JAEA-Data/Code
2014-009

Update of JAEA-TDB: Update of Thermodynamic Data for Palladium and Tin, Refinement of Thermodynamic Data for Protactinium, and Preparation of PHREEQC Database for Use of the Brønsted-Guggenheim-Scatchard Model

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June 2014

Japan Atomic Energy Agency

日本原子力研究開発機構

JAEA-Data/Code

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(Received April 1, 2014)

The latest available thermodynamic data for palladium and tin were critically reviewed and the selected values were included into the JAEA-TDB for performance assessment calculations for geological disposal of radioactive high-level and TRU wastes. We made sure that the selected data are internally consistent with other data included in the compilation. This critical review specifically addressed thermodynamic data for 1) the palladium-hydroxide-chloride system, and 2) the solid oxides and hydroxido complexes of Sn(IV). We also selected thermodynamic data for other tin reactions from critical review of tin by the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA). Furthermore, we refined some thermodynamic data for Protactinium to estimate more reliable solubility values. We prepared text files of the updated thermodynamic database (JAEA-TDB) for geochemical calculation programs of PHREEQC, EQ3/6 and Geochemist's Workbench. Use of the Brønsted-Guggenheim-Scatchard Model (SIT) for ionic strength corrections was applied to the PHREEQC database.

Keywords: Geological Disposal, High-level Radioactive Waste, TRU Waste, Thermodynamic Database, Update of JAEA-TDB, Palladium, Tin, Protactinium, Geochemical Calculation Programs, the Brønsted-Guggenheim-Scatchard Model (SIT)

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* NESI Company Ltd.

JAEA-TDB の更新 : パラジウムおよびスズの熱力学データの更新，プロトアクチニウムの熱力学データの修正，および SIT モデル対応版 PHREEQC データベースの作成

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（2014 年 4 月 1 日受理）

高レベル放射性廃棄物および TRU 廃棄物の地層処分の性能評価に用いるための熱力学データベース（JAEA-TDB）で選定されているパラジウムとスズの熱力学データを更新した。パラジウムの加水分解種および塩化物錯体の熱力学データについては最新の原著論文を，スズの熱力学データについては経済協力開発機構原子力機関（OECD/NEA）が公開した熱力学データベースを基に，選定値のレビューと内部整合性の確認を行ったうえで採用した。また，プロトアクチニウムの一部の熱力学データを修正し，より現実的な溶解度評価が可能なデータセットに更新した。更新した JAEA-TDB のテキストファイルとして，PHREEQC，EQ3/6，Geochemist's Workbench といった地球化学計算コード用フォーマットを整備した。この際，PHREEQC については，SIT 活量補正モデルが利用可能なデータベースファイルとした。

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1. Introduction

Many radionuclides are contained in high-level radioactive waste (HLW) and are part of TRU waste packages, and some of them have long half-lives (more than 10^4 years). It is necessary to estimate the solubility of the radionuclides in groundwaters and porewaters in an engineered barrier system for performance assessment of geological disposal of HLW and TRU wastes. Thermodynamic data (e.g., the equilibrium constant of solubility limiting solids at standard state, i.e. 298.15 K and ionic strength of zero) are needed to estimate the solubility and aqueous species in the groundwater and porewater. These data are also needed to estimate sorption and diffusion behavior of chemical species on/in engineered barriers and host rocks. Therefore, the most reliable thermodynamic data should be compiled to carry out the reliable performance assessment by an implementation and regulatory organization.

Japan Atomic Energy Agency (JAEA) has developed and updated the thermodynamic database (JAEA-TDB) for the performance assessment of geological disposal of radioactive waste [1-3)]. Main part of the thermodynamic data in JAEA-TDB were selected and estimated by JAEA, however, some were taken from the data selected by the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD) [4)] and those selected by Japan Nuclear Cycle Development Institute (JNC; one of the predecessor of JAEA) [5)]. The thermodynamic data were compiled and converted to be available for use in geochemical calculation programs, e.g., PHREEQC [6)], EQ3/6 [7)] and Geochemist's Workbench [8)] (shown in Tables A1 and A2 in the TDB report [3)]).

After publishing the previous update (JAEA-2012) [3)], a critical review paper on the palladium-hydroxide-chloride system [9)] and an extensive experimental study dealing with the tin(IV)-hydroxide-chloride system [10)] and various systems of tin [11)] have been published.

A critical review of thermodynamic data for palladium was performed by Lothenbach *et al.* [12)] for development of JNC-TDB [5)]. Lothenbach *et al.* [12)] selected thermodynamic data for aqueous palladium chloride and ammine systems but did not select those for aqueous hydroxide system due to effect of colloidal species under experimental conditions. The estimated solubility values for palladium using the solubility-limiting solid phase (SSP) of crystalline palladium (Pd(cr)), however, were much lower than those obtained from solubility experiments [13, 14)]. Hence Kitamura and Yui [15)] selected a solubility product value of palladium hydroxide ($Pd(OH)_2(s)$) and hydrolysis species of palladium ($Pd(OH)_n^{(2-n)}$, n: 1 – 3) using the experimental solubility values [14)]. A similar approach was taken by Rai *et al.* [9)] who extended the system from aqueous palladium-hydroxide to aqueous palladium-hydroxide-chloride. All of the experimental data reviewed by Lothenbach *et al.*[12] and Kitamura and Yui [15] were critically reviewed and more comprehensive thermodynamic data for the aqueous palladium-hydroxide-chloride system were determined by Rai *et al.* [9] Therefore, for our TDB revision we have selected thermodynamic data for the palladium-hydroxide-chloride system reported by Rai *et al.* [9].

A critical review of thermodynamic data for tin was also performed by Lothenbach *et al.* [12] for development of JNC-TDB [5] in 1999. Lothenbach *et al.* [12] selected thermodynamic data for divalent tin in the aqueous hydroxide, chloride, fluoride, nitrate and sulfate systems, and those for tetravalent tin in the aqueous hydroxide system. The NEA published the thermodynamic database (NEA-TDB) for tin in 2012 [11]. Previously published thermodynamic data including those reviewed by Lothenbach *et al.* [12] were extensively reviewed and comprehensively complied in NEA-TDB. On the other hand, based on a critical review of the existing data and extensive solubility studies of oxides of Sn(IV) Rai *et al.* [10] developed a comprehensive thermodynamic model for the aqueous Sn-hydroxide-chloride system. Since the equilibrium constants obtained by Rai *et al.* [10] have not reviewed by the NEA, we reviewed the selected data reported by both the NEA [11] and Rai *et al.* [10] and checked these data for internal consistency with the JAEA-TDB.

Furthermore, we refined some thermodynamic data for protactinium and those for actinide(III/IV) isosaccharinate systems to estimate more reliable solubility values.

The previous PHREEQC [6] version used for JAEA-TDB does not include the capability to use the Brønsted-Guggenheim-Scatchard Model (usually called the "specific ion interaction theory (SIT)") [16] for correction of ionic strength for thermodynamic calculations; however the later PHREEQC [6] version 2.17 (released on February 25, 2010) has this capability. We selected ion interaction coefficients for many species in the presently updated PHREEQC [6] database file for ionic strength corrections using the SIT approach.

2. Brief Summary on Development of JAEA-TDB

2.1 Selection of Thermodynamic Data

Selection of thermodynamic data for JAEA-TDB was performed on the basis of the fundamental plan [1)] briefly described below.

