Ho – Mg (Holmium – Magnesium)

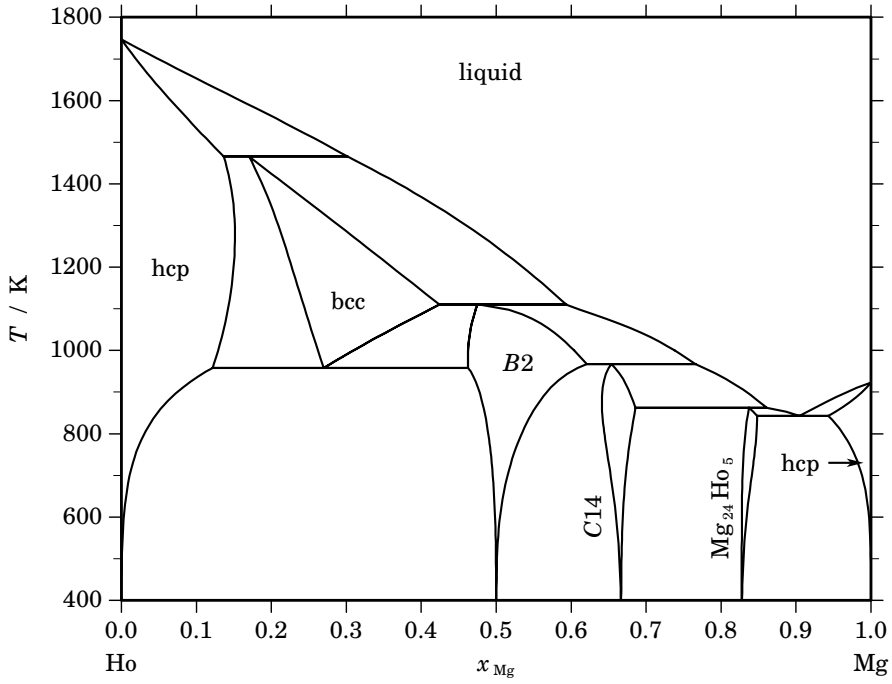

Fig. 1. Calculated phase diagram for the system Ho-Mg.

The rare earth elements have attracted some attention as additives to light metal alloys in the aerospace and automotive industry due to the improvement of mechanical properties of Al- and Mg-alloys at high temperatures. Cacciamani *et al.* [2003Cac] prepared a thermodynamic optimisation of the complete Ho-Mg system, which is primarily based on an experimental investigation of the phase equilibria at elevated temperatures throughout the whole composition range [1993Sac]. The solid solubility of Ho in magnesium has been measured by [1978Rok]. Since no thermodynamic data have been available for the Ho-Mg system the assessors estimated the values based on other systems of Mg with rare-earth metals which have been evaluated in the same publication.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Ho,Mg)_1$
hcp	$A3$	Mg	$hP2$	$P6_3/mmc$	HCP_A3	$(Ho,Mg)_1$
bcc	$A2$	W	$cI2$	$Im\overline{3}m$	BCC_A2	$(Ho,Mg)_1$
$B2$	$B2$	CsCl	$cP2$	$Pm3m$	BCC_B2	$(Ho,Mg)_1(Ho,Mg)_1$
$C14$	$C14$	$MgZn_2$	$hP12$	$P6_3/mmc$	LAVES_C14	$(Ho,Mg)_2(Ho,Mg)_1$
$Mg_{24}Ho_5$	$A12$	αMn	$cI58$	$I\overline{4}3m$	MG24HO5	$Mg_{24}(Ho,Mg)_5$

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Mg}			$\Delta_{\mathrm{r}}H$ / (J/mol)
hcp + liquid $\rightleftharpoons$ bcc	peritectic	1465.7	0.136	0.301	0.170	−1460
bcc + liquid $\rightleftharpoons$ $B2$	peritectic	1110.2	0.424	0.593	0.475	−5711
$B2$ + liquid $\rightleftharpoons$ $C14$	peritectic	967.1	0.621	0.766	0.654	−7328
bcc $\rightleftharpoons$ hcp + $B2$	eutectoid	958.1	0.270	0.122	0.463	−4591
$C14$ + liquid $\rightleftharpoons$ $Mg_{24}Ho_5$	peritectic	862.3	0.686	0.861	0.837	−12294
liquid $\rightleftharpoons$ $Mg_{24}Ho_5$ + hcp	eutectic	842.9	0.905	0.848	0.943	−9355

Table IIIa. Integral quantities for the liquid phase at 1800 K.

x_{Mg}	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	−5705	251	3.309	−840	0.606	0.000
0.200	−9124	−396	4.849	−1635	0.688	0.000
0.300	−11474	−1626	5.471	−2332	0.392	0.000
0.400	−12950	−3123	5.459	−2878	−0.136	0.000
0.500	−13593	−4570	5.013	−3219	−0.751	0.000
0.600	−13376	−5652	4.291	−3303	−1.305	0.000
0.700	−12219	−6051	3.426	−3077	−1.653	0.000
0.800	−9975	−5453	2.512	−2486	−1.649	0.000
0.900	−6343	−3542	1.556	−1478	−1.146	0.000
1.000	0	0	0.000	0	0.000	0.000

