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THE EFFECT OF HIGH PRESSURE ON THE LATTICE PARAMETERS OF INDIUM AND ITS ALLOYS*

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Abstract—The effect of pressure to several hundred kbars has been measured on the lattice parameters of indium of an indium–tin alloy, and of two indium–thallium alloys. All four systems crystallize in the face centered tetragonal structure. All showed a maximum in c/a in the region $V/V_0 = 0{\cdot}88$–$0{\cdot}84$. Pure indium and the thallium alloys behaved very much alike, while the tin alloy has a considerably lower maximum for $c/a/(c/a)_0$ at a lower V/V_0.

THE EFFECT of pressure to several hundred kbars has been measured on the lattice parameters of indium, an indium–tin alloy and two indium–thallium alloys. The high pressure X-ray techniques used have been described elsewhere.[1]

The indium used was purchased from A. D. Mackay Inc. of New York City and is listed as 99·99% pure. To prepare the sample material the indium ingot was filed, the powder produced sealed in a Pyrex tube under a vacuum and annealed for one week at 125°C. The tin and thallium used to prepare the alloys was obtained from Fisher Scientific Co. of Fair Lawn, New York. The alloys were prepared by weighing appropriate amounts of the metals, placing them in a graphite crucible with a small amount of flux, heating the assembly under an argon atmosphere in a Lepel induction furnace to a temperature approximately 30° above the fusing temperature and holding it there for 2 min, and finally allowing the assembly to cool and reweighing the metal to assure no loss of material. The alloy samples were annealed under a vacuum for 1–2 weeks, filed to a fine powder and again annealed for one week under a vacuum at 125°C.

Both indium and the alloys studied have a face centered tetragonal structure with c/a ratios in the range 1·05–1·09. The values of c and a were obtained by averaging results from calculations from pairs of lines in the spectrum. The lines used were 111, 113, 311 at times the 002 and 200 and occasionally the 022. Figures 1–4 show typical data for indium and the indium–tin alloy. For pure indium there appears to be a slight irregularity in c and a near $V/V_0 = 0{\cdot}95$. The magnitude is of the order of our experimental error but we have included it, as it appeared on essentially every run. Pressures were obtained by using a marker of known compressibility (Al, Ag, or MgO). The metal compressibilities were taken from shock wave work,[2] the MgO data were from this

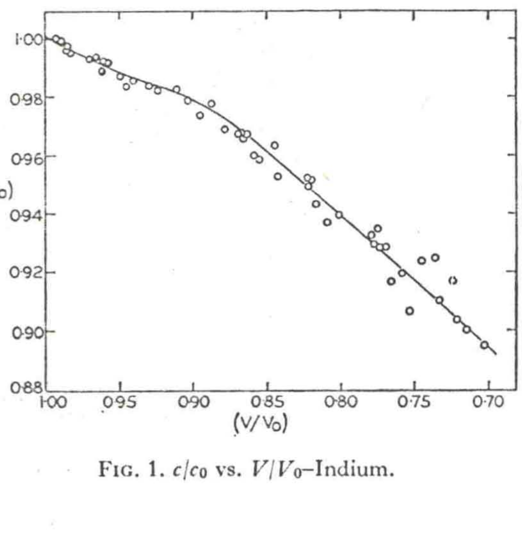

FIG. 1. c/c_0 vs. V/V_0–Indium.

