Cu – Zn (Copper – Zinc)

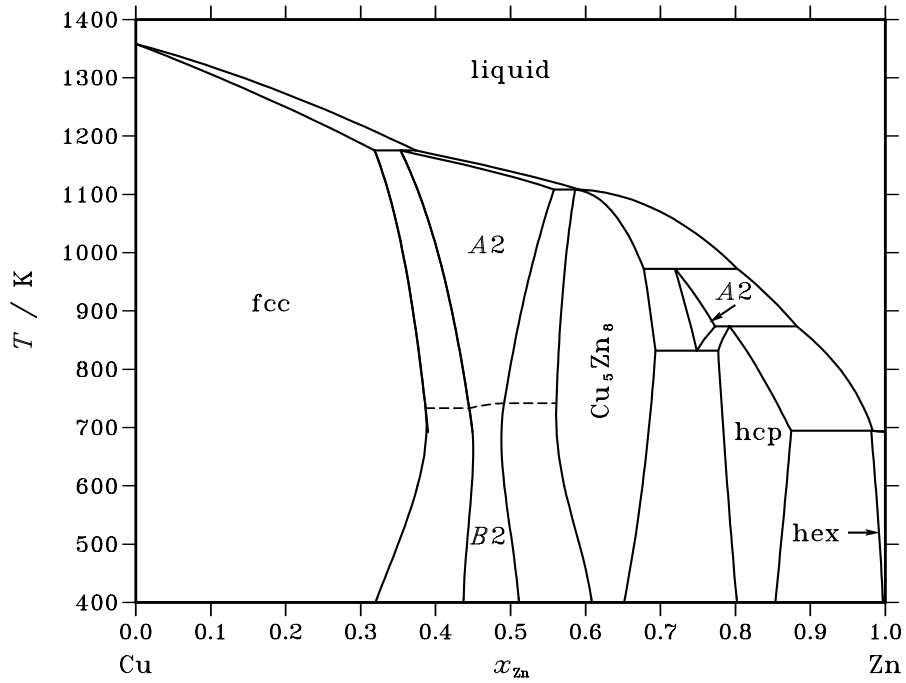

Fig. 1. Calculated phase diagram for the system Cu-Zn.

There have been very many experimental phase diagram and thermodynamic studies of the Cu-Zn system resulting from its importance in commercial alloys, especially the different brasses. On moving from Cu to Zn, the system is characterised by a sequence of peritectic reactions associated with the formation of phases with a wide range of stoichiometry, fcc, $A2$, Cu_5Zn_8 etc. [86Mas]. Ordering of the bcc-phase occurs at temperatures below about 742 K. The thermodynamic assessment of the system by Kowalski and Spencer [93Kow, 98Kow] provides a very good summary of all the experimental information and reproduces known properties and phase boundaries within very close limits.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Cu,Zn)_1$
fcc	$A1$	Cu	$cF4$	$Fm\overline{3}m$	FCC_A1	$(Cu,Zn)_1$
$A2$	$A2$	W	$cI2$	$Im\overline{3}m$	BCC_A2	$(Cu,Zn)_1$
$B2$	$B2$	CsCl	$cP2$	$Pm3m$	BCC_B2	$(Cu,Zn)_1(Cu,Zn)_1$
Cu_5Zn_8	$D8_2$	Cu_5Zn_8	$cI52$	$I\overline{4}3m$	D82_CUZN	$(Cu,Zn)_2(Cu,Zn)_2Cu_3Zn_6$
hcp	$A3$	Mg	$hP2$	$P6_3/mmc$	HCP_A3	$(Cu,Zn)_1$
hex	$A3$	Mg	$hP2$	$P6_3/mmc$	HCP_ZN	$(Cu,Zn)_1$

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Zn}			$\Delta_{\mathrm{r}}H$ / (J/mol)
fcc + liquid $\rightleftharpoons$ $A2$	peritectic	1175.4	0.319	0.373	0.353	−5305
$A2$ + liquid $\rightleftharpoons$ Cu_5Zn_8	peritectic	1108.4	0.558	0.592	0.586	−8407
Cu_5Zn_8 + liquid $\rightleftharpoons$ $A2$	peritectic	972.5	0.678	0.803	0.719	−1395
$A2$ + liquid $\rightleftharpoons$ hcp	peritectic	873.5	0.773	0.882	0.792	−2463
$A2$ $\rightleftharpoons$ Cu_5Zn_8 + hcp	eutectoid	832.0	0.749	0.693	0.777	−1231
hcp + liquid $\rightleftharpoons$ hex	peritectic	694.5	0.874	0.983	0.981	−6858

Table IIIa. Integral quantities for the liquid phase at 1400 K.

