

## No. 5.

## The Allotropism of Gold.

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It can scarcely be considered a matter of doubt, in the present state of our knowledge, that the existence of, at any rate, two well-marked allotropic modifications of gold can be recognized, namely (*a*), the ordinary, yellow variety, and (*b*) the red, brown or purple, non-lustrous, amorphous variety.

There are, indeed, not wanting indications that still other allotropic forms may be capable of existing. It is, for instance, possible that the green colors of gold obtained under certain conditions, or the black powder produced when the alloy of gold with potassium is decomposed by water, may represent further allotropic modifications, although this proposition is open to doubt. It can scarcely be pretended that the two first-named varieties have been absolutely isolated, yet it is, perhaps, quite permissible to speak of the ordinary and the amorphous modifications as having a proved existence.

Ordinary gold is sometimes found crystallized in nature, although never in a state of purity. When gold is melted and cooled slowly, its surface shows crystalline markings, and the fact that it is capable of crystallizing in the cubic system may be looked upon as established. When gold is produced by precipitation, the form which it assumes is dependent on the conditions of precipitation. G. Rose<sup>1</sup> says that gold precipitated by ferrous sulphate from very dilute solutions is so finely divided that no regular form can be recognized, but in more concentrated solutions the precipitate consists of minute cubes. When oxalic acid is used as a precipitant, the gold is coarser and forms octahedral crystals. J. Thomsen<sup>2</sup> has obtained similar results. Working with dilute and with highly-dilute

<sup>1</sup> *Poggendorff's Annalen der Physik und Chemie*, vol. lxxiii., p. 8 (1848).

<sup>2</sup> *Journal für praktische Chemie*, vol. xiii., p. 348.

solutions, I have myself been quite unable to recognize any crystalline structure, even under the highest powers of the microscope; nor did there seem to be even any tendency of the particles to group themselves into arborescent forms, such as might indicate incipient crystallization. Precipitates from solutions containing between 0.0001 and 10 per cent. of gold gave no indications of crystallization, even when magnified 800 diameters.

Thomsen (*loc. cit.*) has also pointed out that the physical characters of precipitated gold differ according as it has been precipitated from solutions of its chloride or its bromide. He also found that these different forms possessed different degrees of thermic energy, and hence deduced a strong argument in favor of their being allotropic varieties.

The specific gravities of various forms of gold differ considerably. G. Rose (*loc. cit.*) found that fused gold had a density of 19.3336 after it had been compressed in a coining-press, it being a little lower before this mechanical treatment. The density of precipitated gold thrown down by ferrous sulphate he found to vary from 19.5419 to 20.6882, the highest figures being obtained from extremely-dilute solutions, the precipitate from which showed no trace of crystalline form; when precipitated by oxalic acid its specific gravity was 19.4791. When such amorphous gold was struck in the coining-press, its density became *reduced* to 18.0194. I have found that the density of gold left on dissolving out various metals alloyed with it, when the gold remains behind in a brown, amorphous, lusterless condition, varies between 20.3 and 19.5.<sup>3</sup>

It is only fair to notice that Rose did not ascribe the differences in the densities of the different forms of gold to allotropism, but has suggested another explanation, which is hardly, to my mind, a sufficient one. It is probably safe to assume that there are two modifications of gold—one a light one, of density 19.3 or thereabouts, and the other a heavy one, the density of which approaches 20.7—while various combinations of these extreme forms are capable of occurring.

In this connection the curious divergencies in the densities of specimens of native gold, from different localities but of

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<sup>3</sup> See note by the writer, *Trans.*, xxii., 117 (1893).

about the same composition, may also be referred to; allotropism may, at any rate, be suggested as a possible explanation of them. There are thus sufficiently well marked differences in physical characteristics to support the hypothesis of allotropism.

As regards chemical properties, Thomsen has also pointed out that when amorphous, pulverulent gold is acted on by chlorine or bromine, auric compounds ( $Au_2Cl_4$  or  $Au_2Br_4$ ) are produced; whereas, these same substances produce auric compounds ( $AuCl_3$  or  $AuBr_3$ ) with ordinary gold.

