5-15-1951

Determination of the Activities of Indium and Mercury and the Vapor Pressures of Mercury over these Amalgams from 0.00216 to 0.02494 Mole Fraction Indium at 25 C and from 0.00067 to 0.02410 Mole Fraction Indium at 70 C by Electromotive Force Measurements

Arthur H. Lutts

DETERMINATION OF THE ACTIVITIES OF

INDIUM AND MERCURY AND THE VAPOR

PRESSURES OF MERCURY OVER

THESE AMALGAMS FROM 0.00216 TO 0.02494

MOLE FRACTION INDIUM AT 25 C AND

FROM 0.00067 TO 0.02410 MOLE FRACTION

INDIUM AT 70 C BY ELECTROMOTIVE

FORCE MEASUREMENTS

by

Arthur H. Lutts

A Thesis

Submitted to the Department of Metallurgy

in Partial Fulfillment of

the Requirements for the Degree of

Bachelor of Science

in Metallurgical Engineering

Montana School of Mines

Butte, Montana

May 15, 1951

DETERMINATION OF THE ACTIVITIES OF

INDIUM AND MERCURY AND THE VAPOR

PRESSURES OF MERCURY OVER

THESE AMALGAMS FROM 0.00216 TO 0.02494

MOLE FRACTION INDIUM AT 25 C AND

FROM 0.00067 TO 0.02410 MOLE FRACTION

INDIUM AT 70 C BY ELECTROMOTIVE

FORCE MEASUREMENTS

by

Arthur H. Lutts

A Thesis

Submitted to the Department of Metallurgy

in Partial Fulfillment of

the Requirements for the Degree of

Bachelor of Science

in Metallurgical Engineering

Montana School of Mines

Butte, Montana

May 15, 1951

22731

TABLE OF CONTENTS

DETERMINATION OF THE ACTIVITIES OF
INDIUM AND MERCURY AND THE VAPOR
PRESSURES OF MERCURY OVER
THESE AMALGAMS FROM 0.00216 TO 0.02494
MOLE FRACTION INDIUM AT 25 C AND
FROM 0.00067 TO 0.02410 MOLE FRACTION
INDIUM AT 70 C BY ELECTROMOTIVE
FORCE MEASUREMENTS

I INTRODUCTION

Abstract

This work was performed to determine by experimental means the activities of both indium and mercury and the vapor pressures of mercury over these amalgams at 25 and 70 C.

Potentials of the various amalgams, contained in a small glass cell, were obtained by means of a precision potentiometer-galvanometer circuit. The cell, immersed in a water bath, was kept at nearly constant temperature conditions.

The indium concentration of one amalgam electrode was varied by adding a known weight of indium to the mercury contained in that leg, while the other electrode was kept at a constant indium content throughout that particular temperature determination. Concentrations of the variable electrode ranged from 0.00462 to 0.02494 mole fraction indium at 25 C, and from 0.00081 to 0.02410 mole fraction at 70 C. That of the constant electrode was maintained at 0.00216 and 0.00067 mole fraction indium at 25 and 70 C, respectively. In addition to the amalgams, the cell contained an electrolyte of indium sulfate -- $In_2(SO_4)_3$.

The method used by Lewis and Randall [1] was employed to determine the activity of the indium at the various concentrations. Procedures, also by these authors, were used to determine the activity of the solvent (mercury) in these amalgams. Vapor pressures of mercury were determined from the relationship between the vapor pressure of mercury (pure) and the activity of that element as stated by Glasstone. [2]

Review of Previous Experiments

Considerable work [3,4,5] has been done on the electromotive force measurements of amalgams to determine the activities of their components at various temperatures and concentrations. Although this work has involved amalgams containing zinc, lead, tin, thallium, cadmium, sodium, and potassium, only one short reference [6] to electromotive force measurements of amalgams containing indium could be found.

Parks and Morgan [7] have investigated the solubility limit of indium in mercury through the temperature range from 0 to 50 C. They report that indium is soluble in mercury from 2.14 atomic per cent at 0 C to 2.27 atomic per cent at 50 C.

---

[1] Lewis and Randall, Thermodynamics and the Free Energy of Chemical Substances, 1st Ed., McGraw-Hill Book Co., Inc., 1923, pp. 263-267.

[2] Glasstone, S., Thermodynamics for Chemists, 1947, D. Van Nostrand Co., Inc., N. Y., pp. 356-357.

[3] Bent, H., Gilfillan, E., "The Activity of Potassium in Dilute Amalgams", Journal, American Chemical Society, Vol. 41, 1922, p. 353.

[4] Bent, H., Gilfillan, E., "The Activity of Sodium in Concentrated Liquid Amalgams", Journal, American Chemical Society, Vol. 56, 1934, p. 1505.

[5] Lewis and Randall, Journal, American Chemical Society, Vol. 43, 1921, p. 233.

[6] Hildebrand, "The Constitution of Certain Liquid Amalgams", Journal, American Chemical Society, Vol. 45, 1913, p. 513.

[7] Parks and Morgan, "The Solubility of Indium in Mercury from 0 to 50 C", Journal, Physical Chemical Society, Vol. 41, 1937, p. 343.

Their paper also contains the recommendation that precise electromotive force measurements of amalgams of this metal should be possible if oxidizing conditions were eliminated.

Theoretical Discussion

The concentration cell is a member of the reversible voltaic cell family. Creighton [8] further classifies concentration cells in the following manner: (a) Those in which the substance producing the ions is of different concentrations, and (b) Those in which the ions are of different concentrations. The amalgam cells are members of the first class, and may be graphically represented as follows:

M amalgam (conc) / MA / M amalgam (dilute).
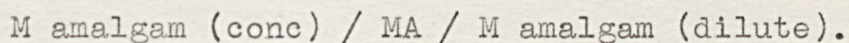
The electromotive force produced by this cell is a result of the tendency of the two concentrations to become equal.

Following the notation of Lewis and Randall [9], the cell used in this investigation may be graphically represented as shown below.

In amalgam (N_2) / $In_2(SO_4)_3$ / In amalgam (N_2')
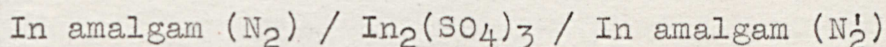
In this cell representation N_2 represents the concentration (in mole fraction) of indium in the concentrated amalgam, and N_2' that in the dilute amalgam. Rossini [10] states, "The convention regarding the sign, positive or negative, of the electromotive force is that the value of the electromotive force represents the tendency for the reaction to proceed with the

[8] Creighton, H. J., _Principles and Applications of Electrochemistry_, Vol. I (Principles), 4th Ed., John Wiley & Sons, N. Y., p. 199.
[9] Lewis and Randall, _Thermodynamics_, McGraw-Hill Book Co., Inc., 1923, p. 265.
[10] Rossini, F., _Chemical Thermodynamics_, John Wiley & Sons, Inc., N. Y., p. 360.

electrons moving clockwise in the system as drawn, left to right in the external circuit above and right to left through the solution below."

