JNC TN8400 99-012

Thermodynamic Data for Predicting Concentrations of AnO_2^{+} and AnO_2^{2+} Species in Geologic Environments

January, 1999

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Thermodynamic Data for Predicting Concentrations of AnO_2^{+} and AnO_2^{2+} Species in Geologic Environments

Gregory R. Choppin**, Mike Bronikowski**, Jianfeng Chen**, Johan Byegard**, Dhanpat Rai***, and Mikazu Yui*

Abstract

This report provides thermodynamic data for predicting concentrations of pentavalent and hexavalent actinide species (AnO_2^{+} and AnO_2^{2+}) in geologic environments, and contributes to an integration of the JNC chemical thermodynamic database, JNC-TDB (previously PNC-TDB), for the performance analysis of geological isolation system for high-level radioactive wastes. Thermodynamic data for the formation of complexes or compounds with hydroxide, chloride, fluoride, carbonate, nitrate, sulfate and phosphate are discussed in this report. The estimation of the stability constants by use of the Born equation is included. The Pitzer parameters for AnO_2^{+} and AnO_2^{2+}, redox potentials and equilibrium constants of redox reactions for actinides are also included.

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JNC TN8400 99−012
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地質環境下におけるアクチニドV価 (AnO_2^+) および アクチニドVI価 (AnO_2^{2+}) の濃度予測に関する 熱力学データの整備

（研究報告）

Gregory R. Choppin**, Mike Bronikowski**, Jianfeng Chen**,
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要　　　旨

本研究では，地層処分システム性能評価のための熱力学データベースJNC-TDB（旧PNC-TDB）整備の一環として，V価およびVI価のアクチニド化学種（AnO_2^+ and AnO_2^{2+}）に関する熱力学データ整備を行った。本研究では，これらの元素に対して，水酸化物錯体の他，塩化物，フッ化物，炭酸，硝酸，硫酸及びリン酸を含む錯体もしくは化合物に関する熱力学データ整備を行った。Born equationによる安定度定数（logβ）の推定，Pitzer parameter の検討，酸化還元反応の電位および平衡定数の検討も併せて行った。

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Acknowledgments

This Research has been conducted at Deperetment of Chemistry Florida State University.

This research is supported by the Japan Nuclear Cycle Development Institute (JNC).

We thank Dr. S. Ueta (Mitsubishi Materials Corporation), Dr. H. Wanner (Swiss Federal Nuclear Safety Inspectorate), and Dr. M. Ochs (BMG Engineering Ltd.) for technical discussions and guidance. Helpful discussions with experts from Japan, including Prof. O. Tochiyama (Tohoku Univ.), Prof. H. Moriyama (Kyoto Univ.), Dr. S. Nakayama (Japan Atomic Energy Research Institute), and Dr. T. Yamaguchi (Japan Atomic Energy Research Institute) are deeply appreciated.

Contents

Thermodynamic Data for Predicting Concentrations of AnO_2^+ and AnO_2^{2+} Species in Geologic Environments

Introduction

This report supplements those on the thermodynamic databases for the trivalent and tetravalent actinides from PNNL [99RAI/RAO-1], [99RAI/RAO-2]. In this report, the stability constants compiled from a review of the literature are presented in a series of tables. In addition, available literature data on the solubility products are tabulated. Finally, an evaluation of the recommended values of log β_1 (stability constants for the 1:1 complexes) are given as a guide for the more reliable values in the tables. The project did not provide time or resources for conducting a critical evaluation comparable to the multi-year, multi-investigator projects of the OECD-NEA. We accept the NEA recommended values for U(VI), Pu(VI) and Pu(V) data as reliable and suggest use of these to determine the more reliable values for the other AnO_2^+ and AnO_2^{2+} systems.

Solubility Product Data

The solubility product values, log K_{sp} listed, for the actinide (V) oxidation state are those for NpO_2^+ from recent studies. Earlier studies do not characterize the solid state well and thus should not be used. Solid state characterization is also a problem for the values of $NpO_2(OH)$. Values for the green amorphous and white crystalline $NpO_2(OH)$ solids have been determined by [92NEC/KIM]; however the crystalline solid may not have had aged sufficiently (2-4 weeks). A recent value for the amorphous solid of log K_{sp} = -8.79 [96ROB/SIL] was determined with more data than the -8.76 value of [92NEC/KIM] and is recommended for the $NpO_2(OH)_{am}$. No values for the crystalline solid have been chosen. Recommended log K_{sp} values for $NaNpO_2CO_3$ and $Na_3NpO_2(CO_3)_2$ are -11.00 and -14.32 respectively [95NEC/RUN].

Solubility products have been determined experimentally for U(VI), Np(VI) and Pu(VI) with various inorganic ligands, i.e., CO_3^{2-}, OH^-, HPO_4^-, SO_3^{2-}, etc. The log K_{sp} values from the recent thermodynamic compilations of NEA [92GRE] and IAEA [92FUG/KHO] are recommended. No recommended values for the hydrolysis compounds of the hexavalent species can be given since for most values, the experiments did use a pure solid state which had been adequately characterized.

Pitzer Parameters for Modeling

Values for the Pitzer parameters of the important species are reported for the most for the actinides in the (V) oxidation state. As one would expect, all of these studies are for the most stable ion, NpO_2^+, obtained from solubility studies. While experimentally, the studies seem equally well done, the β parameters from [95NEC/FAN] are recommended as a consistent set. These can be augmented with the interaction parameters of [96RUN/NEU] which is a more complicated study that included hydrolysis. Values from other studies are not used since they neglect the β(1) determination for important species making the β(0) values too large.

Pitzer parameter values for the actinide (VI) oxidation state are sparse, making recommendation of values difficult. The only experimentally determined values are for UO_2^{2+} systems. The β(0) and β(1) values reported for plutonyl carbonates [97PAS/CZE] are for uranyl carbonate. These plutonyl carbonate values do work well only as a first approximation. All of the other reported Pitzer parameters are unique except for those of UO_2^{2+}-ClO_4^-. An average of the β(0), β(1), and C^Φ determinations from [73PIT/MAY] and [88KIM/FRE] are recommended for use. These estimated values are 0.6, 2.0 and 0.016 for β(0), β(1), and, C^Φ, respectively.

Recommended log $\beta_1°$

A set of values of the stability constant for the reaction

$$An^{m+} + X^{na-} = An^{n-m}$$

where An= AnO_2^+ and AnO_2^{2+} at I = 0 M and 25°C have been selected and listed in a separate section. The basis of selection of these values is given in the Introduction to that section.

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Tables of Stability Constants for AnO_2^+

(NpO_2^+ and PuO_2^+)

Equilibrium constants (β_{mn})[1] for formation of aqueous NpO_2^+ complexes with F^- ($mNpO_2^+ + nF^- \rightleftharpoons (NpO_2)_mF_n^{(m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
1.76		0.1M $NaClO_4$	M:3mM, H:5mM, L:2mM	pot, F^-	[85SAW/RIZ]
1.5		0.1M $NaClO_4$	M:5mM, pH=6.5, L:2mM	pot, F^-	[85SAW/RIZ]
1.26		1M $NaClO_4$	M:tr, pH=3, L:6mM	pot, F^-	[84CHO/RAO]
1.39	2.07	1M $NaClO_4$	M:tr, pH=6.6, L:0.4M	dis	[85INO/TOC2]
1.2		1M $NaClO_4$	M:5mM, pH=6.5, L:0.3mM	pot, F^-	[85SAW/RIZ]
1.35		2M $NaClO_4$		sp	[78RAO/PAT]
0.99		2M $NaClO_4$	M:tr, pH[2], L:60mM	dis	[79RAO/GUD]
0.90		[3]	[3]	nmr	[76VOD/KOL]

1) If m = 1, β_{mn} is written β_n
2) pH not mentioned in the paper
3) No experimental details are given in the paper

Equilibrium constants (β_{mn})[1] for formation of aqueous NpO_2^+ complexes with Cl^- ($mNpO_2^+ + nCl^- \rightleftharpoons (NpO_2)_mCl_n^{(m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
-0.29	<-1	I=0[2]	M:tr, H:1mM, L:5M	dis	[95NEC/FAN]
-0.55		1M Na(ClO_4,Cl)	M:tr, H:1mM, L:1M	dis	[95NEC/FAN]
-0.30		2M H(ClO_4,Cl)	M:tr, H:2M, L:2M	cix	[64GAI/SYK]
-0.42		2M Na(ClO_4,Cl)	M:tr, pH[3], L:1M	dis	[79RAO/GUD]
-0.42		2M Na(ClO_4,Cl)	M:tr, H:1mM, L:2M	dis	[95NEC/FAN]
-0.28	-1.70	3M Na(ClO_4,Cl)	M:tr, H:1mM, L:3M	dis	[95NEC/FAN]
-2.52	-1.55	4M Na (ClO_4,NO_3)	M:tr, H:0.1M, L:4M	dis	[71DAN/CHI]
-0.05	-0.70	5M Na(ClO_4,Cl)	M:tr, H:1mM, L:5M	dis	[95NEC/FAN]

1) If m = 1, β_{mn} is written β_n
2) Etrapolated to zero ionic strength from the results of the same author at the higher ionic strengths.
2) pH not mentioned in the paper

Equilibrium constants (β_{mn})[1] for formation of aqueous NpO_2^+ complexes with NO_3^- ($mNpO_2^+ + nNO_3^- \rightleftharpoons (NpO_2)_m(NO_3)_n^{(m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
-0..25		2M H(ClO_4,NO_3)	M:tr, H:2M, L:2M	cix	[64GAI/SYK]
-0.6		2M Na (ClO_4,NO_3)	M:tr, pH[2], L:1M	dis	[79RAO/GUD]
-1.60	-1.37	4M Na (ClO_4,NO_3)	M:tr, H:0.1M, L:4M	dis	[71DAN/CHI]
-0.28		8M H(ClO_4,NO_3)	M:tr, H:8M, L:8M	dis	[70LAH/KNO]

1) If m = 1, β_{mn} is written β_n
2) pH not mentioned in the paper

Equilibrium constants (β_{mn})[1] for formation of aqueous NpO_2^+ complexes with OH^- ($mNpO_2^+ + nH_2O$] $\rightleftharpoons$ [$(NpO_2)_mOH_n^{(m-n)+} + nH^+$

log β_1	log β_2	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
-10.08		dil. $HClO_4/NH_3$	M:0.025M, pH=6.6	sol	[71MOS3]
-8.7		dil. $HClO_4$/NaOH	M:0.5mM, pH=3	pr/tc	[80SCH/GOR]
-8.89		0.001M $(Na,H)NO_3$	M:tr, H:3e-8M	sp	[76SEV/KHA]
-8.89		0.002M $(Na,H)NO_3$	M:1mM, H:3e-8M	sp	[76SEV/KHA]
-8.88		0.02M $(Na,H)NO_3$	M:10mM, H:2e-7M	gl	[76SEV/KHA]
-8.85		0.1		pH	[48KRA/NEL]
-10.45	-21.95	0.1M (H,Na) (ClO_4,OH)	M:tr, pH=1	tp	[87ROS/MIL]
-9.12		1M $NaClO_4$	M:0.3mM, H:8e-8M	sol	[83MAY]

1) If m = 1, β_{mn} is written β_n

Equilibrium constants (β_{mn})[1] for formation of aqueous NpO_2^+ complexes with OH^- ($mNpO_2^+ + nOH^- \rightleftharpoons (NpO_2)_mOH_n^{(m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
3.30	5.58	I=0[2]	M:0.3mM, pH=6	sol	[92ITA/NAK]
5.7	9.2	I=0.005[3]	M:tr, pH=4	tp	[88NAG/TAN]
5.7	8.6	0.1M HNO_3	M:0.3mM, pH=7	sol	[88NAK/ARI]
	5.16	0.012M $NaClO_4$	M:0.3mM, pH=6	sol	[92ITA/NAK]
3.31	5.74	0.05M $NaClO_4$	M:0.3mM, pH=6	sol	[92ITA/NAK]
6.0	9.9	I=0.01[3]	M:tr, pH=4	tp	[88NAG/TAN]
2.67	5.74	0.1M $NaClO_4$	M:0.3mM, pH=6	sol	[92ITA/NAK]
2.44	4.1	0.1M $NaClO_4$	M:10mM, pH=7	sol	[92NEC/KIM]
4.16		0.2M $NaClO_4$	.	dis	[85BID/TAN]
3.49	4.7	0.4M $NaClO_4$	M:0.3mM, pH=6	sol	[92ITA/NAK]
2.91	5.50	0.8M $NaClO_4$	M:0.3mM, pH=6	sol	[92ITA/NAK]
2.3	4.89	1M $NaClO_4$	M:10mM, pH=7	sol	[85LIE/TRE]
2.67	4.41	1M $NaClO_4$	M:10mM, pH=7	sol	[92NEC/KIM]
3.18	5.15	3M $NaClO_4$	M:1mM, pH=7	sol	[92NEC/KIM]

1) If m = 1, β_{mn} is written β_n
2) Extrapolated to zero ionic strentg using the values presented in the same paper
3) Ion medium not metioned in the paper, only ionic strength

Equilibrium constants (β_{mn})[1] for formation of aqueous NpO_2^+ complexes with CO_3^{2-} $(mNpO_2^+ + nCO_3^{2-} \rightleftharpoons (NpO_2)_m(CO_3)_n^{(m-2n)+}$

log β_1	log β_2	log β_3	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
5.9		16.3	0.05M $NaClO_4$		iE	[83EDE/BUC]
4.34			0.1M $NaClO_4$	M:tr, L:0.1mM	sp	[90NIT/STA]
4.58	6.60	<6.8	0.1M $NaClO_4$	M:1mM, pH=7, L:0.1M	sol	[94NEC/RUN]
4.8			0.1M NaCl	M:1mM, L:0.1M	sol	[96RUN/NEU]
4.13	7.06		0.2M $NaClO_4$	M:tr, pH=8, L:0.01M	dis	[85BID/TAN]
4.49	7.11	8.53	1M $NaClO_4$	M:3mM, L:0.1M	sol	[83MAY]
4.14	6.78		1M	M:tr, L.0.15M	dis	[85INO/TOC]
4.73[2]	7.0[2]		1M (Na,K) (ClO_4,Cl)	M:0.1mM, L:0.1M	sol	[93LEM/BOY]
5.6[3]			1M (Na,K) (ClO_4,Cl)	M:0.1mM, L:0.1M	sol	[93LEM/BOY]
5.2[4]			1M (Na,K) (ClO_4,Cl)	M:0.1mM, L:0.1M	sol	[93LEM/BOY]
4.50	6.96	8.67	1M $NaClO_4$	M:1mM, pH=7, L:0.1M	sol	[94NEC/RUN]
5.09	8.15	10.46	3M $NaClO_4$	M:1mM, pH[2], $[CO_3^{2-}]$=0.05M	sol	[86GRE/ROB]
4.76	7.69	10.30	3M $NaClO_4$	M:1mM, pH=7, L:0.1M	sol	[94NEC/RUN]
4.3	7.1	9.2	3M NaCl	M:1mM, L:0.1M	sol	[96RUN/NEU]
5.00	8.29	11.47	5M $NaClO_4$	M:1mM, pH=7, L:0.1M	sol	[94NEC/RUN]

1) If m = 1, β_{mn} is written β_n
2) T=303 K
3) T=323 K
4) T=348 K
5) pH not mentioned in the paper, only $[CO_3^{2-}]$ are given

Equilibrium constants (β_{mn})[1] for formation of aqueous NpO_2^+ complexes with HCO_3^- ($mNpO_2^+ + nHCO_3^- \rightleftharpoons (NpO_2)_m(HCO_3)_n^{(m-n)+}$)

log β_1	Medium	Maximum Metal/H⁺/Ligand Concentration	Method	Reference
2.15	0.25M NH_4Cl	M:tr, pH=8.5, L:0.12M	cppt	[79MOS/POZ]

1) If m = 1, β_{mn} is written β_x

Equilibrium constants for formation of aqueous NpO_2^+ complexes with various CO_3^{2-}-species

Reaction	log K	Medium	Maximum Metal/H⁺/Ligand Concentration	Method	Reference
$CO_3^{2-} + OH^- + NpO_2^+ \rightleftharpoons NpO_2OHCO_3^-$	4.83	0.2-2M $(NH_4)_2CO_3$	M.0.1mM, pH=8.8, L:2M	sol	[71MOS2]
$CO_3^{2-} + OH^- + NpO_2^+ \rightleftharpoons NpO_2OHCO_3^-$	7.6	3M $NaClO_4$	M:1mM, OH:2M, L:1M	sp	[97NEC/FAN]
$CO_3^{2-} + 2OH^- + NpO_2^+ \rightleftharpoons NpO_2(OH)_2CO_3^{3-}$	9.56	3M $NaClO_4$	M:1mM, OH:2M, L:1M	sp	[97NEC/FAN]
$2CO_3^{2-} + OH^- + NpO_2^+ \rightleftharpoons NpO_2OH(CO_3)_2^{4-}$	4.85	0.2-2M $(NH_4)_2CO_3$	M.0.1mM, pH=8.8, L:2M	sol	[71MOS2]
$2CO_3^{2-} + OH^- + NpO_2^+ \rightleftharpoons NpO_2OH(CO_3)_2^{4-}$	10.06	3M $NaClO_4$	M:1mM, OH:2M, L:1M	sp	[97NEC/FAN]

Equilibrium constants (β_{mn})[1] for formation of aqueous NpO_2^+ complexes with PO_4^{3-} ($mNpO_2^+ + nPO_4^{3-}$) ⇀ $(NpO_2)_m(PO_4)_n^{(m-3n)+}$)

log β_1	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
6.33	0.1M $NaClO_4$	M:tr, pH=6.5, L:2.4mM	sp	[96MOR/KIM]
5.78	1M NH_4Cl	M:tr, pH=8.5, L:0.7M	cppt	[79MOS/POZ]

1) If m = 1, β_{mn} is written β_n

Equilibrium constants (β_{mn})[1] for formation of aqueous NpO_2^+ complexes with HPO_4^{2-}($mNpO_2^+ + nHPO_4^{2-}$ ⇀ $(NpO_2)_m(HPO_4)_n^{(m-2n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
3.38		I=0[2]	M:tr, pH=6.5, L:0.05M	cix	[64MOS/PER]
2.36		0.1M (H,Na)ClO_4	M:tr, pH=7.5, L:0.01M	cix	[84REE/DAN]
2.06[3]		0.1M (H,Na)ClO_4	M:tr, pH=7.5, L:0.01M	cix	[84REE/DAN]
3.11[4]		0.1M (H,Na)ClO_4	M:tr, pH=7.5, L:0.01M	cix	[84REE/DAN]
2.54		0.1M $NaClO_4$	M:tr, pH=6.5, L:2.4mM	sp	[96MOR/KIM]
2.85		0.2M NH_4ClO_4	M:tr, pH=6.5, L:0.05M	cix	[64MOS/PER]
2.9		1M NH_4ClO_4	M:tr, pH=8.5, L:0.7M	cppt	[79MOS/POZ]
2.11	3.43	1M $NaClO_4$	M.tr, pH=1, L=1M	dis	[85INO/TOC2]
4.54	7.49	1M $NaClO_4$	M:tr, pH=2.5, L:0.01M	dis	[94MAT/CHO]

1) If m = 1, β_{mn} is written β_n
2) Extrapolated to zero Ionic strength from the experimental results in the same paper
3) T=308 K
4) T=283 K

