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Some Investigations on Quantitative Measurement of Amalgamation

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SOME INVESTIGATIONS ON

QUANTITATIVE MEASUREMENT

OF AMALGAMATION

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CHARLES MOORE

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SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR A DEGREE

OF BACHELOR OF SCIENCE

IN METALLURGICAL ENGINEERING

TO MONTANA SCHOOL OF MINES

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INTRODUCTION

Amalgamation is a process in which precious metals are collected by mercury. The exact way in which the mercury holds the other metals is not positively known. It is probable that a series of intermetallic compounds forms. Very little work has been done so far on the theory of amalgamation.

Mercury is still used to recover precious metals in placer mining, but the cyanide process has almost completely replaced amalgamation in treatment of lode ores. It is interesting to note that most of the precious metals that enriched Spain following the discovery of the New World were recovered by amalgamation.

It is common knowledge that gold, silver, copper, tin, zinc, lead, cadmium, magnesium, aluminum and bismuth amalgamate readily under normal conditions when their surfaces are clean. Arsenic, antimony and platinum are only slightly amalgamable, while iron, nickel and cobalt are virtually un-amalgamable.

The object of this thesis work was to determine rates of amalgamation of several metals in order that a critical comparison of their relative amalgamabilities might be made.

THE GENERAL METHOD
OF MEASURING RATE OF AMALGAMATION

In this work the method of determining the rate of amalgamation was first developed by experiments on silver. Strips of silver one square centimeter in area were subjected to amalgamation for measured periods of time. The problem was to either remove the residual mercury and amalgam left on a strip after amalgamation or to clean the silver so that the same amount of amalgam would be left after each test. The first method was chosen. The silver specimen with excess mercury and amalgam adhering to its surface was wiped carefully and thoroughly with cloth until only a small amount of amalgam remained. The wiped silver was then heated rapidly with a natural gas burner. The silver surface was seen to cloud over at first and then to become clear after a few seconds. It was found that if the silver was not carefully wiped before heating, a cloudy surface remained on the silver which could not be removed. Qualitative tests for mercury were made on wiped silver and heated silver specimens and a comparison was made. It was found that the specimen which was merely wiped gave a good positive test for mercury, while the heated piece of silver gave a negative test for mercury. Of course, it should be realized that this method does not permit measuring the small

amount of amalgam which is left on the metal and which is de-
composed by the heating. It is my opinion, however, that the
error thus introduced in the experiment is not of great im-
portance.

The method used then is summarized in the following
steps:

(1) weigh a clean piece of metal one square centimeter
in area;

(2) treat with 10 cc of clean mercury for a measured
period of time, using a mechanical stirrer to make
conditions as uniform as possible;

(3) wipe and heat to produce clean metal surface;

(4) weigh cleaned metal;

(5) note loss of weight of specimen during a certain
period of amalgamation.

STUDIES ON GOLD

Pure gold was obtained from a piece of 10 carat gold
by dissolving it in aqua regia, filtering the solution, and
precipitating the gold chloride contained with zinc dust. The
residue from this precipitation was a mixture of gold and cop-
per. It was cupelled with about 30 grams of lead foil to re-
move the copper and to consolidate the gold so that it could
be hammered out into a thin leaf. A soft, ductile bead of gold

was obtained which weighed about ½ gram. This bead was hammered out until a piece one centimeter square could be cut from it. Repeated tests were then made on this one sample. The results show that apparently gold is more soluble in a mixture of mercury and amalgam than in pure mercury. Note that the amount of amalgamation is almost directly proportional to the time of amalgamation.

The results are as follows:

Time of Amalgamation		Amount of Amalgamation
5 minutes	0.0120 grams
10 "	0.0245 "
15 "	0.0380 "
25 "	0.0561 "

See graph and reaction constant calculations following.

STUDIES ON SILVER

Silver seems to have been the ideal metal to study since it is available in a very pure state at low cost and is noble enough that no difficulties are encountered in handling it. The treatment of silver is exactly that which is outlined on the general method discussed on pages 2 and 3. Pure silver sheet was used in making the tests.

