

different state of affairs in treating ores where these or similar compounds exist prepared by the hand of Nature herself. Nature seems to render the base-metallic compounds insoluble, while the gold combined with or contained in them is more easily acted on than the metal itself. This at once raises the question: How does gold exist in base refractory ores; is it combined or free? This question, I admit, I cannot answer satisfactorily to myself. Judging from theoretical considerations only, I think gold should exist almost invariably in the free state, for, if we assume that sulphides, pyrites, &c., were formed by deposition from aqueous solution, the gold would be deposited in the metallic state. This may be shown by dropping some powdered pyrites into a solution of chloride of gold, when gold will be precipitated as metal; on the other hand, let us assume that the pyritous formations carrying gold were formed by igneous agency; in this case the gold ought to be metallic too, because any sulphide of gold already existing would be decomposed by the high temperature, and of course sulphide of gold cannot be formed at a high temperature. It is true that sulphide of gold may combine with any alkaline sulphide and resist decomposition by heat, but such a combination as a matter of fact does not occur in Nature. Telluride of gold, and, I think, antimonide of gold are not decomposed by heat, but they occur in small quantities only and do not affect the general argument. In spite of these theoretical considerations, however, we have strong evidence to show that gold exists in several different states of combination or molecular structure.

"Let me give one case in illustration. A sample of tailings from the ordinary process of stamping and amalgamation was received, and I think it may safely be assumed that the mercury had extracted some gold from the ore which produced these tailings. We treated the finely-ground tailings by alkaline solution of bromine, which extracted a considerable portion of gold, and the bromine treatment was repeated time after time till it ceased to extract gold; then it was treated with a hot solution of ferric bromide, which yielded a further quantity of gold. This treatment was repeated time after time till it ceased to extract gold, and finally the residue of tailings were smelted and a still further quantity of gold produced. As this ore yielded its gold in stages to the four different processes of amalgamation, treatment with bromine, treatment with ferric bromide and smelting, we infer that the gold existed in four different states, mechanical or chemical. Notwithstanding the complex nature of these tailings, which consisted of all sorts of sulphides with the four-fold gold, the cyanide acted on it, almost perfectly extracting 93 per cent. of the precious metal, whilst the higher extraction by any of the bromination methods was about 40 to 50 per cent. The cyanogen seemed to have an affinity for gold, and a power of penetration so much stronger than mercury of bromine, that it broke through barriers impregnable to them and captured the gold.

"Elsner has stated metallic gold dissolves in cyanide of potassium only in presence of oxygen. Not having seen the original account of Elsner's researches, I am not in the position to criticize his experiments, but I never could find that the presence of oxygen was necessary either to dissolve gold by itself or from ores by cyanide. If a piece of gold be immersed in a cyanide solution so that air to act on it would have to penetrate 2in. or 3in. of the solution, the gold will dissolve in its usual slow and steady fashion. The equation shows that either oxygen must be absorbed or hydrogen evolved. I have seen no evidence of the former, and can adduce no proof for the latter, but I think the latter the more probable, because I cannot conceive oxygen penetrating even a film of cyanide solution without at once oxidizing the cyanide to cyanate, whereas in the other case, as suggested to me by my friend Mr. Ellis, the nascent hydrogen may be at once seized by the excess of cyanide present and ammoniacal compounds formed. However, we do not concern ourselves much with the reactions of pure gold, but as a matter of fact we cannot find that oxygen plays any part in the cyanide extraction of gold from ores. We have treated an ore with cyanide with free access of air, and then a parallel experiment was done with boiled water, the bottle filled to the stopper with solution and ore, and the stopper sealed. The extraction was the same in both cases.

"We have so far only considered ores which are refractory from chemical as well as mechanical causes, but ores are frequently found in which the gold is refractory from a purely mechanical cause, which is the extremely fine division of the gold. The cyanide process is quite as applicable to this class of ore as any other. These ores are generally spongy and absorbent, and this, we find, enables us to dispense with stirring the ore and cyanide solution together, the same end being accomplished by allowing this cyanide solution to percolate slowly through the mass—a clear saving in power.

"The advantages claimed for the cyanide process over smelting and chlorination are: As compared with smelting, it requires no furnaces and no coal, and no fluxes, and thus may be used successfully in remote situations where smelting is utterly impossible. As compared with chlorination, cyanide process involves no roasting, therefore no furnaces and no fuel. Moreover, by the cyanide process, ores containing lead, zinc, or earthy carbonates, which cannot be worked to profit by chlorination, may be easily and profitably treated as any other. For chlorination, about 7 per cent. of the weight of the ore to be treated often has to be carried to the ore in the form of bleaching powder, say, $1\frac{1}{2}$ per cent., bisulphate of soda 2 per cent., and sulphate of iron $2\frac{1}{2}$ per cent., with packing, say, of 1 per cent., whereas about 1 per cent. of the ore to be treated will cover the weight of the necessary cyanide, zinc, and packing. Thus, by chlorination, one ton of chemicals will treat only about fourteen tons, whereas by the cyanide method one ton will treat one hundred tons. Moreover, chlorination does not extract any silver, but by the cyanide method the most of the silver—invariably associated with gold in ore—is extracted along with the latter metal at the same operation. For the sake of simplicity, I have not named silver in the body of this paper, but the remarks made in reference to gold generally apply to the silver associated with it.

"From what I have seen of gold mines and gold-mining in the Sierra Nevada, in the Rocky Mountains, in the Southern States of America, in Nova Scotia, from the many kinds of ore I have seen from all parts of the world, and from what I know of the selective and energetic action of cyanides, I confidently predict that cyanide of potassium, hitherto used only to polish amalgamated