Fe – Sn (Iron – Tin)

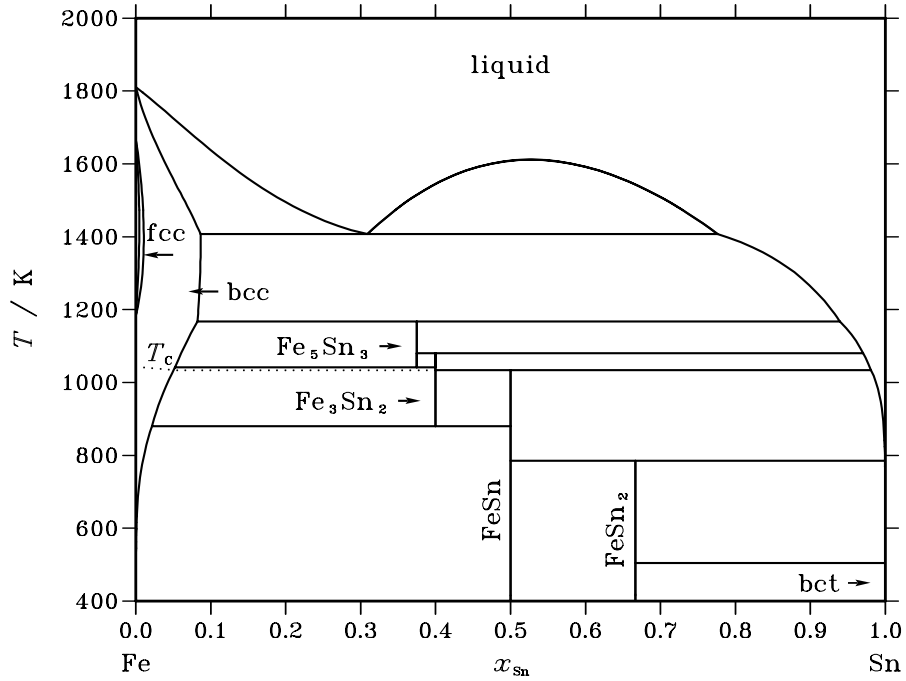

Fig. 1. Calculated phase diagram for the system Fe-Sn.

The thermodynamic assessment of the Fe-Sn system has been given by K.C. Hari Kumar *et al.* [96Har]. The equilibrium phases in the Fe-Sn system are: liquid, encompassing a miscibility gap, bcc, fcc, bct and four intermetallic compounds: Fe_5Sn_3, Fe_3Sn_2, FeSn, and $FeSn_2$. The Fe-Sn phase diagram has been investigated extensively by several authors [58Han, 73Hul, 82Kub, 90Oka, 91Oka]. Experimental studies suggest the existence of a miscibility gap in the liquid phase. Unfortunately the data are so scattered that a realistic estimation of the position of the miscibility gap is very difficult. The assessed miscibility gap is almost symmetric and the calculated critical point of the miscibility gap is lower than reported by [81Yam2, 87Nun]. The calculated monotectic temperature is in good agreement with the experimental values reported by [45Nia, 68Shi, 72Wag, 81Yam2]. Enthalpies of mixing for liquid alloys were measured using calorimetry by a number of investigators [78Pet, 84Bat, 85Lüc]. These results can be reproduced well by the calculations, especially in the Fe-rich region. The calculated Fe activities compare well with experimental values of [68Koz, 87Nun]. The agreement of the calculated Sn activities with experimental values of [81Yam1, 87Nun] is also reasonable. Except for the miscibility gap, the calculated phase diagram agrees well with the experimental data.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Fe,Sn)_1$
fcc	$A1$	Cu	$cF4$	$Fm\overline{3}m$	FCC_A1	$(Fe,Sn)_1$
bcc	$A2$	W	$cI2$	$Im\overline{3}m$	BCC_A2	$(Fe,Sn)_1$
Fe_5Sn_3	$B8_2$	$InNi_2$	$hP6$	$P6_3/mmc$	FE5SN3	Fe_5Sn_3
Fe_3Sn_2	$\cdots$	$\cdots$	$hR10$	$R\overline{3}m$	FE3SN2	Fe_3Sn_2
FeSn	$B35$	CoSn	$hP6$	$P6/mmm$	FESN	Fe_1Sn_1
$FeSn_2$	$C16$	Al_2Cu	$tI12$	$I4/mcm$	FESN2	Fe_1Sn_2
bct	$A5$	βSn	$tI4$	$I4_1/amd$	BCT_A5	Sn_1

