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SOLUBILITY OF PLUTONIUM COMPOUNDS

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M O U N D L A B O R A T O R Y

MIAMISBURG, OHIO

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MONSANTO RESEARCH CORPORATION

A S U B S I D I A R Y O F M O N S A N T O C O M P A N Y

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ABSTRACT

These solubility data for plutonium compounds were compiled from the literature. Classes of plutonium compounds include those of carbon, the halogens, nitrogen, chelates, oxygen, phosphorous and sulfur. Miscellaneous compounds and complex compounds of plutonium were included.

INTRODUCTION

Plutonium metal is highly electropositive and is soluble in all concentrations of hydrochloric acid, 72% perchloric acid, 85% phosphoric acid and concentrated trichloroacetic acid as shown in Table 1. Reaction with water is slow. Nitric acid passivates the surface of the metal such that further reaction with nitric acid is not visible after several hours. Dilute sulfuric acid reacts with plutonium metal slowly; in concentrated sulfuric acid the reaction ceases. Dilute acetic acid does not react with the metal, nor does 2.5 molar sodium hydroxide⁹.

Salts of plutonium in the +3, +4, +5 and +6 valence states have been prepared; however, the most stable valence of plutonium is the +4 state.

Plutonium(III) salts are partially hydrolyzed by water unless the hydrolysis is repressed by the presence of acid, or complexing anions. Plutonium(IV) salts have a stronger tendency to undergo hydrolysis. Except for a few strongly complexed compounds, plutonium(VI) salts contain the plutonyl radical, PuO_2^{+2} . Plutonyl compounds, PuO_2X_2 , are hydrolyzed only to a slight extent⁷⁰. Thus the retention of plutonium in solution is dependent upon the valence state of the plutonium, the pH of the solution and the complexing ability of the media. In the presence of various anions, e.g., citrate, acetate, sulfate, etc., hydrolysis is retarded while solubility is increased.

The following tables compiled from the literature present the available solubility data for known plutonium compounds. The listing is by class type as shown in the Table of Contents.

CARBON CONTAINING COMPOUNDS OF PLUTONIUM

	Formula	Reference	Solubility
A. Carbides:			
Plutonium monocarbide	PuC	(2)	Decomposes in hot water and in HNO_3 containing NaF.
Plutonium sesquicarbide	Pu_2C_3	(2)	Decomposes in hot water and in HNO_3 containing NaF.
B. Carbonates:			
Ammonium plutonium(IV) tetracarbonate	$(\text{NH}_4)_4\text{Pu}(\text{CO}_3)_4 \cdot 4\text{H}_2\text{O}$	(3,4)	Soluble with decomposition in water.
Ammonium plutonium(IV) pentacarbonate	$(\text{NH}_4)_6\text{Pu}(\text{CO}_3)_5 \cdot n\text{H}_2\text{O}$	(3,4)	Soluble with decomposition in water.
Ammonium plutonium(IV) hexacarbonate	$(\text{NH}_4)_8\text{Pu}(\text{CO}_3)_6 \cdot n\text{H}_2\text{O}$	(3,4)	Soluble with decomposition in water.
Ammonium plutonyl(V) carbonate	$\text{NH}_4\text{PuO}_2\text{CO}_3$	(5)	No data
Ammonium plutonyl(VI) carbonate	$(\text{NH}_4)_4\text{PuO}_2(\text{CO}_3)_3$	(6,7,71)	Soluble in acids, see Tables 2, 3 and 4.
Potassium plutonyl(V) carbonate	KPuO_2CO_3	(8)	Decomposes in water.
Nickel(II) plutonium(VI) carbonate		(9)	0.020 g. Pu/liter in 2 moles of $\text{Ni}(\text{NO}_3)_2$ /mole of Pu in 45% K_2CO_3 solution.
Potassium plutonium(IV) tetracarbonate	$\text{K}_4\text{Pu}(\text{CO}_3)_4 \cdot n\text{H}_2\text{O}$	(4)	No data.
Potassium plutonium(IV) pentacarbonate	$\text{K}_6\text{Pu}(\text{CO}_3)_5 \cdot (3-4)\text{H}_2\text{O}$	(4)	No data.
Potassium plutonium(IV) hexacarbonate	$\text{K}_8\text{Pu}(\text{CO}_3)_6 \cdot n\text{H}_2\text{O}$	(4)	No data.
Potassium plutonium(IV) octacarbonate	$\text{K}_{12}\text{Pu}(\text{CO}_3)_8 \cdot n\text{H}_2\text{O}$	(4)	No data.
Plutonium(IV) oxycarbonate dihydrate	$\text{PuOCO}_3 \cdot 2\text{H}_2\text{O}$	(3)	Insoluble in water, and organic solvents, soluble in acids with decomposition.
	$\text{PuO}_2 \cdot \text{PuOCO}_3 \cdot 3\text{H}_2\text{O}$	(3)	Insoluble in water.
C. Oxalates			
Plutonium(III) oxalate	$\text{Pu}_2(\text{C}_2\text{O}_4)_3$	(10,11,71)	See Tables 5,6,7,8,9,10 and 11, $K_{\text{sp}} \text{Pu}_2(\text{C}_2\text{O}_4)_3 \cdot 9\text{H}_2\text{O} = 3.7 \times 10^{-30}$.
Plutonium(IV) oxalate	$\text{Pu}(\text{C}_2\text{O}_4)_2 \cdot 6\text{H}_2\text{O}$	(12,13,14,71)	See Tables 12,13,14 and 15, $K_{\text{sp}} \text{Pu}(\text{C}_2\text{O}_4)_2 \cdot 6\text{H}_2\text{O} = 4.0 \times 10^{-22}$.
Ammonium plutonium pentaoxalate	$(\text{NH}_4)_6\text{Pu}(\text{C}_2\text{O}_4)_5 \cdot n\text{H}_2\text{O}$	(15)	No data.
Bismuth(III) plutonium(IV) tetraoxalate ennahydrate	$\text{Bi PuH}(\text{C}_2\text{O}_4)_4 \cdot 9\text{H}_2\text{O}$	(9)	See Table 16.
Sodium plutonium(IV) tetraoxalate	$\text{Na}_4\text{Pu}(\text{C}_2\text{O}_4)_4 \cdot 5\text{H}_2\text{O}$	(15)	Soluble in water.
Potassium plutonium(IV) tetraoxalate	$\text{K}_4\text{Pu}(\text{C}_2\text{O}_4)_4 \cdot 4\text{H}_2\text{O}$	(15)	Soluble in water.

CARBON CONTAINING COMPOUNDS OF PLUTONIUM (Table continued)

Potassium plutonium(IV) pentaoxalate	$K_6Pu(C_2O_4)_5 \cdot 4H_2O$	(15)	Soluble in water.
Plutonyl(VI) oxalate	$PuO_2C_2O_4 \cdot 3H_2O$	(16)	Slightly soluble in water and acids, soluble in dilute solutions of ammonium carbonate and ammonium oxalate. See Tables 17,18,19,20 and 21.

HALOGEN COMPOUNDS OF PLUTONIUM	Formula	Reference	Solubility
Ammonium plutonium fluoride	$(NH_4)PuF_5$	(17)	70 mg Pu/liter in 0.5M NH_4F 3M HF .
Bistetramethyl ammonium plutonium(IV) chloride	$[(CH_3)_4N]_2 PuCl_6$	(18)	4.8g Pu/liter in 4M HCl 0.18M $(CH_3)_4N^+$.
Calcium plutonium fluoride hydrate	$Ca PuF_6 \cdot nH_2O$	(20)	See Table 22
Cesium plutonium chloride	$Cs_2 PuCl_6$	(18,71)	4.8g Pu/liter in 6M HCl 1M $CsCl$. See Tables 23 and 30.
Metal plutonium fluorides	$M^+[PuO_2 F_3]$, See tables 24 and 29	(9)	See Tables 24 and 29.
Dipyridinium plutonium(IV) chloride	$(C_5H_5NH)_2 PuCl_6$	(18,71)	4.5g Pu/liter in mother liquor, soluble in Alcohols. See Table 30.
Ditetraethylammonium plutonium(IV) chloride	$[(C_2H_5)_4N]_2 PuCl_6$	(19)	No data.
Ditetramethylammonium plutonium(IV) chloride	$[(CH_3)_4N]_2 PuCl_6$	(71)	See Table 30.
Lithium plutonium(IV) fluoride	$LiPuF_5$	(9)	0.12g Pu/liter in 0.5M LiF 3M HF .
Plutonium(IV) bromate hydrate	$Pu(BrO_3)_4 \cdot nH_2O$	(9)	Soluble in Acids and in water.
Plutonium(III) chloride	$PuCl_3$	(9)	Deliquescent, soluble in water, or in Acids.
Plutonium(V) dioxychloride hydrate	$PuO_2Cl \cdot nH_2O$	(9)	>1.8g liter in acid.
Plutonium(VI) dioxydiiodate hexapotassium iodate hydrate	$PuO_2(IO_3)_2 \cdot 6KIO_3 \cdot nH_2O$	(9)	0.6g Pu liter in mother liquor.
Plutonium(V) dioxyperchlorate hydrate	$PuO_2 ClO_4 \cdot nH_2O$	(9)	>5g Pu liter in 0.04M $NaClO_4$ @ pH of 3.5.
Plutonium(III) fluoride	PuF_3	(13)	Insoluble in Acids, soluble in acid solutions containing Al^{+3} , Ce^{+3} , Zr^{+4} . See Table 25. K_{sp} for PuF_3 is 2.5×10^{-16}

HALOGEN COMPOUNDS OF PLUTONIUM (Table continued)