From thermosynamic theory, the transfer of one mole of indium from the left to the right electrode is equal to the difference in chemical potentials of the indium in the two amalgams. This free energy change may be expressed mathematically as follows:

$$\Delta F = RT \ln a_{In}/a'_{In}. \quad (A)$$

In this equation, a_{In} and a'_{In} are the activities of the concentrated and dilute amalgams, respectively. The free energy change may also be equated to the quantity of electrical energy required to return one mole of indium from one electrode to the other.

$$\Delta F = - NFE = - xzFE \quad (B)$$

In the above equation, x is the number of atoms in the indium molecule (one), and z is the valence of the indium ion (plus three). Equating expressions (A) and (B) yields the following relationship:

$$E = - RT/3F \ln a_{In}/a'_{In}. \quad (C)$$

This equation shows that the electromotive force of the cell depends upon the ratio of the activities of the concentrated and dilute amalgams, and not upon the indium concentration of the electrolyte.

The following theory and mathematical operations are those used by Lewis and Randall and as described by Glasstone.[11] By definition, when the activity of a solute is referred to the standard state, the ratio of activity to concentration of that

---

[11] Glasstone, S., Thermodynamics for Chemists, 1947, D. Van Nostrand Co., Inc., N. Y., pp. 363-366.

solute is unity when the concentration is zero (at infinite dilution). Equation (C) may be solved for ln a_{In} to produce relationship (D).

$$\ln a_{In} = -3EF/RT + \ln a'_{In} \quad (D)$$

The term log a_{In}/N_{In}, described in (E) may be obtained by subtracting ln N_{In} from both sides of equation (D) and converting to $\log_{10}$.

$$\log a_{In}/N_{In} = (-3EF/2.303RT - \log N_{In}) + \log a'_{In} \quad (E)$$

In this equation, if E is expressed in volts, R must be expressed in degrees Kelvin.

The procedure from this point on consists of determining the electromotive force of several concentration cells in each of which one amalgam is kept constant in indium content (N'_{In}) while the other amalgam is subsequently changed in indium content. When N_{In} is zero (i.e., at infinite dilution) the term a_{In}/N_{In} becomes unity, and log a_{In}/N_{In} becomes zero. Thus, the term $-\log a'_{In}$ becomes equal to $-3FE/2.303$ RT. Therefore, when the value of the term in curves, in equation (E), is plotted against its corresponding indium concentration, and the curve is extrapolated to N_{In} equals zero, the value $-\log a'_{In}$ can be easily determined. The value a_{In}/N_{In} can then be determined for any other value of N_{In} by simply adding log a'_{In} to the term in curves. Thus, the term a_{In} (activity) for any amalgam within the experimental range can be determined.

The activity of mercury can be obtained from that of the indium by use of the method following that above in Glasstone. In a binary solution the sum of the mole fractions of solvent and solute is unity. Therefore, the expression, $N_{Hg} + N_{In} = 1$,

when differentiated becomes equal to zero ($dN_{Hg} + dN_{In} = 0$).

$$N_{Hg}dN_{Hg}/N_{Hg} + N_{In}dN_{In}/N_{In} = 0 \quad (F)$$

$$\text{or } N_{Hg}dlnN_{Hg} + N_{In}dlnN_{In} = 0 \quad (G)$$

If equation (G) is subtracted from the expression

$$N_{Hg}dlna_{Hg} + N_{In}dlna_{In} = 0 \quad (H)$$

the relationship (I), containing both activities and mole
fraction is obtained.

$$dlna_{Hg}/N_{Hg} = - N_{In}/N_{Hg}dlna_{In}/N_{In} \quad (I)$$

Equation (J) is obtained after integrating both sides of equa-
tion (I) and converting to $\log_{10}$.

$$\log a_{Hg}/N_{Hg} - \log a'_{Hg}/N'_{Hg} = -\int_{N'_{In}}^{N_{In}} N_{In}/N_{Hg} \, dloga_{In}/N_{In} \quad (J)$$

This equation may be simplified by considering that when
N'_{Hg} and N'_{In} represent infinite dilution, or when $N'_{Hg} = 1$ and
$N'_{In} = 0$, the activity of mercury is unity, as defined by the
standard state for a solvent. Thus, a'_{Hg}/N'_{Hg} is unity and
$\log a'_{Hg}/N'_{Hg}$ becomes zero, and equation (J) can be represented
by (K).

$$\log a_{Hg}/N_{Hg} = -\int_{0}^{N_{In}} N_{In}/N_{Hg} \, dloga_{In}/N_{In} \quad (K)$$

The values for N_{In}/N_{Hg} are plotted against values of
$\log a_{In}/N_{In}$ on coordinate paper. The area under the curve
from zero to any N_{In} value will give the term $\log a_{Hg}/N_{Hg}$ for
the solvent (mercury) at N_{Hg} values corresponding to the N_{In}
values.

Following the procedure used by Lewis and Randall [12], the

---

[12] Lewis and Randall, Thermodynamics, McGraw-Hill Book Co, Inc.,
1923, pp. 257-259.

vapor pressures of mercury were determined from a knowledge of activities of mercury at the various concentrations and the vapor pressure of mercury in the standard state.

II EXPERIMENTAL PROCEDURE

The following section of this paper contains a description of chemicals, apparatus, and techniques used in this investigation.

Chemicals

The purity, and use of the two chemical reagents -- mercury and indium -- used in this investigation is described in the sections below.

Mercury The mercury used in this investigation was obtained from the Metallurgy Department. A small, distilling retort [13], partially evacuated of air by an aspirator, was used to purify this reagent. Following distillation, the mercury was washed in dilute nitric acid and rinsed in distilled water.

Indium This reagent, also obtained from Dr. Hames of the Metallurgy Department, was supplied by the Consolidated Mining and Smelting Company of Canada, Limited, and is stamped "Tadanac" and 99.99%.

Apparatus

The following is a description of the different pieces of apparatus used in this investigation. Some mention is also made of the techniques in their use.

Water Bath Nearly constant temperature conditions were maintained by use of a Denver Fire Clay Co., water bath. This apparatus consists of 5 essential parts -- a cylindrical, insulated glass vessel (22 liter capacity), a mercury temperature

[13] This retort was constructed by Mr. J. C. Ruggles of the Chemistry Department, Montana School of Mines, Butte.

regulator, electrical relay circuit, two 100-watt electric lamps, and a mechanically operated stirrer.

At 25 C, the temperature of the bath could be controlled to 25 ± 0.01 C; while at 70 C, the variation was much larger -- about 70 ± 0.15 C. Two 100-watt lamps were used to maintain the bath at 25 C, while an immersion heater, in addition to 1 lamp, was required to maintain the water at 70 C. In addition to the immersion heater, it was found convenient to place a piece of rubberized cloth across the top of the glass vessel to reduce loss of heat by radiation. The water level was kept constant throughout the determinations.

