# STUDIES ON THE COAGULATION OF VON WEIMARN'S $Au_F$—SOLS. I.

By Eiichi IWASE.

Received April 20, 1929. Published May 28, 1929.

**I. Introduction.** The application of P. P. von Weimarn's[1] modification of the "formaldehyde method" makes it possible to produce large amounts of dispersoidal gold solutions of a *beautiful red* colour, which are *always reproducible*; the obtaining of dispersoidal gold solutions by this modification of the formaldehyde method, may be performed in laboratories possessing no expensive equipment; that is to say, without the use of gold condensers for the distillation of water, or of beakers of extra resistant glass, etc.

Of course, in spite of their all possessing the same beautiful red colour when observed with the naked eye, the quantitative properties of these dispersoidal gold solutions are dependent upon the conditions of their preparation; e.g. the coagulation values of these red dispersoidal solutions should vary more or less considerably, in accordance with the conditions of experimenting.

Prof. P.P. von Weimarn suggested to me[2] a systematic investigation of the coagulation phenomena in dispersoidal gold solutions, obtained by his method. The programme of this investigation comprises the elucidation of the influence upon the coagulation values for various electrolytes, of the following variables: 1). Of unreduced gold compounds; 2). Of the excess of KOH and $K_2CO_3$ in the solution; 3). Of water different in purity; 4). Of the materials the vessels are made of; 5). Of the purity of the reagents, and especially of the formaldehyde solutions (redistilled and non-redistilled formaldehyde, its age, etc.) etc.

I wish also to express here to Prof. P.P. von Weimarn my sincere gratitude for giving me the theme of this investigation; in this brief paper are presented certain of the results obtained by me, of the coagulation values for NaCl and $BaCl_2$.

**II. The Dispersoidal Gold Solutions were Prepared in Beakers of Ordinary Laboratory Glass A, with Ordinary Distilled Water; The Measuring Vessels Used were of Ordinary Laboratory Glass C. In the same**

(1) P.P. von Weimarn, *Kolloid-Z.*, **33** (1923) 74 & 228; **36** (1925) 1; **39** (1926) 166 & 278; **45** (1928), 203 & 366. This Bulletin, **4** (1929), 34. *Japanese Journal of Chemistry*, **3** (1929), 165.

(2) P.P. von Weimarn, *Japanese Journal of Chemistry*, **3** (1929), 201.

**Room, Simultaneously with the Dispersoidal Gold Synthesis, were Carried out Other Chemical Experiments.**[1] Dispersoidal solution "Sol $B_1$" was obtained by boiling a mixture of 500 c.c. distilled water (20°C.)+10 c.c. $AuCl_3HCl4H_2O$-solution (0.6%)+3.5 c.c. reagent $F^{10}_{0.2KOH}$. Immediately after the beginning of boiling (it required about 10 minutes' heating) into this mixture were poured, in portions, 150 c.c. distilled water. After about 30 minutes' boiling, the volume of the solution equalled 500 c.c. (at room temperature). The $AuCl_3HCl4H_2O$ and KOH were *extra pure*. The formaldehyde solution was *redistilled*.

In Table 1 are given data of *one* experiment with NaCl (*extra pure*) and in Table 2 of *one* experiment with $BaCl_2$ (*extra pure*).

Table 1. "Sol $B_1$."

| Concentration of NaCl per litre (in millimols): / Colour of sol: | 12 | 14 | 17 | 19 | 22 | 24 | 26 |
|---|---|---|---|---|---|---|---|
| at the time of addition: | red | red | red | red | violet-tish-red | violet-tish-red | violet-tish-red |
| after 5 min. | red | red | red | violet-tish-red | violet-tish-red | violet-tish-red | *violet.* |
| after 15 min. | red | red | red with a violet tinge | reddish-violet | reddish-violet | reddish-violet | violet. |
| after 2 hours: | red | red | red with a violet tinge | reddish-violet | violet | violet | turbid, the intensity of colour falls off. |
| after 20 hours: | red | red | red with a violet tinge | *violet.* | *violet slightly turbid.* | the intensity of colour falls off markedly | almost colourless. |

(1) Glass C is more sensitive to a weak solution of alkalies than is glass A; see P.P. von Weimarn, l.c. The determination of the coagulation values was always carried out in a separate room, which was heated by electricity and in which no other chemical work was performed. The NaCl and $BaCl_2$-, KOH- and $AuCl_3HCl4H_2O$- solutions were prepared with water, redistilled through Jena glass.