Equilibrium constants (β_{mn})[1] for formation of aqueous NpO_2^+ complexes with $H_2PO_4^{2-}$ ($mNpO_2^+ + nH_2PO_4^{2-} \rightleftharpoons (NpO_2)_m(H_2PO_4)_n^{(m-n)+}$)

log β_1	Medium	Maximum Metal/H+/Ligand Concentration	Method	Reference
0.81	0.2M NH_4ClO_4	M:tr, pH=6.5, L:0.05M	cix	[64MOS/PER]
1.04	1M $NaClO_4$	M.tr, pH=1, L=1M	dis	[85INO/TOC2]
2.52	1M $NaClO_4$	M:tr, pH=2.5, L:0.01M	dis	[94MAT/CHO]

1) If m = 1, β_{mn} is written β_n

Equilibrium constants (β_{mn})[1] for formation of aqueous NpO_2^+ complexes with SO_4^{2-} ($mNpO_2^+ + nSO_4^{2-} \leftrightarrow (NpO_2)_m(SO_4)_n^{(m-2n)+}$)

log β_1	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
2.11	I=0[2]	M:tr, pH=8.5, L:0.6M	cppt	[79MOS/POZ]
-0.10	0.5M $NaClO_4$	M:tr, pH[5], L:0.15M	dis	[83HAL/OLI]
0.25[3]	0.5M $NaClO_4$	M:tr, pH[5], L:0.15M	dis	[83HAL/OLI]
-0.43[4]	0.5M $NaClO_4$	M:tr, pH[5], L:0.15M	dis	[83HAL/OLI]
0.06	1M $NaClO_4$	M:tr, pH[5], L:0.3M	dis	[83HAL/OLI]
0.34[3]	1M $NaClO_4$	M:tr, pH[5], L:0.3M	dis	[83HAL/OLI]
-0.18[4]	1M $NaClO_4$	M:tr, pH[5], L:0.3M	dis	[83HAL/OLI]
0.76	1M Na (ClO_4,SO_4)	M.tr, pH=7, L:1M	dis	[85INO/TOC2]
1.04	1.5M NH_4Cl	M:tr, pH=8.5, L:0.6M	cppt	[79MOS/POZ]
0.45	2M $NaClO_4$	M:tr, pH[6], L:0.25M	dis	[79RAO/GUD]
0.19	2M $NaClO_4$	M:tr, pH[5], L:0.3M	dis	[83HAL/OLI]
0.40[3]	2M $NaClO_4$	M:tr, pH[5], L:0.3M	dis	[83HAL/OLI]
-0.04[4]	2M $NaClO_4$	M:tr, pH[5], L:0.3M	dis	[83HAL/OLI]
0.61	2M $NaClO_4$	M:1mM, pH=3, L[7]	sp	[90RIZ/NEC]

1) If m = 1, β_{mn} is written β_n
2) Extrapolated to zero Ionic strength from the experimental results in the same paper
3) T=318 K
4) T=278 K
5) pH between 4 and 7, evidence is provided that the extraction and complexation is independent of the pH in the neutral area.
6) pH not mentioned in the paper

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Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^+ complexes with Cl^- ($mPuO_2^+ + nCl^- \rightleftharpoons (PuO_2)_mCl_n^{(m-n)+}$)

log β_1	Medium	Maximum Metal/H+/Ligand Concentration	Method	Reference
-0.17	2	2	sp	[56NEW], [57KAT/SEA]

1) If m = 1, $\beta_{1,x}$ is written β_x
2) Limited experimental details are given

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^+ complexes with OH^- ($mPuO_2^+ + nH_2O \rightleftharpoons (PuO_2)_mOH_n^{(m-n)+} + nH^+$)

log β_1	Medium	Maximum Metal/H+/Ligand Concentration	Method	Reference
-9.73	0.1M $NaClO_4$	M:tr, pH=3	sp	[92BEN/HOF]

1) If m = 1, $\beta_{1,x}$ is written β_x

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^+ complexes with CO_3^{2-} ($mPuO_2^+ + nCO_3^{2-} \rightleftharpoons (PuO_2)_m(CO_3)_n^{(m-2n)+}$)

log β_1	log β_3	Medium	Maximum Metal/H+/Ligand Concentration	Method	Reference
5.12		I=0[2]	M:tr, pH=6.25, L:3.5mM	sp	[92BEN/HOF]
4.6		0.5M $NaClO_4$	M:tr, pH=6.25, L:3.5mM	sp	[92BEN/HOF]
	10.1	I=1	3	red	[86LIE/KIM]

1) If m = 1, $\beta_{1,x}$ is written β_x
2) Extrapolated to zero ionic strength from the results in the same paper
3) No experimental details available

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^+ complexes with HCO_3^- ($mPuO_2^+ + nHCO_3^- \rightleftharpoons (PuO_2)_m(HCO_3)_n^{(m-n)+}$)

log β_1	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
1.9	0.25M NH_4Cl	M:tr, pH=8.5, L:0.12M	cppt	[79MOS/POZ]

1) If m = 1, $\beta_{1,x}$ is written β_x

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^+ complexes with HPO_4^{2-} ($mPuO_2^+ + nHPO_4^{2-} \rightleftharpoons (PuO_2)_m(HPO_4)_n^{(m-2n)+}$)

log β_1	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
2.39	0.1M NH_4Cl	M:tr, pH=8, L=0.7M	cppt	[79MOS/POZ]

1) If m = 1, $\beta_{1,x}$ is written β_x

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Tables of Stability Constants for AnO_2^{2+}

(UO_2^{2+}, NpO_2^{2+} and PuO_2^{2+})

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with F^- ($mUO_2^{2+} + nF^- \rightleftharpoons (UO_2)_mF_n^{(2m-n)+}$)

log β_1	log β_2	log β_3	log β_4	Medium	Maximum Metal/H+/Ligand Concentration	Method	Reference
4.59	7.93	10.49	11.85	1.0M (H,Na)ClO_4	M:25mM, H:25mM, L:335mM	emf	[54AHR/LAR]
5.30				H_2O	M:0.1M, H:25mM, L:0.6M	est	[56AHR/LAR]
4.54	7.89	10.46	11.81	1.0M NaCl		qh	[56AL]
4.77				H_2O	M:0.02mM, pH=3.0, 0.35M	sp	[61KUT]
4.398				2.0M			[67AHR]
4.65				0.50M $NaClO_4$	M:16mM, H:16mM, L:16M	prx	[69VDO/STE2]
4.58				0.50M			[69VDO/STE2]
4.54	7.98	10.41	11.89	1.0M $NaCl0_4$	M:31mM, H:30mM, L:4.0mM	qh	[71AHR/KUL]
4.54				1.0M $NaCl0_4$		cal	[71AHR/KUL2]
5.37				H_2O	M:8x10^{-8}M, L:2M, H:2.0M	est	[76PAT/RAM]
4.54				1.0M			[76SMI/MAR]
4.30				0.50M			[76SMI/MAR]
4.54				1.0M			[76SMI/MAR]
4.39	7.77	9.83		1.0M NaCl		ise	[77ISH/KAO]
4.70[a]				1.0M $NaClO_4$	L:0.03M, pH=2.6	ise	[84CHO/RAO]
4.52				1.0M $NaClO_4$	L:0.03M, pH=2.6	dis	[84CHO/RAO]
5.08				H_2O		est	[84TRI]
4.56	7.99	10.34		1.0M $NaClO_4$		ise	[85SAW/CHA]

Cont.

$\log \beta_1$	$\log \beta_2$	$\log \beta_3$	$\log \beta_4$	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
4.90				3.62M			[88LEM]
4.54				1.0M			[93FER/SAL]
4.86	8.62	11.71	13.78	3.0M $NaClO_4$	M:1mM, pH=3.5	pot	[93FER/SAL]

1) If m = 1, β_{mn} is written β_n, a)296K

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with F^- ($mUO_2^{2+} + nHF \rightleftharpoons (UO_2)_mF_n^{(2m-n)+} + nH^+$)

log β_1	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
1.52	H_2O		est	[54DAY/POW]
1.71	0.05M $NaClO_4$	M:1x10^{-5}M, H:0.05M, L:10mM	dis	[54DAY/POW]
1.57	0.25M $NaClO_4$	M:1x10^{-5}M, H:0.05M, L:9mM	dis	[54DAY/POW]
1.38	0.50M $NaClO_4$	M:1x10^{-5}M, H:0.05M, L:90mM	dis	[54DAY/POW]
1.43	1.0M $NaClO_4$	M:1x10^{-5}M, H:0.05M, L:10mM	dis	[54DAY/POW]
1.41	2.0M $NaClO_4$	M:1x10^{-5}M, H:0.05M, L:10mM	dis	[54DAY/POW]
1.18	0.5M	M:38.7mM, L:0.2M, H:0.5M	sp	[61CON/PAU]
1.31	2.1M $HClO_4$	M:7.6x10^{-8}M, L:82.6mM, pH=1.1	cix	[68KRY/KOM3]
1.52	1.04M $HClO_4$	M:7.6x10^{-8}M, L:132mM, pH=0.9	cix	[68KRY/KOM3]
1.54	0.51M $HClO_4$	M:7.6x10^{-8}M, L:130mM, pH=0.9	cix	[68KRY/KOM3]
1.57	0.20M $HClO_4$	M:7.6x10^{-8}M, L:80.6mM, pH=1.1	cix	[68KRY/KOM3]
1.57	2.0M $HClO_4$		cix	[68KRY/KOM3]
1.479	4.0M $(H,Na)ClO_4$	M:50mM, L:50mM, H:0.6M	qh	[69GRE/VAR]
1.561	2.0M $HClO_4$	M:8x10^{-5}M, L:2.0M, H:2.0M	qh	[76PAT/RAM]
1.52	1.0M			[80BON/HEF]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with Cl^- ($mUO_2^{2+} + nCl^- \rightleftharpoons (UO_2)_mCl_n^{(2m-n)+}$)

log β_1	log β_2	log β_3	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
-0.3			1.0M $(H,Na)ClO_4$		sp	[51AHR]
-0.1			1.0M $(H,Na)ClO_4$		qh	[51AHR]
0.11			n/a			[51NEL/KRA]
0.38			n/a			[51NEL/KRA]
-0.24[b]			2.0M $(H,Na)ClO_4$	M:$1x10^{-5}$M, H:0.05M, L:1.95M	dis	[54DAY/POW]
-0.056			2.0M $(H,Na)ClO_4$	M:$1x10^{-5}$M, H:0.05M, L:1.95M	dis	[54DAY/POW]
-0.057[g]			2.0M $(H,Na)ClO_4$	M:$1x10^{-5}$M, H:0.05M, L:1.95M	dis	[54DAY/POW]
0.22			H_2O		est	[57BAL/DAV]
0.03			H_2O	L:0.8M	est	[57DAV/MON]
0.21			0.25-0.85M $(H,Na)ClO_4$	L:0.8M	sp	[57DAV/MON]
0.03			H_2O		est	[60HEF/AMI]
1.64			1.238M $(H,Na)ClO_4$		sp	[60HEF/AMI]
0.300[e]			1.0M $NaClO_4$	M:0.2M, pH=2.95	cix	[61BAN/TRI]
0.26[a]			H_2O		fp	[62FAU/CRE]
-0.27			1.06M $(K,Na)(NO_3,ClO_4)$		cix	[67OHA/MOR]
0.15			0.82M $(K,Na)(NO_3,ClO_4)$		cix	[67OHA/MOR]
0.38			0.54M $(K,Na)(NO_3,ClO_4)$		cix	[67OHA/MOR]
1.55			H_2O		cix	[67OHA/MOR]
1.50[f]			H_2O		cix	[67OHA/MOR2]

Cont.

log β_1	log β_2	log β_3	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
0.8			H_2O	M:0.3mM, L:2.0M	est	[74BUN]
0.002			0.60M $HClO_4$	M:0.3mM, L:2.0M	cix	[74BUN]
0.025			2.0M $HClO_4$	M:0.3mM, L:2.0M	cix	[74BUN]
0.303			4.0M $HClO_4$	M:0.3mM, L:2.0M	cix	[74BUN]
-0.46			6.0M $NaClO_4$		mvd	[74JED]
-0.60			1.0M $NaClO_4$		mvd	[74JED]
-0.60			2.0M $NaClO_4$		mvd	[74JED]
-0.52			4.0M $NaClO_4$		mvd	[74JED]
-0.22	-1.00		8.0M $NaClO_4$		mvd	[74JED]
1.57			0.01M HCl	M:1mM, H:0.01M:, L:0.01M	ie	[75ALY/ABD]
1.58			0.10M HCl	M:1mM, H:0.10M:, L:0.10M	ie	[75ALY/ABD]
1.59			0.50M HCl	M:1mM, H:0.5M:, L:0.5M	ie	[75ALY/ABD]
1.65			1.0M HCl	M:1mM, H:1.0M:, L:1.0M	ie	[75ALY/ABD]
-0.102			1.0M HCl?		cix	[76SOU/SHA]
0.055			2.0M HCl?		cix	[76SOU/SHA]
-0.301			1.0M HCl?		cix	[76SOU/SHA]
1.96[i]			0.03M KCl		gl	[77NIK2]
2.23[j]			0.03M KCl		gl	[77NIK2]

Cont.

log β_1	log β_2	log β_3	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
2.40[k]			0.03M KCl		gl	[77NIK2]
-0.12	-0.64		2.0M $HClO_4$		dis	[78BED/FID]
-0.30[c]			1.0M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
-0.28[f]			1.0M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
-0.26[h]			1.0M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
-0.12	-6.4		2.0M $HClO_4$	M:2mM, L:4.M	dis	[81AWA/SUN]
-0.15	-1.29		2.0M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
-0.13[f]	-1.21		2.0M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
-0.11[h]	-1.14		2.0M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
0.15	-0.46		3.5M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
0.17[f]	-0.39		3.5M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
0.19[h]	-0.32		3.5M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
0.26	-0.18	-1.5	4.0M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
0.28[f]	-0.11		4.0M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
0.32[h]	-0.04		4.0M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
0.50[h]	0.48		4.9M $HClO_4$	M:2mM, L:4.M	sp	[81AWA/SUN]
1.481			N/A		est	[87OHA/MOR]
-9.0(?)			H_2O		est	[88CRO/EWA]

Cont.

log β_1	log β_2	log β_3	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
0.10			1.37M			[88LEM]
0.10			3.62M			[88LEM]
-0.32			0.50M			[92FUG/KHO]
-0.400			1.0M			[92FUG/KHO]
-1.00			8.0M NaCl		mvd	[74JED]
0.0			H_2O		est	[78ALL]

a) T=270 K, b) T=283 K, c) T=288 K, d) T=293 K
e) T=303 K, f) T=308 K, g) T=313 K, h) T=318 K
i) T=343 K, j) T=363 K, k) T=373 K

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with NO_3^- ($mUO_2^{2+} + nNO_3^- \rightleftharpoons (UO_2)_m(NO_3)_n^{(2m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H⁺/Ligand Concentration	Method	Reference
-0.68		5.38M(H,Na)ClO_4	M:0.61M, L:2.56M, H=2.0M	sp	[49BET/MIC]
-0.30[b]		1.00M $NaClO_4$		gh	[51AHR]
-0.52[a]		2.00M(H,Na)ClO_4	M:1x10^{-5}M, H:0.05M, L:1.95M	dis	[54DAY/POW]
-0.62		2.00M(H,Na)ClO_4	M:1x10^{-5}M, H:0.05M, L:1.95M	dis	[54DAY/POW]
-0.77[c]		2.00M(H,Na)ClO_4	M:1x10^{-5}M, H:0.05M, L:1.95M	dis	[54DAY/POW]
-1.40[d]	0.50	1.00M $NaClO_4$		cix	[61BAN/TRI]
-0.42		0.54 MNa(Cl,ClO_4)		gl	[67OHA/MOR]
-0.72		1.06 M Na(Cl,ClO_4)		gl	[67OHA/MOR]
-0.47	-1.5	8.0M $HClO_4$		dis	[70LAH/KNO]
0.699		2.0M			[76SOU/SHA]
-0.678		2.0M			[76SOU/SHA]
0.800		H_2O		est	[78ALL/BEA]
-0.82		6.25M $NaClO_4$	M:1.12M, L:4.58M	ram	[80BRO/HUA]
0.66		H_2O		est	[87BRO/WAN]
-0.20		0.71M $HClO_4$		dis	[68PUS/NIK]
-0.54		2.0M $NaClO_4$		sp	[80MAR/DEC]

1) If m = 1, β_{mn} is written β_n

a) T=283 K, b) T=293 K, c) T=305 K, d) T=313 K

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with OH^- $mUO_2^{2+} + nH_2O \rightleftharpoons (UO_2)_m(OH)_n^{(2m-n)+} + nH^+$

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
-4.3				0.16M	M:40mM, pH=1.1	qh	[42HEI]
-4.09				H_2O	M:10mM, pH=3.0	pol	[47HAR/KOL]
			log $\beta_{2,2}$=-5.72[j]	0.06M $Ba(NO_3)_2$		gl	[47SCH/FAU]
			log $\beta_{2,2}$=-5.94 log $\beta_{3,5}$=-16.02	0.15M $NaClO_4$	M:0.1M	gl	[49SUT]
			log $\beta_{2,2}$=-5.99 log $\beta_{3,5}$=-17.84	0.15M $NaClO_4$	M:10mM	gl	[49SUT]
			log $\beta_{2,2}$=-6.10 log $\beta_{3,5}$=-16.74	1M $NaClO_4$	M:60.7mM, pH=4.1	gl, qh	[49AHR]
			log $\beta_{2,2}$=-5.97	0.6M $Ba(NO_3)_2$		gl	[54FEA]
-4.14				H_2O	M:7.67x10^{-3}M, pH=4.0	sol	[55GAY/LEI]
-4.19				H_2O		sp	[55KOM/TRE]
-4.2				0.1M $NaClO_4$		dis	[55RYD]
			log $\beta_{2,2}$=-6.10	1M $NaClO_4$		qh	[56ROS/ROS]
			log $\beta_{2,2}$=-6.68	H_2O		qh	[56ORB/BAR]
-5.82			log $\beta_{2,2}$=-6.15	0.035M $Ba(ClO_4)_2$	M:11.6mM, pH= 3.25	gl	[57HEA/WHI]
-5.1[i]			log $\beta_{2,2}$=-5.92[i]	0.035M $Ba(ClO_4)_2$	M:11.6mM, pH=3.19	gl	[57HEA/WHI]
-5.40			log $\beta_{2,2}$=-5.82	0.35M $Ba(ClO_4)_2$	M:0.1158M, pH=2.45	gl	[57HEA/WHI]
			log $\beta_{2,2}$=-5.99	0.16M NaCl		gl	[58LI/DOO]
			log $\beta_{2,1}$=-3.66 log $\beta_{2,2}$=-6.02	1M $NaClO_4$	M:0.4M, 0.7<pH<3.0	gl, qh	[59HIE/SIL]

Cont.

