Pr – Sb (Praseodymium – Antimony)

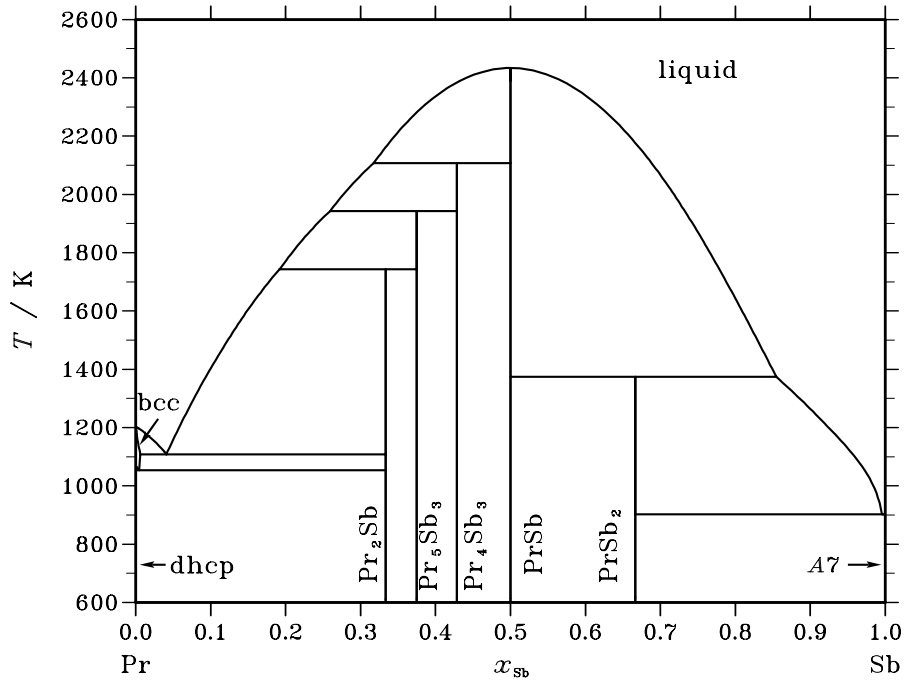

Fig. 1. Calculated phase diagram for the system Pr-Sb.

The thermodynamic assessment of the Pr-Sb system was carried out by Cacciamani *et al.* [92Cac]. The phase diagram was experimentally studied by [72Kob] and [88Abd] using various techniques. The system is characterised by five intermediate compounds: Pr_2Sb, Pr_5Sb_3, Pr_4Sb_3, PrSb and $PrSb_2$. PrSb melts congruently at a temperature much higher than the melting temperatures of the elements. The other compounds, however, decompose peritectically. Two eutectic equilibria are present at compositions very close to the pure elements. All the intermediate phases were described as stoichiometric compounds. The enthalpies of formation of the Pr-Sb compounds calorimetrically determined by [77Bor] and [82Bor] agree well with those derived from the temperature dependence of the vapour pressure data of [84Vik]. Compositions and temperatures describing invariant equilibria were explicitly reported by [72Kob] and [88Abd]. Experimental and calculated invariant equilibria agree satisfactorily.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Pr,Sb)_1$
bcc	$A2$	W	$cI2$	$Im\overline{3}m$	BCC_A2	$(Pr,Sb)_1$
dhcp	$A3'$	αLa	$hP4$	$P6_3/mmc$	DHCP	Pr_1
Pr_2Sb	···	···	$tI12$	$I4/mmm$	NDPR2SB1	Pr_2Sb_1
Pr_5Sb_3	$D8_8$	Mn_5Si_3	$hP16$	$P6_3/mcm$	NDPR5SB3	Pr_5Sb_3
Pr_4Sb_3	$D7_3$	Th_3P_4	$cI28$	$I\overline{4}3d$	NDPR4SB3	Pr_4Sb_3
PrSb	$B1$	NaCl	$cF8$	$Fm\overline{3}m$	NDPR1SB1	Pr_1Sb_1
$PrSb_2$	···	···	$oC24$	$Cmca$	NDPR1SB2	Pr_1Sb_2
$A7$	$A7$	αAs	$hR2$	$R\overline{3}m$	RHOMBOHEDRAL_A7	Sb_1