Plutonium(IV) fluoride hydrate	$\text{PuF}_4 \cdot 2.5\text{H}_2\text{O}$	(13)	In water - 0.1g Pu/liter. In 0.8M HF - 2M HNO_3 - 0.62 g Pu/liter. In 2M HF - 2M HNO_3 - 0.57 g Pu/liter. K_{sp} for PuF_4 is 6×10^{-20} . Soluble if not ignited in solutions containing Ce(III), Zr(IV), Al(III), Fe(III). See Table 26.
Plutonium(VI) fluoride	PuF_6	(21,22)	Hydrolyzed by moist air to yield PuO_2F_2 .
Plutonium(III) iodate	$\text{Pu}(\text{IO}_3)_3$	(9)	1.5mg. Pu/liter in 0.017M KIO_3 - 0.17M H_2SO_4 .
Plutonium(IV) iodate	$\text{Pu}(\text{IO}_3)_4$	(9,23)	See Tables 27 and 28, Dissolves readily in 6% SO_2 solutions.
Plutonium(III) iodide	PuI_3	(24)	No data.
Plutonium(III) oxybromide	PuOBr	(25,26)	Insoluble in water, soluble in dilute Acids.
Plutonium(III) oxychloride	PuOCl	(27)	Insoluble in water, soluble in dilute Acids.
Plutonium(III) oxyiodide	PuOI	(9)	Insoluble in water, soluble in dilute Acids.
Plutonium(VI) dioxychloride hydrate	$\text{PuO}_2 \cdot \text{Cl}_2 \cdot 6\text{H}_2\text{O}$	(9,28)	>350g Pu/liter in dilute HCl.
Plutonium(VI) dioxyfluoride hydrate	$\text{PuO}_2 \cdot \text{F}_2$	(29)	In water - 1.07g Pu/liter.
Potassium diplutonium enneafluoride	KPu_2F_9	(9)	No data.
Cesium diplutonium enneafluoride	$\text{CsPu}_2\text{F}_9 \cdot 3\text{H}_2\text{O}$	(9)	7.0 mg. Pu/liter in 1M HNO_3 - 1M HF - 1M Cs^+ . 45mg. Pu/liter in 0.5M CsF - 0.5M HNO_3 - 3M HF.
Potassium plutonium fluoride	KPuF_5	(9,30)	5mg. Pu/liter in 0.5M KF - 3M HF. Solubility varies from 10 to 50 mg. Pu/liter when the concentration of HNO_3 varies from 0.5M to 2M and the concentration of HF varies from 0.5M to 2M.
Rubidium plutonium fluoride	RbPuF_5	(9,30)	0.03g. Pu/liter in 1.8M HNO_3 - 3M HF - 0.5M RbNO_3 .
Sodium plutonium fluoride	NaPuF_5	(9)	9mg. Pu/liter in 0.5M NaF - 3M HF.
Tetraethylammonium plutonium dioxychloride	$[(\text{C}_2\text{H}_5)_4\text{N}]_2 \text{PuO}_2 \text{Cl}_4$	(19)	No data.
Tetramethylammonium plutonium dioxychloride	$[(\text{CH}_3)_4\text{N}]_2 \text{PuO}_2 \text{Cl}_4$	(19)	No data.

NITROGEN COMPOUNDS OF PLUTONIUM	Formula	Reference	Solubility
Plutonium nitride	PuN	(33)	Hydrolyzed by moist air, slowly by cold water, rapidly by boiling water. Black bulky ppt. results. Soluble in 3M HCL or 3M H_2SO_4 ; small insoluble residue usually remains. Reacts slowly with HNO_3 to give a plutonium nitrate solution and a black hydrated oxide. Dissolution increases with increasing concentration of HNO_3 .
Diammonium plutonium(IV) hexanitrate. $2\text{H}_2\text{O}$	$(\text{NH}_4)_2\text{Pu}(\text{NO}_3)_6 \cdot 2\text{H}_2\text{O}$	(9,71)	See Table 31.
Dicesium plutonium(IV) hexanitrate	$\text{Cs}_2\text{Pu}(\text{NO}_3)_6$	(9,71)	>3.4g. Pu/liter in 12M HNO_3 . See Table 31.
Dipyridinium plutonium(IV) hexanitrate. $14\text{H}_2\text{O}$	$(\text{C}_5\text{H}_5\text{NH})_2\text{Pu}(\text{NO}_3)_6 \cdot 14\text{H}_2\text{O}$	(9,71)	>2g. Pu/liter in 2.5M HNO_3 . See Table 31.
Diquinolinium plutonium(IV) hexanitrate	$(\text{C}_9\text{H}_7\text{NH})_2\text{Pu}(\text{NO}_3)_6$	(9,71)	>0.5g. Pu/liter in 3.7M HNO_3 . See Table 31.
Dirubidium plutonium(IV) hexanitrate	$\text{Rb}_2\text{Pu}(\text{NO}_3)_6$	(9,71)	4.6g. Pu/liter in 12M HNO_3 . See Table 31.
Dipotassium plutonium(IV) hexanitrate	$\text{K}_2\text{Pu}(\text{NO}_3)_6$	(9,71)	>18g. Pu/liter in 12M HNO_3 . See Table 31.
Dithallium plutonium(IV) hexanitrate	$\text{Tl}_2\text{Pu}(\text{NO}_3)_6$	(9,71)	26g. Pu/liter in 12M HNO_3 . See Table 31.
Plutonium(IV) nitrate pentahydrate	$\text{Pu}(\text{NO}_3)_4 \cdot 5\text{H}_2\text{O}$	(35,34)	Soluble in water but hydrolyzes, especially in dilute solution. Solubility in 0.1M HNO_3 - butex solution - 0.71g. Pu/liter. Solubility in 1.5M HNO_3 - butex solution - 5.6g. Pu/liter.
Plutonium(IV) tetraethyl ammonium nitrate	$[(\text{C}_2\text{H}_5)_4\text{N}]\text{Pu}(\text{NO}_3)_6$	(36)	No data.
Plutonium(VI) tetraethyl ammonium nitrate	$[(\text{C}_2\text{H}_5)_4\text{N}]\text{PuO}_2(\text{NO}_3)_3$	(37)	No data.
Plutonium(IV) tetrabutyl ammonium nitrate	$[(\text{C}_4\text{H}_9)\text{N}]_2\text{Pu}(\text{NO}_3)_6$	(36)	No data.

CHELATE COMPOUNDS OF PLUTONIUM	Formula	Reference	Solubility
Plutonium(IV) acetylacetonate	$\text{Pu}(\text{C}_5\text{H}_7\text{O}_2)_4$	(38)	Soluble in benzene.
Plutonium(IV) 8-hydroxyquinolate	$\text{Pu}(\text{C}_9\text{H}_9\text{NO})_4$	(39)	77mg. Pu/liter of HAc - NaAc solution @ pH3-5. 17mg. Pu/liter of HAc - NaAc solution @ pH8.
Plutonium(III) salicylate	$\text{Pu}(\text{C}_7\text{H}_5\text{O}_3)_3 \cdot 1.5\text{H}_2\text{O}$	(40)	See Table 32.
Plutonium(IV) salicylate	$\text{PuO}(\text{C}_7\text{H}_5\text{O}_3)_2$	(40)	See Tables 33 and 34.
Plutonium(IV)-1-sulfonaphthalene-4-azo -5-8-dihydroxy quinaline hydrate	$\text{Pu}(\text{SO}_3\text{HC}_{10}\text{H}_6\text{N}_2\text{C}_9\text{H}_4\text{NOOH})_4 \cdot x\text{H}_2\text{O}$	(9)	No data.
Plutonium tetraisopropoxide	$\text{Pu}[\text{OCH}(\text{CH}_3)_2]_4$	(41)	Hydrolyzed by moist air, soluble in 3:2 mixture of isopropyl alcohol and benzene.

COMPLEX COMPOUNDS OF PLUTONIUM	Formula	Reference	Solubility
Plutonium(IV) chloride acetamide	$\text{PuCl}_4 \cdot 6\text{CH}_3\text{CONH}_2$	(42)	Soluble in hot acetone, methanol, ethanol, acetic acid and acetic anhydride. Hygroscopic. Readily decomposed by presence of water.
Plutonium(IV) diphenyl arsenate hydrate	$\text{Pu}(\text{C}_6\text{H}_5\text{AsO}_3)_2 \cdot x\text{H}_2\text{O}$	(9)	130mg. Pu/liter in 2M HCL - 0.021M $\text{C}_6\text{H}_5\text{AsO}_3\text{H}_2$ immediately after ppt. After 15 days, solubility in above media is 10mg. Pu/liter.
Plutonium ferricyanides	See Table 35	(43)	See Table 35.
Plutonium ferrocyanides	See Table 35	(43)	See Table 35.
Plutonium oxalatophosphate	$\text{Pu}(\text{C}_2\text{O}_4)_{1.58}(\text{PO}_4)_{1.03}$	(44)	No data.
Sodium plutonium(VI) dioxytriacetate	$\text{NaPuO}_2(\text{C}_2\text{H}_3\text{O}_2)_3$	(46)	6g. Pu/liter in water @ 5°C. 19g. Pu/liter in water @ 95°C. See Table 36.

