Dy – Mg (Dysprosium – Magnesium)

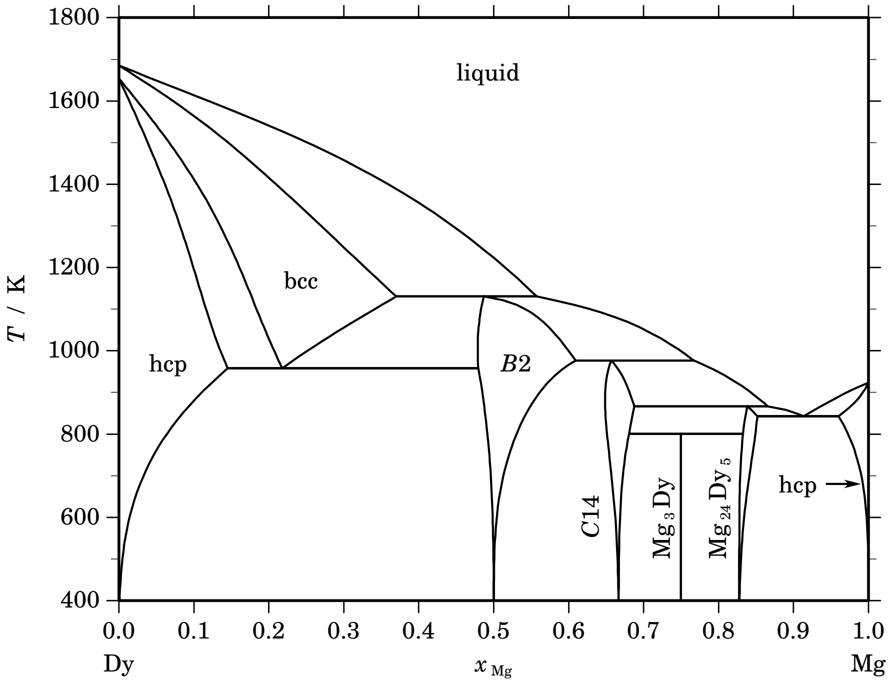

Fig. 1. Calculated phase diagram for the system Dy-Mg.

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 Dy-Mg system, which is primarily based on an experimental investigation of the phase equilibria at elevated temperatures throughout the whole composition range [1991Sac]. The solid solubilities have been measured by [1965Jos] for Mg in hcp-Dy and by [1978Rok] for Dy in magnesium. Since no thermodynamic data have been available for the Dy-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	$(Dy,Mg)_1$
hcp	$A3$	Mg	$hP2$	$P6_3/mmc$	HCP_A3	$(Dy,Mg)_1$
bcc	$A2$	W	$cI2$	$Im\overline{3}m$	BCC_A2	$(Dy,Mg)_1$
$B2$	$B2$	CsCl	$cP2$	$Pm3m$	BCC_B2	$(Dy,Mg)_1(Dy,Mg)_1$
$C14$	$C14$	$MgZn_2$	$hP12$	$P6_3/mmc$	LAVES_C14	$(Dy,Mg)_2(Dy,Mg)_1$
Mg_3Dy	$D0_3$	BiF_3	$cF16$	$Fm\overline{3}m$	MG3LN	Mg_3Dy_1
$Mg_{24}Dy_5$	$A12$	αMn	$cI58$	$I\overline{4}3m$	MG24DY5	$Mg_{24}(Dy,Mg)_5$

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Mg}			$\Delta_r H$ / (J/mol)
bcc + liquid ⇌ $B2$	peritectic	1130.3	0.370	0.558	0.487	−10978
$B2$ + liquid ⇌ $C14$	peritectic	976.6	0.609	0.767	0.657	−7979
bcc ⇌ hcp + $B2$	eutectoid	958.3	0.218	0.145	0.479	−3053
$C14$ + liquid ⇌ $Mg_{24}Dy_5$	peritectic	866.8	0.688	0.866	0.838	−12106
liquid ⇌ $Mg_{24}Dy_5$ + hcp	eutectic	843.0	0.914	0.852	0.960	−9819
$C14$ + $Mg_{24}Dy_5$ ⇌ Mg_3Dy	peritectoid	800.7	0.681	0.833	0.750	−597

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)]	$G^{\mathrm{E}}_{\mathrm{m}}$ [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	−5405	244	3.138	−540	0.435	0.000
0.200	−8648	−330	4.621	−1158	0.460	0.000
0.300	−10924	−1436	5.271	−1782	0.192	0.000
0.400	−12407	−2786	5.345	−2334	−0.251	0.000
0.500	−13116	−4095	5.012	−2742	−0.752	0.000
0.600	−13003	−5076	4.404	−2931	−1.192	0.000
0.700	−11968	−5444	3.624	−2826	−1.455	0.000
0.800	−9841	−4911	2.739	−2352	−1.422	0.000
0.900	−6300	−3192	1.727	−1435	−0.976	0.000
1.000	0	0	0.000	0	0.000	0.000

