Pb – Tl (Lead – Thallium)

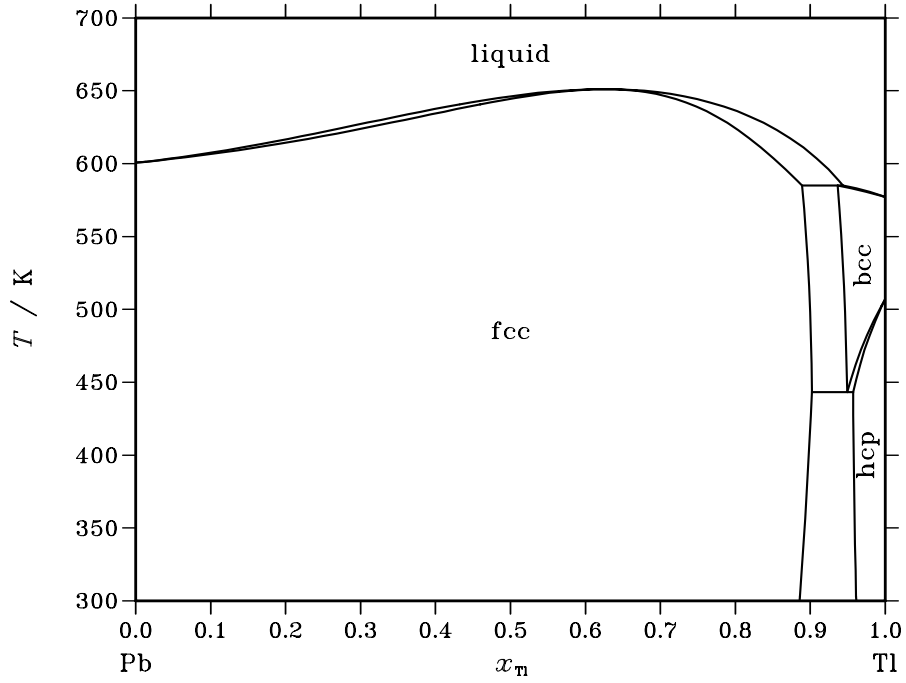

Fig. 1. Calculated phase diagram for the system Pb-Tl.

The main feature of the phase diagram for the Pb-Tl system is the extensive series of fcc solid solutions stretching from pure Pb to nearly 90 at.% Tl. Over this range of compositions the alloys melt over a very narrow range of temperatures, the liquidus temperatures rising from the melting point of Pb reaching a maximum at about 62 at.% Tl and 653 K before falling once again towards pure Tl. On the Tl rich side of the system there are narrow two phase regions between both the bcc and hcp forms of Tl and the fcc phase, the maximum solubility of Pb in bcc Tl being approximately 7 at.%. The liquidus and solidus temperatures are very well defined by experiment as is the equilibrium between the bcc and hcp phases. The enthalpy of formation has been determined calorimetrically and appears to show a clear temperature dependence. Activities of Tl in the liquid phase have been measured using an EMF technique and by vapour pressure measurements.
The critically assessed dataset adopted by SGTE is taken from the work of Fries *et al.* [01Fri] and is in very good agreement with the experimental data.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Pb,Tl)_1$
fcc	$A1$	Cu	$cF4$	$Fm\overline{3}m$	FCC_A1	$(Pb,Tl)_1$
bcc	$A2$	W	$cI2$	$Im\overline{3}m$	BCC_A2	$(Pb,Tl)_1$
hcp	$A3$	Mg	$hP2$	$P6_3/mmc$	HCP_A3	$(Pb,Tl)_1$

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Tl}			$\Delta_{\mathrm{r}}H$ / (J/mol)
liquid $\rightleftharpoons$ fcc	congruent	651.1	0.625	0.625		−5528
fcc + liquid $\rightleftharpoons$ bcc	peritectic	585.0	0.889	0.944	0.937	−3648
bcc $\rightleftharpoons$ fcc + hcp	eutectoid	443.2	0.949	0.902	0.957	−150

Table IIIa. Integral quantities for the liquid phase at 773 K.

x_{Tl}	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	−2220	−291	2.496	−131	−0.207	0.306
0.200	−3528	−552	3.851	−312	−0.310	0.543
0.300	−4419	−760	4.734	−493	−0.345	0.713
0.400	−4961	−899	5.256	−636	−0.340	0.815
0.500	−5168	−957	5.447	−713	−0.316	0.849
0.600	−5035	−929	5.312	−710	−0.283	0.815
0.700	−4549	−812	4.834	−623	−0.245	0.713
0.800	−3676	−612	3.965	−460	−0.196	0.543
0.900	−2331	−336	2.581	−242	−0.122	0.306
1.000	0	0	0.000	0	0.000	0.000