This fundamental plan required the selection of equilibrium constants of different reactions at standard state (K^{o}) and also recommended the selection of values for other thermodynamic parameters such as enthalpy, entropy and heat capacity. Phase designators, (cr), (am), (s), (l) and (aq), accompanying compounds/species denote crystalline, amorphous, undefined-solid, pure liquid, and uncharged aqueous species, respectively.

Thermodynamic data for chemical compounds and species for radioelements with naturally occurring elements (e.g., halogen, oxygen, carbon, nitrogen, sulfur, phosphorus) and some organic ligands were selected. Other needed thermodynamic data for basal species that either form complexes or compounds with radioelements were selected from the "Auxiliary Data" reported by the NEA [4)].

Review and selection of thermodynamic values obtained from experimental data should be based on the "TDB-1" guideline by the NEA [17)]. Thermodynamic values or databases selected by the NEA [4)] and Lothenbach *et al.* [12)], which were based on the "TDB-1" guideline [17)], could be selected to the JAEA-TDB after surveying the latest literature and checking consistency of the value in the database. Otherwise review and selection of thermodynamic values should be performed after surveying the literature to collect proposed thermodynamic data.

Application of chemical analogues and models should be considered to obtain thermodynamic values for some species for which there has been no published experimental data. Some unreliable thermodynamic values, which are important for the performance assessment of geological disposal of radioactive wastes, may be selected as tentative values while specifying their reliability and the need for these values. All thermodynamic values should be standardized to 298.15 K and zero ionic strength using the Brønsted-Guggenheim-Scatchard Model (usually called the "specific ion interaction theory (SIT)") based on the "TDB-2" guideline by the NEA [16)] for correction of ionic strength.

2.2 Calculation of Equilibrium Constant from Gibbs Free Energy of Formation

There are some compounds/species for which equilibrium constants have not been selected and only Gibbs free energies of formation are available. The equilibrium constants are required for use in some geochemical calculation programs such as PHREEQC. Therefore some equilibrium constants were determined from the Gibbs free energy of formation using the following calculation.

Using the Hess's law, change in Gibbs free energy of reaction ($\Delta_r G^\circ_m$) for some arbitrary reaction, e.g.,

$$a\,\mathrm{A} + b\,\mathrm{B} \Leftrightarrow c\,\mathrm{C} + d\,\mathrm{D}\,, \tag{1}$$

where A, B, C and D are substances involving the reaction, and a, b, c and d are coefficients of the substances A, B, C and D, respectively,

is expressed using change in Gibbs free energy of formation ($\Delta_f G^\circ_m$(X) for species or compound X) as follows:

$$\Delta_r G^\circ_m = c\,\Delta_f G^\circ_m(\mathrm{C}) + d\,\Delta_f G^\circ_m(\mathrm{D}) - a\,\Delta_f G^\circ_m(\mathrm{A}) - b\,\Delta_f G^\circ_m(\mathrm{B})\,. \tag{2}$$

Logarithm of equilibrium constant at standard state ($\log_{10} K^\circ$) is derived from $\Delta_r G^\circ_m$ using the following equation:

$$\Delta_r G^\circ_m = -RT \log_e K^\circ \tag{3}$$

where R is the gas constant (8.31451070 $\mathrm{J \cdot K^{-1} \cdot mol^{-1}}$) and T is absolute temperature (which for 25 °C is 298.15 K) (NEA). Therefore at 298.15 K, $\log_{10} K^\circ = -(\Delta_r G^\circ_m)/(5.708)$.

Uncertainty (σ) of $\Delta_r G^\circ_m$ and $\log_{10} K^\circ$ is obtained from error propagation of $\Delta_f G^\circ_m$(X) as follows:

$$\sigma(\Delta_r G^\circ_m) = (c\,\sigma(\Delta_f G^\circ_m(\mathrm{C}))^2 + d\,\sigma(\Delta_f G^\circ_m(\mathrm{D}))^2 + a\,\sigma(\Delta_f G^\circ_m(\mathrm{A}))^2 + b\,\sigma(\Delta_f G^\circ_m(\mathrm{B}))^2)^{1/2} \tag{4}$$

$$\sigma(\log_{10} K^\circ) = \sigma(\Delta_r G^\circ_m)/5.708. \tag{5}$$

The uncertainty in equilibrium constant ($\sigma(\log_{10} K^\circ)$) calculated using reactions (4) and (5) is usually larger than that obtained experimentally. We selected the smallest of the uncertainty values based either on the experimental data or calculations.

For use with geochemical calculation programs, dissociation reactions are defined for all compounds and gaseous species, i.e., the objective compounds and species are put on the left-hand side and aqueous master species of the objective elements are put on right-hand side in their reactions.

3. Additional Selection or Revision of Thermodynamic Data

3.1 Palladium

A critical review of thermodynamic data for palladium was performed by Lothenbach *et al.* [12] for development of JNC-TDB [5]. Lothenbach *et al.* [12] selected thermodynamic data for aqueous palladium chloride and ammine systems but did not select data for aqueous hydroxide system due to the uncertainties, caused by the possible presence of colloidal species, in measured aqueous concentrations. However, the estimated palladium concentrations using Pd(cr) as the solubility-limiting solid phase (SSP) were extremely lower than those obtained from solubility experiments [13,14]. Hence to extend the thermodynamic data to the Pd-OH system, Kitamura and Yui [15] selected solubility product of $Pd(OH)_2(s)$ and hydrolyses species of palladium ($Pd(OH)_n^{(2-n)}$, n: 1 – 3) reported in Middlesworth and Wood [14]. Similar approach was performed by Rai *et al.*[9] with extending the system from aqueous palladium-hydroxide to aqueous palladium-hydroxide-chloride. All available literature including that reviewed by Lothenbach *et al.*[12] and Kitamura and Yui [15] were critically reviewed by Rai *et al.* [9] to develop a more comprehensive thermodynamic data for the aqueous palladium-hydroxide-chloride system. Therefore, we selected the data reported by Rai *et al.*[9] to revise the thermodynamic data for the palladium-hydroxide-chloride system.

Revised thermodynamic data to be included in the present compilation along with the data used in previous JAEA compilation (JAEA-2012) are listed in Table 1 for easy comparision of the proposed changes. All the revised data are from by Rai *et al.* [9] after they were reviewed and checked for internal consistency.

