We propose still to identify the volatile and non-volatile acids found in such small quantities, but as it will require probably several years to collect the material for this work, it has seemed best to give the results so far obtained at the present time.

THE CASSEL-HINMAN GOLD AND BROMINE PROCESS.

By Parker C. McIlhiney.

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THIS process, recently introduced by the Gold & Bromine Co., is for the extraction of gold from low grade ores, and those which will not give up their gold to amalgamation. If an ore is free milling no process yet devised can compete with amalgamation for its treatment, and if it is of sufficiently high grade to bear transportation and smelting charges, and contains nothing to interfere with the process of smelting, there is comparatively little inducement to use a wet process. But for ores such as the telluride ores of Colorado, which will not amalgamate, and in which the gold and tellurium compounds are of such a friable nature that they cannot be concentrated, and which are in addition of too low grade to smelt, some wet process must be used. The wet processes which have proved commercially successful are chlorination and the cyanide process. Of the cyanide process nothing need be said except that on many ores it has been used very successfully and from many others it fails to extract a sufficiently high percentage of the gold present. Chlorination has, after being the subject of a great deal of experimenting, been reduced practically to two methods of operation: the vat process, in which the ore is treated with chlorine gas and water, without agitation, and the Thies barrel process, in which the ore is agitated in a revolving barrel with water, bleaching powder, and oil of vitrol. Of the two the barrel process is more generally applicable as the ore cannot be leached in vats unless it is comparatively free from slime and allows the liquid to pass through it readily. The barrel process is recognized generally as better practice. It is evident that in the vat process the strongest solution of chlorine which can at any time be in contact with the ore will be an aqueous solution saturated at the ordinary temperature and pressure, because it

is impracticable to place the vats under pressure. In the barrel process it has also been found impracticable, on account of mechanical difficulties, to treat the ore with chlorine under any considerable pressure, and, therefore, in the Thies process the strength of the chlorine solution is almost as limited as in the vat process, and moreover it has been found impracticable to introduce the chlorine in the Thies process as free chlorine, and it is now made entirely by means of bleaching powder and oil of vitriol, introduced with the ore. In order to effect the solution of the gold in the ore in a reasonably short time it is not sufficient to introduce a *small* excess of chlorine but a very large excess must be used to so hasten the solution as to bring the time within permissible limits. This excess of chlorine goes to waste, and although very many attempts have been made to recover it, none have ever proved practicable. The only safe way to get the gold out is to use as large an excess of chlorine as possible, and as the solubility of chlorine in water prevents the use of more than a small amount, it sometimes happens, even with careful working, that the ore being improperly roasted no gold is obtained at all.

As a substitute for chlorine, bromine has been used by many experimenters, and its use has been attempted in mills by a simple substitution of bromine for chlorine. But as bromine is very expensive its use without recovery has not been successful.

The properties of the two halogens, as far as concerns their use on ores, are about as follows :

Bromine is, at ordinary temperature, a liquid, boiling at 63° C., and which may be easily liquified again by a condenser supplied with cold water.

Chlorine is a gas which must, according to Nieman,[1] be placed under a pressure of six atmospheres at 0° C. in order to liquefy it, or cooled to —35° C. to condense it without pressure.

Bromine is soluble in water at 15° C. to the extent of three and two tenths per cent; this means about 25.5 pounds in 100 gallons of water.

Chlorine is soluble in water to the extent of about 0.76 per

[1] Brandes Arch., 36, 18 ; Dammer, Handb. Anorg. Chem., 1. 474.

cent. at 15° C.; this means about six pounds in 100 gallons of water.

Bromine is a much less powerful oxidizing agent than chlorine, and, as a result of this fact, oxidizable materials such as pyrites are much less acted upon by bromine than by chlorine. In fact it is possible to treat with bromine water pyrites containing gold and extract most of the gold as bromide without attacking much pyrites, which it is not possible to do with chlorine water.

Bromine dissolves gold more easily than chlorine. The experiments made by T. K. Rose, at the Royal Mint in England, recorded in his "Metallurgy of Gold," page 242, show that a saturated solution of chlorine in water, that is about 0.76 per cent. of chlorine, dissolved 57.6 parts of gold, while a two-tenths per cent. solution of bromine in water, less than one-third the strength of the chlorine, dissolved under exactly similar circumstances, 58.1 parts of gold.

These facts will render it very evident that if some means can be devised for recovering the bromine which has been used in the treatment of the ore much better results can be obtained than can be obtained by chlorination. Several plans have been devised for accomplishing this result, but only one has as yet been put into practical working in a mill. It consists in adding to the liquor which has acted upon the ore, and which stills contains a large excess of bromine as well as some bromides, sufficient chlorine or oxidizing agent and acid to liberate the bromine from the bromides and then to distil off the bromine by steam. The amount of liquid which it is necessary to distil off in order to free an aqueous solution of bromine from its bromine is surprisingly small. Using a solution of about fifteen pounds in 100 gallons the bromine is practically gone when about five per cent. of the liquid has distilled over. The liquid thus freed from bromine is in an ideal condition for the precipitation of gold, and this may be accomplished by any convenient method. It will then be seen that the process is in the main identical with chlorination as far as apparatus is concerned, except that to the liquid an addition of chemicals is made and

it is then heated up by steam and a small portion distilled off before precipitation.

