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J. J. Pinajian

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THE DISTRIBUTION COEFFICIENT OF TRIVALENT GOLD IN METHYL ISOBUTYL KETONE/HYDROCHLORIC ACID AND BIS-(β-CHLOROETHYL) ETHER/HYDROCHLORIC ACID SYSTEMS AS A FUNCTION OF THE CONCENTRATION OF HYDROCHLORIC ACID AND THE CONCENTRATION OF GOLD

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Isotopes Division

NOVEMBER 1966

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ABSTRACT

The bis-(β-chloroethyl) ether and the methyl isobutyl ketone extraction of gold(III) chloride from hydrochloric acid solutions was studied as a function of the gold concentration and the hydrochloric acid concentration. Values of the K_D are given for 0.0125 mM - 100 mM Au(III) chloride and 2 M - 10 M HCl [bis-(β-chloroethyl) ether] and 1 M - 6 M HCl [methyl isobutyl ketone].

The extraction of gold(III) chloride from hydrochloric acid solutions by methyl isobutyl ketone was found to be from 25 to 250 times more efficient than by the use of bis-(β-chloroethyl) ether.

INTRODUCTION

In a recent work[1] the distribution behavior of hydrochloric acid solutions of Au(III) chloride was examined in isopropyl ether, bis-(β-chloroethyl) ether, ethyl acetate, amyl acetate, and methyl isobutyl ketone; of these, bis-(β-chloroethyl) ether and methyl isobutyl ketone were found to have distribution coefficients which were orders of magnitude greater than that of the commonly used ethyl acetate/hydrochloric acid system. Hence, a detailed investigation of the effect of the concentration of trivalent gold as well as of the concentration of hydrochloric acid was initiated.

The use of organic extractants which have distribution coefficients in the range of several hundred to several thousand offers an ideal method for the preparation of solids-free samples suitable for uses such as measurements of the internal conversion coefficient of ^{195}Au.[2] In addition, the technique enables one to remove gold contamination from platinum targets which are to be used for the reactor production of ^{199}Au, and offers a convenient means of extracting ^{199}Au after the neutron irradiation.[3]

Strelow et al.,[4] since the completion of our earlier work, have used methyl isobutyl ketone to extract trivalent gold from a hydrochloric acid solution of gold in cyanide waste solutions.

PROCEDURE

The organic solvents were standard stock reagents, used without preliminary purification. The bis-(β-chloroethyl) ether* had a distillation range of 175-181°C, and the methyl isobutyl ketone** had a distillation range of 114-116°C.

The stock gold solution was made by dissolving gold foil in aqua regia, boiling the solution down to incipient dryness, and then taking up the residue in dilute hydrochloric acid. The solutions, adjusted to the desired acid concentration, were 100 mM, 10 mM, 1.0 mM, 0.10 mM, and 0.0125 mM in gold.

The radioindicator for gold was 64.8-hr ^{198}Au, which was obtained*** as $^{198}AuCl_3$, ~1 M in HCl and HNO_3. Approximately 200 μc of ^{198}Au was used in each experiment.

All aqueous solutions were prepared with demineralized water (1.1 x 10^6-ohm resistance).

The distribution data were obtained by contacting equal volumes (20 ml) of the organic phase with the hydrochloric acid solutions containing the ^{198}Au-labeled gold. In each case, the organic was equilibrated, prior to use, with the same concentration of hydrochloric acid as used in the study. Extractions were made at room temperature (22°C). Preliminary experiments established the equilibrium time at <30 seconds. After contacting the two phases for 0.5 - 1.0 min., the phases were separated, centrifuged, and 1.00-ml aliquots taken for analysis. The analysis was made by counting the 0.412-Mev photopeak of the ^{198}Au using a 3- x 3-in. NaI(Tl) gamma spectrometer.

