I. Experiments on the extraction of gold and silver from their ores by the wet way

John Percy M.D. F.R.S.

To cite this article: John Percy M.D. F.R.S. (1850) I. Experiments on the extraction of gold and silver from their ores by the wet way, Philosophical Magazine Series 3, 36:240, 1-8, DOI: [10.1080/14786445008646412](https://doi.org/10.1080/14786445008646412)

To link to this article: <http://dx.doi.org/10.1080/14786445008646412>

Published online: 30 Apr 2009.

Submit your article to this journal [↗](#)

Article views: 3

View related articles [↗](#)

THE
LONDON, EDINBURGH AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[THIRD SERIES.]

JANUARY 1850.

I. *Experiments on the Extraction of Gold and Silver from their Ores by the Wet Way.* By JOHN PERCY, M.D., F.R.S.*

ATTENTION has of late been directed to the extraction of silver by the *wet way* from many of its ores, of which large quantities are now imported into this country, especially from South America. Several processes have been projected; and one, the subject of a patent, is now extensively practised. It consists in calcining the ore with chloride of sodium, precisely as in the amalgamation process of Freiberg, and then dissolving out the chloride of silver formed during the calcination by a hot saturated solution of chloride of sodium. From this solution the silver is precipitated by metallic copper, and then cupelled. I have examined many South American silver ores, and have found them very variable in respect to the proportion of silver, and the presence of gold and other metals. In one ore I have found as much as $30\frac{1}{4}$ per cent. of fine silver. Several smelting establishments have, I know, attempted to work some of these ores in the dry way, but the results have not been favourable. Hence will appear the importance of directing attention to the economic extraction of the silver by the wet way.

The ore which I subjected to experiment was an auriferous silver ore, which contained a large proportion of blende, with galena, iron pyrites and copper pyrites in small quantity; the non-metallic part of it consisted chiefly of silica. The silver was present as sulphuret. By roasting, the ore swelled up much, and sulphurous acid was copiously disengaged. I received it in the state of coarse brownish-gray powder. I made numerous experiments upon it, to ascertain the best mode of extracting the precious metals by

* Communicated by the Author, having been read before the Chemical Section of the British Association at Swansea, 1848.

Phil. Mag. S. 3. Vol. 36. No. 240. Jan. 1850.

2 Dr. Percy on the Extraction of Gold and Silver

the dry way, and then proceeded with experiments on the extraction of those metals by the wet way, the results of which I now communicate.

The mean of two assays of the roasted ore by the dry way gave of fine silver containing gold—

7·977 grs. in 1000.
55·839 in the pound avoirdupois.
260 $\frac{3}{8}$ oz. in the ton.

The silver contained of gold per cent. 3·78.

Therefore, the total quantity of fine silver in 1000 grs. of roasted ore is 7·676, and of fine gold 0·301.

Or, 250 $\frac{6}{8}$ oz. fine silver in the ton, and 9 oz. 16 dwts. fine gold.

1. Ammonia extracted some silver from the roasted ore, notwithstanding the roasting towards the last was effected at a bright red heat.

2. A solution of hyposulphite of soda also extracted from it a very sensible quantity of silver.

3. I digested 1000 grs. of roasted ore for a few hours with a dilute solution of hyposulphite of soda, containing 150 grs. of the crystallized salt. The digestion was made at a temperature just warm to the hand. I filtered, washed well, added to the filtrate an excess of dilute sulphuric acid, and then boiled. Almost immediately after the addition of the sulphuric acid, sulphurous acid was evolved and sulphur deposited; but until the solution became hot, it did not acquire a dark colour. I boiled for some time, stirring constantly until the supernatant liquor became bright and the dark precipitate subsided. I filtered, washed well and dried. I enclosed this precipitate in a sheet of assay-lead*, and cupelled. I obtained a bead of fine silver weighing 4·800. An accident occurred in this experiment, which may have caused a slight loss. I treated the bead with nitric acid, and obtained a sensible residue of gold. I parted, with the usual precautions, and melted the residue of gold before the blowpipe. The bead of fine gold weighed 0·009. The silver therefore contained 0·187 per cent. of gold. This result appeared to me to be interesting, as showing that hyposulphite of soda dissolved out a sensible amount of gold from the ore roasted *per se*. Is it probable that, in the presence of a large excess of other metallic oxides, the gold itself may, at least in a certain proportion, have existed in combination with oxygen? †

* Lead free from silver.

† See a curious paper by Brandt, *Recueil des Mémoires les plus intéressants de Chymie, &c., dans les Actes de l'Académie d'Upsal, &c.* Paris 1764. vol. ii. p. 357.