OXYGEN CONTAINING COMPOUNDS OF PLUTONIUM

	Formula	Reference	Solubility
Barium plutonium(IV) oxide	BaPuO_3	(45)	No data.
Diammonium diplutonium(V) hexaoxide tetrahydrate	$(\text{NH}_4)_2\text{Pu}_2\text{O}_6 \cdot 4\text{H}_2\text{O}$	(9)	No data.
Diammonium diplutonium heptaoxide	$(\text{NH}_4)_2\text{Pu}_2\text{O}_7$	(71)	See Table 44.
Disodium diplutonium(V) hexaoxide	$\text{Na}_2\text{Pu}_2\text{O}_6 \cdot 4\text{H}_2\text{O} (?)$	(9)	0.52g. Pu/liter @ pH 9.1.
Dipotassium diplutonium(V) hexaoxide	$\text{K}_2\text{Pu}_2\text{O}_6 \cdot 4\text{H}_2\text{O} (?)$	(9)	Soluble in HCl , HClO_4 , HNO_3 ; solubility in 45% K_2CO_3 solution is 22mg. Pu/liter.
Plutonium dioxide	PuO_2	(51,49,50,47,48)	Dissolves slowly in: 85-100% H_3PO_4 @ 200° ; 10 molar HNO_3 - 0.05M HF ; 5M HI ; boiling HBr . High fired oxide is a very refrac- tory material, difficult to dissolve by normal techniques. Soluble in 12N HCl @ 300°C .
Plutonium(III) hydroxide	$\text{Pu}(\text{OH})_3 \cdot x\text{H}_2\text{O}$	(52)	$K_{sp} = 2 \times 10^{-20}$; 90mg. Pu/liter as ppt from 5M NH_4OH . See Table 45.
Plutonium(IV) hydroxide	$\text{Pu}(\text{OH})_4 \cdot n\text{H}_2\text{O}$	(53,54,71)	$K_{sp} = 7 \times 10^{-56}$. See Tables 37, 38 and 45.
Barium plutonate	Unknown	(9)	Soluble in dilute acid. See Tables 39 and 40.
Calcium plutonate	Unknown	(9)	See Table 41.
Magnesium plutonate	Unknown	(9)	See Table 42.
Plutonium oxide	PuO	(9)	Readily soluble in $\text{HCl} > 1\text{M}$.
	Pu_2O_3	(9)	No data.
	$\text{Pu}_2\text{O}_3 - \text{Pu}_4\text{O}_7$	(9)	No data.
Plutonium(IV) peroxide	Formula dependent upon conditions of preparation.	(9)	Soluble in concentration HNO_3 . See Table 43.
Polymeric hydroxide, Pu(IV)	$\text{Pu}_n\text{H}_2\text{O}_x(\text{OH})_y$	(9,71)	Insoluble in water, soluble in acids with difficulty.
Plutonyl hydroxide	$\text{PuO}_2(\text{OH})_2$	(71)	See Table 46.

PHOSPHOROUS CONTAINING COMPOUNDS OF PLUTONIUM

	Formula	Reference	Solubility
Plutonium(IV) hydrogen phosphate	$\text{Pu}(\text{HPO}_4)_2 \cdot x\text{H}_2\text{O}$	(55,56,57,71)	$K_{sp} = 2 \times 10^{-28}$, See Tables 47,48 and 49.
Plutonium hydrogen triphosphate	$\text{Pu}_2\text{H}(\text{PO}_4)_3 \cdot x\text{H}_2\text{O}$	(57)	Attempts to dissolve in acid solution converts back to the hydrogen phosphate.
Plutonium(IV) monobutyl phosphate	$\text{Pu}(\text{C}_4\text{H}_9\text{PO}_4)_2 \cdot x\text{H}_2\text{O}$	(58)	Solubility found to be effected only slightly by the presence of dibutyl phosphate or by increasing the temperature to 55°C. See Table 50.
Plutonium(III) phosphate	$\text{PuPO}_4 \cdot 0.5 \text{H}_2\text{O}$	(44,59)	See Table 51.
Plutonium phosphide	PuP	(60)	No data.
Plutonium(IV) pyrophosphate	PuP_2O_7	(44)	See Table 52.
Plutonium tetrphosphate	$\text{Pu}_3(\text{PO}_4)_4 \cdot x\text{H}_2\text{O}$	(57)	No data.

SULFUR CONTAINING COMPOUNDS OF PLUTONIUM

	Formula	Reference	Solubility
Plutonium(IV) sulfate	$\text{Pu}(\text{SO}_4)_2$	(63,64,65)	Hygroscopic, soluble in water and 5 normal acids, although crystals of an insoluble hydrate will separate from the latter. See Table 54.
Hexasodium plutonium(IV) pentasulfate	$\text{Na}_6\text{Pu}(\text{SO}_4)_5 \cdot \text{H}_2\text{O}$	(67)	Soluble in acids.
Hexaammonium plutonium(IV) pentasulfate	$(\text{NH}_4)_6\text{Pu}(\text{SO}_4)_5 \cdot 2 \cdot 4\text{H}_2\text{O}$	(67)	Soluble in acids.
Tetrarubidium plutonium(IV) tetrasulfate	$\text{Rb}_4\text{Pu}(\text{SO}_4)_4$	(66)	Soluble in acids.
Tetracesium plutonium(IV) tetrasulfate	$\text{Cs}_4\text{Pu}(\text{SO}_4)_4$	(66)	Soluble in acids.
Sodium plutonium(III) sulfate	$\text{NaPu}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$	(68)	Insoluble in mother liquor, methyl alcohol and <u>2M</u> H_2SO_4 .
Thallium plutonium(III) sulfate	$\text{TlPu}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$	(68)	Insoluble in methyl alcohol - $0.6 \text{ M } \text{H}_2\text{SO}_4$.
Plutonium sulfide	PuS	(61)	No data.
Plutonium trisulfide tetrasulfide	$\text{Pu}_2\text{S}_3\text{-Pu}_3\text{S}_4$	(61)	No data.
Plutonium(IV) disulfite hydrate	$\text{Pu}(\text{SO}_3)_2 \cdot x\text{H}_2\text{O}$	(9)	No data.
Plutonium(VI) dioxysulfite hydrate	$\text{PuO}_2(\text{SO}_3) \cdot c\text{H}_2\text{O}$	(9)	No data.
Plutonium oxysulfide	$\text{Pu}_2\text{O}_2\text{S}$	(40)	No data.
Diplutonium(III) trisulfite hydrate	$\text{Pu}_2(\text{SO}_3)_3 \cdot x\text{H}_2\text{O}$	(9)	No data.
Ammonium plutonium(IV) sulfate	$(\text{NH}_4)_4\text{Pu}(\text{SO}_4)_4 \cdot 2\text{H}_2\text{O}$	(9,71)	See Tables 53 and 56.
Potassium plutonium(IV) sulfate dihydrate	$\text{K}_4\text{Pu}(\text{SO}_4)_4 \cdot 2\text{H}_2\text{O}$	(9,71)	See Tables 53 and 56.
Rubidium plutonium(IV) sulfate	$\text{Rb}_4\text{Pu}(\text{SO}_4)_4 \cdot 2\text{H}_2\text{O}$	(9,71)	7mg./ml. in mother liquor. See Tables 53 and 56.
Plutonium(IV) disulfate tetrahydrate	$\text{Pu}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$	(9)	See Tables 54 and 55.
Diplutonium(IV) oxytrisulfate octahydrate	$\text{Pu}_2\text{O}(\text{SO}_4)_3 \cdot 8\text{H}_2\text{O}$	(9)	Dissolves slowly in <u>1M</u> HNO_3 , rapidly in <u>8M</u> HNO_3 .
Plutonium(III) sulfate	$\text{Pu}_2(\text{SO}_4)_3$	(62)	Solubility is approximately 125g. Pu/liter in 0 <u>1M</u> H_2SO_4 . Solubility is lowered by a factor of approximately 100 in 75% ethyl alcohol solution. 3.8g- Pu/liter in 0.5 <u>M</u> H_2SO_4 50% ethyl alcohol. 0.8g- pu liter in 0.025 <u>M</u> H_2SO_4 75% ethyl alcohol.

MISCELLANEOUS PLUTONIUM COMPOUNDS

	Formula	Reference	Solubility
Plutonium aluminate	PuAlO_3	(45)	No data.
Plutonium arsenide	PuAs	(60)	No data
Plutonium(IV) oxychromate dihydrate	$\text{PuOCrO}_4 \cdot 2\text{H}_2\text{O}$	(9)	Soluble in 10M HNO_3 . 0.25g. Pu/liter in 0.1M NaCr_2O_7 0.1M HNO_3 .
Plutonium chromate	PuCrO_3	(45)	No data.
Plutonium oxyselenide	PuOSe	(60)	No data.
Plutonium silicide	PuSi	(69)	No data.
Plutonium silicide	PuSi_2	(69)	No data.
Plutonium silicide	Pu_2Si_3	(69)	No data.
Plutonium telluride	PuTe	(60)	No data.
Plutonium vanadate	PuVO_3	(45)	No data.
Plutonium hydride	$\text{PuH}_{2.7}$	(32)	Insoluble in cold water, decomposed in hot water, behavior towards acids resembles that of metal. See Table 1.
Plutonium molybdate	$\text{Pu}(\text{MoO}_4)_2$	(9)	16mg. Pu liter @ pH 2-4 in excess ammonium molybdate solution
Plutonium manganate	PuMnO_3	(45)	No data

Table 1

REACTION OF PLUTONIUM METAL WITH VARIOUS SOLVENTS

Solvents	Reaction
Acetic Acid	Unattacked by glacial acid, even when hot. Slowly attacked by dilute acid.
Hydrobromic Acid	Rapid dissolution by concentrated or dilute acid.
Hydrochloric	Rapid dissolution by concentrated or dilute acid.
Hydrofluoric Acid	Slowly attacked. Briquets made by pressing Pu metal turnings will often dissolve rapidly and completely, forming insoluble PuF_5 .
Nitric Acid	No attack at any concentration. In the presence of 0.005M HF, boiling concentrated acid will dissolve plutonium.
Perchloric Acid (72%)	Rapid dissolution.
Phosphoric Acid (85%)	Rapid dissolution.
Sulfuric Acid	Concentrated acid caused initially slow reaction to cease. Dilute acid attacks the metal slowly.
Trichloroacetic Acid	Rapid dissolution by concentrated acid, reacts slowly in dilute acid.
Water	Reacts slowly at room temperature, slight increase in reaction rate with temperature.