Table 1 Values of equilibrium constants at standard state ($\log_{10} K°$) for palladium compounds and aqueous species to be included in the present compilation as compared to the values in the older (JAEA-2012 [3]) compilation

Reaction	$\log_{10} K°$			
	Present*		JAEA-2012 [3]	
$Pd^{2+} + H_2O(l) \Leftrightarrow PdOH^+ + H^+$	—		-0.650	± 0.640
$Pd^{2+} + 2\ H_2O(l) \Leftrightarrow Pd(OH)_2(aq) + 2\ H^+$	< -3.490		-3.110	± 0.630
$Pd^{2+} + 3\ H_2O(l) \Leftrightarrow Pd(OH)_3^- + 3\ H^+$	-15.480	± 0.350	-14.200	± 0.630
$Pd^{2+} + Cl^- \Leftrightarrow PdCl^+$	5.000	± 0.240	5.031	± 0.200
$Pd^{2+} + 2\ Cl^- \Leftrightarrow PdCl_2(aq)$	8.420	± 0.310	8.471	± 0.283
$Pd^{2+} + 3\ Cl^- \Leftrightarrow PdCl_3^-$	10.930	± 0.380	10.582	± 0.346
$Pd^{2+} + 4\ Cl^- \Leftrightarrow PdCl_4^{2-}$	13.050	± 0.590	11.464	± 0.400
$Pd^{2+} + 3\ Cl^- + H_2O(l) \Leftrightarrow PdCl_3OH^{2-} + H^+$	3.770	± 0.626	2.500	
$Pd(OH)_2(s) + 2\ H^+ \Leftrightarrow Pd^{2+} + 2\ H_2O(l)$	—		-4.120	± 0.630
$Pd(OH)_2(am) + 2\ H^+ \Leftrightarrow Pd^{2+} + 2\ H_2O(l)$	-3.580	± 0.360	—	
$Pd(OH)_2(colloidal) + 2\ H^+ \Leftrightarrow Pd^{2+} + 2\ H_2O(l)$	-2.410		—	

* Based on Rai *et al.* [9]

3.2 Tin

3.2.1 Previously Selected or Determined Thermodynamic Data

A critical review on thermodynamic data for tin was also performed by Lothenbach *et al.*[12] for development of JNC-TDB [5] in 1999. Lothenbach *et al.* [12] selected thermodynamic data for divalent tin in the aqueous hydroxide, chloride, fluoride, nitrate and sulfate systems, and those for tetravalent tin in the aqueous hydroxide system. The NEA published the thermodynamic database (NEA-TDB) for tin in 2012 [11]. Previously published thermodynamic data including those reviewed by Lothenbach *et al.* [12] were extensively reviewed and comprehensively complied in NEA-TDB [11]. On the other hand, Rai *et al.* [10] determined the solubility products for SnO_2(cass) and SnO_2(am) and the values for hydroxido complexes of Sn^{4+} based on the literature and their own extensive experimental solubility studies conducted in a large range of pH values (0 to 14.5). Much of the experimental data presented in Rai *et al.* were previously unavailable in the literature. Although the publication date of the tin book [11] is later than the Rai *et al.*'s article [10], this article most likely was published when the NEA book was in the production cycle. The Rai *et al.*'s article [10] presented information hitherto unavailable and these data were not available to NEA reviewers. Therefore, we have reviewed the data presented by Rai *et al.* [10] and the corresponding data presented in NEA-TDB [11] for internal consistency and selection for our JAEA-TDB. Based on our review we have decided to select the data presented in Rai *et al.* [10] for our TDB. The reasons for this decision are clearly discussed in Section 3.2.3. One should note that although the values for the formation of hydroxido complexes and the solubility product for SnO_2(am) reported in NEA-TDB [11] and in Rai *et al.* [10] differ over seven orders of magnitude, the values for SnO_2(am) solubility in equilibrium with $Sn(OH)_5^-$ and $Sn(OH)_6^{2-}$ are essentially identical (Table 2).

Previously selected or determined thermodynamic data for tin are listed in Table 2. We tentatively set master species of divalent and tetravalent tin to Sn^{2+} and $Sn(OH)_4$(aq), respectively, based on the selection by JAEA-2012 [3] and NEA-TDB [11]. Equilibrium constants shown in italic letters in Table 2 are calculated values by us using the selected Gibbs free energy of formation ($\Delta_f G^\circ_m$) [11] and equations (2) and (3).

3.2.2 Thermodynamic Data Integration for Tin(0, II)

Following criteria to merge the thermodynamic data of NEA-TDB [11] and JAEA-2012 [3] (same as those by Lothenbach *et al.* [12]) are used.

- Criteria 1: In case selected equilibrium constants in JAEA-2012 [3] are consistent with those of NEA-TDB [11], we will select the data reported in NEA-TDB [11] without any discussion.
- Criteria 2: In case selected equilibrium constants in JAEA-2012 [3] are not consistent with those of NEA-TDB [11], we shall select those of NEA-TDB [11] after checking the review processes used by the NEA [11].
- Criteria 3: In case equilibrium constants selected in NEA-TDB [11] are not listed in JAEA-2012 [3], we will select those of NEA-TDB [11] after checking the review processes used by Lothenbach *et al.* [12].
- Criteria 4: In case equilibrium constants selected in JAEA-2012 [3] are not listed in NEA-TDB [11], we will make a decision whether or not the values from JAEA-2012 [3] will be included into the new compilation after checking the review processes used by the NEA [11].
- Criteria 5: In those cases where new data becomes available which are either not included in the NEA-TDB [11] or these reported values are different than those listed in NEA-TDB [11], we will critically review these publications and then make a decision for the selection of appropriate values.

(1) In case selected equilibrium constants of JAEA-2012 [3)] are consistent with those of NEA-TDB

We selected the values for equilibrium constants from NEA-TDB [11)] for the following species without any discussions because the values in JAEA-2012 [3)] are consistent with the values in NEA-TDB [11)]:

Sn^{2+}, $SnOH^{+}$, $Sn(OH)_2(aq)$, $SnCl^{+}$, $SnCl_2(aq)$, $SnCl_3^{-}$, $SnNO_3^{+}$ and $Sn(NO_3)_2(aq)$.

(2) In case selected equilibrium constants in JAEA-2012 [3)] are not consistent with those of NEA-TDB

We selected the equilibrium constants from NEA-TDB [11)] for following species and compounds:

$Sn_3(OH)_4^{2+}$, $Sn(OH)_3^{-}$, SnF^{+}, $SnF_2(aq)$, SnF_3^{-}, $SnSO_4(aq)$ and SnO(cr) .

We confirmed that the experimentally determined equilibrium constants reviewed by Lothenbach *et al.* [12)] and selected for compilation in JAEA-2012 [3)] were re-reviewed in NEA-TDB [11)]. We agree with the data presented in NEA-TDB [11)], which are different than those reported in Lothenbach *et al.* [12)] and included in JAEA-2012 [3)] compilation, and have selected these values for our current compilation.

The value of the equilibrium constant for SnO(cr) solubility reaction (Eq. 6) was calculated by us using the Gibbs free energies of formation of various species involved in the reaction in Eq. 6 and reported in NEA-TDB [11)]

$$\mathrm{SnO(cr)} + 2\mathrm{H}^{+} \Leftrightarrow \mathrm{Sn}^{2+} + \mathrm{H_2O(l)},\ \log_{10} K^{\circ} = 1.591 \pm 0.144\ . \qquad (6)$$

(3) In case an equilibrium constant selected in NEA-TDB is not listed in JAEA-2012

We also selected the equilibrium constants of NEA-TDB [11)] for following species because no reviews and data selections were performed by Lothenbach *et al.* [12)]:

$SnCl_4^{2-}$, $SnBr^{+}$, $SnBr_2(aq)$, $SnBr_3^{-}$, $SnSCN^{+}$.