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
			log $\beta_{2,1}$=-3.68 log $\beta_{2,2}$=-6.31	3M $NaClO_4$	M:1.4M, 0.7<pH<2.5	gl, qh	[59HIE/SIL]
-6.10			log $\beta_{2,2}$=-5.84 log $\beta_{6,4}$=-17.6	0.1M KNO_3	M:5mM, pH=2.5	gl	[60GUS/RIC]
-5.0	-10.5	-17.1		0.1M $NaNO_3$		dis	[60STA]
			log $\beta_{2,2}$=-5.01[a]	Sat. Ag_2SO_4		sol	[60LIE/STO]
			log $\beta_{2,2}$=-4.27[b]	Sat. Ag_2SO_4		sol	[60LIE/STO]
			log $\beta_{2,2}$=-3.84[c]	Sat. Ag_2SO_4		sol	[60LIE/STO]
			log $\beta_{2,2}$=-3.71[d]	Sat. Ag_2SO_4		sol	[60LIE/STO]
			log $\beta_{2,2}$=-5.96 log $\beta_{3,4}$=-12.79 log $\beta_{3,5}$=-16.21	1.5M Na_2SO_4	M:40mM, pH=1.1	gl	[61PET]
-5.7			log $\beta_{2,2}$=-5.92 log $\beta_{3,5}$=-16.22	0.5M KNO_3	M:20mM, pH=2.0	gl	[62BAE/MEY]
-4.2[k]			log $\beta_{2,2}$=-4.51 log $\beta_{3,5}$=-12.74	0.5M KNO_3	M:20mM, pH=1.6	gl	[62BAE/MEY]
			log $\beta_{2,2}$=-6.2	0.5M $NaNO_3$		sp	[62NIK/PAR]
			log $\beta_{3,5}$=-16	0.5M $NaNO_3$		cix	[62NIK/PAR]
			log $\beta_{2,2}$=-6.1	1M $Ba(NO_3)_2$		gl	[62NIK/PAR]
			log $\beta_{2,2}$=-6.3	1M $Ba(NO_3)_2$		sp	[62NIK/PAR]

Cont.

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H$^+$/Ligand Concentration	Method	Reference
-5.60			log $\beta_{2,2}$=-6.17 log $\beta_{3,4}$=-12.33 log $\beta_{3,5}$=-17.00	1M NaCl	M:0.1M, pH=2.7	gl	[62RUS/JOH]
			log $\beta_{2,1}$=-3.70 log $\beta_{2,2}$=-6.04 log $\beta_{3,5}$=-16.53	3M $NaClO_4$	M:0.100M	gl, qh	[62SCH]
			log $\beta_{2,2}$=-6.64 log $\beta_{3,4}$=-12.54 log $\beta_{3,5}$=-18.07 log $\beta_{4,6}$=-19.96 log $\beta_{4,7}$=-24.91	3M NaCl	M:80mM, pH=2	gl, qh	[63DUN/SIL]
			log $\beta_{2,1}$=-4.16 log $\beta_{2,2}$=-5.96 log $\beta_{3,4}$=-12.79 log $\beta_{3,5}$=-16.21	1M KNO_3	M:80mM	gl	[63DUN/HIE]
-6.0			log $\beta_{2,1}$=-3.81 log $\beta_{2,2}$=-6.25 log $\beta_{3,5}$=-17.18	3M $Mg(ClO_4)_2$	M:1.2M, pH=1.5	gl, qh	[63HIE/ROW]
			log $\beta_{2,1}$=-3.96 log $\beta_{2,2}$=-6.20 log $\beta_{3,5}$=-16.91	3M $Ca(ClO_4)_2$	M:1.2M, pH=1.5	gl, qh	[63HIE/ROW]
-6.10			log $\beta_{2,1}$=-3.70 log $\beta_{2,2}$=-6.02 log $\beta_{3,5}$=-16.54	3M $NaClO_4$	M:1.2M, pH=1.5	gl, qh	[63HIE/ROW]
			log $\beta_{2,2}$=-5.94 log $\beta_{3,5}$=-16.41	1M $NaClO_4$	M:0.1M, pH=3.3	sp	[63RUS/JOH]

Cont.

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
			log $\beta_{2,2}$=-5.91 log $\beta_{3,5}$=-16.43	1M $NaClO_4$	M:0.1M, pH=3.3	gl	[63RUS/JOH]
			log $\beta_{2,1}$=-1.9 log $\beta_{2,2}$=-6.28	0.1M $NaClO_4$		sp	[64BAR/SOM]
			log $\beta_{2,2}$=-6.09	0.1M $NaClO_4$		gl	[64BAR/SOM]
-6.0				H_2O	M:0.2mM, pH=4.3	kin	[67COL/EYR]
			log $\beta_{2,2}$=-4.9[b]	H_2O	M:6mM	con	[67RYZ/NAU]
			log $\beta_{2,2}$=-3.8[d]	H_2O	M:6mM	con	[67RYZ/NAU]
-5.16	-11.97		log $\beta_{2,2}$=-5.83	H_2O		gl	[68NIK/ANT]
			log $\beta_{2,2}$=-6.02 log $\beta_{3,5}$=-16.54	3M $NaClO_4$	M:0.100M	cal	[68ARN/SCH]
-5.38			log $\beta_{2,2}$=-5.92 log $\beta_{3,5}$=-16.16	3M $Mg(NO_3)_2$	M:0.100M, pH=2.0	gl	[68SCH/FRY]
-5.53			log $\beta_{2,2}$=-6.52 log $\beta_{3,5}$=-17.76	5M $Mg(NO_3)_2$	M:0.100M, pH=2.5	gl	[68SCH/FRY]
			log $\beta_{2,2}$=-5.92 log $\beta_{3,5}$=-16.16	0.2M $NaClO_4$	M:6mM, pH=3.0	gl	[68OST/CAM]
-4.39			log $\beta_{2,1}$=-1.9 log $\beta_{2,2}$=-6.09 log $\beta_{3,5}$=-15.64 log $\beta_{3,7}$=-24.03	0.1M $NaClO_4$		gl	[69TSY]
-5.70			log $\beta_{2,2}$=-5.95 log $\beta_{3,5}$=-16.36	0.5M KNO_3	M:6mM, pH=2.7	gl	[69VAN/OST]

Cont.

$\log \beta_1$	$\log \beta_2$	$\log \beta_3$	Other $\log \beta_{mn}$	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
-4.47[a]	-10.4[a]		$\log \beta_{2,2}$=-5.22[a]	H_2O		gl	[71NIK]
-4.00[e]	-9.38[e]		$\log \beta_{2,2}$=-4.80[e]	H_2O		gl	[71NIK]
-4.47[f]			$\log \beta_{2,2}$=-4.41[f]	H_2O		gl	[71NIK]
-3.38[b]	-7.99[b]		$\log \beta_{2,2}$=-4.25[b]	H_2O		gl	[71NIK]
-2.94[g]	-7.00[g]		$\log \beta_{2,2}$=-3.85[g]	H_2O		gl	[71NIK]
-2.55[c]	-6.13[c]		$\log \beta_{2,2}$=-3.50[c]	H_2O		gl	[71NIK]
			$\log \beta_{2,2}$=-6.80	3M $NaClO_4$		gl	[72KAK/AMA]
-5.08	-12.32		$\log \beta_{2,2}$=-5.73	H_2O		sol	[72NIK/SER]
-4.36[a]	-11.3[a]		$\log \beta_{2,2}$=-4.97[a]	H_2O		sol	[72NIK/SER]
-3.20[b]	-9.77[b]		$\log \beta_{2,2}$=-3.26[b]	H_2O		sol	[72NIK/SER]
-2.31[c]	-8.57[c]		$\log \beta_{2,2}$=-2.84[c]	H_2O		sol	[72NIK/SER]
-1.61[d]	-7.62[d]		$\log \beta_{2,2}$=-2.11[d]	H_2O		sol	[72NIK/SER]
			$\log \beta_{2,2}$=-6.0 $\log \beta_{3,5}$=-13	0.5M $NaClO_4$		sp, pH	[73MAV, 74MAV]
-4.00				0.5M NaClO4	M:12mM, pH=2.7	sp	[76GHO/MUK]
-4.03				H_2O	M:47.8mM, pH=3.0	gl, dis	[77VOL/BEL]
-5.2				H_2O	M:0.5mM, pH=3.14	tc	[78SCH/SUL]
			$\log \beta_{2,2}$=-5.63 $\log \beta_{3,5}$=-15.87	0.1M (Et_4NClO_4)		gl	[79SPI/ARN]

Cont.

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
-5.50			log $\beta_{2,2}$=-5.89 log $\beta_{3,4}$=-12.31 log $\beta_{3,5}$=-16.46 log $\beta_{4,7}$=-22.76	0.1M KNO_3	M:1.853x10^{-3}M, pH = 3.2	gl	[79SYL/DAV2]
			log $\beta_{2,1}$=-3.81 log $\beta_{2,2}$=-6.03 log $\beta_{3,5}$=-16.78 log $\beta_{4,6}$=-18.91	0.5M $NaClO_4$	M:0.100M, pH=2.5	gl	[79LAJ/PAR]
			log $\beta_{2,2}$=-6.0 log $\beta_{3,5}$=-16.6	3M $NaClO_4$	M:10mM, pH>5, P_{CO2}=0.97atm	gl	[79CIA/FER]
			log $\beta_{2,2}$=-6.3 log $\beta_{3,2}$=-11.20 log $\beta_{4,6}$=-17.85	3M KCl		gl	[79MIL/ELK]
			log $\beta_{2,2}$=-5.83 log $\beta_{3,5}$=-19	0.2M $NaNO_3$		gl	[80PON/DOU]
			log $\beta_{2,2}$=-5.64 log $\beta_{3,5}$=-15.94	0.024M $NaClO_4$	M:1.0mM	gl	[81VAI/MAK]
			log $\beta_{2,2}$=-5.85 log $\beta_{3,5}$=-16.32	0.105M $NaClO_4$	M:1.0mM	gl	[81VAI/MAK]
			log $\beta_{2,2}$=-5.89 log $\beta_{3,5}$=-16.46	0.254M $NaClO_4$	M:1.0mM	gl	[81VAI/MAK]
			log $\beta_{2,2}$=-5.97 log $\beta_{3,5}$=-16.51	0.506M $NaClO_4$	M:1.0mM	gl	[81VAI/MAK]

Cont.

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
			log $\beta_{2,2}$=-6.06 log $\beta_{3,5}$=-16.67	1.005M $NaClO_4$	M:1.0mM, pH=3.5	gl	[81VAI/MAK]
			log $\beta_{2,2}$=-6.16 log $\beta_{3,5}$=-16.79	2.003M $NaClO_4$	M:1.0mM	gl	[81VAI/MAK]
			log $\beta_{2,2}$=-5.89 log $\beta_{3,5}$=-16.19	0.1M $NaClO_4$	M:2.0mM, pH=5.5, P_{CO2}=3.55atm	gl	[82MAY]
			log $\beta_{2,2}$=-5.95 log $\beta_{3,1}$=-4.5 log $\beta_{3,5}$=-16.54 log $\beta_{4,3}$=-12.5	0.1M KNO_3	pH=3.0	gl	[82OVE/LUN]
			log $\beta_{2,2}$=-6.01 log $\beta_{4,3}$=-12.24	0.5M $NaNO_3$	M:10mM, pH=2.5	gl	[82MIL/SUR]
			log $\beta_{2,2}$=-6.07 log $\beta_{4,3}$=-12.31	1M $NaNO_3$	M:10mM, pH=2.5	gl	[82MIL/SUR]
			log $\beta_{2,2}$=-6.10 log $\beta_{4,3}$=-12.40	1.5M $NaNO_3$	M:10mM, pH=2.5	gl	[82MIL/SUR]
			log $\beta_{2,2}$=-6.13 log $\beta_{4,3}$=-12.41	2M $NaNO_3$	M:10mM, pH=2.5	gl	[82MIL/SUR]
			log $\beta_{2,2}$=-6.13 log $\beta_{4,3}$=-12.48	2.5M $NaNO_3$	M:10mM, pH=2.5	gl	[82MIL/SUR]
			log $\beta_{2,2}$=-6.13 log $\beta_{3,5}$=-16.65	3M $NaNO_3$	M:0.100M, pH=1.0	gl	[82MIL/SUR]
-6.04				0.05M $NaClO_4$	pH=5.64	dis	[83CAC/CHO2]

Cont.

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H$^+$/Ligand Concentration	Method	Reference
-6.09				0.1M $NaClO_4$	pH=4.72	dis	[83CAC/CHO2]
-6.20				0.4M $NaClO_4$	pH=5.55	dis	[83CAC/CHO2]
-6.09				0.7M $NaClO_4$	pH=4.67	dis	[83CAC/CHO2]
-6.03				1M $NaClO_4$	pH=5.54	dis	[83CAC/CHO2]
-3.43				0.5M $NaNO_3$	M:1x10^{-5}M, pH=1.0	ix, sp	[83DAV/EFR]
-5.5			log $\beta_{2,2}$=-6.0 log $\beta_{3,6}$=-17.7	0.1M $NaClO_4$		gl	[83EDE/BUC]
-5.20				H_2O		pol	[84GEI]
-4.57[a]				H_2O		pol	[84GEI]
-4.10[h]				H_2O		pol	[84GEI]
			log $\beta_{2,2}$=-6.45 log $\beta_{3,5}$=-17.29 log $\beta_{4,7}$=-23.12	0.1M KNO_3		gl	[84KOT/EVS]
			log $\beta_{2,2}$=-6 log $\beta_{2,3}$=-10.3 log $\beta_{9,19}$=-69.7	H_2O		gl, sp	[87VIL]
			log $\beta_{1,3}$=-19.69 log $\beta_{3,3}$=-16.54 log $\beta_{3,7}$=-31.9	0.5M $NaClO_4$		sol	[89BRU/SAN]
			log $\beta_{1,3}$=-19.09	0.5M $NaClO_4$		sol	[89BRU/SAN]
			log $\beta_{2,2}$=-6.07 log $\beta_{3,5}$=-16.40	0.5M $NaClO_4$	M:1mM, 3.5<pH<5.2	gl	[91GRE/LAG]

Cont.

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
			log $\beta_{2,2}$= -5.84[l] log $\beta_{3,5}$= -15.95[l]	0.1M $NaClO_4$	M:10mM, 4.5<pH<5.5	sol	[92KRA/BIS]
			log $\beta_{2,2}$=-5.73	0.1M		est, ave	[93MEI/KIMA]
			log $\beta_{2,2}$= -5.97 log $\beta_{3,5}$= -16.93	3.0M $NaClO_4$	M:75mM	pot	[93FER/SAL]

1) If m = 1, β_{mn} is written β_n
a) T= 323 K, b) T= 373 K, c) T= 423 K, d) T= 473 K,
e) T= 343 K, f) T= 363 K, g) T= 398 K, h) T= 347 K,
i) T= 313 K, j) T= 288 K, k) T= 367 K l) assuming log $_{kW}$=14 original log β values are 22.16 and 53.05

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with CO_3^{2-} ($mUO_2^{2+} + nCO_3^{2-} \rightleftharpoons (UO_2)_m(CO_3)_n^{(m-n)+}$)

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H+/Ligand Concentration	Method	Reference
	15.57	20.7		0.2M NH_4NO_3	M:10mM, 7.0<ph<9.0, L:1M H_2CO_3	col	[60BAB/KOD]
9.87				H_2O		sol	[72SER/NIK]
10.0[a]				H_2O		sol	[72SER/NIK]
10.55[c]				H_2O		sol	[72SER/NIK]
11.38[e]				N/A		sol	[72SER/NIK]
12.39[f]				H_2O		sol	[72SER/NIK]
13.54[g]				H_2O		sol	[72SER/NIK]
14.79[h]				H_2O		sol	[72SER/NIK]
		21.54[i]		0.1M $NaNO_3$			[75CIN/SCA]
10.09[a]				H_2O			[76PIR/NIK]
10.25[b]				H_2O			[76PIR/NIK]
10.57[c]				H_2O			[76PIR/NIK]
11.12[d]				H_2O			[76PIR/NIK]
11.62[e]				H_2O			[76PIR/NIK]
9.02				3.0 M			[76SMI/MAR]
9.00	16.22	21.70		0.1M $NaNO_3$			[77SCA]
9.90				H_2O			[82PHI]
	19.19 16.15	31.21 21.81		0.1M $NaClO_4$	M:2mM, pH=5.5, P_{CO2}=3.55atm	gl	[82MAY]
8.3	16.20	22.61	log $\beta_{3,6}$= 56.2	3.0 M $NaClO_4$	6.3<pH<3.5, L: 0.97 atm	sol	[84GRE/FER]

Cont.

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
8.3	15.36	21.46	log $\beta_{3,6}$= 53.7	0.5M $NaClO_4$	6.3<pH<3.5, L: 0.98 atm	sol	[84GRE/FER]
9.86				3.0M $NaClO_4$		cal	[84GRE/SPA]
9.81				0.01M			[84PHI]
9.19				0.10M			[84PHI]
8.50				0.50M			[84PHI]
8.18				1.0M			[84PHI]
7.88				2.0M			[84PHI]
7.73				3.0M			[84PHI]
9.65				H_2O			[84TRI]
9.80				H_2O			[85GRE]
9.80				H_2O			[84TRI]
8.60				3.0M	M:10mM, pH=2.95, P_{CO2}=0.97atm		[85NEW/SUL]
9.87				H_2O	M:10mM, pH=2.95, P_{CO2}=0.97atm	est	[85NEW/SUL]
8.30				1.37M			[88LEM]
8.00				3.62M			[88LEM]
8.70	16.33	23.92		0.1M $NaClO_4$	M:10mM, pH<6.7, L:1x10^{-6} M	sol	[92KRA/BIS]
8.93	15.3	21.0		0.1M $NaClO_4$	M:2mM, 3.5<pH<8, P_{CO2}=1atm	sol	[97PAS/CZR]

1) If m = 1, β_{mn} is written β_n
a) T=323 K, b) T=348 K, c) T=373 K, d) T=398 K,
e) T=423 K, f) T=473 K, g) T=523 K, h) T=573 K, i) T=293 K

Other Equilibrium Constants for Formation of Aqueous UO_2^{2+} Complexes with Various CO_3^{2-}-species

Reaction	log K	Medium	Maximum Metal/H⁺/Ligand Concentration	Method	Reference
$UO_2 CO_{3(c)} = UO_2 CO_{3(aq)}$	-4.366[a]	H_2O			[72SER/NIK]
$UO_2 CO_{3(c)} = UO_2 CO_{3(aq)}$	-4.387	H_2O			[72SER/NIK]
$UO_2 CO_{3(c)} = UO_2 CO_{3(aq)}$	-4.347[c]	H_2O			[72SER/NIK]
$UO_2 CO_{3(c)} = UO_2 CO_{3(aq)}$	-4.337[e]	n/a			[72SER/NIK]
$UO_2 CO_{3(c)} = UO_2 CO_{3(aq)}$	-4.215[f]	H_2O			[72SER/NIK]
$UO_2 CO_{3(c)} = UO_2 CO_{3(aq)}$	-4.37[a]	H_2O			[72SER/NIK]
$UO_2 CO_{3(c)} = UO_2 CO_{3(aq)}$	-4.35[c]	H_2O			[72SER/NIK]
$UO_2 CO_{3(c)} = UO_2 CO_{3(aq)}$	-4.34[e]	H_2O			[72SER/NIK]
$UO_2 CO_{3(c)} = UO_2 CO_{3(aq)}$	-4.30[f]	n/a			[72SER/NIK]
$UO_2 CO_{3(c)} = UO_2 CO_{3(aq)}$	-4.28[g]	H_2O			[72SER/NIK]
$UO_2 CO_{3(c)} = UO_2 CO_{3(aq)}$	-4.23[h]	H_2O			[72SER/NIK]
$CO_{2(g)} + UO_2^{2+} + H_2O = UO_2 CO_{3(aq)} + 2H^+$	-9.0	H_2O	M:10mM, pH>5, P_{CO2}=0.97atm	gl	[79CIA/FER]
$CO_3^{2-} + U^{4+} + 2H_2O = UO_2 CO_{3(aq)} + 4H^+$	0.85	H_2O			[80PAR/THO]
$H_2CO_{2(g)} + UO_2^{2+} + H_2O = UO_2 CO_{3(aq)} + 2H^+$	-6.62	0.01M			[84PHI]
$H_2CO_{2(g)} + UO_2^{2+} + H_2O = UO_2 CO_{3(aq)} + 2H^+$	-6.78	0.10M			[84PHI]
$H_2CO_{2(g)} + UO_2^{2+} + H_2O = UO_2 CO_{3(aq)} + 2H^+$	-6.97	0.50M			[84PHI]
$H_2CO_{2(g)} + UO_2^{2+} + H_2O = UO_2 CO_{3(aq)} + 2H^+$	-7.07	1.0M			[84PHI]0

Cont.