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

Table IIIb. Partial quantities for Pb in the liquid phase at 773 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	−643	−11	0.817	34	−0.059	0.905	1.005
0.800	−1369	−77	1.672	65	−0.183	0.808	1.010
0.700	−2284	−232	2.654	9	−0.311	0.701	1.001
0.600	−3465	−498	3.839	−182	−0.408	0.583	0.972
0.500	−4975	−879	5.299	−520	−0.464	0.461	0.922
0.400	−6872	−1365	7.124	−983	−0.494	0.343	0.858
0.300	−9251	−1930	9.471	−1513	−0.539	0.237	0.790
0.200	−12362	−2532	12.716	−2018	−0.665	0.146	0.731
0.100	−17168	−3114	18.181	−2369	−0.964	0.069	0.692
0.000	$-\infty$	−3604	∞	−2405	−1.551	0.000	0.688

Reference state: Pb(liquid)

Table IIIc. Partial quantities for Tl in the liquid phase at 773 K.

x_{Tl}	ΔG_{Tl} [J/mol]	ΔH_{Tl} [J/mol]	ΔS_{Tl} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Tl}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Tl}}$ [J/(mol·K)]	a_{Tl}	γ_{Tl}
0.000	$-\infty$	−2978	∞	−863	−2.737	0.000	0.874
0.100	−16419	−2810	17.605	−1620	−1.540	0.078	0.777
0.200	−12164	−2452	12.564	−1820	−0.817	0.151	0.753
0.300	−9402	−1991	9.587	−1664	−0.423	0.232	0.772
0.400	−7205	−1500	7.380	−1316	−0.238	0.326	0.815
0.500	−5361	−1036	5.595	−906	−0.168	0.434	0.869
0.600	−3811	−638	4.105	−528	−0.143	0.553	0.921
0.700	−2534	−333	2.846	−241	−0.119	0.674	0.963
0.800	−1505	−132	1.777	−71	−0.079	0.791	0.989
0.900	−683	−27	0.848	−6	−0.028	0.899	0.999
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Tl(liquid)

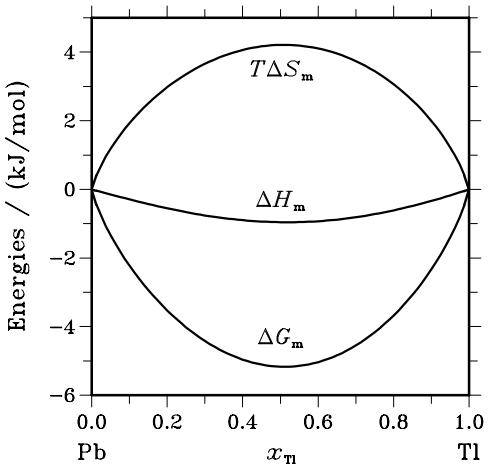

Fig. 2. Integral quantities of the liquid phase at T=773 K.

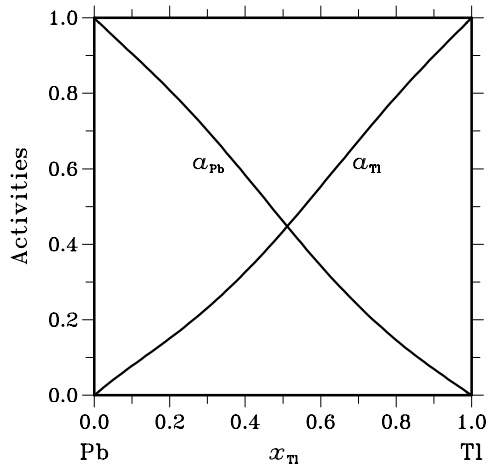

Fig. 3. Activities in the liquid phase at T=773 K.

Table IVa. Integral quantities for the stable phases at 523 K.

Phase	x_{Tl}	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)]
fcc	0.000	0	0	0.000	0	0.000	0.000
	0.100	−1702	−590	2.127	−289	−0.576	−0.245
	0.200	−2795	−1152	3.141	−619	−1.020	−0.490
	0.300	−3595	−1620	3.777	−939	−1.302	−0.735
	0.400	−4130	−1944	4.181	−1204	−1.415	−0.980
	0.500	−4386	−2089	4.392	−1372	−1.371	−1.225
	0.600	−4333	−2038	4.389	−1407	−1.207	−1.470
	0.700	−3934	−1789	4.102	−1278	−0.977	−1.715
	0.800	−3136	−1357	3.401	−960	−0.760	−1.960
	0.898	−1884	−789	2.092	−447	−0.654	−2.199
bcc	0.944	−1149	−327	1.572	−213	−0.219	0.000
	1.000	0	0	0.000	0	0.000	0.000

Reference states: Pb(fcc), Tl(bcc)

Table IVb. Partial quantities for Pb in the stable phases at 523 K.

