Au – Ni (Gold – Nickel)

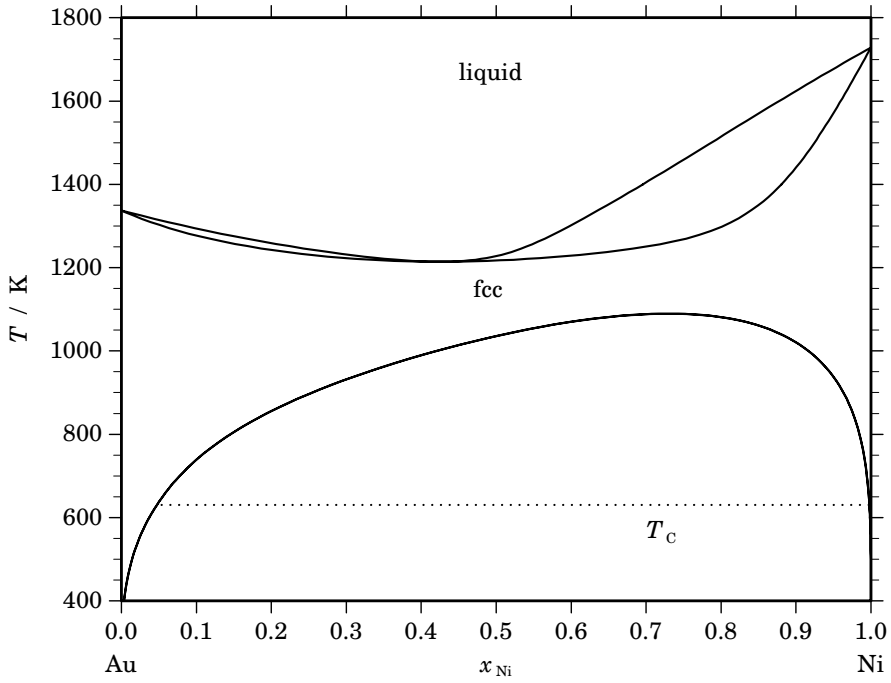

Fig. 1. Calculated phase diagram for the system Au-Ni.

Nickel is a common addition for improving the strength of gold alloys and these materials are frequently encountered in jewellery. A thorough review on the thermodynamics of the gold-nickel system has been given in [1991Oka] and a thermodynamic optimisation has been reported in [2005Wan]. The phase diagram consists of only two phases, the liquid and the the fcc solid solution phase which hosts a broad miscibility gap. The optimisation is based on many experimental investigations of Au-Ni alloys from the literature including phase equilibrium studies, calorimetric and EMF investigations of liquid and solid alloys, and experiments using Knudsen techniques.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Au,Ni)_1$
fcc	$A1$	Cu	$cF4$	$Fm\overline{3}m$	FCC_A1	$(Au,Ni)_1$

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Ni}			$\Delta_r H$ / (J/mol)
liquid $\rightleftharpoons$ fcc	congruent	1214.3	0.424	0.424		−9990
fcc $\rightleftharpoons$ fcc′ + fcc″	critical	1089.2	0.713	0.713	0.713	0

Table IIIa. Integral quantities for the liquid phase at 1820 K.

x_{Ni}	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	−4837	971	3.192	82	0.489	0.000
0.200	−7478	1675	5.029	94	0.869	0.000
0.300	−9188	2131	6.219	56	1.140	0.000
0.400	−10198	2357	6.899	−14	1.303	0.000
0.500	−10584	2375	7.120	−95	1.357	0.000
0.600	−10353	2203	6.899	−169	1.303	0.000
0.700	−9459	1859	6.219	−216	1.140	0.000
0.800	−7788	1365	5.029	−216	0.869	0.000
0.900	−5070	739	3.192	−150	0.489	0.000
1.000	0	0	0.000	0	0.000	0.000

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

Table IIIb. Partial quantities for Au in the liquid phase at 1820 K.

