Cu – Pb (Copper – Lead)

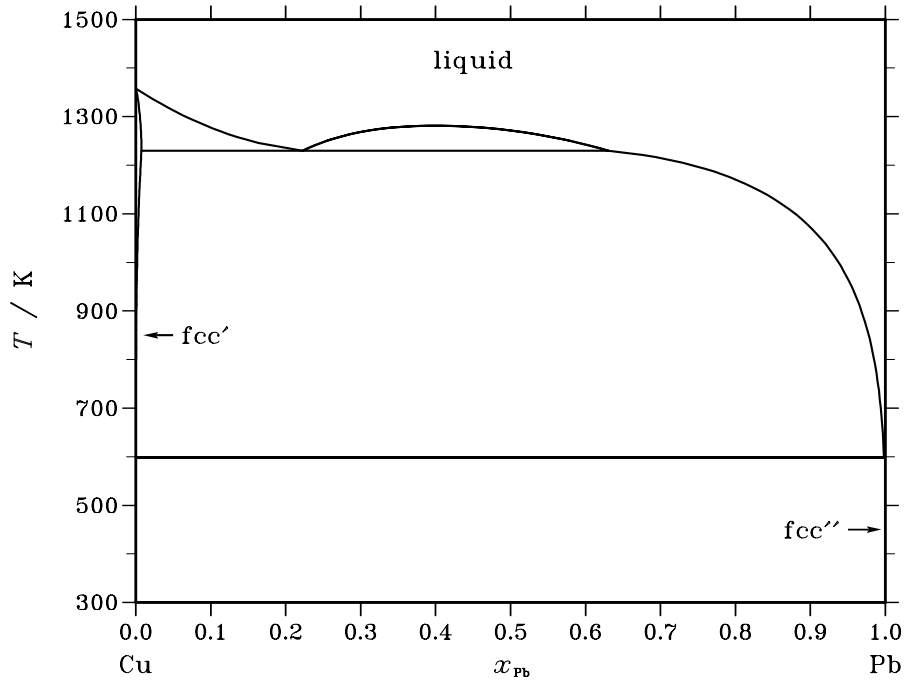

Fig. 1. Calculated phase diagram for the system Cu-Pb.

The Cu-Pb system is of technical importance for the production of high-purity copper and lead-bronze. The experimental data for the system have been reviewed by [84Cha] and an update has been published by [93Oka]. Cu and Pb have a very restricted mutual solubility in the solid state. The solubility of Pb in copper does not exceed 0.09 at.% at 873 K, as determined by X-ray studies and microscopy. In liquid Cu-Pb alloys, a miscibility gap appears below about 1273 K. The results of the liquidus investigation before 1965 pertaining to the miscibility gap including the critical point and the monotectic invariant compositions show large scatter. Recently, a detailed description of the shape of the liquid miscibility gap in this system has been reported by [99Kha] using the γ-ray attenuation technique.

Several thermodynamic assessments of the Cu-Pb system have been published [86Nie, 86Hay, 91Tep, 00Wan]. The thermodynamic dataset of [86Hay] is selected, because the calculated miscibility gap in the liquid phase agrees well with the most recent experimental report [99Kha]. Also, a reasonable value for solid solubility of Pb in copper of 0.05 at.% at 873 K and a good fit to the experimental data on enthalpy and entropy of mixing of liquid phase is obtained. The liquid and fcc phases are modelled as simple substitutional solutions.

In more recent assessment of [00Wan], even better fitting of the whole liquidus has been achieved. However, the calculated phase diagram shows the development of an inverse miscibility gap above 2290 K and the solid solubility of Pb in copper is unreasonably small.

Table I. Phases, structures and models.