Thermometer Temperatures of the bath were read from a precision grade, chemical thermometer (Kimball Glass Co.) graduated in 0.1 C increments. Corrections for the exposed stem were made during the 70 C determination. These corrections were not thought to be necessary at 25 C because the bath temperature was only 2 to 3 C above that of the laboratory.

Potentiometer-Galvanometer Circuit Electromotive force readings were obtained by use of a Leeds and Northrup precision potentiometer (K-2 Model) used in conjuction with a Leeds and Northrup galvanometer (Fig. 1). By the use of this circuit, potentials could be measured to ± 0.000005 volt. The circuit was balanced against a standard cell (Eppley Laboratory, Inc.) rated at 1.0179 volts.

Electricity for the working cell, as well as for the galvanometer lamp, was supplied by 2.1 volt lead storage batteries -- one for the working cell and 2 for the galvanometer lamp.

Immersion Heater The attainment of a temperature of 70 C could

not be realized with the two 100-watt lamps. For this reason, an immersion heater (Thermoletter Products Co.) was used to supply the additional heat. This heater supplies 300 watts at 115 volts.

Techniques Amalgams were prepared by adding a small, weighed amount of indium to a previously weighed portion of mercury contained in a small H-shaped glass cell (Fig. 2). The mercury was dried by passing it through a filter paper containing several small holes at its apex. About 20 grams of mercury, sufficient to make the amalgam-electrolyte interface rise above the platinum electrodes of the cell, were weighed by difference on an anlytical balance. The electrolyte, prepared by dissolving indium in sulfuric acid and adjusting to a pH of 4.5, was placed in the cell. Nitrogen, bubbled through the electrolyte, removed the entrapped air to prevent oxidiation of the amalgams. The weight of indium, when added to the known weight of mercury to produce the desired concentration, was determined to 4 places (0.1 mg.). This indium was added to the cell by simply dropping it through the electrolyte onto the mercury.

Solution of the indium was hastened by stirring the amalgam with a small glass rod and also by heating the cell in a beaker of hot water previous to placing this cell in the 25 C bath.

Potentiometer readings were taken at 5-minute intervals; the potentiometer being checked against the standard cell immediately before and after each reading. The final electromotive force reading was obtained from an average of an hour's best readings. The indium concentration of the variable electrode was increased by simply adding more indium. During each

temperature run, two new pairs of amalgams were prepared. In
this manner, the use of both indium and mercury was reduced to
a minimum.

During the determinations at 25 C, the solubility limit
of indium in mercury, as mentioned on page 2, was approached
slowly by adding a small amount of indium in successive steps.

Experimental results show that the potentials of cells
containing indium concentrations greater than this value drop-
ped suddenly and subsequently rose at greater concentrations.
As might be expected, longer periods of time were required as
the indium content increased. About 30 hours were required
for equilibrium to be reached at the higher concentrations.

III DISCUSSION OF RESULTS AND CONCLUSIONS

The following section contains a discussion of the exper-
imental results, conclusions reached from these results, and
recommendations for future work in this field.

Discussion

As can be seen from Table I (Appendix), the electromotive
forces at 25 C of the various cells rose as the indium concen-
tration increased. This increase continued until the solubil-
ity limit of indium in mercury was attained. A slight increase
in indium content over this limit decreased the potential of
the next cell by nearly one volt. Subsequent increases in ind-
ium content, however, increased the potential.

The same phenomenon is also exhibited at 70 C, as can be
seen in Table II or Fig. 4. It will be noticed in this case
however, that the downward trend of the curve occurs at a low-
er indium content (approximately 0.01588 mole fraction) than

that at 25 C. This is not a true indication of the solubil-
ity limit as concentrations between this value and 0.01974 mole
fraction, the cell of next higher concentration, were not used.
This fact would seem to indicate that the solubility of indium
in mercury at this temperature is probably between these two
concentrations. In subsequent work, it would probably be ad-
vantageous to establish the maximum point in the curve of Fig.
4. more closely.

The fact that near the limit of solubility of indium in
mercury at 25 C was accompanied by more or less erratic elec-
tromotive force measurements should be mentioned at this time.
As the solubility limit was approached, from 24 to 36 hours
were required to acquire agreements between successive poten-
tial readings comparable to those obtained at lower concentra-
tions.

Activities of both indium and mercury have been plotted
against their respective concentrations at both 25 and 70 C,
and are shown in Fig. 5 and Fig. 6. In both instances, it will
be seen that the activity vs. concentration curves for indium
follow the same general trend as the potential vs. concentra-
tion curves. That portion of the curve from the maxima to the
minima is believed to represent either the partial miscibility
zone or a temporary association and disassociation of the ind-
ium and mercury.

The departure of the ratio of activity to concentration
(a/N) from unity, as shown in the fourth columns of Tables I
and II, indicates the departure from that of an ideal solution
as postulated.by Henry. The relation between the activity of
mercury and concentration of mercury is also shown in Fig. 5

and Fig. 6. The change in vapor pressures of mercury over the amalgams at the various temperatures and mercury concentrations of these amalgams are shown in Fig. 7 and Fig. 8. The change in activity of mercury with concentration at 25 C is more uniform than that of the indium at the same temperature (Fig. 5). At 70 C, the change with mercury concentration is more pronounced but is still less than that of the activity change of the indium.

Vapor pressures of mercury in amalgams at 25 and 70 C are lower than the vapor pressures of the mercury (pure) at the corresponding temperatures. The curve (Fig. 7) at 25 C is nearly a straight-line function. At 70 C (Fig. 8) the deviation from a straight-line relationship is more apparent. This deviation may be caused by the same mechanism as that affecting the activity of indium; i.e., either a partial miscibility or association and subsequent disassociation of the indium and mercury.

Because of the nature of the cell, there exists a small, solid-to-liquid (platinum-to-amalgam) contact or Volta potential. Although the magnitude of this contact potential was, for many years, thought to be insignificant, Creighton[14] states that this is not always the case. However, it is believed, that under equilibrium conditions, the magnitude of this potential is very small. Since the calculation of this potential involves information which is also a function of the activities of the amalgam constituents, these calculations would become involved.

---

[14] Creighton, H. J., Principles and Applications of Electrochemistry, Vol. I (Principles), 4th Ed., John Wiley & Sons, N. Y., pp. 183-184.

Conclusions

Based on the results of this experiment, it is believed that the activities of both indium and mercury, up to the reported limit of solubility of the indium in mercury at 25 C, are representative of their true values. The same statement, with the condition stated below, can be made up to about 0.01588 mole fraction indium in the 70 C determination. Because of the better temperature control inherent at 25 C ($\pm$ 0.01 C), it is believed that these results are probably the more accurate of the two determinations.

Above the solubility limit, the change in activities of indium can be explained by either a zone of partial miscibility or, as previously mentioned, by association and disassociation of the indium and mercury. Of course, there is always the possibility of concentration gradients existing around undissolved particles of indium.

