Hg – Sn (Mercury – Tin)

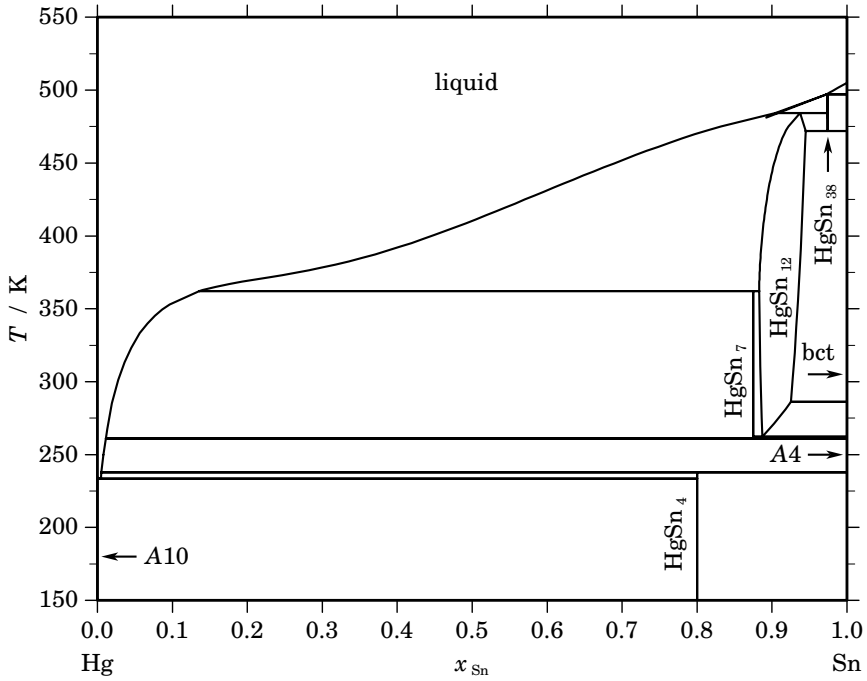

Fig. 1. Calculated phase diagram for the system Hg-Sn.

Mercury-tin alloys are of considerable interest since more than hundred years because traditional dental amalgams are based on the Ag-Hg-Sn system. More recently, tin amalgams have been developed for application in compact fluorescent lamp amalgams. According to the importance of Hg-Sn alloys many experimental investigations of the phase equilibria and their thermodynamic properties are available. The literature has been reviewed by [1993Zab, 2003Yen] and a thermodynamic dataset for Hg-Sn has been optimised in [2003Yen] which describes the phase diagram as well as the mixing properties and the vapour pressure. In the optimisation the liquidus has been optimised to fit the data of about 20 selected investigations from the literature which have been obtained by several techniques such as thermal and chemical analysis and electrochemical methods. The enthalpy of mixing has been reported in several investigations and for different temperatures. These data are mostly in agreement for Hg-rich liquids but they differ in the Sn-rich part. Within these limitations the calculations provide a good description of the experimental results. The activities of Hg and Sn have been determined in many investigations at different temperatures for the homogeneous melt as well as across 2-phase regions and again the calculations provide a good representation of the data within the range of deviation between different authors.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Hg,Sn)_1$
$A10$	$A10$	αHg	$hR1$	$R\overline{3}m$	RHOMBO_A10	$(Hg,Sn)_1$
$HgSn_4$	···	···	···	···	HGSN4	Hg_1Sn_4
$HgSn_7$	···	$HgSn_7$	$o*^*$	···	HGSN7	Hg_1Sn_7
$HgSn_{12}$	···	$HgSn_{12}$	$hP1$	$P6_3/mmm$	HGSN12	$(Hg,\square)_1Sn_6$
$HgSn_{38}$	···	$HgSn_{38}$	$hP1$	···	HGSN38	Hg_1Sn_{38}
bct	$A5$	βSn	$tI4$	$I4_1/amd$	BCT_A5	Sn_1
$A4$	$A4$	C(diamond)	$cF8$	$Fd\overline{3}m$	DIAMOND_A4	Sn_1

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Sn}			$\Delta_r H$ / (J/mol)
liquid + bct $\rightleftharpoons$ $HgSn_{38}$	peritectic	497.1	0.973	1.000	0.974	−4761
liquid + $HgSn_{38}$ $\rightleftharpoons$ $HgSn_{12}$	peritectic	484.2	0.904	0.974	0.937	−4068
$HgSn_{38}$ $\rightleftharpoons$ $HgSn_{12}$ + bct	eutectoid	472.1	0.974	0.945	1.000	−1601
liquid + $HgSn_{12}$ $\rightleftharpoons$ $HgSn_7$	peritectic	362.1	0.136	0.883	0.875	−14
$HgSn_{12}$ + bct $\rightleftharpoons$ $A4$	peritectoid	286.2	0.925	1.000	1.000	−1967
$HgSn_{12}$ $\rightleftharpoons$ $HgSn_7$ + $A4$	eutectoid	262.2	0.887	0.875	1.000	−228
$HgSn_7$ $\rightleftharpoons$ liquid + $A4$	metatectic	261.1	0.875	0.011	1.000	−2117
liquid + $A4$ $\rightleftharpoons$ $HgSn_4$	peritectic	237.7	0.005	1.000	0.800	−1597
liquid $\rightleftharpoons$ A10 + $HgSn_4$	eutectic	233.4	0.005	0.000	0.800	−2357

