence no longer takes place. In this reaction, the free sulphuric acid decomposes the carbonate of copper, and forms sulphate of copper, and the carbonic acid escapes in a gaseous form. The bath should then be acidified anew in order to increase its conducting power. The carbonate of copper may be replaced by the oxide of the metal, which dissolves without effervescence. Many galvanoplastic operators prepare the oxide by calcining at a red heat all the metallic copper waste of their operations. By the combined action of heat and of the oxygen of the air, the copper is transformed into a black substance, which is the binoxide of copper and is easily dissolved in acid baths. If the entire quantity of copper has not been transformed into oxide, the operation is renewed as many times as are necessary.

In the first edition of this work I had mentioned the use of the carbonates of lime and of baryta for neutralizing the excess of acids; but, since then, I have ascertained that the results are unsatisfactory.

If, after very long use, and by the exosmose of the cells, a bath becomes overloaded with free acid and sulphate of zinc, there is no other remedy but to start a fresh one.

CHAPTER XLIX.

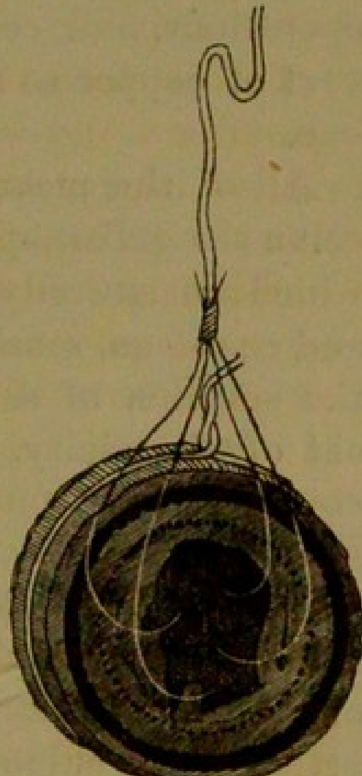
DISPOSITION OF THE PIECES IN THE BATH—GALVANOPLASTIC DEPOSITS UPON METALS (WITH ADHERENCE).

Disposition of the Pieces in the Bath.

We have said that the pieces or moulds were placed vertically, and, as nearly as practicable, parallel to the soluble anodes or to the cells. The depth of the bath should be sufficient to have a few centimetres of liquor above and below the moulds. It often occurs that the moulds are lighter than the solution of sulphate of copper, and it then becomes necessary to sink them with lead pieces covered with varnish or gutta percha, or with stones, glass stoppers, and other substances non-conductors of electricity.

When the object to be covered is metallic, and unacted upon by the solution of sulphate of copper, it is sufficient to attach the conducting wire to any part of its surface, and it will be rapidly covered with an uniform electro-deposit. On the contrary, if the mould is a non-conductor of electricity by itself, and has been covered with some conducting substance, such as *plumbago or graphite*, *bronze powder*, or *reduced silver*, we should, as much as practicable, multiply the points of contact of the electrode. We arrive at this result by uniting the connecting wire (Fig. 101) with a certain number of fine copper wires, like those employed for scratch-brushes, and making their bent extremities touch the mould at various places.

Fig. 101.



When the apparatus is working, we observe that the copper becomes deposited first at these points of contact, from which it radiates in every direction, until the whole surface is covered. We have the advantage, by this method, of a greater rapidity of operation, and of a sensibly uniform thickness of deposit. It is especially needed for moulds having deeply indented surfaces. As soon as the surface is entirely covered, these supplementary wires may be removed.

It often happens that only one face of the mould is intended to receive the electro-deposit; in this case, it will be easy to protect the other surfaces against the action of the bath by a resist varnish, or melted yellow wax, or softened gutta percha. The same precaution may be taken in regard to the conducting wires, except at the points of contact.

Galvanoplastic Deposits upon Metals (with Adherence).

This is the most simple case of the galvanoplastic operations, and consists in covering a metal with a coat of copper so adhering that the two metals make one.

All of the metals are not equally qualified to receive the galvanoplastic deposit; and there are some which are naturally unfit for it. For instance, wrought and cast-iron, steel and zinc, as soon as immersed in the solution of sulphate of copper, and without the aid of electricity, decompose the salt, and become covered with a muddy precipitate of copper without adherence. It is therefore absolutely necessary to give them a previous, and quite thick, coat of copper in the bath of double salts described in the first part of this work, before submitting these metals to the action of the sulphate of copper. Tin, although presenting these inconveniences to a much less degree, reacts upon the sulphate of copper, becomes black, and receives a deposit with slight adherence. It should also be copper electroplated in the solutions of double salts before going into the galvanoplastic bath.

On the other hand, when the metal to be covered is unacted upon by the bath, it is sufficient to cleanse it well, and to submit it to the action of the current for obtaining a rapid and uniform deposit, which adheres more or less perfectly. The coats of copper under these circumstances, should not be too thick, otherwise the surfaces may have a coarse appearance, which impairs the fineness of the lines of the mould. With a good bath, and a well regulated electric current, the delicacy of the pattern will not be defaced by a copper coat having the thickness of stout writing paper. A bright lustre will be imparted to the deposited metal, simply by scratch-brushing or burnishing; or by a passage through aqua fortis and soot, and afterwards through the compound acids for a bright lustre.

CHAPTER L.

GILDING WITH DEAD LUSTRE BY GALVANOPLASTIC DEPOSIT.

Gilding with Dead Lustre by Galvanoplastic Deposit.

Although we have already described in extenso, in Chapter XXV., the galvanoplastic process of gilding zinc with a dead lustre, we cannot think that it is unnecessary to repeat here the method, and to generalize its application to all metals and their alloys and also to non-metallic substances.

Galvanoplastic deposits with adherence furnish us the means of obtaining cheaply a very handsome gilding with a dead lustre, which equals, not the durability, but the appearance of that obtained with mercury, and which we have described in the first part of this work.

We operate in this manner: After having carefully cleansed the mould if metallic, or rendered it a conductor if non-metallic, we immerse it in the solution of sulphate of copper, and allow the deposit to acquire a dead lustre slightly in excess of that desired. After this operation, which may last from two to six hours, we remove the article from the bath, rinse it in plenty of water, and pass it rapidly through the compound acids for a bright lustre, which diminish the previous dulness of the appearance. Next come a rinsing in fresh water; a steeping in a mercurial solution similar to that employed for gilding by dipping; another rinsing; and lastly, the immersion into an electro-gilding bath made of—

Distilled water	10	litres
Phosphate of soda	600	grammes
Bisulphite of soda	100	"
Cyanide of potassium	20	"
Gold (for neutral chloride)	10	"

At first, the current is rendered sufficiently intense by dipping the platinum anode in deeply, afterwards the intensity is diminished by partly withdrawing the anode until the desired shade of gold is obtained. This gilding requires but little gold, since the frosty dead lustre comes from the copper. When the lustre of the copper is very fine and velvety, we may dispense with the dipping into the compound acids, but the rapid passage through the mercurial solution is always desirable.

If the deposited gold be not uniform, or appears partly cloudy, it is proof of an imperfect deposit in the bath, or of an insufficient steeping in the compound acids. The piece should then be removed from the bath, washed in a tepid solution of cyanide of potassium, rinsed in fresh water, dipped in the solution of nitrate of binoxide of mercury, and electro-gilded anew. This gilding bears burnishing well, but we must avoid acid waters and soap, which will produce a red polish, and use only saliva, or the fresh solutions of linseed, or of marshmallow root. The tone of gold thus obtained is richer, deeper, and more durable than that produced upon frosted silver, the latter being recognized by the green color of the burnished parts.

This method is employed for gilding with a dead, or rather frosted, lustre, the ornaments of cigar cases, tablets, etc., the medals under glass for paper weights, and especially, chandeliers, clocks, and other articles of ornament or utility which, at the present day, are sold at one-third or one-fourth of the price of the gilding alone, as made in former times. Many articles of plaster of Paris and wood are also gilt by this process.

Galvanoplastic deposits with adherence give us the means of imparting a uniform appearance to objects composed of heterogeneous substances. For instance, a clock may have a base of copper and ornaments of lead; the whole may be made to appear like bronze after a thin galvanoplastic deposit.

To conclude, this kind of deposit may be employed for binding together substances simply juxtaposited, because the covering coat will be one and continuous. Certain kinds of mosaic works are thus made, and set into a galvanoplastic deposit.

CHAPTER LI.

GALVANOPLASTIC DEPOSITS UPON METALS (WITHOUT ADHERENCE)—GALVANOPLASTIC COPIES FROM DAGUERREOTYPES.

Galvanoplastic Deposits upon Metals (without Adherence).

THE second galvanoplastic problem consists in depositing a coat of copper upon another metal, and in such a manner that, the operation being completed, the deposit may be easily separated from the mould, preserves at the same time with mathematical accuracy the shape and dimensions of the model, and possesses by itself sufficient body and stiffness.

Such is the method used for reproducing medals, basso-relievos, etc., with such a degree of perfection as cannot be obtained by the best processes of plastic casts or moulds from the patterns, which we shall soon describe.

We cannot give a more striking example than the interesting experiment which we have already mentioned, and which consists in reproducing by galvanoplastic methods a daguerreotype with all its minutiæ. The manipulations are very simple, and every one will be desirous to repeat them as follows: Take a daguerreotype and coat its back with a resist varnish, then hold it by a corner and pour upon it a small quantity of alcohol, and rinse it in fresh water. After having connected it with a conducting brass wire, steep it for six or eight hours in the bath of sulphate of copper. The four edges are then cut with strong shears, and, by raising a corner with a penknife or a visiting card, the two sheets will be easily separated, and will furnish two images, one as perfect as the other, but inverted. A cause of astonishment is, that the daguerreotype has not only not received any injury, but is also perfectly dry.

Returning to the general method of galvanoplastic deposits without adherence of metals upon other metals, we will, as has before been said, need to cover zinc, iron, or tin with a previous coat of copper in the baths of double salts.

In this case, or with a metal unacted upon by the bath, we proceed as follows:—

After a thorough cleaning of the pattern, we rub it with a brush charged with plumbago, or, what is better and more easy, with a soft brush slightly passed upon a tallow candle. The film of fatty substance, which prevents the adherence, should not be seen at all. This latter method is just as good, and cheaper than that of covering with gold and silver, sometimes employed to prevent adherence.

It is easily understood that the deposit represents an inverted image of the pattern, and that the raised parts have become hollows, and conversely. This inconvenience is remedied by beginning the same operation anew upon the deposit obtained, and this second deposit is the accurate reproduction of the primitive pattern. A great many copies may be made from the first hollow mould obtained.

CHAPTER LII.

DEPOSITS UPON NON-METALLIC SUBSTANCES.

Deposits upon Non-metallic Substances.

THERE is really but an artificial or relative adherence between a deposited metal and a non-conducting mould. Metals are generally, and by the usual methods, welded or soldered only upon metals, or upon substances, like cast-iron and steel, the properties of which are entirely metallic. When we speak of metallic deposits adhering to non-metallic substances, it will be well understood that the conditions of juxtaposition are such that, without them, the layers will become separated.

If we arrive at the reunion of a metal with another substance, it will be because the non-metallic material is completely enveloped by the metallic deposit, or because the mould is undercut, or held by several points of adhesion.

It is by this process that we are enabled to cover with galvanoplastic deposits porcelain, crystal, plaster of Paris, and other plastic materials, wood, flowers, fruits, animals, and the most delicate insects.

But the first difficulty which we have to overcome in these various operations is, the absence of conductive power for electricity, which characterizes these substances. It is, therefore, absolutely necessary, and before everything else, to proceed to their *metallization.*

CHAPTER LIII.

METALLIZATION—PLUMBAGO—RENDERING MOULDS IMPERVIOUS TO LIQUIDS—METALLIC POWDERS—METALLIZATION BY THE WET WAY.

Metallization.

THE metallization of a non-conducting substance consists in covering all the parts which will receive the galvanoplastic deposit, with a coat of some material which will conduct electricity as well, or nearly as well, as a metal. This coat should be so thin as not to alter the shape or the minutest parts of the model.

We know many methods for imparting the power of conducting the electric fluid to substances which do not possess it naturally. Unhappily, however, none are perfect, and many are so expensive and difficult as to forbid their employment. We shall, nevertheless, enumerate those in common use, and which produce results with which the arts are obliged to be satisfied.

Plumbago—Gilt Plumbago—Silvered Plumbago.

Plumbago, also called black lead or graphite, is the generally preferred metallizing substance. Indeed, in a majority of cases, its conducting power is sufficient; and it may be applied in films thin enough not to impair the sharpness of the mould.

The plumbago found in the trade is rarely pure, and is contaminated with earth, iron, and sometimes with the sulphide of this metal. The impurities are removed by digesting for twenty-four hours with hydrochloric acid a paste made of plumbago and water. Several washings with water, and a slow drying in a stove, finish the operation. In this state, plumbago is nothing but a peculiar kind of mineral carbon. If the plumbago is in large lumps, it should be powdered and passed through a silk sieve.

Plumbago is satisfactory for the metallization of moulds of a certain nature and shape, but will not suit for others. For instance, the conducting power of this substance is sufficient when the surfaces are not deeply indented. At the same time, the mould should be rough enough or sufficiently adhering for the plumbago to stick to it.

Since the publication of my first edition, I have, under the directions of a skilful galvanoplastic operator, M. Tabouret, prepared plumbago with a conducting power much greater than that of the ordinary substance, by incorporating with it gold or silver.

Gilt Plumbago is prepared as follow: In one litre of sulphuric ether dissolve 10 grammes of chloride of gold, and thoroughly mingle with it from 500 to 600 grammes of good plumbago. The whole is then poured into a shallow porcelain vessel, and exposed to the action of air and light. After a few hours the ether is completely volatilized, and the powder is now and then stirred with a glass spatula. The desiccation is finished in a stove, and the product is ready to use.

Silvered Plumbago is obtained by dissolving 100 grammes of crystallized nitrate of silver in 2 litres of distilled water, and mixing this solution with 1 kilogramme of good plumbago. The whole is dried in a porcelain dish, and then calcined at a red heat in a covered crucible. After cooling, the product is powdered again, and sifted.

Plumbago thus metallized conducts electricity nearly as well as a metal, and although very expensive is preferred by intelligent artists.

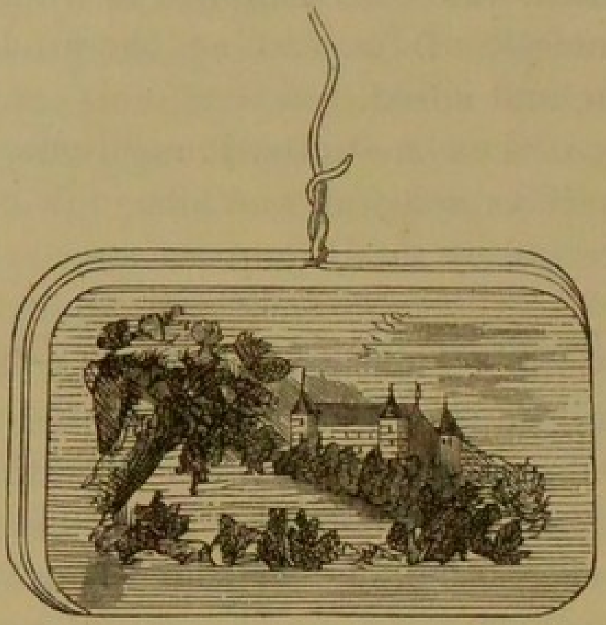
Rendering moulds Impervious to Liquids.

Certain substances, before being coated with plumbago, are submitted to a previous operation, because they are porous, and will be rapidly spoiled by the solution of sulphate of copper which penetrates them. Such are carbonate of lime (chalk and marble), sulphate of lime (plaster of Paris), wood and other spongy materials. It is therefore necessary to render them impervious before the metallization, by covering them with a coat of varnish, or by saturating them with wax, tallow, or, still better, with stearin.

For instance, we shall take a plaster cast, and describe the manipulations: After having cut a groove on the rim of the mould, we place in it a brass wire which is twisted, and one end of which is long enough to facilitate the operation (Fig. 102). The plaster cast, previously dried, is then dipped into a bath of molten stearin kept at a temperature of about 80° to 100° C., and we immediately observe a number of bubbles of air escaping from the mould to the surface. What remains of dampness is also removed.

When the production of air bubbles is considerably diminished, the cast is removed from the bath, and soon becomes dry, by the absorption of the last portions of stearin.*

Fig. 102.



When the cast has become tepid, it is covered with powdered plumbago, and allowed to cool off entirely. Then, after breathing upon it, it is rubbed thoroughly with a brush covered with plumbago; and as upon this operation depends the regularity of the deposit, we must be careful to render the surfaces completely black and bright, without gray or whitish spots.

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* If this operation has been effected with great care and cleanliness (upon *alum plaster*), it is sufficient to rub with a woollen rag, and afterwards burnish the stearined cast, to impart to it a kind of transparency. Thus are made those religious emblems, angels and Christs, fixed upon velvet or ebony, and which so well imitate ivory. In this case, the stearin employed must be very pure, or simply contain a small proportion of *spermaceti*, and it should be melted on a water bath in glass or porcelain vessels. The plaster of Paris may receive, by absorption, various colors before it is plunged into the stearin bath.

When the mould is very indented or undercut, it becomes difficult to employ plumbago, and, in such case, we metallize the whole, or the deep parts only, by the wet way.

It is generally believed that soft brushes should be employed for rubbing plumbago. It is a mistake which prevents many beginners from succeeding; I use myself watchmaker's, and even blacking brushes. I thus obtain sufficient friction for causing the adherence of the plumbago, without injury to the mould. Artist's modelling wax alone requires soft brushes.

The metallization of stearined articles is satisfactory with articles of alabaster, plaster of Paris, wood, etc. For the latter, however, I prefer a protracted steeping in fatty oil, or simply in linseed oil. The object must be rubbed dry before the plumbago is applied.

When the substances to be metallized are not porous, they are covered with a thin coat of varnish, which, when nearly dry, receives the plumbago. This method applies to glass, porcelain, stoneware, horn, and ivory.

It is by analogous processes, that Mr. Oudry has succeeded in the regular manufacture of what may be called "galvanoplastic *chefs d'œuvre*," and which concontribute so much to the decoration of our streets, public gardens, and squares. Such are the monumental fountains and gas candelabra which this inquiring and indefatigable worker has succeeded in coating with a copper deposit, sufficiently uniform to respect the beauty of the ornaments, and durable enough to withstand shocks and friction, and the action of the atmosphere, and to acquire the appearance of bronze. These castings are generally of cast-iron. Many trials had been made to coat them with a sufficient thickness of copper; but all the attempts, which were conducted in one manner, that is to say, a previous cleansing of the cast-iron in acid pickles, a first coating of copper in a bath of double salts, and then a second in that of sulphate of copper, resulted in failures on account of the nature of cast-iron itself. Indeed, this metal is always porous, full of holes, of sand, and of carbon and sulphur; therefore, the deposit of copper presented the same imperfections, and was not continuous. The result was that damp air soon penetrated between the two metals, the iron was oxidized, and the copper raised.

Avoiding the errors of his predecessors, Mr. Oudry, instead of cleansing the cast-iron, covers it with a fat varnish, very plastic and resisting, and, at the same time, sufficiently elastic to follow the dilatations or the contractions of the metal. When this varnish is nearly dry, it is covered with plumbago, and the object is immersed in the galvanoplastic bath. Such is the process by which are coppered and then bronzed a multitude of articles of wrought and cast iron intended to withstand the action of the atmosphere. Mr. Oudry thus manufactures a large quantity of garden benches, fountains, vases, statues, railings, etc., and could cover a whole ship with a continuous copper sheathing, if he had a sufficiently large galvanoplastic trough.

Metallization of Ceramic Articles.

For ceramic wares, other processes are employed, which give more rapid results. For instance:—

After having varnished the portions of the piece to be coppered, they are covered with very finely laminated foils of lead, which bend to all desired shapes; then a brass conducting wire is connected with the lead, and the whole is dipped into the bath, where the copper is immediately deposited upon the metallic parts. It is by similar methods that we succeed in doubling with a continuous coat of copper glass flasks and retorts, tubes, dishes, and other culinary vessels of glass, stoneware, earthenware, or porcelain. Unhappily it was soon found out that the dilatations of the article and of the copper deposit were different, and that an empty space remained between the article and its covering, thus increasing the chances of breakage. It is desirable that the chemical arts should possess vessels of glass, porcelain, or stoneware covered with copper, in order to replace enamelled cast-iron which sinters and scales off rapidly.*

Nevertheless, the arts of luxury have made good use of this kind of deposit, and we may see crystal vases entirely covered with copper, upon which have been deposited other layers of gold and silver. The chaser may then penetrate with his tool at different depths, and uncover one after the other, and at determined places, first the layer of silver, next that of copper, and at last the crystal itself. The vase will appear as if set in a net of various colors. A goblet, a paper weight, and any analogous article may, of course, be treated in the same manner.

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* With the aid of an intelligent manufacturer who has been willing to follow my advice, I am able to furnish chemists and other operators with porcelain dishes (capsules) much superior to all others. These dishes are made as thick as desired, and enjoy the property of *never breaking on the fire.* They may be heated without care, and several metals may be melted in them. They are as white and as well made as those of the manufacture of Sèvres.

A very skilful electrician, and an artist at the same time, Mr. Chablin, ornaments on a large scale, by galvanoplastic processes, porcelain, ceramic, and crystal wares. His method of metallization is quite different from those already described, and he simply uses as a conducting metal the same coat of gold which is applied upon porcelain by the old and well-known processes. The fineness of the details can scarcely be imagined, and the durability and firmness are so great that there is no necessity whatever to imprison the object in the galvanoplastic deposit. Let us suppose that a plate of porcelain is to receive in its centre an ornament or initials in metal and in relief: The gold ornament is first painted with the pencil, and fixed in the usual manner by heating the plate in a muffle. The mere metallic film thus obtained is put in contact with a very thin conducting wire, and the whole immersed in a galvanoplastic bath of copper, silver, or gold, where the deposit takes place in the same manner as upon an ordinary metal, and the adherence is as perfect as that of the film of gold upon the porcelain. The deposit is afterwards polished, chased, or ornamented on the lathe. Nothing is more beautiful than this kind of ornamentation, and the numerous samples seen in our jewelry stores often puzzle the beholder.

Metallic Powders.

We have said that when a metal is plunged into the bath of sulphate of copper, it is immediately covered all over; on the other hand, we know that the deposit begins only at the points of contact of the conducting wire with a surface covered with plumbago, and that it reaches the centre very slowly.

It follows, therefore, that while the metal is an excellent conductor of electricity, plumbago is relatively a poor one.

It has, therefore, been attempted to replace plumbago by exceedingly fine metallic powders; and bronze powders, shell gold, silver reduced by copper or hydrogen, antimony and bismuth in impalpable powder have been successively tried without good results, either from a want of adherence, or from the dissolving action of the copper bath. Some operators, however, continue to use a mixture of bronze powder and plumbago, and claim to be satisfied with it; but we ourselves greatly prefer the gilt or silvered plumbago, prepared in the manner already described.

Metallization by the Wet Way.

If metals applied in impalpable powder, but by purely mechanic means, have not given results as good as expected, such is not the case with the metallization resulting from the reduction upon the mould itself of certain metallic salts. Silver, gold, and platinum, thus reduced from their solutions, have an excellent conducting power, probably because they form a continuous layer.

Silver is generally preferred, and its nitrate is dissolved in certain liquids, variable with the substances to be covered, as we shall indicate further on. The solution is applied with a pencil upon the mould, and allowed to dry, and the operation repeated two or three times. Lastly, the mould is exposed to the action of the sunlight, or of hydrogen, pure or combined with sulphur, phosphorus, or arsenic (never employ the last one). It is still better to fix it to the top of a box which closes hermetically, and at the bottom of which is a porcelain dish holding a small quantity of a concentrated solution of phosphorus in bisulphide of carbon. After a few hours this solution is completely evaporated, and has reduced to the metallic state the nitrate of silver covering the mould, which has become entirely black, and is ready for the galvanoplastic bath.

When we thus metallize wood, porcelain, and other resisting substances, we dissolve 1 part of nitrate of silver in 20 parts of distilled water. With fatty or resinous materials, which cannot be wet by water, we employ aqua ammonia which dissolves the nitrate of silver in all proportions. Lastly, with very delicate articles which will not bear a long manipulation, we operate the solution in alcohol, which evaporates rapidly. Concentrated alcohol dissolves nitrate of silver but slightly: nevertheless, enough will be dissolved for metallizing flowers, leaves, mosses, lichens, etc., if we aid the solution by a trituration in a glass or porcelain mortar.

We have also recourse to the metallization by silver (reduced by phosphorus in bisulphide of carbon) of those deeply indented parts which cannot be reached by even a slender pencil dipped in plumbago. In this case, the mould is plunged entirely into the solution of nitrate of silver, then allowed to dry, and lastly exposed to the phosphorus fumes in the manner indicated.

This process of metallization is so perfect, that a silk cocoon thus prepared may be unspun, and the resulting fibre will possess a conducting power sufficient to immediately deviate the needle of the voltameter, when used as an electrode between this instrument and the battery.

I have seen skeins of raw silk, after such a metallization, covered with a copper deposit so thin and regular, that their natural flexibility was scarcely impaired. These same skeins were afterwards electro-silvered and gilt; but, on account of the impossibility of cleansing in acids, these last deposits were imperfect.

I have also seen laces and mousselines, which were coppered, gilt, and silvered, and which had scarcely, or not at all, lost their primitive suppleness. It was even possible to burnish certain parts, and thus produce contrasts of dead and bright lustres.

It is important to remark that if we fix the conducting wire to the mould before the metallization, the wire must be of gold, silver, or platinum, since the other metals rapidly decompose the solution of nitrate of silver. On the other hand, brass and copper wires may be employed when the metallization is completed, that is to say, after the reduction by phosphorus.

The solution of phosphorus in bisulphide of carbon is prepared as follows: Half fill with this liquid a glass stoppered bottle with a large neck, then gradually introduce the phosphorus gently dried with blotting paper, and shake the bottle now and then. Phosphorus is dissolved more rapidly than candy in water, and is added until no more dissolves. This preparation requires great care in the handling, because in drying upon combustible materials it takes fire spontaneously. A piece of paper or of cloth plunged into it, takes fire after a few moments of exposure to the air.

It is not impossible to obtain galvanoplastic deposits, without previous metallization, of a non-conducting substance. For instance, if we bind a cameo of agate with a single copper wire, and dip it into the bath, the wire alone will receive the deposit, and its volume will increase in every direction. But if we cover with an insulating varnish the exterior of the deposit several times during the operation, it will not increase except from the periphery, and it will by and by cover the whole of the cameo. After separation, the reproduction will be the more perfect from no foreign substance having been interposed. It is from a similar expansion of the deposit that non-metallized parts of moulds often become coated.

CHAPTER LIV.

MOULDING OF THE PATTERN—MOULDING WITH PLASTER OF PARIS—WITH STEARIN—WITH WAX—WITH MARINE GLUE—WITH FUSIBLE METAL—WITH GELATIN, WITH GUTTA PERCHA.

Moulding of the Pattern.

ALL of the preceding operations are effected upon the object itself, which may be considered as a sacrificed, or at least an endangered, mould or pattern. We have mentioned only those objects entirely covered or inclosed by the deposit, or upon which the metallic coating does not adhere, and may be separated.

Let us take a pear, for instance: it either will be inclosed in a copper deposit, which will preserve the shape of the fruit only if the coat be thin and not granular; or after having obtained a thick deposit the whole is cut in two, and each metallic half will be a mould representing exactly one-half of the fruit. We therefore see that in the former case, the galvanoplated object or pattern is sacrificed, since it remains imprisoned in the deposit; and in the latter case, that it is very much endangered. We may add that with most of the objects or patterns, even with flat or not undercut surfaces, and such as medals or basso relievos of plaster, bronze, wax, etc., there is a risk of damaging them if we effect the galvanoplastic deposit directly upon them. Moreover, we thus obtain but an inverted mould, and in order to reproduce the true image, we are obliged to make a second deposit upon the first, which is double work.