Since activity determinations can also be performed by freezing-point measurements, vapor-pressure measurements, and solubility measurements, the results of this work could be checked by one or more of these methods.

The following section contains a summation of the results of this investigation and some recommendations for continued work in this field.

1. The results for the activities of indium in amalgams at 25 C up to the reported limit of solubility of indium in mercury (2.18 atomic per cent), seem to be representative of the true values. Above 2.18 atomic per cent indium, the change in activities is thought to be caused by either a partial miscibility zone or an association and subsequent disassocaition

of indium and mercury.

2. At 70 C, the activities of indium and mercury, up to about 1.588 atomic per cent indium, are probably representative of their true value but, because of the more inaccurate temperature control, are probably not as accurate as those at 25 C.

3. There was no apparent change in the amalgam during the experiment.

4. That portion of the curves in Fig. 3 and Fig. 4 between the maxima and minima should be investigated more throughly.

5. Provisions should be made for better temperature controls, especially in the higher temperature range.

6. The activities of indium and mercury should be checked by one or more of the other existing methods: viz., freezing-point, vapor-pressure, and solubility-measurement methods.
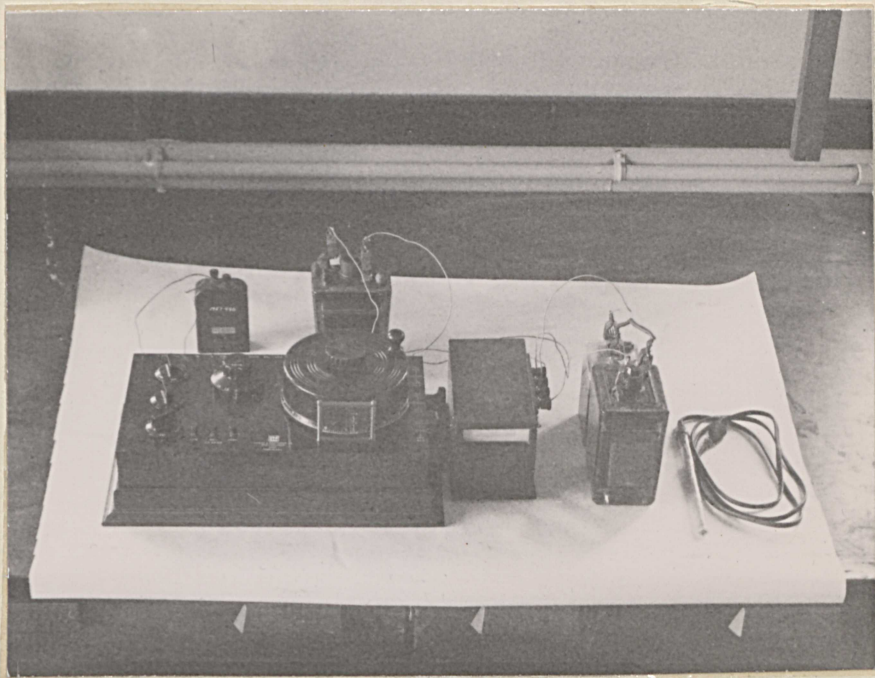
Fig. 1.

Potentiometer-Galvanometer Circuit
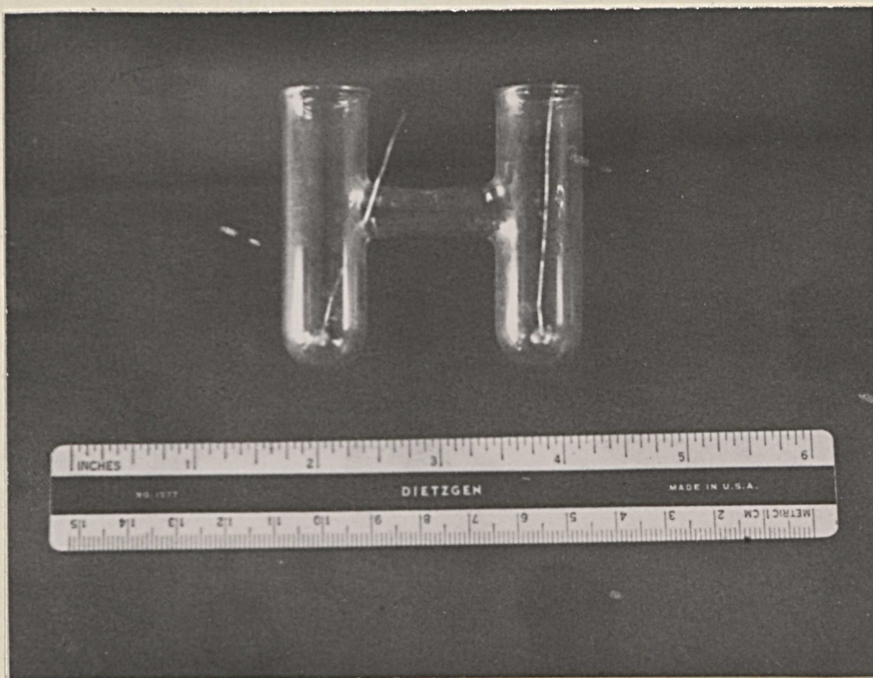
Fig. 2.