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*Obtained from the Union Carbide Corporation, Chemicals Division

**Obtained from Matheson, Coleman, and Bell, Division of the Matheson Co., Inc.

***Obtained from Isotopes Sales Department, Oak Ridge National Laboratory

RESULTS

The results of the distribution study in the bis-(β-chloroethyl) ether/hydrochloric acid system are compiled in Table 1 and are shown in Fig. 1. The results of the distribution of trivalent gold in the methyl isobutyl ketone/hydrochloric acid system are compiled in Table 2 and are shown in Fig. 2.

Using the standard deviation of the ratios of the respective counting rates (with their respective standard deviations) as an index of the reliability of the distribution data, then the following generalizations can be made regarding the accuracy of the distribution coefficient, K_D*:

Range of K_D	Estimated limit of error in data, %
10^3 - 10^4	+50, -30
10^2 - 10^3	+50, -30
10^1 - 10^2	+20, -10
1 - 10	+10, - 5
10^{-1} - 1	+10, - 5
10^{-2} - 10^{-1}	+20, -10
10^{-3} - 10^{-2}	+50, -30

From these results it is apparent that the only advantage of using bis-(β-chloroethyl) ether for the extraction of gold(III) from hydrochloric acid solutions is the facility of manipulating (by remote control, for example) the ether; because of its density (δ = 1.22 g/ml) it is the lower phase during these operations. Hence, extractions may be made repeatedly using the same separatory funnel. At high gold concentrations one must employ strongly acid solutions in order to extract at least 90% of the gold.

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*The distribution coefficient, K_D, is defined as:

$$K_D = \frac{^{198}\text{Au activity in the organic phase}}{^{198}\text{Au activity in the aqueous phase}}$$

Table 1. The distribution coefficient of trivalent gold in bis-(β-chloroethyl) ether as a function of gold and HCl concentrations

Gold concentration, mM	Hydrochloric acid concentration, M				
	2	4	6	8	10
0.0125	279	411	495	408	406
0.10	23	23	31	26	13
1.0	8	23	11	32	28
10.	2	6	12	19	22
100.	0.9	3	6	10	16

Organic phase 20 ml: aqueous phase 20 ml

Table 2. The distribution coefficient of trivalent gold in methyl isobutyl ketone as a function of HCl concentration

Gold concentration, mM	Hydrochloric acid concentration, M			
	1	2	4	6
0.0125	6038	3715	833	1098
0.10	512	544	457	2571
1.0	767	568	832	911
10.	322	466	673	2577
100.	153	551	661	3854