All these considerations have naturally induced the galvanoplastic operators to begin by taking a mould from the pattern or object itself, and to submit this mould to the subsequent operations. If from a bronze medal we have taken a cast in plaster of Paris, this will be a hollow mould which being filled afterwards with the copper deposit, will exactly reproduce the raised appearance of the pattern medal. In this operation we run no risk of damaging a rare and valuable object, and we have the advantage of being able to reproduce it many times and with the same accuracy, since we can make as many casts or moulds as are desired from the pattern.

There are many substances which may be employed for making moulds, but all are not equally convenient, and we should know how to apply them in the manner best adapted to each of them.

Moulding with Plaster of Paris.

Plaster of Paris stands first, not in the order of merit, but as having been employed before other substances. It is convenient for taking casts from plaster of Paris itself, from stucco, marble, alabaster, metals, and wood. Being given a plaster medal in relief, we desire to obtain a hollow mould which will furnish the true relief in copper of the primitive medal. After the original model has been thoroughly rubbed with soap or plumbago, we wrap around the rim a piece of sufficiently stout paper, or a thin lead foil, and we bind it in such a manner that the medal to be copied, face upwards, is at the bottom of the box thus formed. It is desirable to sink this box to a certain depth in a layer of fine sand, which prevents the escape of the semi-fluid plaster of Paris through any defective portion of the apparatus. Then in a vessel filled with a sufficient quantity of water, we sprinkle fine plaster of Paris until the last portions reach the level of the water. After waiting for one or two minutes, the whole mass is stirred, and the thin resulting paste must be employed immediately. With a pencil or painter's brush we give a thin coat of this paste, which is pressed into all the recesses, and expels the air, and we then pour the remainder of the paste up to a proper height, and allow it to set. After a few minutes, the plaster becomes warm and hardens, and may be separated from the paper. What has run between the paper and the rim of the medal is scraped off clean, and the plaster cast will separate from the model.

If, instead of applying the first layer with a brush, the whole of the plaster were run at once into the box, there would be great risk of imprisoning bubbles of air between the model and the mould.

We have seen that moulds of plaster of Paris cannot be introduced into the bath of sulphate of copper without having been previously rendered impervious. This difficulty prevents the more frequent use of this substance for moulding, and we prefer other materials which are unacted upon by the bath, and which it is sufficient to metallize if they are non-conducting. Such are stearin, wax, fusible metal, marine glue, and, especially, gelatin and gutta percha.

Moulding with Stearin, Wax, and Marine Glue.

Stearin is applied in the same manner as plaster of Paris, with this difference, that the former is melted with the aid of heat, and poured upon the model when it is going to set (congeal). When stearin is too new or dry, it crystallizes in cooling, and this impairs the beauty of the cast. In such case it should be mixed with a few drops of olive oil, or with tallow, or suet. On the other hand, if it be too fat, it remains soft and is difficult to separate from the mould. It should then be mixed with virgin wax or spermaceti.

As stearin contracts considerably by cooling, its employment should be avoided when the copies from the model are required to be perfectly accurate.

When we desire to make a cast with stearin of a plaster model, it should be thoroughly saturated with water or stearin beforehand, as we have explained for galvanoplastic deposits upon plaster. It should also be perfectly coated with plumbago before the melted substance is poured upon it, otherwise the two stearins will stick together, and it will not be possible to separate the cast from the model.

Wax is also employed in the same manner, but its price and want of hardness considerably interfere with its application.

Marine glue may be used in the melted state, like wax; or, after having been softened in hot water, it is compressed upon the object and allowed to become hard again. This material is now seldom used.

Moulding with Fusible Metal.

This metal, also known under the name of Darcet's alloy, is a perfect conductor of electricity, and therefore well adapted to the production of homogeneous deposits of equal thickness. Nevertheless, it is seldom employed, on account of the difficulty of the operation, of its crystalline texture, and of the presence of air bubbles.

Here are several formulæ for this alloy:—

I. Pure lead	2 parts in weight.
Tin	3 " "
Bismuth	5 " "

Fusible at 100° C.

II. Pure lead	5 parts in weight.
Tin	3 " "
Bismuth	8 " "

Fusible from 80° to 90° C.

III. Pure lead	2 parts in weight.
Tin	3 " "
Bismuth	5 " "
Mercury	1 " "

Fusible at 70° C.

IV. Pure lead	5 parts in weight.
Tin	3 " "
Bismuth	5 " "
Mercury	2 " "

Fusible at 53° C.

For those alloys without mercury, the component metals may be melted together; on the contrary, when mercury is employed, it should be added when the three other melted metals have been removed from the fire. In order to obtain a thorough mixture, the alloy should be stirred with an iron rod, or melted over and cast several times.

There are several methods of employing the fusible metal: Some run the metal into a small dish, remove the oxide with a card, and then apply the model, and give it a few taps when the setting takes place; others put the model into the dish and pour the clean alloy upon it. I have seldom succeeded with either method, and that which I have found the most satisfactory is as follows: I put the medal at the bottom of a small box of iron or copper, and bury half of its thickness in plaster of Paris; then, covering the medal with the cold fusible alloy, I apply heat until it is melted, when it is allowed to cool off. It is easy to separate the medal from the fusible alloy, since the portion protected by the plaster of Paris may then be grasped.

A well made cast of fusible alloy is the best mould for galvanoplastic operations with silver and gold.

We must not forget that such alloys as contain mercury should not be used for taking casts from metallic medals (iron excepted), which would become amalgamated and injured. Moreover, copper deposits obtained upon such alloys are very brittle, which indicates a combination of the mercury with the copper.

Sulphur, melted at a temperature of from 108° to 110° C., produces very neat and sharp casts, and it is, therefore, to be regretted that it is so very difficult to get it metallized, and that it transforms the deposit of copper into sulphide.

Moulding with Gelatin.

The different substances which we have indicated are employed for moulding those objects, the surfaces of which present no undercut parts which prevent the separation of the pattern from the mould.

In certain peculiar conditions, the elasticity of gelatin and gutta percha allows of the possibility of removing them from undercut or highly wrought parts, and they reacquire the shape and position they had before the removal.

This valuable property is found in gelatin to a higher degree than in gutta percha, but it requires a very rapid deposit, otherwise it will swell and be partly dissolved by too long an immersion in the solution of sulphate of copper. Without this inconvenience, which is capital, no other moulding material would be more convenient for galvanoplastic operations.

For making good gelatin moulds, proceed as follows: Put a sufficient quantity of colorless plates of gelatin (cabinet-maker's glue) in cold water, and let it swell there for about 24 hours; then drain off the water, and heat the swollen stuff upon a water bath until it has become of a syrupy consistency, when it is ready to be poured upon the object, which has been encased in a box of pasteboard or of thin lead. After cooling for about 12 hours, the gelatin cast is separated from the object.

Many attempts have been made to render the gelatin impervious; or, at least, to enable it to bear, without alteration, a longer immersion. Here are several receipts which are considered among the best:—

1. Dissolve 200 grammes of the best gelatin in 1 litre of hot water, and add 4 grammes of tannic acid (tannin), and the same quantity of rock candy; then mix the whole thoroughly, and pour it upon the model in its box. After a few hours the gelatin forms a kind of semi-transparent leather, which may be easily separated from the objects in high relief, of which it is an exact counterpart.

2. A mould having been made with gelatin alone, a solution of water holding 10 per cent. of bichromate of potassa is poured upon it, and after draining, the mould is exposed to the action of the sun.

3. Beat, in one litre of distilled water, the whites of two eggs, filter, and cover with this liquid the entire surface of the gelatin mould. After drying, operate with the solution of bichromate of potassa, as in No. 2. The solar action is sufficient to render insoluble the coat impregnated with bichromate.

4. Pour upon the gelatin mould some varnish, drain carefully, and let it dry. The best varnish for the purpose is a solution of India rubber in benzole, or, still better, in bisulphide of carbon.

At all events, the mould must be metallized, and, when in the bath, submitted to a galvanic current of great intensity at the beginning. When the entire surface is covered with the copper deposit, and when swelling is no longer to be feared, the intensity may be reduced.

Moulding with Gutta Percha.

Gutta percha, the discovery of which is nearly contemporaneous with that made by Jacobi, is a sort of gum resin or the coagulated juice of a peculiar vegetable. It is entirely insoluble in water, in weak acids, and in the solution of sulphate of copper. It possesses the peculiar property of being softened by heat to the point of becoming nearly fluid, and of reacquiring, by cooling, its hardness and previous properties, and that quite an indefinite number of times. It also derives the name of *vegetable leather* from its tenacity and suppleness. It is much less elastic than gelatin, and there is more difficulty in separating it from highly wrought objects; nevertheless, with a little practice, results truly surprising may be attained.

The following is the method of operating with this substance: After its purification by malaxation in boiling water, in order to separate the ligneous and soluble parts, plates of various thicknesses are laminated, or lumps formed. A quantity sufficient for the intended mould is cut from these plates or lumps with a hot knife, or, what is better, with a shoemaker's knife, and put in cold water, which is gradually heated. The gutta percha is now and then moved about, until it is soft enough to be kneaded with the fingers like dough. It is then ready for use in one of the following modes:—

After having pulled the gutta percha in every direction, the edges are turned in so as to form a kind of half ball, the convex and smooth surface of which is applied upon the middle of the model. Then, with a vertical pressure of the palm of the hand, the gutta percha is spread over and forced to penetrate the details of the object. The kneading is continued as long as the material remains sufficiently soft, when it is allowed to cool. As soon as the whole is slightly lukewarm, the gutta percha is separated from the model, and dipped into cold water, when it hardens, and may then be handled without danger of impairing its accuracy.

This method is very imperfect in operation and in results, and its smallest inconvenience is that the casts are seldom free from cavities due to air bubbles or drops of water. It is only practised by beginners who do not possess the utensils necessary for the three methods, which we shall describe, *i. e.*, moulding with the press, moulding in the stove or by sinking, and moulding by hand or by kneading.

Moulding with the Press.

After having raised the screw of the press, the object, carefully coated with plumbago or tallow, is put square and firm upon the table of the tool, and surrounded with a ring or frame of iron, which should be a few centimetres higher than the most raised parts of the object. A piece of gutta percha, with a thickness at least double that of the pattern, is cut so as to fill quite accurately the ring or frame of iron, and then heated, on one of its faces only, before a bright fire. To prevent the gutta percha from running, it is now and then made to rotate. When about two-thirds of its thickness have been softened, it is placed, soft portion downwards, in the iron ring or frame, and the whole is covered with a block of metal exactly fitting. The screw of the press is now made to act slowly at first, and then with more energy as the gutta percha becomes harder and more resisting. Percussion presses are very good. We understand that gutta percha, being imprisoned between the pattern and the metallic block, is obliged to penetrate the most intricate and delicate parts of the object. It is the method employed by electrotypers of type and engravings.

In order to demonstrate the usefulness of this method, I shall presently indicate the processes followed for making the moulds of the electrotypes of the figures printed in this work.

The artist begins by drawing the figure with a black lead pencil upon a piece of hard wood, the surface of which has a coat of white fixed with glue. The figure is therefore black upon a white ground.

With appropriate and sharp tools, the engraver makes all of the whites hollow, whereas the black lines remain in relief. This engraving on wood may be used for printing; but we understand that whatever be the hardness of the wood employed, it will soon be shattered, and cease giving sharp prints, and the time will come when the artist and engravers will have to do the work over again.

By means of electrotypes we avoid all this trouble; and what is more, we entirely preserve the wood-cut. It is sufficient to obtain a good cast or mould in gutta percha, by means of the press, and we will have an accurate hollow counterpart of the pattern in relief. This mould is then coated with plumbago and put into the bath, where it receives a deposit of copper, which is much harder than the wood, and an exact copy of the primitive cut. The electrotype obtained is well trimmed, nailed upon a wooden base, or soldered upon a block of type metal, and is ready for printing.

A few more examples: Masters in the art of engraving trace their works upon a plate of hard and homogeneous steel, and this plate, which is often the work of several years, is used for multiplying by printing the work of the artist. We readily imagine that the fineness of the details, and the sharpness of the print, are in inverse ratio to the number of copies, and that there arrives a time when the work of the artist itself, *i. e.*, the plate, becomes valueless. Thence the great value of the first proofs, which generally belong to a few privileged persons, and which are rarely to be found in the trade. At the present day, and with electrotypes, the primitive plate, which shows all of the characteristic talent of the artist, is entirely preserved. Upon a mould of gutta percha, obtained with the press, we deposit a copper electrotype, which is a mathematical copy of the plate.

Let us now suppose that a new edition is to be made of a book of great value, and which will require no further changes in the text, the Bible for instance. The printer, by depositing in metallic frames a multitude of small prisms, one extremity of which represents a letter, a cipher, or a sign, and called types, will form pages. After the printing of these pages, each little prism will go back to its case, to be used for other pages, and the same operation will have to be done over again at each new edition. Instead of that, and thanks to the galvanoplastic processes, the printer will not work the edition from the composed forms, but from electrotypes made upon gutta percha moulds pressed upon the types of each page. All typographical errors must, of course, have been corrected previously. These electrotypes are much superior in sharpness of print to stereotypes made of fusible alloys.

In order to prevent as much as possible the counterfeiting of its notes, the Bank of France, not only unites upon the same plate all kinds of engravings, but has them executed by different artists, each having his own *modus faciendi* which can be recognized. We see how valuable such a plate is, and how it is to be desired that it should not be submitted to the destructive action of the printing press and ink. Here again all difficulty is avoided by a galvanoplastic reproduction. Not many years ago, a sheet of lead well scraped upon one of its faces, was submitted to an energetic pressure upon the engraved plate, in order to obtain the hollow mould from which the electrotype in relief was produced. This method was open to objections: that with the considerable pressure necessary for forcing the lead into the details of the engraving, there was danger of injuring the latter; and that it is difficult to find lead so free from blown holes, flaws, scales, or oxide, as to make perfect impressions. Upon my advice, followed by M. Sommier, the learned printer of the bank, gutta percha was substituted for lead, and no further trouble is now encountered.

Moulding with a Counter-mould.

When the gutta percha is compressed between a highly wrought pattern and a flat metallic block, its thickness at different places is very variable. This is very objectionable, because these various thicknesses do not cool off at the same time, and often prevent a good mould from being obtained. Many intelligent operators use a *counter-mould*, which they prepare in the following manner: After having cast upon sand a thick block of lead, they hollow out approximately with a graver the places corresponding to the reliefs of the pattern, and conversely, minding at the same time the desired thickness of the gutta percha. It is then possible to spread over the pattern a plate of gutta percha of the same thickness all through, which is compressed by means of the screw press through the intermediary of the lead block. This process produces excellent results. It is even possible to dispense with the softening of the gutta percha, if it be thin, but the pattern and counter-mould should be heated up to about 100° C. There is, however, danger of overheating, in which case the gutta will stick fast to one or other of the surfaces.

Moulding in the Stove or by Sinking.

The moulding with the press, which we have described *in extenso,* is suited to those objects which are comparatively flat, and which will bear pressure. Moreover, it requires the employment of a screw press, which instrument is sufficiently costly to deter amateurs, and even operators, from buying one.

This new method of moulding does not require any press, and is convenient for many brittle articles of plaster of Paris, marble, alabaster, and other analogous substances. The pattern is put upon a dish of iron or earthenware, or simply upon a piece of sheet-iron, the edges of which have been turned up. Then a ball of gutta percha is placed in the middle of the object to be moulded, and the whole is placed in a stove, where the temperature is sufficient to melt the gutta, and not high enough to burn it. The stoves of many ranges, especially those of glazed earthenware heaters, are very good for this purpose. The large operators employ special arched ovens with the fireplace at the bottom, and all of the space is traversed by iron bars for the support of the iron dishes which hold the pattern and the gutta percha. In this manner, it is easy to watch the operation and avoid too much heat. The gutta percha becomes gradually soft and penetrates all the details; when it has sunk completely, it is removed from the stove, and allowed to cool off until it still retains sufficient elasticity to be separated from the pattern. The shape of a sphere or ball given to the gutta percha is intended for driving out, while it sinks, the air which otherwise might become imprisoned between it and the pattern.

Moulding by Hand or by Kneading.

The foregoing process does not suit those objects which will not bear the heat of the stove, but which will support the contact of softened gutta percha, sulphur, wood, statuary, pasteboard, etc., for instance. In this case, we heat the gutta percha slowly in one of the above stoves, or otherwise, until it becomes a semi-fluid paste, and we pour a sufficient quantity of it upon the pattern previously placed in an iron frame or ring. We wait a few minutes, and then with wet, or, which is preferable, oiled fingers, we knead the gutta to make it penetrate all of the details of the pattern, and until it yields to the pressure with difficulty. This last process is employed by the majority of amateurs, and by many professional workers.

Whatever is the method followed, there are certain precautions needed for separating the mould from the pattern. First, we should cut off with a shoemaker's knife all of the useless parts of the gutta percha, and especially those which may have passed under the pattern and bind it. Then the proper position and shape of the covered pattern must be ascertained, because when it is undercut, either the pattern, if brittle, will be broken, or the gutta percha will be torn, if we remove it in the wrong direction.

In moulding with the press, gutta percha without mixture, but of the best quality, is generally employed.

For the other methods of moulding by sinking or kneading, the gutta percha is nearly always mixed with certain substances which increase its fusibility, such as linseed oil, lard, tallow, and yellow wax. Their proportions may vary *ad infinitum*, although they should never be over one-third of the total weight. For instance, the mixture with linseed oil is made by heating in a kettle of iron, copper, or stoneware 1 part of linseed oil, and when its temperature has reached from 80° to 100° C., by adding gradually, and stirring with a wooden rod, 2 parts of gutta percha cut into small pieces. When the whole is in a pasty form, and begins to swell up with the production of thick fumes, the kettle is removed from the fire, and its contents thrown, with the aid of the stick, into a large volume of cold water, where, without loss of time, the paste is kneaded and pulled in every direction. While still hot, it is placed upon a slab of marble or polished stone, and formed into lumps, slabs, etc., which may afterwards be laminated between middling warm rollers.

Gutta percha may be used for quite an indefinite length of time. The old is, up to a certain point, preferred for certain casts, especially those of copperplate engravings, since the impressions are finer and more delicate. After a great deal of use, nevertheless, gutta percha becomes dry and brittle, and holds in it too much plumbago. An addition of fresh gutta restores its previous qualities.

Although it would seem, *à priori*, that gutta percha, on account of the heat necessary for its employment, is not very well adapted to the moulding of animal or vegetable substances, I have, however, seen masterpieces in this line, such as very delicate insects and leaves, reproduced in copper from gutta percha moulds. I shall particularly mention nettle leaves, which were so perfect that all the hairs on their surface were to be seen. The operation was conducted as follows: One of the sides of a fresh leaf was covered by means of a brush with a thin paste of plaster of Paris, and, after the drying of this first coat, other layers were applied until a resisting block had been obtained with the leaf uppermost. The free side was then covered with several coats (always with a brush or pencil) of gutta percha dissolved in bisulphide of carbon, and lastly with melted gutta. The mould was removed from the leaf, metallized, and immersed in the galvanoplastic bath.

Impressions have also been taken with India rubber (caoutchouc), and I possess very fine samples of such moulds. I do not understand why this material is not employed more extensively, since, for certain works, its elasticity renders it much superior to gutta percha.

NOTE.—Models of plaster of Paris, from which moulds of fusible metal or of gelatin (glue) are to be taken, will stand the operation much better if they have been hardened by being saturated with boiled linseed oil, to which a certain proportion of dryer has been added. They are oiled again just before pouring the gelatin over them.—*Trans.*

CHAPTER LV.

GALVANOPLASTIC DEPOSITS ON PATTERNS WITHOUT DELIVERY (UNDERCUT), AND WHICH ARE SACRIFICED—LENOIR'S PROCESS—GALVANOPLASTIC METHOD FOR ARTICLES IN HIGH RELIEF WITH GUTTA-PERCHA MOULDS.

Galvanoplastic Deposits on Patterns without Delivery (Undercut), and which are Sacrificed.

HERE is an ingenious method of obtaining a copper mould and a copy afterwards from patterns so undercut that they must be sacrificed. For instance, a human head in plaster of Paris is rendered impervious, and then metallized. After a galvanoplastic deposit of copper has been effected on its surface, the plaster is removed by boiling, and breaking it through the opening of the neck. The continuous mould of copper thus obtained is slightly greased inside, and serves as a galvanoplastic trough (Fig. 103), which is filled with the solution of sulphate of copper. Bags filled with crystals of blue vitriol are suspended to the edges, and with a separate battery and soluble anode, or with a porous cell placed inside of the mould which is connected with the zinc, another deposit of

Fig. 103.

copper takes place in the cavity. When the thickness of the metal is sufficient, the mould or first deposit is peeled off, and we obtain the copper reproduction of the object in high relief. This process is expensive, but gives sure results with large patterns having large raised parts. With small or narrow objects, or those the protuberances of which are very crooked, we prefer moulds in several parts, although the seams are always seen and require mending.

Lenoir's Process—Galvanoplastic Method for Articles in High Relief with Gutta-Percha Moulds.

It is but natural to insert in this place the galvanoplastic method for articles in high relief with gutta-percha moulds invented by Lenoir, to whom the arts are indebted for several valuable discoveries, especially the gas engine, which bears his name, and the composition of the white enamel upon copper dial plates, which was a secret and monopoly of Venice, until he discovered it for his own countrymen.

Lenoir had been struck by the enormous labor required for finishing up a bronze coming from the foundry; retouching, filling up, scraping, smoothing, and chasing, were as many causes for rendering the object accessible only to the few. Moreover, after a passage through so many hands, the reproduction was but a shadow of the work of the master. He was also well acquainted with the difficulty of soldering together the various parts of galvanoplastic productions, so as to form with them a bust, a group, or a statue.

The problem to be solved was to obtain from a pattern as many galvanoplastic copies in one piece as desired, and with such an accuracy that the artist to whom the model was due could not distinguish it from the reproduction.

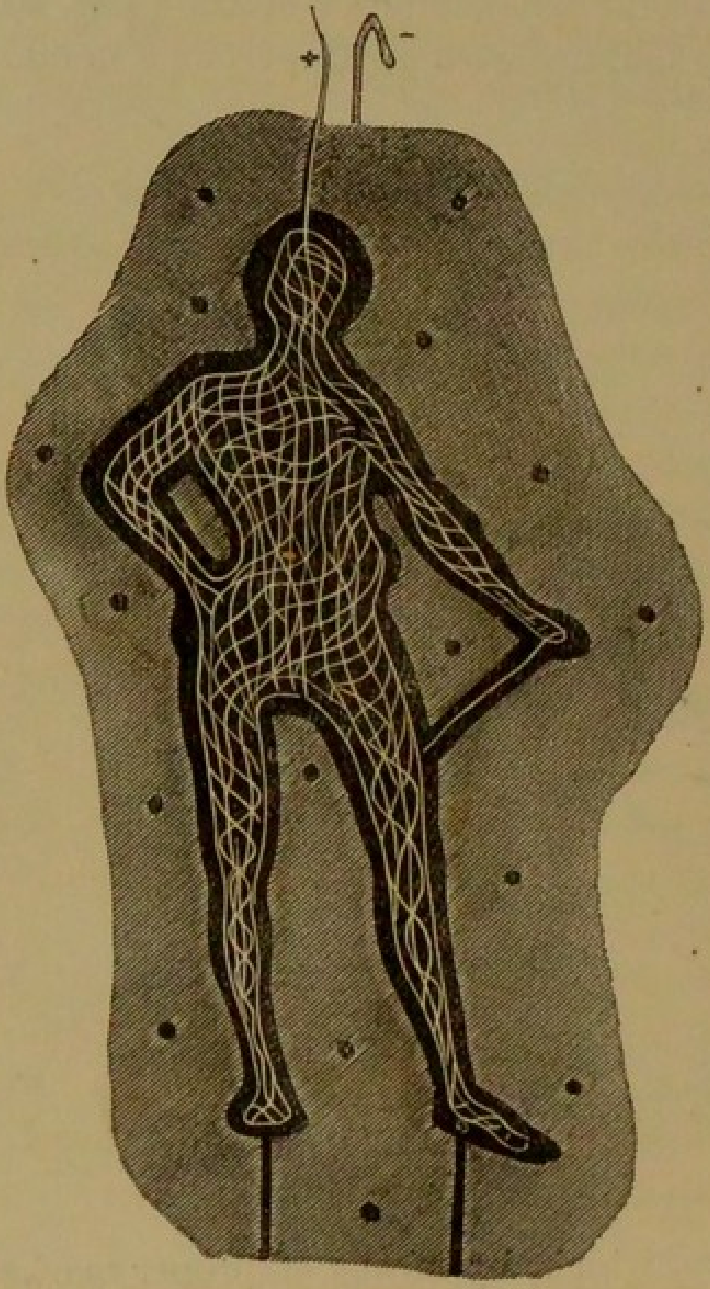
We shall see by what series of processes, more ingenious one than the other, Lenoir resolved the problem.

Let us take for instance, a statue (Fig. 104). We begin by making with gutta percha a mould in several pieces, which, by means of proper marks, may be united together, and form a perfect hollow mould of the pattern. All these parts are carefully coated with plumbago.

Fig. 104.

On the other hand, with platinum wire, a skeleton (Fig. 105) is made, which represents, *grosso modo*, the pattern, and which must be smaller than the mould, since it is suspended in it without any point of contact.

Fig. 105.



We already understand that if the skeleton be inclosed in the metallized gutta-percha mould, and the whole immersed in the galvanoplastic bath, it will be sufficient to connect the inner surface of the mould with the negative pole of the battery, and the skeleton (which should have no point of contact with the metallized surface of the mould) of platinum* wires with the positive pole, for decomposing the solution of sulphate of copper which fills the mould. When the metallic deposit has reached the proper thickness, the gutta-percha mould is removed, and we find underneath a statue which may be finished at a very small expense.

But if the explanation of the process is very simple, its execution is not so easy, and we shall examine all of the precautions devised by the inventor in order to insure success.

First, it is very difficult to ascertain that the skeleton anode is nowhere in contact with the inclosing mould. In order to avoid such contact, Lenoir wraps with a spiral of India-rubber thread all the external parts of the platinum anode. The India rubber, by its thickness, prevents the contact of the metal with the mould. Fig. 106 represents the manner in which the spiral of India-rubber thread runs round the platinum wire.

Fig. 106.

Second, notwithstanding all these precautions, it was still possible that, with the increase of the deposit of copper, which reduced the distance between the mould and the anode, the latter and the deposit would come in

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[*] We have heard that the inventor had proposed to substitute lead wires for those of platinum. They are cheaper, and the lead wires are easily removed by melting them.—*Trans.*

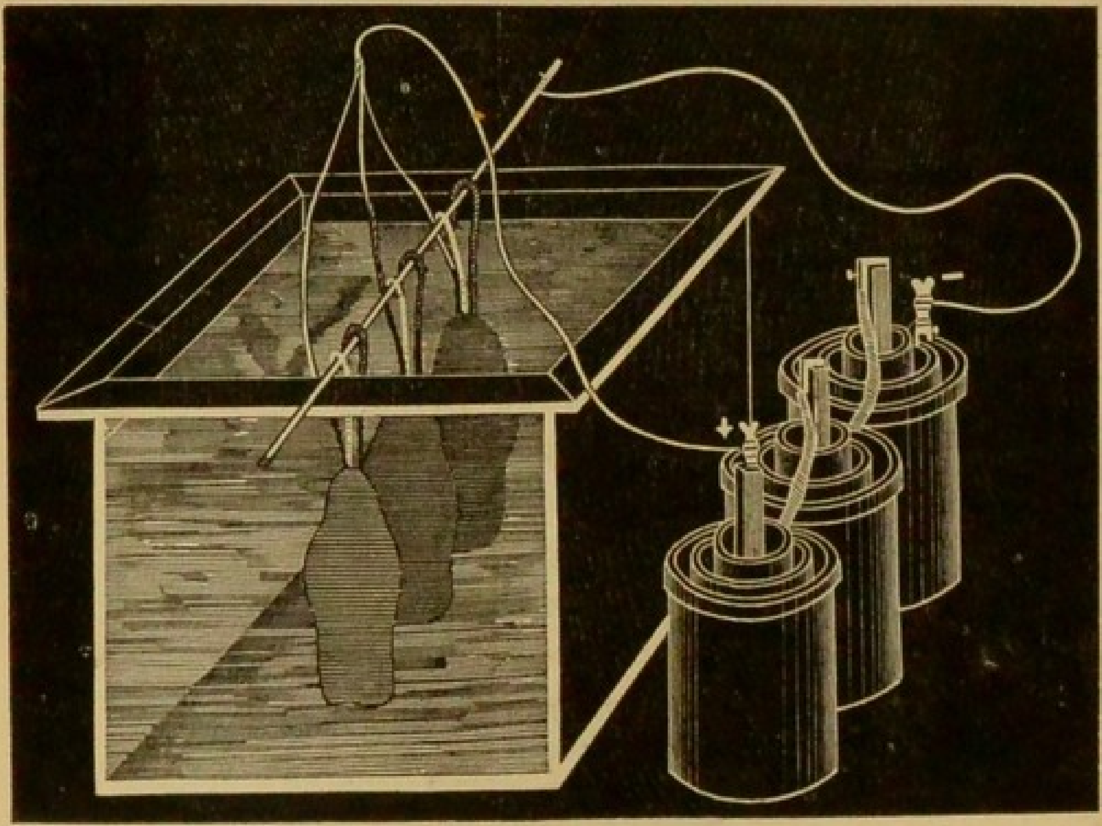
contact, and thence stop the operation without any exterior sign to attract the attention of the operator.

