NATURAL AMALGAMS

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Amalgam is a word of mongrel (Arabic-Greek) origin, the history of which is obscure. However, it has been in use since at least the twelfth century, and its meaning has been clear in the earliest references, as given by Mellor (1923). Present-day chemists and metallurgists use the word in the same sense as did the early alchemists, that is, as a general term referring to the solution of metals in mercury, or the combination of the metals with mercury.

Early mineralogical works of Cronstedt (1758) and Romé de Lisle (1783) used the term *amalgam* in describing the natural mercury alloys, and, because the natural alloy most abundant is silver-amalgam, the term has finally become the name of a supposed mineral species (Dana, 1892). However, aside from the inappropriate usage of a general term for specific designation, the name should no longer be used to designate this supposed mineral species, because silver-amalgam in nature embraces at least two separate minerals, differing widely in most of their properties, as will be shown below. It is suggested here that the word *amalgam* should be used in the mineralogical literature in the same sense that it is used by the metallurgists, and that specific natural alloys of the metals with mercury be given species or varietal names. In the following section redescriptions of the silver-amalgams are given, and the suggested changes in nomenclature are incorporated.

SILVER-AMALGAMS

In a recent study of the artificial system Ag-Hg, Murphy (1931) showed that there are at least three well-defined phases present, as follows: (1) a mercurial silver (α-phase) with Hg entering into solid solution in the face-centered silver lattice to the extent of about 45 per cent, with a consequent distension of the cell edge from 4.077Å to 4.175Å; (2) a close-packed hexagonal phase (β-phase) formed in the region of 60 per cent Hg; (3) a body-centered cubic modification (γ-phase) with $a_0 = 10.0$Å and a composition of 70 to 71 per cent Hg.[1]

Of the three alloys found in the artificial system, probably only two occur in nature, the α and γ phases of Murphy. The α-phase is a mer-

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[1] There is no unanimous agreement among the various recent workers about the composition of this last-mentioned alloy. Westgren (1931) and Stenbeck (1933) are of the opinion that the γ-phase is similar to γ-brass and a number of other alloys of that same type, and it should consequently have a 52-atom unit cell, which would give the alloy a composition $4Ag_5Hg_8$. However, Murphy's work indicates a unit of somewhat fewer atoms. The mineralogical evidence given here tends to favor Murphy's interpretation.

curial silver, and the natural occurrences of this substance should be considered as varieties of silver. Thus *arquerite*, *kongsbergite* and *bordosite* are varietal names under *silver*. Mercurial silver is usually massive or in dull crystals of the typical silver habits; it is malleable, and contains less than about 45 per cent mercury.

Three analyses of natural amalgams are in the range between the α- and γ-phases. Of these, the earliest (Analysis 3 of Table 1) was made in 1795 and the silver was only roughly determined; another is by Domeyko (1879), in 1862, on material of doubtful homogeneity; the third is on Sala material by Nordstrom (1881). Two more recent Sala analyses (see Table 1) indicate that this material certainly contains the γ-phase.

The γ-phase is represented in nature by well-crystallized material with a shiny metallic luster. The crystals are widely different in most of their properties from the variety here designated mercurial silver. The following is a description based on crystals from Moschellandsberg (one of the earliest reported occurrences of natural amalgam).

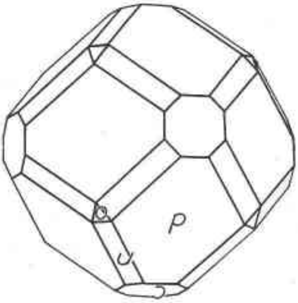

Fig. 1. Moschellandsbergite.

Crystallography: The previously established data, as given by Goldschmidt (1913), for crystals from Moschellandsberg (Fig. 1) have been verified, as follows:

Isometric—I-hexoctahedral—$4/m\ \bar{3}\ 2/m$

Forms: $c(001)$, $a(013)$, $e(012)$, $d(011)$, $n(112)$, $p(111)$, $u(122)$, $x(123)$.