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

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

x_{Dy}	ΔG_{Dy} [J/mol]	ΔH_{Dy} [J/mol]	ΔS_{Dy} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Dy}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Dy}}$ [J/(mol·K)]	a_{Dy}	γ_{Dy}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−1525	457	1.101	52	0.225	0.903	1.003
0.800	−3231	1444	2.598	108	0.742	0.806	1.007
0.700	−5319	2391	4.283	20	1.318	0.701	1.001
0.600	−8008	2724	5.962	−363	1.715	0.586	0.976
0.500	−11562	1870	7.462	−1189	1.699	0.462	0.924
0.400	−16320	−743	8.654	−2607	1.035	0.336	0.840
0.300	−22785	−5688	9.498	−4766	−0.512	0.218	0.727
0.200	−31903	−13537	10.203	−7816	−3.179	0.119	0.593
0.100	−46366	−24864	11.946	−11905	−7.199	0.045	0.451
0.000	$-\infty$	−40240	∞	−17184	−12.809	0.000	0.317

Reference state: Dy(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	$-\infty$	7480	∞	−4755	6.797	0.000	0.728
0.100	−40326	−1672	21.474	−5865	2.329	0.068	0.676
0.200	−30312	−7429	12.713	−6225	−0.669	0.132	0.660
0.300	−24003	−10365	7.577	−5984	−2.434	0.201	0.670
0.400	−19005	−11051	4.419	−5291	−3.200	0.281	0.702
0.500	−14670	−10060	2.561	−4296	−3.202	0.375	0.750
0.600	−10792	−7965	1.570	−3147	−2.677	0.486	0.810
0.700	−7332	−5340	1.107	−1994	−1.859	0.613	0.875
0.800	−4325	−2755	0.872	−986	−0.983	0.749	0.936
0.900	−1848	−784	0.591	−271	−0.285	0.884	0.982
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Mg(liquid)

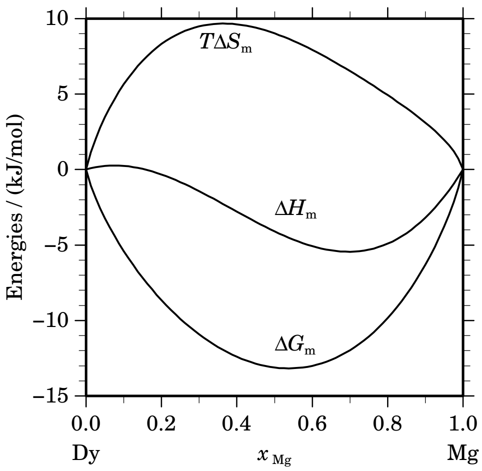

Fig. 2. Integral quantities of the liquid phase at T=1800 K.

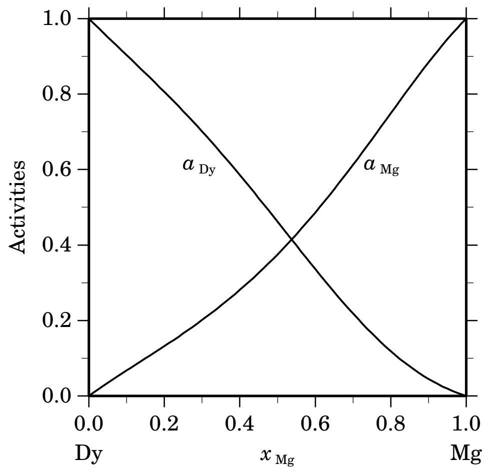

Fig. 3. Activities in the liquid phase at T=1800 K.

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))	$\Delta_{\mathrm{f}}C_P^{\circ}$ / (J/(mol·K))
$B2$	0.500	−12298	−13952	−5.550	−0.383
$C14$	0.667	−12142	−13981	−6.167	−0.241
Mg_3Dy	0.750	−10504	−12386	−6.312	−0.192
$Mg_{24}Dy_5$	0.828	−8790	−10680	−6.339	−0.133

References

[1965Jos] R.R. Joseph, K.A. Gschneidner jr.: Trans. Metall. Soc. AIME **233** (1965) 2063–2069.

[1978Rok] L.L. Rokhlin in: "Probl. Metalloved. Tsvetn. Splavov", N.M. Zhavoronkov (Ed.), Izd. Nauka, Moscow, 1978, pp. 59–70.

[1991Sac] A. Saccone, S. Delfino, D. Macció, R. Ferro: Z. Metallkd. **82** (1991) 568–573.

[2003Cac] G. Cacciamani, S. de Negri, A. Saccone, R. Ferro: Intermetallics **11** (2003) 1135–1151.