x_{Au}	ΔG_{Au} [J/mol]	ΔH_{Au} [J/mol]	ΔS_{Au} [J/(mol·K)]	$G_{\mathrm{Au}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{Au}}^{\mathrm{E}}$ [J/(mol·K)]	a_{Au}	γ_{Au}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−1556	137	0.930	38	0.054	0.902	1.003
0.800	−3250	522	2.072	127	0.217	0.807	1.008
0.700	−5170	1116	3.454	227	0.489	0.711	1.015
0.600	−7429	1882	5.116	301	0.869	0.612	1.020
0.500	−10181	2779	7.120	308	1.357	0.510	1.021
0.400	−13654	3769	9.573	212	1.954	0.406	1.014
0.300	−18247	4813	12.671	−28	2.660	0.299	0.998
0.200	−24805	5873	16.856	−450	3.475	0.194	0.971
0.100	−35937	6911	23.542	−1093	4.397	0.093	0.930
0.000	$-\infty$	7886	∞	−1995	5.429	0.000	0.876

Reference state: Au(liquid)

Table IIIc. Partial quantities for Ni in the liquid phase at 1820 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}
0.000	$-\infty$	11114	∞	1233	5.429	0.000	1.085
0.100	−34368	8479	23.542	476	4.397	0.103	1.032
0.200	−24392	6287	16.856	−37	3.475	0.200	0.998
0.300	−18564	4497	12.671	−345	2.660	0.293	0.977
0.400	−14351	3071	9.573	−486	1.954	0.387	0.968
0.500	−10988	1972	7.120	−499	1.357	0.484	0.968
0.600	−8152	1158	5.116	−422	0.869	0.583	0.972
0.700	−5693	594	3.454	−296	0.489	0.686	0.981
0.800	−3534	238	2.072	−157	0.217	0.792	0.990
0.900	−1640	53	0.930	−46	0.054	0.897	0.997
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Ni(liquid)

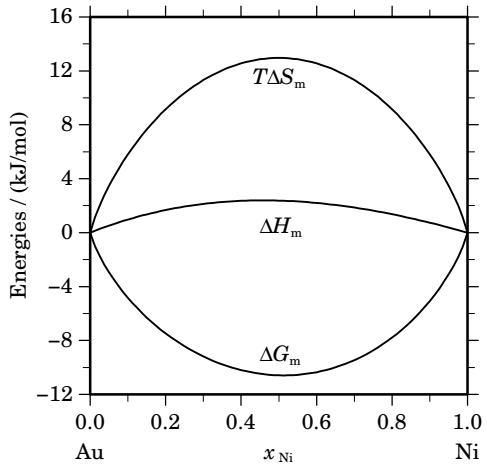

Fig. 2. Integral quantities of the liquid phase at T=1820 K.

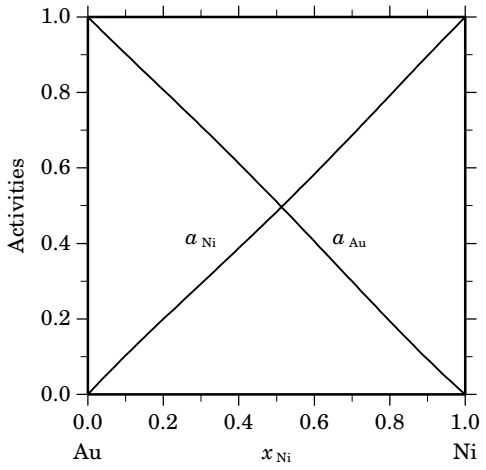

Fig. 3. Activities in the liquid phase at T=1820 K.

Table IVa. Integral quantities for the stable phases at 1150 K.

Phase	x_{Ni}	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)]
fcc	0.000	0	0	0.000	0	0.000	0.000
	0.100	−1825	1944	3.277	1283	0.575	−0.015
	0.200	−2492	3694	5.380	2292	1.219	−0.030
	0.300	−2775	5204	6.939	3066	1.860	−0.045
	0.400	−2818	6403	8.018	3617	2.422	−0.060
	0.500	−2691	7196	8.597	3937	2.833	−0.075
	0.600	−2445	7462	8.615	3990	3.019	−0.089
	0.700	−2122	7059	7.984	3719	2.905	−0.100
	0.800	−1745	5817	6.576	3039	2.415	−0.103
	0.900	−1264	3539	4.177	1844	1.474	−0.081
	1.000	0	0	0.000	0	0.000	0.000

Reference states: Au(fcc), Ni(fcc)

Table IVb. Partial quantities for Au in the stable phases at 1150 K.