Glass Cell
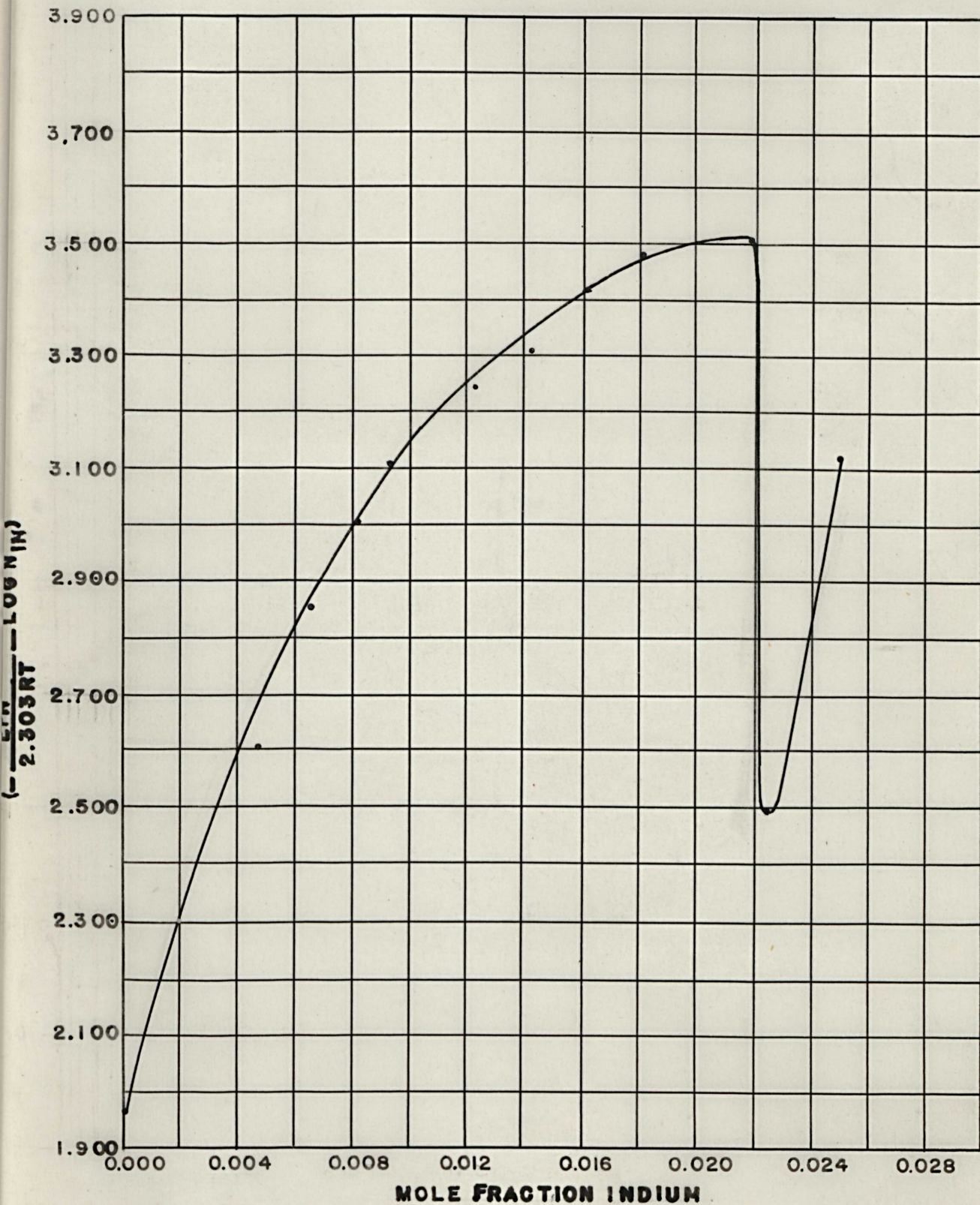
FIG. 3. TERM $\left(-\dfrac{EFN}{2.303RT}\right. - LOG\ N_{IN}$ PLOTTED VS.

MOLE FRACTION INDIUM AT 25° C.