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laboratory.[3] Figures 5 and 6 show typical pressure–vol. data for indium and an indium–thallium alloy. The compressibilities are very close to shock wave values,[2] but smaller than those of BRIDGMAN[4] or of VERESCHAGIN *et al.*[5] who did X-ray work to 120 kbars. The results are tabulated in Tables 1–4. Figure 7 shows c/a ratios for the alloys. All four materials showed a maximum in c/a at $V/V_0 = 0{\cdot}88$–$0{\cdot}84$. The indium and the two thallium alloys behaved very much alike with the c/a maximum about 1·023–1·025 times the atmospheric value. The tin alloy showed a considerably lower maximum at smaller V/V_0. It should be noted that VERESCHAGIN *et al.*[5] also showed a maximum in c/a for pure indium at

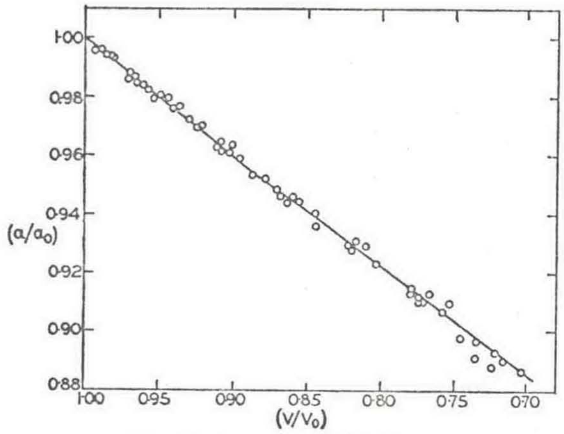

FIG. 2. a/a_0 vs. V/V_0–Indium.

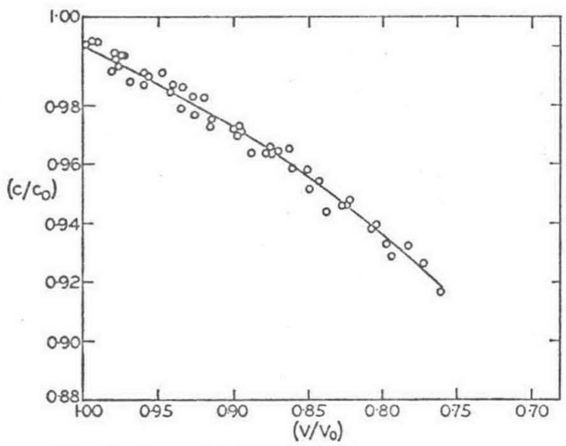

FIG. 3. c/c_0 vs. V/V_0–Indium–4·1% Sn alloy.

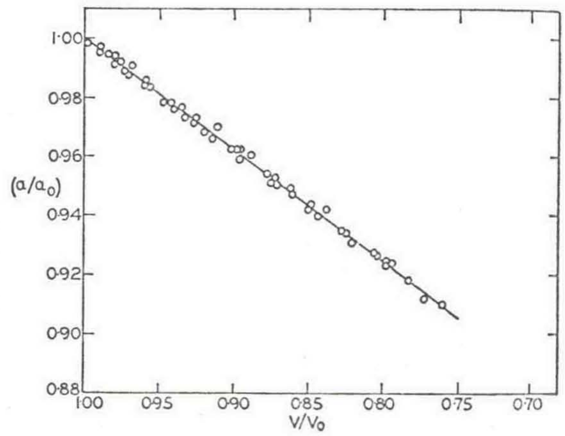

FIG. 4. a/a_0 vs. V/V_0–Indium–4·1% Sn alloy.

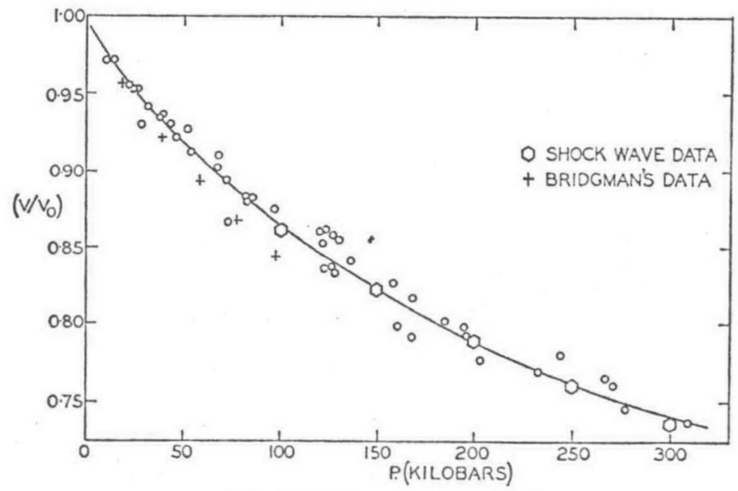

FIG. 5. V/V_0 vs. Pressure–Indium.

