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The Solubilities of Selected Elements
in Liquid Plutonium
XII. Chromium

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D. F. Bowersox

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THE SOLUBILITIES OF SELECTED ELEMENTS
IN LIQUID PLUTONIUM

XII. CHROMIUM

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ABSTRACT

The reversibility of the Cr-Pu system has been demonstrated at low Cr concentrations. The solubility increases from 0.36 wt % Cr at 700°C to 2.00 wt % Cr at 1000°C. The data fit the equation

$$\log N_{\text{Cr}} = 1.32 - 3.03 \times 10^3 T^{-1},$$

where N_{Cr} is the mole fraction of Cr in a saturated solution at absolute temperature T .

INTRODUCTION

The study of the solubility of Cr in liquid Pu continues a program in which a systematic examination of the solubilities of selected elements in liquid Pu is being pursued. The solubilities of C, Ta, W, and Re;⁽¹⁾ Nb;⁽²⁾ Mo;⁽³⁾ V;⁽⁴⁾ Tm;⁽⁵⁾ and Zr⁽⁶⁾ from 700 to 1000°C have been reported.

The Pu-Cr system contains no compounds; Schonfeld predicted appreciable solubility.⁽⁷⁾

These studies should be of interest in several areas, such as liquid metal containment, behavior of impurities during melting and casting operations, and effects of impurities in liquid fuels. The data also should be useful in studies of the basic concepts of liquid metals.

EXPERIMENTAL

Electrorefined Pu⁽⁸⁾ and high purity Cr were used throughout this study. The analyses of both elements are summarized in Table I. The equipment and the procedures employed have been described earlier.⁽¹⁾

The samples were dissolved in acid, and aliquots were analyzed for Cr. The estimated precision of the analytical method ranges between 0.5 and 0.8 relative percent at the Cr concentrations measured.⁽⁹⁾

RESULTS AND CONCLUSION

The data in Table II show that constant solute concentrations were reached in less than 24 hr upon approach to saturation from below and that the rate of dissolution increased with temperature. Other measurements demonstrated that values of the solubility were constant within 7 hr upon approach to saturation from above. Measurements of the solubilities at saturation from both approaches are summarized in Table III. The concentrations were independent of the direction of approach. Apparently the measurements represent equilibrium solubilities. The equilibrium reaction is

Table I
Analyses of Pu and Cr

Element	ppm in Pu ^a	ppm in Cr ^a
Li	< 0.2	< 10
Be	< 0.1	< 1
Na	< 10	< 10
Mg	< 10	10
Ca	< 10	< 10
Al	< 5	< 10
La	< 10	--
Si	6	30
Pb	< 1	< 30
Cu	< 1	< 10
Ni	< 5	< 10
Cr	< 5	100.0%
R	< 0.5	< 10
Mn	< 1	10
Sn	1	30
Bi	< 1	< 10
Co	< 10	< 30
Zn	< 10	< 300
Am	224	--
O ₂	25	--
Mo	< 1	< 10
W	64±2	--
Th	< 15	--
Ta	< 35	--
Zr	< 10	< 30
H ₂	10±5	--
C	20±10	--
F	< 2	--
V	< 30	< 30
Fe	< 20	100
Pu	100.00%	--

^aParts per million parts major element, by weight.

Table II
Solubility of Cr in Liquid Pu as a Function of Time
(Approach from Undersaturation)

Total Time, hr	Solubility, wt % Cr		
	750°C	850°C	950°C
3.0	0.132	0.23	1.29
6.0	0.402	0.77	1.49
24.0	0.45	0.96	1.57
30.0	0.46	1.00	1.57
48.0	0.47	0.96	1.57
72.0	0.49	0.99	1.59

Table III
Solubility of Cr in Liquid Pu as a Function of Direction
of Approach to Saturation

Temp., °C	Solubility, wt % Cr			
	Number	Under-saturation	Number	Over-saturation
750	4	0.47	5	0.49
850	4	0.98	8	0.98
950	4	1.57	6	1.59

A randomized, incomplete block^(10,11) was then used to measure the solubilities so that the results would be independent of all variables except temperature.

Three replications were made, each consisting of seven measurements of the solubility from 700 to 1000°C, with temperatures selected in a random order. The data are summarized in Table IV. The solubility increased from 1.62 at. % Cr at 700°C to 8.58 at. % Cr at 1000°C.

These values are lower than estimates made from the phase diagram.⁽⁷⁾

DISCUSSION

In Fig. 1, the solubility averages are plotted on a logarithmic scale against the inverse of the absolute temperature. The linear relationship between these variables was calculated by least-squares methods from the data included in Table IV. The resulting equation is

$$\log N_{\text{Cr}} = 1.32 - 3.03 \times 10^3 T^{-1}, \quad (1)$$

where N_{Cr} is the mole fraction of Cr in solution at absolute temperature T . The line in Fig. 1 was calculated by Eq. (1).

Measurements not used to construct Eq. (1) were made at 750, 850, and 950°C under equilibrium conditions. In Table V these measurements are compared with values calculated by Eq. (1). The agreement is within 3.1 relative percent in all cases.

Fig. 1. N_{Cr} vs. $1/T$ (average solubility values plotted).

Table IV
Solubility of Cr in Liquid Pu

Temperature, °C	Average Solubility	
	wt %	at. %
700	0.36 ± 0.01	1.62 ± 0.03
750	0.49 ± 0.01	2.23 ± 0.03
800	0.75 ± 0.01	3.26 ± 0.01
850	0.98 ± 0.02	4.35 ± 0.08
900	1.27 ± 0.01	5.59 ± 0.03
950	1.60 ± 0.03	6.94 ± 0.09
1000	2.00 ± 0.02	8.58 ± 0.08

Table V

Calculated vs. Independent Measured Values of the Solubility of Cr in Liquid Pu

Temp., °C	Solubility, at. % Cr		
	Calc. by Eq. (1)	Meas. Average	% Diff.
750	2.30	2.24 ± 0.05	2.6
850	4.22	4.35 ± 0.08	3.1
950	7.01	6.92 ± 0.20	-1.3

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