Table 2 Selected thermodynamic data for tin in NEA-TDB [11], JAEA-2012 [3] and by Rai *et al.* [10] by tentatively setting master species of Sn^{2+} and $Sn(OH)_4(aq)$

Reaction	$\log_{10} K°$		
	NEA [11]	JAEA-2012 [3]	Rai *et al.* [10] *
$Sn^{2+} + H_2O(l) \Leftrightarrow SnOH^+ + H^+$	-3.530 ± 0.400	-3.750	
$3\ Sn^{2+} + 4\ H_2O(l) \Leftrightarrow Sn_3(OH)_4^{2+} + 4\ H^+$	-5.600 ± 0.470	-6.510	
$Sn^{2+} + 2\ H_2O(l) \Leftrightarrow Sn(OH)_2(aq) + 2\ H^+$	-7.680 ± 0.400	-7.710	
$Sn^{2+} + 3\ H_2O(l) \Leftrightarrow Sn(OH)_3^- + 3\ H^+$	-17.000 ± 0.600	-17.540	
$Sn^{2+} + F^- \Leftrightarrow SnF^+$	5.250 ± 0.190	4.460	
$Sn^{2+} + 2\ F^- \Leftrightarrow SnF_2(aq)$	8.890 ± 0.210	7.740	
$Sn^{2+} + 3\ F^- \Leftrightarrow SnF_3^-$	11.500 ± 1.000	9.610	
$Sn^{2+} + Cl^- \Leftrightarrow SnCl^+$	1.520 ± 0.200	1.650	
$Sn^{2+} + 2\ Cl^- \Leftrightarrow SnCl_2(aq)$	2.170 ± 0.170	2.310	
$Sn^{2+} + 3\ Cl^- \Leftrightarrow SnCl_3^-$	2.132 ± 0.190	2.090	
$Sn^{2+} + 4\ Cl^- \Leftrightarrow SnCl_4^{2-}$	2.030 ± 0.400		
$Sn^{2+} + H_2O(l) + Cl^- \Leftrightarrow SnClOH(aq) + H^+$		-2.270	
$Sn^{2+} + Br^- \Leftrightarrow SnBr^+$	1.330 ± 0.180		
$Sn^{2+} + 2\ Br^- \Leftrightarrow SnBr_2(aq)$	1.970 ± 0.210		
$Sn^{2+} + 3\ Br^- \Leftrightarrow SnBr_3^-$	1.930 ± 0.270		
$Sn^{2+} + SO_4^{2-} \Leftrightarrow SnSO_4(aq)$	3.430 ± 0.250	2.910	
$Sn^{2+} + 2\ SO_4^{2-} \Leftrightarrow Sn(SO_4)_2^{2-}$		2.830	
$Sn^{2+} + SCN^- \Leftrightarrow SnSCN^+$	1.500 ± 0.700		
$Sn^{2+} + NO_3^- \Leftrightarrow SnNO_3^+$	1.270 ± 0.310	1.250	
$Sn^{2+} + 2\ NO_3^- \Leftrightarrow Sn(NO_3)_2(aq)$	1.390 ± 0.530	1.740	
$Sn^{2+} + 3\ NO_3^- \Leftrightarrow Sn(NO_3)_3^-$		1.370	
$Sn^{2+} + 4\ NO_3^- \Leftrightarrow Sn(NO_3)_4^{2-}$		0.300	
$Sn(cr) + 4\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq) + 4\ H^+ + 4\ e^-$		-0.770	
$\alpha\text{-}Sn + 4\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq) + 4\ H^+ + 4\ e^-$	*-0.618 ± 0.123***		
$\beta\text{-}Sn + 4\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq) + 4\ H^+ + 4\ e^-$	*-0.639 ± 0.120***		
$Sn(OH)_2(s) + 2\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq) + 2\ H^+ + 2\ e^-$		-2.580	
$SnO(cr) + 3\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq) + 2\ H^+ + 2\ e^-$	*-3.846 ± 0.179***	-2.990	
$SnO(cr) + 2\ H^+ \Leftrightarrow Sn^{2+} + H_2O(l)$	*1.591 ± 0.144***		
$SnClOH(s)+3H_2O(l) \Leftrightarrow Sn(OH)_4(aq)+3H^+ + Cl^- + 2e^-$		-7.820	
$Sn_{21}Cl_{16}(OH)_{14}O_6(cr)+26H^+ \Leftrightarrow 21Sn^{2+}+16Cl^-+20H_2O(l)$	-34.020 ± 3.360		
$Sn^{2+} + 4\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq) + 4\ H^+ + 2\ e^-$	*-5.437 ± 0.131***	-5.400	
$Sn(OH)_4(aq) + 4\ H+ \Leftrightarrow Sn^{4+} + 4\ H_2O(l)$	*-7.545 ± 0.688***	0.400	> 0.620
$Sn(OH)_4(aq) + 3\ H^+ \Leftrightarrow SnOH^{3+} + 3\ H_2O(l)$			> 2.480
$Sn(OH)_4(aq) + H_2O(l) \Leftrightarrow Sn(OH)_5^- + H^+$	-8.600 ± 0.400	-7.970	> -8.580
$Sn(OH)_4(aq) + 2\ H_2O(l) \Leftrightarrow Sn(OH)_6^{2-} + 2\ H^+$	-18.670 ± 0.300	-18.400	> -19.660
$SnO_2(am) + 2\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq)$	*-7.224 ± 0.183***	-7.460	< -7.228
$SnO_2(cass) + 2\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq)$	*-8.060 ± 0.123***	-8.000	< -9.006 ± 0.300
$Na_2Sn(OH)_6(s) \Leftrightarrow Na_2Sn(OH)_6(aq)$			-5.290 ± 0.350

* converted to those corresponding the reactions by us

** calculated by us using the selected Gibbs free energy of formation ($\Delta_f G°_m$) [11] and equations (2) and (3)

(4) In case an equilibrium constant selected in JAEA-2012 [3)] is not listed in those of NEA-TDB

Following species, solids and compounds are matched in this case:

$SnClOH(aq)$, $Sn(SO_4)_2^{2-}$, $Sn(NO_3)_3^{-}$, $Sn(NO_3)_4^{2-}$, $Sn(OH)_2(s)$, $Sn(cr)$ and $SnClOH(s)$.

The NEA did not accept the equilibrium constant for $SnClOH(aq)$ due to discrepancies between experimental and thermodynamical data [11)]. We accepted the NEA's review and removed this equilibrium constant.

The NEA calculated the equilibrium constant for $Sn(SO_4)_2^{2-}$ at zero ionic strength [11)]. The calculated value, however, was neglected in NEA-TDB [11)] due to unreliability of the ion interaction coefficient for the reaction $Sn^{4+} + SO_4^{2-} \Leftrightarrow Sn(SO_4)(aq)$ ($\Delta\varepsilon = 0.85$ kg·mol^{-1}). We tentatively accept the calculated log $K°$ for $Sn(SO_4)_2^{2-}$ (3.3 ± 0.5), which is consistent with that in JAEA-2012 [3)].

The equilibrium constants for $Sn(NO_3)_3^{-}$ and $Sn(NO_3)_4^{2-}$ were not determined by the NEA [11)] because the differentiation between complex formation and medium effect is almost impossible at higher nitrate concentrations. We accepted the NEA's review [11)] and removed these reactions and the corresponding equilibrium constants from our TDB.

The NEA points out that there is only one stable tin(II) hydroxide, $Sn_6O_4(OH)_4$, but no information regarding thermodynamic properties of this compound is available [11)]. Since the value for the equilibrium constant for the solubility of $Sn(OH)_2(s)$ reported in JAEA-2012 [3)], proposed but not characterized, was similar to the value for the solubility of SnO(cr) reported in NEA's review [11)], we replaced the $Sn(OH)_2(s)$ entry with SnO(cr) in our TDB.

