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## Effect of High Pressure on the Compressibilities of Five Alloys\*

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The effect of high pressure has been measured on a series of alloys, including Fe plus 8 at. % Si, which has a (disordered) bcc structure, Fe<sub>3</sub>Al and Fe<sub>3</sub>Si, which have an ordered bcc structure, and FeAl and AgMg, which have the CsCl structure. The compressibilities of all the alloys except Fe<sub>3</sub>Si decrease with increasing pressure and lie between those of the pure components. For Fe<sub>3</sub>Si the compressibility increases slightly with increasing pressure and is less than that either of pure iron or pure silicon.

THE effect of pressure to several hundred kilobars has been measured on the lattice parameters of bcc iron containing 8% silicon, on Fe<sub>3</sub>Al and Fe<sub>3</sub>Si which have an ordered bcc structure, and on FeAl and AgMg

TABLE I.  $V/V_0$  vs pressure. Iron alloys and AgMg.

$V/V_0$	Fe+8.0% Si	Fe <sub>3</sub> Si	Fe <sub>2</sub> Al	FeAl	AgMg
1.00	0 (kbar)	0	0	0	0
0.99	18	26	16	12	10
0.98	37	52	29	27	19
0.97	56	76	45	43	30
0.96	77	100	62	60	40
0.95	98	125	80	79	52
0.94	120	148	98	99	64
0.93	142	172	118	120	76
0.92	166	195	140	142	88
0.91	191	217	162	165	101
0.90	216	238	185	191	115
0.89		260	210	222	130
0.88		282	238	260	144
0.87			268	304	160
0.86					175
0.85					191
0.84					208
0.83					226
0.82					244
0.81					264
0.80		•••	•••	•••	285
Markers	Nb	Nb	Nb	Nb	Nb
about 1 pro		NaF	NaF	CaO	Al
Char -		1 × *			NaCl

which have the CsCl structure. The iron alloys were obtained from Beck, and were those used in his specific heat work.<sup>1,2</sup> The AgMg was obtained from Busk of the Dow Chemical Company.

The high-pressure x-ray techniques have been discussed in detail elsewhere.3 The smoothed data are listed in Table I; Figs. 1 and 2 show typical results for Fe<sub>3</sub>Al and Fe<sub>3</sub>Si. As discussed in Ref. 3, the pressures were established by measuring the lattice parameters of markers, substances of known compressibility mixed



with the sample. The markers used for each substance

are shown in Table I. The metal compressibilities were

from shock-wave data<sup>4,5</sup> corrected to 25°C. The salts

were the data of Perez-Albuerne and Drickamer<sup>6</sup> and

Pagannone and Drickamer.7

FIG. 1. V/V<sub>0</sub> vs pressure—Fe<sub>3</sub>Al. (O, Nb; ▲, NaCl.)

These smoothed results are plotted in Fig. 3 with data on pure iron,<sup>8</sup> silicon,<sup>9</sup> and aluminum.<sup>4</sup> Several points are observable. The bcc iron containing 8% Si has a compressibility very near that of pure iron. By 130 kbar a significant fraction has transformed to the hcp structure, the high-pressure phase of pure iron. (The equilibrium pressure may well be below 130 kbar.) No attempt at detailed study of the hcp phase was made, but at 150 kbar c/a = 1.67.

Both the ordered Fe<sub>3</sub>Al and the FeAl with the CsCl

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Fig. 2.  $V/V_0$  vs pressure—Fe<sub>3</sub>Si. (O, Nb;  $\blacktriangle$ , NaF.)



FIG. 3.  $V/V_0$  vs pressure for iron and alloys. O, Fe;  $\bullet$ , Fe+ 8.0% Si;  $\blacksquare$ , Fe<sub>8</sub>Si;  $\square$ , Si(Bridgman);  $\triangle$ , FeAl;  $\blacktriangle$ , Fe<sub>8</sub>Al;  $\checkmark$ , AgMg;  $\bigtriangledown$ , Al (shock data).

structure have very nearly the same compressibility, intermediate between pure iron and pure aluminum. The compressibility decreases with increasing pressure as is usual for metals. On the other hand, Fe<sub>3</sub>Si is less compressible than either pure iron or pure silicon and has a compressibility which actually increases slightly with increasing pressure. The binding is evidently very different in this alloy. Quite possibly the closer packing accounts for the compressibility less than silicon and the covalent forces account for the compressibility less than iron. There is no simple way of discussing the increase in compressibility with pressure. The AgMg exhibits typical metallic behavior like its analog FeAl.

TABLE II. Initial lattice parameters and Murnaghan constants.

Material	<i>a</i> <sub>0</sub>	B <sub>0</sub> (kbar)	B <sub>0</sub> '	$B_0/B_0'$ (kbar)
Fe (pure)	2.866	5.0	1780	360
Fe+8% Si	2.860	4.6	1740	370
Fe <sub>3</sub> Al	5.792	4.6	1360	300
FeAl	2.909	5.6	1380	240
AgMg	3.311	3.6	860	240
Fe <sub>3</sub> Si	5.655			

The data have been fit to the Murnaghan<sup>10</sup> equation

$$P = (B_0/B_0') \lceil (V_0/V)^{B_0'} - 1 \rceil.$$
(1)

The results are listed in Table II along with the atmospheric lattice parameters. In Murnaghan's derivation  $B_0$  is the zero-pressure bulk modulus and  $B_0'$  its pressure derivative evaluated at zero pressure. Here they have been treated as empirical constants giving the best least-squares fit to the data over the entire range of pressure and volume. They may therefore not correspond exactly to the coefficients evaluated at 1 atm. Further, the calculated pressures are somewhat insensitive to small variations in  $B_0$  and  $B_0'$  if appropriately balanced, so that one should not interpret differences of the order of 10% or so from one material to the next. The results do illustrate the close similarity among Fe, Fe plus 8% Si, Fe<sub>3</sub>Al, and FeAl in considerable contrast to the Fe<sub>3</sub>Si.

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