Reference states: Ho(liquid), Mg(liquid)

Table IIIb. Partial quantities for Ho in the liquid phase at 1800 K.

x_{Ho}	ΔG_{Ho} [J/mol]	ΔH_{Ho} [J/mol]	ΔS_{Ho} [J/(mol·K)]	$G_{\mathrm{Ho}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{Ho}}^{\mathrm{E}}$ [J/(mol·K)]	a_{Ho}	γ_{Ho}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−1590	502	1.162	−13	0.286	0.899	0.999
0.800	−3464	1587	2.806	−125	0.951	0.793	0.992
0.700	−5779	2622	4.667	−441	1.701	0.680	0.971
0.600	−8712	2975	6.493	−1067	2.246	0.559	0.931
0.500	−12484	2015	8.055	−2111	2.292	0.434	0.868
0.400	−17391	−891	9.167	−3678	1.548	0.313	0.782
0.300	−23894	−6376	9.732	−5875	−0.278	0.203	0.675
0.200	−32896	−15071	9.903	−8808	−3.479	0.111	0.555
0.100	−47046	−27608	10.799	−12585	−8.346	0.043	0.431
0.000	$-\infty$	−44620	∞	−17310	−15.172	0.000	0.315

Reference state: Ho(liquid)

Table IIIc. Partial quantities for Mg in the liquid phase at 1800 K.

x_{Mg}	ΔG_{Mg} [J/mol]	ΔH_{Mg} [J/mol]	ΔS_{Mg} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Mg}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Mg}}$ [J/(mol·K)]	a_{Mg}	γ_{Mg}
0.000	$-\infty$	8060	∞	−8442	9.168	0.000	0.569
0.100	−42736	−2006	22.628	−8275	3.483	0.058	0.575
0.200	−31760	−8328	13.018	−7673	−0.364	0.120	0.599
0.300	−24763	−11539	7.347	−6744	−2.664	0.191	0.637
0.400	−19307	−12270	3.909	−5593	−3.709	0.275	0.688
0.500	−14701	−11155	1.970	−4328	−3.793	0.374	0.749
0.600	−10699	−8825	1.041	−3053	−3.206	0.489	0.815
0.700	−7215	−5912	0.724	−1877	−2.242	0.617	0.882
0.800	−4245	−3049	0.664	−905	−1.191	0.753	0.941
0.900	−1821	−868	0.530	−244	−0.346	0.885	0.984
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Mg(liquid)

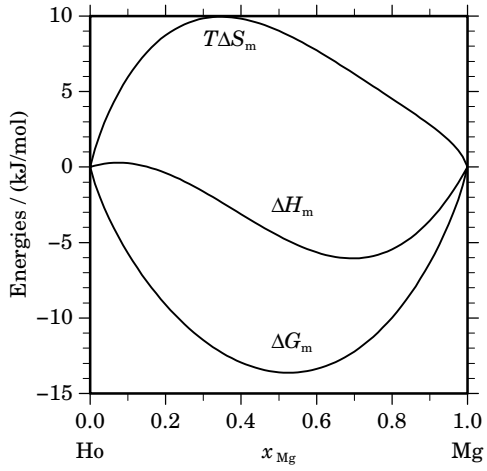

Fig. 2. Integral quantities of the liquid phase at T=1800 K.

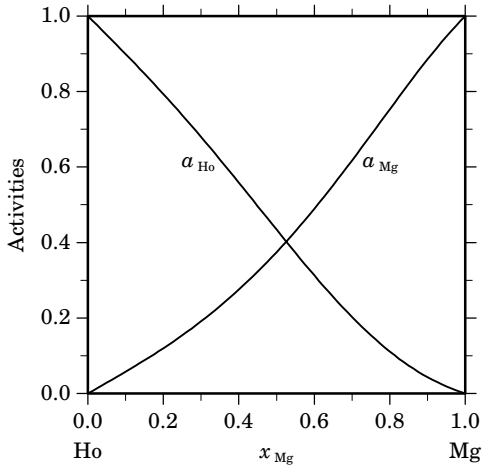

Fig. 3. Activities in the liquid phase at T=1800 K.

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

Compound	x_{Mg}	$\Delta_{\mathrm{f}}G^{\circ}$ / (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))
$B2$	0.500	−11784	−13537	−5.882	0.000
$C14$	0.667	−11803	−13667	−6.250	0.001
$Mg_{24}Ho_5$	0.828	−8516	−10342	−6.124	0.000

References

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[1993Sac] A. Saccone, S. Delfino, D. Macció, R. Ferro: J. Phase Equilibria **14** (1993) 280–287.

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