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Sb}			$\Delta_{\mathrm{r}}H$ / (J/mol)
liquid $\rightleftharpoons$ PrSb	congruent	2433.6	0.500	0.500		−68565
liquid + PrSb $\rightleftharpoons$ Pr_4Sb_3	peritectic	2107.3	0.318	0.500	0.429	−21402
liquid + Pr_4Sb_3 $\rightleftharpoons$ Pr_5Sb_3	peritectic	1943.0	0.259	0.429	0.375	−15943
liquid + Pr_5Sb_3 $\rightleftharpoons$ Pr_2Sb	peritectic	1742.9	0.192	0.375	0.333	−7766
PrSb + liquid $\rightleftharpoons$ $PrSb_2$	peritectic	1374.4	0.500	0.855	0.667	−22653
liquid $\rightleftharpoons$ bcc + Pr_2Sb	eutectic	1108.5	0.041	0.006	0.333	−8588
bcc $\rightleftharpoons$ dhcp + Pr_2Sb	eutectoid	1053.3	0.005	0.000	0.333	−3478
liquid $\rightleftharpoons$ $PrSb_2$ + A7	eutectic	902.3	0.996	0.667	1.000	−20065

Table IIIa. Integral quantities for the liquid phase at 2500 K.

x_{Sb}	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	−23393	−25438	−0.818	−16636	−3.521	0.000
0.200	−40961	−46729	−2.307	−30560	−6.468	0.000
0.300	−53607	−62555	−3.579	−40910	−8.658	0.000
0.400	−61095	−72029	−4.374	−47106	−9.969	0.000
0.500	−63257	−74695	−4.575	−48849	−10.338	0.000
0.600	−60111	−70525	−4.165	−46122	−9.761	0.000
0.700	−51885	−59922	−3.215	−39188	−8.294	0.000
0.800	−38993	−43720	−1.891	−28592	−6.051	0.000
0.900	−21917	−23181	−0.506	−15160	−3.208	0.000
1.000	0	0	0.000	0	0.000	0.000

Reference states: Pr(liquid), Sb(liquid)

Table IIIb. Partial quantities for Pr in the liquid phase at 2500 K.

x_{Pr}	ΔG_{Pr} [J/mol]	ΔH_{Pr} [J/mol]	ΔS_{Pr} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Pr}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Pr}}$ [J/(mol·K)]	a_{Pr}	γ_{Pr}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−3379	−1818	0.624	−1189	−0.252	0.850	0.944
0.800	−10684	−9245	0.576	−6046	−1.280	0.598	0.748
0.700	−23285	−24269	−0.393	−15871	−3.359	0.326	0.466
0.600	−41740	−47589	−2.339	−31122	−6.587	0.134	0.224
0.500	−65819	−78613	−5.118	−51412	−10.881	0.042	0.084
0.400	−94556	−115462	−8.362	−75510	−15.981	0.011	0.026
0.300	−126368	−154962	−11.438	−101342	−21.448	0.002	0.008
0.200	−159445	−192653	−13.283	−125991	−26.665	0.000	0.002
0.100	−193557	−222782	−11.690	−145695	−30.835	0.000	0.001
0.000	$-\infty$	−238308	∞	−155848	−32.984	0.000	0.001

Reference state: Pr(liquid)

Table IIIc. Partial quantities for Sb in the liquid phase at 2500 K.