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

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Pb}			$\Delta_{\mathrm{r}}H$ / (J/mol)
liquid $\rightleftharpoons$ liquid′ + liquid″	critical	1281.4	0.400	0.400	0.400	0
liquid′ $\rightleftharpoons$ fcc′ + liquid″	monotectic	1230.1	0.223	0.008	0.630	−10397
liquid $\rightleftharpoons$ fcc′ + fcc″	eutectic	599.4	0.998	0.000	1.000	−4837

Table IIIa. Integral quantities for the liquid phase at 1473 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	−1876	2943	3.271	2105	0.568	0.000
0.200	−2492	4942	5.047	3636	0.886	0.000
0.300	−2861	6176	6.135	4621	1.056	0.000
0.400	−3150	6783	6.743	5093	1.147	0.000
0.500	−3394	6862	6.963	5095	1.199	0.000
0.600	−3567	6471	6.815	4675	1.219	0.000
0.700	−3591	5630	6.260	3890	1.181	0.000
0.800	−3327	4317	5.190	2801	1.029	0.000
0.900	−2502	2474	3.378	1479	0.676	0.000
1.000	0	0	0.000	0	0.000	0.000

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

Table IIIb. Partial quantities for Cu in the liquid phase at 1473 K.

x_{Cu}	ΔG_{Cu} [J/mol]	ΔH_{Cu} [J/mol]	ΔS_{Cu} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Cu}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Cu}}$ [J/(mol·K)]	a_{Cu}	γ_{Cu}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−999	505	1.021	291	0.145	0.922	1.024
0.800	−1602	1761	2.283	1131	0.428	0.877	1.097
0.700	−1914	3473	3.657	2455	0.692	0.855	1.222
0.600	−2082	5464	5.123	4174	0.876	0.844	1.406
0.500	−2307	7675	6.777	6182	1.013	0.828	1.657
0.400	−2872	10167	8.852	8350	1.234	0.791	1.977
0.300	−4219	13120	11.771	10527	1.760	0.709	2.362
0.200	−7169	16832	16.294	12543	2.912	0.557	2.785
0.100	−13995	21723	24.249	14205	5.104	0.319	3.189
0.000	$-\infty$	28328	∞	15301	8.844	0.000	3.488

Reference state: Cu(liquid)

Table IIIc. Partial quantities for Pb in the liquid phase at 1473 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	$-\infty$	34834	∞	24000	7.355	0.000	7.096
0.100	−9768	24885	23.525	18433	4.380	0.450	4.504
0.200	−6055	17665	16.103	13656	2.722	0.610	3.050
0.300	−5071	12482	11.917	9674	1.906	0.661	2.203
0.400	−4751	8762	9.174	6471	1.555	0.678	1.696
0.500	−4481	6048	7.149	4008	1.385	0.694	1.387
0.600	−4030	4007	5.456	2226	1.209	0.720	1.199
0.700	−3323	2419	3.898	1046	0.933	0.762	1.089
0.800	−2367	1189	2.414	366	0.559	0.824	1.030
0.900	−1225	335	1.060	65	0.184	0.905	1.005
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Pb(liquid)

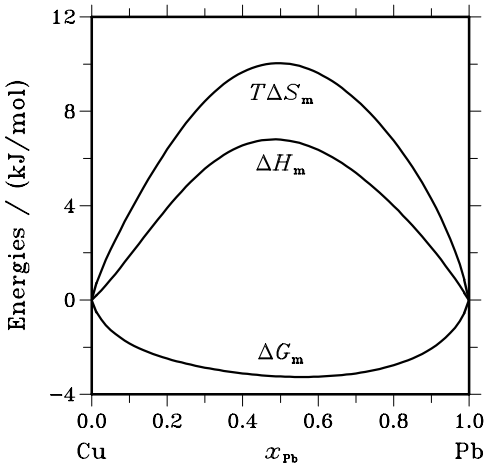

Fig. 2. Integral quantities of the liquid phase at T=1473 K.

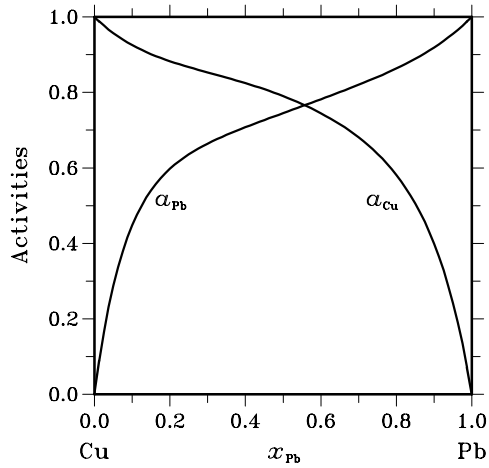

Fig. 3. Activities in the liquid phase at T=1473 K.

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