The results are as follows:

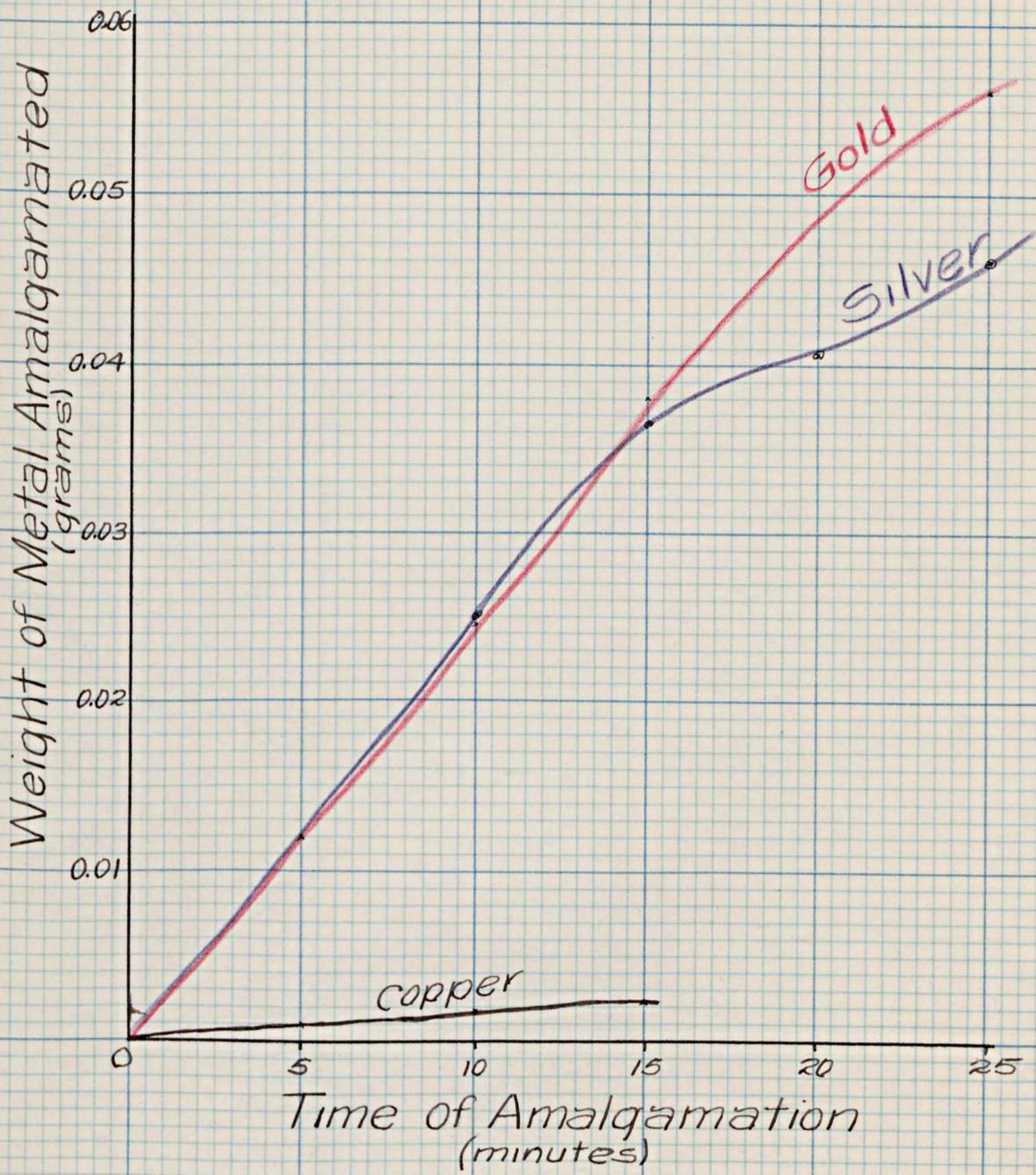| Time of Amalgamation		Amount of Amalgamation
5 minutes	. . . .	0.0120 grams
10 "	. . . .	0.0247 "
15 "	. . . .	0.0366 "
20 "	. . . .	0.0404 "
25 "	. . . .	0.0465 "

STUDIES ON COPPER

The work on copper was complicated by the tendency of this metal to oxidize when heated in air. To prevent this the copper specimens were cleaned of amalgam and excess mercury by heating in a hydrogen atmosphere. The hydrogen was produced in a glass jar by the action of sulphuric acid on zinc beads.