Table IIIa. Integral quantities for the liquid phase at 523 K.

x_{Sn}	ΔG_m [J/mol]	ΔH_m [J/mol]	ΔS_m [J/(mol·K)]	G_m^E [J/mol]	S_m^E [J/(mol·K)]	ΔC_P [J/(mol·K)]
0.000	0	0	0.000	0	0.000	0.000
0.100	−828	451	2.446	585	−0.257	0.000
0.200	−1268	739	3.837	908	−0.324	0.000
0.300	−1612	913	4.827	1044	−0.252	0.000
0.400	−1873	1006	5.506	1053	−0.090	0.000
0.500	−2033	1040	5.876	981	0.113	0.000
0.600	−2067	1019	5.902	859	0.306	0.000
0.700	−1952	935	5.520	705	0.441	0.000
0.800	−1656	765	4.629	520	0.468	0.000
0.900	−1120	471	3.041	294	0.338	0.000
1.000	0	0	0.000	0	0.000	0.000

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

Table IIIb. Partial quantities for Hg in the liquid phase at 523 K.

x_{Hg}	ΔG_{Hg} [J/mol]	ΔH_{Hg} [J/mol]	ΔS_{Hg} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Hg}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Hg}}$ [J/(mol·K)]	a_{Hg}	γ_{Hg}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−314	91	0.773	145	−0.103	0.930	1.034
0.800	−499	291	1.510	472	−0.345	0.892	1.115
0.700	−697	525	2.338	854	−0.628	0.852	1.217
0.600	−1016	760	3.395	1206	−0.852	0.792	1.319
0.500	−1528	1006	4.844	1487	−0.919	0.704	1.408
0.400	−2286	1317	6.890	1698	−0.729	0.591	1.478
0.300	−3350	1790	9.827	1886	−0.183	0.463	1.543
0.200	−4861	2565	14.199	2137	0.817	0.327	1.635
0.100	−7428	3825	21.516	2584	2.371	0.181	1.812
0.000	−∞	5796	∞	3402	4.578	0.000	2.186

Reference state: Hg(liquid)

Table IIIc. Partial quantities for Sn in the liquid phase at 523 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	−∞	5524	∞	7446	−3.676	0.000	5.542
0.100	−5463	3692	17.505	4550	−1.640	0.285	2.847
0.200	−4344	2530	13.142	2655	−0.240	0.368	1.841
0.300	−3746	1817	10.636	1489	0.625	0.423	1.408
0.400	−3160	1376	8.672	825	1.054	0.484	1.209
0.500	−2539	1074	6.908	475	1.144	0.558	1.116
0.600	−1922	821	5.244	300	0.997	0.643	1.071
0.700	−1353	569	3.675	198	0.709	0.733	1.047
0.800	−855	315	2.237	116	0.381	0.822	1.027
0.900	−419	98	0.988	39	0.112	0.908	1.009
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Sn(liquid)

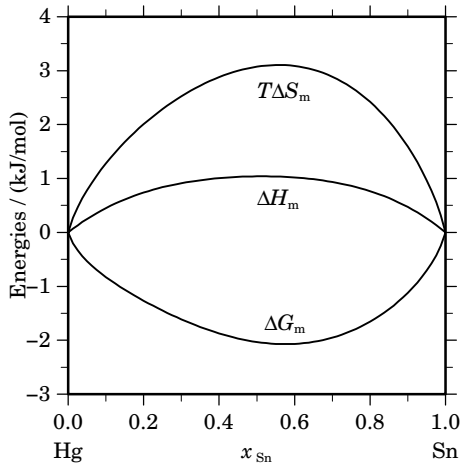

Fig. 2. Integral quantities of the liquid phase at T=523 K.

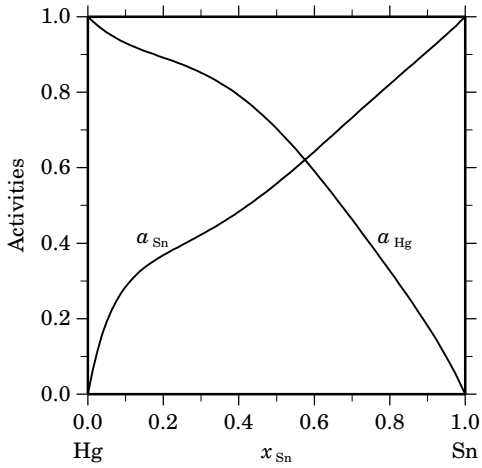

Fig. 3. Activities in the liquid phase at T=523 K.

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))
Hg_1Sn_4	0.800	459	−3109	−11.966	0.183
Hg_1Sn_7	0.875	−237	442	2.278	0.114
Hg_1Sn_{38}	0.974	530	1767	4.151	0.023

References

[1993Zab] L.A. Zabdyr, C. Guminski: J. Phase Equilibria **14** (1993) 743–752.
[2003Yen] Y.-W. Yen, J. Gröbner, S.C. Hansen, R. Schmid-Fetzer: J. Phase Equilibria **24** (2003) 151–167.