Cu – Mn (Copper – Manganese)

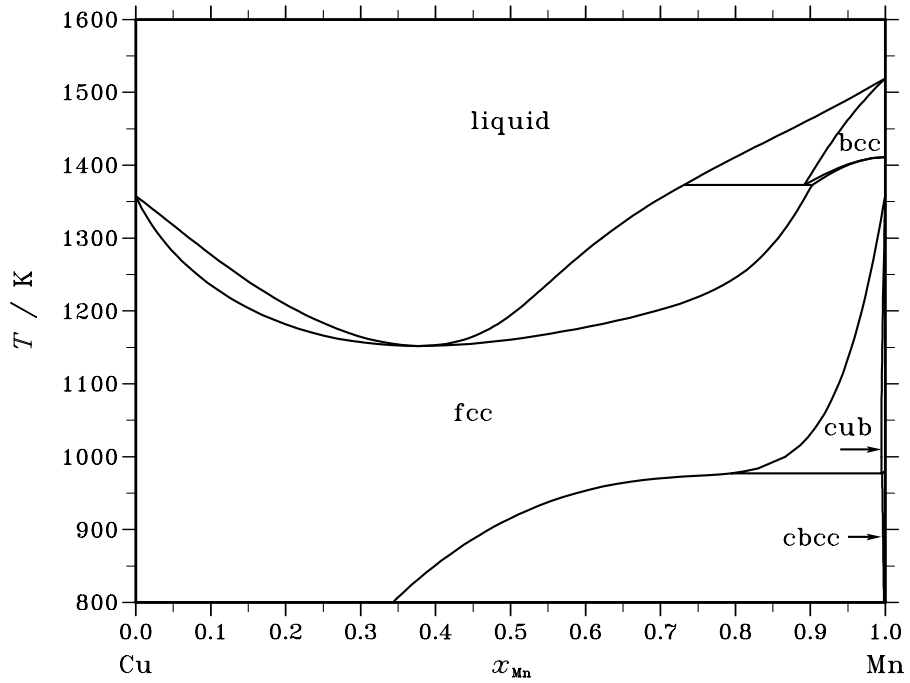

Fig. 1. Calculated phase diagram for the system Cu-Mn.

The Cu-Mn system is of interest because manganese is added to bronzes or brasses in order to increase the strength of these copper alloys. Heusler alloys (Cu-Mn with Al or Zn) are among the strongest non-ferrous metals. F. Heusler found that the prototype of these alloys (Cu_2AlMn) is ferromagnetic although none of the metallic elements shows this effect. Manganese bronzes can be used in the production of devices which resist seawater corrosion and manganin wires (Cu-Mn-Ni) are known for their almost temperature-independent electrical conductivity.
Several thermodynamic assessments of the Cu-Mn system have been reported [93Lew, 96Vre, 03Mie] and that of Miettinen [03Mie] is recommended here because it has been tested to be compatible with ternary and higher-order systems. The assessment takes into account experimental investigations on the phase diagram as well as calorimetric data for the melt.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Cu,Mn)_1$
fcc	$A1$	Cu	$cF4$	$Fm\overline{3}m$	FCC_A1	$(Cu,Mn)_1$
bcc	$A2$	W	$cI2$	$Im\overline{3}m$	BCC_A2	$(Cu,Mn)_1$
cbcc	$A12$	αMn	$cI58$	$I\overline{4}3m$	CBCC_A12	$(Cu,Mn)_1$
cub	$A13$	βMn	$cP20$	$P4_132$	CUB_A13	$(Cu,Mn)_1$

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Mn}			$\Delta_{\mathrm{r}}H$ / (J/mol)
bcc ⇌ liquid + fcc	metatectic	1372.8	0.892	0.731	0.902	−1019
liquid ⇌ fcc	congruent	1152.0	0.380	0.380		−11239
cub ⇌ fcc + cbcc	eutectoid	977.0	0.995	0.795	0.996	−2245

Table IIIa. Integral quantities for the liquid phase at 1523 K.

x_{Mn}	ΔG_{m} [J/mol]	ΔH_{m} [J/mol]	ΔS_{m} [J/(mol·K)]	$G_{\mathrm{m}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{m}}^{\mathrm{E}}$ [J/(mol·K)]	ΔC_P [J/(mol·K)]
0.000	0	0	0.000	0	0.000	0.000
0.100	−5054	−306	3.118	−938	0.415	0.000
0.200	−7654	−336	4.805	−1317	0.644	0.000
0.300	−9005	−168	5.802	−1269	0.723	0.000
0.400	−9448	120	6.283	−926	0.687	0.000
0.500	−9195	450	6.333	−418	0.570	0.000
0.600	−8399	744	6.003	123	0.408	0.000
0.700	−7168	924	5.313	567	0.234	0.000
0.800	−5555	912	4.246	782	0.085	0.000
0.900	−3480	630	2.699	637	−0.004	0.000
1.000	0	0	0.000	0	0.000	0.000

