Pt – Ru (Platinum – Ruthenium)

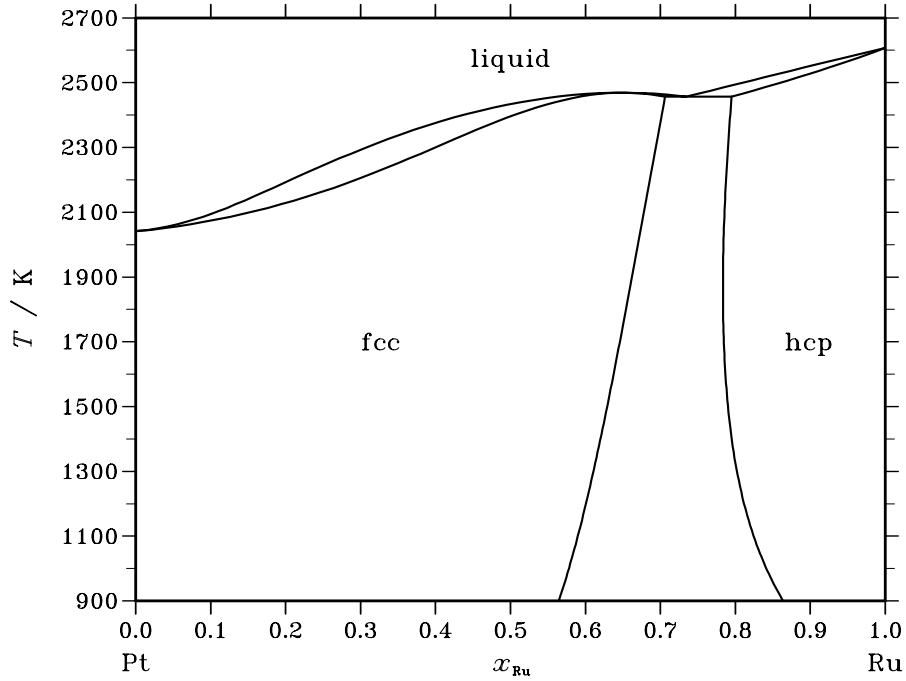

Fig. 1. Calculated phase diagram for the system Pt-Ru.

The Pt-Ru system is characterised by wide solid solution ranges based on fcc-Pt and hcp-Ru. However, the phase diagram is only poorly known. Massalski represents the solidus/liquidus boundaries by dashed curves and the fcc/hcp 2-phase boundaries by compositions at 2 temperatures only [86Mas]. Spencer has used the limited phase diagram information, together with enthalpies of formation for the solid solution phases estimated using the Miedema method [73Mie], to provide a thermodynamic description of the system [98Spe]. Calculated enthalpies of formation for the solid and liquid phases are slightly positive and slightly negative respectively. In view of the uncertainties in the data, the phase diagram and thermodynamic properties presented here should be viewed as of qualitative rather than quantitative significance.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(Pt,Ru)_1$
fcc	$A1$	Cu	$cF4$	$Fm\overline{3}m$	FCC_A1	$(Pt,Ru)_1$
hcp	$A3$	Mg	$hP2$	$P6_3/mmc$	HCP_A3	$(Pt,Ru)_1$

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Ru}			$\Delta_{\mathrm{r}}H$ / (J/mol)
liquid $\rightleftharpoons$ fcc	congruent	2468.9	0.651	0.651		−27159
liquid $\rightleftharpoons$ fcc + hcp	eutectic	2456.5	0.734	0.706	0.795	−28545

Table IIIa. Integral quantities for the liquid phase at 2700 K.

x_{Ru}	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	−8018	−720	2.703	−720	0.000	0.000
0.200	−12514	−1280	4.161	−1280	0.000	0.000
0.300	−15393	−1680	5.079	−1680	0.000	0.000
0.400	−17029	−1920	5.596	−1920	0.000	0.000
0.500	−17561	−2000	5.763	−2000	0.000	0.000
0.600	−17029	−1920	5.596	−1920	0.000	0.000
0.700	−15393	−1680	5.079	−1680	0.000	0.000
0.800	−12514	−1280	4.161	−1280	0.000	0.000
0.900	−8018	−720	2.703	−720	0.000	0.000
1.000	0	0	0.000	0	0.000	0.000

Reference states: Pt(liquid), Ru(liquid)

Table IIIb. Partial quantities for Pt in the liquid phase at 2700 K.