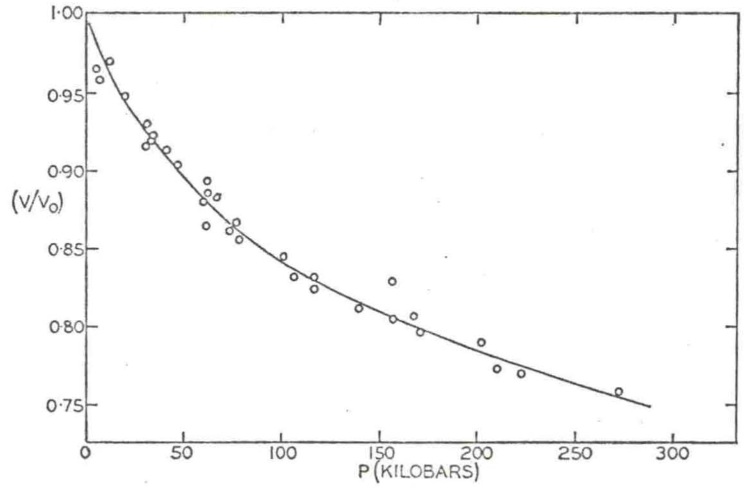

FIG. 6. V/V_0 vs. Pressure–Indium–5·9% Tl Alloy.

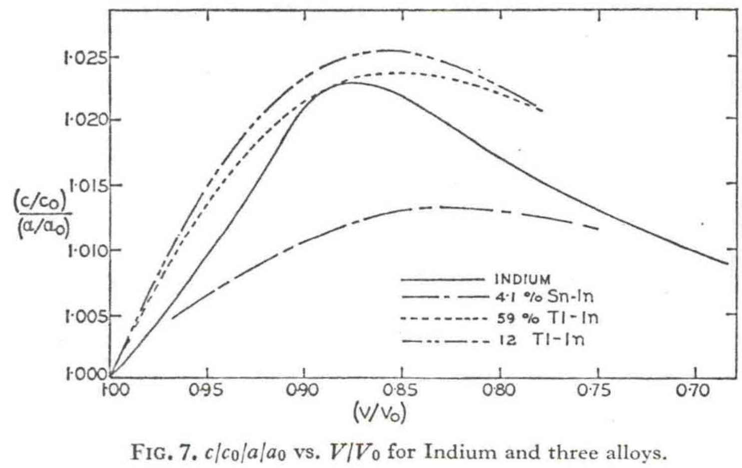

FIG. 7. $c/c_0/a/a_0$ vs. V/V_0 for Indium and three alloys.

about the same V/V_0. There are differences in compressibility among the alloys, but no significant correlation with alloying element or concentration appears.

Thallium is a considerably heavier element than indium but has the same outer electron configuration. Tin is next to indium in the periodic table and has one more valence electron. Attempts to explain the effect of pressure on the lattice parameters of h.c.p. elements such as Mg or Cd[6,7] based on almost free electron arguments have not been very successful. Until detailed information is available about energy gaps, etc., it would seem fruitless to present any extended arguments concerning indium or its alloys.

It is apparent, however, that changing the outer electronic structure has considerably more effect than changing the row of the periodic structure.