Reaction	log K	Medium	Maximum Metal/H$^+$/Ligand Concentration	Method	Reference
$H_2CO_{2(g)} + UO_2^{2+} + H_2O = UO_2\,CO_{3(aq)} + 2H^+$	-7.19	2.0M			[84PHI]
$H_2CO_{2(g)} + UO_2^{2+} + H_2O = UO_2\,CO_{3(aq)} + 2H^+$	-7.27	3.0M			[84PHI]
$CO_3^{2-} + U^{4+} + 2H_2O = UO_2\,CO_{3(aq)} + 4H^+$	0.456	H_2O			[89BRU/PUI]

a) T=323 K, b) T=348 K, c) T=373 K, d) T=398 K,
e) T=423 K, f) T=473 K, g) T=523 K, h) T=573 K

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with $H_2PO_4^-$ ($mUO_2^{2+} + nH_2PO_4^- \rightleftharpoons (UO_2)_m(H_2PO_4)_n^{(2m-n)+}$)

log β_1	Medium	Maximum Metal/H$^+$/Ligand Concentration	Method	Reference
2.3	H_2O		dis	[69MOS]
1.66	0.50 M[2]		dis	[69MOS]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with SO_4^{2-}
($mUO_2^{2+} + nSO_4^{2-} \rightleftharpoons (UO_2)_m(SO_4)_n^{(m-n)+}$)

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
1.75	2.65			1.0M $NaClO_4$	M:30mM, L:0.300M	sp	[51AHR2]
1.70	2.54	3.40	log $\beta_{1,1}$ = 3.79[j] log $\beta_{2,1}$ = 4.60[j]	1.0M $NaClO_4$	M:25mM, L:0.200M	qh	[51AHR2]
3.23				H_2O		est	[54BRO/BUN]
1.80[a]	2.76			2.0M $NaClO_4$	M:1x10^{-5}M, H:0.05M, L:0.09M	dis	[54DAY/POW]
1.90	2.80			2.0M $NaClO_4$	M:1x10^{-5}M, H:0.05M, L:0.11M	dis	[54DAY/POW]
1.98[c]	2.91			2.0M $NaClO_4$	M:1x10^{-5}M, H:0.05M, L:0.09M	dis	[54DAY/POW]
2.94	3.94			0.01-0.3M $NaClO_4$		sp	[57DAV/MON]
2.95				0.30 M $NaClO_4$		sp	[57DAV/MON]
1.53	2.30			1.0M SO_4^{2-}		dis	[58ALL]
2.76				H_2O			[58ALL]
2.93				H_2O			[58ALL]
2.98				H_2O			[58ALL]
1.81	2.29			1.0M		sp	[60MAT]
1.63	3.8			1.0M $NaClO_4$	M:0.201M, pH=3.05	cix	[61BAN/TRI]
3.85				H_2O	M:11.3mM, L:11.3mM, pH=3.27		[63POZ/STE]
2.34				0.10 M NH_4ClO_4	L:34mM, pH=5	dis	[67WAL]

Cont.

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
2.47[b]				0.10 M NH_4ClO_4	pH=5	dis	[67WAL]
2.44				0.075 M NH_4ClO_4	L:25mM, pH=5	dis	[67WAL]
2.51				0.05 M NH_4ClO_4	L:16.9mM, pH=5	dis	[67WAL]
2.62[b]				0.05 M NH_4ClO_4	pH=5	dis	[67WAL]
1.77				1.0M		est	[68AHR]
1.88				2.0M		est	[68AHR]
3.48[d]				H_2O		con	[70NIK]
3.62[e]				H_2O		con	[70NIK]
3.89[f]				H_2O		con	[70NIK]
1.76	2.64	3.51		1.0M $NaClO_4$		cal	[71AHR/KUL3]
1.78	2.65			1.0M $NaClO_4$			[71AHR/KUL3]
1.78	2.71			1.0M $NaClO_4$			[71AHR/KUL3]
1.78	2.80			1.0M $NaClO_4$			[71AHR/KUL3]
1.81	2.71			1.0M $NaClO_4$		est	[71AHR/KUL3]
1.78	2.70	3.18		1.0M $NaClO_4$			[71AHR/KUL3]
1.81	2.76			1.0M $NaClO_4$			[71AHR/KUL3]
1.81	2.80			1.0M $NaClO_4$		est	[71AHR/KUL3]
1.85	2.70			1.0M $NaClO_4$			[71AHR/KUL3]

Cont.

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
1.85	2.80			1.0M $NaClO_4$			[71AHR/KUL3]
1.81				1.0M $NaClO_4$			[71AHR/KUL3]
2.93				H_2O		gl	[71NIK]
1.81	2.29			1.0 M ClO_4^-			[73MAJ]
3.35				H_2O			[76NIK]
3.48[d]				H_2O			[76NIK]
3.62[e]				H_2O			[76NIK]
3.89				H_2O			[76NIK]
2.93				H_2O			[76NIK]
3.20[d]				H_2O			[76NIK]
3.68[e]				H_2O			[76NIK]
4.13[f]				H_2O			[76NIK]
4.37[g]				H_2O			[76NIK]
4.99[h]				H_2O			[76NIK]
5.63[i]				H_2O			[76NIK]
3.10				2M $HClO_4$	M:8x10^{-5}M, L:2M, H:2M		[76PAT/RAM]
1.60				N/A			[83EDE/BUC]
3.22				H_2O	M:54mM, L:1.0M, pH=2.1	cal	[86ULL/SCH]

Cont.

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
1.80				1.37M			[88LEM]
1.60				3.62M			[88LEM]

1) If m = 1, β_{mn} is written β_n

a) T=283 K, b) T=308 K, c) T=313 K, d) T=323 K, e) T=343 K, f) T=363 K, g) T=373 K, h) T=398 K, i) T=423 K, j) T=293K

Equilibrium Constants for Formation of Aqueous UO_2^{2+} complexes with various SO_4^{2-}-species

Reaction	log K	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
$HSO_4^- + UO_2^{2+} \rightleftharpoons UO_2SO_4(aq) + H^+$	0.70	2.0M H_2SO_4	M:20mM, L:2M, H:2M		[49BET/MIC]
$HSO_4^- + UO_2^{2+} \rightleftharpoons UO_2SO_4(aq) + H^+$	0.81	2.0M $NaClO_4$	M:1x10^{-5}M, H:0.05M, L:0.11M	dis	[54DAY/POW]
$HSO_4^- + UO_2^{2+} \rightleftharpoons UO_2SO_4(aq) + H^+$	0.881	2M $HClO_4$	M:8x10^{-5}M, L:2M, H:2M	extr	[76PAT/RAM]

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Equilibrium constants $(\beta_{mn})^1$ for formation of aqueous NpO_2^{2+} complexes with F^- $(mNpO_2^{2+} + nF^- \rightleftharpoons (NpO_2)_mF_n^{(2m-n)+})$

log β_1	log β_2	log β_3	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
4.18	6.96	9.64	0.1M $NaClO_4$	M:4.5mM, H:30mM, L:30mM	pot, F^-	[85SAW/CHA]
4.27			1M $NaClO_4$	M:tr, pH=3, L:6mM	pot, F^-	[84CHO/RAO]
3.94	6.82	8.49	1M $NaClO_4$	M:4.5mM, H:30mM, L:26mM	pot, F^-	[85SAW/CHA]
5.16			1.04M $HClO_4$	M:tr, H:1M, L:70mM	cix	[68KRY/KOM2]
5.16			2.11M $HClO_4$	M:tr, H:2M, L:70mM	cix	[68KRY/KOM2]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants $(\beta_{mn})^1$ for Formation of Aqueous NpO_2^{2+} complexes with F^- $(mNpO_2^{2+} + nHF \rightleftharpoons (NpO_2)_mF_n^{(2m-n)+} + nH^+)$

log β_1	log β_2	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
1.41	1.45	I=0[2]	M:0.4mM, H:0.5M, L:70mM	red	[70ALN/WAI2]
1.20	1.17	0.1M $HClO_4$	M:0.4mM, H:0.1M, L:70mM	red	[70ALN/WAI2]
1.16	1.19	0.2M $HClO_4$	M:0.4mM, H:0.2M, L:70mM	red	[70ALN/WAI2]
1.14	1.20	0.3M $HClO_4$	M:0.4mM, H:0.3M, L:70mM	red	[70ALN/WAI2]
1.12	1.20	0.4M $HClO_4$	M:0.4mM, H:0.4M, L:70mM	red	[70ALN/WAI2]
1.11	1.14	0.5M $HClO_4$	M:0.4mM, H:0.5M, L:70mM	red	[70ALN/WAI2]
0.93	1.11	1M $H(ClO_4,F)$	M:0.44mM, H:1M, L:0.4M	dis	[68AHR/BRA]
1.12		2M $HClO_4$	M:tr, H:2M, L:0.5M	dis	[76PAT/RAM]

1) If m = 1, β_{mn} is written β_n

2) Extrapolated to zero ionic strength from the resuls presented in the same paper

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with Cl^- ($mNpO_2^{2+} + nCl^- \rightleftharpoons (NpO_2)_mCl_n^{(2m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
-0.32		0.3M $H(ClO_4,Cl)$	M:0.4mM, H:0.3M, L:0.1M	red	[70ALN/WAI]
-0.36		0.4M $H(ClO_4,Cl)$	M:0.4mM, H:0.4M, L:0.1M	red	[70ALN/WAI]
-0.35		0.5M $H(ClO_4,Cl)$	M:0.4mM, H:0.5M, L:0.1M	red	[70ALN/WAI]
-0.21		2M $NaClO_4$	M:[5], H:[5], L:[5]	sp	[62SYK/TAY]
-0.04	-0.57	2M $H(ClO_4,Cl)$	M:tr, H:2M, L:2M	dis	[78BED/FID]
0.10[2]	-0.70[2]	3M $H(ClO_4,Cl)$	M:tr, H:3M, L:2.7M	kin	[55COH/SUL]
0.0[3]	-0.74[3]	3M $H(ClO_4,Cl)$	M:tr, H:3M, L:1.4M	kin	[55COH/SUL]
-0.09[4]	-0.80[4]	3M $H(ClO_4,Cl)$	M:tr, H:3M, L:1.4M	kin	[55COH/SUL]
-0.36	-0.94	3M $H(ClO_4,Cl)$	M:tr, H:3M, L:1.4M	kin	[55COH/SUL]
-0.16		4M $Na(ClO_4,Cl)$	M:tr, H:0.1M, L:3.5M	dis	[71DAN/CHI]
-0.46		4M $Na(ClO_4,Cl)$	M:tr, H:0.1M, L:3.5M	dis	[74DAN/CHI]

1) If m = 1, β_{mn} is written β_n
2) T=273 K
3) T=278 K
4) T=283 K
5) No experimental details given in the paper

Equilibrium Constants $(\beta_{mn})^1$ for Formation of Aqueous NpO_2^{2+} complexes with NO_3^- $(mNpO_2^{2+} + nNO_3^- \rightleftharpoons (NpO_2)_m(NO_3)_n^{(2m-n)+})$

log β_1	log β_2	Medium	Maximum Metal/H⁺/Ligand Concentration	Method	Reference
-0.98		0.4M $H(ClO_4,NO_3)$	M:0.4mM, H:0.4M, L:0.1M	red	[70ALN/WAI]
-0.89		0.5M $H(ClO_4,NO_3)$	M:0.4mM, H:0.5M, L:0.2M	red	[70ALN/WAI]
-0.96		0.6M $H(ClO_4,NO_3)$	M:0.4mM, H:0.6M, L:0.2M	red	[70ALN/WAI]
-0.94		0.8M $H(ClO_4,NO_3)$	M:0.4mM, H:0.8M, L:0.2M	red	[70ALN/WAI]
-0.4		2M $H(ClO_4,NO_3)$	M:7mM, H:2M, L:2M	kin	[66RYK/YAK]
-0.68		4M Na (ClO_4,NO_3)	M:tr, H:0.1M, L:3.5M	cix	[71DAN/CHI]
-0.57	-0.55	8M $H(ClO_4,NO_3)$	M:tr, H:8M, L:8M	dis	[70LAH/KNO]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants $(\beta_{mn})^1$ for Formation of Aqueous NpO_2^{2+} complexes with OH^- $(mNpO_2^{2+} + nH_2O \rightleftharpoons (NpO_2)_mOH_n^{(2m-n)+} + nH^+)$

log β_1	log β_2	Other log β_{mn}	Medium	Maximum Metal/H⁺/Ligand Concentration	Method	Reference
-3.37	-5.44		I=0[2]	M:9mM, pH=2.7	sol	[71MOS3]
-5.4			I=0	M:0.5mM, pH=3.95	pr/tc	[83SCH/GOR]
-5.17		log $\beta_{2,2}$=-6.68 log $\beta_{3,5}$=-18.25	1M $NaClO_4$	M.80mM, H:1mM	gl	[72CAS/MAG2]

1) If m = 1, β_{mn} is written β_n

2) No information about medium is given in the paper, the results are extrapolated to zero ionic strength

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with OH^- ($mNpO_2^{2+} + nOH^- \rightleftharpoons (NpO_2)_mOH_n^{(2m-n)+}$)

log β_2	log β_3	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
	19.61	0.1M $NaClO_4$	M:1mM, pH=13	sol	[95MOR/PRA]
21.41		0.3M $(NH_4)_2CO_3$	M:20mM, pH=9, L:0.3M	sol	[71MOS2]

1) If m = 1, β_{mn} is written β_n

Other Equilibrium Constants for Formation of Aqueous NpO_2^{2+} Complexes with OH^-

Reaction	log K	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
$NpO_2(OH)_{2(aq)} + NpO_2OH^+ \rightleftharpoons (NpO_2)_2(OH)_3^+$	-3.54	I=0[1]	M:9mM, pH=2.7	sol	[71MOS3]
$NpO_2(OH)_{2(aq)} + NpO_2(OH)_3^- \rightleftharpoons (NpO_2)_2(OH)_5^-$	-4.66	I=0[1]	M:9mM, pH=2.7	sol	[71MOS3]

1) No information about medium is given in the paper, the results are extrapolated to zero ionic strength

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with CO_3^{2-} ($mNpO_2^{2+} + nCO_3^{2-} \rightleftharpoons (NpO_2)_m(CO_3)_n^{(m-n)+}$)

log β_2	log β_3	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
14.2		I=0[2]	M:20mM, pH=9, L:0.3M	sol	[71MOS2]
17.95		I=0[3]	M:50mM, pH=3, L:0.5M	cal	[88ULL/SCH]
	<17.78	0.1M $NaClO_4$	M:1mM, pH=13, L:0.1M	sol	[95MOR/PRA]
13.0		0.3M $(NH_4)_2CO_3$	M:20mM, pH=9, L:0.3M	sol	[71MOS2]
	22.00	1M $Na_2(SO_4,CO_3)$	M:50mM, H[4], L:0.3M	cal	[85SCH/FRI]

1) If m = 1, β_{mn} is written β_n

2) Varying concentrations of $(NH_4)_2CO_3$ (0.1-0.3M) used as medium. The result is extrapolated to zero ionic strength.

3) Varying concentrations of Na_2CO_3 and Na_2SO_4 used as medium, giving varying ionic strength. The results are extrapolated to zero Ionic strength.

4) pH not mentioned in the paper

Other Equilibrium Constants for Formation of Aqueous NpO_2^{2+} Complexes with Various CO_3^{2-}-species

Reaction	log K	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
$CO_3^{2-} + NpO_2(OH)_2CO_3^{2-} \rightleftharpoons NpO_2(CO_3)_2^{2-} + 2OH^-$	-8.82	0.3M $(NH_4)_2CO_3$	M:20mM, pH=9, L:0.3M	sol	[71MOS2]
$NpO_2^+ + 2OH^- + CO_3^{2-} \rightleftharpoons NpO_2(OH)_2CO_3^{2-}$	20.21	~0.1M $Na(ClO_4,CO_3)$	M:0.3mM, pH=9.6, L:0.17M	sol	[93PRA/MOR]
$NpO_2^+ + 2OH^- + CO_3^{2-} \rightleftharpoons NpO_2(OH)_2CO_3^{2-}$	20.11	0.1M $NaClO_4$	M:1mM, pH=13, L:0.1M	sol	[95MOR/PRA]
$2CO_2(g) + NpO_2^{2+} \rightleftharpoons NpO_2(CO_3)_2^{2-} + 2H^+$	17.71	1M $NaClO_4$	M:1mM, pH=5, pCO_2=1	gl	[84MAY]
$3CO_2(g) + NpO_2^{2+} \rightleftharpoons NpO_2(CO_3)_3^{4-} + 3H^+$	30.18	1M $NaClO_4$	M:1mM, pH=5, pCO_2=1	gl	[84MAY]
$CO_2(g) + 2NpO_2^{2+} + 3H_2O \rightleftharpoons (NpO_2)_2(OH)_2CO_3^{2-} + 4H^+$	18.60	1M $NaClO_4$	M:1mM, pH=5, pCO_2=1	gl	[84MAY]
$3NpO_2(CO_3)_3^{4-} \rightleftharpoons (NpO_2)_3(CO_3)_6^{6-} + 3CO_3^{2-}$	-10.1	3M $NaClO_4$	M:20mM, L:0.1M	sp	[86GRE/RIG]

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with HPO_4^{2-} $(mNpO_2^{2+} + nHPO_4^{2-} \rightleftharpoons (NpO_2)_m(HPO_4)_n^{(m-n)+})$

log β_1	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
8.18	I=0[2]	[2]	dis	[69MOS]
7.18	I=0.5[2]	[2]	dis	[69MOS]

1) If m = 1, β_{mn} is written β_n
2) No details of the experiment is given in the paper.

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with $H_2PO_4^-$ ($mNpO_2^{2+} + nH_2PO_4^- \rightleftharpoons (NpO_2)_m(H_2PO_4)_n^{(2m-n)+}$)

log β_1	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
2.3	I=0[2]	[2]	dis	[69MOS]
1.66	I=0.5[2]	[2]	dis	[69MOS]

1) If m = 1, β_{mn} is written β_n
2) No details of the experiment is given in the paper.