I treated the residual ore a second time with a dilute solution of hyposulphite of soda, and proceeded in the manner just described. I obtained another bead of fine silver, weighing 0.050. Some loss was also again accidentally occasioned in this second determination.

4. Goldleaf was digested in a solution of hyposulphite of soda, but it did not appear to be in any degree acted upon; neither did silver leaf appear to be appreciably dissolved by the same menstruum, although the surface after some time became tarnished, the solution being freely exposed to the atmosphere. A piece of copper wire, which had been previously dipped in nitric acid and washed, was immersed in the solution of hyposulphite containing the silver leaf; but there was not the slightest appearance of the deposition of silver. However, the surface of the copper acquired a dark colour, and by subsequent exposure to the atmosphere became beautifully iridescent.

5. Into a large stoppered bottle I put 1000 grs. of the roasted, finely pounded and sifted ore. I then nearly filled the bottle with distilled water, and passed a stream of chlorine through for an hour, having previously added 50 grs. of chloride of potassium, with a view to form a stable double salt of gold. After shaking the bottle at intervals during the passage of the gas, there was a manifest absorption of the gas, as proved by the rushing in of the air on withdrawing the stopper. The agitation was repeated several times, and with the same effect. I left the whole for about four days, shaking at intervals. When the powder had subsided after shaking, I uniformly observed the disengagement of numerous small bubbles of gas from the ore. On plunging a spill, burning only with a spark, into the neck of the bottle, combustion was evidently increased, the spark burning distinctly brighter. A strong odour of some oxygen compound of chlorine continued to be evolved. I filtered, and obtained a clear and colourless solution, which I reduced considerably by evaporation. During the evaporation, a white scum formed on the surface, and white matter (PbCl) was deposited, which towards the last occasioned succussions. To the solution thus reduced, when cold, 100 grs. of hyposulphite of soda were added; but the deposited matter did not appear sensibly to dissolve. I treated the residual ore with a solution of 200 grs. of hyposulphite of soda; I filtered and washed. I mixed the filtrate with the solution previously mentioned, and carefully washed in the precipitate. I added hydrochloric acid, and digested as usual, stirring continually. Sulphurous acid did not appear to be copiously evolved. The precipitate thus obtained was reddish-brown and not black. It was washed on a filter, dried,

enclosed in 130 grs. of assay-lead, and cupelled. The bead not being clean, was recupelled. I added 100 grs. of hyposulphite to the filtered solution and boiled, when a dark olive-brown precipitate was thrown down, which was dried, detached from the filter (the same as used in the first filtration) as completely as possible, and heated in a porcelain capsule to expel the free sulphur. A small quantity of black matter remained, which was enclosed in about 80 grs. of assay lead, and cupelled. When the lead was melted, I put the filter on it and incinerated, and I also added the bead of silver previously obtained, and enclosed in a small piece of assay lead. I obtained a good bead of fine silver. However, the cupellation was not perfectly satisfactory, as I observed some very minute particles of silver surrounded by black scoria on the sides of the cupel.

The bead weighed 5.385 grs. By parting with nitric acid, it yielded of gold 0.100, or 1.857 per cent.

6. 1000 grs. of the roasted ore were treated with chlorine precisely in the manner described in experiment 5, and left during four months. Bubbles of gas continued to be evolved sensibly for a long time; and even at the end of the four months, on stirring the ore, still continued to be disengaged from its surface. The clear supernatant solution was decanted, and the residue treated with a cold solution of 200 grs. of hyposulphite of soda; it was left for two or three days, filtered and washed with cold water. I then digested the filtrate on the sand-bath with excess of sulphuric acid until the odour of sulphurous acid ceased to be detected. I washed the precipitate with boiling water, when after long washing, it still continued to become turbid by the addition of BaCl (from PbCl). The dry precipitate was seen to be mixed with shining, colourless, acicular crystals. I roasted till no odour of sulphurous acid was evolved, and then cupelled the residue with 200 grs. of lead. There was evidently a considerable quantity of matter present which would not pass into the cupel. I recupelled the bead with a small additional quantity of lead.

I obtained a bead of fine silver, weighing 5.80 grs. On the addition of carbonate of potash to the decanted supernatant liquor, a copious white precipitate was thrown down.