Phase	x_{Au}	ΔG_{Au} [J/mol]	ΔH_{Au} [J/mol]	ΔS_{Au} [J/(mol·K)]	G_{Au}^E [J/mol]	S_{Au}^E [J/(mol·K)]	a_{Au}	γ_{Au}
fcc	1.000	0	0	0.000	0	0.000	1.000	1.000
	0.900	−862	91	0.829	145	−0.047	0.914	1.015
	0.800	−1615	414	1.765	519	−0.091	0.845	1.056
	0.700	−2331	1100	2.983	1079	0.018	0.784	1.119
	0.600	−3024	2349	4.673	1860	0.425	0.729	1.215
	0.500	−3662	4438	7.044	2966	1.280	0.682	1.364
	0.400	−4187	7715	10.350	4574	2.731	0.645	1.613
	0.300	−4576	12605	14.940	6936	4.929	0.620	2.066
	0.200	−5011	19616	21.415	10378	8.033	0.592	2.961
	0.100	−6715	29351	31.361	15302	12.216	0.495	4.955
	0.000	$-\infty$	42539	∞	22194	17.692	0.000	10.187

Reference state: Au(fcc)

Table IVc. Partial quantities for Ni in the stable phases at 1150 K.

Phase	x_{Ni}	ΔG_{Ni} [J/mol]	ΔH_{Ni} [J/mol]	ΔS_{Ni} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Ni}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Ni}}$ [J/(mol·K)]	a_{Ni}	γ_{Ni}
fcc	0.000	$-\infty$	20313	∞	14391	5.150	0.000	4.504
	0.100	−10493	18621	25.316	11524	6.171	0.334	3.337
	0.200	−6001	16814	19.839	9388	6.458	0.534	2.669
	0.300	−3811	14782	16.168	7701	6.157	0.671	2.238
	0.400	−2508	12484	13.036	6253	5.418	0.769	1.923
	0.500	−1719	9953	10.150	4908	4.387	0.835	1.671
	0.600	−1283	7293	7.458	3601	3.211	0.874	1.457
	0.700	−1071	4682	5.002	2340	2.037	0.894	1.277
	0.800	−929	2367	2.866	1205	1.011	0.907	1.134
	0.900	−659	671	1.156	349	0.280	0.933	1.037
	1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Ni(fcc)

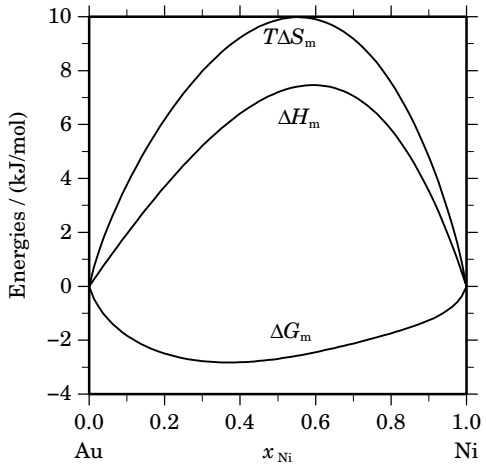

Fig. 4. Integral quantities of the stable phases at T=1150 K.

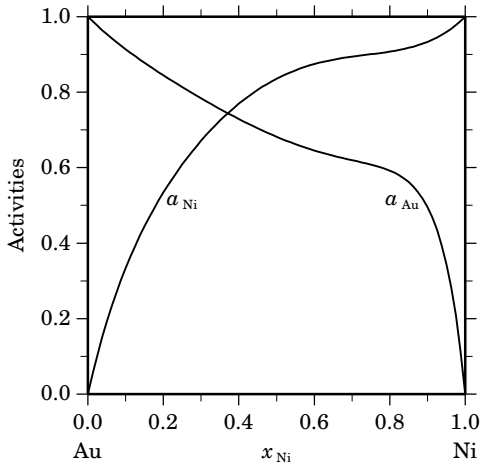

Fig. 5. Activities in the stable phases at T=1150 K.

References

[1991Oka] H. Okamoto, T.B. Massalski in: Phase Diagrams of Binary Nickel Alloys, P. Nash, Ed., ASM Intl., Materials Park, 1991, pp. 16–30.

[2005Wan] J. Wang, X.-G. Lu, B. Sundman, X. Su: Calphad **29** (2005) 263–268.