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with SO_4^{2-} ($mNpO_2^{2+} + nSO_4^{2-} \rightleftharpoons (NpO_2)_m(SO_4)_n^{(m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
3.45	4.4	I=0[2]	M:50mM, pH=2, L:0.25M	cal	[86ULL/SCH]
		I=0[3]	M:0.4mM, H:0.5M, L:50mM	red	[70ALN/WAI2]
2.44		0.1M $HClO_4$	M:0.4mM, H:0.1M, L:8mM	red	[70ALN/WAI2]
2.27		0.2M $HClO_4$	M:0.4mM, H:0.2M, L:18mM	red	[70ALN/WAI2]
2.18		0.3M $HClO_4$	M:0.4mM, H:0.3M, L:30mM	red	[70ALN/WAI2]
2.10		0.4M $HClO_4$	M:0.4mM, H:0.4M, L:45mM	red	[70ALN/WAI2]
2.07		0.5M $HClO_4$	M:0.4mM, H:0.5M, L:50mM	red	[70ALN/WAI2]
1.11		1M $HClO_4$	[4]	red	[58STR/PEE]
1.90	2.78	1M (H,Na)ClO_4	M:tr, H:1M, L:65mM	dis	[68AHR/BRA2]
1.64		2M $NaClO_4$	[4]	sp	[62SYK/TAY]

1) If m = 1, β_{mn} is written β_n
2) Varying concentrations of Na_2SO_4 used as medium, giving varying ionic strength. The results are extrapolated to zero ionic strength
3) Extrapolated to zero ionic strength from the results given in the same paper
4) No experimental details availableEquilibrium Constants for Formation of Aqueous NpO_2^{2+} complexes with various SO_4^{2-}-species

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with HSO_4^-

Reaction	log K	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
$HSO_4^- + NpO_2^{2+} \rightleftharpoons NpO_2SO_{4(aq)} + H^+$	1.07	2M H(ClO_4,SO_4)	M:tr, H:2M, L:0.9M	dis	[76PAT/RAM]
$2HSO_4^- + NpO_2^{2+} \rightleftharpoons NpO_2(SO_4)^{2-} + 2H^+$	0.60	2M H(ClO_4,SO_4)	M:tr, H:2M, L:0.9M	dis	[76PAT/RAM]

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Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with F^- ($mPuO_2^{2+} + nF^- \rightleftharpoons (PuO_2)_mF_n^{(2m-n)+}$)

log β_1	log β_2	log β_3	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
4.11	6.92	9.01	0.1M $NaClO_4$	M:10mM, H:28mM, L:21mM	pot, F^-	[85SAW/CHA]
4.22			1M $NaClO_4$	M:0.05mM, pH=3, L:6mM	pot, F^-	[84CHO/RAO]
3.84	6.31	7.73	1M $NaClO_4$	M:17mM, H:28mM, L:38mM	pot, F^-	[85SAW/CHA]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with F^- ($mPuO_2^{2+} + nHF \rightleftharpoons (PuO_2)_mF_n^{(2m-n)+} + nH^+$)

log β_1	log β_2	log β_3	log β_4	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
2.11	4.15	6.08	6.3	1M $HClO_4$	M:tr, H:1M, L:0.06M	cix	[68KRY/KOM]
2	3.82	5	6.68	2M $HClO_4$	M:tr, H:2M, L:0.06M	cix	[68KRY/KOM]
1.079				2M $HClO_4$	M:tr, H:2M, L:0.5M	dis	[76PAT/RAM]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with Cl^- ($mPuO_2^{2+} + nCl^- \rightleftharpoons (PuO_2)_mCl_n^{(2m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
0.0969	-0.456	2M $HCl/HClO_4$	M:[7], H:2M, L:2M	sp	[57NEW/BAK]
0.085	-0.43	2M $H(Cl,ClO_4)$	M:[7], H:2M, L:2M	sp	[61RAB/MAS]
-0.04[2]	-0.68[2]	2M $H(Cl,ClO_4)$	M:[7], H:2M, L:2M	sp	[61RAB/MAS]
0.0[3]	-0.60[3]	2M $H(Cl,ClO_4)$	M:[7], H:2M, L:2M	sp	[61RAB/MAS]
0.03[4]	-0.55[4]	2M $H(Cl,ClO_4)$	M:[7], H:2M, L:2M	sp	[61RAB/MAS]
0.06[5]	-0.48[5]	2M $H(Cl,ClO_4)$	M:[7], H:2M, L:2M	sp	[61RAB/MAS]
0.11[6]	-0.37[6]	2M $H(Cl,ClO_4)$	M:[7], H:2M, L:2M	sp	[61RAB/MAS]
-0.10	-0.43	2M $H(Cl,ClO_4)$	M:tr, H:2M, L:2M	dis	[78BED/FID]
0.1	-0.8	4.1M $H(Cl,ClO_4)$	M:tr, H:4.1M, L:2M	dis	[65MAZ/SIV]

1) If m = 1, β_{mn} is written β_n
2) T=276 K
3) T=283 K
4) T=288 K
5) T=293 K
6) T=303 K

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with NO_3^- ($mPuO_2^{2+} + nNO_3^- \rightleftharpoons (PuO_2)_m(NO_3)_n^{(2m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H+/Ligand Concentration	Method	Reference
1.86	3.41	2mM HNO_3	M:10mM, pH=2.7, L:2mM	gl	[59KRE/NIK]
-0.03		4.1M H(Cl,NO_3)	M:tr, H:4.1M, L:2M	dis	[65MAZ/SIV]
-0.6		I=4.6	2	dis	[52HEI/HIC]
-0.57	-0.55	8M H(ClO_4,NO_3)	M:tr, H:8M, L:8M	dis	[70LAH/KNO]
	4.65	1-15M HNO_3	M:1e-3M, H:15M, L:15M	sp	[75VAS/AND]

1) If m = 1, β_{mn} is written β_n
2) Noexperimental details avaiable

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with OH^- ($mPuO_2^{2+} + nOH^- \rightleftharpoons (PuO_2)_mOH_n^{(2m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H+/Ligand Concentration	Method	Reference
8.84		I=0[2]	M:0.05M, pH=6	sp	[93PAS/KIM2]
8.69	17.58	1M $NaClO_4$	M:0.05M, pH=6	sp	[93PAS/KIM2]

1) If m = 1, β_{mn} is written β_n
2) Extrapolated to zero ionic strength using the results in the same paper

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with OH^- ($mPuO_2^{2+} + nH_2O \rightleftharpoons (PuO_2)_mOH_n^{(2m-n)+} + nH^+$)

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
-6.3				I=0	M:0.5mM, pH3.79	pr/tc	[83SCH/GOR]
-3.33	-4.05			2mM HNO_3	M:10mM, pH=2.74	gl	[59KRE/NIK]
-3.85	-7.4		log $\beta_{2,3}$=-10.6	0.1M $NaClO_4$	M:1.5mM, pH=0.5	sp	[73MUS/POR]
-5.5	-7.2	-19.0	log $\beta_{2,2}$=-5.6 log $\beta_{3,5}$=-12.7	0.1M $NaClO_4$		sol/sp	[86LIE/KIM]
-6.3	-7.3			0.1M $NaClO_4$	M:tr, pH=3	sp	[93OKA/REE]
-5.71				1M $NaClO_4$	M:0.13M, pcH=4.7	gl	[49KRA/DAM]
-5.97			log $\beta_{2,2}$=-8.51 log $\beta_{3,5}$=-22.16	1M $NaClO_4$		gl	[72CAS/MAG]
			log $\beta_{2,2}$=-8.01 log $\beta_{3,5}$=-21.33	1M $Na(ClO_4,Cl)$	M:0.1M, pH=1.62	Ram	[84MAD/BEG]
			log $\beta_{2,2}$=-8.21 log $\beta_{3,5}$=-21.72	3M $NaClO_4$	M:0.13M, pH=3	gl	[71SCH]
			log $\beta_{2,2}$=-8.23	3M $NaClO_4$	M:0.2M, pH=3	gl	[75SCH]
-3.39	-5.25			varying	M:60mM, pH=3.3	sol	[62MOS/ZAI]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with CO_3^{2-} ($mPuO_2^{2+} + nCO_3^{2-} \rightleftharpoons (PuO_2)_m(CO_3)_n^{(m-n)+}$)

log β_1	log β_2	log β_3	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
12	15.1		I=0[2]	M:tr, pH=9.5, L:0.44M	sol	[62GEL/MOS]
	15.1	18.5	I=0[3]	M:15mM, pH=2.8, L:0.2M	cal	[88ULL/SCH]
8.7	14.1	17.8	0.1M $NaClO_4$	M:1mM, pH=3.5, pCO_2=1	sol	[97PAS/CZE]
8.6	13.6	18.2	3M $NaClO_4$	M:2, pH=5, L:3mM	sp	[87ROB/VIT]

1) If m = 1, β_{mn} is written β_n
2) Varying concentrations of $(NH_4)_2CO_3$ (0-0.44M) used as medium. The results are extrapolated to zero ionic strength
3) Varying concentrations of Na_2CO_3 and Na_2SO_4 used as medium, giving varying ionic strength. The results are extrapolated to zero ionic strength

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with HCO_3^- ($mPuO_2^{2+} + nHCO_3^- \rightleftharpoons (PuO_2)_m(HCO_3)_n^{(2m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
2.67	4.39	0.1M $NaClO_4$	M:5mM, pH=8.3, L:0.1M	sp/cal	[82SUL/WOO]

1) If m = 1, β_{mn} is written β_n

Other Equilibrium Constants for Formation of Aqueous PuO_2^{2+} Complexes with Various CO_3^{2-}-species

Reaction	log K	Medium	Maximum Metal/H+/Ligand Concentration	Method	Reference
$2HCO_3^- + PuO_2(OH)_2(aq) \rightleftharpoons PuO_2(CO_3)_2^{2-}$	4.36	0.1M $NaClO_4$	M:0.005M, pH=8.3, L:0.1M	sp/cal	[82SUL/WOO]
$CO_3^{2-} + OH^- + PuO_2^{2+} \rightleftharpoons PuO_2OHCO_3^-$	23.85	I=0[1]	M:tr, pH=9.5, L:0.44M	sol	[62GEL/MOS]
$CO_3^{2-} + 2OH^- + PuO_2^{2+} \rightleftharpoons PuO_2(OH)_2CO_3^-$	23	I=0[1]	M:tr, pH=9.5, L:0.44M	sol	[62GEL/MOS]
$HCO_3^- + PuO_2(OH)_2(aq) \rightleftharpoons PuO_2(OH)_2HCO_3^-$	2.67	0.1M $NaClO_4$	M:5mM, pH=8.3, L:0.1M	sp/cal	[82SUL/WOO]
$3PuO_2(CO_3)_3^{4-} \rightleftharpoons (PuO_2)_3(CO_3)_6^{6-} + 3CO_3^{2-}$	-7.4	3M $NaClO_4$	M:16mM, L:0.1M	sp	[86GRE/RIG]

Equilibrium Constants $(\beta_{mn})^1$ for Formation of Aqueous PuO_2^{2+} complexes with HPO_4^{2-} $(mPuO_2^{2+} + nHPO_4^{2-} \rightleftharpoons (PuO_2)_m(HPO_4)_n^{(2m-2n)+})$

log β_1	Medium	Maximum Metal/H+/Ligand Concentration	Method	Reference
8.19	I=0[2]	[2]	dis	[69MOS]

1) If m = 1, β_{mn} is written β_n
2) No experimental details are given in the paper

Equilibrium Constants $(\beta_{mn})^1$ for Formation of Aqueous PuO_2^{2+} complexes with $H_2PO_4^{2-}$ $(mPuO_2^{2+} + nH_2PO_4^{2-} \rightleftharpoons (PuO_2)_m(H_2PO_4)_n^{(2m-n)+})$

log β_1	Medium	Maximum Metal/H+/Ligand Concentration	Method	Reference
2.3	I=0[2]	[2]	dis	[69MOS]
1.66	I=0.5[2]	[2]	dis	[69MOS]
3.93	0.02-0.2 M H_3PO_3	M:tr, H:0.05M, L:0.175M	sol	[67DEN/SHE]

1) If m = 1, β_{mn} is written β_n
2) no experimental details are given in the paper

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with SO_4^{2-} ($mPuO_2^{2+} + nSO_4^{2-} \rightleftharpoons (PuO_2)_m(SO_4)_n^{(m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H⁺/Ligand Concentration	Method	Reference
3.45	4.4	I=0[2]	M:0.05M, pH=2.1, L:0.25M	cal	[86ULL/SCH]

1) If m = 1, β_{mn} is written β_n

2) Varying concentrations of Na_2SO_4 used as medium, giving varying ionic strength. The results are, however only given for I=0; Davies equation has been used to recalculate the experimental obtained stability constants.

Equilibrium Constants for Formation of Aqueous PuO_2^{2+} complexes with various SO_4^{2-}-species

Reaction	log K	Medium	Maximum Metal/H⁺/Ligand Concentration	Method	Reference
$HSO_4^- + PuO_2^{2+} \rightleftharpoons PuO_2SO_{4(aq)} + H^+$	1.16	2M $HClO_4$	M:tr, H:2M, L:0.86M	dis	[76PAT/RAM]

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Tables of Solubility Products for AnO_2^+

(NpO_2^+)

Np(V) solubility product with Carbonates and Sodium:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$Na^+ + NpO_2^+ + CO_3^{2-} = NaNpO_2CO_{3(s)}$	-10.14	1.0 $NaClO_4$	M:3mM, L:1.0mM	sol	[83MAY]
$Na^+ + NpO_2^+ + CO_3^{2-} = NaNpO_2CO_{3(s)}$	-10.56	3.0 $NaClO_4$	M:1mM, L:0.5M	sol	[86GRE/ROB]
$Na^+ + NpO_2^+ + CO_3^{2-} = NaNpO_2CO_{3(s)}$	-9.77[a]	1.0 NaCl		sol	[94RUN/KIM]
$Na^+ + NpO_2^+ + CO_3^{2-} = NaNpO_2CO_{3(s)}$	-9.61[a]	5.0 NaCl		sol	[94RUN/KIM]
$Na^+ + NpO_2^+ + CO_3^{2-} = NaNpO_2CO_{3(s)}$	-10.28	0.1M $NaClO_4$	M:0.2mM, L:10^{-3}atm, 6.8<pH<10.5	sol	[95NEC/RUN]
$Na^+ + NpO_2^+ + CO_3^{2-} = NaNpO_2CO_{3(s)}$	-10.10	1.0M $NaClO_4$	M:0.2mM, L:10^{-3}atm, 6.8<pH<10.5	sol	[95NEC/RUN]
$Na^+ + NpO_2^+ + CO_3^{2-} = NaNpO_2CO_{3(s)}$	-10.45	3.0M $NaClO_4$	M:0.2mM, L:10^{-3}atm, 6.8<pH<10.5	sol	[95NEC/RUN]
$Na^+ + NpO_2^+ + CO_3^{2-} = NaNpO_2CO_{3(s)}$	-11.06	5.0M $NaClO_4$	M:0.2mM, L:10^{-3}atm, 6.8<pH<10.5	sol	[95NEC/RUN]
$Na^+ + NpO_2^+ + CO_3^{2-} = NaNpO_2CO_{3(s)}$	-11.00°	I = 0	M:0.2mM, L:10^{-3}atm, 6.8<pH<10.5	est	[95NEC/RUN]
$Na^+ + NpO_2^+ + CO_3^{2-} = NaNpO_2CO_{3(s)}$	-10.63	5.0M NaCl	M:0.2mM, L:10^{-3}atm, 6.8<pH<10.5	sol	[95NEC/RUN]
$Na^+ + NpO_2^+ + CO_3^{2-} = NaNpO_2CO_{3(s)}$	-10.4[a]	1.0M NaCl	M:10mM, L:0.1M, 7<pH<13	soi	[96RUN/NEU]
$Na^+ + NpO_2^+ + CO_3^{2-} = NaNpO_2CO_{3(s)}$	-9.4[a]	3.0M NaCl	M:10mM, L:0.1M, 7<pH<13	sol	[96RUN/NEU]

o) log Ksp°, a)296K

Np(V) solubility product with Carbonates and Sodium:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$3Na^{+} + NpO_2^{+} + 2CO_3^{2-} = Na_3NpO_2(CO_3)_{2(s)}$	-12.44	3.0M $NaClO_4$	M:1mM, L:0.5M	sol	[86GRE/ROB]
$3Na^{+} + NpO_2^{+} + 2CO_3^{2-} = Na_3NpO_2(CO_3)_{2(s)}$	-11.46[a]	5.0M NaCl		sol	[94RUN/KIM]
$3Na^{+} + NpO_2^{+} + 2CO_3^{2-} = Na_3NpO_2(CO_3)_{2(s)}$	-12.23	1.0M $NaClO_4$	M:0.2mM, L:10^{-3}atm, 6.8<pH<10.5	sol	[95NEC/RUN]
$3Na^{+} + NpO_2^{+} + 2CO_3^{2-} = Na_3NpO_2(CO_3)_{2(s)}$	-12.59	3.0M $NaClO_4$	M:0.2mM, L:10^{-3}atm, 6.8<pH<10.5	sol	[95NEC/RUN]
$3Na^{+} + NpO_2^{+} + 2CO_3^{2-} = Na_3NpO_2(CO_3)_{2(s)}$	-13.57	5.0M $NaClO_4$	M:0.2mM, L:10^{-3}atm, 6.8<pH<10.5	sol	[95NEC/RUN]
$3Na^{+} + NpO_2^{+} + 2CO_3^{2-} = Na_3NpO_2(CO_3)_{2(s)}$	-14.32°	I = 0	M:0.2mM, L:10^{-3}atm, 6.8<pH<10.5	est	[95NEC/RUN]
$3Na^{+} + NpO_2^{+} + 2CO_3^{2-} = Na_3NpO_2(CO_3)_{2(s)}$	-12.48	5.0M NaCl	M:0.2mM, L:1atm, 6.8<pH<10.5	sol	[95NEC/RUN]

o) log Ksp°, a)296K

Np(V) solubility product with Hydroxide:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$NpO_2^{2+} + 2OH^- = NpO_2(OH)_{2(s)}$	-9.20	0.1M NaCl	M:mM, 6<pH<13	titr	[48KRA/NEL]
$NpO_2^+ + OH^- + xH_2O =$ $NpO_2(OH)\cdot xH_2O_{(s)}$	-9.02[b]	dil $NaClO_4/NH_3$	M: 25mM, pH:6.6	spec	[71MOS]
$NpO_2^+ + OH^- + xH_2O =$ $NpO_2(OH)\cdot xH_2O_{(s)}$	-9.73[a]	0.02M $(Na,H)NO_3$	M: 10mM, pH:7.7	spec	[76SEV/KHA]
$NpO_2^+ + OH^- = NpO_2(OH)_{(s)}$	-8.81	1.0M $NaClO_4$	M:1x10^{-5}mM, 6<pH<13	gl	[85LIE/TRE]
$NpO_2^+ + OH^- = NpO_2(OH)_{(s)}$	-10.7	0.01M $NaNO_3$	M:0.1mM, 6<pH<13	sol	[88NAK/ARI]
$NpO_2^+ + OH^- = NpO_2(OH)_{(am)}$	-8.56	0.1M $NaClO_4$	M:30mg, 7.3<pH<13.7	ls,spec	[92NEC/KIM]
$NpO_2^+ + OH^- = NpO_2(OH)_{(am)}$	-8.76[c]	I = 0	M:30mg, 7.3<pH<13.7	ls,spec	[92NEC/KIM]
$NpO_2^+ + OH^- = NpO_2(OH)_{(cr)}$	-9.30	1.0M $NaClO_4$	M:30mg, 7.3<pH<13.7	est	[92NEC/KIM]
$NpO_2^+ + OH^- = NpO_2(OH)_{(cr)}$	-9.85	3.0M $NaClO_4$	M:30mg, 7.3<pH<13.7	ls,spec	[92NEC/KIM]
$NpO_2^+ + OH^- = NpO_2(OH)_{(cr)}$	-9.44[c]	I =0	M:30mg, 7.3<pH<13.7	est	[92NEC/KIM]
$NpO_2^+ + OH^- = NpO_2(OH)_{(s)}$	-10.21	0.8M $NaClO_4$	M:20mM, 7.0<pH<13.5	sol,prop	[92ITA/NAK]
$NpO_2^+ + OH^- = NpO_2(OH)_{(s)}$	-9.61	0.4M $NaClO_4$	M:20mM, 7.0<pH<13.5	sol,prop	[92ITA/NAK]
$NpO_2^+ + OH^- = NpO_2(OH)_{(s)}$	-8.94	0.1M $NaClO_4$	M:20mM, 7.0<pH<13.5	sol,prop	[92ITA/NAK]
$NpO_2^+ + OH^- = NpO_2(OH)_{(s)}$	-8.91	0.05M $NaClO_4$	M:20mM, 7.0<pH<13.5	sol,prop	[92ITA/NAK]
$NpO_2^+ + OH^- = NpO_2(OH)_{(s)}$	-8.04	0.012M $NaClO_4$	M:20mM, 7.0<pH<13.5	sol,prop	[92ITA/NAK]
$NpO_2^+ + OH^- = NpO_2(OH)_{(s)}$	-8.68[c]	I = 0	M:20mM, 7.0<pH<13.5	est	[92ITA/NAK]
$NpO_2^+ + OH^- = NpO_2(OH)_{(s)}$	-9.56[a]	5.0M NaCl		sol	[94RUN/KIM]
$NpO_2^+ + OH^- = NpO_2(OH)_{(am)}$	-8.61[c]	0.3M NaCl	M:0.3mM, pH<10	sol	[96ROB/SIL]
$NpO_2^+ + OH^- = NpO_2(OH)_{(am)}$	-8.56[c]	0.59M NaCl	M:0.3mM, pH<10	sol	[96ROB/SIL]

Cont.