Table 2

SOLUBILITY OF AMMONIUM PLUTONYL CARBONATE IN
AMMONIUM CARBONATE AND NITRATE SOLUTIONS AT 20°

$(\text{NH}_4)_2\text{CO}_3$ Conc. (Wt. %)	$(\text{NH}_4)_4\text{PuO}_2(\text{CO}_3)_3$ Solubility (g/kg sol.)	NH_4NO_3 Conc. (Wt.%)	$(\text{NH}_4)_4\text{PuO}_2(\text{CO}_3)_3$ Solubility (g/kg sol.)	NH_4NO_3 in Saturated $(\text{NH}_4)_2\text{CO}_3$ sol. (Wt.%)	$(\text{NH}_4)_4\text{PuO}_2(\text{CO}_3)_3$ Solubility (g/kg sol.)
5	3.53	10	2.32	5	0.28
10	1.90	20	0.83	10	0.21
15	0.97	30	0.42	15	0.16
20	0.66	40	0.17	20	0.13
25	0.40	50	0.077	25	0.10
		63.9	0.021		
		Saturated	0.027		

Table 3

SOLUBILITY OF $(\text{NH}_4)_4[\text{PuO}_2(\text{CO}_3)_3]$ IN AMMONIUM CARBONATE SOLUTIONS (71)

Initial $(\text{NH}_4)_2\text{CO}_3$ concentration (c) (mole/liter)	Equilibrium solution pH	Solubility of $(\text{NH}_4)_4[\text{PuO}_2(\text{CO}_3)_3](\text{S})$ (mole/liter)	$K=cS$
0.438	9.10	$2.18 \cdot 10^{-2}$	$9.5 \cdot 10^{-3}$
0.876	9.02	$9.29 \cdot 10^{-3}$	$8.1 \cdot 10^{-3}$
1.314	9.12	$6.65 \cdot 10^{-3}$	$8.7 \cdot 10^{-3}$
1.752	9.14	$4.26 \cdot 10^{-3}$	$7.4 \cdot 10^{-3}$
2.190	9.22	$3.27 \cdot 10^{-3}$	$7.2 \cdot 10^{-3}$
Mean value (8.2 ± 1.1) $\cdot 10^{-3}$			

Table 4

SOLUBILITY OF AMMONIUM PLUTONYL CARBONATE IN
 NH_4NO_3 AND $\text{NH}_4\text{NO}_3-(\text{NH}_4)_2\text{CO}_3$ SOLUTIONS (71)

Solution composition (M)		Solubility of $(\text{NH}_4)_4[\text{PuO}_2(\text{CO}_3)_3]$ (mole/liter)	SP $=[\text{NH}_4^+]^2[\text{PuO}_2(\text{CO}_3)_2]$
NH_4NO_3	$(\text{NH}_4)_2\text{CO}_3$		
1.25	—	$9.70 \cdot 10^{-3}$	$1.9 \cdot 10^{-2}$
2.50	—	$3.48 \cdot 10^{-3}$	$2.5 \cdot 10^{-2}$
3.75	—	$1.77 \cdot 10^{-3}$	$2.7 \cdot 10^{-2}$
5.00	—	$7.20 \cdot 10^{-4}$	$1.9 \cdot 10^{-2}$
6.25	—	$3.20 \cdot 10^{-4}$	$1.3 \cdot 10^{-2}$
Mean value (2.1 ± 0.7) $\cdot 10^{-2}$			
Saturated solution	—	$1.00 \cdot 10^{-4}$	—
Same	0.088	$1.07 \cdot 10^{-4}$	—
Same	0.438	$0.81 \cdot 10^{-4}$	—
0.625	0.438	$6.44 \cdot 10^{-3}$	$1.5 \cdot 10^{-2}$
1.25	0.876	$2.51 \cdot 10^{-3}$	$2.3 \cdot 10^{-2}$
2.50	1.752	$5.70 \cdot 10^{-4}$	$2.0 \cdot 10^{-2}$
Mean value (1.9 ± 0.4) $\cdot 10^{-2}$			
0.625	2.19	$1.17 \cdot 10^{-3}$	$2.9 \cdot 10^{-2}$
1.250	2.19	$8.91 \cdot 10^{-4}$	$2.8 \cdot 10^{-2}$
1.875	2.19	$6.90 \cdot 10^{-4}$	$2.7 \cdot 10^{-2}$
2.500	2.19	$5.48 \cdot 10^{-4}$	$2.6 \cdot 10^{-2}$
3.125	2.19	$4.27 \cdot 10^{-4}$	$2.4 \cdot 10^{-2}$
Mean value (2.7 ± 0.2) $\cdot 10^{-2}$			

Table 5

SOLUBILITY OF HYDRATED PLUTONIUM(III) OXALATE

H ⁺ Conc. (M)	H ₂ C ₂ O ₄ Conc (M)	Pu Conc. in Supernate (mg/liter)
3.7	0.5	460
1.96	.2	290
0.75	.2	21
.22	.14	6

Table 6

SOLUBILITY OF PLUTONIUM(III) OXALATE
VS. POTASSIUM OXALATE CONCENTRATION (71)

K ₂ C ₂ O ₄ Concentration (mole/liter)	Equilibrium pH of solution	Solubility of Pu ₂ (C ₂ O ₄) ₃ · 9H ₂ O (mole/liter)
0.00	6.8	4.32 · 10 ⁻⁶
0.06	8.6	2.86 · 10 ⁻⁵
0.30	8.7	2.53 · 10 ⁻⁴
0.60	8.7	5.50 · 10 ⁻⁴
0.90	8.8	1.11 · 10 ⁻³
1.20	8.9	2.23 · 10 ⁻³
1.51	9.0	3.68 · 10 ⁻³
1.81	9.2	3.38 · 10 ⁻³
2.00	9.2	1.06 · 10 ⁻²
2.41	9.4	1.96 · 10 ⁻²
3.01	9.4	1.85 · 10 ⁻²

Table 7

EFFECT OF TEMPERATURE ON THE SOLUBILITY OF Pu₂(C₂O₄)₃ · 9H₂O IN 1.8 AND 2.4 M SOLUTIONS OF K₂C₂O₄ (71)

K ₂ C ₂ O ₄ Concentration (mole/liter)	Equilibrium pH solution of	Temperature (°C)	Plutonium content (g/liter)	Solubility of Pu ₂ (C ₂ O ₄) ₃ · 9H ₂ O (mole/liter)
1.81	9.2	20	4.01	8.23 · 10 ⁻³
1.81	9.2	90	9.26	1.94 · 10 ⁻²
2.41	9.4	20	9.37	1.96 · 10 ⁻²
2.41	9.4	40	9.89	2.07 · 10 ⁻²
2.41	9.4	60	11.27	2.36 · 10 ⁻²
2.41	9.5	90	11.97	2.50 · 10 ⁻²

Table 8

**SOLUBILITY OF HYDRATED PLUTONIUM(III) OXALATE
VS. AMMONIUM OXALATE CONCENTRATION (71)**

$(\text{NH}_4)_2\text{C}_2\text{O}_4$ Concentration (mole/liter)	Solubility of $\text{Pu}_2(\text{C}_2\text{O}_4)_3 \cdot 9\text{H}_2\text{O}$ (mole/liter)	$(\text{NH}_4)_2\text{C}_2\text{O}_4$ Concentration (mole/liter)	Solubility of $\text{Pu}_2(\text{C}_2\text{O}_4)_3 \cdot 9\text{H}_2\text{O}$ (mole/liter)
0.00	$1.88 \cdot 10^{-5}$	0.41	$8.19 \cdot 10^{-4}$
0.07	$2.02 \cdot 10^{-4}$	0.49	$9.75 \cdot 10^{-4}$
0.13	$2.90 \cdot 10^{-4}$	0.56	$1.14 \cdot 10^{-3}$
0.22	$4.70 \cdot 10^{-4}$	0.62	$1.50 \cdot 10^{-3}$
0.28	$5.66 \cdot 10^{-4}$	0.66	$2.05 \cdot 10^{-3}$
0.35	$6.90 \cdot 10^{-4}$	0.70	$2.25 \cdot 10^{-3}$

Table 9

**EFFECT OF TEMPERATURE ON THE SOLUBILITY OF $\text{Pu}_2(\text{C}_2\text{O}_4)_3 \cdot 9\text{H}_2\text{O}$ IN
 $(\text{NH}_4)_2\text{C}_2\text{O}_4$ SOLUTIONS SATURATED AT THE GIVEN TEMPERATURE (71)**

Equilibrium pH	Temperature (°C)	Solubility of $\text{Pu}_2(\text{C}_2\text{O}_4)_3 \cdot 9\text{H}_2\text{O}$ (mole/liter)	Pu content of solution (g/liter)
7.4	20	$5.12 \cdot 10^{-4}$	0.245
7.6	70	$2.26 \cdot 10^{-3}$	1.08
7.6	90	$1.13 \cdot 10^{-2}$	5.38
7.6	100	$1.75 \cdot 10^{-2}$	8.37

