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*Indicates key paper.
#Indicates presence of a phase diagram.

Cr-Ru evaluation contributed by **M. Venkatraman** and **J.P. Neumann,** Materials Dept., University of Wisconsin-Milwaukee, P.O. Box 784, Milwaukee, WI 53201. This work was supported in part by ASM International under Grant FG-104-1A and in part by the National Science Foundation through the Joint Program on Critical Compilation of Physical and Chemical Data coordinated through the Office of Standard Reference Data, National Bureau of Standards. Literature searched through 1985. Professor Neumann is the ASM/NBS Data Program Category Editor for binary chromium alloys.

The Cr-Ta (Chromium-Tantalum) System

51.996 180.9479

By M. Venkatraman and J.P. Neumann
The University of Wisconsin-Milwaukee

Equilibrium Diagram

The assessed Cr-Ta phase diagram shown in Fig. 1 is based primarily on the investigations by [48Kub2], [52Duw], [59Gri1], [61Aul], [67Geb], [69Rud], and [73Koc], which are in reasonable agreement with each other. The diagram, which closely resembles the Cr-Nb phase diagram, exhibits a single intermediate phase, Cr_2Ta; this phase forms a eutectic with each of the terminal solid solutions, (Cr) and (Ta).

The assessed diagram is similar to the one presented by [69Rud]. It has now been firmly established that Cr_2Ta melts congruently and not peritectically as shown in the earlier review by [Hansen], who took the phase diagram from [48Kub1] and [48Kub2]. The formula Cr_3Ta_2, which had been assigned by [48Kub1] and [48Kub2] to the intermediate phase, is incorrect.

The values of the congruent melting temperature of Cr_2Ta reported by various investigators, are in good

Fig. 1 Assessed Cr-Ta Phase Diagram

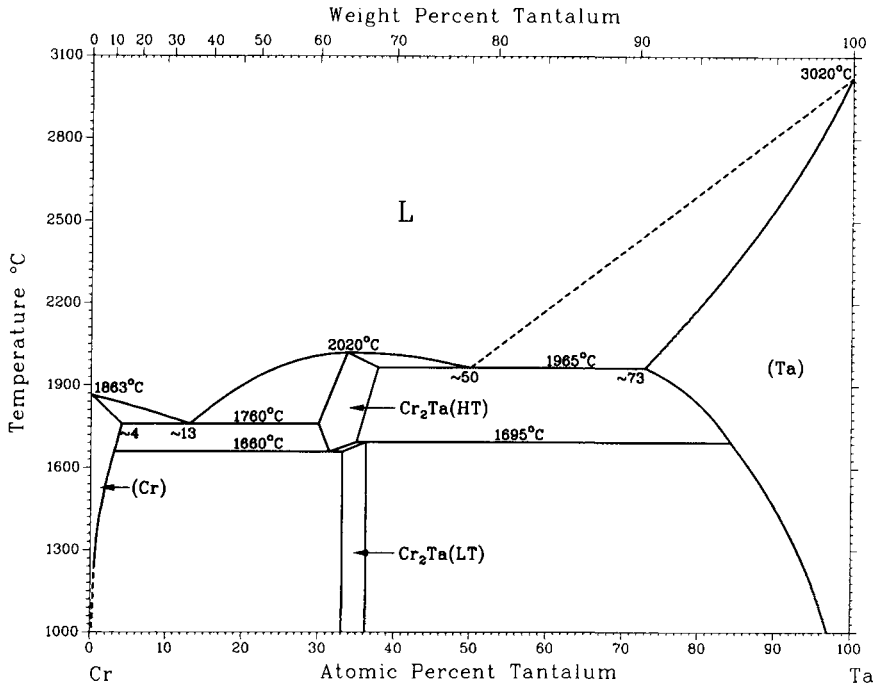

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Fig. 2 Cr_2Ta Region of the Cr-Ta Phase Diagram