Organic phase 20 ml: aqueous phase 20 ml

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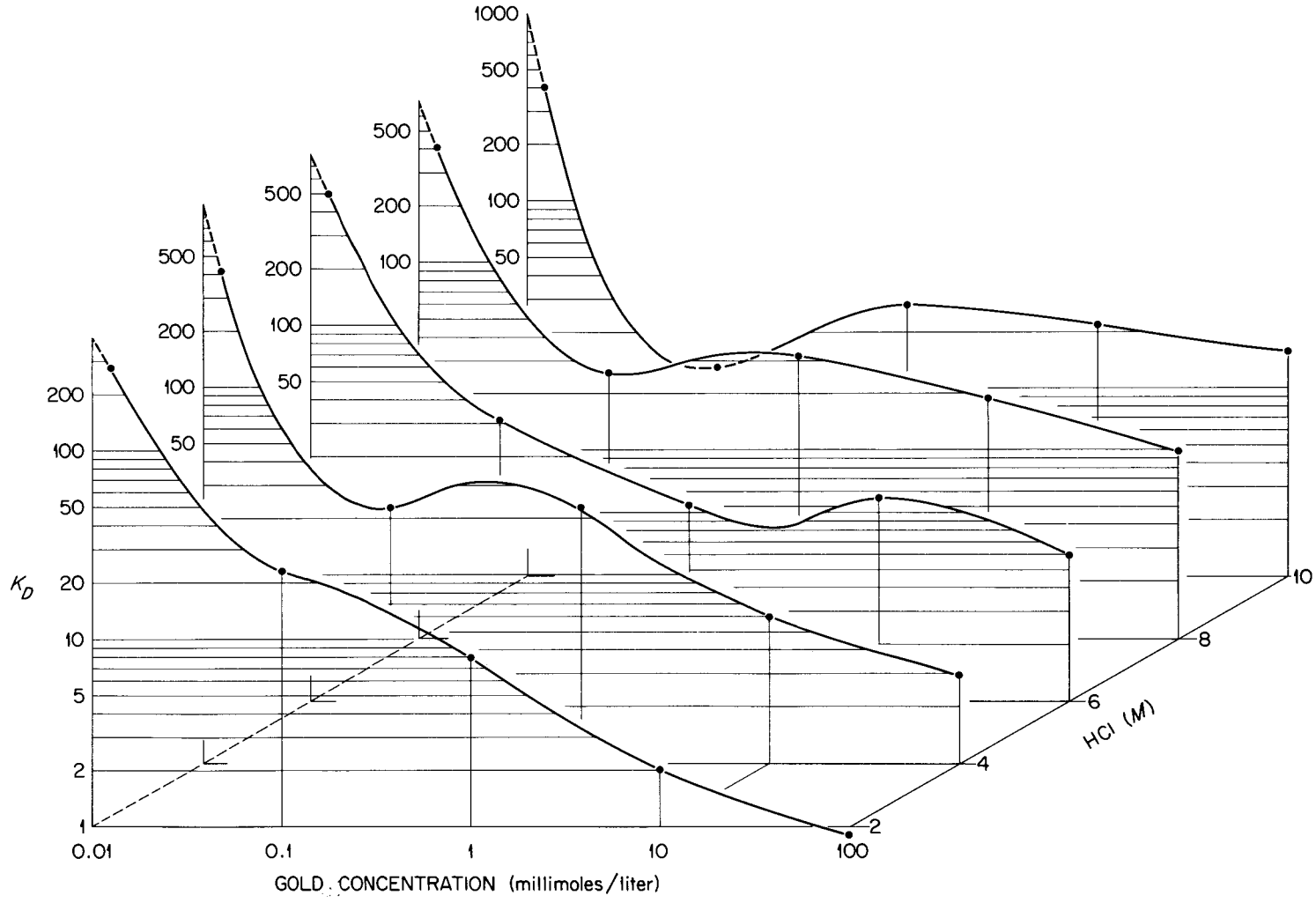

Fig. 1. The Distribution Coefficient of Trivalent Gold in bis-(β-Chloroethyl) Ether as a Function of HCl and Gold Concentrations.