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

Table IIIb. Partial quantities for Cu in the liquid phase at 1523 K.

x_{Cu}	ΔG_{Cu} [J/mol]	ΔH_{Cu} [J/mol]	ΔS_{Cu} [J/(mol·K)]	$G_{\mathrm{Cu}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{Cu}}^{\mathrm{E}}$ [J/(mol·K)]	a_{Cu}	γ_{Cu}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−1635	−151	0.974	−301	0.098	0.879	0.977
0.800	−3855	−500	2.203	−1029	0.347	0.738	0.922
0.700	−6438	−891	3.642	−1921	0.677	0.601	0.859
0.600	−9185	−1168	5.264	−2716	1.017	0.484	0.807
0.500	−11928	−1175	7.061	−3151	1.298	0.390	0.780
0.400	−14566	−756	9.068	−2963	1.449	0.317	0.791
0.300	−17137	245	11.413	−1891	1.402	0.258	0.861
0.200	−20051	1984	14.468	329	1.087	0.205	1.026
0.100	−25199	4617	19.577	3958	0.433	0.137	1.367
0.000	$-\infty$	8300	∞	9259	−0.630	0.000	2.078

Reference state: Cu(liquid)

Table IIIc. Partial quantities for Mn in the liquid phase at 1523 K.

x_{Mn}	ΔG_{Mn} [J/mol]	ΔH_{Mn} [J/mol]	ΔS_{Mn} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Mn}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Mn}}$ [J/(mol·K)]	a_{Mn}	γ_{Mn}
0.000	$-\infty$	−4700	∞	−12604	5.190	0.000	0.370
0.100	−35825	−1701	22.406	−6668	3.261	0.059	0.591
0.200	−22850	320	15.213	−2470	1.832	0.165	0.823
0.300	−14994	1519	10.842	252	0.832	0.306	1.020
0.400	−9844	2052	7.811	1759	0.192	0.460	1.149
0.500	−6462	2075	5.606	2315	−0.157	0.600	1.201
0.600	−4287	1744	3.960	2181	−0.287	0.713	1.188
0.700	−2896	1215	2.699	1620	−0.266	0.796	1.137
0.800	−1931	644	1.690	895	−0.165	0.859	1.073
0.900	−1067	187	0.823	268	−0.053	0.919	1.021
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Mn(liquid)

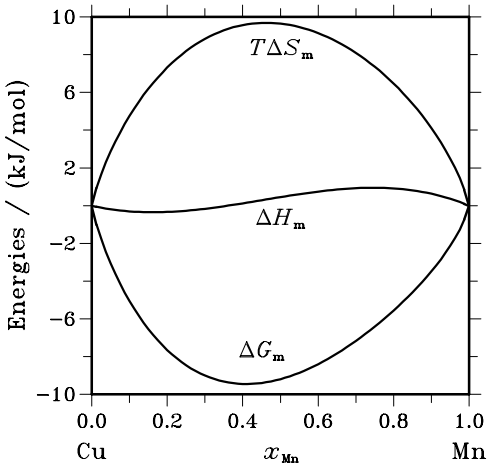

Fig. 2. Integral quantities of the liquid phase at T=1523 K.

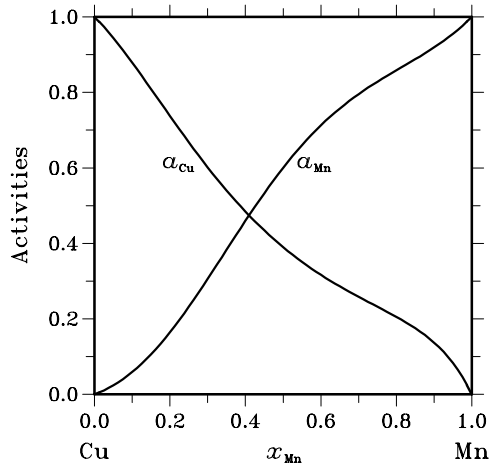

Fig. 3. Activities in the liquid phase at T=1523 K.

Table IVa. Integral quantities for the stable phases at 1100 K.

Phase	x_{Mn}	ΔG_{m} [J/mol]	ΔH_{m} [J/mol]	ΔS_{m} [J/(mol·K)]	$G_{\mathrm{m}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{m}}^{\mathrm{E}}$ [J/(mol·K)]	ΔC_P [J/(mol·K)]
fcc	0.000	0	0	0.000	0	0.000	0.000
	0.100	−2667	294	2.692	306	−0.011	0.001
	0.200	−3742	1139	4.437	834	0.277	0.001
	0.300	−4138	2176	5.740	1449	0.661	0.002
	0.400	−4112	3184	6.633	2044	1.037	0.003
	0.500	−3809	4037	7.132	2531	1.369	0.005
	0.600	−3324	4652	7.251	2831	1.655	0.009
	0.700	−2719	4949	6.971	2868	1.892	0.017
	0.800	−2023	4801	6.203	2553	2.043	0.032
	0.900	−1194	3984	4.707	1780	2.004	0.059
	0.938	−791	3433	3.839	1341	1.901	0.073
cub	0.995	−101	178	0.254	178	0.000	0.000
	1.000	0	0	0.000	0	0.000	0.000

Reference states: Cu(fcc), Mn(cub)

Table IVb. Partial quantities for Cu in the stable phases at 1100 K.

