Ti – V (Titanium – Vanadium)

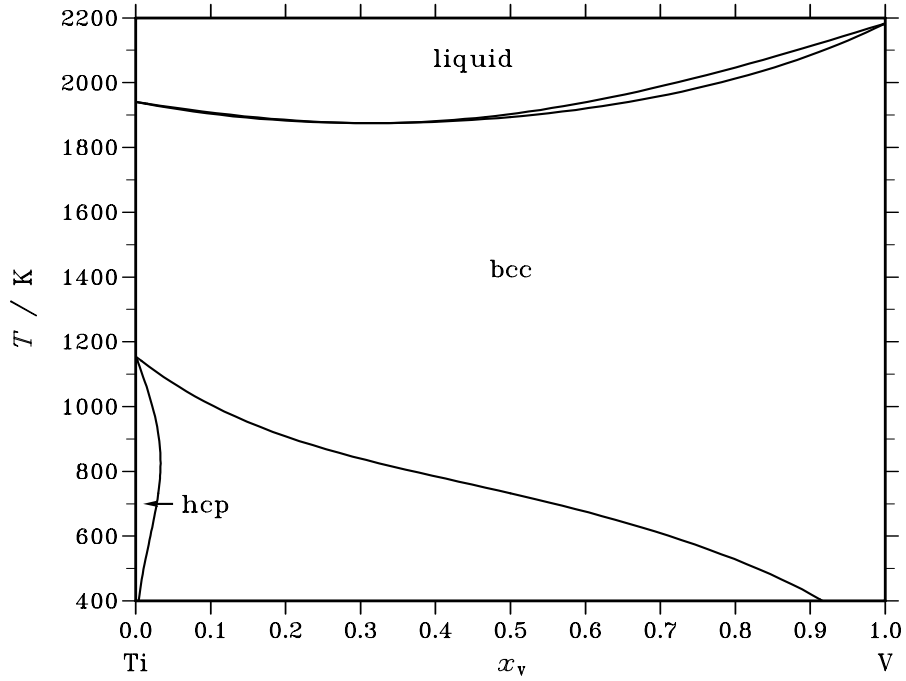

Fig. 1. Calculated phase diagram for the system Ti-V.

Titanium and vanadium are important additions to many alloys, such as superalloys and refractory alloys. The Ti-V system is fairly simple with only three condensed stable phases, liquid, bcc and hcp. Several thermodynamic descriptions for this system have been developed. The description of [87Mur] produces a miscibility gap in the bcc phase. However, the existence of a miscibility gap is considered unlikely by the majority of evaluations. The most recent descriptions of [98Sau] and [02Gho] reproduce the experimental data well. The major differences between these descriptions are the calculated solubilities in the bcc and hcp phases. Reliable solubility data are only available for V concentrations below 0.4. The description of [02Gho] shows an excellent fit of these data, thus is recommended.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Ti,V)_1$
bcc	$A2$	W	$cI2$	$Im\overline{3}m$	BCC_A2	$(Ti,V)_1$
hcp	$A3$	Mg	$hP2$	$P6_3/mmc$	HCP_A3	$(Ti,V)_1$

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_V		$\Delta_r H$ / (J/mol)
liquid $\rightleftharpoons$ bcc	congruent	1875.3	0.315	0.315	−14644

Table IIIa. Integral quantities for the liquid phase at 2200 K.

x_{V}	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	−5709	238	2.703	238	0.000	0.000
0.200	−8822	331	4.161	331	0.000	0.000
0.300	−10858	316	5.079	316	0.000	0.000
0.400	−12086	225	5.596	225	0.000	0.000
0.500	−12587	92	5.763	92	0.000	0.000
0.600	−12359	−48	5.596	−48	0.000	0.000
0.700	−11335	−161	5.079	−161	0.000	0.000
0.800	−9367	−214	4.161	−214	0.000	0.000
0.900	−6118	−171	2.703	−171	0.000	0.000
1.000	0	0	0.000	0	0.000	0.000

Reference states: Ti(liquid), V(liquid)

Table IIIb. Partial quantities for Ti in the liquid phase at 2200 K.

