Ni – V (Nickel – Vanadium)

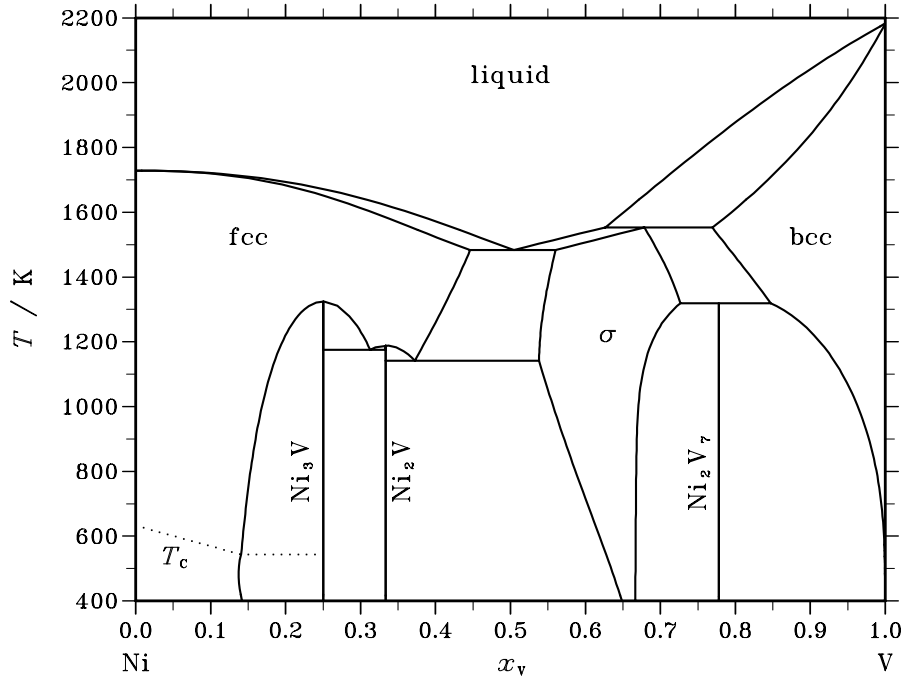

Fig. 1. Calculated phase diagram for the system Ni-V.

The thermodynamic description by Korb and Hack [98Kor] is based on the critical assessment of all the available experimental data for the system. The Ni-V system is characterised by complete mixing in the liquid phase, substantial solubility of Ni in bcc-V (up to 23.3 at.% Ni at 1552 K), also substantial solubility of V in fcc-Ni (up to 44.3 at.% V at 1485 K), the Ni_3V and Ni_2V phases melting congruently and the Ni_2V_7 and σ-phases decomposing peritectically. The intermetallic phases were studied by structural [52Pea, 54Ros, 64Mal, 68Tan, 74Mor] and diffusion couple [79Khl] investigations. The homogeneity ranges of the Ni_3V, Ni_2V and Ni_2V_7 phases are small and the phases were described as stoichiometric compounds. Pietrokowsky and Duwez [50Pie] and Pearson *et al.* [51Pea] were the first to report a σ phase in the Ni-V system. The σ phase is stable below its peritectic temperature and has a maximum range of about 55 to 73 at.% V near 1150 K [54Gre, 70Ste]. In the thermochemical assessment it is described as a solution phase. The experimental and calculated phase diagrams are in good agreement.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Ni,V)_1$
fcc	$A1$	Cu	$cF4$	$Fm\overline{3}m$	FCC_A1	$(Ni,V)_1$
Ni_3V	$D0_{22}$	Al_3Ti	$tI8$	$I4/mmm$	D022_NI3V	Ni_3V_1
Ni_2V	$\cdots$	$MoPt_2$	$oI6$	$\cdots$	NI2V	Ni_2V_1
σ	$D8_b$	σCrFe	$tP30$	$P4_2/mnm$	D8B_SIGMA	$(Ni,V)_{10}V_4(Ni,V)_{16}$
Ni_2V_7	$A15$	Cr_3Si	$cP8$	$Pm\overline{3}n$	A15_NI2V7	Ni_2V_7
bcc	$A2$	W	$cI2$	$Im\overline{3}m$	BCC_A2	$(Ni,V)_1$