This was a great objection, sufficient to render the whole process entirely useless. Indeed, if in a trough holding many moulds, one point of contact were established between the two poles (mould and skeleton), all the electricity of the battery would escape at that place, and the working of the bath would stop entirely.

In order to obviate this possible inconvenience, Lenoir has devised the following process:—

All the moulds of the same bath are supported by hooks suspended to a metallic rod. These hooks have no contact with the metallized surfaces of the moulds, which are connected with the negative pole by means of metallic wires terminated above the

Fig. 107.



liquid by other *iron wires* as fine as hair. The connecting wires of the skeleton anode pass through the same opening as the negative electrodes, but without contact, and are united to the positive pole (Fig. 107).

It results from this disposition that, as long as there is no contact between the skeleton and the interior of the mould, the electric fluid finds sufficient passage through the several slender iron wires which

Fig. 108.

connect the moulds with the battery; but, if any contact takes place, the whole of the electricity rushes to that point, and, being too abundant for the small section of the iron wire, it heats and burns it out rapidly. The galvanoplastic work is thus instantaneously stopped for this mould, and continues for the others. Moreover, the broken wire shows the operator where the defect is.

The iron wire should be very short, in order to burn rapidly. One or two centimetres are sufficient.

Lastly, it is easily understood that, in closed moulds and with an insoluble platinum anode, the solution of sulphate of copper will be rapidly transformed into sulphuric acid and water. Hence the necessity of allowing at the lower part of the mould (under the feet for instance), room for two holes, through which and the opening at the head, left for the passage of the electrode, a free circulation of the liquor in the bath may take place (Fig. 108).

When the operation is completed, the gutta-percha mould is removed, and the skeleton anode pulled out by force. We have still to close three holes in the statue, and to file off the seams left at the junction of the different parts of the mould, in order to have a perfectly accurate copy of the model.

CHAPTER LVI.

LENGTH OF THE OPERATION.

Length of the Operation.

THERE are no precise rules for determining the length of time necessary for a galvanoplastic deposit. It depends upon the thickness of the desired deposit, the intensity of the current, the dimensions, and the more or less irregular shape of the object. The article may be removed from the bath when the thin copper deposit has spread all over the mould; but in this case, the pellicle is not sufficiently firm, and is often perforated with many holes. Nevertheless, a quantity of these thin and defective deposits are to be met in the trade, and an appearance of firmness is given them by tinning the back side, and filling it with tin or some solder. These strengthened objects are sometimes put again into the galvanoplastic bath, in order to cover the solder with a light layer of copper, and make it appear as though the thickness of the deposit were considerable, whereas the firmness is simply due to the solder added.

It is by analogous processes that are manufactured the multitude of ornamented plates for portemonnaies or cigar cases, which have contributed not a little to the present discredit of such galvanoplastic products. It is to be hoped that, in the future, manufacturers will be more intelligent and careful, and will not begrudge a little more copper. It will be time to strengthen the deposit with solder when it shall have no holes, and a sufficient thickness. Such is the rule of those who endeavor to sell durable articles.

The firm of Ch. Christofle & Co. possesses a patent for filling with copper solder (copper and zinc) galvanoplastic reproductions. By this process, they are enabled to furnish to the trade a quantity of perfectly finished and durable articles for furniture and cabinet maker's use. Similar objects were previously made of melted bronze or brass, which required trimming, chasing, rose turning, etc., before being ready for use.

For filling galvanoplastic reproductions with brass solder, their exterior is first covered with clay, plaster of Paris, or Spanish white mixed with charcoal dust, and the whole is perfectly dried in a stove-room. This coat is intended for preventing the copper deposit from losing its shape and being oxidized by the action of a high temperature. The interior of the article is then filled with the softest brass solder to be found, and with powdered borax, which are melted by a gas or turpentine blowpipe. All the hollow parts are soon filled with the solder, which imparts to them at least as much firmness and durability as is to be found in cast articles.

CHAPTER LVII.

REMOVING THE MOULD—FINISHING UP THE ARTICLES.

Removing the Mould.

THIS operation consists in separating the galvanoplastic deposit from the substance of the mould, and it is evident that there will be nearly as many methods as there are substances employed.

With a metallic mould the operation is very simple, and it is sufficient, after having removed the useless portions of the deposits with a file, a saw, or otherwise, to pass a card or a blade of horn or ivory between the model and the deposit for obtaining their separation without injury.

The operation is about the same with moulds of plaster of Paris, porcelain, marble, glass, or wood; but it is very difficult to save a plaster mould which has been in the bath, and which is nearly always sacrificed and separated into fragments.

Moulds of wax, stearin, fusible metal, gelatin, or gutta percha are heated in boiling water or otherwise, and, therefore, their separation presents no difficulty whatever.

Finishing up the Articles.

The articles separated from the moulds are generally spotted with plumbago, grease, or other still adhering substances from the moulds. It is usual to heat them, so as to burn out the impurities, and to cleanse them by a more or less protracted immersion in a pickle of diluted sulphuric acid. The heating presents the advantage of rendering the copper deposit softer and more malleable; on the other hand, it may result in injury to the minute details and the fineness of the copy. Therefore, for delicate reproductions, it will be preferable to clean with alcohol, turpentine, gasoline, or benzole, and to rub the surface with quite a stiff brush. We may finish with a paste of Spanish white (levigated chalk) in water, which is allowed to dry upon the object before it is wiped out. In this case, should any Spanish white still remain in the hollows, it may be dissolved in water holding one-tenth of its volume of hydrochloric acid, which does not corrode the copper. The operation is completed by rinsing in fresh water, and drying in sawdust or otherwise.

When it is desired to anneal the articles without injury to their surface, we may plunge them into boiling colza, or linseed oil, or simply grease, which will bear a heat sufficient for annealing, and will, from their nature itself, prevent the oxidizing action of the air. This annealing in fatty substances is especially to be recommended in the case of highly undercut moulds of gutta percha, which may have left part of their substance in the deep recesses of the galvanoplastic copy. The gutta percha is first softened, and then dissolved in the fatty material.

CHAPTER LVIII.

GALVANOPLASTIC OPERATIONS WITH GOLD OR SILVER—GALVANOPLASTIC BATHS FOR SILVER AND GOLD.

Galvanoplastic Operations with Gold or Silver.

We have said that is was possible to obtain galvanoplastic deposits of gold or silver; but the processes, known at the present time, are more difficult and less effective than those for copper. Indeed, the latter metal is obtained by the reduction of simple salts, *i. e.*, compounds of one acid and one base; whereas the galvanoplastic operations with gold or silver require baths of double salts, such as the double cyanide of gold and potassium, or the double cyanide of silver and potassium. The sulphate of copper is very soluble and easily reduced; on the contrary, the sulphate of silver is but slightly soluble in water. The sulphate of gold exists only hypothetically. As for the nitrate of silver and the chloride of gold, which are the most soluble salts of these metals, they have been tried without success.

A very great disadvantage with the galvanoplastic baths of gold or silver is their alkaline state, which prevents the use of a great many substances, especially the fatty ones, for the preparation of the moulds. Moreover, these liquors possess a less conducting power for electricity, and require a better metallization than that with plumbago. We cannot even use the reduced metals from solutions of nitrate of silver or chloride of gold, because they are immediately dissolved. Therefore, in the case of somewhat deeply wrought moulds, we are obliged to turn the difficulty in this manner: After having deposited by the ordinary process a thin pellicle of copper, the whole is plunged into the silver bath, which then works very well. After the separation of the copy from the mould, it is allowed to rest in a solution of ammonia or of very dilute nitric acid, which, after a certain length of time, dissolves the pellicle of copper, and leaves the silver deposit alone.

We readily understand how imperfect such a reproduction must be, since there has been, between the mould and the precious metal, an intermediary layer of copper of unequal thickness. This is, however, the only process we know of, when we operate upon non-conducting and undercut moulds. On the other hand, when the surfaces are even, or but slightly in relief, we may employ moulds of lead, tin, or fusible metal, upon which silver or gold will deposit well and without adherence. We prefer lead to the other metals, especially when the mould may be obtained by pressure.

Here is a process by which we are enabled to employ non-conducting moulds for galvanoplastic operations with gold or silver: The pattern is covered with a foil of lead very thin and larger than the object, then the gutta percha is applied upon it, and the whole pressed, as has been explained before. The lead foil, without being torn, follows all the details of the pattern, and may be separated afterwards with the gutta percha which it has metallized. Instead of lead, we may employ silver or gold foils, which are so thin that the seams disappear by simple pressure. I recommend this method, which is very simple and easy, to those amateurs desirous of obtaining good deposits of silver or gold.

A somewhat thick sheet of very pure lead may be employed for taking moulds of engravings upon copper or steel. The lead and the engraved plate are passed between rollers, or simply pressed under a screw press.

Galvanoplastic Baths for Silver and Gold.

The bath for galvanoplastic operations with silver is composed of—

Distilled water	1 litre
Cyanide of potassium	200 grammes
Nitrate of silver, fused	75 "

A more economical solution is obtained by using half of the quantities of cyanide and nitrate of silver, for the same proportion of water.

The gold galvanoplastic bath is made of—

Distilled water	1 litre
Cyanide of potassium	150 grammes
Neutral chloride of gold*	50 "

These baths generally work with separate batteries, and with anodes of the metal used in the solution. Nevertheless, the porous cells and zincs may be put into the bath itself, provided that the exciting liquor be a more or less concentrated solution of cyanide of potassium, or of common salt, but we do not like this latter substance. The zincs must not be amalgamated, unless in separate batteries.

Green gold is obtained by mixing ten parts of gold bath with one of silver bath, or, what is preferable, by employing for a certain length of time a silver anode in the gold solution.

The galvanoplastic deposits of gold and silver, after their separation from the mould, should be heated and scratch-brushed; and it will be advantageous to give them a proper shade by a short sojourn in ordinary electro-gilding or silvering baths.

CHAPTER LIX.

GALVANIC ETCHING—THE FUTURE.

Galvanic Etching.

We have said that, with baths working by separate batteries, the *soluble anode* or plate of the same

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* In this case, we mean the weight of the chloride of gold, and not that of the metal employed for its preparation.

metal as that in solution was connected with the positive pole, and was dissolved at the same time as the metallic deposit was effected at the other pole.

From this phenomenon to galvanic etching there is only one step. Indeed, it is evident that, if certain portions of the anode be covered with some insulating material, the others will be dissolved slowly and more or less uniformly, and will form the hollows of an engraving, in which the reliefs will be the covered parts.

Galvanic etching is obtained by several methods, which differ but little one from another.

The most simple process consists in covering entirely a copper plate, for instance, with an insulating varnish, which is not acted upon by the bath, and then in tracing the drawing with a graver, which should penetrate through the coat of varnish, and expose the copper. By using this plate as the soluble anode of a bath of sulphate of copper, and suspending another copper plate at the negative pole, the latter will receive the deposit, whereas the former becomes hollow at the places uncovered by the graver. The engraving produced will need only a slight finishing up.

Instead of using wax, varnish, or any similar substance as an insulating material, we may employ a metallic film, which cannot be dissolved in the bath. Let us suppose, for instance, that the copper plate has been strongly gilt with the aid of the battery, and that with a graver we trace a drawing deep enough to uncover the copper, this plate, being submitted to the same electric conditions as above, will be corroded where the graver has passed, while the gilt portions will remain entirely unacted upon, since the acid of the sulphate of copper does not dissolve gold.

It is equally easy to produce a drawing in relief instead of a countersunk one, by making the drawing with some insulating material like varnish or a lithographic pencil. The uncovered portions around the lines of the drawing will become hollow, and the image will be in relief. We may also make the drawing with the lithographic pencil or some varnish, and gild strongly the uncovered parts; then if the varnish or the grease of the pencil is removed, the etching will follow these lines, which will become hollow.

The baths employed generally hold in solution the same metal as that to be engraved; thus, baths of sulphate of copper are used for etching copper plates, solutions of sulphate of zinc for zinc plates, and gold or silver baths for the corresponding metals.

Nevertheless, it is possible to engrave copper and zinc plates with the aid of the battery in baths of water simply acidulated with either nitric, hydrochloric, sulphuric, or acetic acid; and this process seems to be coming more and more into use.

Here is a process, not for engraving, but for substituting a drawing upon which galvanoplastic copies ready for printing may be obtained: Upon a varnished plate of copper, a drawing is traced; this plate is dipped into a weak solution of nitrate of binoxide of mercury, and then set perfectly level. By covering it with metallic mercury, this becomes fixed upon the lines traced by the graver, and takes the *meniscus* (curved) shape, that is to say, the relief is the greater as the engraved line is larger. Therefore, all the drawing is reproduced in relief by the mercury. We may now cover the plate with a thin paste of plaster of Paris, and when the latter has set (become hard), the two moulds are separated, and the mercury still adheres to the copper. The plaster mould will be treated by one of the described methods, either for getting a counter-mould from it, or for directly obtaining a galvanoplastic deposit after its metallization.

Here is another similar method which gives a mould immediately ready for the bath: The copper plate is varnished as above, and with the graving tool, the parts which will produce the blacks of the engraving are uncovered. A solution of neutral protochloride of zinc is poured upon the plate, and quite a quantity of Darcet's metal, fusible at from 80° to 100° (see page 340), is melted by means of an alcohol lamp moved about under the copper plate. The operation is facilitated by spreading the fused metal with a small iron rod, all over the plate. The same result is obtained as with the mercury, except that the mould may be immediately reproduced by galvanoplastic methods.

I have never personally practised galvanic etching; therefore, I have simply described the processes which I have seen used, and every one will choose what is best for his particular use.

In order to complete the second edition of this work, and to furnish my readers with sure processes passed into regular practice, I have obtained the aid of M. Eugene Berthoud, director of the engraving works, for printing rollers, of the important manufactory of MM. Gros, Roman and Marozeau, at Wesserling. With the disinterested consent of his employers, this intelligent worker, always ready to impart his discoveries to the public, has addressed to me the following letter, which I transcribe literally, being desirous to preserve all its sincerity and practical character:—

"WESSERLING, March 23, 1865.

"Mr. ROSELEUR:—

"You may have considered me guilty of neglect for not having answered sooner your favor of February 25th, but I was quite unwell when I received it, and I beg to be excused for the delay. Moreover, I had to consult, on this subject of galvanic etching, one of our employers who was then absent, and as soon as I had obtained his full consent, I went to work.

"I have first to thank you for all the information you gave me in regard to the deposits of copper for moulds, and the metallization of moulds. I have simplified the work, which is now regular and certain, although requiring great care. I have succeeded in obtaining in four days deposits 2½ millimetres thick, and the copper is malleable, with an excellent texture.

"If, in the information I am trying to give you on galvanic etching, my expressions are not sufficiently technical, or do not well reproduce my thoughts, I beg to be excused, since I have never attended any lectures on chemistry or physics, and all that I may say is the result of my observations and experience. I rely on your knowledge for correcting all that may be incorrect.

"The first thought of galvanic etching came to me after witnessing the danger of nitrous fumes to which the engravers are exposed who etch with nitric acid. Moreover, this mode of operation is variable and uncertain, whereas that by the battery is regular and sure in its results, when the operation is conducted with intelligence.

"The primitive idea of galvanic etching came from inverting the poles, when, the plate or object to be engraved being substituted for the anode, it became dissolved under the influence of the current at those parts unprotected by the varnish. It seemed but natural to suspend opposite the object to be engraved a catode of the same volume, surface, and metal. The first trials made and based on this supposition showed me that I was entirely mistaken; there was an exaggerated production of hydrogen at the pole zinc or catode, and the etching was irregular. I was induced by these failures to employ only the extremity of the conducting wire, and since then my operations have been certain and regular. I afterwards ascertained that a similar opinion was set forth in the *Manuel de Galvanoplastie*, by MM. Smee, Jacobi, and de Valicourt.

"I am now going to explain rapidly my mode of operation, which I have rendered as simple as I could, in order to facilitate the manipulation.

"The amount of electricity which, after three years of experiment, I found most suitable is obtained from two Daniell's elements. They have been modified in different ways, but the shape which I prefer is that with balloon (represented in the first part of this work). My exciting liquor is a solution of common salt, and, instead of a simple copper ribbon in the porous cell, I employ a cylinder of sheet copper perforated with many holes for the free circulation of the solution of sulphate of copper.

"The conducting wires are one metre long, and one-half millimetre in diameter. Their metal is iron for etching iron and steel, and copper or brass for articles of copper, brass, or zinc.

"For iron, steel, and copper and its alloys, the bath is water mixed with nitric acid until the specific gravity is 3° Baumé. We should not get beyond this, because it is sufficient that the bath conducts electricity well, for working under good conditions. When the plate or the object to be etched has been graved with a tool or the diamond, it is fastened in a kind of stirrup, with which it is suspended in the bath. The conducting wire from the pole copper is connected with this stirrup.

"When everything has been arranged in the above indicated manner, the object to be engraved and the end of the connecting wire from the pole zinc are immersed at the same time in the bath. If the operation is well conducted, hydrogen will immediately escape at the end of the pole zinc, which should dip from two to three centimètres, and *no more.* If the escape of hydrogen does not take place, the two conducting wires should be rubbed one against the other until hydrogen bubbles appear, which is the indication of good working.

"For the past three years we have practised galvanic etching in our works, we have operated with equal success upon steel cylinders weighing from eighty grammes up to eight and ten kilogrammes, and the battery and conducting wires were the same as those already mentioned.

"The length of the operation varies from one to two hours, according to the kind of engraving, and especially the variable fineness of the details. It is possible, as when etching by aqua fortis, to varnish the parts which are sufficiently corroded.

"The Daniell's battery, and the nitric acid bath at 3° Baumé, which I employ, produce such trifling fumes that the etching may be performed in the office of the draughtsmen. It is a great advantage for the artist, who can superintend the operation without loss of time.

"When the etching goes on regularly, the furrow produced is neat, deep and without fraying, which is not always the case with the ordinary etching by acids, and the depth of the furrow is regular even upon the largest rollers presenting a great surface.

"I believe that I can give you a useful recipe for amateurs in the galvanoplastic art, who become more numerous every day; and I think that it will not be out of place in your new edition. I mean a mastic for rendering impervious the decomposing troughs; those of gutta percha being always expensive, especially for persons of limited means. By means of the mastic which we have employed for from six to eight years, a well joined and screwed (or bolted) oak trough will certainly last from twelve to fifteen years. This mastic is composed of:—

Burgundy pitch	1500	grammes
Gutta percha (old and cut into small pieces)	250	"
Pumice-stone (finely powdered)	750	"

"Melt the gutta and mix it (by kneading) with the pumice-stone, then add the Burgundy pitch.

"When these three substances are thoroughly mixed and in the liquid state, several coats of the compound are spread over the inside of the trough. The angles and corners receive a greater proportion of material, which is run in by means of an iron ladle. These various coats are coarse and irregular; but an even surface is obtained by a heated sad iron, or a soldering iron for the angles. The heat causes the penetration of the wood by the mastic, and the adherence is increased. The exterior of the trough and the iron parts are varnished, either with a fat varnish or the residuum of some turpentine varnish. It is evident that a trough thus prepared will resist the galvanoplastic baths at 28° Baumé, composed of sulphuric acid and sulphate of copper, and even pure nitric or sulphuric acid, provided that neither of these latter remain long in it. On the other hand, this mastic will not stand the cyanides.

"In order to facilitate the use of this mastic by amateurs, could you not prepare it in the form of cakes or lumps, which will simply require melting and spreading? It would be a new article for your catalogue, and a useful one, since all the component parts are cheap. The gutta percha employed by us comes from old machinery belts.

"Here are, my dear sir, many details which will seem useless to you; but I consider the galvanic etching as a philanthropic progress, since it will preserve the health of many heads of families whose lungs would be ruined by nitrous vapors. As an exhibit, I send you a sample of galvanic etching, obtained in half an hour and with an old varnish.

"And receive, dear sir, my sincere salutations,

EUGENE BERTHOUD."

After reading this letter, summing up in a clear and sincere manner one of the most interesting applications of this science to the arts, every one will be convinced that the writer should not be so modest, and, on the contrary, should be proud of having been his own teacher.

The Future.

On the eve of finishing our hydroplastic manipulations, let us say that the galvanoplastic art is open to an infinite number of applications which the artist will discover rather than be told of. Thus, by cutting an open pattern upon a sheet of copper, spreading it even upon another metallic plate, and dipping the whole into a bath of silver or gold, the empty spaces will be filled with the new metals, and the whole will form a kind of mosaic work which may be very rich and variegated. It is by an analogous process that, after having fastened by a thin coat of varnish precious stones or other objects upon a metallic plate, and the whole being steeped in the bath after metallization, it will be possible to *set* artificially different parts of an artistic production. A pattern may be hollowed out with a graver from a plate of ivory or mother of pearl, and the whole metallized and immersed in the galvanoplastic bath. After the whole surface has become covered with the metallic deposit, it is sufficient to grind and polish it until the reliefs of ivory or mother of pearl reappear, and the metal will form the incrustations. In fact, we may say that there is scarcely any industry in which the galvanoplastic art will not be found serviceable.

CHAPTER LX.

BRONZING—BRONZE FOR MEDALS—ANOTHER RECIPE—BRONZE FOR ZINC—GREEN OR ANTIQUE BRONZE—BLACK BRONZE—BRONZE POWDERS OR BRONZINES.

Bronzing.

THIS operation is intended to give to new metallic objects the appearance of old ones, by imitating as far as practicable, whether by simple coats mechanically applied, or by chemical reactions, the characteristic appearance imparted by age and atmospheric influences to the metals or metallic compounds, and especially to copper and its alloys. According to the composition of the metal, and also according to circumstances, the oxidization results in a great variety of colors, tones, and shades, which the operator tries his best to imitate. We shall not give a complete description of the art of bronzing, since there are special treatises on the subject, which may be profitably consulted by those who desire to obtain a great variety of colors and shades; but we shall mention two or three processes which will be easily applied by galvanoplastic operators to the various articles of their manufacture, and especially to medals.

Bronze for Medals.

The most simple is obtained by applying with a brush upon the cleansed object a thin paste made of water with equal parts of plumbago and sanguine (peroxide of iron with a certain proportion of clay). The whole is heated, and when the object is entirely cold, it is brushed in every direction and for a long time with a middling stiff brush, which is frequently passed upon a block of yellow wax, and afterwards upon the mixture of plumbago and sanguine. This process, which is very similar to that used at the mint of Paris, gives a very bright and red bronze, suitable for medals kept in a show case.

This bronze may also be produced by plunging the article into a mixture of equal parts of perchloride and nitrate of sesquioxide of iron, and heating until these salts are entirely dry. The rubbing is then made with the waxed brush, as has just been explained.

Another Recipe.

Cleanse the article, and cover it with hydrosulphate of ammonia, which is allowed to dry entirely; then brush with sanguine and plumbago, and afterwards with the waxed brush.

If we heat gently the piece impregnated with hydrosulphate of ammonia, we obtain a black bronze called *smoky bronze*, which, being uncovered (lightened) at certain places, produces a good effect. This last bronzing is used for many teakettles, and is greatly improved by burnishing. Originally it was obtained (and from thence it derives its name) by heating the copper articles upon a lighted bundle of wet straw or hay, and it was necessary to burnish the surface in order to make the oxide penetrate the metal.

Bronze for Zinc.

The zinc which is to be bronzed must receive an electro-deposit of brass, which is then dipped into a weak solution of sulphate of copper if we desire a red tinge. When it is dry, it is wetted with a rag dipped into hydrosulphate of ammonia, or a solution of liver of sulphur (polysulphide of potassium), or protochloride of copper dissolved in hydrochloric acid. After another drying, the surface is brushed over with a mixture of sanguine and plumbago, or carbonate of iron and plumbago, according to the tone desired. The brush may be slightly wetted with essence of turpentine, which aids the adhesion of the powders. The raised parts are set off (strongly rubbed), in order to uncover the brass, and make it appear as if it had been used up by friction. The object may afterwards receive a coat of colorless varnish.

Green or Antique Bronze.

Dissolve in 100 grammes of acetic acid No 8, or in 200 grammes of ordinary strong vinegar, 30 grammes of carbonate or hydrochlorate of ammonia, and 10 grammes each of common salt, cream of tartar, and acetate of copper, and add some water. When an intimate mixture has been obtained, smear with it the copper object, and let it dry at the ordinary temperature for twenty-four or forty-eight hours. After that time, the object is entirely covered with verdigris, which presents various tinges. Then brush the whole, and especially the reliefs, with the waxed brush. If necessary, the most raised parts are set off with sanguine, or chrome yellow, or other suitable colors. Light touches with ammonia give a blue shade to the green portions, and carbonate of ammonia deepens the color of the parts on which it is laid.

All kinds of bronze liquors are to be found in the trade, and they bear the name of acid bronzes or water bronzes. They are applied with a brush.

Black Bronze.

The oxidized silver, and the deep black with ammonia and blue ashes, which we have described in Chapter XL., furnish a fine black bronze much in favor of late years. A *steel bronze* is more easily obtained by wetting the copper articles with a diluted solution of chloride of platinum, and slightly heating. This bronze will sometimes scale off by friction. It is also obtained by plunging the cleansed copper into a weak and warm solution of chloride of antimony, (butter of antimony) in hydrochloric acid. But it happens sometimes that the coloration is violet instead of black.

Bronze Powders or Bronzines.

We also find in the trade bronze powders made of impalpable brass, and which present the most varied shades, according to the degree of oxidization of the brass heated in contact with the air.

These bronze powders or bronzines are applied upon metals to imitate bronze, and also upon articles of plaster of Paris, and ceramic wares.

The mode of operation is entirely mechanical. After the object has been more or less cleaned, it receives a thin coat of fatty drying varnish, which is allowed to become nearly dry. The bronze powder is then laid upon it with a badger brush or otherwise, and adheres strongly. After drying, the whole is covered with a coat of transparent and colorless varnish. This process evidently fills up the details, and is suited only to large pieces which are imperfectly finished, such as cast-iron dogs for fireplaces, show-cases, common lamps, plaster statues, &c. It will not do for galvanoplastic reproductions, which are intended to respect the smallest details.

PART III.

CHEMICAL PRODUCTS AND APPARATUS USED IN THE ART.

CHAPTER LXI.

CHEMICAL SYNONYMY.

As this book is intended especially for artists, operators, and amateurs, the majority of whom are not conversant with the chemical vocabulary, we believe that we cannot begin this third part better than with a table of the principal chemicals used in galvanoplastic and electroplating operations. In this manner, many beginners will be saved the expense of buying substances which they already possess, and which in the book or the formula bear different names.

Chemical Synonymy.

NEW NAMES.	OLD NAMES.
Acetate of copper	Refined verdet,—crystals of Venus.
Acetate of copper (basic)	Artificial verdigris.
Acetate of lead	Sugar of lead,—Saturn's salt.
Acetate of lead (basic)	Extract of Saturn.
Acetic acid	Vinegar, when very diluted,—pyroligneous acid, when extracted from wood,—radical vinegar, when distilled from acetate of copper,—glacial acetic acid, when it congeals at a few degrees above 0° C.
Arsenious acid	White arsenic,—arsenic,—rat bane.
Hyponitric acid	Nitrous acid or gas,—nitrous vapors.
Nitric acid	Spirit of nitre,—azotic acid,—aqua fortis.