x_{Pt}	ΔG_{Pt} [J/mol]	ΔH_{Pt} [J/mol]	ΔS_{Pt} [J/(mol·K)]	$G_{\mathrm{Pt}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{Pt}}^{\mathrm{E}}$ [J/(mol·K)]	a_{Pt}	γ_{Pt}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−2445	−80	0.876	−80	0.000	0.897	0.996
0.800	−5329	−320	1.855	−320	0.000	0.789	0.986
0.700	−8727	−720	2.966	−720	0.000	0.678	0.968
0.600	−12748	−1280	4.247	−1280	0.000	0.567	0.945
0.500	−17561	−2000	5.763	−2000	0.000	0.457	0.915
0.400	−23450	−2880	7.619	−2880	0.000	0.352	0.880
0.300	−30948	−3920	10.010	−3920	0.000	0.252	0.840
0.200	−41251	−5120	13.382	−5120	0.000	0.159	0.796
0.100	−58171	−6480	19.145	−6480	0.000	0.075	0.749
0.000	$-\infty$	−8000	∞	−8000	0.000	0.000	0.700

Reference state: Pt(liquid)

Table IIIc. Partial quantities for Ru in the liquid phase at 2700 K.

x_{Ru}	ΔG_{Ru} [J/mol]	ΔH_{Ru} [J/mol]	ΔS_{Ru} [J/(mol·K)]	$G_{\mathrm{Ru}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{Ru}}^{\mathrm{E}}$ [J/(mol·K)]	a_{Ru}	γ_{Ru}
0.000	$-\infty$	−8000	∞	−8000	0.000	0.000	0.700
0.100	−58171	−6480	19.145	−6480	0.000	0.075	0.749
0.200	−41251	−5120	13.382	−5120	0.000	0.159	0.796
0.300	−30948	−3920	10.010	−3920	0.000	0.252	0.840
0.400	−23450	−2880	7.619	−2880	0.000	0.352	0.880
0.500	−17561	−2000	5.763	−2000	0.000	0.457	0.915
0.600	−12748	−1280	4.247	−1280	0.000	0.567	0.945
0.700	−8727	−720	2.966	−720	0.000	0.678	0.968
0.800	−5329	−320	1.855	−320	0.000	0.789	0.986
0.900	−2445	−80	0.876	−80	0.000	0.897	0.996
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Ru(liquid)

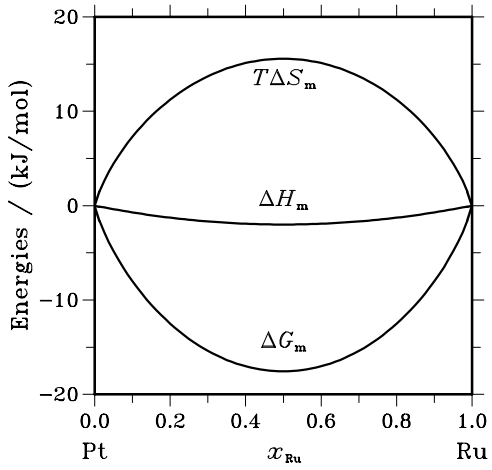

Fig. 2. Integral quantities of the liquid phase at T=2700 K.

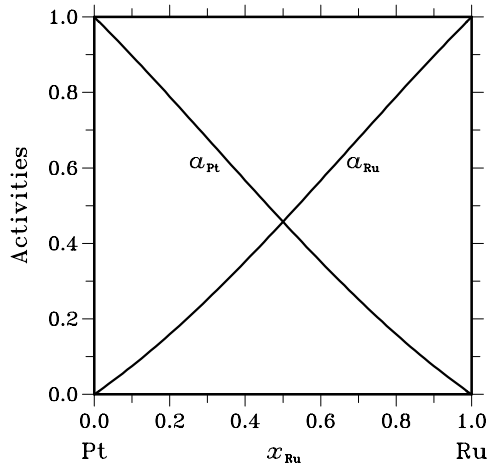

Fig. 3. Activities in the liquid phase at T=2700 K.

Table IVa. Integral quantities for the stable phases at 1800 K.

Phase	x_{Ru}	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	−5095	647	3.190	−230	0.487	0.000
	0.200	−8138	1006	5.080	−649	0.919	0.000
	0.300	−10241	1235	6.376	−1099	1.297	0.000
	0.400	−11494	1493	7.215	−1421	1.619	0.000
	0.500	−11832	1938	7.650	−1458	1.887	0.000
	0.600	−11123	2727	7.695	−1051	2.099	0.000
	0.654	−10243	3353	7.553	−591	2.191	0.000
hcp	0.784	−7674	2513	5.660	143	1.316	0.000
	0.800	−7337	2388	5.403	152	1.242	0.000
	0.900	−4718	1407	3.403	147	0.700	0.000
	1.000	0	0	0.000	0	0.000	0.000

Reference states: Pt(fcc), Ru(hcp)

Table IVb. Partial quantities for Pt in the stable phases at 1800 K.