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Sn}			$\Delta_{\mathrm{r}}H$ / (J/mol)
liquid $\rightleftharpoons$ liquid′ + liquid″	critical	1610.6	0.527	0.527	0.527	0
liquid′ $\rightleftharpoons$ bcc + liquid″	monotectic	1407.2	0.309	0.086	0.776	−11376
bcc + liquid″ $\rightleftharpoons$ Fe_5Sn_3	peritectic	1167.8	0.082	0.939	0.375	−14513
Fe_5Sn_3 + liquid″ $\rightleftharpoons$ Fe_3Sn_2	peritectic	1080.3	0.375	0.970	0.400	−5111
Fe_5Sn_3 $\rightleftharpoons$ bcc + Fe_3Sn_2	eutectoid	1041.5	0.375	0.052	0.400	−3296
Fe_3Sn_2 + liquid″ $\rightleftharpoons$ FeSn	peritectic	1034.4	0.400	0.981	0.500	−11893
Fe_3Sn_2 $\rightleftharpoons$ bcc + FeSn	eutectoid	880.0	0.400	0.022	0.500	−4049
FeSn + liquid″ $\rightleftharpoons$ $FeSn_2$	peritectic	785.6	0.500	1.000	0.667	−12255
$FeSn_2$ + liquid″ $\rightleftharpoons$ bct	degenerate	505.1	0.667	1.000	1.000	−7029

Table IIIa. Integral quantities for the liquid phase at 1873 K.

x_{Sn}	ΔG_{m} [J/mol]	ΔH_{m} [J/mol]	ΔS_{m} [J/(mol·K)]	$G_{\mathrm{m}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{m}}^{\mathrm{E}}$ [J/(mol·K)]	ΔC_P [J/(mol·K)]
0.000	0	0	0.000	0	0.000	0.000
0.100	−4285	1493	3.085	778	0.382	0.000
0.200	−5775	3289	4.839	2017	0.679	0.000
0.300	−6245	4937	5.970	3268	0.891	0.000
0.400	−6240	6148	6.614	4241	1.018	0.000
0.500	−6020	6761	6.824	4774	1.061	0.000
0.600	−5678	6710	6.614	4802	1.018	0.000
0.700	−5192	5990	5.970	4321	0.891	0.000
0.800	−4439	4626	4.839	3354	0.679	0.000
0.900	−3142	2636	3.085	1920	0.382	0.000
1.000	0	0	0.000	0	0.000	0.000

Reference states: Fe(liquid), Sn(liquid)

Table IIIb. Partial quantities for Fe in the liquid phase at 1873 K.

x_{Fe}	ΔG_{Fe} [J/mol]	ΔH_{Fe} [J/mol]	ΔS_{Fe} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Fe}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Fe}}$ [J/(mol·K)]	a_{Fe}	γ_{Fe}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−1962	−242	0.918	−321	0.042	0.882	0.980
0.800	−4069	−276	2.025	−594	0.170	0.770	0.963
0.700	−5731	539	3.347	−176	0.382	0.692	0.989
0.600	−6798	2429	4.926	1158	0.679	0.646	1.077
0.500	−7448	5333	6.824	3346	1.061	0.620	1.240
0.400	−8092	9039	9.146	6178	1.527	0.595	1.487
0.300	−9327	13317	12.090	9423	2.079	0.549	1.831
0.200	−12098	18052	16.097	12966	2.716	0.460	2.299
0.100	−18917	23379	22.582	16941	3.437	0.297	2.968
0.000	−∞	29813	∞	21866	4.243	0.000	4.072