x_{Sb}	ΔG_{Sb} [J/mol]	ΔH_{Sb} [J/mol]	ΔS_{Sb} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Sb}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Sb}}$ [J/(mol·K)]	a_{Sb}	γ_{Sb}
0.000	$-\infty$	−269656	∞	−176349	−37.323	0.000	0.000
0.100	−203521	−238017	−13.799	−155658	−32.944	0.000	0.001
0.200	−162069	−196665	−13.838	−128615	−27.220	0.000	0.002
0.300	−124359	−151890	−11.012	−99333	−21.023	0.003	0.008
0.400	−90128	−108690	−7.425	−71081	−15.044	0.013	0.033
0.500	−60694	−70776	−4.033	−46286	−9.796	0.054	0.108
0.600	−37148	−40567	−1.367	−26530	−5.615	0.167	0.279
0.700	−19964	−19190	0.309	−12550	−2.656	0.383	0.547
0.800	−8880	−6486	0.958	−4242	−0.898	0.652	0.815
0.900	−2846	−1003	0.737	−656	−0.139	0.872	0.969
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Sb(liquid)

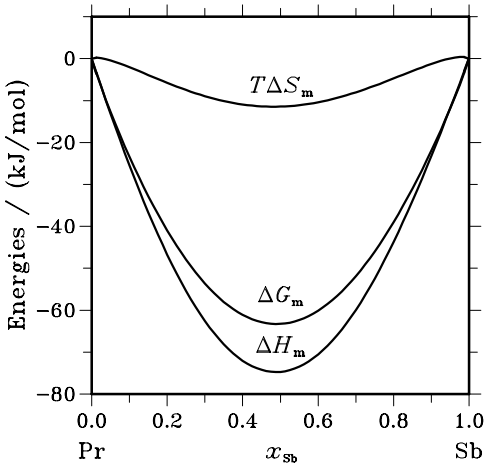

Fig. 2. Integral quantities of the liquid phase at T=2500 K.

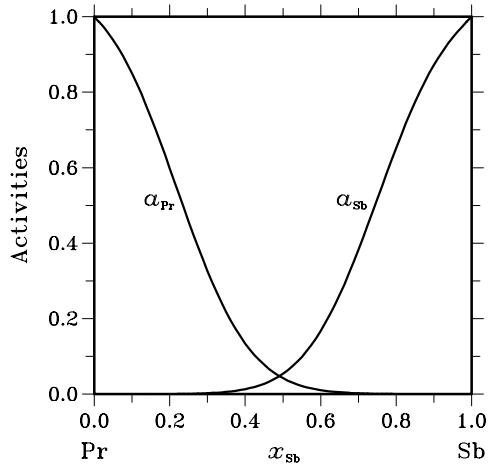

Fig. 3. Activities in the liquid phase at T=2500 K.

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

Compound	x_{Sb}	$\Delta_{\mathrm{f}}G^{\circ}$ / (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))
Pr_2Sb_1	0.333	−97242	−101986	−15.909	0.000
Pr_5Sb_3	0.375	−106863	−112043	−17.374	0.000
Pr_4Sb_3	0.429	−114746	−119945	−17.438	0.000
Pr_1Sb_1	0.500	−123304	−128565	−17.647	0.000
Pr_1Sb_2	0.667	−92578	−97632	−16.952	0.000

References

[72Kob] G.F. Kobzenko, V.B. Chernogorenko, E.L. Martinchuk, K.A. Lynchak, R.V. Skolozdra: Russ. Metall. **3** (1972) 176–177.
[77Bor] A. Borsese, R. Ferro, R. Capelli, S. Delfino: J. Less-Common Met. **55** (1977) 77–83.
[82Bor] G. Borzone, A. Borsese, G. Zanicchi, R. Ferro: J. Therm. Anal. **25** (1982) 433–440.
[84Vik] G.Sh. Viksman, S.P. Gordienko: Izv. Akad. Nauk SSSR, Neorg. Mater. **20** (1984) 1441–1444.
[85Bor] G. Borzone, A. Borsese, S. Delfino, R. Ferro: Z. Metallkd. **76** (1985) 208–213.
[88Abd] M.N. Abdusalyamova, O.I. Rahmatov, N.D. Faslyeva, A.G. Tchuiko: J. Less-Common Met. **141** (1988) L23–L26.
[92Cac] G. Cacciamani, R. Ferro, H.L. Lukas: Z. Metallkd. **83** (1992) 669–672.