Table 10

**SOLUBILITY $\text{Pu}_2(\text{C}_2\text{O}_4)_3 \cdot 9\text{H}_2\text{O}$ IN 0.3 M $\text{K}_2\text{C}_2\text{O}_4$ SOLUTION IN THE PRESENCE OF
 HNO_3 , HCl , AND H_2SO_4 AT VARIOUS CONCENTRATIONS AT 20° (71)**

Acid Concentration	Pu content of solution (g/liter)	Solubility of $\text{Pu}_2(\text{C}_2\text{O}_4)_3 \cdot 9\text{H}_2\text{O}$ (g/liter)	Acid Concentration	Pu content of solution (g/liter)	Solubility of $\text{Pu}_2(\text{C}_2\text{O}_4)_3 \cdot 9\text{H}_2\text{O}$ (g/liter)	
HNO_3 , M	0.124	$2.59 \cdot 10^{-4}$	0.2	0.0355	$7.42 \cdot 10^{-5}$	
0.1	0.024	$5.02 \cdot 10^{-5}$	0.5	0.017	$3.55 \cdot 10^{-5}$	
0.2	0.0215	$4.50 \cdot 10^{-5}$	1.0	0.00585	$1.22 \cdot 10^{-5}$	
0.5	0.0086	$1.80 \cdot 10^{-5}$	2.0	0.062	$1.30 \cdot 10^{-4}$	
1.0	0.0056	$1.17 \cdot 10^{-5}$	H_2SO_4 , N			
2.0	0.037	$7.75 \cdot 10^{-5}$		0.2	0.013	$2.72 \cdot 10^{-5}$
HCl , M				0.5	0.0023	$4.81 \cdot 10^{-6}$
	0.1	0.084		1.0	0.00195	$4.08 \cdot 10^{-6}$
			2.0	0.026	$5.44 \cdot 10^{-5}$	

Table 11

SOLUBILITY OF $\text{Pu}_2(\text{C}_2\text{O}_4)_3 \cdot 9\text{H}_2\text{O}$ IN MIXED SOLUTIONS OF AMMONIUM OXALATE AND OXALIC ACID IN THE PRESENCE OF HNO_3 AT VARIOUS CONCENTRATIONS (71)

Solution composition (M)		Solubility of $\text{Pu}_2(\text{C}_2\text{O}_4)_3 \cdot 9\text{H}_2\text{O}$ (mole/liter)	Solution composition (M)		Solubility of $\text{Pu}_2(\text{C}_2\text{O}_4)_3 \cdot 9\text{H}_2\text{O}$ (mole/liter)
HNO_3	$(\text{NH}_4)_2\text{C}_2\text{O}_4$		HNO_3	$\text{H}_2\text{C}_2\text{O}_4$	
—	0.28	$5.12 \cdot 10^{-4}$	—	0.64	$5.44 \cdot 10^{-6}$
0.1	0.28	$1.17 \cdot 10^{-4}$	0.5	0.64	$1.07 \cdot 10^{-5}$
0.2	0.28	$3.76 \cdot 10^{-5}$	1.0	0.64	$0.95 \cdot 10^{-5}$
0.5	0.28	$7.32 \cdot 10^{-6}$	2.0	0.64	$0.92 \cdot 10^{-4}$
1.0	0.28	$1.63 \cdot 10^{-5}$			
1.5	0.28	$2.51 \cdot 10^{-5}$			
2.0	0.28	$7.95 \cdot 10^{-5}$			

Table 12

SOLUBILITY OF PLUTONIUM(IV) OXALATE IN VARIOUS ACIDS AT 20°

H_2SO_4 Conc (M)	Solubility (g Pu/liter)	HNO_3 Conc (M)	Solubility (g Pu/liter)	HClO_4 Conc (M)	Solubility (g Pu/liter)
0.025	0.031	0.0025	0.11	0.1	0.13
0.1	0.045	0.1	0.14	0.1	0.24
0.5	0.12	0.25	0.25	1.0	0.38
1.0	0.19	0.5	0.33		
		1.0	0.66		

Table 13

SOLUBILITY OF PLUTONIUM(IV) OXALATE IN NITRIC ACID-OXALIC ACID SOLUTIONS AFTER 2-3 WEEKS AGITATION AT 27°C

HNO_3 Conc (M)	$\text{H}_2\text{C}_2\text{O}_4$ Conc. (M)	Solubility (mg Pu/liter)	HNO_3 Conc (M)	$\text{H}_2\text{C}_2\text{O}_4$ Conc. (M)	Solubility (mg Pu/liter)
0.	0.	45.9	1.18	0.0071	16.3
0.	0.05	334.	1.61	0.002	65.8
0.	0.25	242	1.61	0.015	15
0.1	0.	26.6	2.00	0	128
.1	0.5	132.	2.00	0.05	9.7
.5	0.	69.0	2.00	0.25	15.1
.5	0.05	26.6	2.34	0.01	15.3
.5	0.25	97.1	2.34	0.005	24.9
.5	0.60	361.	2.52	0.025	16.7
.78	0.40	144.	3.52	0.005	92.1
1.00	0.	122	3.52	0.01	45.8
1.00	0.05	13.3	3.52	0.05	18
1.00	0.25	36.9	3.52	0.1	18.2
1.00	0.60	133	3.52	0.5	21.4

Table 14

**SOLUBILITY OF PLUTONIUM(IV) OXALATE
VS. CONCENTRATION OF AMMONIUM OXALATE (71)**

(NH ₄) ₂ C ₂ O ₄ conc (mole/liter)	Solubility of Pu(C ₂ O ₄) ₂ ·6H ₂ O (mole/liter)	(NH ₄) ₂ C ₂ O ₄ conc. (mole/liter)	Solubility of Pu(C ₂ O ₄) ₂ ·6H ₂ O (mole/liter)
0.001	6.19·10 ⁻⁵	0.175	2.38·10 ⁻⁴
0.002	5.02·10 ⁻⁵	0.210	3.35·10 ⁻⁴
0.003	4.58·10 ⁻⁵	0.233	4.18·10 ⁻⁴
0.004	4.06·10 ⁻⁵	0.257	5.37·10 ⁻⁴
0.005	3.55·10 ⁻⁵	0.280	6.87·10 ⁻⁴
0.010	4.30·10 ⁻⁵	0.303	8.92·10 ⁻⁴
0.050	5.77·10 ⁻⁵	0.327	1.13·10 ⁻³
0.140	1.80·10 ⁻⁴	0.350	1.37·10 ⁻³

Table 15

SOLUBILITY OF Pu(C₂O₄)₂·6H₂O IN WATER AND ACIDS AT 20°, IN MOLE/LITER (71)

Solubility of Pu(C ₂ O ₄) ₂ ·6H ₂ O in water	H ₂ SO ₄ Conc.	Solubility of Pu(C ₂ O ₄) ₂ ·6H ₂ O	HNO ₃ Conc.	Solubility of Pu(C ₂ O ₄) ₂ ·6H ₂ O	HClO ₄ Conc.	Solubility of Pu(C ₂ O ₄) ₂ ·6H ₂ O
10.3·10 ⁻⁵	0.025	1.3·10 ⁻⁴	0.025	4.8·10 ⁻⁵	0.1	5.5·10 ⁻⁵
	0.1	1.9·10 ⁻⁴	0.1	5.7·10 ⁻⁵	0.5	10.1·10 ⁻⁵
	0.5	5.0·10 ⁻⁴	0.25	10.3·10 ⁻⁵	1.0	15.7·10 ⁻⁵
	1.0	8.0·10 ⁻⁴	0.5	13.8·10 ⁻⁵		
			1.0	27.5·10 ⁻⁵		

Table 16

SOLUBILITY OF BISMUTH(III) PLUTONIUM(IV) OXALATE AT ROOM TEMPERATURE

Initial Pu Conc (g/liter)	C ₂ O ₄ ⁻ (mole/liter)	K ⁺ (mole/liter)	Bi(III) (mole/liter)	HCl (mole/liter)	Color of precipitate	Solubility (g Pu/liter)
2	0.14	0.1	0.75	5	Dark pink	0.012
2	0.35	0.1	0.75	5	Dark pink	0.090
2	0.35	None	0.75	5	Light pink	0.125
2	0.1	0.1	0.75	5	Dark pink	0.050
2	0.05	0.05	0.75	5	Dark pink	0.040
2	0.1	None	0.75	5	Light pink	0.050
2.5	0.15	None	None	6	Yellow green	0.080
2.5	0.15	None	0.75	5	Light pink	0.020

Table 17

**SOLUBILITY OF PLUTONYL(VI) OXALATE IN NITRIC ACID-
OXALIC ACID SOLUTIONS AT 20°C**

HNO ₃ Conc. (M)	Solubility, g Pu/liter in Presence of Various H ₂ C ₂ O ₄ ·2H ₂ O Concs. in Wt. %					
	0	1	2	4	3	8
1.1	3.2	0.95	0.64	0.59	0.51	0.49
2.0	3.91	1.28	0.91	0.62	0.57	0.49
3.08	6.75	2.35	1.3	0.76	0.61	0.59

Table 18

**SOLUBILITY OF PLUTONYL(VI) OXALATE IN NITRIC ACID-
AMMONIUM OXALATE SOLUTIONS AT 20°C.**

HNO ₃ Conc. (M)	Solubility, g Pu/liter in Presence of Various (NH ₄) ₂ C ₂ O ₄ ·H ₂ O Concs. in Wt. %				
	1	2	3	4	6
0.5	0.71	0.92	1.60	—	—
1.0	0.90	0.80	0.77	0.87	1.16
2.0	1.66	1.19	0.81	0.71	0.63
3.0	2.51	1.44	1.17	0.93	0.76