7. I digested 1000 grs. of the finely-pounded roasted ore with a solution of hyposulphite of soda containing 200 grs. of the salt, at a temperature just warm to the hand, and then filtered. I boiled the filtrate, which became brown. I added to the boiling solution excess of dilute sulphuric acid, and continued to digest for some time at about 212° F., stirring continually. I filtered and dried. I detached the precipitate from the fil-

ter, and expelled the excess of sulphur by a gentle heat. I enclosed the residuum in about 100 grs. of assay lead, and cupelled. The bead weighed 0·802 gr. This is a very much smaller quantity than that previously obtained (exp. 3) by treating the roasted ore in the state of coarse powder without *subsequent* trituration, as was practised in the present experiment. Is it probable that by the act of trituration the associated matter present, which existed in so large a proportion compared with that of silver, may have protected the silver from the action of the hyposulphite?

On adding sulphuretted hydrogen water to the filtrate, after precipitation by sulphuric acid, not the slightest blackness was produced. A precipitate of the pure colour of sulphur, canary-yellow, was produced from the reaction of the sulphuretted hydrogen upon the sulphurous acid remaining in the solution. I transferred the ore, after treatment with the salt of soda, into a glass jar, and passed through a stream of chlorine for nearly an hour, stirred well, and left the jar with its contents covered until the following morning. The odour of chlorine still continued to be strongly evolved. I added chloride of sodium, and digested for several hours on the sand-bath, replacing from time to time the water removed by evaporation: the surface became covered with small white crystals. Afterwards I added a solution containing 200 grs. of hyposulphite of soda, and digested at a temperature just warm to the hand, stirring well. I filtered and washed, and again treated the residual ore with a further solution of hyposulphite containing 50 grs. of the salt. I then filtered and washed. I mixed the two solutions, and digested as usual with dilute SO^3 in excess, and filtered. On the addition of HS water to the filtrate, the latter became dark-coloured. I then added an excess of HS water until the odour of HS persisted, when after standing the filtrate did not again become discoloured. I washed and dried. The filtrate, which was readily detached from the filter without sensible loss, was gently heated in a porcelain capsule to expel the free sulphur. It then weighed 24 grs. I enclosed it, together with the ash of the filter, which was incinerated in the same capsule as used for expelling the free sulphur, in 200 grs. of assay-lead. The capsule was not stained, and every appreciable trace of matter was removed. By cupellation I obtained a bead weighing 5·005 grs.

I again exposed the residual ore diffused through water to the action of a stream of chlorine precisely as before, except that after digestion during a few hours I added KO until an alkaline reaction was obtained, the reaction having been found to be acid. White matter, apparently similar to that pre-

viously observed under the same circumstances, again occurred on the surface. I treated with a solution of 200 grs. of hyposulphite of soda. On testing the wash-water with HS water, S was precipitated, and there was not the slightest dark discoloration. I proceeded exactly as before, and cupelled with about 60 grs. of assay lead. The bead of fine silver weighed 0.675 gr. I again treated the residual ore in a similar manner with Cl for about an hour and a half, and then digested for a considerable time on the sand-bath. On the following day I dissolved out with a solution of 200 grs. of hyposulphite. I treated the filtrate as usual with dilute SO^3 , and tested the wash-water with HS water. I proceeded as before. I employed 100 grs. of assay lead for cupellation. The bead of fine silver weighed 0.154. The total amount of fine silver obtained is 6.636 grs. By parting with NO^5 , I obtained of gold 0.197. The silver therefore contained of gold 2.968 per cent.

I now boiled the residual ore with a solution containing 100 grs. of KCy, filtered and washed. By addition of HCl in excess to the filtrate, a white precipitate was produced; but on continuing the digestion until the odour of hydrocyanic acid could no longer be detected, it became dark-coloured, which I believed to be owing to the presence of S in some form. I digested the precipitate with NO^5 , and obtained a pale blue solution, which did not become in the slightest degree turbid by the addition of HCl. On the filter remained only a minute quantity of matter, like sulphur in appearance, somewhat discoloured; and by heat the characteristic odour of sulphur was evolved, and only a minute quantity of matter was left.

8. In another experiment, in which I heated 1000 grs. of the *finely*-pounded ore, triturated after roasting, with a solution of 200 grs. of hyposulphite, I obtained a bead of fine silver weighing only 0.81.

9. I digested 1000 grs. of roasted ore with a solution of common chloride of lime (hypochlorite) on the sand-bath during two or three days. I then washed and digested the residuum, at a *warm* temperature, with a solution of 150 grs. of hyposulphite of soda. I filtered and washed. To the filtrate I added an excess of dilute SO^3 , and heated till the supernatant liquor became quite clear. I filtered, washed slightly and dried. I enclosed the filter, with its contents, in 200 grs. of assay lead, and I subsequently added on the cupel 100 grs. I obtained a bead of fine silver weighing 5.469, and containing gold, but only to the extent of .02. I do not, however, place much confidence in this determination of the

gold, as the manipulation was hardly conducted with the requisite care.