Phase	x_{Cu}	ΔG_{Cu} [J/mol]	ΔH_{Cu} [J/mol]	ΔS_{Cu} [J/(mol·K)]	$G_{\mathrm{Cu}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{Cu}}^{\mathrm{E}}$ [J/(mol·K)]	a_{Cu}	γ_{Cu}
fcc	1.000	0	0	0.000	0	0.000	1.000	1.000
	0.900	−1100	−350	0.682	−137	−0.194	0.887	0.985
	0.800	−2389	−837	1.411	−349	−0.444	0.770	0.963
	0.700	−3675	−975	2.455	−413	−0.511	0.669	0.956
	0.600	−4845	−601	3.859	−173	−0.389	0.589	0.981
	0.500	−5842	307	5.590	498	−0.173	0.528	1.056
	0.400	−6643	1819	7.692	1737	0.074	0.484	1.209
	0.300	−7281	4237	10.471	3730	0.461	0.451	1.504
	0.200	−7971	8287	14.780	6749	1.398	0.418	2.092
	0.100	−9869	15299	22.880	11190	3.735	0.340	3.399
	0.062	−12049	19126	28.341	13348	5.253	0.268	4.303
cub	0.005	−12050	36756	44.369	36756	0.000	0.268	55.635
	0.000	$-\infty$	37092	∞	37092	0.000	0.000	57.718

Reference state: Cu(fcc)

Table IVc. Partial quantities for Mn in the stable phases at 1100 K.

Phase	x_{Mn}	ΔG_{Mn} [J/mol]	ΔH_{Mn} [J/mol]	ΔS_{Mn} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Mn}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Mn}}$ [J/(mol·K)]	a_{Mn}	γ_{Mn}
fcc	0.000	$-\infty$	−1466	∞	1406	−2.611	0.000	1.166
	0.100	−16770	6084	20.776	4290	1.631	0.160	1.598
	0.200	−9154	9043	16.543	5566	3.161	0.368	1.838
	0.300	−5218	9527	13.404	5794	3.394	0.565	1.884
	0.400	−3011	8862	10.793	5369	3.175	0.719	1.799
	0.500	−1776	7766	8.675	4563	2.912	0.823	1.647
	0.600	−1111	6541	6.957	3561	2.709	0.886	1.476
	0.700	−763	5255	5.471	2499	2.505	0.920	1.314
	0.800	−536	3929	4.059	1505	2.204	0.943	1.179
	0.900	−230	2727	2.688	734	1.811	0.975	1.084
	0.938	−43	2391	2.213	544	1.679	0.995	1.061
cub	0.995	−43	1	0.040	1	0.000	0.995	1.000
	1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Mn(cub)

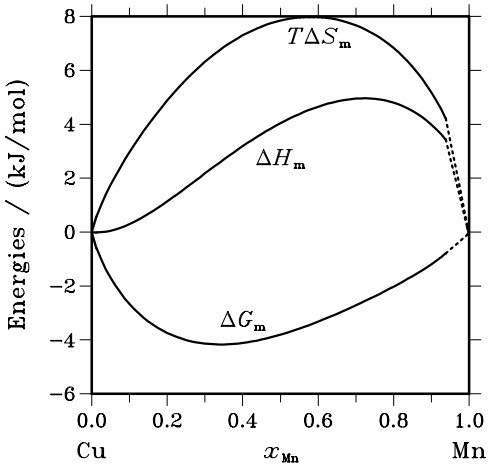

Fig. 4. Integral quantities of the stable phases at T=1100 K.

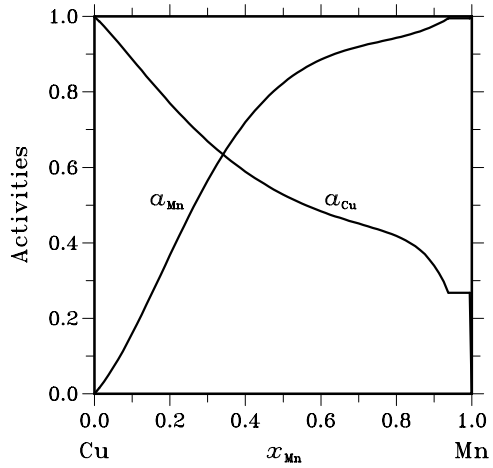

Fig. 5. Activities in the stable phases at T=1100 K.

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