x_{Zn}	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	−6008	−2895	2.224	−2224	−0.479	0.000
0.200	−9772	−5638	2.953	−3947	−1.208	0.000
0.300	−12228	−7914	3.082	−5118	−1.997	0.000
0.400	−13548	−9481	2.905	−5713	−2.691	0.000
0.500	−13814	−10174	2.600	−5745	−3.163	0.000
0.600	−13089	−9903	2.276	−5255	−3.320	0.000
0.700	−11426	−8653	1.981	−4316	−3.098	0.000
0.800	−8856	−6484	1.694	−3031	−2.466	0.000
0.900	−5321	−3529	1.280	−1537	−1.423	0.000
1.000	0	0	0.000	0	0.000	0.000

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

Table IIIb. Partial quantities for Cu in the liquid phase at 1400 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	−1466	−17	1.034	−239	0.158	0.882	0.980
0.800	−3639	−527	2.223	−1042	0.367	0.732	0.914
0.700	−6618	−2049	3.263	−2466	0.298	0.566	0.809
0.600	−10421	−4875	3.962	−4475	−0.286	0.409	0.681
0.500	−15007	−9073	4.239	−6939	−1.525	0.275	0.551
0.400	−20299	−14488	4.151	−9633	−3.467	0.175	0.437
0.300	−26255	−20735	3.943	−12240	−6.068	0.105	0.349
0.200	−33082	−27209	4.195	−14348	−9.187	0.058	0.292
0.100	−42253	−33077	6.554	−15450	−12.591	0.027	0.265
0.000	$-\infty$	−37280	∞	−14946	−15.953	0.000	0.277

Reference state: Cu(liquid)

Table IIIc. Partial quantities for Zn in the liquid phase at 1400 K.

x_{Zn}	ΔG_{Zn} [J/mol]	ΔH_{Zn} [J/mol]	ΔS_{Zn} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Zn}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Zn}}$ [J/(mol·K)]	a_{Zn}	γ_{Zn}
0.000	$-\infty$	−28475	∞	−24493	−2.844	0.000	0.122
0.100	−46892	−28797	12.925	−20089	−6.220	0.018	0.178
0.200	−34304	−26082	5.873	−15570	−7.509	0.052	0.262
0.300	−25319	−21598	2.658	−11305	−7.352	0.114	0.379
0.400	−18237	−16389	1.320	−7571	−6.299	0.209	0.522
0.500	−12621	−11275	0.961	−4552	−4.802	0.338	0.676
0.600	−8283	−6847	1.025	−2336	−3.222	0.491	0.818
0.700	−5071	−3475	1.140	−919	−1.826	0.647	0.924
0.800	−2799	−1302	1.069	−202	−0.786	0.786	0.983
0.900	−1217	−246	0.694	9	−0.182	0.901	1.001
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Zn(liquid)

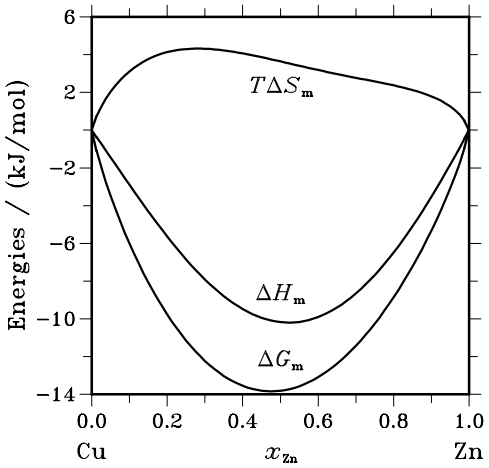

Fig. 2. Integral quantities of the liquid phase at T=1400 K.

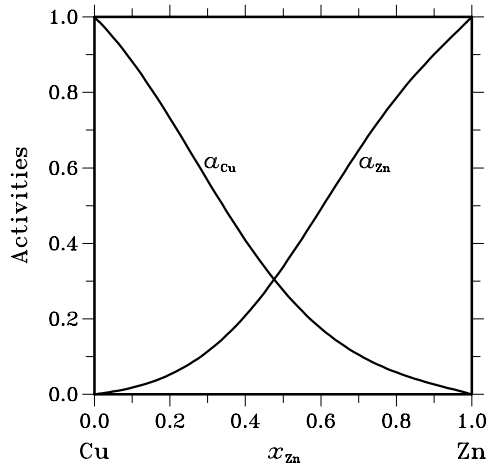

Fig. 3. Activities in the liquid phase at T=1400 K.

Table IVa. Integral quantities for the stable phases at 573 K.

Phase	x_{Zn}	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	−4249	−2824	2.488	−2701	−0.215	0.000
	0.200	−7443	−5452	3.475	−5059	−0.686	0.000
	0.300	−9773	−7548	3.883	−6862	−1.196	0.000
	0.370	−10844	−8556	3.993	−7705	−1.485	0.000
$B2$	0.447	−11763	−10498	2.208	−8488	−3.508	7.222
	0.494	−12160	−11141	1.779	−8858	−3.984	7.976
Cu_5Zn_8	0.577	−12547	−10936	2.810	−9300	−2.855	0.113
	0.600	−12603	−11293	2.285	−9396	−3.311	0.329
	0.673	−11275	−9392	3.287	−8265	−1.967	0.063
hcp	0.791	−8055	−5946	3.679	−5611	−0.586	0.000
	0.800	−7794	−5720	3.620	−5410	−0.540	0.000
	0.866	−5504	−3683	3.178	−3628	−0.096	0.000
hex	0.989	−522	−156	0.639	−225	0.120	0.000
	1.000	0	0	0.000	0	0.000	0.000

Reference states: Cu(fcc), Zn(hex)

Table IVb. Partial quantities for Cu in the stable phases at 573 K.