Table 19

SOLUBILITY OF PLUTONYL OXALATE IN HNO₃ IN PRESENCE OF H₂C₂O₄ (71)

HNO ₃ Conc. (mole/liter)	H ₂ C ₂ O ₄ Concentration, mole/liter				
	0	0.11	0.23	0.45	0.75
1.10	0.0134	4.00·10 ⁻³	2.69·10 ⁻³	2.46·10 ⁻³	2.21·10 ⁻³
2.01	0.0163	5.35·10 ⁻³	3.81·10 ⁻³	2.61·10 ⁻³	2.40·10 ⁻³
3.08	0.0280	9.83·10 ⁻³	5.40·10 ⁻³	3.19·10 ⁻³	2.55·10 ⁻³

Table 20

**SOLUBILITY OF PLUTONYL OXALATE IN HNO₃
SOLUTIONS OF VARIOUS CONCENTRATIONS (71)**

HNO ₃ Conc (mole/liter)	Solubility of PuO ₂ C ₂ O ₄ ·3H ₂ O (mole/liter)	Calculated conc of C ₂ O ₄ ²⁻ ions (mole/liter)	SP=[PuO ₂ ²⁺][C ₂ O ₄ ²⁻]
1.1	1.34·10 ⁻²	6.98·10 ⁻⁸	9.3·10 ⁻¹⁰
2.0	1.63·10 ⁻²	2.60·10 ⁻⁸	4.2·10 ⁻¹⁰
3.0	2.80·10 ⁻²	1.97·10 ⁻⁸	5.5·10 ⁻¹⁰
			Mean value 6.3·10 ⁻¹⁰

Table 21

**SOLUBILITY OF PLUTONYL OXALATE VS
CONCENTRATION OF AMMONIUM OXALATE (71)**

(NH ₄) ₂ C ₂ O ₄ Conc (mole/liter)	Solubility of PuO ₂ C ₂ O ₄ · 3H ₂ O (mole/liter)	(NH ₄) ₂ C ₂ O ₄ Conc (mole/liter)	Solubility of PuO ₂ C ₂ O ₄ · 3H ₂ O (mole/liter)
0.070	3.76 · 10 ⁻³	0.305	3.87 · 10 ⁻³
0.140	3.30 · 10 ⁻³	0.355	4.40 · 10 ⁻³
0.256	3.39 · 10 ⁻³	0.369	4.60 · 10 ⁻³
0.284	3.60 · 10 ⁻³	0.398	4.88 · 10 ⁻³

Table 22

**SOLUBILITY OF PLUTONIUM AS CaPuF₆ IN
NITRIC HYDROFLUORIC ACID MIXTURES**

HF (M)	Plutonium solubility, (g/liter) HNO ₃ (M)								
	1.0	1.4	2.0	3.0	4.0	6.0	8.0	10.0	11.0
1.0	0.34	0.60	0.71	0.16	0.38				
2.0	0.17	0.20	0.27	1.0	0.062	0.056	0.046	0.043	0.066
3.0	0.22	0.29	0.28	0.17	0.091				
4.0	0.33	0.24	0.28	0.16	0.12				
5.0	0.25	0.20	0.019	0.028	0.098				

Table 23

**SOLUBILITY OF CESIUM PLUTONIUM(IV)
HEXACHLORIDE IN HYDROCHLORIC ACID**

HCl (M)	Solubility (g/liter)
4	171
5	80
6	41
7	17
8	8
9	5
10	4

Table 24

**PREPARATION, SOLUBILITY, AND PLUTONIUM CONTENT
OF VARIOUS PLUTONYL FLUORIDES**

Precipitant	Amount added (mg)	Pu(VI) (mg)	CH ₃ OH (ml)	Final HF concentration (mole/liter)	Final volume (ml)	Solubility* (g Pu/liter)	Pu in solid (%)
K ⁺	14	4.0	0.150	9	0.450	0.71	39.3
Rb ⁺	45	4.0	0.200	7	0.700	0.60	⁺
Cs ⁺	20	8.0	0	12	0.360	2.0	41.5
(CH ₃) ₄ N ⁺	28	4.0	0	9	0.460	0.17	42.7
C ₅ H ₅ N	28	4.0	0	15	0.233	0.50	44.7

*Concentration of plutonium in the supernatant liquid after precipitation.

⁺Not analyzed.

Table 25

**SOLUBILITY OF PLUTONIUM TRIFLUORIDE IN NITRIC-
HYDROFLUORIC ACID MIXTURES AT 25°C**

HNO ₃ Conc (M)	HF Conc (M)	Solubility (g Pu(III)/liter)	HNO ₃ Conc (M)	HF Conc (M)	Solubility (g Pu(III)/liter)
0.05	0.00	0.157	1.15	0.3	0.084*
	0.54	0.080		0.8	0.047*
	0.96	0.067		1.25	0.040*
	1.65	0.049		1.65	0.014*
	2.5	0.038		0.00	2.691*
	3.9	0.039	1.20	0.57	0.319
	6.07	0.041		1.17	0.102
	7.45	0.044		1.73	0.088
	0.00	0.202		2.37	0.065
	0.52	0.137		3.97	0.053
0.16	1.00	0.082	2.25	6.87	0.048
	1.68	0.064		0.3	0.073*
	3.3	0.057		0.7	0.053 [†]
	4.94	0.046		1.15	0.038*
	6.84	0.037		1.55	0.019*
	7.94	0.024		3.00	0.055*
	0.00	0.955		4.35	0.59*
	0.59	0.068		0.00	4.589
	1.33	0.049		0.35	0.141
	2.09	0.050		0.65	0.097
0.30	0.00	1.710	2.40	2.31	0.064
	0.57	0.233			
	1.07	0.074			
	2.01	0.058			
	3.07	0.070			

Table 26

**SOLUBILITY OF PLUTONIUM TETRAFLUORIDE
IN NITRIC ACID AT 26 8°C**

HNO ₃ Conc (M)	Solubility (g Pu(IV)/liter)
0.0	0.060
0.015	0.088
0.15	0.460
0.30	0.820
0.59	2.24
0.74	2.90
1.00	4.19
1.59	5.8
3.19	10.4

Table 27

**SOLUBILITY OF PLUTONIUM TETRAIODATE IN
POTASSIUM IODATE-NITRIC ACID SOLUTIONS**

KIO ₃ (M)	Solubility, (mg/liter) HNO ₃ (M)					
	1	2	3	4	5	6
0.1	3.7	5.4	6.6	13.7	46.5	04.5
0.15	1.6	2.1	2.5	6.9	16.5	24.9

Table 28

SOLUBILITY OF Pu(IO₃)₄

Solvent	Solubility mg Pu/liter
0.1M KIO ₃ -1M HNO ₃	3.7
0.1M KIO ₃ -2M HNO ₃	5.4
0.1M KIO ₃ -3M HNO ₃	6.6
0.1M KIO ₃ -4M HNO ₃	13.7
0.1M KIO ₃ -5M HNO ₃	46.5
0.1M KIO ₃ -6M HNO ₃	94.5
0.15M KIO ₃ -1M HNO ₃	1.6
0.15M KIO ₃ -2M HNO ₃	2.1
0.15M KIO ₃ -3M HNO ₃	2.5
0.15M KIO ₃ -4M HNO ₃	6.9
0.15M KIO ₃ -5M HNO ₃	16.5
0.15M KIO ₃ -6M HNO ₃	24.9

Table 29

SOLUBILITY AND COMPOSITION OF $\text{Me}^+[\text{PuO}_2\text{F}_3]$ (71)

Me^+	K^+	Rb^+	Cs^+	$(\text{CH}_3)_4\text{N}^+$	$\text{C}_5\text{H}_5\text{NH}^+$	$\text{C}_9\text{H}_7\text{NH}^+$
Pu concentration in mother solution after precipitation of $\text{Me}^+[\text{PuO}_2\text{F}_3]$	0.71	0.60	2.0	0.17	0.50	1.44
Pu content, wt. %	39.3	-	41.5	42.7	44.7	50.8

Table 30

COMPOSITION AND SOLUBILITY OF PLUTONIUM (IV) HEXACHLORIDES (71)

Cation	Color	Pu content of mother solution, (g/liter)	Chemical analysis data, %	
			Pu	Cl
Cs^+	Light yellow	4.8	35.2	35.7
$(\text{CH}_3)_4\text{N}^+$	-	4.8	38.6	33.2
$\text{C}_5\text{H}_5\text{NH}^+$	-	4.5*	40.7	35.4
$\text{C}_9\text{H}_7\text{NH}^+$	-	4.8	33.4	28.0

*Soluble in alcohol.