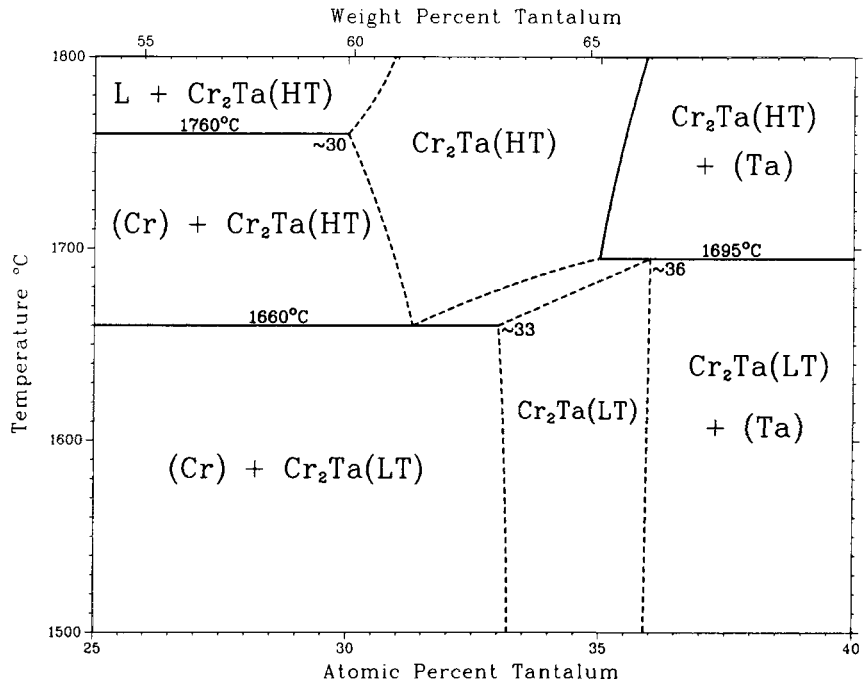

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Fig. 3 Cr-Rich Region of the Cr-Ta Phase Diagram

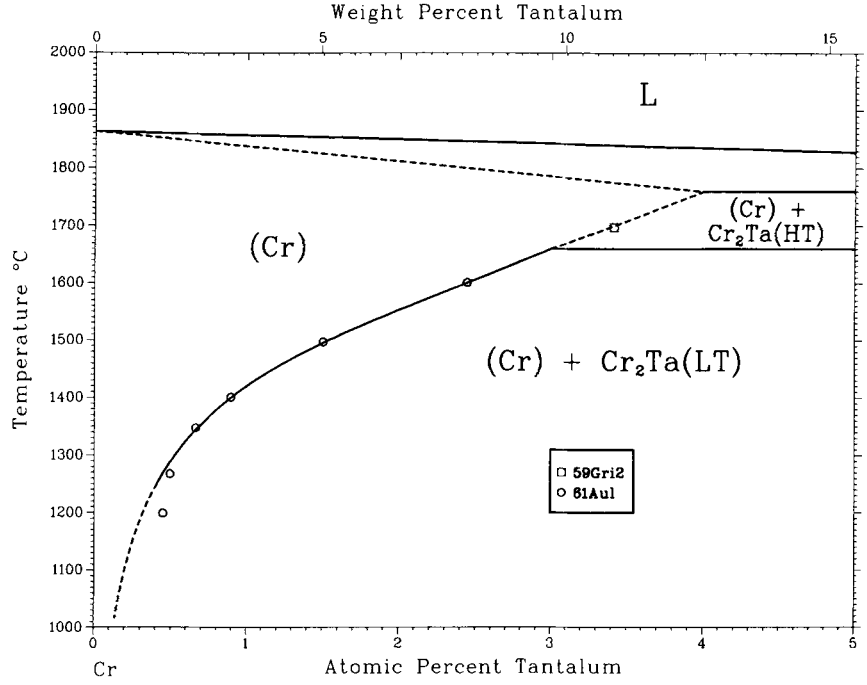

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Table 1 Cr-Ta Crystal Structure Data

Phase	Composition, at.% Ta	Stability range, °C	Pearson symbol	Space group	Strukturbericht designation	Prototype
(Cr)	0 to 4	<1863	*cI2*	*Im3m*	*A2*	W
Cr_2Ta(HT)	30 to 38	1660 to 2020	*hP12*	$P6_3/mmc$	*C14*	$MgZn_2$
Cr_2Ta(LT)	33 to 36	<1695	*cF24*	*Fd3m*	*C15*	$MgCu_2$
(Ta)	73 to 100	<3020	*cI2*	*Im3m*	*A2*	W

agreement: 2015 °C [58Ell], 2020 °C [59Gri1], 2020 °C [69Rud], 2040 °C [73Koc]. A value of 2020 ± 20 °C is selected.

