Au – Pb (Gold – Lead)

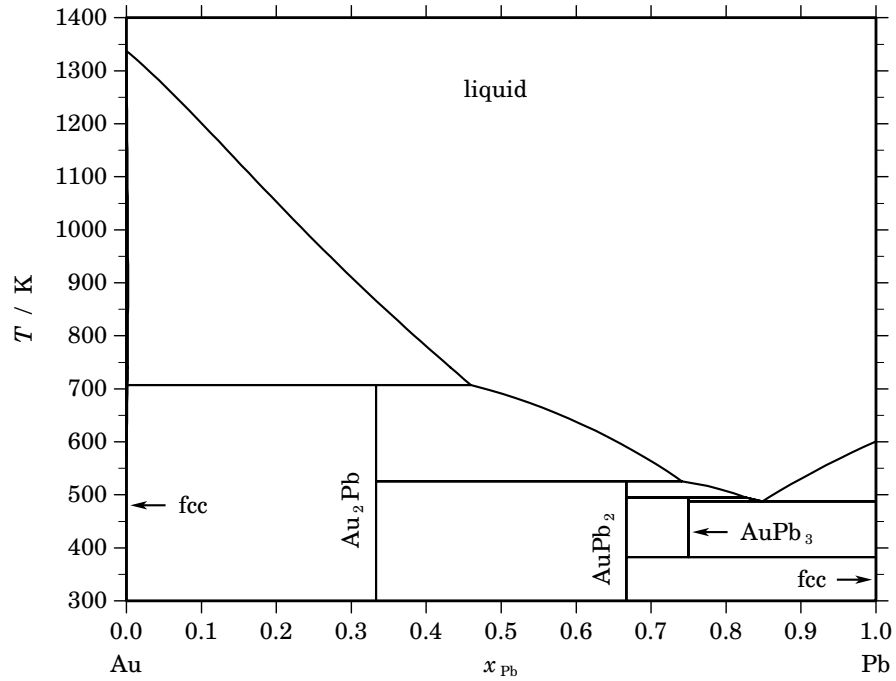

Fig. 1. Calculated phase diagram for the system Au-Pb.

The knowledge of the Au-Pb system is required for an understanding of the interactions between Sn-Pb solder and gold-plated contacts of electronic components. An old thermodynamic assessment of this system has been presented in the first volume of this series [2002SGTE]. Since then several additional investigations of Au-Pb have been published which have been incorporated in a recent optimisation [2004Wan]. The assessment takes into account several experimental investigations on the phase diagram from the literature, measurements of the enthalpy of mixing in the liquid at different temperatures and determination of the Pb activities in the liquid from several sources. In addition the assessment takes account of the experimental standard enthalpies of formation of the compounds. The mixing properties of the melt seem to be very temperature dependent and there are pronounced discrepancies between the various experimental datasets in the literature.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Au,Pb)_1$
fcc	$A1$	Cu	$cF4$	$Fm\overline{3}m$	FCC_A1	$(Au,Pb)_1$
Au_2Pb	$C15$	Cu_2Mg	$cF24$	$Fd\overline{3}m$	AU2PB	Au_2Pb_1
$AuPb_2$	$C16$	Al_2Cu	$tI12$	$I4/mcm$	AUPB2	Au_1Pb_2
$AuPb_3$	$\cdots$	αV_3S	$tI32$	$I\overline{4}2m$	AUPB3	Au_1Pb_3

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Pb}			$\Delta_{\mathrm{r}}H$ / (J/mol)
fcc + liquid $\rightleftharpoons$ Au_2Pb	peritectic	707.1	0.002	0.459	0.333	−8256
Au_2Pb + liquid $\rightleftharpoons$ $AuPb_2$	peritectic	525.7	0.333	0.741	0.667	−6003
$AuPb_2$ + liquid $\rightleftharpoons$ $AuPb_3$	peritectic	495.2	0.667	0.827	0.750	−2800
liquid $\rightleftharpoons$ $AuPb_3$ + fcc	eutectic	487.8	0.848	0.750	1.000	−5443
$AuPb_3$ $\rightleftharpoons$ $AuPb_2$ + fcc	eutectoid	382.4	0.750	0.667	1.000	−202

Table IIIa. Integral quantities for the liquid phase at 1373 K.

x_{Pb}	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	−5425	394	4.238	−1713	1.535	1.299
0.200	−8608	615	6.717	−2895	2.557	2.310
0.300	−10576	695	8.209	−3602	3.130	3.031
0.400	−11574	666	8.915	−3891	3.319	3.464
0.500	−11730	560	8.951	−3817	3.188	3.609
0.600	−11121	410	8.398	−3438	2.802	3.464
0.700	−9784	246	7.305	−2810	2.226	3.031
0.800	−7703	102	5.685	−1990	1.524	2.310
0.900	−4746	9	3.463	−1035	0.760	1.299
1.000	0	0	0.000	0	0.000	0.000