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Table 1. *High pressure data, indium.* $a_0 = 4{\cdot}599$ Å; $c_0 = 4{\cdot}9467$ Å; $c_0/a_0 = 1{\cdot}076$

P (kbars)	V/V_0	a/a_0	c/c_0	$\frac{c/c_0}{a/a_0}$
0	1·000	1·000	1·000	1·000
8	0·980	0·9920	0·996	1·004
19	0·960	0·9840	0·991	1·007
32	0·940	0·9760	0·987	1·011
48	0·920	0·9675	0·983	1·016
65	0·900	0·9590	0·979	1·021
83	0·880	0·9510	0·973	1·023
103	0·860	0·9440	0·965	1·022
126	0·840	0·9370	0·957	1·021
151	0·820	0·9300	0·948	1·019
180	0·800	0·9230	0·939	1·017
216	0·780	0·9160	0·930	1·015
258	0·760	0·9085	0·921	1·014
302	0·740	0·9010	0·912	1·012
(345)	0·720	0·8930	0·903	1·011
—	0·700	0·8850	0·894	1·010

Markers used: Al, Ag, MgO.

Table 2. *High pressure data,* 4·1% *tin–indium alloy* (4·1 at.% *tin,* 95·9 at.% indium). $a_0 = 4{\cdot}585$ Å; $c_0 = 4{\cdot}989$ Å; $c_0/a_0 = 1{\cdot}088$

P (kbars)	V/V_0	a/a_0	c/c_0	$\frac{c/c_0}{a/a_0}$
0	1·000	1·000	1·000	1·000
5	0·980	0·9925	0·9950	1·003
13	0·960	0·9845	0·9900	1·006
23	0·940	0·9775	0·9840	1·007
36	0·920	0·9700	0·9780	1·008
53	0·900	0·9620	0·9720	1·010
72	0·880	0·9545	0·9660	1·012
93	0·860	0·9470	0·9590	1·013
116	0·840	0·9395	0·9520	1·013
142	0·820	0·9320	0·9440	1·013
169	0·800	0·9245	0·9360	1·012
(204)	0·780	0·9170	0·9280	1·012
—	0·760	0·9090	0·9200	1·012

Markers used: Al, MgO.

Table 3. *High pressure data,* 5·9% *thallium–indium alloy* (5·9 at.% *thallium,* 94·1 at.% *indium*). $a_0 = 4{\cdot}617$ Å; $c_0 = 4{\cdot}935$ Å; $c_0/a_0 = 1{\cdot}069$

P (kbars)	V/V_0	a/a_0	c/c_0	$\frac{c/c_0}{a/a_0}$
0	1·000	1·000	1·000	1·000
5	0·980	0·9910	0·998	1·007
12	0·960	0·9825	0·995	1·013
22	0·940	0·9745	0·990	1·016
34	0·920	0·9665	0·985	1·019
47	0·900	0·9585	0·980	1·022
62	0·880	0·9510	0·973	1·023
79	0·860	0·9435	0·966	1·024
103	0·840	0·9365	0·958	1·023
123	0·820	0·9290	0·950	1·023
169	0·800	0·9215	0·942	1·022
210	0·780	0·9140	0·934	1·022
258	0·760	0·9065	0·925	1·020

Markers used: Al, MgO.

Table 4. *High pressure data,* 12% *thallium–indium alloy* (12 at.% *thallium,* 88 at.% *indium*). $a_0 = 4{\cdot}642$; $c_0 = 4{\cdot}912$; $c_0/a_0 = 1{\cdot}058$

P (kbars)	V/V_0	a/a_0	c/c_0	$\frac{c/c_0}{a/a_0}$
0	1·000	1·000	1·000	1·000
8	0·980	0·9910	0·998	1·007
18	0·960	0·9825	0·995	1·013
31	0·940	0·9740	0·991	1·017
43	0·920	0·9660	0·986	1·021
60	0·900	0·9585	0·980	1·023
78	0·880	0·9505	0·974	1·025
98	0·860	0·9430	0·967	1·025
124	0·840	0·9360	0·959	1·025
154	0·820	0·9285	0·951	1·024
187	0·800	0·9215	0·942	1·022

Markers used: Al, MgO.

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