The necessary steps may be stated as follows:

1. Crushing the ore preferably in a Blake crusher.
2. Drying.
3. Reducing to twenty to thirty mesh preferably by rolls.
4. Roasting, unless it is already almost completely oxidized.
5. Treating with bromine solution, preferably by agitation in a barrel, under some circumstances also by percolation in vats.
6. Drawing off the liquor and washing the ore with weak wash water from a previous operation, and after that either with water, or else with liquor from which the gold has been precipitated in a previous operation.
7. Adding to the strong liquor from leaching the ore sufficient chlorine, bleaching powder and acid, potassium permanganate and acid, or some other oxidizing agent, in sufficient quantity to liberate the bromine present as bromides.
8. Distilling off the bromine by steam.
9. Precipitating the gold.

With regard to the reduction of the ore to a proper fineness nothing need be said. It should be done exactly as if the ore were to be treated by chlorination.

The roasting, however, need not with ores which lose gold on roasting be carried so far as if the ore were to be chlorinated. The reasons why this is true are evident from a consideration of what has been said with regard to the differences in properties between chlorine and bromine; the less powerful oxidizing action of the bromine, the greater solvent power on the gold, and above all the possibility of making a strong solution of bromine, while in chlorination the solution is weak, render it possible to stop the roasting at a very much less perfect degree. The advantages of this will be apparent when the losses in gold, which occur during the last stages of roasting, are taken into account,[1] losses which result both from the volatility of the gold itself, and also from the fine particles being carried away by the current of air in the furnace. In roasting tellurides especially the losses in gold are enormous if the roasting is carried

[1] Rose, Metallurgy of Gold, p. 222.

too far. Küstel records the loss of twenty per cent. of the gold present during the oxidizing roasting of certain tellurides of gold and silver, and states that it is not a mechanical loss, but is due to volatilization. Rose records many other results which place beyond doubt the great advantage of restricting the roasting as much as possible. This loss of gold toward the end of the roasting causes one of the greatest difficulties in chlorination. Since one per cent. of sulphur requires 200 pounds of chlorine per ton of ore, the loss must be borne because it is necessary to carry on the roasting to a high degree, otherwise no gold at all, or only a part, will be obtained.

The mechanical treatment of the ore during the action of the bromine upon it is not different in any material way from the treatment with chlorine; the ore is charged into the barrel in the same way. The bromine solution is added at the bottom, through the pipe which serves to draw it off again after the treatment. If the percolation process in vats is used the bromine solution is introduced into a covered vat, using the same precautions to avoid packing of the ore, etc., that are now used in the vat process for chlorination, and in the cyanide process.

After the ore has been acted upon by the bromine solution for a sufficient length of time the liquor is drawn off at the bottom and weak wash water from a previous operation introduced at the top of the ore, the first liquor, which is strong, being sent to a strong liquor tank, and the subsequent weaker liquor being reserved in a weaker liquor tank for subsequent use in leaching ore. From the strong liquor tank the solution runs into a still. One form of apparatus which has been used successfully, but which is now being superseded by an improved form consists of a covered stone tank heated by live steam, and provided with an outlet for the vapors, which leads to a stoneware condenser. Into the condenser, weak liquor from the weak liquor tank is allowed to enter with the vapors and in this way a bromine solution of the proper strength to run into the barrel with more ore is obtained. To the liquid in the still, before steam is turned on, bleaching powder and oil of vitrol, or

potassium permanganate and oil of vitrol, is introduced in sufficient quantity to free the bromine present as bromides. The chemicals used for this purpose in the mill have been bleaching powder and oil of vitriol. It may be asked why, if bleaching powder and acid are to be used to liberate the bromine from bromide, it would not be just as well to treat the ore with them in the first instance; to this it may be answered that in the process only as much chlorine is used as will liberate the amount of bromine which has actually combined with the ore, whereas in chlorination an excess is used which amounts to several times this amount. After the bromine is out of the liquid in the still it is run hot into the precipitating tanks, where it may be precipitated in any desired way. The only difference between the precipitation here and in chlorination is that here there is no troublesome excess of chlorine to be disposed of by sulphur dioxide or to use up large quantities of precipitants. The precipitant actually used in the mill has been powdered sulphide of iron, which in the hot liquor precipitates the gold quickly and completely. The gold is caught in a filter press and refined as usual.

Where ores are to be treated, in which the gold is present partly in too large pieces to dissolve rapidly in the bromine solution, the washed ore must be allowed to run over amalgamated plates, and as the gold is in perfect condition to amalgamate, it is easily caught.

The details of the process have been worked out by the Nellie Bly Gold Mining & Reduction Co., in Magnolia, Colorado, using an ore which has never before been successfully treated. It is a siliceous ore containing from $8.00 to $20.00 in gold per ton as tellurium compounds and nothing else of value. It cannot be amalgamated, concentrated, treated by the cyanide process, nor shipped to the smelters in Denver at a profit, and consequently presents a very difficult problem which has, however, been solved with entire success.

The process is also about to be introduced in other localities, and it seems entirely probable that it may in the near future displace chlorination to a great extent, at least.

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