Pb – Sb (Lead – Antimony)

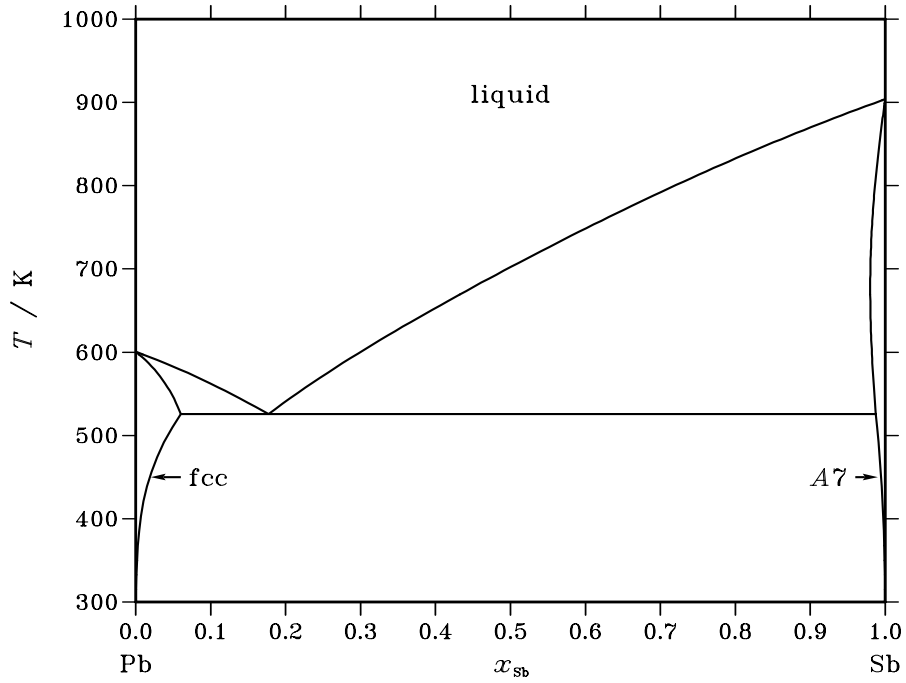

Fig. 1. Calculated phase diagram for the system Pb-Sb.

A good knowledge and understanding of the phase diagram and thermodynamic properties of the Pb-Sb system is important in order to predict and control the behaviour of a range of low melting point liquids for solders and typesetting materials. Even now when there has been a growing requirement for the development of alternative solders which are more environmentally sound and provide fewer potential health problems such solders may nevertheless come into contact with conventional lead-tin solders.
The Pb-Sb system shows a very simple eutectic type phase diagram with appreciable solubility of Sb in fcc Sn (maximum 6 at.%) and low solubility of Sn in rhombohedral Sb (maximum 2 at.%). The eutectic temperature is 525 K with the corresponding eutectic liquid composition of approximately 18 at.% Sb. Several studies have been carried out to determine the liquidus surface and the agreement between these is very good. There is some uncertainty associated with the solubility of Pb in Sb. There have been a number of papers reporting calorimetric studies of the enthalpy of mixing in the liquid phase. All studies agree that the magnitude of the enthalpy of mixing is small although it is still uncertain whether there is an exothermic or endothermic effect on mixing the two liquid metals. Measurements of the activities of Pb and Sb by EMF techniques show a slight negative deviation from ideality.
The critically assessed data adopted by SGTE are from the work of Ohtani *et al.* [95Oht] and shows very good agreement with the experimental data for the system. Other critically assessments have been carried out by Taskinen *et al.* [89Tas, 92Tas] and Lee *et al.* [94Lee].

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Pb,Sb)_1$
fcc	$A1$	Cu	$cF4$	$Fm\overline{3}m$	FCC_A1	$(Pb,Sb)_1$
$A7$	$A7$	αAs	$hR2$	$R\overline{3}m$	RHOMBOHEDRAL_A7	$(Pb,Sb)_1$

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Sb}			$\Delta_{\mathrm{r}}H$ / (J/mol)
liquid $\rightleftharpoons$ fcc + A7	eutectic	525.5	0.177	0.060	0.987	−5723

Table IIIa. Integral quantities for the liquid phase at 905 K.