The composition and temperature of the eutectic L ⇄ (Cr) + Cr_2Ta have been determined by [48Kub2], [59Gri1], [69Rud], and [73Koc]. Giving more weight to the more recent temperature determinations by [69Rud] and [73Koc], a temperature of 1760 ± 20 °C is selected. [48Kub2] and [59Gri1] reported a eutectic temperature of 1700 °C. The selected value of 13 at.% Ta for the composition of the eutectic was reported by [48Kub2], [59Gri1], and [73Koc]. According to [69Rud], the composition is 10.5 at.% Ta.

For the eutectic L ⇄ Cr_2Ta + (Ta), the determinations of composition and temperature by [59Gri1], [69Rud], and [73Koc] agree, within the stated uncertainties, with the selected values of 50 ± 4 at.% Ta and 1965 ± 20 °C.

The adopted melting temperatures of Cr and Ta are 1863 °C and 3020 °C, respectively.

The intermediate phase Cr_2Ta exhibits two modifications, both of them Laves phases [52Duw, 59Gri1, 61Aul, 64Fes, 65Gus, 69Rud, 73Koc]. The high-temperature form, Cr_2Ta(HT), has the hexagonal $MgZn_2$-type (*C14*) structure, whereas the low-temperature form, Cr_2Ta(LT), has the cubic $MgCu_2$-type (*C15*) structure. The transformation between these two forms is sluggish, which explains the wide range of transformation temperatures that have been reported in the literature: 1375 to 1590 °C [52Duw], 1805 °C [59Gri1], 1600 to 1640 °C [64Fes], 1660 to 1695 °C [69Rud], and 1640 to 1740 °C [73Koc]. The results by [69Rud], shown in Fig. 2, are preferred. They indicate that the transformation temperature increases from 1660 °C at the Cr-rich side to 1695 °C at the Ta-rich side.

Lattice parameter measurements as a function of composition of the Cr_2Ta phase [64Fes, 65Gus, 69Rud, 73Koc] indicate that the homogeneity range of both modifications extends over several atomic percent. These investigations supersede the earlier study by [59Gri1], who reported a very small homogeneity range. The partial phase diagram shown in Fig. 2 is based on [69Rud]. Further information concerning the Cr_2Ta phase is given in the section "Crystal Structures".

Partial diagrams of the adopted terminal solid solution regions (Cr) and (Ta) are given in Fig. 3 and Fig. 4, respectively. Figure 3 is based primarily on the X-ray and metallographic studies by [61Aul], whereas Fig. 4 is

taken mainly from the analogous investigations by [67Geb].

Crystal Structures

The crystal structures of the phases that occur in the Cr-Ta system are given in Table 1.

Based on their studies of the Cr-rich region of the Cr-Ta system, [59Gri2] and [60Gri] claim the existence of five allotropic forms of pure Cr. These findings have been refuted by other investigators and the existence of only one form of Cr, the bcc modification, is accepted here.

According to [73Koc], an additional intermediate phase with the stoichiometric composition of Cr_3Ta_2 occurs at 40 at.% Ta. This phase has the hexagonal $MgNi_2$-type (*C36*) structure with lattice parameters of a = 0.4963 nm and c = 1.626 nm; it decomposes peritectoidally at 1825 °C into Cr_2Ta(HT) and (Ta) [73Koc]. The existence of this phase is questionable, because it has not been corroborated by other investigators.

The atomic volume of Ta is approximately 50% larger than that of Cr, that is, 0.018 nm^3/atom as compared to 0.012 nm^3/atom. In agreement with this fact, it has been observed that the lattice parameters of all phases in the Cr-Ta system increase with increasing Ta content [61Aul, 69Rud, 73Koc]. The lattice parameters of the hexagonal Cr_2Ta(HT) phase are approximately a = 0.494 nm and c = 0.810 nm [52Duw, 58Ell, 69Rud]. According to [69Rud], the a parameter increases from 0.491 nm at the Cr-rich side to 0.498 nm at the Ta-rich side, whereas the c parameter increases from 0.805 nm to 0.816 nm.

The lattice parameter of the cubic Cr_2Ta(LT) phase is a = 0.697 ± 0.003 nm [52Duw, 73Koc]. According to [73Koc], it increases from a = 0.694 nm at the Cr-rich side to a = 0.700 nm at the Ta-rich side.