NEW NAMES.	OLD NAMES.
Boracic acid	Boric acid,—sedative salt of Homberg.
Hydrocyanic acid	Cyanhydric acid,—prussic acid.
Hydrochloric acid	Chlorhydric acid,—muriatic acid,—spirit of salt.
Chloronitric acid	Aqua regia.
Gallic acid	Gall-nuts' mildew.
Oxalic acid	Sorrel's acid.
Phosphoric acid	Glass of phosphorus, when in the solid vitreous state.
Hydrofluoric acid	Fluorhydric acid,—phtorhydric acid,—fluoric acid.
Pyrophosphoric acid	Paraphosphoric acid.
Silicic acid	Silicia,—quartz,—flint,—silex,—oxide of silicium.
Stannic acid	Binoxide of tin,—metastannic acid.
Stearic acid	Stearin.
Hydrosulphuric acid	Sulphydric acid,—sulphuretted hydrogen gas.
Sulphurous acid	Sulphurous gas,—spirit of sulphur.
Sulphuric acid	Oil of vitriol.
Tannic acid	Tannin.
Tartaric acid	Tartric acid,—acid of tartar.
Alcohol	Spirit of wine, of beet roots, of whiskey, etc. etc.
Alloy of silver and copper	Monetary alloy,—silver solder.
Alloy of lead, bismuth, and tin	Fusible alloy,—Darcet's alloy.
Alloy of copper and tin	Bronze,—bell metal.
Alloy of copper and zinc	Brass,—yellow copper.
Alloy of tin and lead	Plumber's solder,—soft solder,—tin solder,—lead solder.
Alloy of nickel, copper, and zinc	German silver,—argentan,—maillechort or melchior.
Amalgams	Alloys of one or several metals with mercury.
Antimony	Regulus,—stibium.
Nitrate of silver	Lunar caustic,—lapis infernalis,—salt of Diana.
Nitrate of bismuth	Azotate of bismuth.
Subnitrate of bismuth	Face powder,—flowers of bismuth.
Nitrate of protoxide of mercury	Proto or subnitrate of mercury.
Nitrate of binoxide of mercury	Binitrate of mercury,—acid nitrate of mercury,—gas of gilders.
Nitrate of copper	Azotate of copper.

NEW NAMES.	OLD NAMES.
Nitride of hydrogen	Ammonia,— volatile alkali,— hartshorn.
Nitride of gold	Ammoniuret of gold,— gold ammonium, — fulminating gold, — termoxyde of gold.
Biborate of soda	Borax,—borate of soda,—tinckal.
Caoutchouc	India rubber,—gum elastic.
Carbonate of potassa	Subcarbonate of potassa,—potash,—potash pearlash,—potash of America, Russia,—salt of tartar,—ashes.
Bicarbonate of potassa	Carbonate of potassa,—saleratus.
Carbonate of soda	Subcarbonate of soda,—soda ash,—crystals of soda,—soda of Alicante, or of Dantzic, or of sea-weeds.
Bicarbonate of soda	Carbonate of soda,—Vichy salt,—raising powder.
Carbonate of Lime	Chalk,—marble,— limestone,— Spanish or Meudon White.
Carbonate of baryta	Heavy spar.
Sesquicarbonate of ammonia	Subcarbonate of ammonia,—carbonate of ammonia,—sal volatile.
Carbonate of iron	Saffron of Mars.
Chlorine	Oxygenated muriatic acid.
Chloride of silver	Horn silver,—muriate of silver,—hydrochlorate of silver.
Protochloride of antimony	Butter of antimony.
Protochloride of tin	Tin salt,—muriate of tin, —hydrochlorate of tin.
Protochloride of mercury	Calomel,— sweet sublimate,— white precipitate,—etc.
Bichloride of mercury	Corrosive sublimate,—bimuriate of mercury,—hydrochlorate of mercury.
Perchloride of gold	Chloride of gold,—muriate of gold, —gold salt.
Perchloride of platinum	Chloride of platinum,—muriate of platinum,—bichloride of platinum.
Chloride of sodium	Common salt,—muriate of soda,—rock salt,—sea salt,—codfish salt, —etc.
Chloride of zinc	Butter of zinc,—muriate or hydrochlorate of zinc.
Cyanide of silver	Hydrocyanate, cyanhydrate, or prussiate of silver.

NEW NAMES.	OLD NAMES.
Cyanide of copper	Prussiate or hydrocyanate of copper.
Cyanide of potassium	Hydrocyanate of potassa, — white prussiate of potash.
Ferrocyanide of potassium	Yellow prussiate of potash,—ferrocyanate of potassa,—Cyanoferride of potassium,—Blood's salt.
Cyanide of gold	Prussiate of gold,—hydrocyanate of gold.
Cyanide of zinc	Prussiate of zinc,—hydrocyanate of zinc.
Gelatin	Glue,—glue of Flanders, Givet, etc.,—isinglass.
Benzine	Benzole, gasoline, gaseine, etc. etc.
Arsenetted hydrogen	Arsenide of hydrogen.
Phosphuretted hydrogen	Phosphide of hydrogen.
Mercury	Quicksilver,—hydrargyrum.
Binoxalate of potassa	Sorrel's salt.
Oxide of silver	Silver lime or chalk.
Oxide of copper	Binoxide of copper,—copper scales.
Binoxide of tin	Stannic acid,—tin putty, when mixed with oxide of lead.
Oxide of potassium	Potassa, — caustic potash, — alcohol potassa,—etc.
Protoxide of lead	Litharge,—massicot,—white oxide of lead, when hydrated.
Sesquioxide of lead	Red lead,—minium,—orange mineral.
Binoxide of lead	Peroxide of lead.
Oxide of sodium	Soda,—alcohol soda,—caustic soda.
Phosphate of lime (tribasic)	Subphosphate of lime,—bone earth,—calcined bones.
Biphosphate of lime	Acid phosphate of lime,—superphosphate of lime.
Phosphate of soda	Fusible salt,—microcosmic salt,—admirably pearled salt.
Plumbago	Black lead,—graphite.
Spermaceti	Whale's white.
Double sulphate of alumina and potassa	Potash alum,—Roman alum,—cubic or octahedric alum.
Double sulphate of alumina and ammonia	Alum,—ammonia alum.
Sulphate of lime	Plaster of Paris,—gypsum,—alabaster,—selenite.
Sulphate of copper	Blue copperas,—blue vitriol.

NEW NAMES.	OLD NAMES.
Sulphate of iron	Green copperas,—green vitriol.
Sulphate of zinc	White copperas,—white vitriol.
Sulphate of soda	Glauber's salt.
Sulphite of soda	Sulphurous salt,—Stahl's salt.
Sulphide of ammonium	Hydrosulphide of ammonium,—sulphydrate of ammonia.
Trisulphide of calcium	Liver of sulphur of lime.
Bisulphide of carbon	Sulphuret of carbon,—spirit or liquor of Lampadius.
Quintisulphide of potassium	Polysulphide of potassium,—liver of sulphur.
Monosulphide of sodium	Hydrosulphate of soda,—sulphuret of sodium.
Bitartrate of potassa	Cream tartar,—tartar,—argols, white or red.

CHAPTER LXII.

CHEMICAL PRODUCTS ESPECIALLY EMPLOYED IN THE ART.

From the preceding list we shall choose a certain number of especially important substances, which we shall describe completely. As for those materials which are found sufficiently pure in the trade, we shall simply point out their principal characteristics, and refer the reader, desirous of more information, to the numerous and valuable works on chemistry.

Acetate of Copper, neutral (highly poisonous).

(Verdet. Crystals of Venus.)

It is found in the trade either in the form of dark-green crystals, or of a bright-green powder—*highly poisonous*—soluble in water, which becomes green; very soluble in ammonia, and the solution is of a sky-blue color; forms colorless double salts with cyanide of potassium and sulphite of soda; powerful acids, like sulphuric acid, combine with the oxide of copper, and the acetic acid set free is recognized by its smell; is used for preparing electro-baths of copper and brass; manufactured with copper corroded by fermenting grape-mash, and by other processes.

Acetate of Copper, basic (poisonous).

(Verdigris.)

Powder of a fine turquoise bluish-green. Imperfectly soluble in water, and difficult to combine with the sulphites and cyanides, unless it has been previously treated by ammonia. It is often used for adulterating the salt above named.

Acetate of Lead (poisonous).

(Sugar of lead.)

This is ordinarily in the shape of masses formed of mingled needle-like crystals; white; light, although having lead for its base; very soluble; savor, sugar like at first, and metallic afterwards; gives by calcination, fumes of vinegar and acetone, and the residue is oxide of lead with a certain proportion of metallic lead. Does not precipitate by carbonic acid and water, unless there is mixed with it some basic acetate. Obtained by dissolving litharge or massicot (protoxide of lead) in an excess of vinegar or acetic acid. Its solution forms, with caustic potassa or soda, a white precipitate which is soluble in an excess of alkali, and then constitutes the bath for *colored rings*.

Sub-acetate of Lead (poisonous).

(Extract of Saturn.)

In solid masses, or syrupy. Savor, sweet but more metallic than the preceding. Heavy; white precipitate by carbonic acid; obtained by boiling a solution of acetate with an excess of litharge. Used for the same galvanoplastic processes. Renders turbid distilled water holding carbonic acid.

Acetic Acid.

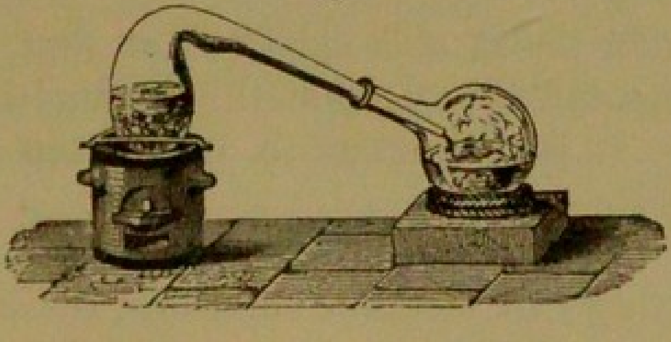
(Vinegar. Pyroligneous acid.)

It is more or less concentrated and pure, according to the mode of manufacture. The most concentrated crystallizes at —4° C., and often remains so up to 10° and 12° C. above 0.

Wood vinegar or pyroligneous acid is employed in large quantities, and is colorless or more or less yellow. It often possesses an empyreumatic smell, and generally marks 8° of the hydrometer for acids.

Wine vinegar is more or less colored, and may be concentrated. Its smell is easily distinguished.

Fig. 109.



Glacial or crystallizable acetic acid is obtained by the distillation of perfectly dry acetate of soda, or acetate of lead, with concentrated sulphuric acid.

The vapors are condensed in a glass receiver (Fig. 109) which should be surrounded by ice, sometimes mixed with common salt.

Arsenious Acid (poisonous).

(White arsenic. Arsenic. Rat bane.)

Generally in the shape of a white powder, and sometimes in vitreous-like lumps, which resemble porcelain. Slightly soluble in water; savor, scarcely sensible at first, but hot and sharp afterwards, with constriction of the throat. When thrown upon incandescent charcoal, emits abundant fumes which are fallow-brown at the base, and white at the summit, and with a characteristic smell of garlic. Introduced into Marsh's apparatus, it furnishes arsenical rings and spots; is employed in certain silver whitening baths, and also in the electro-baths for brass.

Nitrous and Hyponitric Acids (poisonous).

(Nitrous gas. Nitrous vapors.)

We may describe these two acids together. They are gases of an orange-yellow color, more or less deep, and are always produced by the action of nitric acid upon a metal.

The smell is flat and nauseous at first, but soon suffocating and heavy upon the extremities of the bronchia. It is dangerous to inhale too much of these gases.

They color aqua fortis yellow, and also impart a greenish tinge to metallic solutions, those of silver for instance, which may appear as holding copper. This coloration disappears by heating, which it will not do if copper be present. They are abundantly produced during the cleansing of copper and its alloys in aqua fortis. A lower temperature or a certain pressure transforms these gases into two different liquids: nitrous acid is blue; and hyponitric acid is of a fallow-yellow color.

Nitric Acid (poisonous).

(Aqua fortis. Spirit of nitre.)

It is found in the trade of various colors and strengths, but rarely chemically pure.

Liquid, light and nauseous smell; very acid savor. The skin and the majority of organic matters become yellow by its contact; in this case, the use of alkalies causes the yellow to turn mahogany color instead of disappearing, as with many other acids; dissolves many metals, always with a production of orange vapors; contains one equivalent of water in the monohydrated state, and then is employed for the manufacture of gun cotton, or xyloïdin.

It is bought at 40° Baumé, colorless or dark yellow; and at 36° Baumé, colorless or more or less deep yellow. This coloration is generally due to the presence of nitrous and hyponitric gases, and is perfectly satisfactory for cleansing copper; but it often results from the presence of hydrochloric acid, thus forming aqua regia, or, what is worse, of iodine, bromine, or chlorine, and then the cleansing processes with it are unsuccessful.

Pure nitric acid is absolutely necessary for the preparation of nitrate of silver. The presence of chlorine, hydrochloric acid, or sulphuric acid will transform a part of the metal into insoluble, or scarcely soluble, compounds.

A pure nitric acid is obtained: 1st. By distilling in a large glass retort (see preceding figure) the commercial article, and collecting the product only when it no longer produces a precipitate or turbidity in a solution of nitrate of silver. The distillate is then collected into a glass receiver and cooled with fresh water or ice. The operation is terminated when about five-sixths have been distilled, otherwise the sulphuric acid will also pass over.

2d. By precipitating with nitrate of silver and nitrate of baryta, the hydrochloric and sulphuric acids of commercial aqua fortis, and then distilling the whole nearly to dryness. The residuum in the retort is composed of sulphate of baryta, chloride of silver, and the excess of the nitrates of these two bases.

3d. By distilling in a glass retort a mixture of 100 parts of pure nitrate of potassa (saltpetre), with 60 parts of pure concentrated sulphuric acid (oil of vitriol), and 40 parts of distilled water. The heat is gradually raised, and stopped when, after having disappeared, the yellow vapors reappear. The acid thus obtained is slightly yellow, and is *bleached*, by heating it near the boiling point. It is useless to remind the reader of the continual use of nitric acid in our art.

Boracic Acid (boric acid).

(Sedative salt of Homberg.)

United with soda, it constitutes borax. It is found in the condensed steam of certain small, muddy volcanoes of Tuscany, and is extracted in the manufactories of M. de Larderelle.

It is very likely that the boracic acid of these *lagoni* is due to the subterranean decomposition of the sulphide of boron by steam. The small craters of that country produce at the same time sulphuretted hydrogen.

Boracic acid is found in the arts in the shape of scales, mother of pearl like, and greasy to the touch. When it is in vitreous masses more or less translucent, it is anhydrous, and has been subjected to igneous fusion. Dissolved in alcohol, and the fluid being ignited afterwards, the flame is colored a fine green. It is also obtained in the form of scales by decomposing, with a powerful acid, a concentrated and boiling solution of borax; the boracic acid crystallizes by cooling. It is used for making the platinum adhere, by the heat of a muffle, to ceramic wares; thus causing the metallization of surfaces which were not naturally conducting. It is also employed for increasing the whiteness of silver alloys, and for the decomposition of the subsalts deposited in electro-baths containing cyanide of potassium.

Hydrocyanic Acid (extremely poisonous).

(Cyanhydric or prussic acid.)

It exists in nature only in a state of combination with certain vegetables and fruits, and especially in their stones; for instance, the peach, the berries of the cherry laurel, bitter almonds, the stones of the apricot, of plums, cherries, etc., but still this opinion is contested.

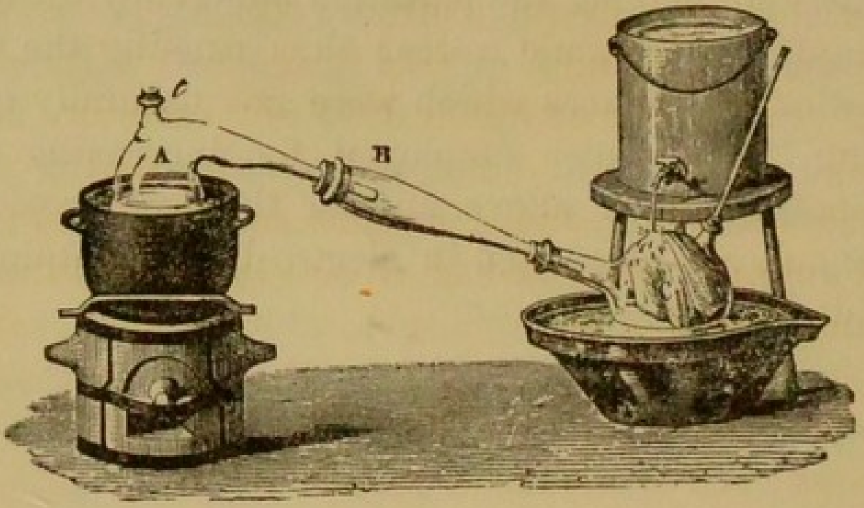
It may be obtained anhydrous; but in this state, it is useless, and very difficult to preserve from decomposition.

Diluted hydrocyanic acid is colorless (although it is sometimes colored blue by a small proportion of Prussian blue, which does not change its properties), with a bitter taste, and the characteristic smell of bitter almonds or peach-tree flowers, although less aromatic, more pungent and deleterious.

When it is somewhat concentrated, it is decomposed by light, becomes brown, and is deposited in the form of flakes. During this decomposition, it is transformed into cyanate and carbonate of ammonia, and lastly into the brown substance called *azulmic acid.*

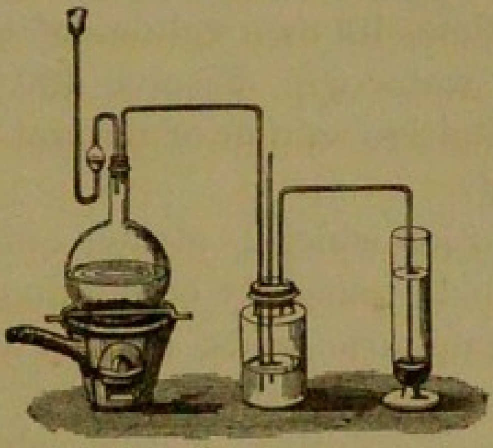
It is prepared by introducing into a large retort fixed to a receiver, which is cooled by ice (Fig. 110), 1 kilogramme of the double cyanide of iron and potassium (yellow prussiate of potassa), 1 litre of water, and 1.5 kilogramme of concentrated sulphuric acid. The acid and water should be mixed beforehand and allowed to cool. The distillation is effected in a sand-bath, and the condensed liquid is clear and colorless. The operation is stopped when the substances in the retort begin to swell up, otherwise a certain proportion of blue cyanide of iron and sulphate of potassa will pass into the receiver. We must avoid inhaling the vapor produced during this preparation.

Fig. 110.



Hydrocyanic acid may also be obtained by passing a stream of washed sulphuretted hydrogen through a tall glass vessel (Fig. 111) holding water and cyanide of mercury. The latter compound is transformed into the insoluble sulphide of mercury, whereas the hydrocyanic acid remains in solution. After filtering, the liquor is gently heated in order to expel the remaining sulphuretted hydrogen, which is more volatile than hydrocyanic acid. This method is not so simple as the preceding one, and for gilding is open to the inconvenience of often having the acid contaminated with undecomposed cyanide of mercury or sulphuretted hydrogen.

Fig. 111.



Hydrocyanic acid is sold in the trade under the denominations of acid *one-fourth*, *one-eighth*, or *one-sixteenth*, according to the ratio of the water with the real acid. We generally use that of the first two degrees of dilution. It is employed for maintaining the metal strength of gold dipping baths with pyrophosphates, and for decomposing the alkaline carbonates formed in baths with cyanide of potassium.

Hydrochloric Acid (poisonous).

(Chlorhydric or muriatic acid. Spirit of salt.)

During the preparation of this acid, it is gaseous, and emits abundant and thick fumes in contact with the air. Water, at the temperature of 20° C., dissolves 460 times its own volume of this acid, that is, one litre of water will dissolve 460 litres of this gas, and the primitive volume of the water is increased about one-third.

It is this solution which is always employed in the arts, and which is generally contaminated with sulphurous and sulphuric acids, and by perchloride of iron, imparting a yellow color to it.

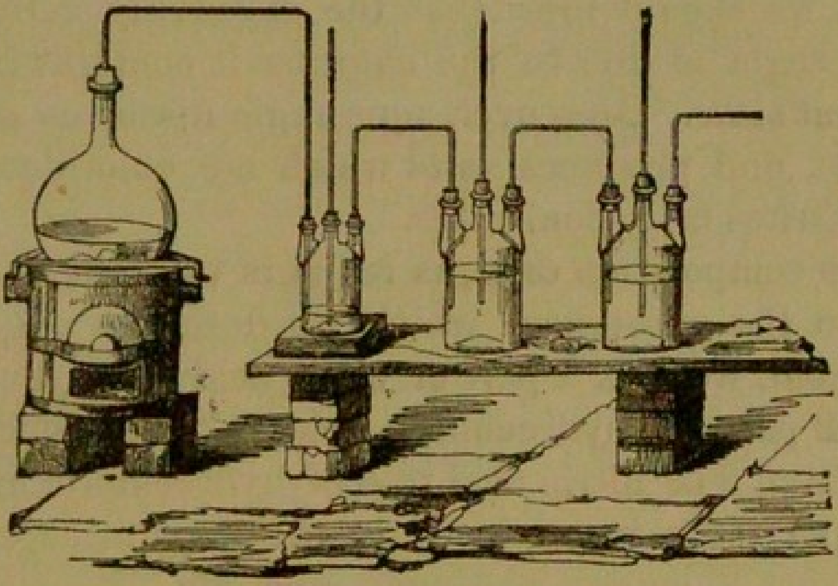
A concentrated solution of hydrochloric acid in contact with damp air emits thick fumes, which are the more apparent as there are other ammoniacal vapors floating in the room. Its smell and flavor are very sharp. It dissolves zinc with the production of hydrogen; and with a silver solution, it produces an abundant, white, heavy, and flocculent precipitate of chloride of silver, which becomes blue, and then black, by the action of solar light. This precipitate is insoluble in strong acids, either cold or boiling, but is soluble without coloration in cyanides, sulphites, hyposulphites, alkaline or earthy chlorides, and especially in ammonia.

Pure hydrochloric acid (in concentrated solution) is colorless, fuming, and presents the same reactions. A trace of organic substance is sufficient to impart to it a greenish-yellow tinge, as if it were colored by an iron salt.

In our art, it is employed for preparing the chlorides of certain metals, for instance that of zinc; it enters into the composition of aqua regia; and the common salt, added to certain cleansing acids, is intended to form a small quantity of hydrochloric acid.

It is prepared by introducing into a glass balloon (Fig. 112) common salt and an excess of commercial sulphuric acid. A gentle heat is gradually applied, and the gas is collected and dissolved in a series of tubulated bottles. These receivers should be constantly cooled by a stream of water or by ice, because the elevation of temperature caused by the combination of the water and acid, would prevent the liquid from becoming thoroughly saturated. This disposition of tubulated bottles is called a Woolf's apparatus. The first bottle contains but little water, and is intended to arrest the impurities mechanically carried by the gas. The glass balloon, after the operation, contains acid sulphate of soda.

Fig. 112.



Aqua Regia (poisonous).

(Nitro-muriatic or chloro-nitric acid.)

When nitric and hydrochloric acids are mixed, there is formed, beside water, a combination of chlorine and hyponitric acid, which remains in the liquor and colors it red, in the cold. On the contrary, the heated liquid disengages fumes of a fallow color. This mixture is called aqua regia, because it dissolves gold, which was formerly named the king of metals.

Chlorine alone will also dissolve gold, and as the resulting salt is the same as that obtained by aqua regia, we should infer that the dissolving action of aqua regia is due to the chlorine it contains in the nascent state. Moreover, aqua regia dissolves all the metals, and produces salts which are chlorides, and not nitrites or hyponitrates.

The composition of aqua requa is variable, according to the substances which we desire to dissolve. For gold, we mix 1 part of nitric acid at 40° Baumé, with 2 parts of hydrochloric acid at 22° Baumé; for platinum, 3 of nitric acid to 5 of hydrochloric acid.

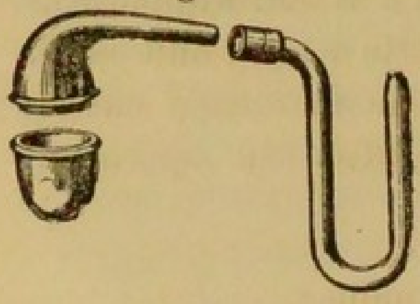
Aqua regia is employed in the preparation of the chlorides of copper, platinum, gold, etc.

Hydrofluoric Acid (very poisonous).

(Fluoric acid.)

This acid is gaseous when freed from its combinations, but condenses by cooling into a colorless liquid possessing a sharp smell and a savor analogous to that of hydrochloric acid. It corrodes glass and silicates, and combines with their silica to form a new acid called hydrofluosilicic or fluosilicic acid.

Fig. 113.



Hydrofluoric acid is prepared by decomposing in a lead retort (Fig. 113) a paste of fluoride of calcium (fluor spar) and sulphuric acid. The various joints of the retort are carefully luted with clay or plaster of Paris, and the receiver is a bent tube of lead plunged into a mixture of 3 parts of broken ice, and 2 of common salt, or more simply, into ice alone. The end of the receiver is perforated with a small hole, in order to aid the condensation by a small pressure. A gentle heat is applied at the bottom of the retort.

This acid is kept in lead bottles which are but slightly acted upon, or in platinum vessels upon which it has no action whatever. For several years past, gutta-percha bottles have been substituted for the metallic ones, and appear to stand the acid well when it is not too concentrated.

We must avoid any contact with the vapors of hydrofluoric acid, otherwise, after a few hours, even the less sensible parts of the skin will be covered with painful blisters.

This acid is employed for unpolishing glass, and other vitreous substances, and thus to prepare a ground more easily metallized. The parts which should not be corroded, are protected by a coat of virgin wax.

When we operate upon a level surface, a pane of glass for instance, the most easy process consists in covering it entirely with wax, and drawing the pattern with a pointed tool, which should penetrate to the glass. The object is then placed upon a shallow dish of lead holding the mixture for the production of the acid. At the ordinary temperature, or more rapidly with the aid of a feeble heat, the vapors of the acid attack the glass where it has been uncovered. On the other hand, if large surfaces are to be unpolished, the acid vapors are produced in a leaden box of suitable size, and perfectly luted. The objects may also be plunged into a trough of lead or gutta percha filled with a more or less diluted solution of hydrofluoric acid. This last process is employed for the production of patterns, hollow or in relief, upon doubled glass, that is, composed of several coats of differently colored glass. Glass pearls or beads, treated in the same manner, acquire a beautiful dead lustre.

Stearic Acid.

(Stearine.)

We may consider all fatty substances of animal origin, and tallow particularly, as composed of a base, called *glycerin*, which is united with *oleic*, *margaric*, and *stearic* acids. The last one is the most important for us, since we take moulds with it, and render impervious certain substances which otherwise would be penetrated and injured by the sulphate of copper of the galvanoplastic baths.

This acid is white, nearly without savor or smell, and more or less greasy to the touch according as it is more or less deprived of margaric and oleic acids. Its fracture is rarely crystalline, but often granular. It melts at a temperature from 60° to 65° C. into a clear liquid, which again solidifies by cooling. It is this property which renders stearic acid valuable for taking casts. If it be too greasy, it sticks to the pattern, and especially to plaster of Paris coated with plumbago; in this case, it should be mixed with a certain proportion of wax or spermaceti. When too dry, on the other hand, it contracts considerably by cooling, often breaks, and the galvanoplastic deposits have a crystalline surface. This defect is corrected by tallow or olive oil.

Between 280° and 300° C. stearic acid is partly charred, becomes brown, and loses certain volatile products; it is then too dry, and much less valuable for our purposes.

The manufacturers of stearic acid candles extract this acid from tallow especially. It can be bought in plates two or three centimetres thick or more.

Hydrosulphuric Acid (poisonous).

(Sulphuretted hydrogen. Sulphydric acid.)

This acid is generally in the gaseous form, but may be dissolved in water, which absorbs two or three times its own volume of it at the ordinary temperature, and which then acquires the same properties as the gas itself.