The copper was relatively much less amalgamable than either gold or silver. The specimens had to be sandpapered and then washed with a cyanide solution so that the copper could be readily amalgamated. The procedure is the same as for the other metals except that a hydrogen atmosphere was used in heating the copper.

The results are as follows:

Time of Amalgamation		Amount of Amalgamation
5 minutes	. . . .	0.0008 grams
10 "	. . . .	0.0017 "
15 "	. . . .	0.0021 "

Weight of Metal Amalgamated (grams) vs Time of Amalgamation (minutes)

Gold

Silver

copper

0.06
0.05
0.04
0.03
0.02
0.01

0 5 10 15 20 25

DETERMINATION AND INTERPRETATION
OF REACTION CONSTANTS

For any reaction in which a solid is consumed by a liquid, it should be possible to calculate a reaction constant by use of the following formula:

$$k = \frac{2.3026 \; V}{A(t)} \; x \; \log \frac{a}{a-x}$$

where

    V = volume of liquid
    A = area of solid
    t = time of reaction
    a = original weight of solid
    x = amount of solid consumed

(See "Theoretische Chemie," by Walther Nernst)

Using the above formula and the following data, reaction constants for the various metals were calculated (10 cc of mercury and a piece of metal 2 square centimeters in area were used in each case):

Metal	Time	a	a-x	k
Gold	5 min.	0.2490 g	0.2370 g	0.0506
Gold	10 min.	0.2370	0.2125	0.0541
Gold	15 min.	0.1910	0.1530	0.0744
Gold	25 min.	0.1530	0.0979	0.0893
Silver	5 min.	0.0855	0.0735	0.152
Silver	10 min.	0.0842	0.0595	0.1735
Silver	15 min.	0.0823	0.0457	0.1965
Silver	20 min.	0.0875	0.0471	0.155
Silver	25 min.	0.0860	0.0373	0.1675
Copper	5 min.	0.3332	0.3324	0
Copper	10 min.	0.3248	0.3231	0
Copper	15 min.	0.3243	0.3222	0

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The reaction constant for gold rises as the time increases. This may be due to a number of factors. One of these is that a number of gold-mercury compounds are formed rather than one, which would account to some extent for the variation in the value of the constant. Another factor is that the gold is apparently more soluble in a mixture of mercury and amalgam than in mercury alone. It appears that the value of the constant is rather steady for the short time measurements, but as the time of reaction increases outside influences become increasingly important and the value of the constant changes.

In the case of the silver there is also a variation in the value of the constant but it is much more stable than that for the gold. The constant is seen to rise and then to decrease. This is probably due to compensating factors which affect the value of the constant.

The constant for copper is practically zero since in each measurement the log of a quantity which is only slightly greater than unity is involved.

SUGGESTIONS FOR FURTHER STUDIES ON AMALGAMATION

The results of this thesis might be combined with studies of contact angles of mercury on various metals. The degree of amalgamability should be proportional to the size of the contact angle. This would permit a comparison of all metals which can be amalgamated. The metals which could be

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tested by the method outlined in this thesis had to have melting points well above the boiling point of mercury to permit cleaning. Thus, such metals as lead, zinc, tin, etc. had to be ignored since they melt before all the excess mercury and amalgam could be distilled off them.

CONCLUSIONS

The results of these investigations indicate that gold and silver in a pure state are almost equally amalgamable, while copper is about one-seventh as amalgamable as these others. In actual commercial amalgamation, however, gold would seem to be more amalgamable than silver since it occurs native to a much larger extent than does silver. The variation in the reaction constants indicates that amalgamation is not a simple chemical process. Up to certain limiting values, the presence of amalgam seems to increase the rate of amalgamation.

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