Phase	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}
fcc	1.000	0	0	0.000	0	0.000	1.000	1.000
	0.900	−632	−34	1.045	−131	0.169	0.876	0.973
	0.800	−1899	−630	2.215	−836	0.360	0.671	0.839
	0.700	−4158	−2336	3.179	−2458	0.214	0.418	0.597
	0.630	−6431	−4347	3.637	−4231	−0.201	0.259	0.411
$B2$	0.553	−6431	−1669	8.310	−3610	3.387	0.259	0.469
	0.506	−9841	−7834	3.503	−6594	−2.165	0.127	0.251
Cu_5Zn_8	0.423	−9841	−1981	13.719	−5747	6.573	0.127	0.299
	0.400	−12907	−2574	18.033	−8541	10.414	0.067	0.166
	0.327	−29726	−34436	−8.219	−24397	−17.519	0.002	0.006
hcp	0.209	−29726	−24735	8.711	−22274	−4.295	0.002	0.009
	0.200	−30931	−25917	8.751	−23264	−4.631	0.002	0.008
	0.134	−40730	−35393	9.314	−31152	−7.402	0.000	0.001
hex	0.011	−40730	−13504	47.515	−19427	10.336	0.000	0.017
	0.000	$-\infty$	−13832	∞	−19895	10.581	0.000	0.015

Reference state: Cu(fcc)

Table IVc. Partial quantities for Zn in the stable phases at 573 K.

Phase	x_{Zn}	ΔG_{Zn} [J/mol]	ΔH_{Zn} [J/mol]	ΔS_{Zn} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Zn}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Zn}}$ [J/(mol·K)]	a_{Zn}	γ_{Zn}
fcc	0.000	$-\infty$	−27863	∞	−27860	−0.007	0.000	0.003
	0.100	−36801	−27933	15.478	−25831	−3.667	0.000	0.004
	0.200	−29621	−24743	8.514	−21953	−4.868	0.002	0.010
	0.300	−22874	−19708	5.524	−17138	−4.486	0.008	0.027
	0.370	−18365	−15730	4.600	−13626	−3.672	0.021	0.057
$B2$	0.447	−18365	−21430	−5.348	−14527	−12.046	0.021	0.047
	0.494	−14533	−14525	0.014	−11176	−5.846	0.047	0.096
Cu_5Zn_8	0.577	−14533	−17513	−5.201	−11910	−9.779	0.047	0.082
	0.600	−12400	−17106	−8.213	−9966	−12.461	0.074	0.123
	0.673	−2320	2763	8.871	−435	5.581	0.614	0.913
hcp	0.791	−2320	−975	2.348	−1202	0.396	0.614	0.777
	0.800	−2010	−671	2.338	−947	0.482	0.656	0.820
	0.866	−57	1220	2.230	628	1.034	0.988	1.141
hex	0.989	−57	−2	0.097	−3	0.001	0.988	0.999
	1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Zn(hex)

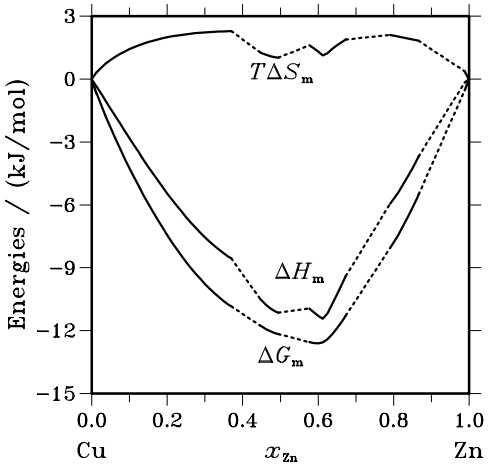

Fig. 4. Integral quantities of the stable phases at T=573 K.

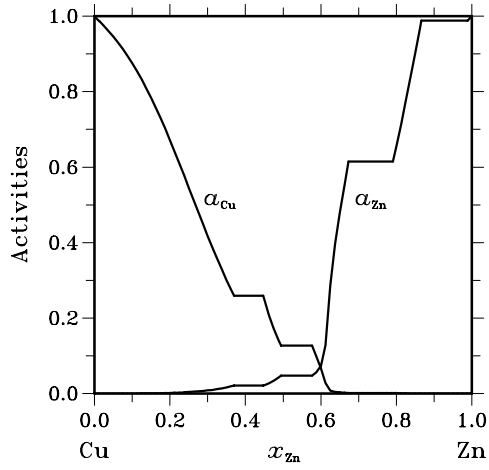

Fig. 5. Activities in the stable phases at T=573 K.

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