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

Table IIIb. Partial quantities for Au in the liquid phase at 1373 K.

x_{Au}	ΔG_{Au} [J/mol]	ΔH_{Au} [J/mol]	ΔS_{Au} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Au}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Au}}$ [J/(mol·K)]	a_{Au}	γ_{Au}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−1478	92	1.143	−275	0.267	0.879	0.976
0.800	−3573	325	2.839	−1025	0.983	0.731	0.914
0.700	−6209	635	4.985	−2138	2.019	0.580	0.829
0.600	−9330	957	7.493	−3499	3.245	0.442	0.736
0.500	−12908	1229	10.296	−4995	4.533	0.323	0.646
0.400	−16975	1384	13.371	−6514	5.753	0.226	0.565
0.300	−21688	1360	16.787	−7943	6.776	0.150	0.499
0.200	−27541	1092	20.855	−9168	7.473	0.090	0.448
0.100	−36363	516	26.860	−10077	7.715	0.041	0.414
0.000	$-\infty$	−432	∞	−10555	7.373	0.000	0.397

Reference state: Au(liquid)

Table IIIc. Partial quantities for Pb in the liquid phase at 1373 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}
0.000	$-\infty$	4915	∞	−19981	18.132	0.000	0.174
0.100	−40943	3115	32.089	−14657	12.944	0.028	0.277
0.200	−28748	1777	22.232	−10375	8.850	0.081	0.403
0.300	−20764	836	15.732	−7020	5.722	0.162	0.541
0.400	−14939	230	11.048	−4479	3.429	0.270	0.675
0.500	−10552	−108	7.607	−2639	1.843	0.397	0.794
0.600	−7219	−240	5.083	−1387	0.835	0.531	0.886
0.700	−4682	−231	3.242	−611	0.276	0.664	0.948
0.800	−2743	−146	1.892	−196	0.037	0.786	0.983
0.900	−1233	−47	0.864	−30	−0.012	0.898	0.997
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Pb(liquid)

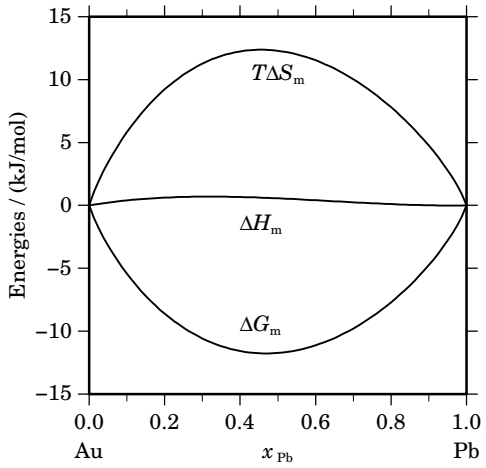

Fig. 2. Integral quantities of the liquid phase at T=1373 K.

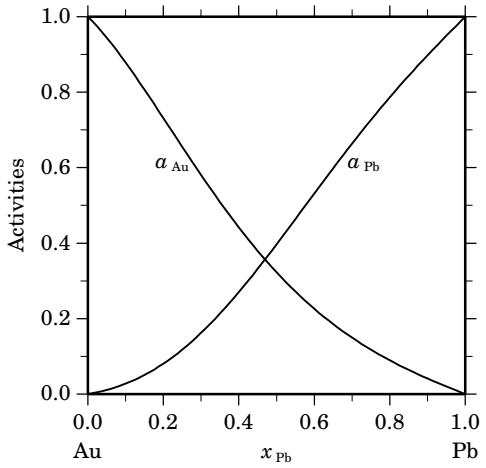

Fig. 3. Activities in the liquid phase at T=1373 K.

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

Compound	x_{Pb}	$\Delta_{\mathrm{f}}G^{\circ}$ / (J/mol)	$\Delta_{\mathrm{f}}H^{\circ}$ / (J/mol)	$\Delta_{\mathrm{f}}S^{\circ}$ / (J/(mol·K))	$\Delta_{\mathrm{f}}C^{\circ}_{P}$ / (J/(mol·K))
Au_2Pb_1	0.333	−2861	−3010	−0.500	0.000
Au_1Pb_2	0.667	−2368	−2800	−1.450	0.000
Au_1Pb_3	0.750	−1733	−1900	−0.560	0.000

References

[2002SGTE] SGTE in: Landolt-Börnstein, New Series, IV/19 B1, Springer-Verlag, Berlin Heidelberg, 2002, pp. 280–282.

[2004Wan] J. Wang, H.S. Liu, Z.P. Jin: Calphad **28** (2004) 91–95.