Hydrosulphuric acid is colorless; its smell is fetid, and resembles that of rotten eggs. It is slightly acid, and reddens blue litmus paper, but the primitive color reappears by heating. It precipitates in the form of white, black, yellow, etc., sulphides; nearly all the metallic solutions and some of these sulphides appear as conducting electricity. Such is the reason why we employ it sometimes for transforming into sulphides the chloride of gold and the nitrate of silver, with which are impregnated certain substances which we desire to render conducting. It is nevertheless possible that this conductibility is due to the reduction of these salts by the hydrogen, which nearly always accompanies hydrosulphuric acid.

This gas is so poisonous, that a man could not live in an atmosphere holding one hundredth part (in volume) of it. It is this acid, more or less combined with ammonia, which escapes from privies, and has often occasioned the asphyxia of those engaged in cleaning cesspools.

Hydrosulphuric acid is obtained by the reaction of hydrochloric acid, or diluted sulphuric acid, upon many sulphides, such as those of antimony, iron, barium, strontium, etc. The gas is collected under receivers filled with mercury, or is dissolved in a Woolf's apparatus, such as that described in the manufacture of hydrochloric acid. The distilled water employed should be deprived of air by ebullition, otherwise the solution will be milky from the partial decomposition of the acid, the hydrogen of which unites with the oxygen, whereas the sulphur is separated.

We should be careful not to put in contact with this gas, not only metallic salts, and gilt or silvered articles, but also pure gold and silver which are rapidly blackened by it. Hydrosulphuric acid is sometimes employed for the production of *oxydé*.

Sulphurous Acid.

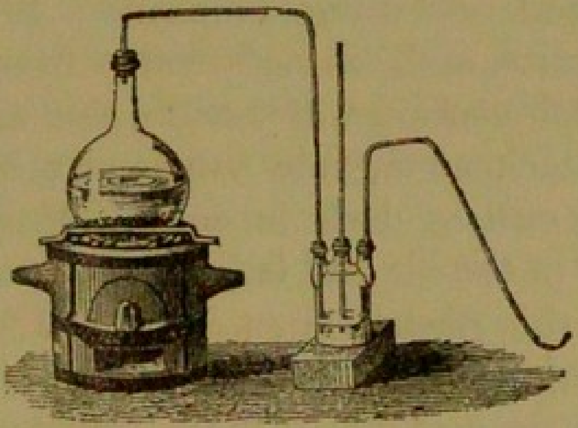
(Sulphur gas.)

It is gaseous, colorless, and possesses a taste flat and sharp at the same time. Its smell is penetrating and suffocating, and is that produced by burning sulphur in the open air. One volume of water, at the ordinary temperature, dissolves about thirty-three volumes of that gas, and acquires its characteristic properties.

Sulphurous acid decolorizes and bleaches a great many organic substances. It reduces many metallic salts by absorbing their oxygen; it may therefore be employed, possibly more advantageously than sulphuretted hydrogen, for the metallization by means of nitrate of silver or chloride of gold. It is employed in the preparation of the sulphites, and bisulphites, which we shall study further on.

It is obtained by burning sulphur in the air, from which it takes the two equivalents of oxygen necessary for its composition; or by decomposing in a closed vessel (Fig. 114) concentrated sulphuric acid by a substance possessing a great affinity for oxygen. Sulphur, charcoal, dry sawdust, copper, mercury, etc., may be used for the purpose, although copper is generally preferred. This metal finely divided (chips, filings, or turnings) is rapidly corroded, produces a pure gas, and leaves a residuum of sulphate of copper useful for galvanoplastic operators. Gaseous sulphurous acid is collected in bells or jars filled with mercury, and its aqueous solution is effected in Woolf's apparatus.

Fig. 114.



Sulphuric Acid (poisonous).

(Oil of vitriol.)

This acid, the most powerful and useful in the arts, may exist in the solid state or anhydrous. It is always used in a more or less hydrated form. Its name of oil of vitriol comes from its oily consistency, and from the green vitriol (sulphate of iron) from which it was formerly distilled in closed vessels. It is now produced in large quantities, by oxidizing in large lead chambers wet sulphurous acid by nitric acid.

Commercial sulphuric acid generally marks 66° of the hydrometer of Baumé, and is colorless, dense, flowing like oil, without smell, but with an intolerable acid taste. On the other hand, if it be very diluted (one gramme in two litres of water), it furnishes a cooling and refreshing lemonade. It decomposes nearly all salts, and extracts water from most substances which contain water or its elements. It corrodes and blackens organic substances, and becomes itself more or less dark in color. The particles of dust flying in the air and falling into it are sufficient to produce this phenomenon.

Poured into a concentrated solution of hydrochloric acid, sulphuric acid absorbs the water with production of heat, and the former gas escapes. It displaces all the other acids from their combinations, in the wet way, and forms very stable compounds with metallic oxides.

We employ it in our art for nearly everything, either for cleansing and for dipping acids, for the preparation of many products, for our batteries, etc. etc.

Tannic Acid.

(Tannin.)

This substance, which should not be confounded with gallic acid, although it produces it by fermentation and other chemical reactions, appears to be already formed in gall-nuts, which are supposed to be the result of the bite of a certain kind of insect upon oak leaves. Tannic acid exists also in many vegetables, and especially in the bark of certain trees, such as oak, chestnut, elm, etc.

This acid is generally prepared by digesting powdered gall-nuts, at a temperature of about 30° C., in commercial ether, and in closed vessels. After about eight days, the settled liquid, which is quite syrupy, is decanted and spread upon many dishes which are put into a stove. The ether is evaporated, and the nearly pure tannic acid remains in the form of uncrystallized scales, which are light, thin, yellowish, and with the lustre of mother of pearl. It is purified by solution in boiling water, which, by cooling, allows it to deposit in the shape of needle-like crystals.

Tannic acid possesses the singular property of coagulating, and rendering insoluble, certain gums, gluten, and gelatin especially, the latter being transformed into leather which will not putrefy.

It will be remembered that in the article on *moulding with gelatin*, we have indicated the employment of a small proportion of this acid for preventing the dissolving action of the baths. Gallic acid cannot take the place of tannic acid for this purpose.

Alloys.

We thus call the combination or mixture effected by the fusion of two or more different metals. The hydroplastic operator will rarely work upon pure metals; therefore it is well that he be acquainted with the composition of the most usual alloys, and that he learn the preparation of several of them, which, like the fusible alloys of Darcet, will often be serviceable.

Fusible Alloys of Darcet.

Bismuth	8 parts
Lead	4 "
Tin	4 "
	16

ANOTHER.

Bismuth	8 parts
Lead	5 "
Tin	3 "
	16

ANOTHER.

Bismuth	5 parts
Tin	3 "
Lead	2 "
	10

All the metals are melted together in a crucible, stirred with an iron rod, and cast. Various proportions of mercury are added to these alloys, when great fusibility is desired.

Copper Alloys.

BRASS FOR ARTICLES WORKED WITH THE HAMMER.

Copper	70 parts
Zinc	30 "
	100

BRASS FOR TURNING.

Copper	66 parts
Zinc	32 "
Lead	2 "
	100

SIMILOR.

Copper	100 parts
Zinc	12 "
	112

ANOTHER.

Copper	100 parts
Zinc	8 "
	108

STATUARY BRASS.

Copper	91.4 parts
Zinc	5.5 "
Lead	1.7 "
Tin	1.4 "
	100.0

PINCHBECK.

Copper	5 parts
Zinc	1 "
	6

BRONZE FOR BELLS.

Copper	78 parts
Tin	22 "
	100

BRONZE FOR CYMBALS.

Copper	80 parts
Tin	20 "
	100

BRONZE FOR GONGS.

Copper	100 parts
Tin	25 "
	125

TELESCOPIC MIRRORS.

Copper	100 parts
Tin	50 "
Arsenic	1 "
	151

BELLS FOR CLOCKS.

Copper	75 parts
Tin	25 "
	100

MAILLECHORT, OR MELCHIOR (GERMAN SILVER).

Copper	50 parts
Zinc	3.5 “
Nickel	4 “
	57.5

ANOTHER.

Copper	53 parts
Zinc	31.25 “
Nickel	15.75 “
	100.00

ANOTHER.

Copper	8 parts
Nickel	3 “
Zinc	3.5 “
	14.5

ANOTHER.

Copper	4 parts
Nickel	1 “
Zinc	1 “
	6

ANOTHER.

Copper	55 parts
Zinc	17 “
Nickel	23 “
Iron	3 “
Tin	2 “
	100

ELASTIC ARGENTAN.

Copper	57.4 parts
Zinc	25 “
Nickel	13 “
Iron	9 “
	104.4

POTIN.

Copper	11.9 parts
Zinc	24.9 “
Lead	0.2 “
Tin	1.2 “
	38.2

YELLOW TOMBAC.

Copper	16 parts
Zinc	1 “
Tin	1 “
	18

RED TOMBAC.

Copper	11 parts
Zinc	1 “
	12

CHRYSOCALE.

Copper	80 parts
Zinc	10.5 “
Tin	8 “
	98.5

BRONZE FOR LARGE ORDNANCE.

Copper	90 parts
Tin	10 “
	100

BRONZE FOR SMALL ORDNANCE.

Copper	93 parts
Tin	7 “
	100

BRONZE FOR MEDALS.

Copper	100 parts
Tin	8 “
	108

It is evident that it is possible to vary *ad infinitum* the mixtures and the proportions of the component metals, and thus to arrive at an unlimited number of alloys, which, on account of slight differences of color, ductility, sonorousness, etc., will receive different names, such as *Wolfram*, *French gold*, *Kalcogène*, *Auréide*, etc. etc.*

Amalgams.

Such is the name given to the alloys of one or several metals with mercury, but the latter must absolutely be one of the component parts.

Only two amalgams are of importance in our art: that of Darcet, already described; and that of gold, which is the basis of gilding by fire and mercury.

Whatever be the proportions of gold and mercury put together, an amalgam is always formed; but there are certain proportions which are more or less favorable for obtaining a certain result. Thus, the gold amalgam for gilding *by stirring* should be more fluid, and therefore contain more mercury, than that prepared for gilding by fire for a dead lustre, or for or moulu. The latter should be of the consistency of hard cold butter, a little rough to the touch, and with a crystalline texture which causes the production of a noise when the amalgam is pressed between the fingers. That for gilding by stirring should be of the consistency of honey and quite soft, since it is more easily spread over the surface of a multitude of small articles.

An amalgam is generally prepared by heating distilled mercury to a temperature of about 200° C.,

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* For a full description of alloys and amalgams see "*A Practical Guide for the Manufacture of Metallic Alloys*," from the French of A. Guettier, by A. A. Fesquet. Philadelphia: H. C. Baird, 1872.

and adding to it foils or ribbons of gold, which become readily incorporated. The whole is then thrown into cold water. If the proportion of mercury has been too great, the amalgam may be heated over the fire, until part of the mercury is volatilized, and the proper consistency is reached. On the other hand, should the amalgam be too hard, an addition of mercury will soon become mixed with the mass.

When an amalgam is heated at a dull red heat, all of the mercury is volatilized, and the gold remains in the form of a spongy and crumbling mass. Gold, in presence of mercury salts, does not form amalgams like copper; it is absolutely necessary that the two metals should be in the metallic state to arrive at an amalgam.

We meet often, in the trade, mercury adulterated by the addition of bismuth, lead, or tin; and it is evident that these various metals, which do not volatilize, remain with the gold and produce a bad effect.

Ammonia.

(Nitride of hydrogen. Hartshorn. Volatile alkali, etc.)

This compound, which generally bears the name of ammoniacal gas when in the gaseous form, and of ammonia when in solution, presents properties similar to those of potassa, soda, and other alkalies which are metallic oxides. Therefore it is considered as the oxide of a metal, *ammonium*, which is composed of nitrogen and hydrogen. This hypothesis, whether correct or not, has the advantage of getting rid of a chemical anomaly, and of placing ammonia under the same rules which govern the oxides of other well-known metals.

At all events, ammonia is generally in the gaseous state, but dissolves in water eagerly, since one volume of this cold liquid may absorb about 500 volumes of the gas. Notwithstanding this remarkable solubility, ammoniacal gas does not produce any visible fumes even in contact with very moist air, as is the case with hydrochloric acid and other substances; and this fact adds weight to the ammonium theory. Indeed, acids possessing a great affinity for water begin by appropriating the dampness of the atmosphere, which is condensed in a vesicular form, without dissociation of its elements; on the other hand, ammoniacal gas, holding three equivalents of hydrogen, decomposes the water to form the ammonium with four equivalents of hydrogen, which is at the same time oxidized, and becomes oxide of ammonium. Although we have resolved to leave aside all purely scientific demonstration, we cannot refrain from representing the reaction by formulæ:—

Chemists represent water by . $H+O$
And ammoniacal gas by . . NH^3
And their combination becomes NH^4O

Therefore the ammoniacal gas NH^3 has separated the elements of the water HO, to produce the metal ammonium NH^4, which being oxidized by oxygen O, becomes NH^4O. The complete formula is $NH^3+HO=NH^4O$.

Therefore, if we consider ammoniacal gas dissolved in water (aqua ammonia) as an oxide of ammonium, we may assimilate it to the other alkalies, and, indeed, it acts in an identical manner in chemical reactions.

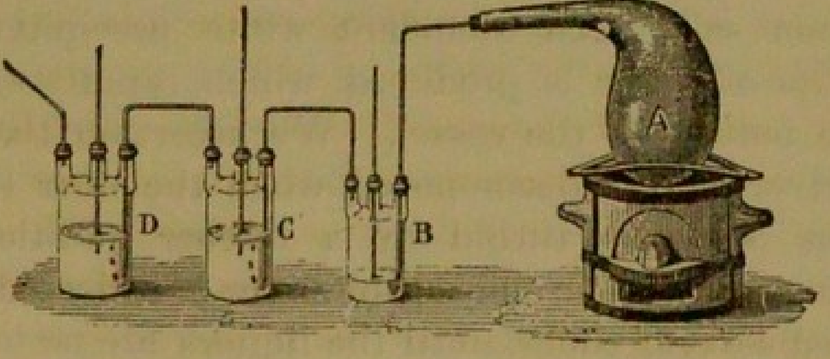
Aqua ammonia is a colorless liquid, with a more or less penetrating smell, which is so characteristic that it is never forgotten after having been once tried.

If we inhale without precaution from a bottle filled with this liquid, the brain is affected as by a blow on the head, and it would be dangerous to repeat the experiment several times consecutively.

Ammonia restores the blue color of litmus reddened by an acid, and saturates the most powerful acids; and, on this account, is often employed for removing acid stains upon clothes. We should except, however, the stains produced by nitric acid, which become more visible, instead of disappearing. All ammoniacal salts, except the carbonates, are colorless and odorless.

Ammonia is obtained, even in the cold, by treating any kind of ammoniacal salt by a fixed alkali. Sulphate or hydrochlorate of ammonia is generally employed, and is heated in a stoneware retort with slaked lime. The gas produced is received either under glass bells or tubes filled with mercury, if we desire to keep it in the gaseous state; or is dissolved in the water contained in the bottles of a Woolf's apparatus (Fig. 115), if we desire its solution. After the operation, there remains in the retort sulphate of lime or chloride of calcium.

Fig. 115.



A great proportion of the commercial aqua ammonia is, at the present time, extracted from urine and ammoniacal liquors from gas-works, and is of an amber color, or white, or half white. It marks 18°, 20°, 22°, and 25° of the hydrometer.

Ammonia is employed for aiding the solution of the copper salts entering into the composition of the baths for electro-deposits of copper or brass, for ageing freshly made silver-baths, for precipitating gold ammonium from the chloride of gold, and for dissolving the film of copper deposited at the beginning of galvanoplastic operations with silver, etc.

Silver.

We use silver in different forms, in plates, foil, powder, or granulated, according to the purpose for which it is intended.

We should, as far as practicable, employ it pure; but the silver found in the trade, even under the name of *virgin silver*, retains traces of copper. The silver coin (French standard) contains one-tenth of copper, and stamped silverware, a greater or less proportion according to the standard.

Silver is purified by several methods:—

1. The impure metal is dissolved by nitric acid, and the solution being largely diluted with water, we add to it an excess of a filtered solution of common salt. An abundant white precipitate of chloride of silver is produced, which rapidly settles to the bottom of the vessel. We ascertain that all the silver salt is decomposed, when the clear liquid is not rendered turbid by a further addition of common salt. The chloride of silver is collected, and washed several times, until the liquors are no longer colored brown by yellow prussiate of potassa. This is the proof that all the copper has been washed out.

The washed chloride of silver is mixed with two or three times its own weight of carbonate of soda, dried, and melted in a crucible. After cooling, the metal is found in the shape of a button (rather conical) at the bottom of the crucible. If we desire to granulate it, the molten silver is poured from a certain height (about 1 metre) into a large volume of water.

2. The alloy of copper and silver is dissolved in nitric acid, and the solution evaporated until the salts fuse. After cooling, the fused mass is gradually thrown into a red-hot crucible, when the nitric acid escapes, leaving behind the silver in the metallic state, and the copper as oxide. The separation of the two takes place naturally, and is aided by the addition of dry borax, which dissolves the oxide of copper.

3. The chloride of silver is prepared as in the first method; then, after having washed out the copper salt, zinc, sulphuric or hydrochloric acid and water are added. Hydrogen gas is immediately produced in abundance, and, combining with the chlorine of the chloride of silver, reduces the metal to the form of a fine powder, which is separated when all the zinc is dissolved. As it very rarely happens that commercial zinc is free from lead or carbon, this method is seldom employed. The substitution of iron for zinc is not more advantageous.

Silver is easily dissolved in pure nitric acid, but not so rapidly in one contaminated by chlorine or hydrochloric acid, which produces a coat of chloride of silver around the metal, and therefore forms an obstacle to its solution.

Sulphuric acid also combines with silver, and the resulting salt is but slightly soluble. As for hydrochloric acid, the trace of silver which may be corroded is immediately transformed into chloride.

Cyanide of potassium dissolves metallic silver slowly and gradually, and forms a double salt with it. On the other hand, the sulphites dissolve only the silver salts, and have a tendency to reduce them to the metallic state.

Pure silver is employed for the preparation of the nitrate and other silver salts, and for soluble anode in silver-baths. In the form of impalpable powder and mixed with cream tartar, it is used for silvering with a brush, and for the paste with which watch parts are grained before being gilt, according to the method of Geneva and Besançon. In this case, the silver powder is prepared by decomposing a very diluted solution of the nitrate of this metal by the addition of bands of pure copper. This powder should be washed several times with ammonia, which will remove all the copper which may be present.

Nitrate of Silver (poisonous).

(Lunar caustic. Lapis infernalis.)

This salt is found in the trade under three forms: either as crystallized nitrate of silver in thin rhombic and transparent plates; or in amorphous, opaque, and white plates of fused nitrate; or in small cylinders, which are white, or gray, or black, according to the nature of the mould employed, and constitute the lunar caustic for surgical uses.

The crystallized nitrate of silver still retains a small proportion of nitric acid and water; the white fused one is pure when it has not been fraudulently adulterated by nitrate of potassa or soda. The third kind, or lunar caustic, generally has its surface coated with a film of reduced silver and of oxide of copper from the moulds; its color may also be due to the inferior quality of the silver employed.

Nitrate of silver is very soluble in distilled water,* and with ordinary water gives a precipitate which is the more abundant as there is more chlorine salt in the liquid. This precipitate is white at first, and then becomes blue and black by solar light, but this transformation does not take place when it contains even traces of chloride of mercury.

The solution of nitrate of silver forms yellow precipitates by the iodides, phosphates, and bromides; and white ones with the soluble chlorides, sulphites, cyanides, hyposulphites, and pyrophosphates. With the exception of the phosphates and pyrophosphates, the other reagents, when employed in greater or less excess, will redissolve the precipitate and form double salts.

It is precisely this property of cyanides, sulphites, and hyposulphites, which is the basis of the preparation of silver-baths by dipping or with the battery. Ammonia dissolves even the most insoluble silver salts; but as this solution attacks copper, it cannot be used for baths, notwithstanding the advice of M. Boetger.

Nitrate of silver is prepared by dissolving pure silver, granulated or laminated, in double its own weight of pure nitric acid at 40° Baumé, and the operation is effected in a glass flask or in a porcelain

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* However, when the nitrate of silver has been kept too long in igneous fusion, it is less fusible in distilled water, and the white turbidity of the liquid is probably due to the formation of a subnitrate of silver.

capsule. Abundant nitrous vapors are disengaged, and the metal soon disappears to form a colorless liquid (blue or green if there be copper). After cooling, and a rest of a few hours, a mass of crystals of nitrate of silver is found, which is drained, and washed with a little distilled water already saturated with nitrate of silver, in order to remove the excess of acid. The crystals are dried in a stove, and kept away from solar light. If, instead of cooling the liquid after the silver has been dissolved, the evaporation be continued, the mass will become spongy, and then fuse by a greater heat into a grayish liquid which may be run into moulds. The fused mass, obtained by the fusion of the separated crystals of nitrate of silver, is whiter.

This salt, whatever be its mode of preparation, should be kept in black or blue bottles, and without the presence of organic substances which would reduce the metal.

It is employed for preparing baths, metallizing moulds, and many other purposes.

Nitrate of Binoxide of Mercury (poisonous).

(Acid nitrate of mercury.)

This salt is generally sold in the form of a colorless and oily liquid, which is the denser as it contains more free acid. It stains the skin a violet red, and in contact with water produces a pulverulent and yellowish-white precipitate, which is a subnitrate, sometimes called *nitrous turbith.* This precipitate disappears by the addition of a few drops of sulphuric or nitric acid, and the liquor becomes clear. Should the solution of nitrate of binoxide of mercury be concentrated, sulphuric acid, instead of dissolving the precipitate, would increase it, because an insoluble subsulphate of mercury would be formed.

This salt is used in our art for slightly amalgamating the pieces which are to be silvered or gilt. This amalgam is a kind of solder between the deposited metal and that which is coated.

Nitrate of binoxide of mercury is obtained by dissolving at the temperature of about 100° C. a certain quantity of mercury in double its own weight of nitric acid at 40° Baumé, and continuing the heat until yellow fumes no longer appear.

If, instead of operating with the aid of heat, the reaction were effected in the cold; or if the proportion of mercury were in excess of the necessary quantity of nitric acid, we would then obtain a salt of protoxide which is not so suitable for our purpose. Nitrate of binoxide of mercury may be obtained in the crystallized state, but it possesses then little stability, and presents no further advantage for our art.

Nitrate of Potassa.

(Saltpetre. Nitre.)

This salt is sometimes produced by the decomposition of carbonate of potassa by nitrate of lime; the latter substance being spontaneously formed in old, damp walls which contain lime, and which are exposed to the emanations or contact of decomposing vegetable or animal matters.

A saltpetre with soda for base (nitrate of soda) is gathered in the plains of Egypt, India, and Chili, after strong rains followed by great dryness. The crystals creep to the surface by capillarity.

Nitrate of potassa is colorless, odorless, and with a fresh and salted taste; it is very soluble in water, and a concentrated solution deposits, on cooling, fine prismatic crystals, which are more or less translucent. Thrown upon burning coals, it fuses, and increases the combustion by parting with a portion of its oxygen, and there remains a solid salt upon the spot where it has fallen. Concentrated sulphuric acid, poured upon nitrate of potassa, disengages white fumes of nitric acid; on the other hand, these vapors are yellow when a metallic powder, such as copper, iron, zinc, etc., has been mixed with the nitrate of potassa.

Distilled in closed vessels with more or less diluted sulphuric acid, nitrate of potassa produces nitric acid or aqua fortis of various degrees of concentration.

Before using the crude nitrates of soda or potassa for the manufacture of aqua fortis, it is advantageous to purify them by one or two crystallizations, in order to separate in the mother liquors the chlorides, iodides, and bromides.

We employ salpetre for producing a dead lustre upon objects gilt by fire, and for desilverizing baths.

Bicarbonate of Potassa.

This salt is white and colorless, and crystallizes either in the tabular form, like nitrate of silver, or in cubes, like common salt or iodide of potassium. It is soluble in tepid water, without decomposition; but at the boiling point, it loses one-fourth of its carbonic acid and becomes a sesquicarbonate. A red heat transforms it into carbonate, that is to say, it loses another fourth of carbonic acid.

Bicarbonate of potassa blues red litmus paper, and possesses little savor. Its cold solution is not precipitated by that of sulphate of magnesia, but an abundant precipitate is formed by applying heat, because, then, part of the carbonic acid is disengaged, and an insoluble sesquicarbonate of magnesia is formed.

This salt, which is employed for the preparation of certain gilding baths by dipping, and for that of the ordinary cyanide of potassium, is obtained by conducting a stream of carbonic acid through a concentrated solution of carbonate of potassa, until the liquor is no longer rendered turbid by the addition of sulphate of magnesia or nitrate of lime. It crystallizes soon after, because it is much less soluble than the protocarbonate.

Bicarbonate of Soda.

(Vichy salt. Raising powder.)

It is in the form of spongy and amorphous masses. Its properties, uses, and preparation correspond with those of the bicarbonate of potassa.

Binoxalate of Potassa (poisonous).

(Sorrel salt.)

It is a crystalline and white salt, which is already formed in the juice of certain plants, and especially in sorrel (*Rumex acetosella*), from which it is extracted by the simple concentration of the liquors.

This salt is acid, and decrepitates in the fire, since its acid is decomposed and part of it becomes gaseous. It enters into the composition for silver paste for cold rubbing.

Bitartrate of Potassa.

(Cream tartar. Argols.)

This salt is nearly pure in wine, from which it becomes separated in the shape of small white or red crystals, according to the color of the liquid. It is gathered on the sides of wine casks, and purified by bone black.* Before this purification, it was crude tartar or argols.

Bitartrate of potassa is acid, slightly soluble in water, and it decrepitates in the fire, where it becomes charred and produces a smell like that of burnt sugar. It is employed for the preparation of the whitening silver baths, for those of tin, and for the silvering paste by rubbing.

Biborate of Soda.

(Borax. Borate of soda. Tincal.)

This well-known compound is generally in the shape of colorless, or more or less yellowish, crystals of different systems, according to the proportions of water or alkali they hold. The octahedral crystals are preferred.

Borax is soluble in water, has an alkaline reaction, and a bitter and salted taste. When heated, it melts in its water of crystallization, and then swells up considerably. A further increase of heat causes its fusion, and it becomes transformed into a kind of transparent and colorless glass, which may be spun.

Vitreous (fused) borax is a powerful solvent of most metallic oxides, which impart to it various

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* The price of cream tartar varies with that of wine. This substance is often adulterated with alum, saltpetre, etc. It is therefore preferable to buy it in the crystallized form, and to pulverize it in the shop.

colors. This property of dissolving metallic oxides renders borax very useful for soldering, brazing, or welding different metals.

A powerful acid, poured into a hot and concentrated solution of borax, separates the boracic acid in the form of scales. Borax ground with a little sulphuric acid and alcohol imparts to the flame of the latter a characteristic green color.

The biborate of soda is prepared by saturating with an excess of boracic acid, a hot and concentrated solution of carbonate of soda. Sometimes the tincal of India, which is composed mostly of borax, is simply purified by several crystallizations.

Borax is employed for restoring the shade of defective gildings, and for destroying the subcyanide of silver deposited in electro-silvering baths, and which will make electro-silver deposits turn yellow.

India-Rubber.

(Caoutchouc. Gum-elastic.)

This substance is white when pure; but its color is generally brown or red, caused by the smoke of the fires employed for drying it.

India-rubber is extracted from the sap flowing from incisions made on the trunks of the *Ficus elastica* or *Cahuca*, a tree which grows in Java. The milky sap, by settling, becomes divided into two layers, the lower one of which is liquid, and the other thicker and cream-like, and formed of a multitude of small globules. These globules are removed, washed with salt water, and spread in thin layers upon tables or over clay balls shaped like pears. The drying is made at the ordinary temperature, or with the aid of heat; and, in the latter case, the smoke colors the substance.

India-rubber is essentially elastic, and this property renders it very valuable for many purposes, for instance the moulding of highly wrought patterns. The elasticity increases with the temperature; but at 120° to 125° C. this gum melts, and furnishes a viscous liquid which seldom returns to its primitive consistency. If the temperature be raised still higher, the mass remains always liquid and sticky. Lastly, at a still greater heat, India-rubber will burn with a fuliginous flame.