Phase	x_{Pt}	ΔG_{Pt} [J/mol]	ΔH_{Pt} [J/mol]	ΔS_{Pt} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Pt}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Pt}}$ [J/(mol·K)]	a_{Pt}	γ_{Pt}
fcc	1.000	0	0	0.000	0	0.000	1.000	1.000
	0.900	−1456	170	0.903	121	0.027	0.907	1.008
	0.800	−3067	470	1.965	273	0.110	0.815	1.018
	0.700	−5199	583	3.213	139	0.247	0.707	1.009
	0.600	−8243	193	4.687	−597	0.439	0.577	0.961
	0.500	−12626	−1016	6.450	−2252	0.686	0.430	0.860
	0.400	−18855	−3362	8.607	−5141	0.989	0.284	0.709
	0.346	−23210	−5212	9.999	−7326	1.174	0.212	0.613
hcp	0.216	−23210	8234	17.469	−305	4.744	0.212	0.980
	0.200	−24296	8699	18.331	−209	4.949	0.197	0.986
	0.100	−33726	12058	25.436	735	6.291	0.105	1.050
	0.000	$-\infty$	16414	∞	2392	7.790	0.000	1.173

Reference state: Pt(fcc)

Table IVc. Partial quantities for Ru in the stable phases at 1800 K.

Phase	x_{Ru}	ΔG_{Ru} [J/mol]	ΔH_{Ru} [J/mol]	ΔS_{Ru} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Ru}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Ru}}$ [J/(mol·K)]	a_{Ru}	γ_{Ru}
fcc	0.000	$-\infty$	8435	∞	−828	5.146	0.000	0.946
	0.100	−37849	4936	23.769	−3388	4.624	0.080	0.797
	0.200	−28423	3148	17.539	−4336	4.157	0.150	0.748
	0.300	−22005	2756	13.756	−3986	3.746	0.230	0.766
	0.400	−16371	3442	11.007	−2657	3.389	0.335	0.837
	0.500	−11038	4891	8.850	−664	3.087	0.478	0.957
	0.600	−5969	6787	7.087	1676	2.839	0.671	1.118
	0.654	−3383	7884	6.260	2972	2.729	0.798	1.220
hcp	0.784	−3383	933	2.398	267	0.370	0.798	1.018
	0.800	−3097	810	2.171	242	0.316	0.813	1.016
	0.900	−1495	224	0.955	82	0.079	0.905	1.005
	1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Ru(hcp)

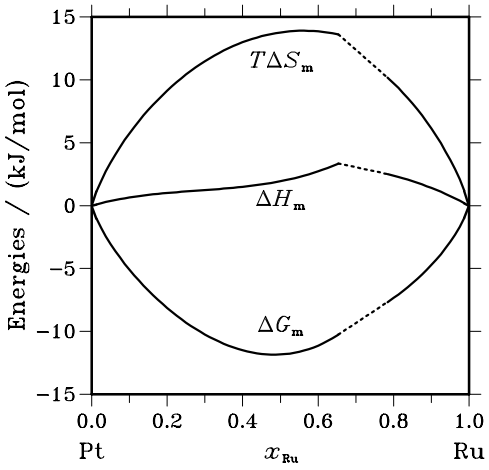

Fig. 4. Integral quantities of the stable phases at T=1800 K.

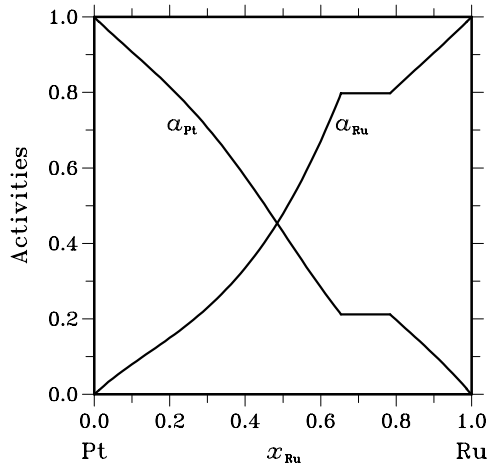

Fig. 5. Activities in the stable phases at T=1800 K.

References

[73Mie] A.R. Miedema: J. Less-Common Met. **32** (1973) 117–136.
[86Mas] T.B. Massalski (ed.): Binary Alloy Phase Diagrams, ASM, Metals Park, Ohio, 1986.
[98Spe] P.J. Spencer: unpublished work, 1998.