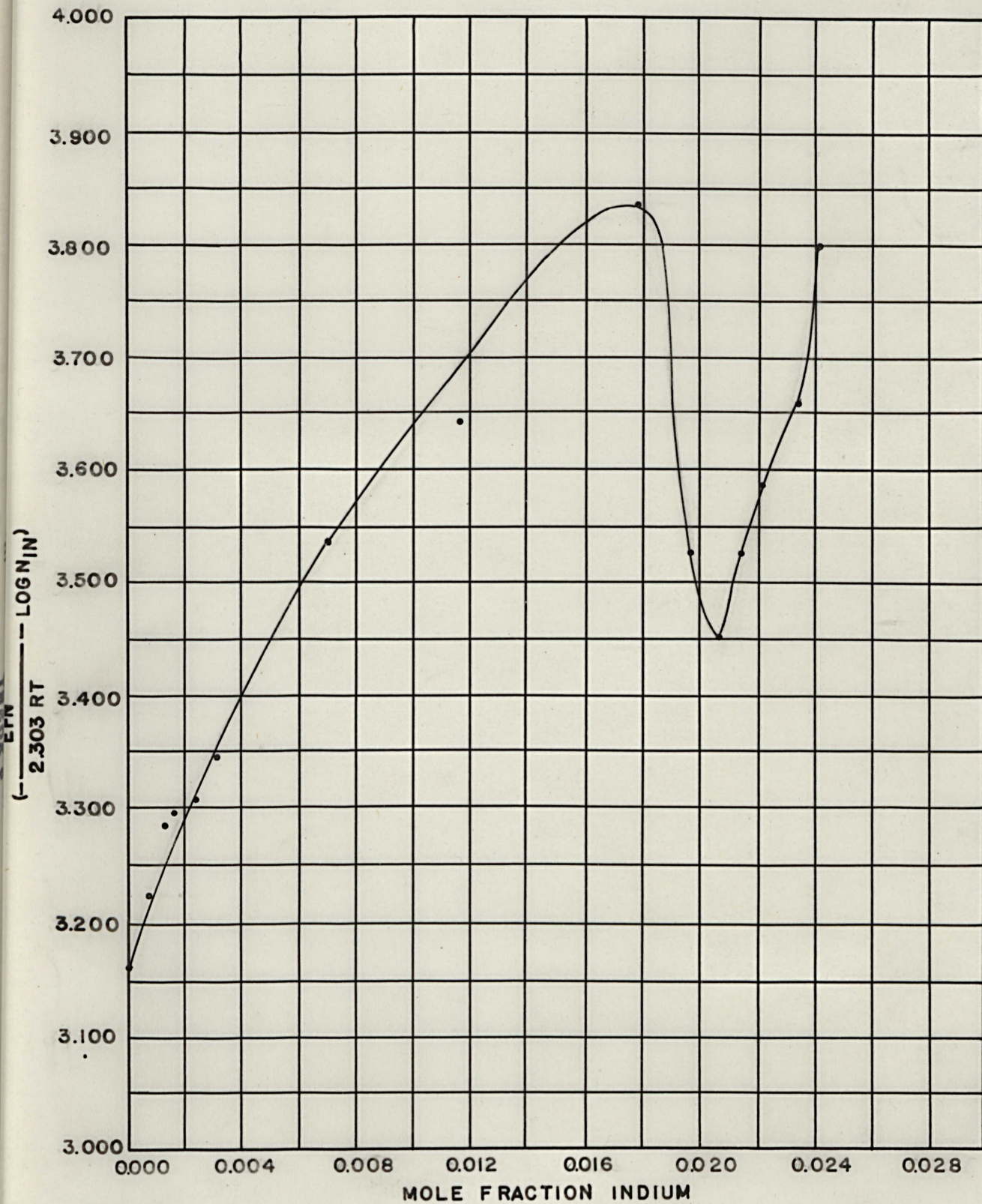
FIG. 4. TERM $\left(-\dfrac{EFN}{2.303RT} - \text{LOG } N_{IN}\right)$ PLOTTED VS.
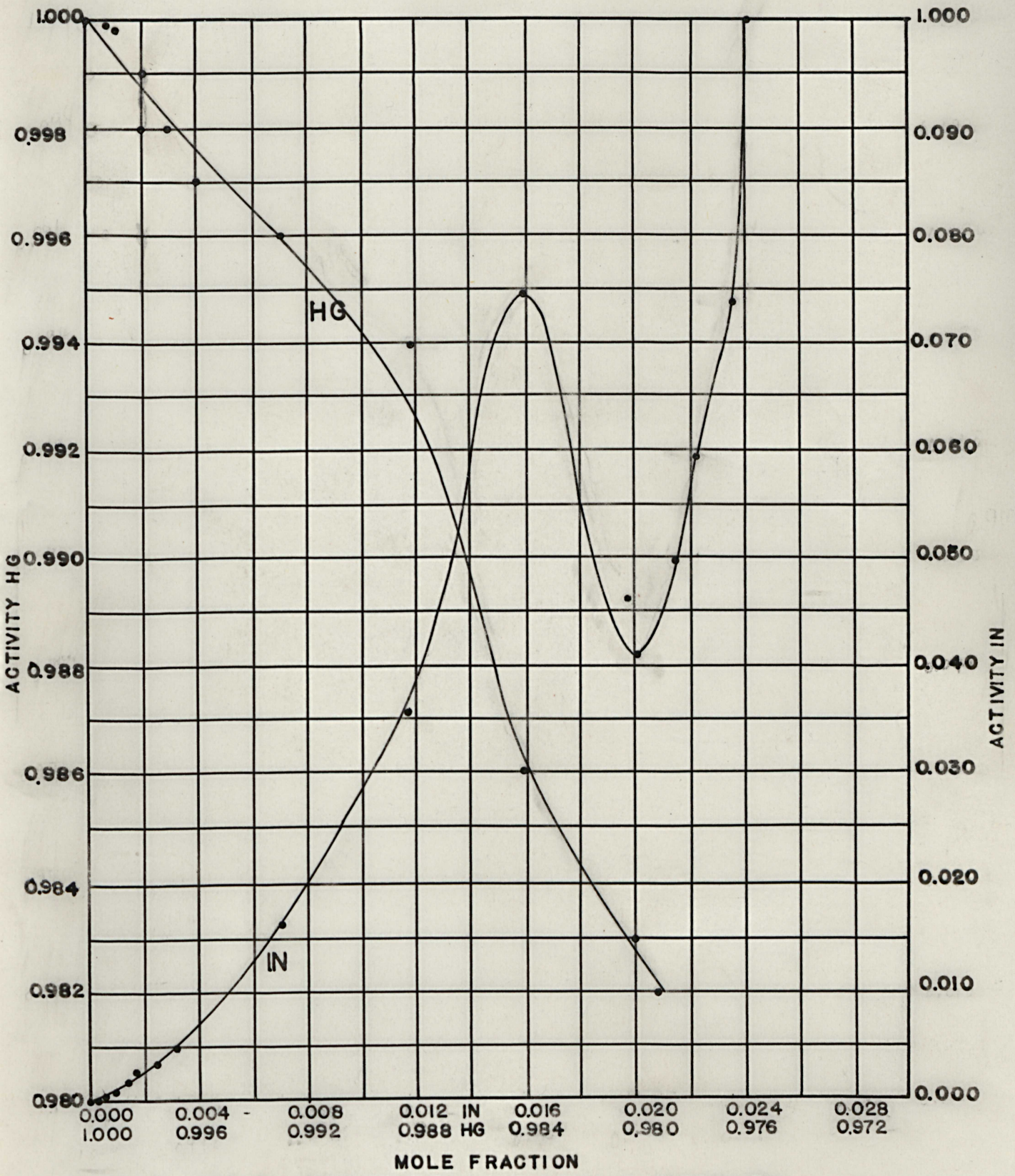
MOLE FRACTION INDIUM AT 70° C.