Phase	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}
fcc	1.000	0	0	0.000	0	0.000	1.000	1.000
	0.900	−428	−1	0.817	30	−0.059	0.906	1.007
	0.800	−922	−102	1.568	48	−0.287	0.809	1.011
	0.700	−1591	−411	2.255	−40	−0.711	0.694	0.991
	0.600	−2534	−989	2.956	−313	−1.292	0.558	0.931
	0.500	−3851	−1845	3.834	−837	−1.929	0.412	0.825
	0.400	−5643	−2944	5.162	−1659	−2.457	0.273	0.683
	0.300	−8049	−4197	7.366	−2814	−2.644	0.157	0.524
	0.200	−11319	−5470	11.184	−4320	−2.198	0.074	0.370
	0.102	−16041	−6555	18.139	−6132	−0.808	0.025	0.244
bcc	0.056	−16041	−5397	20.351	−3494	−3.639	0.025	0.448
	0.000	$-\infty$	−6347	∞	−4142	−4.216	0.000	0.386

Reference state: Pb(fcc)

Table IVc. Partial quantities for Tl in the stable phases at 523 K.

Phase	x_{Tl}	ΔG_{Tl} [J/mol]	ΔH_{Tl} [J/mol]	ΔS_{Tl} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Tl}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Tl}}$ [J/(mol·K)]	a_{Tl}	γ_{Tl}
fcc	0.000	$-\infty$	−5772	∞	−2495	−6.267	0.000	0.563
	0.100	−13166	−5885	13.921	−3153	−5.224	0.048	0.484
	0.200	−10284	−5351	9.433	−3286	−3.949	0.094	0.470
	0.300	−8273	−4440	7.329	−3038	−2.682	0.149	0.497
	0.400	−6524	−3376	6.019	−2539	−1.599	0.223	0.558
	0.500	−4921	−2332	4.949	−1906	−0.814	0.323	0.645
	0.600	−3460	−1434	3.874	−1238	−0.374	0.451	0.752
	0.700	−2171	−757	2.703	−620	−0.263	0.607	0.867
	0.800	−1090	−329	1.455	−120	−0.400	0.778	0.973
	0.898	−268	−132	0.261	201	−0.637	0.940	1.047
bcc	0.944	−268	−27	0.461	−19	−0.017	0.940	0.996
	1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Tl(bcc)

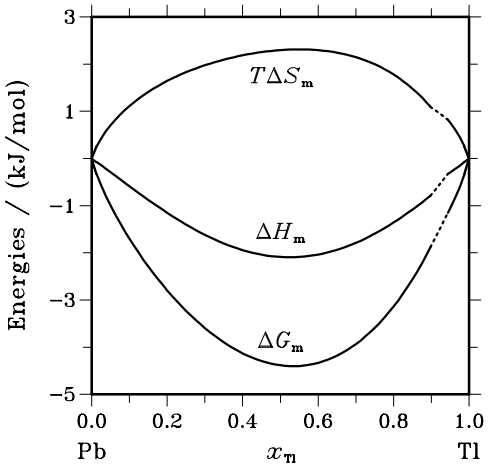

Fig. 4. Integral quantities of the stable phases at T=523 K.

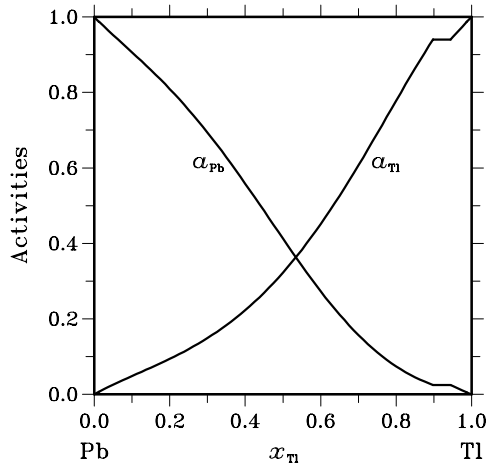

Fig. 5. Activities in the stable phases at T=523 K.

References

[01Fri] S.G. Fries, I. Ansara, H.L. Lukas: J. Alloys Comp. **320** (2001) 228–233.