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{V}			$\Delta_{\mathrm{r}}H$ / (J/mol)
liquid + bcc $\rightleftharpoons$ σ	peritectic	1552.6	0.626	0.769	0.679	−11860
liquid $\rightleftharpoons$ fcc + σ	eutectic	1483.1	0.504	0.446	0.560	−12975
fcc $\rightleftharpoons$ Ni_3V	congruent	1324.5	0.250	0.250		−2191
σ + bcc $\rightleftharpoons$ Ni_2V_7	peritectoid	1319.1	0.727	0.847	0.778	−6459
fcc $\rightleftharpoons$ Ni_2V_7	congruent	1189.3	0.333	0.333		−1907
fcc $\rightleftharpoons$ Ni_3V + Ni_2V_7	eutectoid	1175.5	0.313	0.250	0.333	−1823
fcc $\rightleftharpoons$ Ni_2V_7 + σ	eutectoid	1141.8	0.373	0.333	0.538	−2385
Ni_3V $\rightleftharpoons$ fcc + Ni_2V_7	eutectoid	386.1	0.250	0.143	0.333	−738

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	−7652	−4673	1.354	−1705	−1.349	0.000
0.200	−12185	−8308	1.762	−3032	−2.398	0.000
0.300	−15153	−10905	1.931	−3979	−3.148	0.000
0.400	−16858	−12463	1.998	−4548	−3.598	0.000
0.500	−17416	−12982	2.016	−4737	−3.747	0.000
0.600	−16858	−12463	1.998	−4548	−3.598	0.000
0.700	−15153	−10905	1.931	−3979	−3.148	0.000
0.800	−12185	−8308	1.762	−3032	−2.398	0.000
0.900	−7652	−4673	1.354	−1705	−1.349	0.000
1.000	0	0	0.000	0	0.000	0.000

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

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

x_{Ni}	ΔG_{Ni} [J/mol]	ΔH_{Ni} [J/mol]	ΔS_{Ni} [J/(mol·K)]	$G_{\mathrm{Ni}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{Ni}}^{\mathrm{E}}$ [J/(mol·K)]	a_{Ni}	γ_{Ni}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−2117	−519	0.726	−189	−0.150	0.891	0.990
0.800	−4840	−2077	1.256	−758	−0.600	0.768	0.959
0.700	−8230	−4673	1.616	−1705	−1.349	0.638	0.911
0.600	−12376	−8308	1.849	−3032	−2.398	0.508	0.847
0.500	−17416	−12982	2.016	−4737	−3.747	0.386	0.772
0.400	−23582	−18694	2.222	−6822	−5.396	0.275	0.689
0.300	−31308	−25444	2.665	−9285	−7.345	0.181	0.602
0.200	−41567	−33233	3.788	−12127	−9.594	0.103	0.515
0.100	−57467	−42061	7.003	−15349	−12.142	0.043	0.432
0.000	$-\infty$	−51927	∞	−18949	−14.990	0.000	0.355

Reference state: Ni(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_V^E [J/mol]	S_V^E [J/(mol·K)]	a_V	γ_V
0.000	$-\infty$	−51927	∞	−18949	−14.990	0.000	0.355
0.100	−57467	−42061	7.003	−15349	−12.142	0.043	0.432
0.200	−41567	−33233	3.788	−12127	−9.594	0.103	0.515
0.300	−31308	−25444	2.665	−9285	−7.345	0.181	0.602
0.400	−23582	−18694	2.222	−6822	−5.396	0.275	0.689
0.500	−17416	−12982	2.016	−4737	−3.747	0.386	0.772
0.600	−12376	−8308	1.849	−3032	−2.398	0.508	0.847
0.700	−8230	−4673	1.616	−1705	−1.349	0.638	0.911
0.800	−4840	−2077	1.256	−758	−0.600	0.768	0.959
0.900	−2117	−519	0.726	−189	−0.150	0.891	0.990
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: V(liquid)