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$NpO_2^+ + OH^- = NpO_2(OH)_{(am)}$	-8.51[c]	0.98 NaCl	M:0.3mM, pH<10	sol	[96ROB/SIL]
$NpO_2^+ + OH^- = NpO_2(OH)_{(am)}$	-8.56[c]	1.7M NaCl	M:0.3mM, pH<10	sol	[96ROB/SIL]
$NpO_2^+ + OH^- = NpO_2(OH)_{(am)}$	-8.73[c]	2.8M NaCl	M:0.3mM, pH<10	sol	[96ROB/SIL]
$NpO_2^+ + OH^- = NpO_2(OH)_{(am)}$	-9.02[c]	5.0M NaCl	M:0.3mM, pH<10	sol	[96ROB/SIL]
$NpO_2^+ + OH^- = NpO_2(OH)_{(am)}$	-8.79[oc]	I = 0	M:0.3mM, pH<10	sol	[96ROB/SIL]

o) log Ksp°, a)296K, b)293K, c)294K

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Tables of Solubility Products for AnO_2^{2+}

(UO_2^{2+}, NpO_2^{2+} and PuO_2^{2+})

U(VI) solubility product with Carbonates:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-10.73	0.2M NH_4NO_3	M:10mM, 7.0<ph<9.0, L:1M H_2CO_3	col	[60BAB/KOD]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-14.26	var	M:2.5mM, ph<7.0, L:1 atm	col	[72SER/NIK]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-14.37	var 50C	M:1.2mM, ph<7.0, L:1 atm	col	[72SER/NIK]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-14.90	H_2O 100C	M:0.4mM, ph<7.0, L:1 atm	col	[72SER/NIK]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-15.72	H_2O 150 C	M:0.5mM, ph<7.0, L:1 atm	col	[72SER/NIK]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-16.69	H_2O 200 C	M:0.6mM, ph<7.0, L:1 atm	col	[72SER/NIK]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-17.82	250 C		est	[72SER/NIK]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-19.02	300 C		est	[72SER/NIK]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-14.50° -14.15 -14.84[d] -15.04[f] -15.22[g] -16.14[h] -17.4[i]	I = 0.01 M	4.18<ph< 3.67, L=2 atm	sol	[76NIK]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-14.46[m]	I=0 M		est,rev	[78LAN]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-14.2[o] -14.7[oe] -15[og] -17[oi] -18[oj]			est	[80LEM/TRE]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-14.4	I = 0 M	6.3<pH<3.5, L: 0.98 atm	est	[84GRE/FER]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-13.21	0.5M $NaClO_4$	6.3<pH<3.5, L:0.98 atm	sol	[84GRE/FER]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-13.94	3.0M $NaClO_4$	6.3<pH<3.5, L: 0.97 atm	sol	[84GRE/FER]

Cont.

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-13.29	0.1M $NaClO_4$	M: 0.01 M, ph<6.7, L:1 atm	gl,sol	[92KRA/BIS]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-14.47[o]			est	[92GRE]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-14.18	0.1M $NaClO_4$	L:1 atm		[93MEI/KIM]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-13.89[c]	0.1M $NaClO_4$	M:2 mM, 2.8<ph<4.6, L:1 atm	gl, pot	[93MEI/KIMA]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-13.35[a] -14.22[oa]	0.1M $NaClO_4$	M:18.6 mM, pH<4.0, L: 1 atm	sp, ICP-AES, est	[93PAS/RUN]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-14.49°			est	[95SIL/BID]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-14.10	0.1M $NaClO_4$	M:20 mM, ph<5.0, L:1 atm	sol,ls	[96KAT/KIM]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-13.50	0.1M $NaClO_4$	M:>10^{-5}M, ph<6.3, L:100 kPa	uv-vis,sp	[96MEI/KLE]
$UO_2^{2+} + CO_3^{2-} = UO_2CO_{3(s)}$	-14.47[oa]	0.1M $NaClO_4$	M:0.4 mM, ph<6.0, L:1 atm	sol,est	[97PAS/CZE]

o) log Ksp°, a)295K, b)293K, c)297K, d)323K, e)333K, f)348K, g)373K, h)398K, i)423K, j)473K, k)523K, l)573K, m)calculated from fit of literature data between 25-300°C K_{sp} = 4.54-0.03318T-2716/T

U(VI) solubility product with Hydroxide:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$UO_2^{2+} + 2OH^- = UO_2(OH)_{2(s)}$	-23.5	0.1 M $NaNO_3$			[43KRA/NEL]
$UO_2^{2+} + 2OH^- = UO_2(OH)_{2(s)}$	-21.9	NH_3/HNO_3	M:4.2mM, 4.5<pH<6.2	sol	[54MIL]
$UO_2^{2+} + 2OH^- = UO_2(OH)_{2(s)}$	-21.74	0.2 M NH_4NO_3	m:150mM, 3.6<pH<5.3	sol,col	[60BAB/KOD]
$UO_2^{2+} + 2OH^- = UO_2(OH)_{2(s)}$	-22.44[o,n]			est,rev	[78LAN]
$UO_2^{2+} + 2OH^- = UO_2(OH)_{2(s)}$	-22.4[o]			est	[80ALL/KIP]
$UO_2^{2+} + 2OH^- = UO_2(OH)_{2(s)}$	-22.21	0.1M $NaClO_4$	M:0.01 M, pH<5.71	ls,gl	[92KRA/BIS]

o) log Ksp°, n)calculated from fit of literature data between 25-300°C K_{sp} = 6.16-0.03261T-5628/T

U(VI) solubility product with Hydroxide:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$UO_2^{2+} + 2OH^- = UO_3 \cdot H_2O_{(s)}$	-21.96	$NaOH/HClO_4$	M:0.65M, 4.1<pH<5.2	sol	[55GAY/LEI]
$UO_2^{2+} + 2OH^- = UO_3 \cdot 2H_2O_{(s)}$	-22.34[c]	0.1 M $NaClO_4$	M:2mM, 2.8<pH<4.6, 0.03 atm CO_2	gl,pot	[93MEI/KIMA]
$UO_2^{2+} + 2OH^- = UO_3 \cdot 2H_2O_{(s)}$	-22.20[c]	0.1 M $NaClO_4$	M:2mM, 2.8<pH<4.6, 0.98 atm CO_2	gl,pot	[93MEI/KIMA]
$UO_2^{2+} + 2OH^- = UO_3 \cdot 2H_2O_{(s)}$	-22.28[c]	0.1 M $NaClO_4$	M:2mM, 2.8<pH<4.6	ave	[93MEI/KIMA]
$UO_2^{2+} + 2OH^- = UO_3 \cdot 2H_2O_{(s)}$	-22.15	0.1 M $NaClO_4$	M:20mM, pH<5.0 0.03% CO_2	sol	[96KAT/KIM]
$UO_2^{2+} + 2OH^- = UO_3 \cdot 2H_2O_{(am)}$	-20.34	0.5 M $NaClO_4$	N_2 atm	est	[93MEI/KIM]
$UO_2^{2+} + 2OH^- = UO_3 \cdot 2H_2O_{(cr)}$	-21.26	0.5 M $NaClO_4$	N_2 atm	est	[93MEI/KIMA]

o) log Ksp°,c)297K

U(VI) solubility product with Sodium and Carboxide:

Reaction	log Ksp	Method	Reference
$4Na^{+} + UO_2(CO_3)_3^{4-} = Na_4UO_2(CO_3)_{3(s)}$	-5.340°	est	[92GRE]

o) log Ksp°

U(VI) solubility product with Sulphite:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$UO_2^{2+} + SO_3^{2-} = UO_2SO_{3(s)}$	-8.59	2 M $(NH_4)_2SO_3$	M:0.4M, L:0.2M, pH <7	sol	[59KLY/KOL]

o) log Ksp°,

U(VI) solubility product with Sulphate:

Reaction	log Ksp	Method	Reference
$UO_2^{2+} + SO_4^{2-} + 2.5H_2O = UO_2SO_4 \bullet 2.5H_2O_{(s)}$	-1.589°m	est	[92GRE]
$UO_2^{2+} + SO_4^{2-} + 3.5H_2O = UO_2SO_4 \bullet 3.5H_2O_{(s)}$	-1.585°m	est	[92GRE]

o) log Ksp°,m) calculated from $\Delta_r G°_m$

U(VI) solubility product with Iodate:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$UO_2^{2+} + 2IO_3^{-} = UO_2(IO_3)_{2(s)}$	-7.0	0.2 M NH_4Cl	M:M, L:0.2M, 2.03<pH<4.75	sol	[59KLY/SMI2]
$UO_2^{2+} + 2IO_3^{-} = UO_2(IO_3)_{2(s)}$	-6.65e	0.2 M NH_4Cl	M:M, L:0.2M, 2.03<pH<4.75	sol	[59KLY/SMI2]
$UO_2^{2+} + 2IO_3^{-} = UO_2(IO_3)_{2(s)}$	-7.88°			est	[92GRE]

o) log Ksp°, e) 333K

U(VI) solubility product with phosphate:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$4H_2O + UO_2^{2+} + HPO_4^{2-} = UO_2HPO_4 \cdot 4H_2O_{(s)}$	-12.17	0.3M var	M:7.7mM, L:81mM, 0.7<pH<2.0	sol	[65VES/PEK]
$4H_2O + UO_2^{2+} + H_3PO_4 = 2H^+ + UO_2HPO_4 \cdot 4H_2O_{(s)}$	-2.500°	I = 0M		est	[92GRE]
$4H_2O + 3UO_2^{2+} + 2PO_4^{3-} = (UO_2)_3(PO_4)_2 \cdot 4H_2O_{(s)}$	-49.7	0.3M var	M:56mM, L:0.37mM, 0.6<pH<2.0	sol	[65VES/PEK]
$4H_2O + 3UO_2^{2+} + 2PO_4^{3-} = (UO_2)_3(PO_4)_2 \cdot 4H_2O_{(s)}$	-48.48	0.5M $NaClO_4$	L:0.1M, 3<pH<9	sol	[91SAN]
$4H_2O + 3UO_2^{2+} + 2H_3PO_4 = 6H^+ + (UO_2)_3(PO_4)_2 \cdot 4H_2O_{(s)}$	-5.960°			est	[92GRE]
$Na^+ + UO_2^{2+} + PO_4^{3-} + xH_2O = UO_2PO_4 \cdot xH_2O_{(s)}$	-24.21	0.22M var	M:7.7mM, L:81mM, pH:1.5	sol	[65VES/PEK]
$K^+ + UO_2^{2+} + PO_4^{3-} + xH_2O = UO_2PO_4 \cdot xH_2O_{(s)}$	-25.50	0.22M var	M:7.7mM, L:81mM, pH:1.5	sol	[65VES/PEK]
$Rb^+ + UO_2^{2+} + PO_4^{3-} + xH_2O = UO_2PO_4 \cdot xH_2O_{(s)}$	-25.72	0.22M var	M:7.7mM, L:81mM, pH:1.5	sol	[65VES/PEK]
$Cs^+ + UO_2^{2+} + PO_4^{3-} + xH_2O = UO_2PO_4 \cdot xH_2O_{(s)}$	-25.41	0.22M var	M:7.7mM, L:81mM, pH:1.5	sol	[65VES/PEK]
$NH_4^+ + UO_2^{2+} + PO_4^{3-} + xH_2O = UO_2PO_4 \cdot xH_2O_{(s)}$	-26.23	0.22M var	M:7.7mM, L:81mM, pH:1.5	sol	[65VES/PEK]

o) log Ksp°,

References

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Np(VI) solubility product with Carbonates:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$NpO_2^{2+} + CO_3^{2-} = NpO_2CO_{3(s)}$	-13.8	var	var	est	[83ALL]
$NpO_2^{2+} + CO_3^{2-} = NpO_2CO_{3(s)}$	-14.62	0.1M $NaClO_4$	M=20mM, pH=2.9-4.9, L=0.8atm	sol,ls	[96KAT/KIM]
$NpO_2^{2+} + CO_3^{2-} = NpO_2CO_{3(s)}$	-13.92	0.1M $NaClO_4$	M=20mM, pH=2.9-6.8, L=0.8atm	sol,ls	[97KAT/KIM]

o) log Ksp°, a)295K, b)293K

Np(VI) solubility product with Hydroxide:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$NpO_2^{2+} + 2OH^- = NpO_2(OH)_{2(s)}$	-22.70^{ob}	var	pH=3.5-8.5	sol,gl	[71MOS]
$NpO_2^{2+} + 2OH^- = NpO_2(OH)_{2(s)}$	-21.4^{o}			est	[76BAE/MES]
$NpO_2^{2+} + 2OH^- = NpO_2(OH)_{2(s)}$	-22.7^{o}			est	[80ALL/KIP]

o) log Ksp°,

Np(VI) solubility product with Hydroxide:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$NpO_2^{2+} + 2OH^- = NpO_3 \bullet H_2O_{(s)}$	-21.72	0.1M $NaClO_4$	M=20mM, pH=2.9-4.9, L=0.0003atm	sol,ls	[96KAT/KIM]
$NpO_2^{2+} + 2OH^- = NpO_3 \bullet H_2O_{(s)}$	-21.74	0.1M $NaClO_4$	M=20mM, pH=2.9-4.9, L=0.0099atm	sol,ls	[96KAT/KIM]

o) log Ksp°,

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Pu(VI) solubility product with Carbonates:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$PuO_2^{2+} + CO_3^{2-} = PuO_2CO_{3(s)}$	-12.8[b]	1M $(NH_4)_2CO_3$	pH=9.5, L=0.44M	sol	[62GEL/MOS]
$PuO_2^{2+} + CO_3^{2-} = PuO_2CO_{3(s)}$	-13.8[o]			est	[83ALL/RYD]
$PuO_2^{2+} + CO_3^{2-} = PuO_2CO_{3(s)}$	-13.5[b]	3.0M $NaClO_4$	M=3.0mM, pH<9.62, L=$10^{-3.5}$ atm	sol	[87ROB/VIT]
$PuO_2^{2+} + CO_3^{2-} = PuO_2CO_{3(s)}$	-13.98[a] -14.84[oa]	0.1M $NaClO_4$	M=1.5 mM, pH<7.0, L= 1 atm	spc, est	[93PAS/RUN]
$PuO_2^{2+} + CO_3^{2-} = PuO_2CO_{3(s)}$	-14.85[oa]	0.1M $NaClO_4$	M=0.4 mM, ph<6.0, L=1 atm	est	[97PAS/CZE]

o) log Ksp°, a)295K, b)293K

Pu(VI) solubility product with Hydroxide:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$PuO_2^{2+} + OH = PuO_2(OH)_{2(s)}$	-22.74	var		sol	[53MAN/FRA]
$PuO_2^{2+} + OH = PuO_2(OH)_{2(s)}$	-20.5	0.1 M $NaNO_3$			[56KRA/NEL]
$PuO_2^{2+} + OH = PuO_2(OH)_{2(s)}$	-22.74	var	pH=3.25	sol	[62MOS/ZAI]
$PuO_2^{2+} + OH = PuO_2(OH)_{2(s)}$	-24.52	0.186mM HNO_3	M: mM,	sol	[62GEL/MOS]
$PuO_2^{2+} + OH = PuO_2(OH)_{2(s)}$	-24.05	0.1M $NaClO_4$	M: 1.51mM, pH<7.5	abs,spc	[73MUS/POR]
$PuO_2^{2+} + OH = PuO_2(OH)_{2(s)}$	-22.8[o]			est	[80ALL/KIP]
$PuO_2^{2+} + OH = PuO_2(OH)_{2(s)}$	-23.0[o]			est	[83ALL/RYD]
$PuO_2^{2+} + OH = PuO_2(OH)_{2(s)}$	-23.0	0.1M $NaClO_4$	M: 0.22mM, 5<pH<12	sol	[86LIE/KIM]
$PuO_2^{2+} + OH = PuO_2(OH)_{2(s)}$	-21.1[a]	0.1M $NaClO_4$	M: 10mM, pH<7.0	spc,est	[95PAS/KIM]

o) log Ksp°,

Pu(VI) solubility product with Phosphate:

Reaction	log Ksp	Medium	Max. Concentration	Method	Reference
$PuO_2^{2+} + HPO_4^{2-} = PuO_2HPO_{4(s)}$	-12.5	1M $NaClO_4$	M:71mM, L:5.88M, 0.65<pH<2.2	Sol	[67DEN/SHE]
$PuO_2^{2+} + HPO_4^{2-} = PuO_2HPO_{4(s)}$	-12.6°			est	[83ALL/RYD]
$2PuO_2^{2+} + 3PO_4^{3-} = (PuO_2)_3(PO_4)_{2(s)}$	-23.5°			est	[83ALL/RYD]

o) log Ksp°,

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Pitzer Parameters for AnO_2^+ and AnO_2^{2+} species

(NpO_2^+, UO_2^{2+} and PuO_2^{2+})

Pitzer (V)