The combination of sulphur with India-rubber furnishes a peculiar product, the elasticity of which is far from being diminished, and which possesses distinct properties. This product is vulcanized India-rubber, and, when treated in a certain manner by alkalies, it produces a substance resembling hard soap, which possesses nearly all the properties of horn, and with which many articles of "hard India-rubber" are manufactured.

Water, alcohol, and acids do not dissolve India-rubber; on the other hand, ethers, bisulphide of carbon, essential oils, and benzole dissolve and abandon it after their volatilization. These solutions give us the means of obtaining very delicate moulds; but, in this case, we should only apply very thin and successive coats of the solution, otherwise the exterior surface being the first to solidify, will prevent the drying of the intermediary coats.

Chloride of Silver.

(Horn silver. Muriate of silver.)

This substance, when obtained by precipitation, is of a pure white, which soon becomes blue and then black by exposure to the light; therefore it should be kept in blue or black bottles. It melts at a high temperature, and acquires the appearance of horn, from which it derives its name of horn silver.

When chlorine water, hydrochloric acid, or a soluble chloride is introduced into a solution of a silver salt, there is immediately produced an abundant precipitate of chloride of silver, which is insoluble in water and in concentrated acids, but soluble in ammonia, cyanides, and the hyposulphites and sulphites of alkaline or earthy bases. This precipitate is but slightly soluble in the bromides, iodides, chlorides, and fluorides of the alkaline or earthy metals.

Chloride of silver is employed in the preparation of the baths for electro-silvering, and for whitening, and for the pastes for silvering in the cold by rubbing.

Protochloride of Tin (poisonous).

(Muriate of tin. Chloride of tin. Tin salt.)

This salt is manufactured in large quantities, and is in the shape of small needle-like crystals. It is greasy to the touch, melts easily, communicates to the fingers a characteristic smell resembling that of fish or of rubbed tin, and its taste is salty at first, and then astringent and caustic.

Protochloride of tin is soluble in water, but is partly precipitated in the state of a white subsalt, which is easily dissolved in a slight excess of acid.

Alums, pyrophosphates, tartrates and bitartrates precipitate at first the aqueous solution of this salt, but an excess of the reagent redissolves the precipitate. This reaction is the basis of the preparation of the tinning baths, which we have described in the first part of this work.

The protochloride of tin is prepared by dissolving granulated zinc (in excess) in hot hydrochloric acid, evaporating the solution, and letting it crystallize.

If the crystals are heated, they first melt in their water of crystallization, which soon evaporates, carrying off a small proportion of hydrochloric acid. The operation is completed when thick, white fumes begin to be evolved, which are proof that the salt itself volatilizes. The melted chloride of tin thus obtained is preferable for tinning with alkaline liquors.

Chloride of Gold.

(Sesquichloride of gold. Muriate of gold.)

This salt is in masses of needle-like crystals, which are yellow, red, or brown-red, according as it has been more or less deprived of acid. That generally sold by manufacturers of chemical products is a light yellow; and, besides the fact that it contains less gold than it ought to, it still retains an excess of acid, which is injurious to the baths.

Chloride of gold is decomposed by light into the metal and chlorine; thence the necessity of keeping it in black bottles, with ground glass stoppers. Cork, like other organic substances, decomposes this salt.

Chloride of gold absorbs the dampness of air, and becomes resolved into a liquid of a fine yellow color. It produces violet stains on the skin, and is very soluble in water.

Its characteristics are to give a precipitate of purple of Cassius by protochloride of tin, and to be reduced to a metallic sponge by heat. A diluted solution of chloride of gold is decolorized by sulphurous acid, and, after a certain time, or more rapidly by heat, the metal is precipitated as a powder, which is green by transparency, and red by reflected light.

If we pour, drop by drop, a solution of this salt into a diluted solution of sulphite or hyposulphite of soda, there is produced a colorless double salt employed for fixing Daguerrean images. On the contrary, should we pour the solution of the sulphite or hyposulphite into that of gold, this metal is immediately and completely precipitated.

The soluble cyanides or prussiates precipitate the chloride of gold at first in the state of cyanide, and in *concentrated* solutions; but an excess of reagent redissolves the precipitate, and forms with it colorless double salts, which form the basis of the preparation of electro-gilding baths.

Carbonates, bicarbonates, and pyrophosphates also produce double salts, which may be crystallized, and which, in certain cases, form the gilding baths by dipping.

Chloride of gold may be prepared by different methods; the most simple of which consists in dissolving the finely laminated, or otherwise comminuted, metal in aqua regia formed of two parts of pure hydrochloric acid to one of pure nitric acid. The operation is effected in a glass flask, and with the aid of a gentle heat, until all of the gold is dissolved into a yellow liquid which retains a great excess of acid. The heat is then slightly increased, and continued until the liquid is a hyacinth-red. After cooling, we obtain a crystallized mass of a fine yellow color, which is well adapted to the preparation of the gilding baths by dipping. On the other hand, for baths working with a battery, we should continue the action of the fire until the liquid in the flask appears a dark blackish-red, without ceasing to be fluid. By cooling, the crystals are brown-red. I advise the employment of a glass flask preferably to a porcelain capsule or dish, because the evaporation is too rapid in the latter, and part of the chloride of gold may be carried mechanically out of the vessel.

The flask should stand upon a plate of sheet iron perforated in the centre with a hole, the diameter of which is not larger than the layer of liquid after evaporation. We thus avoid the reduction by an excess of heat of a portion of the chloride of gold. Should the heat be too great, or too protracted over the time necessary to expel the excess of acid, the sesquichloride of gold would be transformed first into the insoluble protochloride, and then into the metallic state, and the operation would have to be begun anew.

Many operators buy their aqua regia already made, which is wrong, because the acids react one upon the other, even without the presence of the metal; the useful portion becomes lost, and what remains in the bottle is nearly useless. It is therefore preferable to make the mixture just before using it. Some persons prepare the chloride of gold with a mixture of nitric acid and sal ammoniac, and even common salt. It is an old and defective method, which is retained only by gilders on porcelain wares. Lastly, gold may be dissolved in chlorine gas, or chlorine water; but this process is expensive.

Bichloride of Platinum.

(Chloride of platinum. Muriate of platinum.)

This salt is amorphous, reddish-yellow, or blackish-red, according to the degree of evaporation of the acids in excess. It has a great analogy with the chloride of gold, both as to appearance and to deliquescent property (when acid); but it is not so easily decomposed by light and organic substances.

Its diluted solution is gold-yellow, and dark yellow when concentrated; but never wine-red, unless it contains palladium, iridium, or rhodium. The platinum solution is colored a wine-red by that of iodide of potassium, and traces of either of these reagents will be detected by this reaction. The intensity of the coloration is in the ratio of the quantity of metal or iodine. Potassa and its salts in concentrated solution give a yellow precipitate with chloride of platinum; sometimes it is necessary to stir the mixture with a glass rod before the precipitate takes place. Soda does not produce this result, unless highly concentrated. Ammonical salts also give a yellow precipitate, which, by calcination, is transformed into spongy platinum.

The chloride of platinum resists the action of the fire better than that of gold; however, it becomes first protochloride of platinum, and lastly metal.

When a brass article is rubbed with chloride of platinum, it acquires the color and lustre of steel, and this coat is often quite durable.

Perfectly neutral chloride of platinum, mixed under a muller with certain fatty and essential oils, furnishes a paste for applying thin coats of metal upon stoneware, pottery, glass, and porcelain.

Chloride of platinum is easily soluble in caustic soda, and in the carbonate and phosphate of this base, and thus furnishes more or less satisfactory baths for platinum deposits.

This salt is prepared like the chloride of gold; but the aqua regia is composed of five parts of hydrochloric acid to three of nitric acid. The product is evaporated nearly to dryness in a porcelain dish, and then removed after cooling. If it be desired to have it more acid, and therefore more easy to dissolve, it is poured still fluid, but emitting little fumes, into a porcelain plate, from which it is easily separated after cooling.

Chloride of Zinc (poisonous).

(Hydrochlorate or muriate of zinc. Butter of zinc.)

This substance is more or less gray, or white, according as it has been prepared in iron or porcelain vessels, or has been more or less desiccated. It is caustic, greasy, and hot to the touch. It absorbs dampness with such energy, that a few minutes of exposure to the air are sufficient to make it fall into *deliquium*. It may be distilled like mercury and other volatile substances, and possesses then the appearance of butter.

Chloride of zinc is employed for aiding soldering, brazing, or welding operations, and in this case it should be as neutral as possible, in order not to act as an acid upon the metals. It enters into the composition of the brass or zinc baths.

It is prepared by dissolving zinc in hydrochloric acid, filtering the solution left for a few days in contact with an excess of zinc, and evaporating it down to igneous fusion. At that moment, abundant and thick white fumes are disengaged. The mass is then cast into plates which are put into well closed vessels immediately after cooling.

Cyanide of Silver.

(Prussiate or hydrocyanate of silver.)

This substance is white, becomes slowly black when exposed to the light, and is insoluble in water and in cold acids, which, however, will dissolve it, the temperature being raised sufficiently. It is dissolved and decomposed by the sulphites, hyposulphites, and chlorides; the cyanides and prussiates form with it double salts. A cyanide of silver is always formed when any kind of soluble silver salt is treated by a small proportion of a cyanide.

If introduced dry into a small tube, which is closed at one end, and the other extremity of which is afterwards melted and drawn, leaving but a fine aperture, it produces at a red heat a deposit of metallic silver with carbon, and cyanogen gas which burns with a blue and purple flame.

Cyanide of silver is prepared by passing cyanogen gas through, or adding hydrocyanic acid to, a cold solution of nitrate of silver. The precipitate formed is thoroughly washed, and kept wet in blue or black bottles.

We have given, in the article on *Cold electro-gilding baths*, all the directions necessary for preparing this substance. We should not forget that, whatever be the silver salt put in contact with cyanide of potassium, it is first transformed into cyanide of silver, which is redissolved in an excess of cyanide of potassium to form the double cyanide of potassium and silver.

Cyanide of Copper.

(Hydrocyanate of copper. Prussiate of copper.)

A few operators on brass electro-deposits, and many gilders, still use cyanide of copper.

This salt is found in the trade with two different colors; either as a powder of a maroon or Van Dyck brown color, and it has then been obtained by the precipitation of a soluble copper salt by yellow prussiate of potassa, or as a dirty white powder with a greenish-yellow tinge, and has resulted from the precipitation of a soluble copper salt by cyanide of potassium.

Whatever be its mode of production, it is easily soluble in all the alkaline cyanides, and even in the yellow prussiate of potassa if it has been recently prepared, but with difficulty in the contrary case.

By its solution in an excess of cyanide it forms the double cyanide of potassium and copper, for electro-coppering.

Cyanide of Ammonium (poisonous).

(Hydrocyanate of ammonia. Prussiate of ammonia.)

We may obtain with this salt the same baths as with the cyanide of potassium. It is, however, little used, because it is easily decomposed, and has the smell of dead bodies. It is obtained by exactly saturating ammonia with hydrocyanic acid.

Cyanide of Calcium (poisonous).

(Hydrocyanate or prussiate of lime.)

This salt is employed for decomposing the carbonates formed in the baths of cyanide of potassium. It is readily understood that, by double decomposition, an insoluble carbonate of lime is formed, while a proportional quantity of cyanide of potassium is reconstituted. This salt should be preferred to hydrocyanic acid in the majority of cases.

A solution of cyanide of calcium is obtained by adding hydrocyanic (prussic) acid to a paste of caustic lime in excess. By filtration, the excess of lime remains behind, and the cyanide of calcium is in the liquor. This salt cannot be obtained in the solid state, is decomposed by heat, and it is better to use it when recently prepared.

Cyanide of Gold.

(Prussiate or hydrocyanate of gold.)

It is of a fallow yellow color, and behaves with reagents very much like the cyanide of silver. Cyanide of gold is prepared by pouring a *concentrated* solution of cyanide of potassium into a *concentrated* one of chloride of gold. An excess of alkaline cyanide will dissolve the precipitate and form an electro-gilding bath holding a double cyanide of gold and potassium. This salt may be employed for the preparation of gold baths; but it is more expensive, and does not seem to us to give better results than any other gold salt, and particularly the gold ammonium, the preparation of which has been fully explained in the chapter on *Electro-gilding in the cold.*

Cyanide of Potassium (extremely poisonous).

(Hydrocyanate or cyanhydrate of potassa. White prussiate of potassa.)

No other product is more important to the electroplater than the cyanide of potassium, which is the basis of most of the baths employed, and the purity of which is so necessary for the success of the operation.

At the same time, nothing resembles more in aspect a good cyanide than a bad one. This fact has aided many manufacturers in producing, at cheap rates, products which have nothing in common with real cyanide but the name.

In order that every one may be advised against the consequences of such products, we shall describe the various processes for obtaining a good cyanide, suitable for the baths and formulæ described in this book. We shall also indicate the principal characteristics of a good cyanide.

Cyanide of Potassium, Pure.

(For medicinal uses.)

Formerly, and only for medical uses, the pure cyanide of potassium was prepared as follows:—

A certain quantity of pure and dried yellow prussiate of potassa was heated to a white heat in a stoneware retort, the aperture of which was closed by a tube plunged in mercury or water. When gases no longer escaped from the tube, or rather when the mercury and water had a tendency to be absorbed, the tube was removed and the aperture of the retort carefully closed to prevent air or moisture from penetrating it. The retort was allowed to cool in the furnace, and was afterwards broken, in order to extract the contents, forming generally two layers, the lower one containing iron, and the other formed of pure cyanide, which was separated. Sometimes the mass was spongy, and the mechanical separation of the iron from the cyanide was impossible. It was then treated by absolute alcohol, which dissolved the cyanide only, and, after filtration, the solution was rapidly evaporated. In either case, the resulting cyanide was immediately put into blue or black bottles, well closed.

Cyanide of Potassium, Pure (100 per cent.).

(For the arts.)

At the present time we manufacture for the arts large quantities of cyanide of potassium, which is at least as pure as the preceding one, and at a cost which is not the tenth part of that of the medical cyanide. The various stages of the operation are as follows:—

1. The recrystallization of the commercial yellow prussiate of potassa until it is entirely free from sulphates.

2. The thorough drying of the pure crystals at a temperature of from 100° to 120° C.

3. The melting at a white heat of the dried prussiate in thick iron crucibles, with their covers on.

4. Keeping the contents for some time in a state of quiet fusion, in order to permit of the settling of the iron at the bottom of the crucible.

5. And when the surface of the molten cyanide appears transparent, the withdrawing of the crucible with iron tongs, and the pouring, without shaking, of its contents upon a polished iron pan, the bottom of which is immersed in water. The iron generally remains in a spongy mass at the bottom of the crucible; but, as a further precaution, the molten cyanide is sometimes passed through a fine metallic sieve, which has been previously raised to a red heat. An iron ladle, perforated with numerous holes, may also be filled with the iron of the previous operations, and the whole being raised to a red heat, the molten cyanide is filtered through it.

The polished iron pan, without water under it, will be rapidly burned out, and it will be difficult to remove the cooled cyanide.

During the fusion of the cyanide, it is proper, now and then, to rapidly plunge into it a dry glass rod; if the cyanide gathered upon it is perfectly white and clean, the moment has arrived to pour the contents out.

In manufactories, where quantities of 50 kilogrammes at a time are poured out, it may happen that it is necessary to remelt the cyanide in order to have it perfectly white. This is more a question of appearance, than an improvement in the real value of the product.

The cyanide manufactured in this manner is our cyanide No. 1, which we often designate by cent. per cent. It is of a milky white, more or less translucent, and its fracture is crystalline and vitreous. It is completely odorless, when perfectly dry, but if it has absorbed the least quantity of water, it possesses the characteristic smell of the bitter almond. Exposed to the damp air, it soon falls into *deliquium*, and is decomposed into many products, such as the carbonates and formiates of potassa and ammonia.

If very hot cyanide were put into a small quantity of water, it would be immediately decomposed with production of ammonia. On the other hand, its cold solution may be raised to the boiling point without sensible decomposition. Nevertheless, all solutions of cyanides are altered and transformed after a certain length of time.

When a cyanide is to be kept for a long while, it is prepared with a pure yellow prussiate of soda, and the product is rather efflorescent than hygrometric, that is to say, it repels dampness instead of attracting it like the cyanide of potassium.

Cyanide of Potassium (Liebig's method).

(Ordinary cyanide.)

It will be remembered that we have sometimes recommended in this work, the substitution for the pure cyanide marking 96°, 98°. or 100° (from 96 to 100 per cent. of real cyanide) of one not so rich, and which owes to free potassa the property of improving the conducting power of freshly made baths. The facility of its manufacture allows of a much lower price, even relatively to the proportion of real cyanide it contains.

We have also said that we manufacture three qualities of this product:—

The *first*, or pure cyanide already described, especially suitable for the gold or silver-bath;

The *second*, marking about 75° (75 per cent. of real cyanide), and intended for several freshly made baths, and for those of brass and copper;

The *third*, marking about 55° (55 per cent. of real cyanide), and applied to photographic uses.

In order to obtain the last two qualities we raise to a red heat, in covered iron crucibles, the following mixture for quality No. 2:—

8 parts of purified and dried yellow prussiate of potassa,
and 4 parts of bicarbonate of potassa,
or 3 parts of pure carbonate of potassa,

and for quality No. 3, equal parts in weight of yellow prussiate and pure carbonate of potassa.

The remainder of the operation is exactly as has been described for the pure cyanide, excepting that the temperature does not require to be so high. The trial pellicle upon the glass rod should be porcelain white. The fracture of these cyanides is more or less crystalline or granular, according as the cooling has been sudden or gradual.

The presence of sulphates in the yellow prussiate or the carbonate of potassa employed, is sufficient to impart to the cyanide a pink, green, or blue coloration; a very small proportion of this impurity is sufficient to color the product.

Cyanide of potassium, or rather all of the alkaline cyanides, precipitate at first metallic solutions, and then redissolve the metallic cyanide to form double salts for our baths. However, a certain number of metals should be excepted, such as platinum, bismuth, antimony, tin, nickel, etc.

Cyanide of potassium forms with the salts of peroxide of iron a precipitate of Prussian blue, especially in the presence of an excess of hydrochloric acid.

Ferrocyanide of Potassium (not very dangerous).

(Cyanoferride of potassium. Yellow prussiate of potassa.)

This product is always manufactured on a large scale for many uses in the arts. It is in the shape of fine yellow, and semi-translucent, crystals which break gradually and without noise. The fracture is jagged, and filled with a multitude of small bright spots.

The dried salt is yellowish white; at a higher temperature it decrepitates, and is decomposed into white cyanide of potassium, and cyanide of iron, the cyanogen of which is in its turn expelled as gas, whereas the iron is reduced to the metallic state, or to a carbide.

The solution of ferrocyanide of potassium is straw yellow, and like the simple cyanide of potassium, precipitates and redissolves afterwards nearly all metallic salts. However, its dissolving power is much less energetic. The soluble anodes are but little, or not at all, dissolved in the baths composed of yellow prussiate, which renders the use of such baths expensive.

This double cyanide is scarcely poisonous, and does not emit any smell, or absorb dampness.

This salt is prepared by carbonizing animal residue such as blood, horn, hair, etc., with a mixture of carbonate of potassa and iron scraps. The mass is then lixiviated with water, and the solution crystallized. We should avoid, for the manufacture of white cyanide of potassium, those crystals of yellow prussiate which, viewed obliquely, present other small bright crystals of sulphate of potassa which is injurious to the operation.

Cyanide of Zinc.

(Hydrocyanate of zinc. Prussiate of zinc.)

A few brass electroplaters still employ this salt, although it is costly, and does not present any real advantage over the other zinc salts. It is white or dirty white, according as the zinc salt was without, or with iron.

It is insoluble in water, but soluble in ammonia, and in the earthy or alkaline sulphites and cyanides, with which it forms double salts, suitable for zinc electro-baths. Its solution is the more easy as it has been more recently prepared.

Cyanide of zinc is obtained by incompletely precipitating with cyanide of potassium, a solution of sulphate, nitrate, chloride, or acetate of zinc. The precipitate is drained upon a filter of paper or calico, and completely washed to remove the remaining soluble zinc salt.

Gelatin.

(Isinglass. Glue.)

Everybody knows what gelatin is, and that it is extracted by means of acids, or by superheated water, from bones, skin, cartilage, and similar substances; and that it is more or less colored, according to its degree of purity. The common sorts are called glue, and are employed for making galvanoplastic moulds. The least colored are preferred, because the casts are more delicate.

Cold water swells up and softens gelatin, but hot water will dissolve it in all proportions. This property, which is very useful for the production of the moulds, is, on the contrary, disadvantageous when the mould is in the galvanoplastic bath. This inconvenience is partly remedied by adding to the gelatin, before pouring it upon the pattern, a few hundredths of tannic acid which combines with it, and forms a kind of leather which resists the action of the liquids better. At all events, gelatin moulds should be rapidly coated with the metallic deposit, otherwise they will give very imperfect or valueless copies.

If it be true that hot water dissolves a great proportion of gelatin, which sets (takes consistency) by cooling, this property disappears by a too long ebullition, and there remains a syrup which will not coagulate.

Benzine.

(Benzole. Gaseine. Light oil from coal tar.)

When coal tar is distilled, there remains in the retort a thick mastic called pitch, and the distillate is composed of essential oils, having different specific gravities and points of ebullition. Those which are lighter than water, are collected apart, and are deprived of their coloring matter by a treatment with concentrated sulphuric acid, and then with soda. After the proper washings and one or several distillations, a liquid is obtained which is colorless, smelling strongly of gas, with a sharp and bitter taste, and which is completely insoluble in water, although it imparts its smell to the latter. This product becomes oxidized and reddens under the action of solar light, when it has not been perfectly rectified.

Benzine dissolves perfectly well all the oils, resins, gum-resins, varnishes, fats, etc., and is therefore very useful in our art. It is much superior to the alcohol and essence of turpentine formerly employed for removing resist varnishes, and may be used in the cold, which is a great advantage with inflammable substances. A small proportion of naphthaline is sufficient to give a pink, red, or brown tinge to benzine; but this is of no consequence for our operations. The preparation of this substance involves too great a danger of fire for us to undertake it. Moreover it is found in the trade cheap and pure enough for our purposes.

Phosphate of Ammonia.

This salt, which is absolutely necessary for the composition of baths for thick platinum deposits, is obtained by the *exact saturation* of phosphoric acid with ammonia.

The liquid obtained is then evaporated at a gentle heat, and a few drops of ammonia are now and then added, in order to compensate for that removed by the decomposition of small quantities of the salt.

When the liquid becomes syrupy it is set aside to crystallize in a cool place.

This salt may also be prepared by decomposing, with carbonate of ammonia, the biphosphate of lime resulting from the digestion in sulphuric acid of ground and calcined bones.

Phosphate of Soda.

(Tribasic phosphate.)

This salt crystallizes in fine, transparent, and colorless prisms; its taste is slightly bitter and salted, and it effloresces by losing part of its water of crystallization. It is soluble in distilled water without producing any precipitate, but causes a deposit of white phosphate of lime in calcareous waters. This salt is formed of one equivalent of phosphoric acid, saturating two equivalents of soda, and one of water, acting a base. Thence its name of *tribasic.*

At a temperature of about 200° C., phosphate of soda diminishes in volume, and loses all of its water of crystallization, but not that combined. By still raising the temperature, it melts like a glass and loses the combined water, which it will not reacquire except by remaining a very long time in solution. Its nature and properties have been entirely changed; and it gives now a white precipitate with nitrate of silver, instead of a yellow one as was the case previously to its transformation into *pyrophosphate,* that is, a bibasic phosphate capable of combining with a metallic base, in place of the equivalent of water lost. It is this property which renders the pyrophosphate valuable for the preparation of gilding baths by dipping, and of tinning baths by the battery or by the method of double affinity. In these cases, it assimilates an equivalent of oxide of gold, or of oxide of tin.

Phosphate of soda is used for hot electro-gilding baths, and is prepared by treating calcined and powdered bones with sulphuric acid, and letting the mixture rest for several days. The acid phosphate of lime is then removed by washing the residue, and the filtered liquid is saturated by carbonate of soda until carbonic acid is no longer disengaged. The clear settled liquor is then concentrated until it marks 33° Baumé, and is allowed to crystallize once or several times.

Pyrophosphate of Soda.

(Bibasic phosphate.)

The commercial salt is generally in the form of a white powder, odorless, and with a hot, salted, alkaline, and then bitter taste. It is soluble in water, but not so readily as the preceding salt, and it requires distilled water, since it produces precipitates in calcareous waters.

The pyrophosphate of soda gives a white precipitate with nitrate of silver, whereas that of the ordinary tribasic phosphate is yellow.

It is employed for the preparation of gilding baths by dipping; and is obtained by fusing the ordinary dried tribasic phosphate, which by this operation loses an equivalent of combined water, and becomes *bibasic.* The temperature required is quite high, and few crucibles will stand the heat and the action of this substance which acts as a flux.

Plumbago.

(Black lead. Graphite.)

It is nearly pure carbon, and is generally found in amorphous masses in several countries, as in England, Russia, Germany, Ceylon, the United States, etc. This carbon is black, with a certain lustre, soft to the touch, without smell or taste, and is difficult to burn.

Plumbago, in the natural state, is generally mixed with a variable proportion of oxide or sulphide of iron, and earths, which should be removed by washing with hydrochloric acid.

Plumbago is not the same everywhere, especially in regard to its molecular arrangements. The best plumbago for our art is very black, and without much lustre, except after rubbing; it should firmly adhere to articles of wax and plaster of Paris, and should not become detached from them by being immersed into a liquid. The best manner of ascertaining its quality and purity is to apply a galvanoplastic deposit upon it, and the sooner it is regularly coated the better it is.

It is employed for rendering conducting certain substances which are not naturally so, and for preventing the adherence between two superposed metals. Plumbago is also used for bronzing; but, in this case, it is useless to purify it with hydrochloric acid.

When plumbago is moistened with a solution of chloride of gold in ether, and then allowed to dry in a shallow vessel exposed to solar light, we obtain the gilt *plumbago*, which is much more conducting than plumbago alone. We also manufacture a *silvered plumbago*, by calcining at a red heat, and in a closed crucible, a plumbago which has been moistened with an aqueous or ammoniacal solution of 50 to 100 grammes of nitrate of silver per kilogramme of graphite employed.

Amalgamating Salt (poisonous).

This is a triple salt of mercury, or rather a mercury salt with three acids, and is composed of the sulphate, nitrate, and bichloride of this metal. It is liquid, more or less colored, very dense, and gives in water a yellow precipitate, which is dissolved by an excess of acid. It produces a violet stain on the skin, and amalgamates copper and its alloys thoroughly and rapidly. It is used for amalgamating the zincs of batteries, and dispenses with the metallic mercury. If it is not more economical than mercury alone, it is more easily applied and prevents much trouble in gilding works. It may be substituted for the nitrate of binoxide of mercury, but the converse is not true, because nitrate of mercury, employed as amalgamating salt, rapidly perforates the zinc.

It is prepared by boiling the nitrate of binoxide of mercury upon an excess of a powder composed of equal parts of bisulphate and bichloride of mercury; the liquor only, remaining after cooling, is used.

Sulphate of Copper (poisonous).

(Blue vitriol. Blue copperas.)

This salt is manufactured in large quantities for dyeing, preserving wood, the galvanoplastic operations, etc. It is generally in the shape of large rhombric cystals, translucent and of a fine blue color. Its taste is acid, metallic, and astringent, like ink, but more persisting. By desiccation it loses its water and becomes white; and, at a higher temperature, the sulphuric acid is expelled and there remains a blackish-brown binoxide of copper. It is easily soluble in water, especially when the latter contains some free acid, and the solution is blue. Hot water dissolves much more of this salt than cold, and it crystallizes by cooling.

The solution of sulphate of copper constitutes the galvanoplastic baths proper, which are rendered more conducting by the addition of one-tenth (in volume) of sulphuric acid.

When dissolved, sulphate of copper attacks and is decomposed, without galvanic action, by certain metals such as iron, zinc, and steel, which are coated by copper. Tin and bismuth are blackened.

