Al – Dy (Aluminium – Dysprosium)

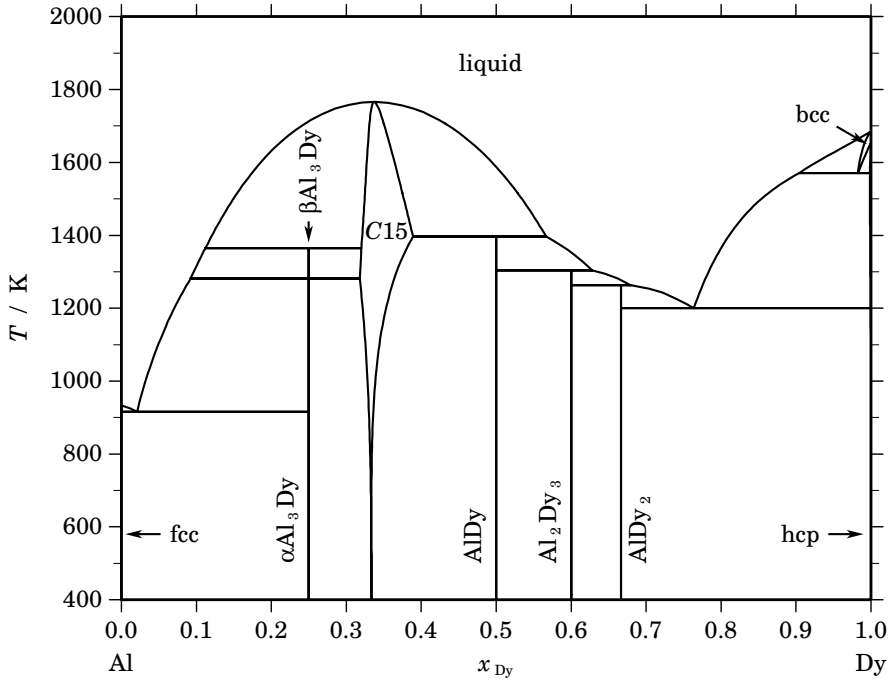

Fig. 1. Calculated phase diagram for the system Al-Dy.

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 Al-Dy system, which is based on a review of the Al-rich part [1988Gsc] and an experimental investigation of the phase equilibria in the range from 0 to 67 at.% Al [2000Sac]. Except for the standard enthalpy of formation of the Al_2Dy phase [1985Col] no other thermodynamic data for the intermetallic compounds have been available. Despite this lack of data, the assessment [2003Cac] can be considered as quite reasonable since other similar systems (Al-Gd, Al-Ho) have been evaluated simultaneously and data have been estimated taking advantage of the close relations between the involved rare earth elements. The dataset should not be used at too high temperatures because an artificial inverse miscibility gap opens in the liquid above 3500 K.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Al,Dy)_1$
fcc	$A1$	Cu	$cF4$	$Fm\overline{3}m$	FCC_A1	Al_1
αAl_3Dy	$D0_{24}$	Ni_3Ti	$hP16$	$P6_3/mmc$	AL3DY	Al_3Dy_1
βAl_3Dy	···	Al_3Ho	$hR20$	$R\overline{3}m$	AL3LN	Al_3Dy_1
$C15$	$C15$	Cu_2Mg	$cF24$	$Fd\overline{3}m$	C15_LAVES	$(Al,Dy)_2(Al,Dy)_1$
AlDy	···	AlEr	$oP16$	$Pmma$	ALLN	Al_1Dy_1
Al_2Dy_3	···	Al_2Zr_3	$tP20$	$P4_2/mnm$	AL2LN3	Al_2Dy_3
$AlDy_2$	$C23$	Co_2Si	$oP12$	$Pnma$	ALLN2	Al_1Dy_2
bcc	$A2$	W	$cI2$	$Im\overline{3}m$	BCC_A2	$(Al,Dy)_1$
hcp	$A3$	Mg	$hP2$	$P6_3/mmc$	HCP_A3	$(Al,Dy)_1$

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Dy}			$\Delta_{\mathrm{r}}H$ / (J/mol)
liquid $\rightleftharpoons C15$	congruent	1765.9	0.337	0.337		−28321
bcc $\rightleftharpoons$ liquid + hcp	metatectic	1571.1	0.983	0.904	0.999	−2316
$C15$ + liquid $\rightleftharpoons$ AlDy	peritectic	1396.2	0.389	0.567	0.500	−14359
liquid + $C15 \rightleftharpoons \beta Al_3Dy$	peritectic	1364.8	0.112	0.320	0.250	−1293
AlDy + liquid $\rightleftharpoons Al_2Dy_3$	peritectic	1303.9	0.500	0.628	0.600	−14224
$\beta Al_3Dy \rightleftharpoons \alpha Al_3Dy$	polymorphic	1281.2	0.250	0.250		−5000
Al_2Dy_3 + liquid $\rightleftharpoons AlDy_2$	peritectic	1262.9	0.600	0.680	0.667	−13697
liquid $\rightleftharpoons AlDy_2$ + hcp	eutectic	1200.0	0.763	0.667	1.000	−13069
liquid $\rightleftharpoons$ fcc + αAl_3Dy	eutectic	916.1	0.021	0.000	0.250	−10950