x_{Sb}	ΔG_{m} [J/mol]	ΔH_{m} [J/mol]	ΔS_{m} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{m}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{m}}$ [J/(mol·K)]	ΔC_P [J/(mol·K)]
0.000	0	0	0.000	0	0.000	0.000
0.100	−2583	−20	2.832	−137	0.129	0.000
0.200	−4040	−23	4.439	−275	0.278	0.000
0.300	−4993	−12	5.504	−397	0.425	0.000
0.400	−5552	6	6.142	−488	0.546	0.000
0.500	−5754	28	6.388	−538	0.625	0.000
0.600	−5603	47	6.243	−539	0.647	0.000
0.700	−5082	58	5.680	−486	0.601	0.000
0.800	−4142	58	4.641	−377	0.480	0.000
0.900	−2659	40	2.983	−213	0.280	0.000
1.000	0	0	0.000	0	0.000	0.000

Reference states: Pb(liquid), Sb(liquid)

Table IIIb. Partial quantities for Pb in the liquid phase at 905 K.

x_{Pb}	ΔG_{Pb} [J/mol]	ΔH_{Pb} [J/mol]	ΔS_{Pb} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Pb}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Pb}}$ [J/(mol·K)]	a_{Pb}	γ_{Pb}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−789	−10	0.861	4	−0.015	0.900	1.000
0.800	−1689	−33	1.830	−10	−0.025	0.799	0.999
0.700	−2754	−58	2.979	−70	0.013	0.693	0.991
0.600	−4042	−76	4.382	−199	0.135	0.584	0.974
0.500	−5621	−78	6.126	−406	0.363	0.474	0.948
0.400	−7588	−51	8.328	−693	0.709	0.365	0.912
0.300	−10113	13	11.189	−1054	1.179	0.261	0.869
0.200	−13581	124	15.144	−1470	1.762	0.164	0.822
0.100	−19243	293	21.587	−1917	2.442	0.078	0.775
0.000	$-\infty$	530	∞	−2357	3.190	0.000	0.731

Reference state: Pb(liquid)

Table IIIc. Partial quantities for Sb in the liquid phase at 905 K.

x_{Sb}	ΔG_{Sb} [J/mol]	ΔH_{Sb} [J/mol]	ΔS_{Sb} [J/(mol·K)]	G^E_{Sb} [J/mol]	S^E_{Sb} [J/(mol·K)]	a_{Sb}	γ_{Sb}
0.000	$-\infty$	−310	∞	−1296	1.090	0.000	0.842
0.100	−18728	−115	20.566	−1401	1.421	0.083	0.830
0.200	−13445	17	14.875	−1335	1.493	0.167	0.837
0.300	−10217	95	11.395	−1158	1.384	0.257	0.857
0.400	−7817	130	8.782	−922	1.163	0.354	0.885
0.500	−5886	133	6.651	−671	0.887	0.457	0.915
0.600	−4280	112	4.853	−436	0.605	0.566	0.944
0.700	−2926	78	3.319	−242	0.354	0.678	0.968
0.800	−1782	41	2.015	−103	0.160	0.789	0.986
0.900	−817	12	0.916	−24	0.040	0.897	0.997
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Sb(liquid)

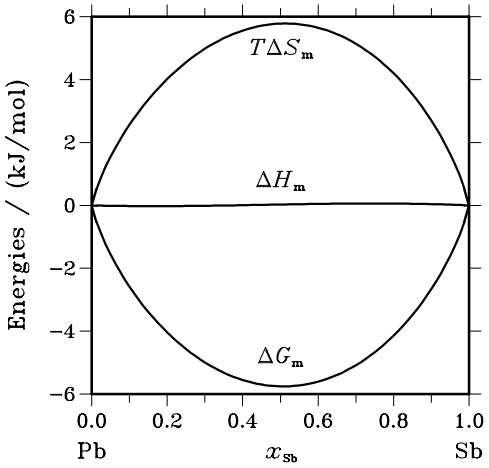

Fig. 2. Integral quantities of the liquid phase at T=905 K.

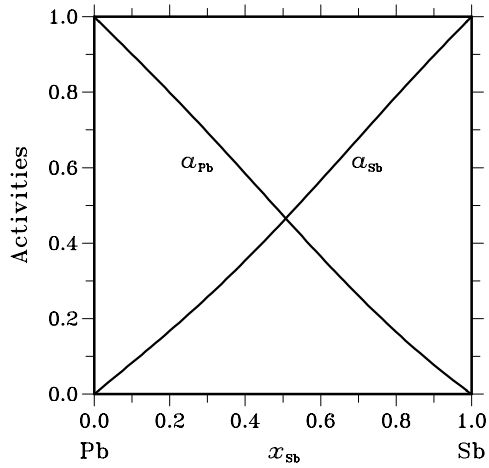

Fig. 3. Activities in the liquid phase at T=905 K.

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