Reference state: Fe(liquid)

Table IIIc. Partial quantities for Sn in the liquid phase at 1873 K.

x_{Sn}	ΔG_{Sn} [J/mol]	ΔH_{Sn} [J/mol]	ΔS_{Sn} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Sn}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Sn}}$ [J/(mol·K)]	a_{Sn}	γ_{Sn}
0.000	−∞	11441	∞	3494	4.243	0.000	1.252
0.100	−25189	17106	22.582	10669	3.437	0.198	1.984
0.200	−12600	17550	16.097	12464	2.716	0.445	2.226
0.300	−7445	15199	12.090	11305	2.079	0.620	2.067
0.400	−5404	11727	9.146	8866	1.527	0.707	1.767
0.500	−4592	8189	6.824	6202	1.061	0.745	1.489
0.600	−4070	5157	4.926	3886	0.679	0.770	1.283
0.700	−3420	2850	3.347	2135	0.382	0.803	1.147
0.800	−2524	1269	2.025	951	0.170	0.850	1.063
0.900	−1389	331	0.918	251	0.042	0.915	1.016
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Sn(liquid)

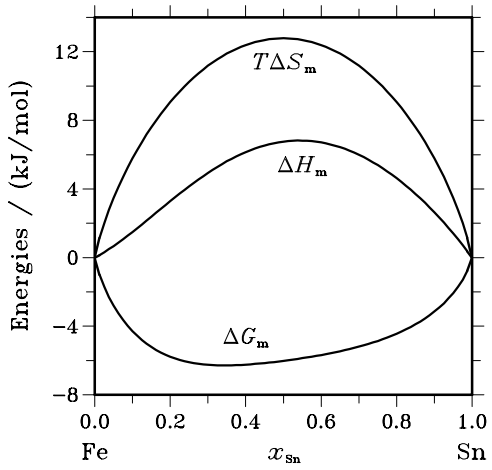

Fig. 2. Integral quantities of the liquid phase at T=1873 K.

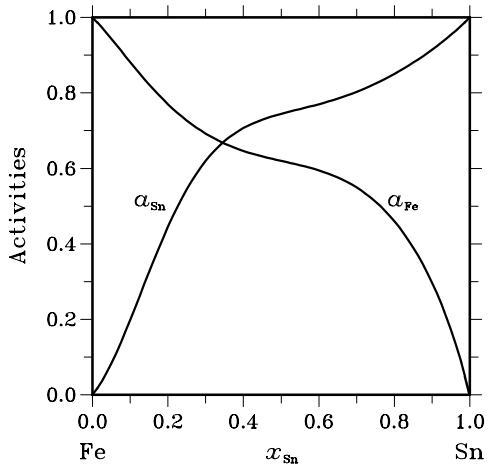

Fig. 3. Activities in the liquid phase at T=1873 K.

Table IV. Standard reaction quantities at 298.15 K for the compounds per mole of atoms.

Compound	x_{Sn}	$\Delta_{\mathrm{f}}G^{\circ}$ / (J/mol)	$\Delta_{\mathrm{f}}H^{\circ}$ / (J/mol)	$\Delta_{\mathrm{f}}S^{\circ}$ / (J/(mol·K))	$\Delta_{\mathrm{f}}C_P^{\circ}$ / (J/(mol·K))
Fe_5Sn_3	0.375	−6149	−6265	−0.389	−0.261
Fe_3Sn_2	0.400	−9434	−10766	−4.468	−0.250
Fe_1Sn_1	0.500	−15687	−19461	−12.660	−0.209
Fe_1Sn_2	0.667	−17101	−22890	−19.414	−0.139

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