Thermodynamic data for two crystalline tin solids (α-Sn and β-Sn) were selected by NEA-TDB [11)], while JAEA-2012 [3)] included the data only for Sn(cr) in its compilation. We calculated and selected for our compilation the values for the α-Sn and β-Sn solubility reactions involving Sn^{4+} species from the Gibbs free energies of formation reported in NEA[11)].

The NEA reevaluated solubility data on "$Sn(OH)Cl(\cdot xH_2O)(s)$" with slope analysis and redetermined the solubility-limiting solid phase as $Sn_{21}Cl_{16}(OH)_{14}O_6(cr)$ [11)]. We accepted the NEA's review [11)] and replaced the reaction and the equilibrium constant value for SnClOH(s) solubility with the reaction and equilibrium constant value for $Sn_{21}Cl_{16}(OH)_{14}O_6(cr)$ solubility.

3.2.3 Thermodynamic Data Integration for Tin (IV)

As already mentioned, Rai *et al.*'s article [10] was not reviewed by the NEA [11], probably because the article appeared after the book was in the production cycle. NEA publications are highly regarded internationally for their thoroughness and accuracy and are used by scientists worldwide for making decisions regarding the safe disposal of nuclear wastes. Therefore it is essential that when new data become available they be used to modify the values recommended in the NEA publications.

Rai *et al.* [10] determined the $\log_{10} K°$ of -63.39 ± 0.30 for the SnO_2(cass) solubility reaction (see Table 3) based on extensive solubility data covering a wide range in pH values (0 to 14.5). This $\log_{10} K°$ value is within the range of values (-63.7 to -64.5) reported in various compilations of thermodynamic data (Feitknecht and Schindler [18], Wagman *et al.* [19], Seby *et al.* [20]), which lends credence to the experimental value reported in Rai *et al.*[10] However, a value (-71.61 ± 0.68; calculated by us using $\Delta_f G°_m$ values in NEA-TDB [11]) that is over seven orders of magnitude lower than Rai *et al.*'s experimental value [10] was obtained by the NEA [11]. The NEA's value [11] is also more than seven orders of magnitude lower than any of the known values for oxides of tetravalent elements. The NEA's calculated value [11] is dependent on $\Delta_f G°_m$ (SnO_2(cass), 298.15 K) and $\Delta_f G°_m$ (Sn^{4+}, 298.15 K), which are based on disparate studies that may not be internally consistent. The $\Delta_f G°_m$ (SnO_2(cass), 298.15 K) = -(516.640 ± 0.206) $kJ \cdot mol^{-1}$ based on an extensive critical review of the heat capacity data reported in NEA-TDB [11] appears reasonable and is very similar to the value -519.6 $kJ \cdot mol^{-1}$ reported in Wagman *et al.* [19] Considering that the $\Delta_f G°_m$ (SnO_2(cass), 298.15 K) [11] and the solubility product [10] values for SnO_2(cass) are reliable, we calculate $\Delta_f G°_m$ (Sn^{4+}, 298.15 K) = 5.530 ± 0.695 $kJ \cdot mol^{-1}$, which is similar to the value (2.5) reported in Wagman *et al.* [19] but is drastically different than the value (46.711 ± 3.871) selected in NEA-TDB [11]. Therefore, we wonder about the reliability of the $\Delta_f G°_m$ (Sn^{4+}, 298.15 K) value reported in NEA-TDB [11], especially considering that the value is 1) determined from high ionic strength (3 to 5 $mol \cdot dm^{-3}$) HCl solutions, 2) based on the values for $SnCl_x^{4-x}$ complexes determined from very high ionic strength (4.5 to 8.0 $mol \cdot dm^{-3}$) data, and 3) based on the $\Delta_f G°_m$ (Sn^{2+}, 298.15 K) value again determined from different sources. For these reasons we select the experimental SnO_2(cass) solubility product value based on internally consistent hydroxido constants reported in Rai *et al.* [10].

Rai *et al.* [10] also determined the values for hydroxido complexes from the solubility of SnO_2(cass) and showed that these values are consistent with extensive SnO_2(am) solubility data in a wide range of pH values (1 to 12). Rai *et al.* [10] were then able to determine a reliable value ($\log_{10} K°$ = -61.80 ± 0.29) for the SnO_2(am) solubility reaction (see Table 3), which is consistent with a value of -61.0 reported by Feitknecht and Schindler [18] for a precipitated solid phase they termed SnO_2(active). The NEA's [11] value of -70.78 ± 0.68 (calculated by us from their reported $\Delta_f G^0_m$ for appropriate species) for the solubility product of SnO_2(am) is about nine orders of magnitude lower than the value of Rai *et al.* [10].

The equilibrium constant value for the formation of $SnOH^{3+}$ was not selected by the NEA but is reported by Rai *et al.*[10] (Eq. 7).

$$SnO_2(cass) + 3\,H^+ \Leftrightarrow SnOH^{3+} + H_2O(l)\ ,\ \log_{10} K° = -6.52 \pm 0.43\quad , \qquad (7)$$

Oda and Amaya [20] determined solubility of SnO_2(am) in a wide range of pH values (2 to 12) from the oversaturation direction. The major aqueous species in equilibrium with SnO_2(am) in this study can be $Sn(OH)_4$(aq), $Sn(OH)_5^-$ and $Sn(OH)_6^{2-}$. However, Rai *et al.*[10] point out that because of the detection limit and interference from unfilterable colloids in the determination of soluble concentrations, it is not possible to determine an accurate value for $Sn(OH)_4$(aq).

On the other hand, the Oda and Amaya's data [20] as interpreted by the NEA [11] allows the calculation of reasonable values for the SnO_2(am) solubility reactions involving $Sn(OH)_5^-$ and $Sn(OH)_6^{2-}$ which do not depend on the questionable values of $Sn(OH)_4$(aq). The obtained $\log_{10} K°$ values for $Sn(OH)_5^-$ and $Sn(OH)_6^{2-}$ by Rai *et al.* [10] are very similar to those selected by the NEA [11] as shown in Table 2. Therefore we decided to use $Sn(OH)_5^-$ as a master species of tin(IV) in the revised JAEA-TDB. Considering of the internal consistency, we have opted to select the data reported in Rai *et al.* [10] The $\log_{10} K°$ value for a redox reaction between Sn^{2+} and $Sn(OH)_5^-$ was determined using $\Delta_f G°_m$ values selected by the NEA [11].

The equilibrium constants selected by the present study are listed in Table 4.