I have found another point of difference, of far greater practical importance, in the behavior of these modifications towards mercury. Ordinary gold, of course, amalgamates readily, as is well known. I have found that gold precipitated from highly-dilute solutions by ferrous sulphate is not attacked at all by mercury when freshly precipitated, and only slightly after drying on an air-bath. Near the boiling-point of mercury, partial amalgamation took place, but it was by no means complete. Mercury containing a large amount of sodium amalgam was equally without effect on the dry gold, although it readily and completely amalgamated it when moist. In these observations I seem to have been partly anticipated by Ludwig Knaffl,<sup>4</sup> who, however, appeared to attach little importance to his observations. In a brief note on the preparation of certain amalgams of gold, he says:

“Gold precipitated by green vitriol or mercurous nitrate is not suitable for amalgamation, as it is too finely divided and always floats on the surface of the mercury<sup>5</sup> as a black powder, whether heated mercury be poured upon heated gold or *vice versa*. I examined this floating black powder, and found it to contain gold and mercury. . . . Gold precipitated either by means of arsenious acid or by boiling a solution of the chloride in amylic alcohol, when it separates out in small, lustrous octahedra, is best suited for amalgamation.”

It may also be added that the purple of Cassius, which probably contains an allotropic modification of gold, is not attacked by mercury. The black pulverulent form of gold resulting from the decomposition of the potassium-gold alloy likewise resists amalgamation. On the other hand, the coherent gold

<sup>4</sup> *Dingler's Polytechnisches Journal*, vol. clxviii, p. 282 (1863).

<sup>5</sup> The italics are mine.—H. L.

sponge left on dissolving out the alloying metal from a gold-alloy amalgamates fairly readily, as does also the coherent pale-brown powder produced by precipitating with sulphurous acid a strong solution of auric chloride.

All forms of gold are converted into the ordinary yellow, lustrous variety by the action of heat. A very high temperature is not required, but the exact point has not yet been determined; it is certainly well above  $200^{\circ}\text{C}$ ., but probably under  $600^{\circ}\text{C}$ .<sup>6</sup> Powerful mechanical action, such as percussion, friction, or compression, has the same effect.

I do not pretend that the above data form anything like a complete chain of evidence proving irrefragably the allotropism of gold, or that our knowledge of this subject is precise or definite; yet I venture to think that the facts do warrant us in looking upon the following deductions as probably correct:

1. Gold is capable of existing in allotropic modifications.
2. One of these modifications is capable of amalgamation only with great difficulty, if at all.
3. This modification is capable of being produced and of subsisting under conditions that may reasonably be supposed to exist in nature when gold is deposited in reefs.

Whatever may have been the nature of the solution by means of which gold has been introduced into the deposits in which we find it, whether as a soluble haloid salt, as is generally supposed, or as an alkaline aurate, as I venture to suggest,<sup>7</sup> it must have been precipitated from such solution in various ways and under varying conditions. We have but few indications of the cause of this precipitation, but it is reasonable to conjecture that such reagents as ferrous sulphate or sulphurous acid, both resulting, perhaps, from the slow oxidation of iron pyrites, may have found their way, in solution, into the fissures within which the gold-solution was circulating, and may thus have caused the deposition of gold within the reefs. Now, if the gold, thus deposited from highly-dilute solutions, happened never to be exposed to a particularly high temperature, or to violent mechanical action, the conditions would be favorable

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<sup>6</sup> I am at present engaged in investigating this point, and hope to publish shortly the result of my research.—H. L.

<sup>7</sup> On the Mode of Occurrence of Gold, *Mineralogical Magazine*, vol. x., No. 47, p. 241.

to the production of that allotropic modification of gold which is indifferent to the action of mercury. In other words, under the above conditions, an auriferous deposit will have been produced in which a greater or smaller part, or perhaps even the whole, of the gold is what gold-miners term "rusty." I have little doubt that the "rustiness" of gold is in different cases due to widely-different causes—that, in fact, there is more than one kind of "rustiness;" but I venture to think, also, that there is sufficient evidence to warrant us in classing allotropism among such causes of "rustiness." If this is correct, I need hardly point out either the great practical value or the application of this deduction. The gold which is thus allotropically indifferent to mercury is in a condition in which it is readily attacked by such reagents as chlorine and potassic cyanide. I have pointed out long ago that the gold of the Witwatersrand deposits of the Transvaal was probably deposited *in situ* under some such conditions as I have sketched above, and it is now notorious that a large proportion of the gold in them is not attacked by mercury, but readily by potassic cyanide solution. Again, in some cases it may be economically feasible to convert the non-amalgamable modification of gold into the common amalgamable variety by heating the ore to a moderate temperature, or the same end may be attained by mechanical means. In any case, the only really sound method of preventing losses of gold in the process of gold-extraction is that of ascertaining, in the first place, the ultimate causes of such loss; and I venture to hope that it will be found that among such causes, the one here treated of—namely, allotropism of gold—will be found worthy of more consideration than it has hitherto received from scientific gold-miners.