Many kinds of commercial sulphate of copper are impure, and hold variable proportions of the sulphates of iron and zinc, which are injurious when their amount is too great. Sulphate of zinc is detected by passing through the acid solution a current of sulphuretted hydrogen gas. The sulphide of copper produced is separated by filtration, and the clear liquor is treated by ammonia, which produces a white precipitate of oxide of zinc, soluble in an excess of alkali. The iron remains also in the acid liquor filtered from the copper, and its presence is ascertained by the red prussiate of potassa which gives a blue coloration. Another process for the detection of iron consists in adding to a small quantity of the solution of sulphate of copper, enough ammonia to dissolve all of the oxide of copper precipitated at first, and the brown oxide of iron will be seen floating in the intensely blue liquor.

The best sulphate of copper comes from the refining of silver coin by sulphuric acid, or from the solution in the same acid of the scales of copper oxide produced in rolling sheets of this metal. That obtained by the spontaneous oxidization of copper pyrites, is always contaminated with iron or zinc.

We should avoid, for our art, those cheap copper sulphates extracted from old acid dipping liquors, since they contain zinc and other metals, and also nitrate of copper with free nitric acid. Galvanoplastic baths prepared with them are a nuisance. These sulphates are generally very wet and in small crystals.

Sulphate of Protoxide of Iron.

(Green copperas. Green vitriol.)

This salt crystallizes like the preceding one, and is of a fine green color. Its taste is that of ink, and it is very soluble in water which is colored a lighter green. It is rapidly oxidized by contact with the air, and becomes yellow, then reddish, and is transformed into a sulphate of sesquioxide of iron, which possesses other properties.

By heating, sulphate of iron loses its water of crystallization and becomes white. At a red white heat, it is decomposed into sulphurous and sulphuric acids, which escape, and there remains a red and pulverulent residue which is called *colcothar*, *anhydrous sesquioxide of iron*, *English rouge*, *etc.*

The sulphate of protoxide of iron is employed for precipitating gold from its acid solutions. The sulphate of sesquioxide does not possess this property.

It is prepared, either by evaporating and crystallizing the liquors used for cleansing iron, or by the oxidization in the air of iron pyrites. The salt obtained by this latter process generally contains some copper, which is precipitated by iron scraps put in the solution.

Sulphate of Mercury (poisonous).

Mercury and sulphuric acid form two combinations; the sulphate of protoxide and that of binoxide, the latter being sometimes and wrongly, called bisulphate, the sulphate of binoxide is employed for the Marié Davy battery.

This latter salt is white, pulverulent, and more or less dry, according as it retains a less or greater proportion of acid. It is decomposed by water, especially when the latter is hot, and forms two new salts, one of which is very acid and is called the supersulphate of mercury, whereas the other is basic, and becomes precipitated as a yellow powder of subsulphate or *mineral turbith.* The subsulphate of mercury is the really useful salt of the Marié Davy battery, since the sulphate employed is always moistened.

The sulphate of binoxide of mercury is prepared by heating in a porcelain dish one part of mercury with two parts of concentrated sulphuric acid, and completely drying the product. Great quantities of sulphurous acid, and then of sulphuric acid, are disengaged during the operation, and when the end is near the paste should be constantly stirred with a glass rod.

Sulphate of Zinc.

(White vitriol. White copperas.)

The trade furnishes this salt in three forms: either in white or opaque plates, or in large transparent crystals, or in a mass formed of a quantity of needle-like crystals, resembling those of sulphate of magnesia or of tin salt.

Its taste is sour, styptic, and metallic, and it is very soluble in water which remains colorless. It is decomposed by a strong heat, and oxide of zinc forms the residue. Its neutral solutions give a white precipitate with sulphuretted hydrogen, and no precipitate is produced in acid solutions. The sulphide of zinc is the only white metallic sulphide which is known; and this is the reason why zinc paints remain white, notwithstanding the presence of sulphur gases which so rapidly blacken paints made of white lead and other metals.

Sulphate of zinc is employed for zinc and brass electro-baths, in the preparation of acids for a dead lustre, and for a frosted lustre upon clocks and jewelry.

Sulphite and Bisulphite of Soda.

The former salt forms white crystals of various sizes, which are rapidly transformed into an amorphous powder by efflorescence.

It possesses no smell, but its taste is flat and salted and sulphurous at the same time. It is very soluble in water, and is gradually transformed into sulphate by the absorption of the oxygen of the air. Powerful acids decompose it with abundant production of sulphurous acid, which is easily recognized by its smell of burning sulphur. During this reaction, the liquor remains clear, and is thus distinguished from the hyposulphite, which also disengages sulphurous acid, but deposits sulphur in the solution.

Sulphite of soda, and generally all the soluble sulphites, dissolve the salts of gold, silver, copper, etc., under certain circumstances, and transform them into double colorless salts which possess more or less stability, and are employed for electro-baths.

The sulphite of soda may absorb an excess of sulphurous acid, and thus become a bisulphite, which should always be preferred to the neutral salt.

The neutral sulphite of soda is prepared by passing a stream of sulphurous gas through a solution of carbonate of soda until the liquor neither turns red litmus paper blue, nor reddens a blue one. If the solution be very concentrated, a quantity of small crystals of bicarbonate of soda become precipitated during the middle of the operation, and should be stirred to prevent them from obstructing the gas tube. An excess of sulphurous acid decomposes them with abundant production of carbonic acid. The saturated liquor crystallizes by cooling if concentrated; in the other case it should be evaporated to a certain point.

The bisulphite of soda is produced by continuing the passage of the sulphurous gas, and the solution reddens, and even destroys the color of blue litmus paper. This salt loses in the air its excess of sulphurous gas, then becomes neutral sulphite, and, after a long while, sulphate of soda, by the absorption of oxygen.

Sulphide of Ammonium (poisonous).

(Sulphydrate or hydrosulphate of ammonia.)

This salt is liquid, and of a deeper reddish-yellow color, as it contains more sulphur. Its smell is that of a mixture of ammonia and rotten eggs, and its taste is alkaline and nauseous. The sides of the bottles in which it is kept are often covered with a pellicle of sulphur or sulphide. By rapid evaporation a residue of sulphur is left.

It rapidly forms sulphides with the metals, and produces on silver the black coating misnamed *oxidé*.

We have also seen that it is often employed for bronzing, and that it produces peculiar *patines* on the surface of various metals or alloys. It is prepared by saturating ammonia with sulphuretted hydrogen gas.

We generally employ it with an excess of sulphur, that is to say, after it has been kept for a few hours with an excess of flowers of sulphur, and at a temperature of about 70° C. The liquid is then of a dark reddish-yellow.

It may also be prepared by the decomposition of the sulphide of barium, calcium, or strontium, by carbonate of ammonia.

We should avoid opening a bottle of sulphide of ammonium in silver plating rooms.

Sulphides of Calcium, Potassium, and Sodium (poisonous).

(Livers of sulphur, or polysulphides of calcium, potassium, and sodium.)

These salts are obtained in solution by boiling the alkali and the flowers of sulphur in a certain quantity of water. They are produced in the dry way by projecting powdered quicklime, or potassa, or soda into melted sulphur, and then casting the mixture on a marble slab.

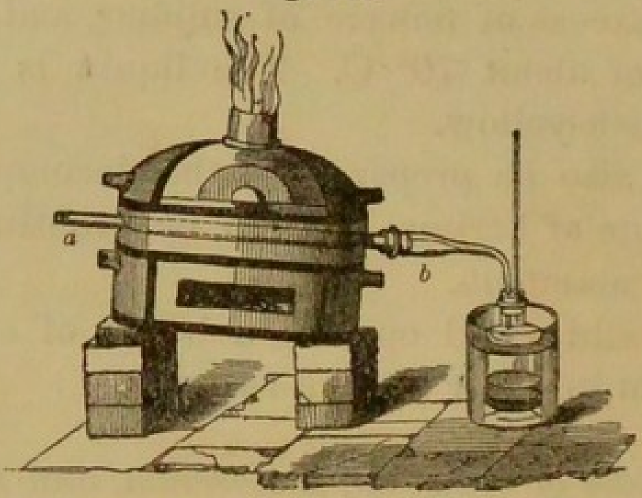
These dry sulphides are generally in the shape of plates, which are greenish or whitish at the surface, and reddish-yellow inside. They are soluble in water, which is colored yellow or red, according to the degree of concentration. By spontaneous decomposition they have the smell of rotten eggs; and, when treated by an acid, they emit sulphuretted hydrogen with a deposit of sulphur at the same time. Their uses in our art are the same as those of sulphide of ammonium.

Bisulphide of Carbon.

(Sulphide of carbon. Liquor of Lampadius.)

If we bring to a red heat a stoneware or porcelain tube (Fig. 116) filled with charcoal, and then introduce (and immediately close the aperture) fragments of sulphur into it, the liquid which results from the combination of the sulphur and carbon is condensed at the bottom of the water in the receiver, and, after a distillation in another vessel, is a pure bisulphide of carbon.

Fig. 116.

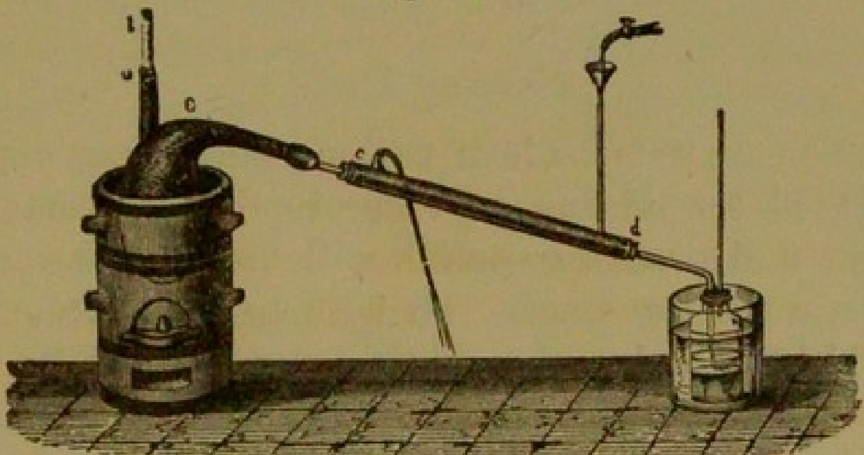


It is a colorless and transparent liquid, which is very dense, and possesses the double refraction. Its smell is characteristic, and may be compared to that of rotten turnips, or of certain gases from the intestines. It is very volatile, and produces upon the hand a disagreeable sensation of cold. It burns with a blue flame of sulphurous acid, and carbonic acid is produced at the same time. No residue is left.

Bisulphide of carbon dissolves many kinds of resins, fats, and gum resins, such as India-rubber and gutta percha, and also sulphur and phosphorus. This last solution is employed in our art for reducing the nitrate of silver to the metallic state upon certain moulds, which thus become conducting.

The apparatus for the manufacture of the bisulphide of carbon imitates on a larger scale the disposition of the fig. 117. A large stoneware retort is heated in a furnace, and carries a tubulure, through which passes a stoneware tube reaching to the bottom of the charcoal, and the upper end of which is closed by a stopper. The neck of the retort projects from the furnace, and penetrates a connecting tube fixed to a receiver filled with water. When the retort is brought to a red heat, a few fragments of sulphur are introduced by the top of the stoneware tube, which is quickly closed. The vapor of sulphur is obliged to pass through the mass of incandescent charcoal, combines with it, and condenses in the water of the receiver.

Fig. 117.



The product thus obtained contains an excess of sulphur, which is removed by distillation in a water bath. Pure bisulphide of carbon should volatilize without leaving any residue.

Sulphide of carbon is now obtained in the trade at a very low price.

CHAPTER LXIII.

INSTRUMENTS AND APPARATUS DAILY EMPLOYED IN THE ART.

Stirring Rods.

THESE are rods made of various substances, and are employed for mixing together liquids, or pastes, or liquids and pastes, or solids with liquids, or various solids in the dry state. Their length and thickness should be suited to the volumes to be mixed.

The best stirring rods are those which are without chemical action upon the substances with which they are in contact; neither should they become impregnated with them. Rods made of glass, stoneware, or porcelain are the best in most cases. Wood and most metals should be avoided, because the former is absorbing, and the latter are corroded and easily oxidized.

The operator in the various branches of our art should always have, near at hand, a complete assortment of glass stirrers of various sizes, and with melted or ground ends, in order not to scratch the vessels in which he operates.

Anodes.

We thus call the plates or wires of different metals, placed at the end of the connecting wire starting from the positive pole of a battery.

The anodes are soluble or insoluble, that is, they become dissolved under the influence of the galvanic current to partly maintain the metallic strength of the bath, or they simply bring the current into the bath without being dissolved.

Generally the soluble anodes are of the same metal with which the bath is composed; and the insoluble anodes are of platinum, graphite of gas retorts, carbon, or any other conducting and insoluble substance.

Soluble anodes are generally completely immersed in the solution, and connected with the conducting wire by other platinum wires. Insoluble anodes, on the contrary, are rarely completely immersed, and, by dipping them more or less, we increase or diminish at will the amount of electricity.

Hydrometers.

(Arometers for acids and salts.)

These are instruments generally made of glass, for ascertaining the specific gravities of liquids. There are hydrometers for acids, salts, alkalies, syrups, alcohol, ether, liquors, etc.

A great many operators think that hydrometers will not only indicate the specific gravity, but also the composition and the quality of their baths; they imagine, for instance, that if they have once had good results with a bath marking 9°, any other bath marking also 9° must be equally good. It is a great mistake, which should be corrected.

A hydrometer, in general, is an instrument intended to indicate the specific gravity of a liquid, relating to the specific gravity of distilled water at its maximum of density, that is, at 4° C. above O.

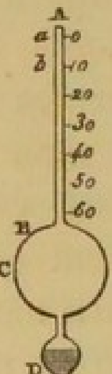
As there are liquids lighter and heavier than water, it is necessary to have two kinds of hydrometers, or rather, two different graduations of this instrument.

Baumé, an apothecary of Paris, was the first to construct a hydrometer of constant weight. It is a glass tube, the lower third of which is composed of a large bulb or cylinder, ended by a smaller bulb, in which is put a certain weight of lead or mercury acting as ballast for sinking the instrument more or less in the liquid. The cylindrical and narrow tube, above the large bulb, receives a small cylinder of paper upon which are marked the divisions or degrees of the scale.

This instrument is graduated by two different methods, according as it is intended for determining the specific gravity of liquids heavier or lighter than water at + 4° C.

If it be intended for liquids heavier than water, for acids and saline solutions, for instance, mercury or lead are put in the lower bulb until the instrument has sunk nearly to the top in water, and the 0 of the paper scale is made level with that of the liquid (Fig. 118). The hydrometer is then dipped into a solution of 15 parts of common salt (chloride of sodium) in 85 parts of distilled water, and the line where the level of the liquid touches the tube is marked 15°. The space between 0 and 15° is divided into 15 equal parts, and this graduation is continued upon the remainder of the scale. 66° is the specific gravity of concentrated sulphuric acid with Baumé's hydrometer.

Fig. 118.



For liquids lighter than water, the graduation of the preceding hydrometer is reversed (Fig. 119). The 0 is at the lower part of the stem, and is determined by plunging the instrument into a solution of 10 parts of common salt in 90 parts of water. 10° is marked at the level line in distilled water, and the space between 0 and 10° is divided into 10 equal parts, and the same graduation continued for the remainder of the scale.

Fig. 119.

A similar method may be employed for constructing special hydrometers for special saline solutions, one of common salt, for instance. The 0 of the instrument is at the level line in distilled water; 5° in a solution of 5 parts of salt in 95 of water; 10° in a solution of 10 parts of salt in 90 of water; and so on.

But such an instrument cannot be employed for determining the *composition* of different solutions; and queer mistakes would be made if we desired to ascertain the composition of a solution of nitrate of silver with an hydrometer graduated especially for one of sulphite of soda for instance. It is also evident that the same hydrometer will not do for determining the composition of a solution containing two different salts. Thus, a photographer may arrive at the composition of a pure solution of nitrate of silver with an hydrometer especially constructed for the purpose; but the same instrument will give no indication whatever as to the proportion of silver contained in an electro-silvering bath, which contains many other salts besides that of silver.

Therefore, hydrometers are useful only for verifying the degree of the acids bought, and as an indication whether the specific gravities of his baths are too much above or below the limits known for the easy passage of the galvanic current.

Glass Balloons and Flasks.

These are spheres of thin blown glass, with necks of various dimensions in length and diameter. They are employed for heating acids, dissolving metals, and a great many other uses. They should be placed upon triangular supports of iron, and at a certain distance from the fire. The thinner they are, the more easily they bear sudden changes of temperature. We prefer them to porcelain evaporating dishes, for dissolving gold, because there is much less danger of losing a part of the product by its projection outside.

Kettles and Boiling Pans.

These are of various shapes, hemispheric, or with flat bottom, and are made of different materials.

Those of copper are employed for whitening with silver and cream of tartar. Cast and sheet iron are preferable for cleansing with caustic alkalies, or for evaporating residues.

The stoneware pans or jars for desilvering (stripping), or for giving a dead lustre to copper in warm acids, are heated on sand or water baths.

The cast-iron enameled kettles are used for hot baths of copper, silver, gold, and platinum.

Notwithstanding their enamel, these vessels become gradually impregnated with the solutions they have held, and it is dangerous to employ them for other kinds of baths. Thus an enameled kettle which has been used for silvering, will not be suitable, even after the most thorough washing, for a gold bath, because the gilding will certainly be white or green, according to the quantity of silver furnished by the vessel.

Brushes.

A definition of this tool is unnecessary; and we shall simply indicate the various kinds suitable to the different operations of our art.

The gilder with fire employs, for equalizing the coat of amalgam, a long handled brush, the bristles of which are long and very stiff.

The electro-gilder uses a brush (Fig. 120) with long and flexible bristles.

For scouring with sand and pumice-stone dust those alloys holding nickel, such as maillechort and German silver, which are difficult to cleanse in acids, the preceding brush with smaller and stiffer bristles is used.


Fig. 120.

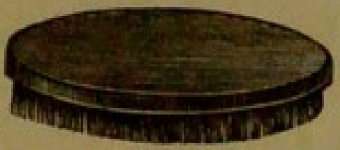


Fig. 121.


Fig. 122.

The gilder of watch-parts has an oval brush (Fig. 121), with stiff and short bristles for graining the silver.

The galvanoplastic operator, for coating moulds with plumbago, uses not only tools and pencils, but also three kinds of brushes—the watchmaker's (Fig. 122), a hat brush, and a boot-shining brush.

The bronzing operator uses all kinds of brushes.

Brushes are perfectly deprived of adherent grease by benzine or sulphide of carbon.

Burnishing Tools.

We have already described them in this work.

Evaporating Dishes or Capsules.

These are vessels of porcelain or of other ceramic paste, and are intended to bear a high temperature. The best are thin and uniformly so. The same as glass balloons and flasks, they should be supported above the fire upon an iron triangle. As far as practicable they should be gradually heated and cooled. When taken from the fire, they should be placed upon rings made of plaited straw. They are made with or without lips, and some have a socket for a wooden handle. Glass evaporating dishes are not durable.

We find in the trade several kinds of evaporating dishes:—

1. Those of Sèvres, fine, but not sufficiently refractory;
2. Those of Bayeux, tawny or bluish, which are in general use, but are open to several objections;
3. Those of Orchamp, thick, and often with a brown enamel inside. They crack at various places by the action of the fire, but do not break apart;
4. Those of the Anglo-French Co. of Saint-Gaudens, which are as white as those of Sèvres, but much more refractory. They are manufactured especially for our house.

Conducting wires, Electrodes. Reophores.

These are the names applied to the metallic wires, bands, spirals, or ribbons, which carry the electric current to the baths.

The conducting wires are either employed with their natural metallic surface, or are covered with some insulating, or poorly conducting, substance, such as cotton, silk, India-rubber, gutta percha, and various varnishes. It is evident that covered electrodes should be bare and clean at their extremities, which are connected with the battery and the anodes, or catodes (objects to be coated). Pure copper possesses the best conducting power; and after it come brass, gold, silver, platinum, iron, zinc, etc.

We do not mean that conducting wires should always be of copper; but, if two wires, one of copper, and another of iron, were starting from the same place on a battery, it is very likely that all of the electricity would preferably pass through the copper wire. On the other hand, when there is no choice, the current will pass through any kind of metallic substance.

Insulated electrodes may come in contact with each other without inconvenience. Such is not the case with bare electrodes, because the electricity will pass through the shortest circuit, and will not go through the bath if the two electrodes are in metallic contact.

Glass Jars.

These are glass vessels, generally cylindrical, closed at one end, and of very variable capacities.

They are employed for small gilding, silvering, and galvanoplastic baths in the cold. They are very handy and serviceable for amateurs, because their transparency permits of the watching of the operation at all times.

Retorts.

These are pear shaped vessels, with a neck nearly at a right angle with the body. They are with or without tubulures; and their material is glass, porcelain, stoneware, refractory clay, or metal.

They are employed for the preparation of gases or the distillation of liquids, and the product is collected in suitable receivers.

Crucibles.

These are vessels, the shape of which is generally an inverted truncated cone, the smaller end being closed, and the larger open. Sometimes the opening is triangular.

Crucibles are made of many kinds of materials: metals, refractory clay, stoneware, porcelain, plumbago or graphite, etc. They are generally provided with a cover of the same material, and are raised above the grate bars of the furnace by means of bricks or cylinders of clay.

Metallic crucibles may be heated rapidly, but the others require to have their temperature raised gradually and carefully.

They are employed for the preparation of many salts, for the fusion of metals, etc. Non-metallic crucibles are rarely used for more than one operation.

Troughs.

These are made of different substances, and their shape is circular, square, or rectangular. They should be perfectly tight, impervious to the solutions, and unacted upon by them.

Stoneware, glass, or porcelain troughs are the best; but they are brittle and expensive. Those of wrought or cast iron are suitable only for neutral or alkaline solutions, and they must be insulated from the anodes or articles plunged into them, so as not to have the galvanic current passing through them.

Wooden troughs should have their insides covered with heavy coats of varnish or pitch, resisting the action of the baths, or with a sheathing of gutta percha or India-rubber. They are sometimes lined with sheet lead, welded by the gas process, since any kind of tin solder should be discarded. Such troughs are satisfactory for galvanoplastic operations, provided that the lead lining be insulated from the electric circuit.

Diaphragms. Porous Cells.

These are vases, plates, or partitions which, from their porousness or permeability, allow liquids of different natures to be separated and connected at the same time. Thus, if we divide a trough by a partition plate, made of baked pipe clay, and fill one side with diluted sulphuric acid, and the other with a solution of potassa (both liquids being at the same level), the two liquids will penetrate the porous plate or diaphragm and there react upon each other without their masses participating in the action.

We have seen, in Daniell's battery, that the porous cell separates the exciting liquid (solution of salt or sulphuric acid) from the solution of sulphate of copper. In Grove's and Bunsen's batteries, they separate the acids; and also the acidulated liquor in the simple galvanoplastic apparatus.

Any porous substance, unacted upon by the solutions, is suitable for the manufacture of diaphragms. Wood, sail cloth, leather, gold beater's skin, bladders, baked porcelain and pipe clay, etc., are employed. Nevertheless, diaphragms or porous cells made of porcelain paste, and rendered neither too much nor too little porous by a proper baking, are preferable to all others for durability and good working.

Filters.

Filtering a solution, a bath, or any other liquor, consists in making it pass through a permeable substance, the pores or meshes of which are sufficiently closed to retain all the undissolved substances, which are thus separated from the liquid part.

Filters are of very different materials and shapes.

Cloths, calico, etc., are coarse filters made in the form of pockets. Their clean filtering power is considerably improved by covering them with a layer of sand, wool, bone black, etc. These latter substances themselves, properly fixed, will be sufficient to filter.

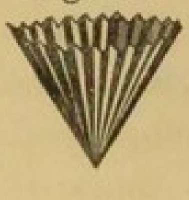
Fig. 123.

Felted wool (generally rabbit's hair) is made in the shape of a conical pocket (Fig. 123), and is suited only for neutral substances. Alkalies destroy it rapidly.

Concentrated acids are filtered upon *amianthus, or asbestos*, compressed in the neck of a glass funnel upon broken fragments of glass. Many acids may be filtered upon gun cotton.

But the most important filter for us is that made of unsized paper. This filter (Fig. 124) is prepared by folding diagonally a square piece of paper which thus prepared forms a triangle, again doubled up. Then, beginning at one edge, smaller folds are made alternately to the right and to the left, but all converging towards the point, like a fan. The filter

Fig. 124.

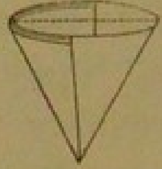


being incompletely opened, we see that the two end folds are incomplete and present surfaces requiring another fold in the middle. The filter is then trimmed on top and introduced into the funnel, with care that all the outward edges rest against it.

If it be feared that the filter will not resist the weight of the liquid, the point is twisted to the left or to the right, and while it is still held between two fingers of the left hand, the whole filter is turned over, so that the inward folds become the outward ones. A filter with such a rounded point is better supported in the funnel and filters more rapidly.

This method is preferable for rapid filtration; but if we desire to recover precipitates, the filter represented by fig. 125 is more suitable. The paper is twice doubled up, and by opening it with one finger, three thicknesses of paper are laid on one side, whereas one single thickness remains on the other side. This filter requires, however, that the angle of aperture of the funnel should be of about 60°.

Fig. 125.



A piece of straw or of paper placed between the neck of the bottle and the funnel, will permit of the escape of the air.

Sieves made of metallic, silk, or hair gauze, are nothing but more or less coarse filters.

Scratch-brushes.

We have already, in this book, given *in extenso* the description and use of these tools.

Syphons.

The most simple and handy syphon in many cases, is a piece of lead pipe bent into two unequal branches, the smaller of which plunges into the liquid to be drawn out. A piece of India-rubber tube may be employed for similar purposes.

But, as these materials may be acted upon by various solutions, glass syphons are used with or without a suction tube.

A syphon is a true balance, the pans of which are represented by columns of liquid filling the two unequal branches; the longer, and of course the heavier, column breaks the equilibrium on its side, and the liquid falls. While the liquor runs out, a vacuum cannot take place inside of the syphon, and therefore new liquor penetrates through the short branch and is carried away by the longer, as long as the short branch remains immersed.

In order to start a syphon with rigid branches, the two openings are turned up, and a certain quantity of liquor or water is poured in. When the liquid reaches the lower opening, this is closed with the thumb, and the long branch is filled. Then, closing the upper opening with the thumb of the other hand, the syphon is returned to its normal position, and the small branch plunged into the liquor. The thumb is removed first from the opening in the liquid, before the thumb closing the longer branch is withdrawn. Without this precaution air will penetrate in the syphon, and the operation will have to be begun again.

If the syphon be an India-rubber tube, it is entirely plunged into the liquid, and when filled, one extremity is closed by pinching it between the fingers, then withdrawn from the vessel, and bent into a longer branch than that remaining in the liquor.

For syphoning corrosive solutions which cannot be touched with the fingers, we employ a syphon with a suction tube. The shorter branch is plunged into the liquid, and the longer one is closed with the finger or an India-rubber pad pressed against it. Then, with the mouth, we carefully suck by the lateral suction tube until the liquid fills the longer branch.

If there be danger in inhaling, the action of the mouth may be replaced by an India-rubber ball, fastened to the suction tube. The longer branch of the syphon is closed as aforesaid, and the ball compressed in order to remove the air. By its elasticity the ball resumes its former volume, and sucks the liquor.

For pouring acids, etc., from vessels with comparatively small apertures, carboys for instance, an India-rubber cover fastened to the syphon and the aperture is employed. The air in the carboy is not sucked, but compressed by means of the small flexible tube. (Figs. 126 and 127.)

Fig. 126.

Fig. 127.

Thermometer.

It is an instrument intended for ascertaining the temperature of fluids or liquids in which it is plunged. It works by the dilatation of the mercury or colored alcohol contained in a bulb of thin glass, which is attached to a capillary tube deprived of air, and upon which the graduation is marked.

The scale employed in this work is the Centigrade or Celsius one, that is to say, where the 0 is the point of melting ice, and 100° that of boiling water.

CHAPTER LXIV.

MIXTURES.

RED OR MOULU—YELLOW OR MOULU—DEAD LUSTRE FOR JEWELRY—DEAD LUSTRE (HARD) FOR CLOCKS—DEAD LUSTRE (SOFT) FOR SMOOTH SURFACES AND FIGURES—GREEN FOR RED LUSTRE—WAX FOR GILDING.