FIG. 6. ACTIVITIES OF INDIUM & MERCURY
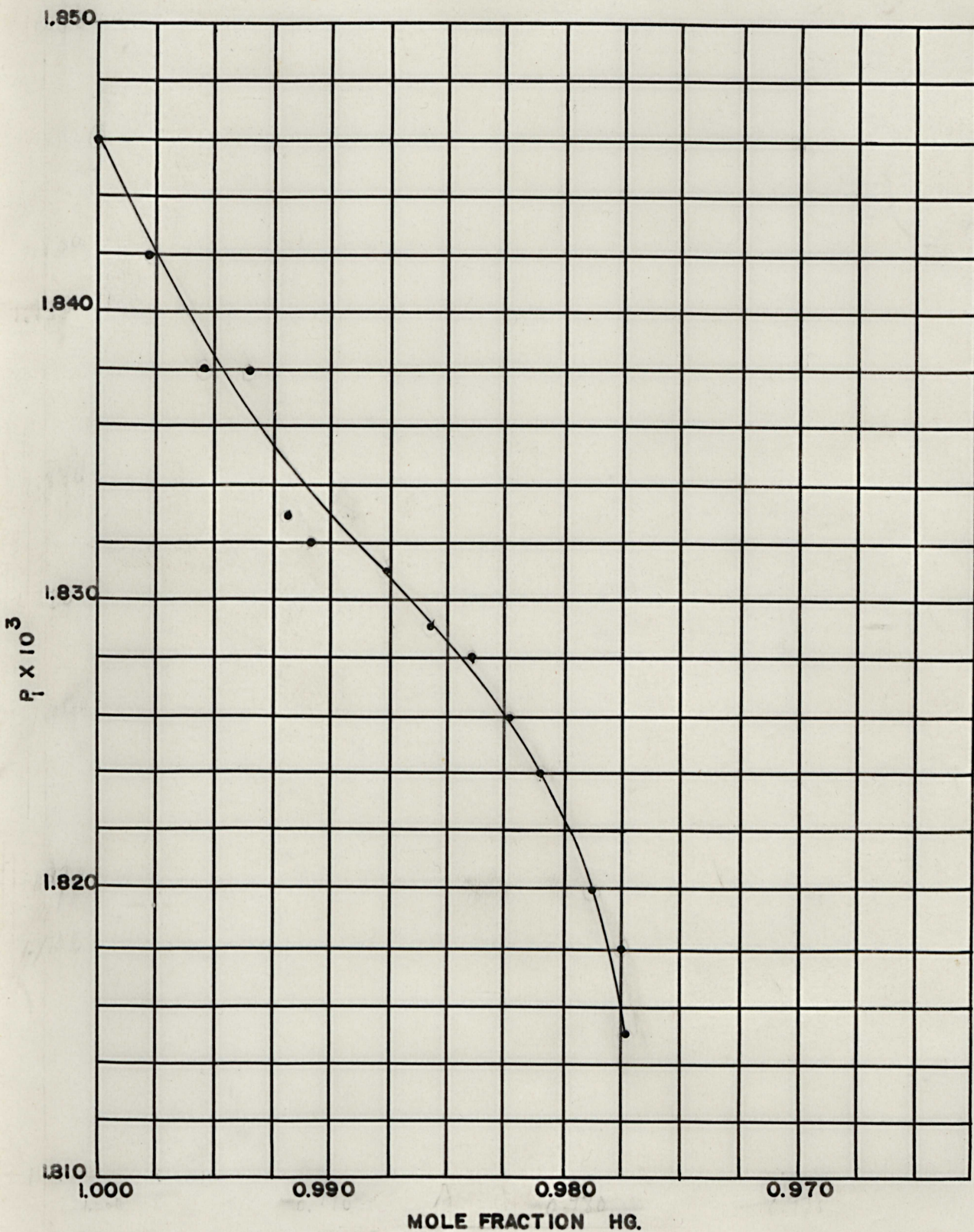
AT 70°C VS. MOLE FRACTIONS

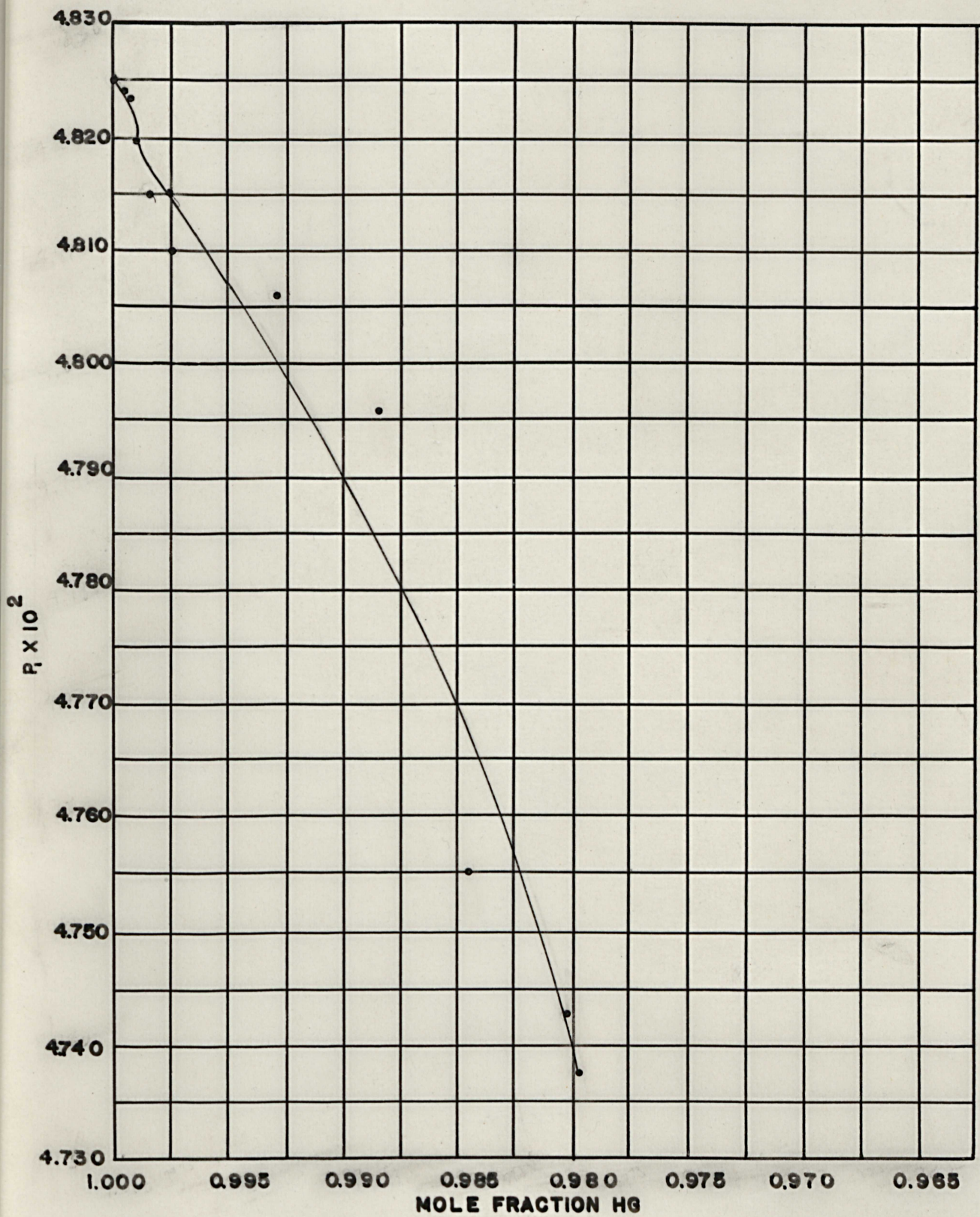FIG. 7. VAPOR PRESSURE OF HG IN AMALGAMS
VS. MOLE FRACTION HG AT 25°C

FIG. 8. VAPOR PRESSURE OF HG. IN AMALGAMS

VS. MOLE FRACTION HG. AT 70° C.

IV APPENDIX

Table I

At 25 C.

N_{In}	$- E$	$(-\dfrac{EFN}{2.303RT} - \log N_{In})$	a_{In}/N_{In}	a_{In}
0.00000	–	(1.9540)	1.000	0.00000
0.00216	0.000000	2.66555	5.147	0.01111
0.00462	0.005375	2.608097	4.509	0.02083
0.00644	0.013180	2.859721	8.049	0.05183
0.00831	0.018220	3.006695	11.29	0.09382
0.00926	0.021220	3.110039	14.32	0.13260
0.01232	0.026320	3.244629	19.52	0.24049
0.01422	0.028675	3.301860	22.28	0.31682
0.01611	0.032035	3.418085	29.11	0.46896
0.01800	0.034155	3.477508	33.38	0.60084
0.01990	0.035640	3.509317	35.92	0.71481
0.02180	0.036300	3.509733	35.95	0.78371
0.02249	0.016630	2.491741	3.449	0.07756
0.02494	0.030020	3.126103	14.86	0.37061

Table II

At 70 C.

N_{In}	$- E$	$(-\dfrac{EFN}{2.303RT} - \log N_{In})$	a_{In}/N_{In}	a_{In}
0.00000	–	(3.16400)	1.000	0.00000
0.00067	0.000000	3.173934	1.023	0.00068
0.00081	0.003150	3.221026	1.140	0.00092
0.00130	0.009795	3.288552	1.332	0.00173
0.00174	0.013095	3.297401	1.340	0.00233
0.00243	0.017050	3.316410	1.420	0.00345
0.00318	0.020680	3.347334	1.525	0.00485
0.00699	0.033670	3.538910	2.371	0.01657
0.01171	0.041770	3.647681	3.046	0.03567
0.01588	0.049600	3.836974	3.709	0.07478
0.01974	0.044500	3.532887	2.338	0.04615
0.02072	0.043200	3.458435	1.970	0.04082
0.02143	0.045330	3.531561	2.331	0.04995
0.02220	0.047160	3.591562	2.676	0.05941
0.02350	0.049495	3.662488	3.151	0.07402
0.02410	0.052105	3.799934	4.324	0.10421

Table III

At 25 C.