Table 3 Conversion of log $K°$ values from Rai *et al.* [10)] to those for JAEA-TDB

Compounds and Species	Rai *et al.* [10)]	present (for JAEA-TDB)
SnO_2(cass)	-64.39 ± 0.30*	-17.586 ± 0.454***
SnO_2(am)	-61.80 ± 0.29*	-14.996 ± 0.448***
Sn^{4+}		9.200 ± 0.340****
$SnOH^{3+}$	1.86 ± 0.32**	11.060 ± 0.467****
$Sn(OH)_4$(aq)	≤ 0.62 **	≤ 8.580 ****
$Sn(OH)_5^-$	-9.20 ± 0.34**	
$Sn(OH)_6^{2-}$	-20.28 ± 0.34**	-11.080 ± 0.481****

*For reactions SnO_2(cass or am) + 2 H_2O(l) ⇌ Sn^{4+} + 4 OH^-

**For reactions Sn^{4+} + n H_2O(l) ⇌ $Sn(OH)_n^{4-n}$ + n H^+ (n: 1, 4, 5 and 6)

***For reactions SnO_2(cass or am) + 3 H_2O(l) ⇌ $Sn(OH)_5^-$ + H^+

****For reactions $Sn(OH)_5^-$ + (5 – n) H^+ ⇌ $Sn(OH)_n^{4-n}$ + (5 – n) H_2O(l) (n: 0, 1, 4 and 6)

Table 4 Thermodynamic data for tin selected in the present study

Reaction	$\log_{10} K°$			
	present [ref.]			JAEA-2012 3)
$Sn^{2+} + H_2O(l) \Leftrightarrow SnOH^+ + H^+$	-3.530	± 0.400	[11]	-3.750
$3\ Sn^{2+} + 4\ H_2O(l) \Leftrightarrow Sn_3(OH)_4^{2+} + 4\ H^+$	-5.600	± 0.470	[11]	-6.510
$Sn^{2+} + 2\ H_2O(l) \Leftrightarrow Sn(OH)_2(aq) + 2\ H^+$	-7.680	± 0.400	[11]	-7.710
$Sn^{2+} + 3\ H_2O(l) \Leftrightarrow Sn(OH)_3^- + 3\ H^+$	-17.000	± 0.600	[11]	-17.540
$Sn^{2+} + F^- \Leftrightarrow SnF^+$	5.250	± 0.190	[11]	4.460
$Sn^{2+} + 2\ F^- \Leftrightarrow SnF_2(aq)$	8.890	± 0.210	[11]	7.740
$Sn^{2+} + 3\ F^- \Leftrightarrow SnF_3^-$	11.500	± 1.000	[11]	9.610
$Sn^{2+} + Cl^- \Leftrightarrow SnCl^+$	1.520	± 0.200	[11]	1.650
$Sn^{2+} + 2\ Cl^- \Leftrightarrow SnCl_2(aq)$	2.170	± 0.170	[11]	2.310
$Sn^{2+} + 3\ Cl^- \Leftrightarrow SnCl_3^-$	2.132	± 0.190	[11]	2.090
$Sn^{2+} + 4\ Cl^- \Leftrightarrow SnCl_4^{2-}$	2.030	± 0.400	[11]	—
$Sn^{2+} + H_2O(l) + Cl^- \Leftrightarrow SnClOH(aq) + H^+$	—			-2.270
$Sn^{2+} + Br^- \Leftrightarrow SnBr^+$	1.330	± 0.180	[11]	—
$Sn^{2+} + 2\ Br^- \Leftrightarrow SnBr_2(aq)$	1.970	± 0.210	[11]	—
$Sn^{2+} + 3\ Br^- \Leftrightarrow SnBr_3^-$	1.930	± 0.270	[11]	—
$Sn^{2+} + SO_4^{2-} \Leftrightarrow SnSO_4(aq)$	3.430	± 0.250	[11]	2.910
$Sn^{2+} + 2\ SO_4^{2-} \Leftrightarrow Sn(SO_4)_2^{2-}$	3.300	± 0.500 *	[11]	2.830
$Sn^{2+} + SCN^- \Leftrightarrow SnSCN^+$	1.500	± 0.700	[11]	
$Sn^{2+} + SO_4^{2-} + CO_3^{2-} + NO_3^- + 20\ H^+ + 16\ e^- \Leftrightarrow SnSCN^+ + 10\ H_2O(l)$	158.472	± 1.004	[11]	—
$Sn^{2+} + NO_3^- \Leftrightarrow SnNO_3^+$	1.270	± 0.310	[11]	1.250
$Sn^{2+} + 2\ NO_3^- \Leftrightarrow Sn(NO_3)_2(aq)$	1.390	± 0.530	[11]	1.740
$Sn^{2+} + 3\ NO_3^- \Leftrightarrow Sn(NO_3)_3^-$	—			1.370
$Sn^{2+} + 4\ NO_3^- \Leftrightarrow Sn(NO_3)_4^{2-}$	—			0.300
$Sn(cr) + 4\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq) + 4\ H^+ + 4\ e^-$	—			-0.770
$\alpha\text{-}Sn \Leftrightarrow Sn^{2+} + 2\ e^-$	4.819	± 0.060	[11]	—
$\beta\text{-}Sn \Leftrightarrow Sn^{2+} + 2\ e^-$	4.798	± 0.053	[11]	—
$Sn(OH)_2(s) + 2\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq) + 2\ H^+ + 2\ e^-$	—			-2.580
$SnO(cr) + 3\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq) + 2\ H^+ + 2\ e^-$	—			-2.990
$SnO(cr) + 2\ H^+ \Leftrightarrow Sn^{2+} + H_2O(l)$	1.591	± 0.144	[11]	—
$SnClOH(s) + 3\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq) + 3\ H^+ + Cl^- + 2\ e^-$	—			-7.820
$Sn_{21}Cl_{16}(OH)_{14}O_6(cr) + 26\ H^+ \Leftrightarrow 21\ Sn^{2+} + 16\ Cl^- + 20\ H_2O(l)$	-34.020	± 3.360	[11]	—
$Sn^{2+} + 4\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq) + 4\ H^+ + 2\ e^-$	—			-5.400
$Sn^{2+} + 5\ H_2O(l) \Leftrightarrow Sn(OH)_5^- + 5\ H^+ + 2\ e^-$	-14.037	± 0.422	[11]	—
$Sn(OH)_4(aq) + 4\ H+ \Leftrightarrow Sn^{4+} + 4\ H_2O(l)$	—			0.400
$Sn(OH)_5^- + 5\ H+ \Leftrightarrow Sn^{4+} + 5\ H_2O(l)$	9.200	± 0.340	[10]	—
$Sn(OH)_5^- + 4\ H^+ \Leftrightarrow SnOH^{3+} + 4\ H_2O(l)$	11.060	± 0.467	[10]	—
$Sn(OH)_4(aq) + H_2O(l) \Leftrightarrow Sn(OH)_5^- + H^+$	—			7.970
$Sn(OH)_5^- + H^+ \Leftrightarrow Sn(OH)_4(aq) + H_2O(l)$	≤ 8.580		[10]	—
$Sn(OH)_4(aq) + 2\ H_2O(l) \Leftrightarrow Sn(OH)_6^{2-} + 2\ H^+$	—			-18.400
$Sn(OH)_5^- + H_2O(l) \Leftrightarrow Sn(OH)_6^{2-} + H^+$	-11.080	± 0.481	[10]	—
$SnO_2(cass) + 2\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq)$	—			-8.000
$SnO_2(cass) + 2\ H_2O(l) \Leftrightarrow Sn(OH)_5^- + H^+$	-17.586	± 0.454	[10]	—
$SnO_2(am) + 2\ H_2O(l) \Leftrightarrow Sn(OH)_4(aq)$	—			-7.460
$SnO_2(am) + 2\ H_2O(l) \Leftrightarrow Sn(OH)_5^- + H^+$	-14.996	± 0.448	[10]	—

3.3 Protactinium

3.3.1 Problems of Previous Data Selection

Previously selected thermodynamic data for protactinium are listed in Table 5. Most of selected data are taken from JNC-TDB [5]. The data for protactinium(V) hydrolysis species, a chloride complex, and sulfate complexes were revised in JAEA-TDB (2010) [1] and were included in the JAEA-2012 [3]) compilation. These data are included in our current compilation. After the update of JNC-TDB to JAEA-TDB (2010) [1], following two inconsistencies in the previous data were noted:

- Thermodynamic data for both $PaO(OH)_3$(aq) and $Pa(OH)_5$(aq) (equivalent to $PaO(OH)_3$(aq) + H_2O(l)) were selected although these species are experimentally indistinguishable ,
- The equilibrium constant value for Pa_2O_5(cr) solubility reaction is not correct and the crystallinity of Pa_2O_5(cr) is unknown .