Table 31

TABLE 31. COMPOSITION AND SOLUBILITY OF PLUTONIUM(IV) HEXANITRATES (71)

Outer-sphere cation	Analysis results, %	Plutonium content of mother solution (g/liter)	Comments
NH_4^+	-	-	The salt (dihydrate) is isomorphous with $(\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6 \cdot 2\text{H}_2\text{O}$. The product contained some free KNO_3 .
K^+	K 29.7	18.0 (1°)	
Rb^+	Pu 31.8	4.6	
Cs^+	Pu 26.8	3.4 (28°)	The salt contained 14 molecules of water and melted at 110°
	Cs 31.0		
Ti^+	Pu 24.2	26	
$\text{C}_5\text{H}_5\text{NH}^+$	Pu 23.4	2	
$\text{C}_9\text{H}_7\text{NH}^+$	Pu 27.2	0.5	

Table 32

**SOLUBILITY OF PLUTONIUM (III) SALICYLATE AT pH
OF 3.5 AND TEMPERATURE OF 20°C**

Final Salicylate Ion Conc., (g/liter)	Plutonium (III) Salicylate Solubility, (as mg plutonium/liter)
27	140.0
50	45.0
77	7.0
90	3.5
120	2.0

Table 33

**SOLUBILITY OF PLUTONIUM (IV) SALICYLATE AT
pH OF 4.5 AND TEMPERATURE OF 20°C**

Final Salicylate Ion Conc., g liter	Plutonium (IV) Salicylate Solubility, as mg plutonium/liter ,
50	5.4
100	12.0
120	14.0
200	23.2
300	40.0

Table 34

**SOLUBILITY OF PLUTONIUM (IV) SALICYLATE
IN DILUTE HYDROCHLORIC ACID AT 25°C**

pH of Solution	Plutonium (IV) Salicylate Solubility, as mg plutonium/liter :
5.7	0.3
5.2	0.5
3.0	1.3
2.0	6.2
1.5	50.0
0.4	71.0

Table 35

PLUTONIUM FERROCYANIDES AND FERRICYANIDES

Compound	Oxidation State of Plutonium	Oxidation State of Iron	Color	Solubility (g Pu/liter)
$\text{HPuFe}(\text{CN})_6 \cdot 7\text{H}_2\text{O}$	3	2	Sky blue	0.0088
$\text{PuFe}(\text{CN})_6 \cdot 7\text{H}_2\text{O}$	3	3	Black	0.012
$\text{PuFe}(\text{CN})_6 \cdot 3.5\text{H}_2\text{O}$	4	2	Black	10
$\text{Pu}_3[\text{Fe}(\text{CN})_6]_4 \cdot 15\text{H}_2\text{O}$	4	3	Black	7.5
$(\text{PuO}_2)_3[\text{Fe}(\text{CN})_6]_2 \cdot x\text{H}_2\text{O}$	6	3	Red-brown	0.40

Table 36

SOLUBILITY OF $\text{NaPuO}_2(\text{C}_2\text{H}_3\text{O}_2)_3$ IN ACETIC ACID-SODIUM
ACETATE-SODIUM NITRATE SOLUTIONS

Composition of Aqueous Phase	Solubility (mg Pu/liter)
0.6M HAc-0.2M NaAc-0.8M NaNO_3	1000
0.6M HAc-0.2M NaAc-2.1M NaNO_3	280
0.6M HAc-0.2M NaAc-4.0M NaNO_3	170
0.6M HAc-0.2M NaAc-5.7M NaNO_3	70

SOLUBILITY OF $\text{NaPuO}_2(\text{C}_2\text{H}_3\text{O}_2)_3$ IN WATER AT
VARIOUS TEMPERATURES

Temperature, (°C)	Solubility (mg Pu/liter)
5	6.1×10^3
25	9.6×10^3
55	11.1×10^3
95	18.7×10^3

Table 37

**SOLUBILITY OF PLUTONIUM(IV) "HYDROXIDE" IN SODIUM SULFATE-SULFURIC
ACID SOLUTIONS AND IN SODIUM PERCHLORATE-PERCHLORIC ACID SOLUTIONS**

Aqueous Phase	pH	Solubility, (mg Pu/liter)	Remarks
0.01M Na ₂ SO ₄	2.50-2.90	$\log S = 6.0 - \text{pH}^*$	2- to 5-day equilibration period
0.01M Na ₂ SO ₄	3.0-4.2	$\log S = 3.4 - \text{pH}^*$	2- to 5-day equilibration period
0.1M Na ₂ SO ₄	5.40	0.018	2- to 5-day equilibration period
0.341M Na ₂ SO ₄	2.11	409	Yellow-brown solid phase;
0.406M Na ₂ SO ₄	3.09	30	29-day equilibration period
0.333M Na ₂ SO ₄	3.88	4.7	Greenish-brown solid phase;
			29-day equilibration period
0.333M Na ₂ SO ₄	4.25	2.9	Light-green solid phase;
			29-day equilibration period
0.1M NaClO ₄		$\log S = 2.11 - 0.83 \text{ pH}^*$	Over pH range 2.60-3.25

* The solubility here is given in equation form for the indicated pH range.

Table 38

**SOLUBILITY OF PLUTONIUM(IV) "HYDROXIDE" IN
1M SODIUM SULFATE SOLUTIONS OF VARIOUS pH VALUES**

pH	Solubility (mg Pu/liter)	Equilibration period, (days)
1.91	2390	15
2.23	860	8
2.69	274	7
3.21	355	6
3.60	300	6
4.15	217	2
4.17	71	6
5.09	16	2
6.25	1.11	6
2.44	204	27
2.80	66	27
3.15	65	26
3.35	16	24
3.64	48	24
3.90	111(?)	24
6.2	5.9	22

Table 39

**APPARENT SOLUBILITY OF BARIUM PLUTONATE* IN 0.1M BARIUM NITRATE-
6M AMMONIUM HYDROXIDE-1M SODIUM HYDROXIDE SOLUTIONS**

Time after precipitation	Apparent solubility (mg Pu/liter)
10 min	282
20 min	245
30 min	275
55 min	279
2.75 hr	172
15 hr	56

*Initial conditions of precipitation: 0.1M Ba(NO₃)₂-0.0019M Pu(VI)-approximately 6M NH₄OH-1M NaOH.

Table 40

**APPARENT SOLUBILITY OF BARIUM PLUTONATE* IN 0.1M BARIUM NITRATE-
5M AMMONIUM HYDROXIDE SOLUTIONS**

Time after precipitation min	Apparent solubility, (mg Pu/liter)
0	112
10	87
25	89
55	119
115	122

*Initial conditions of precipitation: 0.1M Ba(NO₃)₂-0.0019M Pu(VI)-approximately 5M NH₄OH.

Table 41

APPARENT SOLUBILITY* OF CALCIUM PLUTONATE

Time After precipitation	Apparent solubility, (mg Pu/liter)
10 min	338
30 min	313
60 min	290
1.5 hr	332
2.5 hr	316
6.25 hr	411
42.75 hr	536

*Initial conditions of precipitation 0.1M $\text{Ca}(\text{NO}_3)_2$ -0.0019M
Pu(VI)-approximately 6M NH_4OH .

Table 42

APPARENT SOLUBILITY OF MAGNESIUM PLUTONATE*

Time After precipitation min	Apparent solubility, (mg Pu/liter)
5	69.2
15	49.3
30	36.4 †
60	39.3
135	63.9

*Initial conditions of precipitation 0.1M $\text{Mg}(\text{NO}_3)_2$ -0.0019M
Pu(VI)-approximately 6M NH_4OH .

†A second preparation of the magnesium compound showed a
solubility of 18 mg of plutonium per liter about 30 min after
mixing the reagents.

Table 43

SOLUBILITY OF PLUTONIUM PEROXIDE IN THE PRESENCE OF VARIOUS ACIDS

H_2O_2 , (moles/liter)	H_2SO_4 , (moles/liter)	HNO_3 , (moles/liter)	HCl , (moles/liter)	Apparent solubility, (mg Pu/liter)
3.3	0.5	0	0	10.7
3.3	0.5	0	0	5.1
3.3	0.25	0.5	0	5.4
3.3	0.25	0.5	0	3.3
3.3	0.25	1.5	0	6
3.3	0	1.0	0	31
3.3	0	1.0	0	15
3.3	0	1.0	0	29
1.67	0	1.0	0	62
1.67	0	0	1.0	245
1.78	0	0	1.0	153

Table 44

SOLUBILITY OF $(\text{NH}_4)_2\text{Pu}_2\text{O}_7$ IN WATER AT VARIOUS pH VALUES (71)

Equilibrium pH of solution	Solubility of $(\text{NH}_4)_2\text{Pu}_2\text{O}_7$		Equilibrium pH of solution	Solubility of $(\text{NH}_4)_2\text{Pu}_2\text{O}_7$	
	(mole/liter)	(g/liter)		(mole/liter)	(g/liter)
9.3	$2.28 \cdot 10^{-4}$	0.109	8.2	$4.20 \cdot 10^{-4}$	0.201
9.0	$3.14 \cdot 10^{-3}$	1.50	6.4	$8.65 \cdot 10^{-3}$	4.14
8.7	$2.24 \cdot 10^{-3}$	1.072	6.2	$1.80 \cdot 10^{-2}$	8.62
8.4	$1.215 \cdot 10^{-3}$	0.581	5.0	$4.195 \cdot 10^{-2}$	20.0
8.3	$5.83 \cdot 10^{-4}$	0.279	3.5	$5.65 \cdot 10^{-2}$	27.0

Table 45

SOLUBILITY OF PLUTONIUM HYDROXIDES (71)

Compound	Solubility product
$\text{Pu}(\text{OH})_4$	$7 \cdot 10^{-56}$
$\text{PuO}_2(\text{OH})_2$	$3 \cdot 10^{-25}$
$\text{Pu}(\text{OH})_3$	$2 \cdot 10^{-20}$

Table 46

RELATION OF SOLUTION pH TO PLUTONYL NITRATE
CONCENTRATION IN 0.000186 M HNO_3 (71)

Plutonyl nitrate concentration, mole/nitrate	pH	Calculated concentration of PuO_2^{2+} ion in solution, (%)	Calculated concentration of $\text{PuO}_2(\text{OH})^+$ ion in solution, (%)	Ksp = $[\text{PuO}_2^{2+}][\text{OH}]^2$ $\cdot 10^{25}$
0.010	2.74	78.5	20.2	2.4*
0.008	2.83	75.0	23.8	2.7*
0.007	2.88	72.8	- -	2.2*
0.006	2.88	71.8	25.6	2.5
0.005	2.93	69.2	27.7	2.5
0.004	3.05	63.7	33.0	3.1
0.003	3.18	55.0	39.1	3.8
0.002	3.33	45.2	45.4	4.1
0.001	3.48	35.5	50.4	3.2