An x-ray powder picture of material used for the crystallographic and chemical study verified the findings of Preston (1931) on the artificial preparations; that is, the powder picture could be indexed as a body-centered cubic lattice with $a_0 = 10.1$Å. The space group is $Im\ 3m$,[2] and the unit cell contains $Ag_{20}Hg_{30}$.

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[2] $h+k+l$ all even, hhl all missing, okl with $k+l$ even; checked by zero and first layer Weissenberg photographs.

The crystal habit is dominantly dodecahedral, frequently modified by *c*(001) and *n*(112), so that the morphological development is consistent with the space group, according to the rules of Donnay (1937).

Physical Properties: This substance is easily distinguished from mercurial silver in its physical properties. The cleavage is distinct on *d*(011) and *c*(001). The fracture is conchoidal; the brittleness is such that the material crushes easily to a powder. $H=3\frac{1}{2}$. $G=13.48$ to 13.71 (13.73 calculated from *x*-ray data for a 52-atom cell, 13.49 calculated for a 50-atom cell). Silver white and shiny.

Chemistry: Crystals from a Moschellandsberg specimen were crushed for the chemical work. It was found that free mercury was attached to the crystal fragments. This was removed by centrifuging. Other specimens examined showed this same saturation with mercury, implying that silver-amalgams cannot retain more than the amount of mercury demanded by the formula Ag_2Hg_3, that is, there is little or no solid solution in the system Ag_2Hg_3-Hg, at room temperatures.

The following is a tabulation of analyses of this material, including a new analysis by Mr. F. A. Gonyer, of this laboratory, on the crystals of this study.

TABLE 1. ANALYSES.

	1.	2.	3.	4.	5.	6.	7.
Ag	25.16	27.04	36	27.5	26.48	29.91	26.39
Hg	74.84	72.94	(64)	72.5	73.44	70.44	73.61
Total	100.00	99.98	100.	100.0	99.92	100.00	100.00
G	13.73	13.48			13.71		13.49

1. Theoretical composition for Ag_5Hg_8.
2. Moschellandsberg. Crystals freed from adhering mercury by centrifuging. Gonyer analyst.
3. Moschellandsberg. Klaproth analyst (*Beitr.*, vol. **1**, p. 182, 1795—*Dana System*, p. 23, 1892).
4. Calanches near Allemont. Cordier analyst. (*J. Mines*, vol. **12**, p. 1, 1802).
5. Sala. Mauzelius analyst (in Sjögren, *Geol. Fören. Förh.*, vol. **22**, p. 187, 1900) Crystals.
6. Sala. Mauzelius analyst (in Sjögren). Massive. After deducting 8.89 per cent sulphide silicate impurities.
7. Theoretical composition for Ag_2Hg_3.

Occurrence: Silver-amalgams with a composition near Ag_2Hg_3 have been found at three localities. At Moschellandsberg (Landsberg near Ober-Moschel), Bavaria, and at Sala, Sweden, fine crystals have been found. They have also been reported and analyzed from Calanches, near Allemont, Isere, France.

Name: It is proposed that the silver amalgam having a composition near Ag_2Hg_3, here described, be named *moschellandsbergite* after the locality at which fine crystals have been found and described.

GOLD-AMALGAM

In the artificial system Au-Hg as reviewed by Hansen (1936), there are a number of phases present, one of which, Au_2Hg_3, corresponds in composition to the natural gold-amalgam from Colombia reported by Marchand (1848) and by Sonnenschein (1854) from the Mariposa region in California. Nothing is known of the crystallography or physical properties of these natural occurrences; but the close similarity of the formulae of this gold-amalgam and the body-centered cubic, silver-amalgam, moschellandsbergite, indicates that the natural occurrence probably represents a species which is the gold equivalent of this mineral. However, the writers have not been able to obtain natural crystals of the gold-amalgam and the study has not been pursued further.

PALLADIUM-AMALGAM

The mineral *potarite*, recently described by Spencer (1928), represents an alloy of palladium and mercury (Pd, Hg), but it has been shown by Cissarz (1930) that the originally described material was not homogeneous and two phases may be represented by the analyses.

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