3.3.2 Neutral Hydrolysis Constant of Protactinium(V)

The equilibrium constant value for the formation of $PaO(OH)_3$(aq) was taken from Guillaumont *et al.* [22], which is based on solubility experiments in 3 mol·dm^{-3} (H, Li)ClO_4 electrolytes. In contrast, the value for $Pa(OH)_5$(aq) was determined by Trubert *et al.* [23] using a solvent extraction method. Because the determination of the equilibrium constant by Trubert *et al.* [23] is more precise and traceable than that by Guillaumont *et al.* [22], we have selected the value reported by Trubert *et al.* [23] and have removed the value reported by Guillaumont *et al.* [22] from our compilation.

3.3.3 Equilibrium Constant of Protactinium(V) Oxide

The equilibrium constant value ($\log_{10} K° = -8.72$) for the Pa_2O_5(cr) solubility reaction (Pa_2O_5(cr) + 2 e^- + 10 H^+ ⇔ 2 Pa^{4+} + 5 H_2O(l)) selected in JNC-TDB [5] (Table 5) was erroneously calculated from the sum of $\log_{10} K°$ values for the following reactions [24] (Eqs. 8 – 10):

$$Pa_2O_5(cr) + 2\,H^+ \Leftrightarrow 2\,PaO_2^+ + H_2O \qquad \log_{10} K° < -4\,, \qquad (8)$$

$$2\,PaO_2^+ + 2\,H^+ \Leftrightarrow 2\,PaOOH^{2+} \qquad \log_{10} K° = 1.0\times2 = 2.0\,, \qquad (9)$$

$$2\,PaOOH^{2+} + 6\,H^+ + 2\,e^- \Leftrightarrow 2\,Pa^{4+} + 4\,H_2O \qquad \log_{10} K° = -3.72\,. \qquad (10)$$

Since the $\log_{10} K°$ for reaction (8) was changed from 2.0 to 2.48 after the update of JNC-TDB to JAEA-TDB (2010) [1], the correct value for the equilibrium constant for the $Pa_2O_5(cr)$ solubility reaction is -5.24. Furthermore, we changed $Pa_2O_5(cr)$ to $Pa_2O_5(s)$ because the crystallinity of the compound is unknown. Finally, we selected the $\log_{10} K°$ value of ≤ -1.520 for the following reaction because this reaction is independent of redox potentials:

$$Pa_2O_5(s) + 4\ H^+ \Leftrightarrow 2\ PaOOH^{2+} + H_2O(l) \qquad \log_{10} K° \leq -1.520\ . \qquad (11)$$

The refined thermodynamic data for protactinium are also listed in Table 5.

3.3.4 Solubility Calculations Using the Revised Thermodynamic data for Pa

Predicted protactinium concentrations as a function of pH and in equilibrium with $Pa_2O_5(s/cr)$ (SSP) using the PHREEQC [6] code with the thermodynamic data reported in (JAEA-2012 [3]) and in the revised JAEA-TDB are shown in Figure 1 and Figure 2, respectively. The results using the revised JAEA-TDB show higher solubility values under acidic conditions and lower solubility values under alkaline conditions as compared to the predicted concentrations using the thermodynamic data reported in JAEA-2012 [3]. The predicted Pa concentrations in the alkaline region with the revised JAEA-TDB are similar to the average of experimental value (1.4×10^{-9} mol·dm^{-3}) reported by Berry *et al.* [25] for solutions separated from suspensions using membrane filters (molecular weight cut-off 25,000 (25 kDa) (Figure 3). If we would fit the $\log_{10} K°$ of $Pa_2O_5(s)$ to the maximum solubility value after 25 kDa filtration, the $\log_{10} K°$ of $Pa_2O_5(s) + 4\ H^+ \Leftrightarrow 2\ PaOOH^{2+} + H_2O(l)$ would be approximately ≤ -0.4.

Table 5 Refined thermodynamic data for Protactinium compared with previous data

Reaction	$\log_{10} K°$		
	present	JAEA-2012 [3)]	JNC-TDB [5)]
$Pa^{4+} + H_2O(l) \Leftrightarrow PaOH^{3+} + H^+$	0.840	0.840	0.840
$Pa^{4+} + 2\ H_2O(l) \Leftrightarrow Pa(OH)_2^{2+} + 2\ H^+$	-0.020	-0.020	-0.020
$Pa^{4+} + 3\ H_2O(l) \Leftrightarrow Pa(OH)_3^{+} + 3\ H^+$	-1.500	-1.500	-1.500
$PaOOH^{2+} + H_2O(l) \Leftrightarrow PaO(OH)_2^{+} + H^+$	-1.240 ± 0.020	-1.240 ± 0.020	-1.010
$PaOOH^{2+} + 2\ H_2O(l) \Leftrightarrow PaO(OH)_3(aq) + 2\ H^+$	—	-5.460	-5.460
$PaOOH^{2+} + 3\ H_2O(l) \Leftrightarrow Pa(OH)_5(aq) + 2\ H^+$	-8.270 ± 0.151	-8.270 ± 0.151	—
$PaOOH^{2+} + Cl^- \Leftrightarrow PaOOHCl^+$	1.922 ± 0.020	1.922 ± 0.020	—
$PaOOH^{2+} + SO_4^{2-} + H^+ \Leftrightarrow PaOSO_4^{+} + H_2O(l)$	3.890 ± 0.180	3.890 ± 0.180	—
$PaOOH^{2+} + 2\ SO_4^{2-} + H^+ \Leftrightarrow PaO(SO_4)_2^{-} + H_2O(l)$	7.000 ± 0.200	7.000 ± 0.200	—
$PaOOH^{2+} + 3\ SO_4^{2-} + H^+ \Leftrightarrow PaO(SO_4)_3^{3-} + H_2O(l)$	8.590 ± 0.230	8.590 ± 0.230	—
$Pa^{4+} + 2\ H_2O(l) \Leftrightarrow PaOOH^{2+} + e^- + 3\ H^+$	1.860	1.860	1.860
$PaO_2(cr) + 4\ H^+ \Leftrightarrow Pa^{4+} + 2\ H_2O(l)$	0.600	0.600	0.600
$PaCl_4(s) \Leftrightarrow Pa^{4+} + 4\ Cl^-$	24.010	24.010	24.010
$Pa_2O_5(cr) + 2\ e^- + 10\ H^+ \Leftrightarrow 2\ Pa^{4+} + 5\ H_2O(l)$	—	-8.720	-8.720
$Pa_2O_5(s) + 4\ H^+ \Leftrightarrow 2\ PaOOH^{2+} + H_2O(l)$	≤ -1.520	—	—
$PaCl_5(cr) - e^- \Leftrightarrow Pa^{4+} + 5\ Cl^-$	32.850	32.850	32.850