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

x_{Dy}	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	−10561	−15104	−2.523	−5696	−5.226	0.000
0.200	−17753	−26988	−5.131	−10264	−9.291	0.000
0.300	−22522	−35330	−7.116	−13380	−12.195	0.000
0.400	−24950	−39964	−8.341	−14877	−13.937	0.000
0.500	−25117	−40875	−8.754	−14744	−14.517	0.000
0.600	−23193	−38207	−8.341	−13121	−13.937	0.000
0.700	−19448	−32256	−7.116	−10305	−12.195	0.000
0.800	−14239	−23474	−5.131	−6750	−9.291	0.000
0.900	−7926	−12468	−2.523	−3061	−5.226	0.000
1.000	0	0	0.000	0	0.000	0.000

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

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

x_{Al}	ΔG_{Al} [J/mol]	ΔH_{Al} [J/mol]	ΔS_{Al} [J/(mol·K)]	$G_{\mathrm{Al}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{Al}}^{\mathrm{E}}$ [J/(mol·K)]	a_{Al}	γ_{Al}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−2075	−1543	0.295	−498	−0.581	0.871	0.967
0.800	−5838	−6679	−0.467	−2498	−2.323	0.677	0.846
0.700	−11752	−15821	−2.261	−6414	−5.226	0.456	0.651
0.600	−19838	−28917	−5.044	−12193	−9.291	0.266	0.443
0.500	−29692	−45450	−8.754	−19319	−14.517	0.138	0.275
0.400	−40523	−64439	−13.287	−26809	−20.905	0.067	0.167
0.300	−51239	−84438	−18.444	−33220	−28.454	0.033	0.109
0.200	−60727	−103536	−23.783	−36640	−37.165	0.017	0.086
0.100	−69155	−119360	−27.892	−34694	−47.037	0.010	0.098
0.000	$-\infty$	−129070	∞	−24544	−58.070	0.000	0.194

Reference state: Al(liquid)

Table IIIc. 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}
0.000	$-\infty$	−165670	∞	−61144	−58.070	0.000	0.017
0.100	−86943	−137148	−27.892	−52482	−47.037	0.003	0.030
0.200	−65412	−108221	−23.783	−41325	−37.165	0.013	0.063
0.300	−47652	−80851	−18.444	−29633	−28.454	0.041	0.138
0.400	−32617	−56533	−13.287	−18904	−20.905	0.113	0.283
0.500	−20542	−36300	−8.754	−10169	−14.517	0.253	0.507
0.600	−11640	−20719	−5.044	−3995	−9.291	0.459	0.766
0.700	−5823	−9892	−2.261	−485	−5.226	0.678	0.968
0.800	−2617	−3459	−0.467	722	−2.323	0.840	1.049
0.900	−1123	−591	0.295	454	−0.581	0.928	1.031
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Dy(liquid)

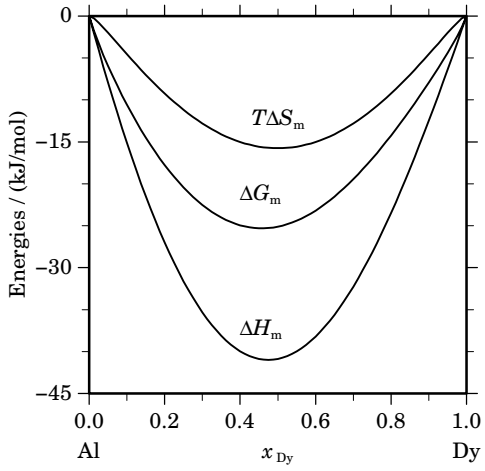

Fig. 2. Integral quantities of the liquid phase at T=1800 K.

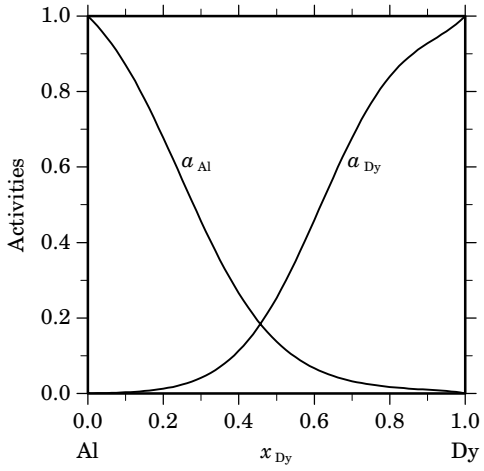

Fig. 3. Activities in the liquid phase at T=1800 K.

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

Compound	x_{Dy}	$\Delta_{\mathrm{f}}G^{\circ}$ / (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))
αAl_3Dy_1	0.250	−39408	−42486	−10.324	−0.192
βAl_3Dy_1	0.250	−35571	−37486	−6.422	−0.192
$C15$	0.333	−49997	−53981	−13.362	−0.256
AlDy	0.500	−45439	−49471	−13.523	−0.385
Al_2Dy_3	0.600	−40130	−43966	−12.864	−0.462
Al_1Dy_2	0.667	−35022	−38462	−11.538	−0.513

References

[1985Col] C. Colinet, A. Pasturel, K.H.J. Buschow: J. Chem. Thermodyn. **17** (1985) 1133–1139.
[1988Gsc] K.A. Gschneidner, F.W. Calderwood: Bull. Alloy Phase Diagrams **9** (1988) 673–675.
[2000Sac] A. Saccone, A.M. Cardinale, S. Delfino, R. Ferro: Z. Metallkd. **91** (2000) 17–23.
[2003Cac] G. Cacciamani, S. de Negri, A. Saccone, R. Ferro: Intermetallics **11** (2003) 1135–1151.