I dried the residual ore, and by trituration reduced it to a very fine state of division, so that it was passed through the finest copper sieve. I suspended it in cold distilled water, and passed through a stream of Cl during about a quarter of an hour, stirring continually. I then digested on the sand-bath, and left till the next day, when I still perceived a faint odour of Cl. I added 100 grs. of hyposulphite of soda, and digested at a gentle temperature, stirring occasionally. I decanted and filtered the supernatant liquor. I again digested the residue with an additional quantity of 100 grs. of hyposulphite, filtered and washed. I boiled the filtrate, as usual, with an excess of dilute SO^3 . The precipitate soon became dark-coloured. I digested until the supernatant liquor became clear, filtered, washed and dried. I detached the precipitate from the filter, which was done without appreciable loss; heated it in a capsule, to expel the free sulphur, and digested it with aqua regia. As the white product which was obtained by this means was mixed with minute acicular crystals like chloride of lead, I treated it, after washing, with zinc and dilute hydrochloric acid. I washed and dried the metallic residue, enclosed it in 110 grs. of assay lead, and cupelled. I obtained a bead of fine silver weighing 0.829 gr., making a total of fine silver 6.298.

I examined the liquid left after digestion of the first precipitate with aqua regia, for gold. I diluted it considerably, and boiled with oxalic acid. On the following day (the oxalic acid being added at night) I observed a film of reduced gold of a reddish-brown colour; and a few days afterwards I distinctly recognised minute particles having the colour and metallic lustre of gold.

10. I treated 1000 grs. of the well-roasted ore, in its coarsely pounded state, with a cold solution of Fe^2Cl^3 . Fe^2O^3 was soon precipitated, being displaced doubtless by the oxide of zinc*. The supernatant liquor became clear and colourless. I added HCl, which redissolved the Fe^2Cl^3 , but it was again precipitated. I added a considerable quantity of HCl, and obtained a greenish-yellow brown solution. I filtered and washed, and treated the residue with a solution of 150 grs. of hyposulphite of soda. I proceeded as usual with SO^3 . I used 200 grs. of assay lead in the cupellation, and obtained a bead of fine silver weighing 4.909 grs.

11. I confirmed the fact, that when chloride of silver is dissolved in a solution of hyposulphite of soda, and treated with a

* Oxide of copper will also displace it.

mineral acid, a copious precipitation of dark-coloured matter takes place, which is doubtless AgS. But whether the whole of the silver is precipitated under these circumstances as sulphuret I did not ascertain; though from the copious precipitate produced, I think that such is probably the case.

Concluding Observations.

1. The loss of fine silver in the most satisfactory experiment was $13\frac{1}{2}$ per cent. Formerly, in the old amalgamation process in Mexico, my respected friend Mr. John Taylor informs me, the loss frequently amounted to 35 per cent. But at present, since the introduction of the barrel-process, the loss has been reduced to 9 or even 5 per cent. My results therefore may be regarded as sufficiently satisfactory to justify attention to them with reference to their œconomic application. It is probable that on the large scale, with proper appliances, the silver would be much more completely extracted.

2. I would especially direct attention to chloride of lime and chlorine as the agents for effecting the conversion of the silver into chloride, and to hyposulphite of lime, which may readily be obtained as a cheap substitute for hyposulphite of soda to dissolve the chloride. The silver it is obvious might be precipitated either as metal or sulphuret.

3. Since many of the South American silver ores contain gold, it is desirable that both the silver and gold should be extracted by one process; and to this end chlorine or chloride of lime seems to be indicated by the preceding experiments.

II. On Annuities and Assurances on Successive Lives.

By THOMAS WEDDLE, *F.R.A.S.**

MILNE, in his Treatise on Annuities (Chapter VII.), has discussed this subject with much clearness and elegance; yet his method of investigation does not seem to be the best possible, nor do I think that his results are given in forms well adapted to numerical applications. It may therefore be not altogether useless to consider the subject in a somewhat different manner, and so to exhibit the formulas as best to meet the wants of the computer.

Problem I. To determine the present value (a_n) of an assurance of £1 payable on the failure of the last of n successive lives A' , A'' $A^{(n)}$.

Let $a^{(p)}$ denote the value at the time of nomination of an assurance of £1 payable on the death of $A^{(p)}$; $A^{(p)}$ itself de-

* Communicated by the Author.