The Mercury-Indium Equilibrium Diagram

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PUBLISHED phase diagrams for binary amalgam systems show that only mercury-thallium exhibits an extended range of concentrations that are liquid at 20° C., with the possible exception of mercury-indium. The phase diagram of the mercury-indium system has never been completely worked out, and the two previous investigations of portions of the diagram have produced highly discordant results (*2, 4*) which have been discussed (*1, 3*).

The present investigation establishes the equilibrium diagram for the mercury-indium system from 0 to 54 wt. % indium, and thus resolves the conflict in data.

EXPERIMENTAL

Method. The method utilized was thermal analysis involving cooling and heating curves. Dilatometry was used to obtain the liquidus for one alloy; no thermal effect was observed.

Materials. The mercury used was A.C.S. grade with reported maximum base metal impurity of 0.0001% and maximum silver and gold (combined) impurity of 0.0005%. The indium used was analyzed by the manufacturer to have a purity greater than 99.999% and contained 0.0001% lead, less than 0.0001% iron, and a trace of magnesium. No other impurities were spectrographically detected.

Procedure. The alloys were made by mixing weighed portions of mercury and indium in pyrex test tubes. Throughout the concentration range studied, the indium was readily soluble in mercury at room temperature, but to ensure homogeneity the alloys were alternately heated and cooled for several cycles, meanwhile being constantly stirred with a glass rod. Following Spicer and Banick, some of the alloys were covered with mineral oil to protect against oxidation, but most samples were prepared without covering. Neither mercury nor indium oxidize rapidly in air and the amalgam retains its bright surface during measurements.

Temperature was measured with a glass-sheathed copper-constantan thermocouple immersed in the amalgam. It was possible to read to one microvolt (approximately 0.02° C.) on a Leeds and Northrup model 7552 potentiometer. The thermocouple was calibrated at the boiling point of water, melting point of ice, freezing point of mercury, and the sublimation temperature of solid carbon dioxide. The calibration was repeated after completion of the work and the thermocouple was found unchanged.

Phase changes were observed by thermal analysis. Either heating or cooling curves, and sometimes both, were obtained. Temperature readings were made every ½ minute. Heating rates were approximately ½° per minute, and cooling rates somewhat less. Cooling was provided by a dry ice–acetone bath.

RESULTS

Liquidus and solidus temperatures for the thermal analysis of 39 alloys containing 0 to 54 wt. % indium are given in Table I. The equilibrium diagram (Figure 1) was constructed from this data and that of Spicer and Banick (*4*). The solubility data of Parks and Moran is also shown.

The major features of the equilibrium diagram are summarized in Table II, and the estimated accuracy for the establishment of each feature is indicated. The peritectic composition must lie quite close to the mercury edge of the phase diagram, although the exact composition was not established. The presence of a peritectic rather than an eutectic was confirmed by recalibrating the thermocouple to ensure that the peritectic temperature was above the freezing temperature of mercury.

Table I. Thermal Analysis Data for the System: Mercury-Indium

Sample No.	Hg, Wt. %	Temp., ° C. Liquidus	Temp., ° C. Solidus
1	99.95	−36.7	−37.7
2	99.90	−35.3	−35.3
3	99.80	−34.0	−36.0
4	99.56	−31.6	−35.8
5	99.21	−29.4	−35.3
6	98.90	−26.0	−35.6
7	98.73	−24.0	−35.0
8	98.70	−25.3	−34.2
9	98.60	−24.5	−34.5
10	98.37	−23.5	−34.5
11	98.03	−24.7	−35.0
12	97.49	−19.7	−34.0
13	96.97	−21.0	−37.0
14	96.00	−17.4	−25[a]
15	94.63	−16.0	−18
16	93.21	−12.3	−14
17	91.85	−12.0	−13
18	91.25	−12.4	−12.4
19	90.70	−12.8	−12.8
20	90.40	−14.1	−14
21	90.07	−13.0	−14
22	88.98	−13.9	−17
23	87.54	−14.6	−20
24	87.06	−16.0	−20
25	85.82	−17.0	−33.2[b]
26	84.50	−18.0	−32.9
27	82.35	−22.0	−33.3
28	79.02	−28.3	−33.2
29	76.89	−32.0	−33.1
30	75.32	−30.0	−33.0
31	69.22	−19.1	−33.0
32	66.15	−17.0	−33.0
33	63.66	−16.6	−16.6
34	58.91	−19.2	−29.0
35	54.03	−25.0	−28.0
36	51.53	−27.6	−28.6
37	49.99	−28.6	−28.6
38	48.02	−3.5[c]	−28.7[d]
39	46.03	−10.8	−28.5

[a] Temperatures given to nearest unit were derived from rather rounded heating and cooling curves. [b] A long arrest was observed at −27°. The arrest at −33.2° was a momentary inflection. [c] Observed by dilatometric method. [d] Observed by dilatometry and thermal analysis.

The liquidus temperature reported for sample 38 was obtained by observing the volume change of the sample upon cooling. A sharp slope change in the temperature-volume plot was observed at −3.5°. No thermal effects could be detected, although visual observation established the formation of a solid at approximately this temperature during cooling.