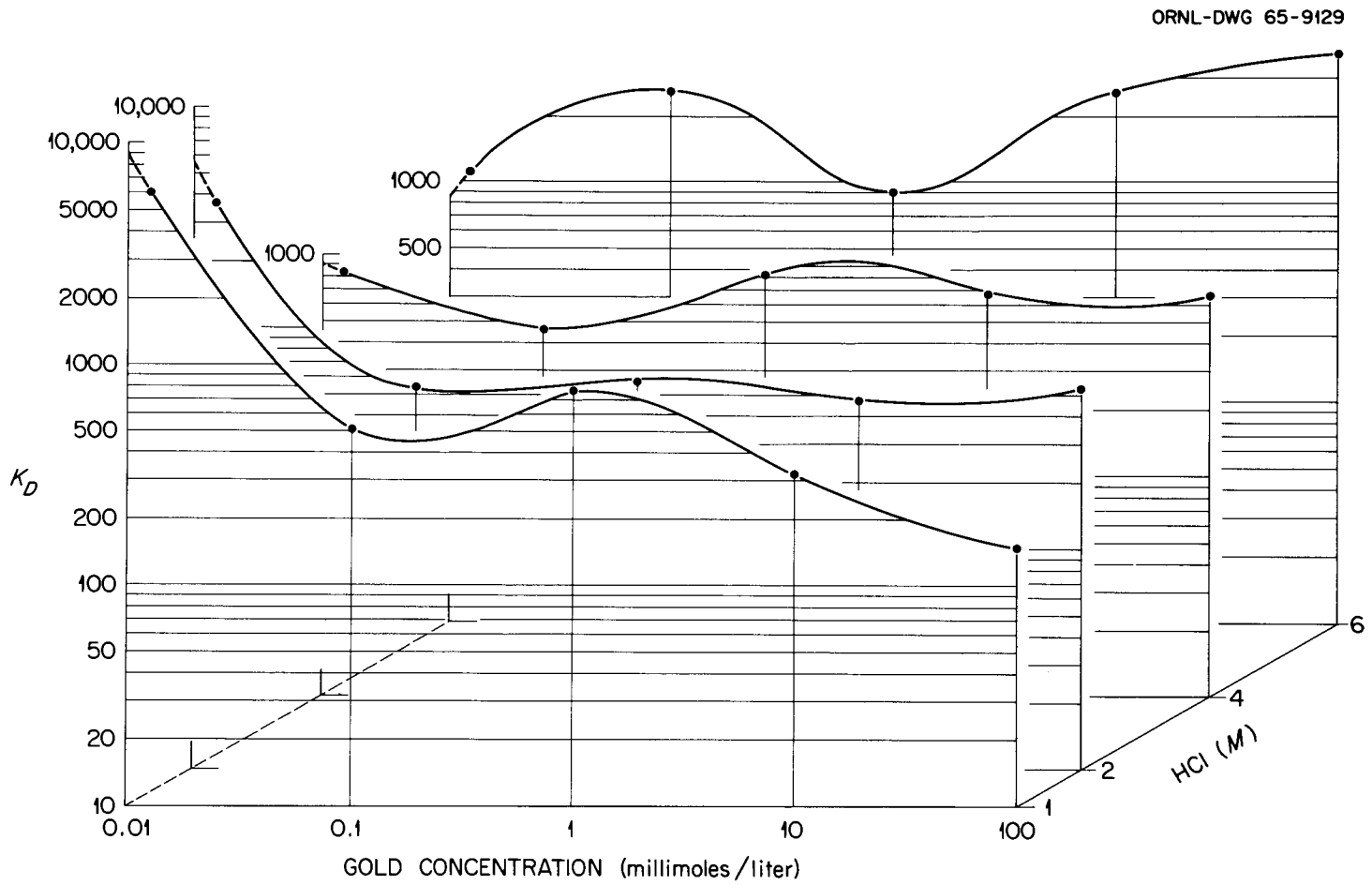

Fig. 2. The Distribution Coefficient of Trivalent Gold in Methyl Isobutyl Ketone as a Function of HCl and Gold Concentrations.

On the other hand, the methyl isobutyl ketone/hydrochloric acid system offers distribution coefficients one or two orders of magnitude greater than that of the bis-(β-chloroethyl) ether system. For very low concentrations of gold, methyl isobutyl ketone is unquestionably more useful, since one may use dilute hydrochloric acid solutions (e.g. 1 M HCl). Here the K_D is 25 times that of the ether. For high concentrations of gold in strongly acid solutions, the methyl isobutyl ketone has a K_D ~250 times that of the ether.

For ~5 mM gold, the distribution coefficients were found by interpolation to be a factor of 2 to 4 less than those found by Strelow et al.[4] This discrepancy is outside of the limits of error assigned to this work. Strelow et al. used methyl isobutyl ketone extraction for the gold (non-radioactive) and determined the gold by atomic absorption spectrometry. They also used a high ratio of aqueous phase to solvent phase (100 ml aqueous: 10 ml organic) to enhance the gold concentration in the extractant.

ACKNOWLEDGMENTS

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