Thermodynamics

By means of calorimetric and activity measurements, [64Fes] obtained the following thermodynamic values for Cr_2Ta(LT):

- Gibbs energy of formation at 1472 K:

  $\Delta G = -9.2 \pm 0.5$ kJ/mol of atoms

- Enthalpy of formation at 1693 K:

  $\Delta H = -8.5 \pm 0.5$ kJ/mol of atoms

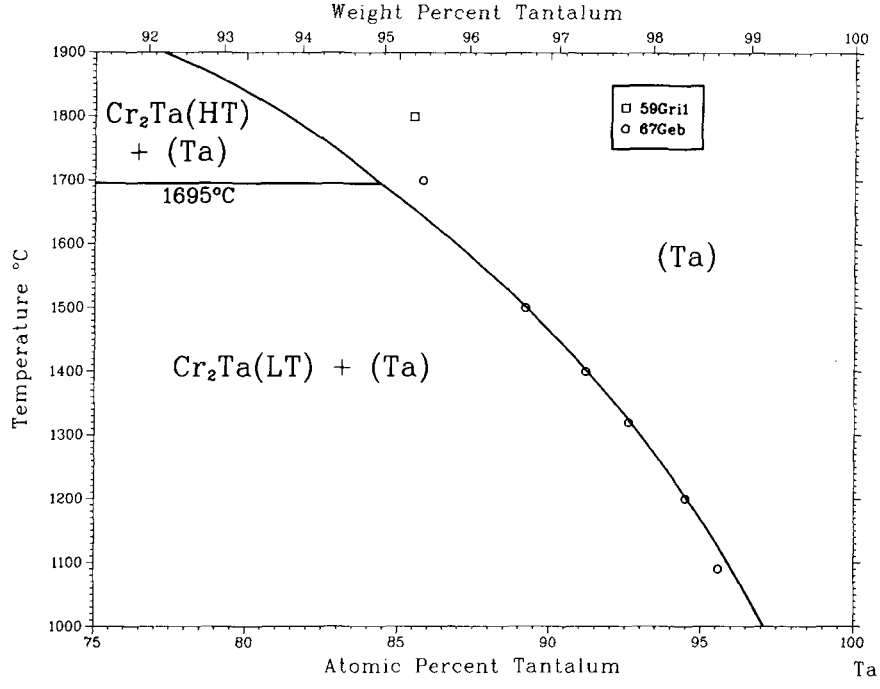
- Entropy of formation at 1472 K:

  $\Delta S = +0.4 \pm 0.7$ J/K · mol of atoms

Combining the value for the enthalpy of formation of Cr_2Ta at 1693 K, obtained by [64Fes], with an estimated value for the specific heat between 298 and 1693 K, [70Mar] obtained a value of $\Delta H = -9.0 \pm 1.0$ kJ/mol of atoms for the standard enthalpy of formation of Cr_2Ta at 298 K.

Using Miedema's model, [82Boe] calculated the enthalpy of formation of Cr_2Ta as $\Delta H = -9$ kJ/mol of atoms, in good agreement with the experimental value by [64Fes].

Fig. 4 Ta-Rich Region of the Cr-Ta Phase Diagram



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Magnetism

The influence of Ta on the Nèel temperature of Cr was studied by [69Ara] and [73Ara] by means of electrical resistivity measurements on alloys quenched from 1400 K. The Nèel temperature of Cr is lowered by additions of Ta from 311.5 K for pure Cr to 213 K at 1.5 at.% Ta. The effect of Ta is similar to that of V and Nb [73Ara].

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* Indicates key paper
#Indicates presence of a phase diagram.

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The Mg-Po (Magnesium-Polonium) System

24.305 (209)

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The equilibrium phase diagram of the Mg-Po system has not been determined. The melting points of pure Mg and Po are 650 and 254 °C, respectively.

[60Wit] prepared the MgPo intermetallic compound by the "micro technique" (a selective distillation technique).

The structure was determined by powder X-ray diffraction and was analyzed as being the NiAs type (see Tables 1 and 2). However, [67Per], in his review of binary Mg compounds, classified MgPo as the MgTe type.

It appears that the solid solubility of Po in (Mg) and vice-versa is negligible.

Crystal structures and lattice parameters are shown in Tables 1 and 2, respectively.

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