Table 2. "Sol $B_1$."

| Concentration of $BaCl_2$ per litre (in millimols): / Colour of sol: | 0.06 | 0.09 | 0.11 | 0.14 | 0.16–0.17 | 0.18 |
|---|---|---|---|---|---|---|
| at the time of addition: | red | red | red | red | red | violettish-red |
| after 5 min. | red | red | red with a violet tinge | violettish-red | *violet* | violet |
| after 15 min. | red | red | red with a violet tinge | violettish-red | violet. | violet |
| after 2 hours: | red | red | violettish-red | violet with a red nuance | violet | the intensity of colour falls off, the sol is slightly turbid |
| after 20 hours: | red | red | violettish-red | *violet* | *violet, slightly turbid.* | almost colourless. |

In Tables 3 and 4 are shown similar data for "Sol $B_1$+150 c.c. KOH, 0.02 norm.; the method of preparation of this sol was quite similar to that of "Sol $B_1$," the only difference being that, instead of 150 c.c. distilled water, there were added, for a more complete reduction, 150 c.c. of KOH-solution, 0.02 norm. *extra pure.*

Table 3. "Sol $B_1$+150 c.c. KOH, 0.02 norm."

| Concentration of NaCl per litre (in millimols): / Colour of sol: | 4 | 5 | 7 | 10 | 12 | 14 | 16 |
|---|---|---|---|---|---|---|---|
| at the time of addition: | red | red | red | red | red | red with a violet tinge | red with a violet tinge |
| after 5 min. | red | red | red | red | red with a violet tinge. | violettish-red | *violet.* |
| after 15 min. | red | red | red with a violet tinge | violettish-red | reddish-violet | reddish-violet | violet |
| after 2 hours: | red | red | red with a violet tinge | reddish-violet | violet | violet | violet |
| after 20 hours: | red | red with a violet nuance | violettish-red. | *violet.* | violet | *violet, turbid,* | the intensity of colour falls off, the sol is turbid. |

Table 4. "Sol $B_1$+150 c.c. KOH, 0.02 norm.

| Concentration of $BaCl_2$ per litre (in milli-mols): / Colour of sol: | 0.006 | 0.011 | 0.016 | 0.021 | 0.026 | 0.030 | 0.035 |
|---|---|---|---|---|---|---|---|
| at the time of addition: | red | red | red | red | red | red | red |
| after 5 min. | red | red | red | red | red | violet-tish-red | *violet* |
| after 15 min. | red | red | red | red with a violet tinge | violet-tish-red | violet | violet |
| after 2 hours: | red | red with a violet tinge | red with a violet tinge | reddish-violet | violet | violet | violet |
| after 20 hours: | red | *violet.* | violet | violet | *violet, slightly turbid.* | violet, turbid | almost colour-less. |

In Table 5 are summed up the results of different experiment (by I, II, III, and IV are designated dispersoidal gold solutions prepared at different times; by a, b and c are designated the coagulation values for different portions of one and the same dispersoidal gold solution).

Table 5. (Red→violet after 5 minutes).

| | "Sol $B_1$" | | "Sol $B_1$+150 c.c. KOH, 0.02 norm." | |
|---|---|---|---|---|
| | NaCl | $BaCl_2$ | NaCl | $BaCl_2$ |
| I | 27 | 0.16 | a. 16, b. 16 | 0.03 |
| II | a. 26, b. 26 | 0.16 | a. 16, b. 16 | between 0.03–0.035 |
| III | a. 28, b. 28 | a. 0.18, b. 0.17, c. 0.17 | a. 16, b. 16 | between 0.03–0.035 |
| IV | — | — | — | 0.04 |
| Mean | 27 | 0.17 | 16 | 0.03 |

**III. The Dispersoidal Gold Solutions were Prepared with Ordinary Distilled Water, in Beakers of Glass A; the Measuring Vessels were of Jena Glass and of Glass A; no Other Chemical Experiments were Performed in the Room.** Under these conditions, the intensity of colour (at room temperature), of "Sol $B_1$+150 c.c. KOH. 0.02 norm." when compared with "Sol $B_1$," showed a much smaller increase, than in similar experiments described in Section II.