Species	$\beta^{(0)}$	$\beta^{(1)}$	$\beta^{(2)}$	C^{ϕ}	References
NpO_2^+-ClO_4^-	0.312				[94NOV/ROB]
NpO_2^+-ClO_4^-	0.257	0.180		0.0081	[95Nec/Fan]
NpO^{2+}-ClO_4^-	0.2306	0.3474		0.0067	[96Run/Neu]
Na^+-$NpO_2(OH)_2^-$	-0.069				[96Run/Neu]
Na^+-$NpO_2(CO_3)^-$	0.161				[94NOV/ROB]
Na^+-$NpO_2(CO_3)^-$	0.128				[96Run/Neu]
Na^+-$NpO_2(CO_3)_2^{3-}$	0.407				[94NOV/ROB]
Na^+-$NpO_2(CO_3)_2^{3-}$	0.461	4.584			[96Run/Neu]
Na^+-$NpO_2(CO_3)_3^{5-}$	1.97	16			[94NOV/ROB]
Na^+-$NpO_2(CO_3)_3^{5-}$	1.691	23.981			[96Run/Neu]
K^+-$NpO_2(CO_3)_3^{5-}$	2.34	22.7	-96.0	-0.22	[97Nov/Mah]
NpO_2^+-Cl^-	0.169				[94NOV/ROB]
NpO_2^+-Cl^-	0.1415	0.281		0	[95Nec/Fan]
NpO_2^+-Cl^-	0.1467	0.2010		0	[96Run/Neu]

Species	λ_{ni}	References
Na^+-$NpO_2OH(aq)$	-0.101	[96Run/Neu]
Na^+-$NpO_2OH(aq)$	-0.21[a]	[96Run/Neu]

[a] i = Cl^-

Species	θ_{ij}	Ψ_{ijk}	References
Na^+-$NpO_2(CO_3)^-$- Cl^-	−0.206		[96Run/Neu]
Na^+-$NpO_2(CO_3)_2^{3-}$- Cl^-	−0.267		[96Run/Neu]
Na^+-$NpO_2(CO_3)_3^{5-}$- Cl^-	−0.496	0.098	[96Run/Neu]
Na^+-$NpO_2(OH)_2^-$-Cl^-	−0.18		[96Run/Neu]

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Pitzer (VI)

Species	$\beta^{(0)}$	$\beta^{(1)}$	C^{ϕ}	References
UO_2^{2+}-ClO_4^-	0.62346	1.97357	0.02084	[88Kim/Fre]
UO_2^{2+}-ClO_4^-	0.6113[a]	2.144[a]	0.01084[b]	[73Pit/May]
Na^+-$UO_2(CO_3)_2^{2-}$	0.212	2.5	0	[97Pas/Cze]
Na^+-$UO_2(CO_3)_3^{4-}$	1.25	11.6	0	[97Pas/Cze]
UO_2^{2+}-Cl^-	0.4274[a]	1.644[a]	-0.01843[b]	[73Pit/May]
UO_2^{2+}-NO_3^{2-}	0.4607[a]	1.613[a]	-0.01577[b]	[73Pit/May]
UO_2^{2+}-SO_4^{2-}	0.322	1.827	-0.0176	[91Pit]
[c]Na^+-$PuO_2(CO_3)_2^{2-}$	0.212	2.5	0	[97Pas/Cze]
[c]Na^+-$PuO_2(CO_3)_3^{4-}$	1.25	11.6	0	[97Pas/Cze]

a originally reported as $4/3\beta$

b originally reported as $2/3(2)^{5/2}$

c UO_2^{2+} values used for PuO_2^{2+}

Species	λ	References
Na^+-UO_2CO_3	0.5	[97Pas/Cze]
ClO_4^--UO_2CO_3	0.5	[97Pas/Cze]

Species	θ_{ij}	Ψ_{ijk}	References
Na^{+}-UO_2^{2+}-ClO_4^{-}	0.0231	−0.0437	[88Kim/Fre]
H^{+}-UO_2^{2+}-ClO_4^{-}	0.1377	−0.0 319	[88Kim/Fre]

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Literature "Recommended" Values of log β_i°

Introduction

Values of log β_1 (the stability constant for the reaction M + X = (MX) at I = 0(M)) have been calculated by various authors as reported in the preceding tables of "recommended" equilibrium constants and in the report for the tetravalent (99RAI/RAO-2) actinides. Since, in a number of cases, these reported values differ significantly, we have made estimates of the most reliable values to choose the set of values we recommend. The basis for our evaluation were the log β_1 values of Sm(III) and UO_2^{2+} since the complexation of these cations can be performed at macro concentrations without concern for perturbing effects due to the radioactivity of the metal ions and with no variation in metal ion redox changes.

Sm(III) has complexation very similar to Am(III). Moreover, linear correlations are found for plots of log β_1 (SmX) and log β_1 of An(IV)X. The similar linear dioxo structure of An(V)O_2^+ and An(VI)O_2^{2+} species allow the values of log β_1 of UO_2X to be used to screen the reported values of log β_1 for NpO_2^+, NpO_2^{2+}, PuO_2^+ and PuO_2^{2+} with the ligands of interest.

The electrostatic nature of the metal-ligand bond in f-element (Ln and An) complexation with hard base donors(e.g., O and F) allow use of the Born equation to estimate values of log β_1 for An-X and An-O complexes. The form of the equation used was:

$$\log \beta_1(MX) = \log \beta_1(AnX) \bullet [Z(An)/Z(M)] \bullet [D(M)/D(An)] \bullet [R(MX)/R(AnX)] \qquad (1)$$

M=Sm(III) or U(VI)O_2^{2+}; An=Am(III), Pu(III), Th(IV), U(IV), Np(IV), Pu(IV), Np(V)O_2^+, Pu(V)O_2^+, Np(VI)O_2^{2+} and Pu(VI)O_2^{2+}. The Z is the effective positive charge on the actinide metal ion, the O is the effective dielectric constant for the solution of the metal ion and R is the bond distance of the metal-donor atom bond (using Shannon radii, [76Shan]). The values used in the estimates are listed in Table 1. The estimated values from equation 1 are presented in Table 2. These values were used to screen the "recommended" values in which we have sufficient confidence to recommend their use. Only log $\beta_1°$ values were screened but it is reasonable to assume that references in which the log $\beta_1°$ values are reliable are likely to also have the more reliable log $\beta_2°$, etc values. Our recommended values from this screening analysis for log $\beta_1°$ at I=0(M), T=25.0°C are listed in Table 3.

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Table 1
Parameters Used in Born Estimates

Cation	Z(An)	D(An)	R(An-F), Å	R(An-O), Å
Sm(III)	+3	57	2.63	2.40
Pu(III)	+3	57	2.40	2.45
Am(III)	+3	57	2.37	2.44
Th(IV)	+4	50	2.22	2.26
U(IV)	+4	50	2.17	2.21
Np(IV)	+4	50	2.15	2.19
Pu(IV)	+4	50	2.14	2.18
$Np(V)O_2^+$	+2.2	65	2.03	2.07
$Pu(V)O_2^+$	+2.2	65	2.02	2.06
$U(VI)O_2^{2+}$	+3.3	55	1.99	2.03
$Np(VI)O_2^{2+}$	+3.3	55	2.00	2.04
$Pu(VI)O_2^{2+}$	+3.3	55	1.99	2.03

Table 2
Values Estimated from Extended Born Equation
log β_1°

	F^-	Cl^-	NO_3^-	OH^-	CO_3^{2-}	SO_4^{2-}	HPO_4^-	HPO_4^{2-}	
*Sm(III)	4.2	0.3	1.2	6.1	7.3	3.7	5.23	5.35	
Pu(III)	4.1	0.3	1.2	6.0	7.2	3.6	2.2	5.2	
Am(III)	4.2	0.3	1.2	6.0	7.2	3.6	2.2	5.2	
Th(IV)	6.8	0.5	1.9	9.9	11.8	5.9	3.6	8.6	
U(IV)	6.9	0.5	2.0	10.1	12.1	6.1	3.7	8.8	
Np(IV)	7.0	0.5	2.0	10.2	12.2	6.1	3.7	8.9	
Pu(IV)	7.0	0.5	2.0	10.2	12.2	6.1	3.7	9.0	
	F^-	Cl^-	NO_3^-	OH^-	CO_3^{2-}	SO_4^{2-}	HPO_4^-	HPO_4^{2-}	PuO_4^{3-}
*U(VI)O_2^{2+}	5.09	0.17	0.3	8.8	9.68	3.15	3.26	7.24	13.23
Np(V)O_2^+	2.8	-0.07	0.17	4.9	5.4	1.8	1.8	4.0	7.4
Pu(V)O_2^+	2.8	-0.07	0.17	4.9	5.4	1.8	1.8	4.0	7.4
Np(VI)O_2^{2+}	5.1	0.17	0.3	8.8	9.6	3.1	3.2	7.2	13.2
Pu(VI)O_2^{2+}	5.1	0.17	0.3	8.8	9.7	3.2	3.3	7.2	13.2

Table 3

Log β_1° "Screened" and Recommended for AnO_2^+ and AnO_2^{2+}

V Ions	Cl	F	NO_3	OH	CO_3	HPO_4	H_2PO_4	SO_4
NpO_2^+	(-0.07)	1.9[d]	1.1[c]	5[e]	5.1[d]	3.4[d]	(1.5)	2[a]
PuO_2^+	(-0.07)	(1.9)	(1.1)	5[c]	5[a]	(3.4)	(1.5)	2[a]

VI Ions	Cl	F	NO_3	OH	CO_3	HPO_4	H_2PO_4	SO_4
UO_2^{2+}	0.17[d]	6.1[d]	0.3[d]	8.8[d]	9.68[d]	7.24[d]	3.26[d]	3.5[d]
NpO_2^{2+}	0.4[d]	5.7[a]	(0.3)	8.4[f]	10.1[a]	(8)	(3.3)	3.4[b]
PuO_2^{2+}	0.1[d]	5.7[a]	(0.3)	8.9[f]	(10)	(8)	(3.3)	(3.4)

a = [86WAN]
b = [83FUG2]
c = [78ALL/BEA]
d = [92FUG/KHO]
e = [80ALL/KIP]
f = [83ALL]
( ) : estimated

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Recommended Values

Equilibrium Constants $(\beta_{mn})^1$ for Formation of Aqueous NpO_2^+ complexes with F^- ($mNpO_2^+ + nF^- \rightleftharpoons (NpO_2)_mF_n^{(m-n)+}$)

log β_1	Medium	Reference
3.7	I=0	[86WAN]
1.9	I=0	[92FUG/KHO]
1.76	I=0.1	[92FUG/KHO]
0.99	I=2	[76SMI/MAR]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants $(\beta_{mn})^1$ for Formation of Aqueous NpO_2^+ complexes with NO_3^- ($mNpO_2^+ + nNO_3^- \rightleftharpoons (NpO_2)_m(NO_3)_n^{(m-n)+}$)

log β_1	Medium	Reference
1.1	I=0	[78ALL/BEA]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants $(\beta_{mn})^1$ for Formation of Aqueous NpO_2^+ complexes with OH^- ($mNpO_2^+ + nH_2O \rightleftharpoons (NpO_2)_mOH_n^{(m-n)+} + nH^+$)

log β_1	Medium	Reference
-8.85	I=0	[76BAE/MES]
-8.9	I=0	[86WAN]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^+ complexes with OH^- ($mNpO_2^+ + nOH^- \rightleftharpoons (NpO_2)_mOH_n^{(m-n)+}$)

log β_1	log β_2	Medium	Reference
5.1	10	I=0	[78ALL/BEA]
5	10	I=0	[80ALL/KIP]
4	9.9	I=0	[82JEN]
5.1		I=0	[83ALL]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^+ complexes with CO_3^{2-} ($mNpO_2^+ + nCO_3^{2-} \rightleftharpoons (NpO_2)_m(CO_3)_n^{(m-2n)+}$)

log β_1	log β_2	log β_3	Medium	Reference
5.9	11.1	16.3	I=0	[83ALL]
4.49	7.11		I=0	[85NEW/SUL]
5.9	11.1		I=0	[86WAN]
4.9	7.05		I=0	[92FUG/KHO]
4.4	7.1		I=0.1	[92FUG/KHO]
4.4	7.1		I=1	[92FUG/KHO]
5.1	8.1		I=3	[92FUG/KHO]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^+ complexes with HPO_4^{2-} ($mNpO_2^+ + nHPO_4^{2-} \rightleftharpoons (NpO_2)_m(HPO_4)_n^{(m-2n)+}$)

log β_1	Other log β_{mn}	Medium	Reference
3.4		I=0	[92FUG/KHO]

1) If m = 1， β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^+ complexes with SO_4^{2-} ($mNpO_2^+ + nSO_4^{2-} \rightleftharpoons (NpO_2)_m(SO_4)_n^{(m-2n)+}$

log β_1	Medium	Reference
2.0	I=0	[86WAN]
0.6	I=0	[92FUG/KHO]
-0.1	I=0.5	[92FUG/KHO]
-0.06	I=1	[92FUG/KHO]
0.45	I=2	[76SMI/MAR]
0.19	I=2	[92FUG/KHO]

1) If m = 1, β_{mn} is written β_n

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Recommended Values

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^+ complexes with F^- ($mPuO_2^+ + nF^- \rightleftharpoons (PuO_2)_mF_n^{(m-n)+}$)

log β_1	Medium	Reference
3.7	H_2O	[86WAN]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^+ complexes with Cl^- ($mPuO_2^+ + nCl^- \rightleftharpoons (PuO_2)_mCl_n^{(m-n)+}$)

log β_1	Medium	Reference
-0.17	H_2O	[77RAI/SER]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^+ complexes with OH^- ($mPuO_2^+ + nOH^- \rightleftharpoons (PuO_2)_mOH_n^{(m-n)+}$)

log β_1	log β_2	Medium	Reference
5	10	H_2O	[78ALL/BEA]
4.3	9	H_2O	[80ALL/KIP]
4.3		H_2O	[82JEN]
4.3		H_2O	[83ALL]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^+ complexes with OH^- ($mPuO_2^+ + nH_2O \rightleftharpoons (PuO_2)_mOH_n^{(m-n)+} + nH^+$)

log β_1	Medium	Reference
-9.7	H_2O	[76BAE/MES]
-9.7	H_2O	[77RAI/SER]
-10	H_2O	[80LEM/TRE]
-9.7	H_2O	[86WAN]
-9.49	I=0.026	[79CLE]
<-9.7	I=0.03	[49KRA/DAM]
-9.7	I=0.03	[79CLE]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^+ complexes with CO_3^{2-} ($mPuO_2^+ + nCO_3^{2-} \rightleftharpoons (PuO_2)_m(CO_3)_n^{(m-2n)+}$)

log β_1	log β_2	log β_3	Medium	Reference
5	10	15.3	H_2O	[83ALL]
5	10	15.3	H_2O	[86WAN]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^+ complexes with SO_4^{2-} ($mPuO_2^+ + nSO_4^{2-} \rightleftharpoons (PuO_2)_m(SO_4)_n^{(m-2n)+}$)

log β_1	Medium	Reference
2	H_2O	[86WAN]

1) If m = 1, β_{mn} is written β_n

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Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with F^- ($mUO_2^{2+} + nF^- \rightleftharpoons (UO_2)_mF_n^{(2m-n)+}$)

log β_1	Medium	Method	Reference
4.80	I = 0	est	[78ALL/BEA]
5.10	I = 0	est	[80LEM/TRE]
5.16	I = 0	est	[81TUR/WHI]
4.54	I = 0	est	[82JEN]
4.70	I = 0	est	[86WAN]
4.90	I = 0	est	[87BRO/WAN]
5.41	I = 0	est	[92FUG/KHO]
5.09	I = 0	est	[92GRE/FUG]

1) If m = 1, β_{mn} is written β_n.

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with Cl^- ($mUO_2^{2+} + nCl^- \rightleftharpoons (UO_2)_mCl_n^{(2m-n)+}$)

log β_1	log β_2	log β_3	Medium	Method	Reference
1.66[a]			I = 0	est	[67OHA/MOR]
0.21			I = 0	est	[76SMI/MAR]
0.21			I = 0	est	[78ALL/BEA]
2.00			I = 0	est	[80LEM/TRE]
-0.100			I = 0	est	[82JEN]
0.21			I = 0	est	[81TUR/WHI]
1.174			I = 0	est	[86MOR/OHA]
1.517			I = 0	est	[86MOR/OHA]
0.2			I = 0	est	[86WAN]
0.45	0.600	0.57	I = 0	est	[87BRO/WAN]
0.45			I = 0	est	[92FUG/KHO]
0.17	-1.100		I = 0	est	[92GRE/FUG]

a) T=288 K,

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with NO_3^- ($mUO_2^{2+} + nNO_3^- \rightleftharpoons (UO_2)_m(NO_3)_n^{(2m-n)+}$)

log β_1	Medium	Method	Reference
0.300	I = 0	est	[92GRE/FUG]
0.100	I = 0	est	[78ALL/BEA]
0.200	I = 0	est	[87BRO/WAN]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with OH^- ($mUO_2^{2+} + nH_2O \rightleftharpoons (UO_2)_m(OH)_n^{(2m-n)+} + nH^+$)

log β_1	Other log β_{mn}	Medium	Method	Reference
	log $\beta_{2,2}$=-5.54 log $\beta_{3,5}$=-15.64	I = 0	est	[81VAI/MAK]
-5.88		I = 0	est	[83CAC/CHO2]
-5.2	log $\beta_{2,2}$= -5.62 log $\beta_{3,5}$= -15.55	I = 0	est	[92GRE/FUG]
-5.76	log $\beta_{2,2}$= -5.54 log $\beta_{3,5}$= -15.44	I = 0	est	[92FUG/KHO]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with CO_3^{2-} ($mUO_2^{2+} + nCO_3^{2-} \rightleftharpoons (UO_2)_m(CO_3)_n^{(m-n)+}$)

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Method	Reference
12.0				I = 0	est	[78ALL/BEA]
9.87				I = 0		[80FUG/KHO]
10.10				I = 0		[80LEM/TRE]
7.50				I = 0		[81TUR/WHI]
10.10				I = 0		[82JEN]
10.10				I = 0		[83ALL]
9.5	16.6	21.3	log $\beta_{3,6}$= 53.4	I=0	est	[84GRE/FER]
10.17				I = 0	est	[84PHI]
10.05				I = 0	est	[86WAN]
8.29				I = 0	est	[87BRO/WAN]
10.0				I = 0	est	[92FUG/KHO]
9.68				I = 0	est	[92GRE/FUG]
9.67				I = 0	est	[95SIL/BID]

1) If m = 1, β_{mn} is written β_n

Other Equilibrium Constants for Formation of Aqueous UO_2^{2+} Complexes with Various CO_3^{2-}-species

Reaction	log K	Medium	Reference
$UO_2CO_{3(c)} = UO_2CO_{3(aq)}$	-4.39	I = 0	[72SER/NIK]
$H_2CO_{2(g)} + UO_2^{2+} + H_2O = UO_2CO_{3(aq)} + 2H^+$	-6.53	I = 0	[84PHI]