N_{Hg}	N_{In}	N_{In}/N_{Hg}	a_{In}/N_{In}	$\log a_{In}/N_{In}$
1.00000	0.00000	0.00000	1.000	0.000,000
0.99784	0.00216	0.00216	5.147	0.712
0.99538	0.00462	0.00462	4.509	0.654
0.99356	0.00644	0.00648	8.049	0.906
0.99169	0.00831	0.00839	11.29	1.053
0.99084	0.00926	0.00935	14.32	1.156
0.98768	0.01232	0.01247	19.52	1.291
0.98578	0.01422	0.01443	22.28	1.350
0.98389	0.01611	0.01637	29.11	1.464
0.98200	0.01800	0.01833	33.38	1.524
0.98010	0.01990	0.02304	35.92	1.555
0.97820	0.02180	0.02228	35.95	1.556
0.97751	0.02249	0.02307	3.449	0.538
0.97506	0.02494	0.02557	14.86	1.172

Table IV

At 70 C.

N_{Hg}	N_{In}	N_{In}/N_{Hg}	a_{In}/N_{In}	$\log a_{In}/N_{In}$
1.00000	0.00000	0.00000	1.000	0.000
0.99923	0.00067	0.00067	1.023	0.010
0.99919	0.00081	0.00081	1.140	0.056
0.99870	0.00130	0.00130	1.332	0.125
0.99826	0.00174	0.00174	1.340	0.127
0.99757	0.00243	0.00243	1.420	0.152
0.99682	0.00318	0.00319	1.525	0.173
0.99301	0.00699	0.00704	2.371	0.375
0.98829	0.01171	0.01184	3.046	0.484
0.98412	0.01588	0.01614	4.706	0.673
0.98026	0.01974	0.02014	2.338	0.369
0.97928	0.02072	0.02116	1.970	0.294
0.97857	0.02143	0.02190	2.330	0.368
0.97780	0.02220	0.02270	2.676	0.428
0.97650	0.02350	0.02406	3.151	0.498
0.97590	0.02410	0.02469	4.324	0.636

Table V

At 25 C.

N_{Hg}	$\log a_{Hg}/N_{Hg}$	a_{Hg}/N_{Hg}	a_{Hg}
1.00000	0.00000	1.000	1.000
0.99784	0.00018	1.000	0.998
0.99538	0.00042	1.001	0.995
0.99356	0.00070	1.002	0.995
0.99169	0.00104	1.002	0.993
0.99084	0.00124	1.003	0.992
0.98768	0.00196	1.005	0.992
0.98578	0.00246	1.006	0.991
0.98389	0.00298	1.007	0.990
0.98200	0.00339	1.008	0.989
0.98010	0.00366	1.008	0.988
0.97820	0.00366	1.008	0.986
0.97751	0.00366	1.008	0.985
0.97506	0.00367	1.008	0.983

Table VI

At 70 C.

N_{Hg}	$\log a_{Hg}/N_{Hg}$	a_{Hg}/N_{Hg}	a_{Hg}
1.00000	0.00000	1.000	1.000
0.99923	0.00000	1.000-	0.999 +
0.99919	0.00004	1.000	0.999 ++
0.99870	0.00009	1.000	0.999 ++
0.99826	0.00012	1.000	0.998
0.99757	0.00017	1.000	0.998
0.99682	0.00035	1.001	0.997
0.99301	0.00041	1.001	0.996
0.98829	0.00050	1.001	0.994
0.98412	0.00079	1.002	0.986
0.98026	0.00117	1.003	0.983
0.97928	0.00129	1.003	0.982

Table VII

At 25 C $p_1^0 = 0.001846$ mm Hg.[15]

N_{Hg}	a_{Hg}	$p_1^0 \times 10^3$	$p_1 \times 10^3$
1.00000	1.000	1.846	1.846
0.99784	0.998	"	1.842
0.99538	0.995	"	1.838
0.99356	0.995	"	1.838
0.99169	0.993	"	1.833
0.99084	0.992	"	1.832
0.98768	0.992	"	1.831
0.98578	0.991	"	1.829
0.98389	0.990	"	1.828
0.98200	0.989	"	1.826
0.98010	0.988	"	1.824
0.97820	0.986	"	1.820
0.97751	0.985	"	1.818
0.97506	0.983	"	1.815

[15] Hodgman, Charles D., Handbook of Chemistry and Physics, 30th Ed., Chemical Rubber Publishing Co., Cleveland, Ohio, p. 1832.

Table VIII

At 70 C $p_1^0 = 0.04825$ mm Hg.[16]

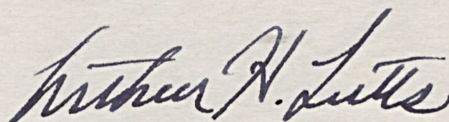| N_{Hg}	a_{Hg}	$p_1^0 \times 10^2$	$p_1 \times 10^2$
1.00000	1.000	4.825	4.825
0.99923	0.999 +	"	4.820 +
0.99919	0.999 +	"	4.820 +
0.99870	0.999	"	4.820
0.99826	0.998	"	4.815
0.99757	0.998	"	4.815
0.99682	0.997	"	4.810
0.99301	0.996	"	4.806
0.98829	0.994	"	4.796
0.98412	0.986	"	4.755
0.98026	0.983	"	4.743
0.97928 -	0.982	"	4.738

[16] ibid.

V BIBLIOGRAPHY

Books

1. Creighton, H. J., <u>Principles and Applications of Electro-</u><u>chemistry</u>, Vol. 1 (Principles), 4th Ed., New York, John Wiley & Sons, 1948.

2. Glasstone, S., <u>Thermodynamics for Chemists</u>, New York, D. Van Nostrand Co., Inc., 1947.

3. Hodgman C. D., (Ed. In Chief) <u>Handbook of Chemistry and Physics</u>, 30th Ed., Cleveland, Ohio, Chemical Rubber Publishing Co., 1947.

4. Lewis and Randall, <u>Thermodynamics and the Free Energy of Chemical Substances</u>, New York, McGraw-Hill Book Co., Inc., 1923.

5. Rossini, F., <u>Chemical Thermodynamics</u>, New York, John Wiley & Sons, Inc., 1950.

Periodicals

1. Bent, H., and Gilfillan, E., "The Activity of Potassium in Dilute Amalgams", <u>Journal</u>, <u>American Chemical Society</u>, Vol. 41. p. 353, 1922.

2. Bent, H., and Gilfillan, E., "The Activity of Sodium in Concentrated Liquid Amalgams", <u>Journal</u>, <u>American Chemical Society</u>, Vol. 56, p. 1505, 1934.

3. Hildebrand, "The Constitution of Certain Liquid Amalgams", <u>Journal</u>, <u>American Chemical Society</u>, Vol. 45, p. 513, 1913.

4. Lewis and Randall, <u>Journal</u>, <u>American Chemical Society</u>, Vol. 43, p. 233, 1921.

5. Parks and Morgan, "The Solubility of Indium in Mercury from 0 to 50 C", <u>Journal</u>, <u>Physical Chemical Society</u>, Vol. 41, p. 343, 1937.

ACKNOWLEDGMENTS