Table 6. (Red→violet after 5 minutes).

| | "Sol $B_1$" | | "Sol $B_1$+150 c.c. KOH, 0.02 norm." | |
|---|---|---|---|---|
| | NaCl | $BaCl_2$ | NaCl | $BaCl_2$ |
| I | between 27–28 | 0.21 | 19 | 0.06 |
| II | — | — | 17 | 0.06 |
| III | — | — | 19 | 0.08 |
| Mean | 27.5 | 0.21 | 18 | 0.07 |

In Table 6 are summed up the data, pertaining to the coagulation values for NaCl and $BaCl_2$; these values are considerably greater than those obtained in dispersoidal synthesis carried out in a room where other chemical experiments are being performed at the same time, and with measuring vessels made of glass C, which is more sensitive to weak solutions of alkalies.

**IV. The Dispersoidal Gold Solutions were Prepared in Beakers of Jena Glass, with Water Redistilled Through a Condenser of Jena Glass.**

Table 7. (Red→violet after 5 minutes).

| | "Sol $B_1$". | | "Sol $B_1$+150 c.c. KOH, 0.02 norm." | |
|---|---|---|---|---|
| | NaCl | $BaCl_2$ | NaCl | $BaCl_2$ |
| I | between 24–25 | between 0.17–0.18 | 13 | 0.03 |
| II | 25 | 0.18 | a. 14, b. 14 | 0.03 |
| III | a. 24, b. 24 | 0.17 | — | — |
| Mean | 24 | 0.17 | 14 | 0.03 |

From the data given in Table 7, it is clearly seen that the coagulation values for NaCl and $BaCl_2$ are *not* increased by using, instead of ordinary distilled water, water redistilled through a Jena glass condenser, nor are they by using Jena glass beakers, instead of those made of glass A.

**V. Conclusion.** The above coagulation numbers for NaCl and $BaCl_2$ admit of the following conclusions:

*A.* By varying the conditions of obtaining "Sol $B_1$," the coagulation values are changed relatively little; for NaCl the changes are within the limits of 27.5 and 24, or 14 per cent, and for $BaCl_2$, between 0.21 and 0.17, or 23 per cent.

*B.* By varying the conditions of obtaining "Sol $B_1$+150 KOH, 0.02 norm.," the coagulation values become changed considerably; viz. for NaCl they are between 18 and 14, or 28 per cent. For $BaCl_2$ the changes in coagulation values are very great; they are expressed between 0.03 and 0.07, or 133 per cent.

*C.* The greatest difference in the coagulation values for "Sol $B_1$" and "Sol $B_1$+150 c.c. KOH, 0.02 norm.," is for NaCl between 27.5 and 14, a difference of 96 per cent; and for Ba $Cl_2$ between 0.21 and 0.03, a difference of 600 per cent.

*D.* Dispersoidal solutions "Sol $B_1$+150 c.c. KOH, 0.02 norm." although the difference in their coagulation values for $BaCl_2$ rises up to 600 per cent. preserve their *pure red* colouring; only the colour becomes darker (more intense) and the brownish opalescence in reflected light increases. Other conditions being equal, the darker the red colour, and the stronger the opalescence, the less is the coagulation value for $BaCl_2$.

I shall devote my future papers to the consideration of the influence of separate variables upon the coagulation values, now I wish only to point out that the intensity of the red colour of "Sol $B_1$+150 c.c. KOH, 0.02 norm." prepared in a gold beaker, with water redistilled through a gold condenser, differs very little from that of "Sol $B_1$" (prepared also in a gold beaker and with the same *extra pure* water); in this case, the coagulation numbers of "Sol $B_1$+150 c.c. KOH, 0.02 norm.," for NaCl are 20 and for $BaCl_2$, 0.08.

In conclusion, I wish to extend my hearty thanks to Prof. P. P. von Weimarn for kindly guiding me into the world of Dispersoidology, during my stay in his laboratory, from September 1926 to April 1929.

Dispersoidological Department of the Imperial Industrial Research Institute of Osaka.