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with PO_4^{3-} ($UO_2^{2+} + PO_4^{2-} \rightleftharpoons (UO_2)(PO_4)^-$)

log β_1	Medium	Reference
13.65	I = 0	[87BRO/WAN]
13.23	I = 0	[92GRE/FUG]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous UO_2^{2+} complexes with SO_4^{2-} ($mUO_2^{2+} + nSO_4^{2-} \rightleftharpoons (UO_2)_m(SO_4)_n^{(m-n)+}$)

log β_1	log β_2	Medium	Maximum Metal/H^+/Ligand Concentration	Method	Reference
2.73		I = 0	Sat Ag_2SO_4.	est	[60LIE/STO]
3.14		I = 0		est	[67WAL]
2.71		I = 0		est	[68AHR]
2.95	4.0	I = 0		est	[76SMI/MAR]
2.95		I = 0		est	[78ALL/BEA]
2.90		I = 0		est	[80LEM/TRE]
2.95		I = 0		est	[81TUR/WHI]
1.81		I = 0		est	[82JEN]
3.00		I = 0		est	[86WAN]
2.65		I = 0		est	[87BRO/WAN]
3.36		I = 0		est	[92FUG/KHO]
3.15	4.14	I = 0		est	[92GRE/FUG]

1) If m = 1, β_{mn} is written β_n

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Recommended Values

Equilibrium Constants $(\beta_{mn})^1$ for Formation of Aqueous NpO_2^{2+} complexes with F^- $(mNpO_2^{2+} + nF^- \rightleftharpoons (NpO_2)_mF_n^{(2m-n)+}s)$

log β_1	log β_2	log β_3	log β_4	Medium	Reference
4.60				I=0	[76SMI/MAR]
4.6	7.5	10.0	11.0	I=0	[78ALL/BEA]
3.85	6.97			I=0	[82JEN]
5.7	11.1	15.9	18.8	I=0	[86WAN]
4.59				I=0	[88PHI/HAL]
4.66	7.8	10.4		I=0	[92FUG/KHO]
	7.01			I=0.1	[76SMI/MAR]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants $(\beta_{mn})^1$ for Formation of Aqueous NpO_2^{2+} complexes with F^- $(mNpO_2^{2+} + nHF \rightleftharpoons (NpO_2)_mF_n^{(2m-n)+} + nH^+)$

log β_1	log β_2	Medium	Reference
0.93	1.11	I=1	[80BON/HEF]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with Cl^- ($mNpO_2^{2+} + nCl^- \rightleftharpoons (NpO_2)_mCl_n^{(2m-n)+}$)

log β_1	log β_2	Medium	Reference
	-0.8	I=0	[76SMI/MAR]
0.2	0.0	I=0	[78ALL/BEA]
-0.1	-0.8	I=0	[82JEN]
0.4		I=0	[92FUG/KHO]
-0.3		I=0.5	[76SMI/MAR]
-0.95		I=0.5	[92FUG/KHO]
-0.45		I=1	[92FUG/KHO]
-0.35		I=2	[76SMI/MAR]
-0.46		I=2	[92FUG/KHO]
-0.37	-0.95	I=3	[92FUG/KHO]
0.10		I=4	[92FUG/KHO]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with NO_3^- ($mNpO_2^{2+} + nNO_3^- \rightleftharpoons (NpO_2)_m(NO_3)_n^{(2m-n)+}$)

log β_1	Medium	Reference
1.0	I=0	[78ALL/BEA]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with OH^- ($mNpO_2^{2+} + nOH^- \rightleftharpoons (NpO_2)_mOH_n^{(2m-n)+}$)

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Reference
8.9			log $\beta_{2,2}$=21.6 log $\beta_{3,5}$=52.5	I=0	[76SMI/MAR]
8.9	18		log $\beta_{2,1}$=10 log $\beta_{2,2}$=21.6 log $\beta_{3,5}$=52.5	I=0	[78ALL/BEA]
9.1	17.8	23	log $\beta_{2,1}$=10 log $\beta_{2,2}$=21.6 log $\beta_{3,4}$=43 log $\beta_{3,5}$=53	I=0	[80ALL/KIP]
8.6	17	21.3	log $\beta_{2,2}$=20.9 log $\beta_{3,5}$=50.7	I=0	[82JEN]
8.9	17.8	23	log $\beta_{2,2}$=21.6 log $\beta_{3,5}$=53	I=0	[83ALL]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with OH^- ($mNpO_2^{2+} + nH_2O \rightleftharpoons (NpO_2)_mOH_n^{(2m-n)+} + nH^+$)

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Reference
-5.15			log $\beta_{2,2}$=-6.39 log $\beta_{3,5}$=-17.49	I=0	[76BAE/MES]
-5.15	-10.2	-19	log $\beta_{2,1}$=-4.0 log $\beta_{2,2}$=-6.39 log $\beta_{3,4}$=-13 log $\beta_{3,5}$=-17.49	I=0	[82PHI]
-5.1	-10.4	-19	log $\beta_{2,2}$=-6.4 log $\beta_{3,5}$=-17	I=0	[86WAN]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with CO_3^{2-} ($mNpO_2^{2+} + nCO_3^{2-} \rightleftharpoons (NpO_2)_m(CO_3)_n^{(m-n)+}$)

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Reference
10.1	16.7	23.8	log β_{36}=60.1	I=0	[83ALL]
10.1	16.7	23.8	log β_{36}=60.1	I=0	[86WAN]
	13	20.2		I=0.1	[85NEW/SUL]

1) If m = 1, β_{mn} is written β_n.

Other Equilibrium Constants for Formation of Aqueous NpO_2^{2+} Complexes with Various CO_3^{2-}-species

Reaction	log K	Medium	Reference
$CO_3^{2-} + 3OH^- + 2NpO_2^{2+} \rightleftharpoons (NpO_2)_2(OH)_3CO_3^-$	41	I=0	[83ALL]
$CO_3^{2-} + 3H_2O + 2NpO_2^{2+} \rightleftharpoons (NpO_2)_2(OH)_3CO_3^- + 3H^+$	-1	I=0	[86WAN]

Other Equilibrium Constants for Formation of Aqueous NpO_2^{2+} Complexes with Various PO_4^{3-}-species

Reaction	log K	Medium	Reference
$H^+ + PO_4^{3-} + NpO_2^{2+} \rightleftharpoons NpO_2HPO_{4(aq)}$	20.8	I=0	[86WAN]
$2H^+ + 2PO_4^{3-} + NpO_2^{2+} \rightleftharpoons NpO_2(HPO_4)_2^{2-}$	43.2	I=0	[86WAN]
$2H^+ + PO_4^{3-} + NpO_2^{2+} \rightleftharpoons NpO_2H_2PO_4^+$	22.5	I=0	[86WAN]

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous NpO_2^{2+} complexes with SO_4^{2-} ($mNpO_2^{2+} + nSO_4^{2-} \rightleftharpoons (NpO_2)_m(SO_4)_n^{(m-n)+}$)

log β_1	log β_2	log β_3	Medium	Reference
3.27			I=0	[76SMI/MAR]
3.27	4.1	5	I=0	[78ALL/BEA]
1.82	2.62		I=0	[82JEN]
3.0	4.3		I=0	[86WAN]
3.4			I=0	[92FUG/KHO]
	3.8		I=0.1	[76SMI/MAR]

1) If m = 1, β_{mn} is written β_n

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Recommended Values

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with F^- ($mPuO_2^{2+} + nF^- \rightleftharpoons (PuO_2)_mF_n^{(2m-n)+}$)

log β_1	log β_2	log β_3	log β_4	Medium	Reference
5.6	11	15.9	18.8	I=0	[80LEM/TRE]
5.7				I=0	[83FUG2]
4.03				I=0	[85COW/JEN]
5.7	11.1	15.9	18.8	I=0	[86WAN]
4.57	8.24	9.8		I=0	[92FUG/KHO]
4.21				I=0.1	[76SMI/MAR]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with F^- ($mPuO_2^{2+} + nHF \rightleftharpoons (PuO_2)_mF_n^{(2m-n)+} + nH^+$)

log β_1	log β_2	log β_3	log β_4	Medium	Reference
2.11	4.15	6.08	6.3	I=1	[80BON/HEF]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with Cl^- ($mPuO_2^{2+} + nCl^- \rightleftharpoons (PuO_2)_mCl_n^{(2m-n)+}$)

log β_1	log β_2	Medium	Reference
0.1	-0.35	I=0	[76SMI/MAR]
0.4	0	I=0	[78ALL/BEA]
-0.3		I=0	[80LEM/TRE]
0.1	-0.35	I=0	[82JEN]
0.09	-0.45	I=0	[83FUG2]
0.068	-2.07	I=0	[85COW/JEN]
0.1	-0.45	I=2	[77RAI/SER]
0.09	-0.45	I=2	[92FUG/KHO]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with NO_3^- ($mPuO_2^{2+} + nNO_3^- \rightleftharpoons (PuO_2)_m(NO_3)_n^{(2m-n)+}$)

log β_1	Medium	Reference
-1.14	I=0	[85COW/JEN]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with OH^-($mPuO_2^{2+} + nOH^- \rightleftharpoons (PuO_2)_mOH_n^{(2m-n)+}$)

log β_1	log β_2	log β_3	log β_4	Other log β_{mn}	Medium	Reference
8.4				log $\beta_{2,2}$=19.6 log $\beta_{3,5}$=48.4	I=0	[76SMI/MAR]
8.4	16	22		log $\beta_{2,1}$=10 log $\beta_{2,2}$=19.6 log $\beta_{3,4}$=37 log $\beta_{3,5}$=48.4	I=0	[78ALL/BEA]
8.9	17.6	22		log $\beta_{2,1}$=10 log $\beta_{2,2}$=20.3 log $\beta_{3,4}$=41 log $\beta_{3,5}$=50	I=0	[80ALL/KIP]
7.9	17	21.3		log $\beta_{2,2}$=20.1 log $\beta_{3,5}$=49.3	I=0	[82JEN]
8.4	17.6	22		log $\beta_{2,2}$=19.7 log $\beta_{3,5}$=48.4	I=0	[83ALL]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with OH^- ($mPuO_2^{2+} + nH_2O \rightleftharpoons (PuO_2)_mOH_n^{(2m-n)+} + nH^+$)

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Reference
-5.3	-11	-20.7		I=0	[54HIN]
-5.71				I=0	[54HIN]
-5.6			log $\beta_{3,5}$=-21.65	I=0	[76BAE/MES]
-5.3	-11.01	-20.71		I=0	[77RAI/SER]
--3.62	-7.98	-17.68		I=0	[79CLE]
<-5.6			log $\beta_{2,2}$=-8.3 log $\beta_{3,5}$=-21.6	I=0	[80LEM/TRE]
-9.7	-10.4	-20	log $\beta_{2,2}$=-8.36 log $\beta_{3,4}$=-15 log $\beta_{3,5}$=-21.65	I=0	[82PHI]
			log $\beta_{2,2}$=-8.2 log $\beta_{4,7}$=-29.11	I=0	[85COW/JEN]
-5.6	-10.2	-20	log $\beta_{2,2}$=-8.3 log $\beta_{3,5}$=-21.6	I=0	[86WAN]
			log $\beta_{2,2}$=-8.51 log $\beta_{3,5}$=-22.16	I=1	[77RAI/SER]

1) If m = 1, β_{mn} is written β_n

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with CO_3^{2-} ($mPuO_2^{2+} + nCO_3^{2-} \rightleftharpoons (PuO_2)_m(CO_3)_n^{(m-n)+}$)

log β_1	log β_2	log β_3	Other log β_{mn}	Medium	Reference
	15.04			I=0	[77RAI/SER]
	15.04			I=0	[79CLE]
	15			I=0	[80LEM/TRE]
12	15	18.3		I=0	[82JEN]
9	15	22	log β_{36}=60.1	I=0	[83ALL]
9	15	22	log β_{36}=60.1	I=0	[86WAN]
	13.1			I=0.1	[85NEW/SUL]
		6.2		0.15M $NaClO_4$	[78WOO/MIT]
		20		I=0.15	[85NEW/SUL]
12				I=1	[77RAI/SER]

1) If m = 1, β_{mn} is written β_n.

Other Equilibrium Constants for Formation of Aqueous PuO_2^{2+} Complexes with Various CO_3^{2-}-species

Reaction	log K	Medium	Reference
$CO_3^{2-} + OH^- + PuO_2^{2+} \rightleftharpoons PuO_2OHCO_3^-$	23.85	I=0	[77RAI/SER]
$CO_3^{2-} + OH^- + PuO_2^{2+} \rightleftharpoons PuO_2OHCO_3^-$	23.85	I=0	[79CLE]
$CO_3^{2-} + OH^- + PuO_2^{2+} \rightleftharpoons PuO_2OHCO_3^-$	23.85	I=0	[82JEN]
$CO_3^{2-} + 2OH^- + PuO_2^{2+} \rightleftharpoons PuO_2(OH)_2CO_3^-$	23	I=0	[77RAI/SER]
$CO_3^{2-} + 2OH^- + PuO_2^{2+} \rightleftharpoons PuO_2(OH)_2CO_3^-$	23	I=0	[79CLE]
$CO_3^{2-} + 2OH^- + PuO_2^{2+} \rightleftharpoons PuO_2(OH)_2CO_3^-$	23	I=0	[82JEN]
$HCO_3^- + 2OH^- + PuO_2(OH)_{2(aq)} \rightleftharpoons PuO_2(OH)_2HCO_3^-$	20	I=0.1	[85NEW/SUL]
$CO_3^{2-} + 3OH^- + 2PuO_2^{2+} \rightleftharpoons (PuO_2)_2(OH)_3CO_3^-$	41	I=0	[83ALL]
$CO_3^{2-} + 3H_2O + 2PuO_2^{2+} \rightleftharpoons (PuO_2)_2(OH)_3CO_3^- + 3H^+$	-1	I=0	[86WAN]
$CO_3^{2-} + 3OH^- + 3PuO_2^{2+} \rightleftharpoons (PuO_2)_3(OH)_3CO_3^+$	43	I=0	[83ALL]
$CO_3^{2-} + 3H_2O + 3PuO_2^{2+} \rightleftharpoons (PuO_2)_3(OH)_3CO_3^+ + 3H^+$	1	I=0	[86WAN]

Other Equilibrium Constants for Formation of Aqueous PuO_2^{2+} Complexes with Various PO_4^{3-}-species

Reaction	log K	Medium	Reference
$H^+ + PO_4^{3-} + PuO_2^{2+} \rightleftharpoons PuO_2HPO_{4(aq)}$	20.8	I=0	[86WAN]
$2H^+ + 2PO_4^{3-} + PuO_2^{2+} \rightleftharpoons PuO_2(HPO_4)_2^{2-}$	43.2	I=0	[86WAN]
$H^+ + HPO_4^{2-} + PuO_2^{2+} \rightleftharpoons PuO_2H_2PO_4^+$	11	I=0	[80LEM/TRE]
$2H^+ + PO_4^{3-} + PuO_2^{2+} \rightleftharpoons PuO_2H_2PO_4^+$	22.5	I=0	[86WAN]

Equilibrium Constants (β_{mn})[1] for Formation of Aqueous PuO_2^{2+} complexes with SO_4^{2-} ($mPuO_2^{2+} + nSO_4^{2-} \rightleftharpoons (PuO_2)_m(SO_4)_n^{(m-n)+}$)

log β_1	log β_2	Medium	Reference
3		I=0	[80LEN/TRE]
3.374		I=0	[85COW/JEN]
3	4.3	I=0	[86WAN]
2.17		I=2	[76SMI/MAR]

1) If m = 1, β_{mn} is written β_n

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Reduction Potentials and Equilibrium Constants for Redox Reactions for Actinides

Table 1 of this section lists the reduction potentials for U, Np and Pu at pH 0, 8, and 14. The values at pH 8 and 14 include the effects of hydrolysis in such solutions.

Table I
T = 25.0°C., I = 1.0 (M)

Half-cell	Potential (V.)
pH = 0	
U(III) – U(IV) + e^-	-0.631
U(VI) – U(V)	+0.613
U(VI) – U(VI)	+0.338
U(V) – U(VI)	+0.063
	+0.155
Np(III) – Np(IV)	
Np(IV) – Np(V)	+0.739
Np(IV) – Np(VI)	+0.938
Np (V) – Np(VI)	+1.136
Pu(III) – Pu(IV)	+0.982
Pu(IV) – Pu(V)	+1.170
Pu(IV) – Pu(VI)	+1.043
Pu(V) – Pu(VI)	+0.916

pH = 8	
U(III) – U(IV)	-1.95±0.17
U(IV) – U(V)	+0.08±0.12
U(IV) – U(VI)	+0.07±0.08
U(V) – U(VI)	-1.13±0.14
Np(III) – Np(IV)	-1.13±0.05
Np(IV) – Np(V)	+0.15±0.13
Np(IV) – Np(VI)	+0.48±0.09
Np(V) – Np(VI)	-0.18±0.08
Pu(III) – Pu(IV)	-0.39±0.15

pH = 8	
Pu(IV) – Pu(V)	+0.70±0.12
Pu(IV) – Pu(VI)	+0.65±0.08
Pu(V) – Pu(VI)	+0.60±0.04

ph = 14	
U(III) – U(IV)	-2.78±0.34
U(IV) – U(V)	-0.03±0.24
U(IV) – U(VI)	-0.36±0.24
U(V) – U(VI)	-0.69±0.24
Np(III) – Np(IV)	-1.88±0.24
Np(IV) – Np(V)	-0.09±0.24
Np(IV) – Np(VI)	+0.15±0.12
Np(V) – Np(VI)	+0.38±0.24
Pu(III) – Pu(IV)	-1.04±0.24
Pu(IV) – Pu(V)	+0.52±0.24
Pu(IV) – Pu(VI)	+0.34±0.12
Pu(V) – Pu(VI)	+0.16±0.24

Table 2 Selected Equilibrium Constants and Standard Reduction Potentials of Important Redox Reactions Involving Actinides.

Reaction	Log K°	E°(volts)	Reference
$U^{4+}+e^- \rightleftharpoons U^{3+}$	-9.353	-0.55	Grenthe et al. (1992)
$UO_2^{2+}+2e^-+4H^+ \rightleftharpoons U^{4+}+2H_2O$	9.038	0.27	Grenthe et al. (1992)
$UO_2^{2+}+e^- \rightleftharpoons UO_2^+$	1.484	0.09	Grenthe et al. (1992)
$Np^{4+}+e^- \rightleftharpoons Np^{3+}$	2.49	0.15	Fuger and Oetting (1976)
$NpO_2^++e^-+4H^+ \rightleftharpoons Np^{4+}+2H_2O$	10.89	0.64	Fuger and Oetting (1976)
$NpO_2^{2+}+e^- \rightleftharpoons NpO_2^+$	20.89	1.24	Fuger and Oetting (1976)
$Pu^{4+}+e^- \rightleftharpoons Pu^{3+}$	16.99	1.01	Fuger and Oetting (1976)
$PuO_2^++e^-+4H^+ \rightleftharpoons Pu^{4+}+2H_2O$	18.60[1]	1.10	Rai (1984)
$PuO_2^{2+}+e^- \rightleftharpoons PuO_2^+$	16.16[1]	0.96	Rai (1984)
$Am^{4+}+e^- \rightleftharpoons Am^{3+}$	39.59	2.34	Fuger and Oetting (1976)
$AmO_2^++e^-+4H^+ \rightleftharpoons Am^{4+}+2H_2O$	18.66	1.10	Fuger and Oetting (1976)
$AmO_2^{2+}+e^- \rightleftharpoons AmO_2^+$	26.91	1.59	Fuger and Oetting (1976)

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[1] The log K° values for these reactions are also similar to those reported by Fuger and Oetting (1976).