x_{Ti}	ΔG_{Ti} [J/mol]	ΔH_{Ti} [J/mol]	ΔS_{Ti} [J/(mol·K)]	$G_{\mathrm{Ti}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{Ti}}^{\mathrm{E}}$ [J/(mol·K)]	a_{Ti}	γ_{Ti}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−1850	77	0.876	77	0.000	0.904	1.004
0.800	−3817	265	1.855	265	0.000	0.812	1.015
0.700	−6031	493	2.966	493	0.000	0.719	1.027
0.600	−8649	695	4.247	695	0.000	0.623	1.039
0.500	−11877	802	5.763	802	0.000	0.522	1.045
0.400	−16015	746	7.619	746	0.000	0.417	1.042
0.300	−21564	459	10.010	459	0.000	0.308	1.025
0.200	−29567	−127	13.382	−127	0.000	0.199	0.993
0.100	−43200	−1081	19.145	−1081	0.000	0.094	0.943
0.000	$-\infty$	−2470	∞	−2470	0.000	0.000	0.874

Reference state: Ti(liquid)

Table IIIc. Partial quantities for V in the liquid phase at 2200 K.

x_{V}	ΔG_{V} [J/mol]	ΔH_{V} [J/mol]	ΔS_{V} [J/(mol·K)]	$G_{\mathrm{V}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{V}}^{\mathrm{E}}$ [J/(mol·K)]	a_{V}	γ_{V}
0.000	$-\infty$	3207	∞	3207	0.000	0.000	1.192
0.100	−40441	1678	19.145	1678	0.000	0.110	1.096
0.200	−28841	599	13.382	599	0.000	0.207	1.033
0.300	−22121	−98	10.010	−98	0.000	0.298	0.995
0.400	−17241	−480	7.619	−480	0.000	0.390	0.974
0.500	−13297	−618	5.763	−618	0.000	0.483	0.967
0.600	−9921	−577	4.247	−577	0.000	0.581	0.969
0.700	−6951	−427	2.966	−427	0.000	0.684	0.977
0.800	−4317	−235	1.855	−235	0.000	0.790	0.987
0.900	−1997	−70	0.876	−70	0.000	0.897	0.996
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: V(liquid)

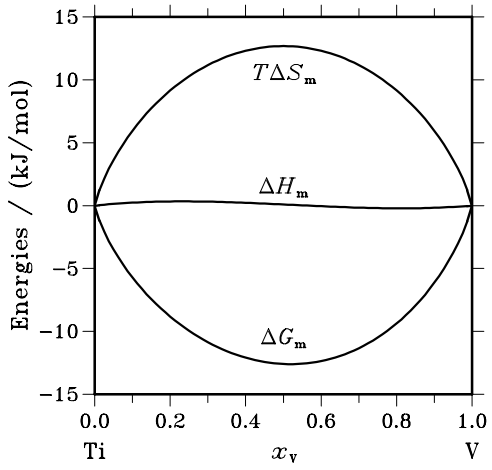

Fig. 2. Integral quantities of the liquid phase at T=2200 K.

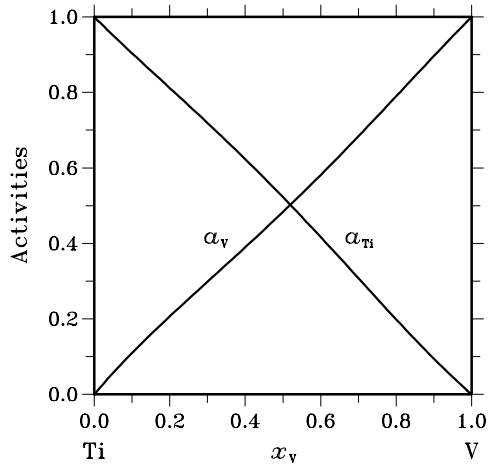

Fig. 3. Activities in the liquid phase at T=2200 K.

Table IVa. Integral quantities for the stable phases at 1500 K.

Phase	x_V	ΔG_m [J/mol]	ΔH_m [J/mol]	ΔS_m [J/(mol·K)]	G_m^E [J/mol]	S_m^E [J/(mol·K)]	ΔC_P [J/(mol·K)]
bcc	0.000	0	0	0.000	0	0.000	0.000
	0.100	−3321	733	2.703	733	0.000	0.000
	0.200	−5003	1238	4.161	1238	0.000	0.000
	0.300	−6079	1540	5.079	1540	0.000	0.000
	0.400	−6731	1663	5.596	1663	0.000	0.000
	0.500	−7014	1631	5.763	1631	0.000	0.000
	0.600	−6925	1468	5.596	1468	0.000	0.000
	0.700	−6419	1200	5.079	1200	0.000	0.000
	0.800	−5392	849	4.161	849	0.000	0.000
	0.900	−3613	441	2.703	441	0.000	0.000
	1.000	0	0	0.000	0	0.000	0.000

Reference states: Ti(bcc), V(bcc)

Table IVb. Partial quantities for Ti in the stable phases at 1500 K.