DISCUSSION

Our results were in good agreement with those of Spicer and Banick, who reported thermal effects for ten amalgams

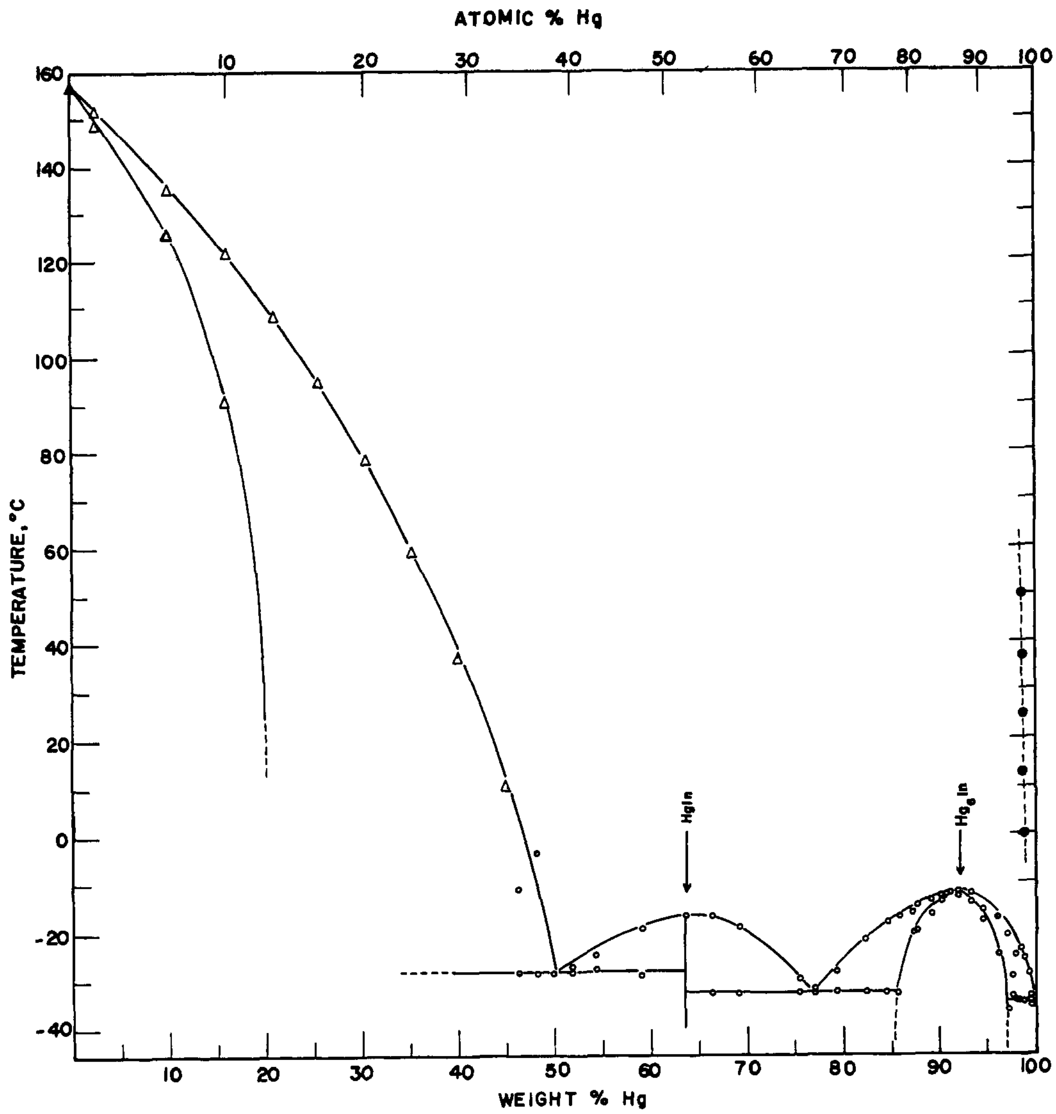

Figure 1. The mercury-indium equilibrium diagram
△ Spicer and Banick
● Parks and Moran
○ This work

in the range of 54.92 to 100 wt. % indium. They found lower indium concentrations to result in alloys liquid at 20° C. If their liquidus line is extrapolated, it extends to the eutectic composition we found at 50.0 wt. % indium, and the liquidus temperatures of samples No. 38 and 39 (48.02 and 46.03 wt. % mercury) lie close to this extrapolation.

On the other hand, our results do not agree at all with the solubility data of Parks and Moran. Of the 11 samples in the range of 0 to 2 wt. % indium, indium was found to be considerably more soluble in mercury than they had reported.

Table II. Important Features of the Mercury-Indium Equilibrium Diagram

Feature	Compn., Wt. % Hg	Temp., ° C.
Peritectic	99.5 ± 0.5	−35.0 ± 0.5
Eutectic	77.0 ± 0.5	−33.1 ± 0.1
Eutectic	50.0 ± 0.5	−28.6 ± 0.1
Congruent melting intermediate phase (HgIn)	63.5 ± 0.2	−16.6 ± 0.1
Congruent melting intermediate phase (Hg_6In)	91.3 ± 0.7	−12.4 ± 0.4

LITERATURE CITED

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