Mixtures.

After having enumerated the principal chemical products, apparatus, and instruments employed in our art, there remains for us to give the formulæ of certain mixtures employed in gilding by fire or by the wet processes.

RED OR MOULU

Is composed of—

	Exact numbers.	Without odd numbers.
Potassa alum	28.4	30
Nitrate of potassa	31.6	30
Sulphate of zinc	8	8
Common salt	3.5	3
Red ochre	27.5	28
Sulphate of iron	1	1
	100.0	100

We may add to it a small proportion of annotto, madder, cochineal, or other coloring matter, ground in water or in weak vinegar.

YELLOW OR MOULU.

	Exact numbers.	Without odd numbers.
Red ochre	16.5	17
Potassa alum	50.9	50
Sulphate of zinc	10.5	10
Common salt	2.1	3
Nitrate of potassa	20	20
	100.0	100

DEAD LUSTRE FOR JEWELRY.

Sulphate of iron	Equal parts of each.
Sulphate of zinc	
Potassa alum	
Nitrate of potassa	

All the salts are melted in their water of crystallization; and if the gilding be strong and durable, a small proportion of common salt may be added.

DEAD LUSTRE (HARD) FOR CLOCKS.

	Exact numbers.	Without odd numbers.
Water	5	5
Nitrate of potassa	36.62	37
Potassa alum	42.05	42
Common salt	12.33	12
Pulverized glass and sulphate of lime	4	4
	100.00	100

The whole is thoroughly ground and mixed.

DEAD LUSTRE (SOFT) FOR SMOOTH SURFACES AND FIGURES.

	Exact numbers.	Without odd numbers.
Water	5	5
Nitrate of potassa	46.32	46
Potassa alum	45.82	46
Common salt	2.86	3
	100.00	100

The same treatment as the preceding mixture.

GREEN FOR RED LUSTRE.

	Exact numbers.	Without odd numbers.
Bitartrate of potassa	65.7	65
Common salt	25	25
Acetate of copper	9.3	10
	100.0	100

The whole is ground together.

WAX FOR GILDING.

Oil	25
Yellow wax	25
Acetate of copper	13
Red ochre or sanguine	37
	100

The whole is melted, and kept stirred until cold.

CHAPTER LXV.

OF GENERAL USEFULNESS.

ANTIDOTES AND HYGIENE OF THE WORKSHOP.

We have seen that the majority of the chemical products employed in our art are very poisonous, or at least unhealthy. It is therefore our duty, after having pointed out the dangerous substances, to furnish the means of neutralizing their effects, either entirely, or at least sufficiently so to await the coming of the professional doctor.

We shall also state the precautions which the operator should take for avoiding the effects of the noxious gases and vapors which often surround him.

Poisons may be introduced into the animal system in three different ways:—

1. Through the *organs of respiration* when they are gaseous, or in vapors, or in powders sufficiently light to float in the atmosphere;

2. By *endermic absorption*, that is, when in contact with the skin, they may be more or less rapidly absorbed;

3. By *deglutition*, when they are introduced into the stomach either as liquids or solids.

Although each poison has a peculiar mode of action, we may place in four categories those which now occupy our attention.

Those of the first category corrode and disorganize the tissues with which they are in contact; and such are the concentrated acids and alkalies, and also certain metallic or organic salts.

The second category comprises those which are without immediate action upon the organs, but become dangerous when they have passed into the circulation; such are diluted acids and alkalies, and many substances of animal or vegetable origin.

The poisons of the third category seem to attack certain particular organs, for instance, the brain, the spinal marrow, or the heart, etc.; such are the cyanogen compounds.

The fourth category is composed of those which act more or less rapidly and powerfully upon the bronchiæ and lungs, and produce suffocation or asphyxia; such are certain deleterious gases, like chlorine, sulphuretted hydrogen, sulphurous acid, ammonia, etc.

We shall now examine those poisons to which the operator in our art is the most exposed.

Poisoning by Acids.

All the powerful acids, with the exception of hydrocyanic (prussic) acid, operate nearly in the same manner. Their action is the more energetic as they are more concentrated.

We should not forget that, when very diluted, these substances lose their poisonous properties; WATER, therefore, in the greatest abundance will be the first thing to give. Tepid water and distilled water will act as emetics, and should be preferred if they are at hand. Milk and the white of eggs, which coagulate with the acids and partly neutralize them, may be successfully employed; but nothing is better than CALCINED MAGNESIA, or the carbonate of this base, which may be introduced into the stomach without danger, and will completely neutralize the acids, forming with them purgative salts. In the absence of magnesia, we will use chalk or Spanish white made into a paste with water, or even soap water. Even egg-shells may be employed. It should be well understood that in this, and any other case, the remainder of the treatment should be continued by a regular doctor.

Poisoning by Hydrocyanic (Prussic) Acid, Cyanogen, or Cyanides.

If hydrocyanic acid or cyanides be concentrated or absorbed in large proportions, their action is as rapid as lightning, and there is little hope of saving the victim, although everything should be tried.

But, if these substances be diluted, and allow of time for remedying them, we may say that the danger is in inverse ratio with the length of time past since they were absorbed.

In this kind of poisoning, the *coldest water possible* should be run upon the head and the spine of the patient, and he should be made to inhale, *carefully and moderately*, chlorine gas, chlorine water, bleaching powder, or Javel water (hypochlorite of soda).

Should these poisons be introduced into the stomach, we should administer as soon as possible the hydrate of sesquioxide of iron, or, what is better, diluted solutions of the acetate, citrate or tartrate of iron. With proper precautions, a very diluted solution of sulphate of zinc may be given.

Poisoning by Alkalies.

We should use weak acids, such as vinegar, lemon juice, etc., and, in their absence, sulphuric, hydrochloric, or nitric acid diluted to the strength of lemonade. After the pain in the stomach has been diminished, it is well to give a few spoonfuls of olive oil.

Poisoning by most Metallic Salts.

An abundance of water, and the patient made to VOMIT when practicable. Milk and whites of eggs are very good, but far inferior to *flowers of sulphur* or natural sulphurous waters, like those of Barèges, Pulna, or Enghien. The sulphur, alkaline sulphides, and sulphuretted hydrogen contained in these waters transform into insoluble sulphides, which are temporarily inert, most of the metallic salts. They should be administered as long as there is a suspicion that any of the poison is still retained in the system.

Poisoning by Mercury Salts.

Mercury salts, and particularly the bichloride (corrosive sublimate), form with the white of eggs (albumen) a compound entirely insoluble and inert. The remedy is therefore indicated. Sulphur and sulphuretted water are also convenient for the purpose.

Poisoning by Lead Salts.

Besides sulphur and sulphuretted waters, we may also employ a lemonade of sulphuric acid, or an alkaline solution holding gaseous carbonic acid, such as Vichy water. Bicarbonate of soda is good.

Poisoning by Hydrosulphuric Acid (Sulphuretted Hydrogen).

The patient should be made to inhale carefully chlorine water, Javel water, or bleaching powder. Energetic friction, especially at the extremities of the limbs. Large quantities of warm and emollient drinks. Exposure in the open air from the beginning.

Poisoning by Chlorine, Sulphurous Acid, Nitrous and Hyponitric Gases.

A great deal of fresh AIR, and LIGHT inspirations of ammonia. An abundance of hot drinks. Friction, in order to preserve the heat and perspiration of the skin. Hot foot-baths, to remove the blood from the lungs. Afterwards maintain in the mouth of the patient some substance which, melting slowly, keeps the throat moist, such as jujube and marshmallow paste, molasses candy, and liquorice paste. Milk is excellent.

We wish to have it well understood, that we do not pretend to take the place of a regular professional doctor, and that we have simply stated the first cares and remedies to be taken in urgent cases. None of these precautions, no matter what be the results obtained, should dispense with the care of the doctor, who alone will be able fully to counteract the shock produced by the poison in the vital system.

HYGIENE OF THE WORKSHOP.

The operator who is constantly exposed to the action of acid gases or vapors will more or less neutralize their effects by alkaline drinks, as Vichy water or a decoction of liquorice root, with a spoonful of magnesia or bicarbonate of soda per litre of liquor. The enamel of his teeth will be preserved by eating now and then a little of these alkalies.

The cyanide solutions occasion by their contact with the hands very painful crevices, which are felt from the finger nails to the shoulders. The remedy is a wash of very dilute sulphuric acid, or a solution of sulphate of zinc. But what is preferable is friction with a kind of pomatum made by beating some fat oil with an excess of lime-water. This lime-water is prepared by slaking in one litre of water one piece of quick-lime of the size of a walnut, stirring, and decanting the clear liquid.

Mercury gilders will, every morning before their work, take a spoonful of a mixture of equal parts of sulphur and honey. They will also drink sulphuretted waters. Alternate Barèges and vapor-baths will be highly beneficial. These gilders should well understand that prevention is much better than cure.

This same treatment is equally well adapted to those who polish copper, who should also dip their hands into a concentrated solution of chloride of calcium. This salt, which keeps the hands moist, prevents the absorption of oil saturated with copper. Every evening they may use a wash of water holding some ammonia.

Fresh gold and silver stains on the skin are removed by solutions of sulphite or hyposulphite of soda, or with those of the iodide, bromide, and cyanide of potassium. Old stains require a first washing with concentrated acetic acid, followed by one in cyanide of potassium.

Clothes stained with acids (except nitric acid) will have nearly always their primitive color restored by a diluted solution of ammonia, or of carbonate of ammonia. Should concentrated ammonia be put upon a recent stain of a concentrated acid, the heat produced by the reaction will be sufficient to completely disorganize the tissue, and produce a hole.

APPENDIX.

THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

The United States being the first to introduce the decimal system into the coinage of the country, and to demonstrate its superior utility, it is remarkable that we have hesitated so long in regard to the substitution of the same simple and rational system of weights and measures for the complicated and confused standards in general use.

In May, 1866, the Committee on Coinage, Weights, and Measures presented to the House of Representatives an exhaustive report, accompanied by bills authorizing the introduction of the *metric system* into the various departments of trade, and making all contracts, based on this system of weights and measures, valid before any court in the United States. They said:—

"THE METRIC SYSTEM.

"It is orderly, simple, and perfectly harmonious, having useful relations between all its parts. It is based on the METER, which is the principal and only arbitrary unit. The meter is a measure of length, and was intended to be, and is, very nearly one ten-millionth of the distance on the earth's surface from the equator to the pole. It is 39.37 inches, very nearly.

"The *are* is a surface equal to a square whose side is 10 meters. It is nearly four square rods.

"The *liter* is the unit for measuring capacity, and is equal to the contents of a cube whose edge is a tenth part of the meter. It is a little more than a wine quart.

"The *gramme* is the unit of weight, and is the weight of a cube of water, each edge of the cube being one one-hundredth of the meter. It is equal to 15.432 grains.

"The *stere* is the cubic meter.

"Each of these units is divided decimally, and larger units are formed by multiples of 10, 100, &c. The successive multiples are designated by the prefixes, *deka*, *hecto*, *kilo*, and *myria*; the subordinate parts by *deci*, *centi*, and *milli*, each having its own numerical significance.

"The nomenclature, simple as it is in theory, and designed from its origin to be universal, can only become familiar by use. Like all strange words, these will become familiar by custom, and obtain popular abbreviations. A system which has incorporated with itself so many different series of weights, and such a nomenclature as 'scruples,' 'pennyweights,' 'avoirdupois,' and with no invariable component word, can hardly protest against a nomenclature whose leading characteristic is a short component word with a prefix signifying number. We are all familiar with *thermometer*, *barometer*, *diameter*, *gasometer*, &c., with *telegram*, *monogram*, &c., words formed in the same manner.

"After considering every argument for a change of nomenclature, your committee have come to the conclusion that any attempt to conform it to that in present use would lead to confusion of weights and measures, would violate the early learned order and simplicity of metric denomination, and would seriously interfere with that universality of system so essential to international and commercial convenience.

"When it is remembered that of the value of our exports and imports, in the year ending June 30, 1860, in all $762,000,000, the amount of near $700,000,000 was with nations and their dependencies that have now authorized, or taken the preliminary steps to authorize, the metric system, even denominational uniformity for the use of accountants in such vast transactions assumes an important significance. In words of such universal employment, each word should represent the identical thing intended, and no other, and the law of association familiarizes it.

"Your committee unanimously recommend the passage of the bills and joint resolutions appended to this report. . . . . . The metric system is already used in some arts and trades in this country, and is especially adapted to the wants of others. Some of its measures are already manufactured at Bangor, in Maine, to meet an existing demand at home and abroad. The manufacturers of the well-known Fairbanks' scales state: 'For many years we have had a large export demand for our scales with French weights, and the demand and sale are constantly increasing.' Its minute and exact divisions specially adapt it to the use of chemists, apothecaries, the finer operations of the artisan and to all scientific objects. It has always been and is now used in the United States coast survey. Yet in some of the States, owing to the phraseology of their laws, it would be a direct violation of them to use it in the business transactions of the community. It is, therefore, very important to legalize its use, and to give to the people, or that portion of them desiring it, the opportunity for its legal employment, while the knowledge of its characteristics will be thus diffused among men."

TABLES

SHOWING THE

RELATIVE VALUES OF FRENCH AND ENGLISH WEIGHTS AND MEASURES, &c.

Measures of Length.

Millimetre	=	0.03937	inch.
Centimetre	=	0.393708	"
Decimetre	=	3.937079	inches.
Metre	=	39.37079	"
"	=	3.2808992	feet.
"	=	1.093633	yard.
Decametre	=	32.808992	feet.
Hectometre	=	328.08992	"
Kilometre	=	3280.8992	"
"	=	1093.633	yards.
Myriametre	=	10936.33	"
"	=	6.2138	miles.
Inch ($\frac{1}{36}$ yard)	=	2.539954	centimetres.
Foot ($\frac{1}{3}$ yard)	=	3.0479449	decimetres.
Yard	=	0.91438348	metre.
Fathom (2 yards)	=	1.82876696	"
Pole or perch (5½ yards)	=	5.029109	metres.
Furlong (220 yards)	=	201.16437	"
Mile (1760 yards)	=	1609.3149	"
Nautical mile	=	1852	"

Superficial Measures.

Square millimetre	=	$\frac{1}{645}$	square inch.
“ “	=	0.00155	“ “
“ centimetre	=	0.155006	“ “
“ decimetre	=	15.50059	“ inches.
“ “	=	0.107643	“ foot.
“ metre or centiare	=	1550.05989	“ inches.
“ “ “	=	10.764299	“ feet.
“ “ “	=	1.196033	“ yard
Are	=	1076.4299	“ feet.
“	=	119.6033	“ yards.
“	=	0.098845	rood.
Hectare	=	11960.3326	square yards.
“	=	2.471143	acres.
Square inch	=	645.109201	square millimetres.
“ “	=	6.451367	“ centimetres
“ foot	=	9.289968	“ decimetres.
“ yard	=	0.836097	“ metre.
“ rod or perch	=	25.291939	“ metres.
Rood (1210 sq. yards)	=	10.116775	ares.
Acre (4840 sq. yards)	=	0.404671	hectare.

Measures of Capacity.

Cubic millimetre	=	0.000061027	cubic inch.
“ centimetre or millilitre	=	0.061027	“ “
10 “ centimetres or centilitre	=	0.61027	“ “
100 “ “ “ decilitre	=	6.102705	“ inches.
1000 “ “ “ litre	=	61.0270515	“ “
“ “ “ “ “	=	1.760773	imp'l pint.
“ “ “ “ “	=	0.2200967	“ gal'n.
Decalitre	=	610.270515	cubic inches.
“	=	2.2009668	imp. gal'ns.
Hectolitre	=	3.531658	cubic feet.
“	=	22.009668	imp. gal'ns.
Cubic metre or stere or kilolitre	=	1.30802	cubic yard.
“ “ “	=	35.3165807	“ feet.
Myrialitre	=	353.165807	“ “

Cubic inch = 16.386176 cubic centimetres.
" foot = 28.315312 " decimetres.
" yard = 0.764513422 " metre.

American Measures.

Winchester or U.S. gallon (231 cub. in.) = 3.785209 litres.
" " bushel (2150.42 cub. in.) = 35.23719 "
Chaldron (57.25 cubic feet) = 1621.085 "

British Imperial Measures.

Gill = 0.141983 litre.
Pint (⅛ gallon) = 0.567932 "
Quart (¼ gallon) = 1.135864 "
Imperial gallon (277.2738 cub. in.) = 4.54345797 litres.
Peck (2 gallons) = 9.0869159 "
Bushel (8 gallons) = 36.347664 "
Sack (3 bushels) = 1.09043 hectolitre.
Quarter (8 bushels) = 2.907813 hectolitres.
Chaldron (12 sacks) = 13.08516 "

Weights.

Milligramme = 0.015438395 troy grain.
Centigramme = 0.15438395 " "
Decigramme = 1.5438395 " "
Gramme = 15.438395 " grains.
" = 0.643 pennyweight.
" = 0.0321633 oz. troy.
" = 0.0352889 oz. avoirdupois.
Decagramme = 154.38395 troy grains.
" = 5.64 drachms avoirdupois.
Hectogramme = 3.21633 oz. troy.
" = 3.52889 oz. avoirdupois.
Kilogramme = 2.6803 lbs. troy.
" = 2.205486 lbs. avoirdupois.
Myriagramme = 26.803 lbs. troy.
" = 22.05486 lbs. avoirdupois.
Quintal metrique = 100 kilog. = 220.5486 lbs. avoirdupois.
Tonne = 1000 kilog. = 2205.486 " "

Different authors give the following values for the gramme:—

Gramme = 15.44402 troy grains.
" = 15.44242 "
" = 15.4402 "
" = 15.433159 "
" = 15.43234874 "

AVOIRDUPOIS.

Long ton = 20 cwt. = 2240 lbs. = 1015.649 kilogrammes.
Short ton (2000 lbs.) = 906.8296 "
Hundred weight (112 lbs.) = 50.78245 "
Quarter (28 lbs.) = 12.6956144 "
Pound = 16 oz. = 7000 grs. = 453.4148 grammes.
Ounce = 16 dr'ms. = 437.5 grs. = 28.3375 "
Drachm = 27.344 grains = 1.77108 gramme.

TROY (PRECIOUS METALS).

Pound = 12 oz. = 5760 grs. = 373.096 grammes.
Ounce = 20 dwt. = 480 grs. = 31.0913 "
Pennyweight = 24 grs. = 1.55457 gramme.
Grain = 0.064773 "

APOTHECARIES' (PHARMACY).

Ounce = 8 drachms = 480 grs. = 31.0913 gramme.
Drachm = 3 scruples = 60 grs. = 3.8869 "
Scruple = 20 grs. = 1.29546 gramme.

CARAT WEIGHT FOR DIAMONDS.

1 carat = 4 carat grains = 64 carat parts.
" = 3.2 troy grains.
" = 3.273 " "
" = 0.207264 gramme
" = 0.212 "
" = 0.205 "

Great diversity in value.

Proposed Symbols for Abbreviations.

M—myria — 10000	Mm	Mg	Ml	
K—kilo — 1000	Km	Kg	Kl	
H—hecto — 100	Hm	Hg	Hl	Ha
D—deca — 10	Dm	Dg	Dl	Da
Unit — 1	metre—m	gramme—g	litre—l	are—a
d—deci — 0.1	dm	dg	dl	da
c—centi — 0.01	cm	cg	cl	ca
m—milli — 0.001	mm	mg	ml	

Km = Kilometre. Hl = Hectolitre. cg = centigramme. c. cm = $\overline{\mathrm{cm}}^3$ = cubic centimetre. $\overline{\mathrm{dm}}^2$ = sq. dm = square decimetre. Kgm = Kilogrammetre. Kg° = Kilogramme degree.

Celsius or Centigrade.	Fahrenheit.	Réaumur.
— 15°	+ 5°	— 12°
— 10	+ 14	— 8
— 5	+ 23	— 4
0 melting	+ 32	ice 0
+ 5	+ 41	+ 4
+ 10	+ 50	+ 8
+ 15	+ 59	+ 12
+ 20	+ 68	+ 16
+ 25	+ 77	+ 20
+ 30	+ 86	+ 24
+ 35	+ 95	+ 28
+ 40	+104	+ 32
+ 45	+113	+ 36
+ 50	+122	+ 40
+ 55	+131	+ 44
+ 60	+140	+ 48
+ 65	+149	+ 52
+ 70	+158	+ 56
+ 75	+167	+ 60
+ 80	+176	+ 64
+ 85	+185	+ 68
+ 90	+194	+ 72
+ 95	+203	+ 76
+100 boiling	+212	water + 80
+200	+392	+160
+300	+572	+240
+400	+752	+320
+500	+932	+400

1° C. = 1°.8 Ft. = $\frac{9}{5}$° Ft. = 0°.3 R. = $\frac{4}{5}$° R.

1° C. × $\frac{9}{5}$ = 1° Ft. 1° Ft. × $\frac{5}{9}$ = 1° C. 1° R. × $\frac{9}{4}$ =1° Ft.

1° C. × $\frac{4}{5}$ = 1° R. 1° Ft. × $\frac{4}{9}$ = 1° R. 1° R. × $\frac{5}{4}$ =1° C.

Calorie (French) = unit of heat
= kilogramme degree } English.

It is the quantity of heat necessary to raise 1° C. the temperature of 1 kilogramme of distilled water.

Kilogrammetre = Kgm = the power necessary to raise 1 kilogramme, 1 metre high, in one second. It is equal to $\frac{1}{75}$ of a French horse power. An English horse power = 550 foot pounds, while a French horse power = 542.7 foot pounds.

Ready-made Calculations.

No. of units.	Inches to centimetres.	Feet to metres.	Yards to metres.	Miles to Kilometres.	Millimetres to inches.
1	2.53995	0.3047945	0.91438348	1.6093	0.03937079
2	5.0799	0.6095890	1.82876696	3.2186	0.07874158
3	7.6199	0.9143835	2.74315044	4.8279	0.11811237
4	10.1598	1.2197680	3.65753392	6.4373	0.15748316
5	12.6998	1.5239724	4.57191740	8.0466	0.19685395
6	15.2397	1.8287669	5.48630088	9.6559	0.23622474
7	17.7797	2.1335614	6.40068436	11.2652	0.27559553
8	20.3196	2.4383559	7.31506784	12.8745	0.31496632
9	22.8596	2.7431504	8.22945132	14.4838	0.35433711
10	25.3995	3.0479450	9.14383480	16.0930	0.39370790

No. of units.	Centimetres to inches.	Metres to feet.	Metres to yards.	Kilometres to miles.	Square inches to square centimetres.
1	0.3937079	3.2808992	1.093633	0.6213824	6.45136
2	0.7874158	6.5617984	2.187266	1.2427648	12.90272
3	1.1811237	9.8426976	3.280899	1.8641472	19.35408
4	1.5748316	13.1235968	4.374532	2.4855296	25.80544
5	1.9685395	16.4044960	5.468165	3.1069120	32.25680
6	2.3622474	19.6853952	6.561798	3.7282944	38.70816
7	2.7559553	22.9662944	7.655431	4.3496768	45.15952
8	3.1496632	26.2471936	8.749064	4.9710592	51.61088
9	3.5433711	29.5280928	9.842697	5.5924416	58.06224
10	3.9370790	32.8089920	10.936330	6.2138240	64.51360

No. of units.	Square feet to sq. metres.	Sq. yards to sq. metres.	Acres to hectares.	Square centimetres to sq. inches.	Sq. metres to sq. feet.
1	0.0929	0.836097	0.404671	0.155	10.7643
2	0.1858	1.672194	0.809342	0.310	21.5286
3	0.2787	2.508291	1.204013	0.465	32.2929
4	0.3716	3.344388	1.618684	0.620	43.0572
5	0.4645	4.180485	2.023355	0.775	53.8215
6	0.5574	5.016582	2.428026	0.930	64.5858
7	0.6503	5.852679	2.832697	1.085	75.3501
8	0.7432	6.688776	3.237368	1.240	86.1144
9	0.8361	7.524873	3.642039	1.395	96.8787
10	0.9290	8.360970	4.046710	1.550	107.6430

No. of units.	Square metres to sq. yards.	Hectares to acres.	Cubic inches to cubic centimetres.	Cubic feet to cubic metres.	Cubic yards to cubic metres.
1	1.196033	2.471143	16.3855	0.02831	0.76451
2	2.392066	4.942286	32.7710	0.05662	1.52902
3	3.588099	7.413429	49.1565	0.08494	2.29354
4	4.784132	9.884572	65.5420	0.11325	3.05805
5	5.980165	12.355715	81.9275	0.14157	3.82257
6	7.176198	14.826858	98.3130	0.16988	4.58708
7	8.372231	17.298001	114.6985	0.19819	5.35159
8	9.568264	19.769144	131.0840	0.22651	6.11611
9	10.764297	22.240287	147.4695	0.25482	6.88062
10	11.960330	24.711430	163.8550	0.28315	7.64513

No. of units.	Cubic centimetres to cubic inches.	Litres to cubic inches.	Hectolitres to cubic feet.	Cubic metres to cubic feet.	Cubic metres to cubic yards.
1	0.06102	61.02705	3.5317	35.31659	1.30802
2	0.12205	122.05410	7.0634	70.63318	2.61604
3	0.18308	183.08115	10.5951	105.94977	3.92406
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6	0.36617	366.16230	21.1902	211.89954	7.84812
7	0.42720	427.18935	24.7219	247.21613	9.15614
8	0.48823	488.21640	28.2536	282,53272	10.46416
9	0.54926	549.24345	31.7853	317.84931	11.77218
10	0.61027	610.27050	35.3166	353.16590	13.08020

No. of units.	Grains to grammes.	Ounces avoir. to grammes.	Ounces troy to grammes.	Pounds avoir. to kilogrammes.	Pounds troy to kilogrammes.
1	0.064773	28.3375	31.0913	0.4534148	0.373096
2	0.129546	56.6750	62.1826	0.9068296	0.746192
3	0.194319	85.0125	93.2739	1.3602444	1.119288
4	0.259092	113.3500	124.3652	1.8136592	1.492384
5	0.323865	141.6871	155.4565	2.2670740	1.865480
6	0.388638	170.0250	186.5478	2.7204888	2.238576
7	0.453411	198.3625	217.6391	3.1739036	2.611672
8	0.518184	226.7000	248.7304	3.6273184	2.984768
9	0.582957	255.0375	279.8217	4.0807332	3.357864
10	0.647730	283.3750	310.9130	4.5341480	3.730960

No. of units.	Long tons to tonnes of 1000 kilog.	Pounds per square inch to kilogrammes per square centimetre.	Grammes to grains.	Grammes to ounces avoir.	Grammes to ounces troy.
1	1.015649	0.0702774	15.438395	0.0352889	0.0321633
2	2.031298	0.1405548	30.876790	0.0705778	0.0643266
3	3.046947	0.2108322	46.315185	0.1058667	0.0964899
4	4.062596	0.2811096	61.753580	0.1411556	0.1286532
5	5.078245	0.3513870	77.191975	0.1764445	0.1608165
6	6.093894	0.4216644	92.630370	0.2117334	0.1929798
7	7.109543	0.4919418	108.068765	0.2470223	0.2251431
8	8.125192	0.5622192	123.507160	0.2823112	0.2573064
9	9.140841	0.6324966	138.945555	0.3176001	0.2894697
10	10.156490	0:7027740	154.383950	0.3528890	0.3216330

No. of units.	Kilogrammes to pounds avoirdupois.	Kilogrammes to pounds troy.	Metric tonnes of 1000 kilog to long tons of 2240 pounds.	Kilog. per square millimetre to pounds per square inch.	Kilog. per square centimetre to pounds per square inch.
1	2.205486	2.6803	0.9845919	1422.52	14.22526
2	4.410972	5.3606	1.9691838	2845.05	28.45052
3	6.616458	8.0409	2.9537757	4267.57	42.67578
4	8.821944	10.7212	3.9383676	5690.10	56.90104
5	11.027430	13.4015	4.9229595	7112.63	71.12630
6	13.232916	16.0818	5.9075514	8535.15	85.35156
7	15.438402	18.7621	6.8921433	9957.68	99.57682
8	17.643888	21.4424	7.8767352	11380.20	113.80208
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