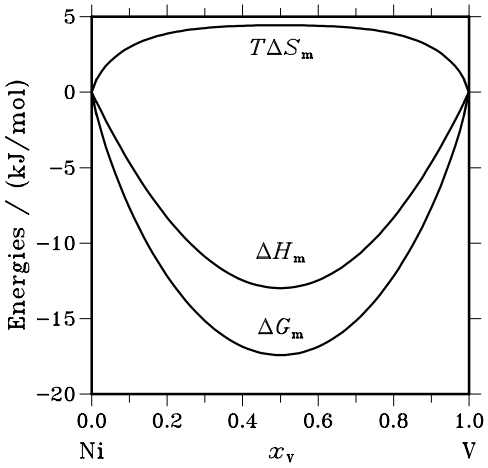

Fig. 2. Integral quantities of the liquid phase at T=2200 K.

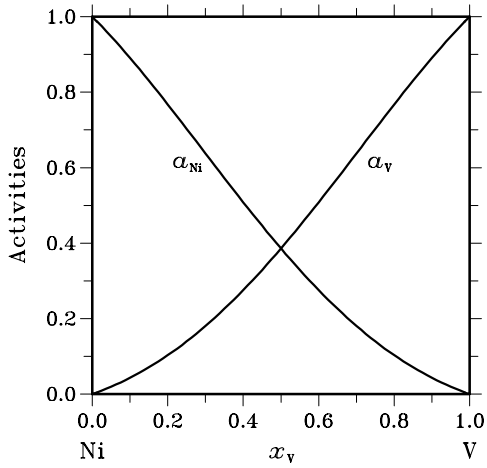

Fig. 3. Activities in the liquid phase at T=2200 K.

Table IVa. Integral quantities for the stable phases at 1400 K.

Phase	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)]
fcc	0.000	0	0	0.000	0	0.000	0.000
	0.100	−5699	−2275	2.445	−1914	−0.258	−0.020
	0.200	−8947	−3783	3.689	−3122	−0.472	−0.030
	0.300	−10770	−4737	4.310	−3660	−0.769	−0.032
	0.400	−11391	−5250	4.386	−3557	−1.209	−0.031
	0.430	−11358	−5322	4.311	−3403	−1.371	−0.030
σ	0.552	−11023	−9289	1.239	−3018	−4.479	6.735
	0.600	−10771	−10051	0.514	−2937	−5.082	8.760
	0.700	−9369	−9664	−0.211	−2258	−5.290	9.665
	0.713	−9083	−9354	−0.194	−2109	−5.175	9.144
bcc	0.821	−6688	−2920	2.691	−1219	−1.215	−0.010
	0.900	−4567	−1873	1.924	−783	−0.779	−0.006
	1.000	0	0	0.000	0	0.000	0.000

Reference states: Ni(fcc), V(bcc)

Table IVb. Partial quantities for Ni in the stable phases at 1400 K.

Phase	x_{Ni}	ΔG_{Ni} [J/mol]	ΔH_{Ni} [J/mol]	ΔS_{Ni} [J/(mol·K)]	$G_{\mathrm{Ni}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{Ni}}^{\mathrm{E}}$ [J/(mol·K)]	a_{Ni}	γ_{Ni}
fcc	1.000	0	0	0.000	0	0.000	1.000	1.000
	0.900	−1587	−428	0.828	−360	−0.048	0.873	0.970
	0.800	−3985	−1375	1.864	−1388	0.009	0.710	0.888
	0.700	−7172	−2567	3.289	−3020	0.324	0.540	0.771
	0.600	−11165	−4033	5.094	−5219	0.847	0.383	0.639
	0.570	−12540	−4573	5.691	−5992	1.014	0.341	0.598
σ	0.448	−12540	1572	10.080	−3194	3.404	0.341	0.760
	0.400	−15492	−3281	8.722	−4826	1.103	0.264	0.661
	0.300	−23709	−24355	−0.461	−9695	−10.472	0.130	0.435
	0.287	−24953	−27353	−1.714	−10407	−12.104	0.117	0.409
bcc	0.179	−24953	−11835	9.370	−4925	−4.936	0.117	0.655
	0.100	−33474	−15981	12.495	−6672	−6.650	0.056	0.564
	0.000	$-\infty$	−21779	∞	−9114	−9.047	0.000	0.457