Phase	x_{Ti}	ΔG_{Ti} [J/mol]	ΔH_{Ti} [J/mol]	ΔS_{Ti} [J/(mol·K)]	G_{Ti}^E [J/mol]	S_{Ti}^E [J/(mol·K)]	a_{Ti}	γ_{Ti}
bcc	1.000	0	0	0.000	0	0.000	1.000	1.000
	0.900	−1196	118	0.876	118	0.000	0.909	1.010
	0.800	−2344	439	1.855	439	0.000	0.829	1.036
	0.700	−3533	915	2.966	915	0.000	0.753	1.076
	0.600	−4874	1497	4.247	1497	0.000	0.677	1.128
	0.500	−6508	2137	5.763	2137	0.000	0.593	1.187
	0.400	−8642	2786	7.619	2786	0.000	0.500	1.250
	0.300	−11621	3395	10.010	3395	0.000	0.394	1.313
	0.200	−16157	3916	13.382	3916	0.000	0.274	1.369
	0.100	−24418	4299	19.145	4299	0.000	0.141	1.412
	0.000	$-\infty$	4498	∞	4498	0.000	0.000	1.434

Reference state: Ti(bcc)

Table IVc. Partial quantities for V in the stable phases at 1500 K.

Phase	x_V	ΔG_V [J/mol]	ΔH_V [J/mol]	ΔS_V [J/(mol·K)]	G_V^E [J/mol]	S_V^E [J/(mol·K)]	a_V	γ_V
bcc	0.000	$-\infty$	8549	∞	8549	0.000	0.000	1.985
	0.100	−22449	6268	19.145	6268	0.000	0.165	1.653
	0.200	−15638	4434	13.382	4434	0.000	0.285	1.427
	0.300	−12018	2998	10.010	2998	0.000	0.382	1.272
	0.400	−9517	1911	7.619	1911	0.000	0.466	1.166
	0.500	−7520	1124	5.763	1124	0.000	0.547	1.094
	0.600	−5781	590	4.247	590	0.000	0.629	1.048
	0.700	−4189	259	2.966	259	0.000	0.715	1.021
	0.800	−2700	83	1.855	83	0.000	0.805	1.007
	0.900	−1301	13	0.876	13	0.000	0.901	1.001
	1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: V(bcc)

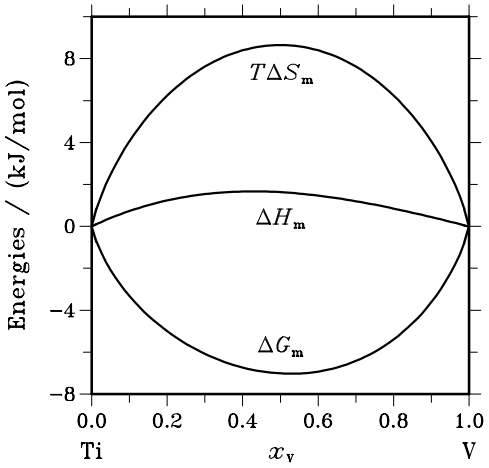

Fig. 4. Integral quantities of the stable phases at T=1500 K.

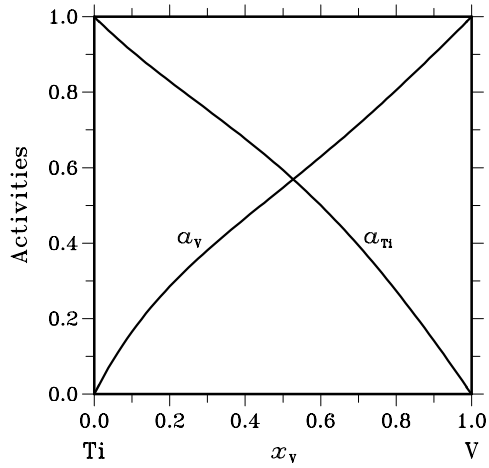

Fig. 5. Activities in the stable phases at T=1500 K.

References

[87Mur] J.L. Murray: in "Phase Diagrams of Binary Titanium Alloys", Ed. J.L. Murray, ASM International, Metals Park, OH, 1987, pp. 319–327.

[98Sau] N. Saunders in: I. Ansara, A.T. Dinsdale, M.H. Rand (eds.): COST 507, "Thermochemical database for light metal alloys", Vol. 2, EUR 18499, 1998, 297–298.

[02Gho] G. Ghosh: J. Phase Equilibria **23** (2002) 310–328.