Table 47

**SOLUBILITY OF PLUTONIUM (IV) HYDROGEN PHOSPHATE
IN VARIOUS SOLUTIONS AT 20°C**

Aqueous H ₃ PO ₄		H ₃ PO ₄ in 2 N HNO ₃		HNO ₃ - LiNO ₃ Solutions			HClO ₄ - NaClO ₄ Solutions		
H ₃ PO ₄ Conc., (M)	Solubility, (M/liter)	H ₃ PO ₄ Conc., (M)	Solubility (M/liter x 10 ⁴)	HNO ₃ Conc., (M)	LiNO ₃ Conc., (M)	Solubility, (M/liter x 10 ⁴)	HClO ₄ Conc., (M)	NaClO ₄ , Conc., (M)	Solubility, (M/liter x 10 ⁴)
0.03	5.4 x 10 ⁻⁷	0.012	8.5				0	2.0	0.0059
0.10	1.1 x 10 ⁻⁶	0.02	4.58	0	2.0	0.798	0.1	1.9	0.99
0.2	3.0 x 10 ⁻⁶	0.028	3.0	0.1	1.9	0.257	0.3	1.7	0.66
0.4	5.5 x 10 ⁻⁶	0.04	1.96	0.3	1.7	1.95	0.6	1.4	1.55
.8	2.0 x 10 ⁻⁵	0.06	0.13	0.6	1.4	2.40	1.0	1.0	3.73
2.8	8.2 x 10 ⁻⁴	0.071	1.11	1.0	1.0	6.47	1.4	0.6	5.47
3.9	1.99 x 10 ⁻⁴	0.101	1.06	1.41	0.59	17.6	2.0	0	7.17
		0.20	1.33	1.7	0.3	21.3			
		0.25	1.44	2.0	0	27.5			
		0.40	1.88						
		0.63	3.31						
		0.80	4.1						
		1.20	7.74						
		1.60	13.6						
		2.00	29.0						

Table 48

SOLUBILITY OF Pu(HPO₄)₂·nH₂O IN VARIOUS MEDIA (71)

Solution Composition	Equilibrium pH of solution	Solubility of Pu(HPO ₄) ₂ · xH ₂ O, (mole/liter)
Distilled water	3.6	3.5 · 10 ⁻⁶
2M NaClO ₄	3.0	5.9 · 10 ⁻⁷
0.1M HClO ₄ -1.9M NaClO ₄	0.8	9.9 · 10 ⁻⁶
2M LiNO ₃	2.7	7.98 · 10 ⁻⁶
0.1 M HNO ₃ -1.9M LiNO ₃	0.78	2.57 · 10 ⁻⁶

Table 49

SOLUBILITY OF $\text{Pu}(\text{HPO}_4)_2 \cdot n\text{H}_2\text{O}$ VS H_3PO_4 CONCENTRATION (71)

Initial H_3PO_4 concentration, (mole/liter)	Solubility of $\text{Pu}(\text{HPO}_4)_2 \cdot x\text{H}_2\text{O}$, (mole/liter)	Initial H_3PO_4 concentration, (mole/liter)	Solubility of $\text{Pu}(\text{HPO}_4)_2 \cdot x\text{H}_2\text{O}$, (mole/liter)
0.012	$8.50 \cdot 10^{-4}$	0.40	$1.88 \cdot 10^{-4}$
0.028	$3.00 \cdot 10^{-4}$	0.80	$4.10 \cdot 10^{-4}$
0.040	$1.96 \cdot 10^{-4}$	1.20	$7.74 \cdot 10^{-4}$
0.060	$1.13 \cdot 10^{-4}$	1.60	$1.36 \cdot 10^{-3}$
0.101	$1.06 \cdot 10^{-4}$	2.00	$2.90 \cdot 10^{-3}$
0.200	$1.33 \cdot 10^{-4}$		

Table 50

SOLUBILITY OF PLUTONIUM (IV) MONOBUTYL PHOSPHATE AT 25°C AS A
FUNCTION OF NITRIC ACID AND MONOBUTYL PHOSPHATE CONCENTRATIONS

Initial plutonium concentrations. 20 - 80 mg/liter

HNO_3 Conc., (M)	Solubility (mg Pu)	MBP Conc., (M)	Solubility (mg Pu/liter)
0.6	0.306	0.0006	>20
1.6	0.333	0.0031	>20
3.0	0.45	0.0062	13.2
5.0	0.664	0.0187	1.47
10	3.93	0.031	0.72
15	43.2	0.062	0.45
		0.075	0.34
		0.124	0.42
		0.230	0.41
		0.311	0.59
		0.622	1.21
		1.24	22.2

Table 51

SOLUBILITY* OF PLUTONIUM (III) PHOSPHATE IN VARIOUS SOLUTIONS

Solution	Temperature (°C)	
	25 - 30°	90 - 100°
Concentrated HCl	Slight	Complete
Concentrated HNO ₃	Incomplete	Complete
Concentrated H ₂ SO ₄	- -	Complete**
85 percent H ₃ PO ₄	Negligible	Incomplete
Glacial acetic acid	- -	No reaction
6 normal NaOH	- -	Incomplete***

*1 gram sample stirred 4 - 5 hours with 25 milliliters of each solution.

**Metathesis occurred; product insoluble in concentrated acid but soluble in dilute acid.

***Metathesis occurred; product insoluble in NaOH or water, but soluble in acid.

Table 52

SOLUBILITY* OF PLUTONIUM (IV) PYROPHOSPHATE IN VARIOUS SOLUTIONS

Solution	Temperature (°C)	
	25 - 30°	90 - 100°
Concentrated HCl	Complete	Complete
Concentrated HNO ₃	Slight	Incomplete
Concentrated H ₂ SO ₄	Complete**	Complete**
85 percent H ₃ PO ₄	Complete	Complete
Glacial acetic acid	- -	Negligible
6 normal NaOH	- -	Complete***

*1 gram sample stirred 4 - 5 hours with 25 milliliters of each solution.

**Metathesis occurred; product insoluble in concentrated acid, but soluble in dilute acid.

***Metathesis occurred; product insoluble in NaOH or water, but soluble in acid.

Table 53

APPARENT SOLUBILITY OF $(\text{NH}_4)_4\text{Pu}(\text{SO}_4)_4 \cdot 2(?)\text{H}_2\text{O}$

Concentrated NH_4OH , (ml)	Concentrated H_2SO_4 , (ml)	Pu , (mg)	CH_3OH , (ml)	Solubility, (g Pu /liter)
0.1	0.05	19.2	0.30	1.44
0.1	0.05	19.2	0.25	5.87
0.1	0.05	19.2	0.10	9.15

Table 54

SOLUBILITY OF $\text{Pu}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$

Composition of solution	Solubility, (g Pu /liter)
0.1M H_2SO_4	~ 125
1.0M H_2SO_4	~ 90
9.0M H_2SO_4	1.66
12.0M H_2SO_4	3.13
2.7M H_2SO_4 -26 vol. % CH_3OH	5.6
7.2M H_2SO_4 -20 vol. % CH_3OH	0.20
0.2M H_2SO_4 -0.25M Cs_2SO_4 -29 vol. % CH_3OH	0.26
0.2M H_2SO_4 -0.34M Na_2SO_4 -24 vol. % CH_3OH	~ 0.4

Table 55

**CONCENTRATION OF PLUTONIUM (IV) IN EQUILIBRIUM WITH
VARIOUS SULFATE CONCENTRATIONS IN NITRIC ACID**

2 M HNO ₃ , Pu (g/liter)	25°C SO ₄ ²⁻ (M)	4 M HNO ₃ , Pu (g/liter)	25°C SO ₄ ²⁻ (M)	6 M HNO ₃ , Pu (g/liter)	25°C SO ₄ ²⁻ (M)	6 M HNO ₃ , Pu (g/liter)	55°C SO ₄ ²⁻ (M)
234	0.183	249	0.126	218	0.063	249	0.110
168	0.203	61.2	0.122	176	0.103	118	0.117
135	0.198	18.1	0.360	136	0.093	39.8	0.146
113	0.188	12.6	0.469	107	0.098	14.3	0.270
73.4	0.182	7.5	0.738	71.9	0.094	3.45	1.19
61.2	0.258			52.6	0.124	2.22	1.57
57.4	0.390			50.7	0.102	1.71	1.80
53.5	0.314			32.0	0.171	1.39	2.11
47.0	0.232			17.0	0.234		
39.9	0.315			16.7	0.232		
38.5	0.424			2.46	1.06		
38.5	0.452			1.38	1.48		
35.8	0.249						
35.4	0.323						

Table 56

COMPOSITION AND SOLUBILITY OF PLUTONIUM(IV) TETRASULFATES (71)

Outersphere cation	Analysis results, (%)	Pu content of mother solution, (mg/liter)	Comments
K ⁺	K 19.3 Pu 30.2 SO ₄ ²⁻ 48.0 NH ₄ ⁺ 9.6	20.0 1440-9150	Monohydrate Dihydrate; isomorphous with (NH ₄) ₄ Ce(SO ₄) ₄ · 2H ₂ O
NH ₄ ⁺	Pu 33.0 SO ₄ ²⁻ 53.5		
Rb ⁺	Rb 35.2 Pu 23.2	7.0	Dihydrate

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