Reference state: Ni(fcc)

Table IVc. Partial quantities for V in the stable phases at 1400 K.

Phase	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}
fcc	0.000	$-\infty$	−27558	∞	−22823	−3.382	0.000	0.141
	0.100	−42705	−18900	17.003	−15902	−2.142	0.026	0.255
	0.200	−28793	−13412	10.986	−10059	−2.395	0.084	0.421
	0.300	−19167	−9800	6.691	−5152	−3.320	0.193	0.642
	0.400	−11730	−7075	3.325	−1064	−4.294	0.365	0.913
	0.430	−9792	−6315	2.483	26	−4.529	0.431	1.002
σ	0.552	−9792	−18103	−5.937	−2875	−10.877	0.431	0.781
	0.600	−7624	−14565	−4.958	−1677	−9.205	0.519	0.866
	0.700	−3223	−3368	−0.104	929	−3.069	0.758	1.083
	0.713	−2707	−2123	0.417	1224	−2.391	0.793	1.111
bcc	0.821	−2707	−977	1.235	−412	−0.404	0.793	0.965
	0.900	−1355	−305	0.750	−129	−0.126	0.890	0.989
	1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: V(bcc)

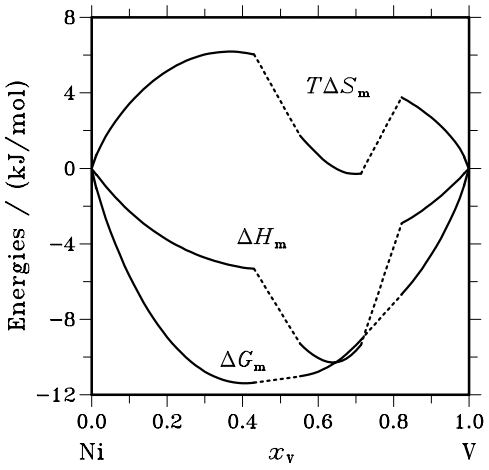

Fig. 4. Integral quantities of the stable phases at T=1400 K.

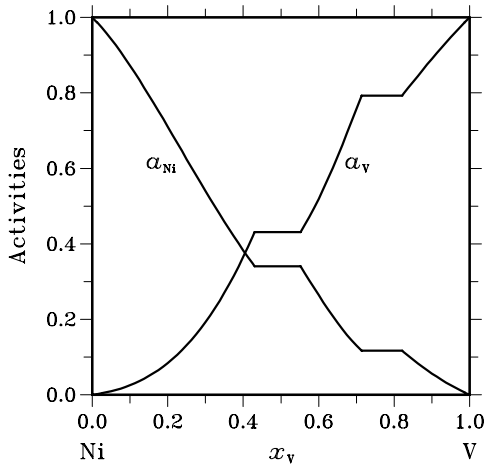

Fig. 5. Activities in the stable phases at T=1400 K.

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

Compound	x_{V}	$\Delta_{\mathrm{f}}G^{\circ}$ / (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))
Ni_3V_1	0.250	−5538	−3787	5.873	0.842
Ni_2V_1	0.333	−7250	−5800	4.863	−0.711
Ni_2V_7	0.778	−11687	−12737	−3.522	−0.197

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