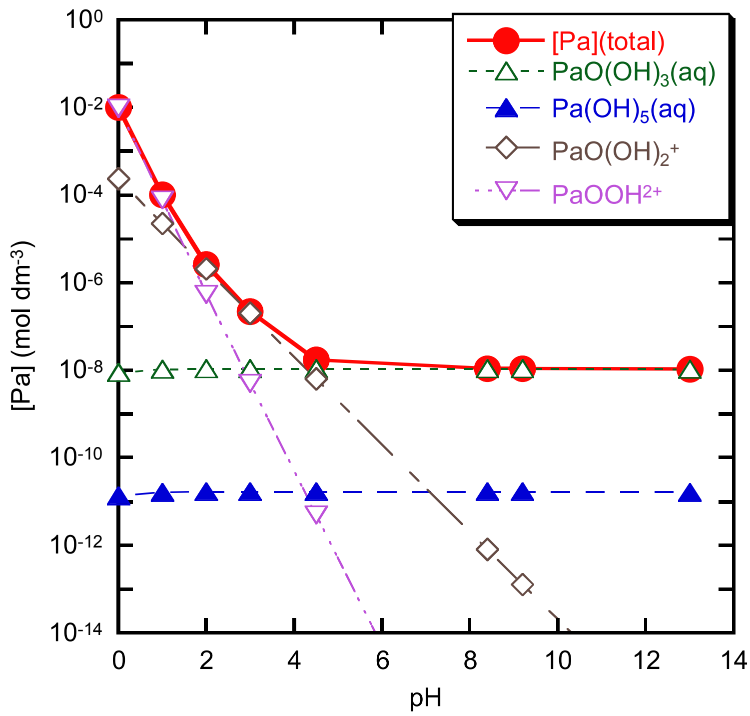

Figure 1 Calculated protactinium concentrations in equilibrium with $Pa_2O_5(s)$ and as a function of pH using the thermodyamic data reported in JAEA-2012

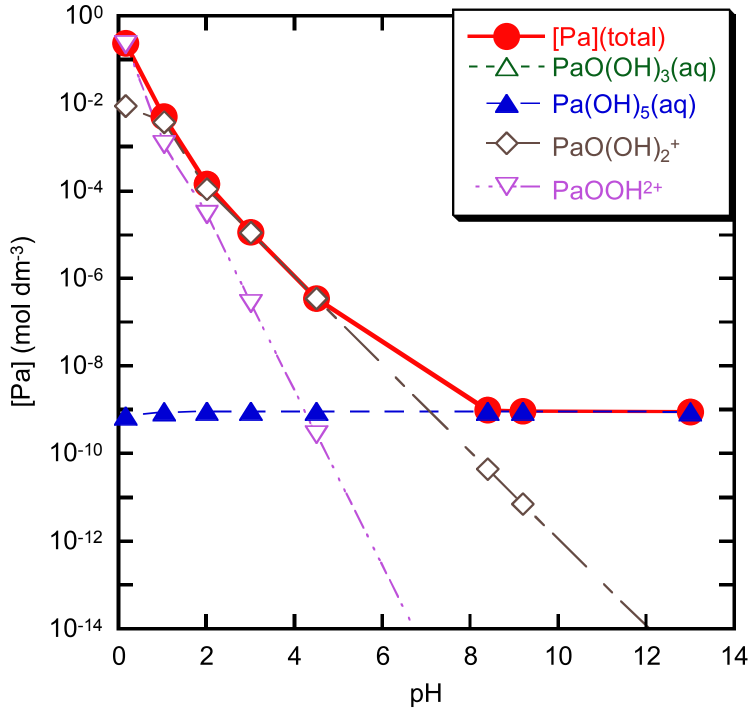

Figure 2 Calculated protactinium concentrations in equilibrium with $Pa_2O_5(s)$ and as a function of pH using the thermodyamic data reported in JAEA-TDB

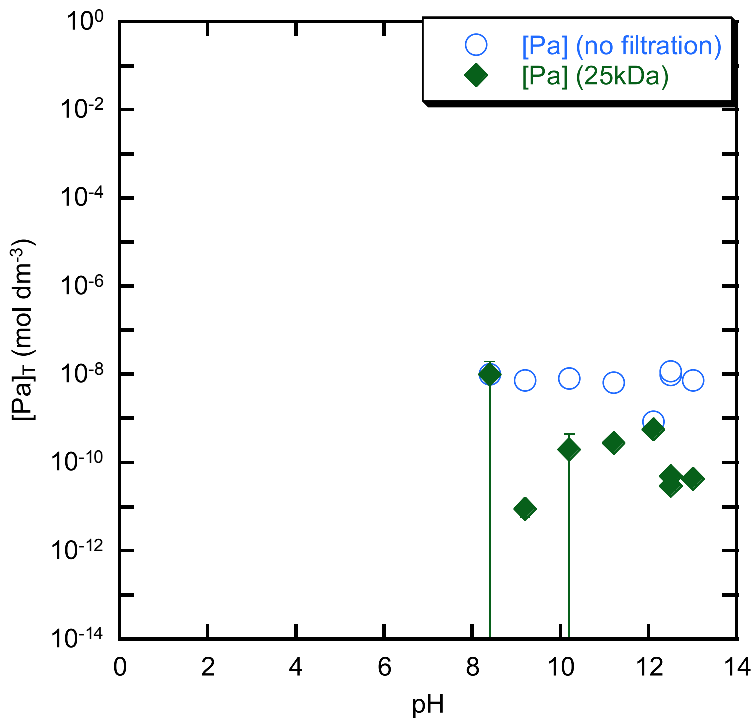

Figure 3 Experimental solubility values obtained by Berry *et al.* [25)]

3.4 Use of the Brønsted-Guggenheim-Scatchard Model (SIT)

The previous PHREEQC [6] version used for JAEA-TDB does not include the capacity to use the Brønsted-Guggenheim-Scatchard Model (usually called the “specific ion interaction theory (SIT)”) [4] for correction of ionic strength for thermodynamic calculations; however the later PHREEQC [6] version 2.17 (released on February 25, 2010) has this capacity. We selected ion interaction coefficients for many species in the presently updated PHREEQC [6] database file for ionic strength corrections using the SIT approach.

Activity coefficient γ_j for species j using the SIT is modeled as follows:

$$\log \gamma_j = -z_j^2 D + \sum_k \varepsilon(j,k) m_k \quad , \qquad (12)$$

$$D = \frac{A\sqrt{I_m}}{1 + Ba_j\sqrt{I_m}} \quad , \qquad (13)$$

where z_j denotes electric charge of the species j, ε is ion interaction coefficient between species j and counter ion k at ionic strength of I_m, m_k is molar concentration of ion k (equals to I_m for 1:1 electrolytes, e.g. $NaClO_4$ and KCl), A and B are constants which are temperature dependent, and a_j is the effective diameter of the hydrated ion j. The proposed value of A at 298.15 K is 0.509 and the proposed value of Ba_j is 1.5 $kg^{1/2}\cdot mol^{1/2}$ for moderate temperature intervals (between 298.15 and 473.15 K) in the NEA’s TDB-2 guideline [16]. An ion interaction coefficient ($\varepsilon(j,k)$) is defined as a coefficient of ion j against a counter solute ion k. The ion interaction coefficient $\varepsilon(j,k)$ is assumed to be zero for most ions with the same charge and for uncharged species whenever the experimental accuracy justifies this.

Many ion interaction coefficient $\varepsilon(j,k)$ values have been selected by the NEA [11,16] and we accepted most of them. The $\varepsilon(j,k)$ values that the NEA has not selected or that are different from the selected values by the NEA [11,16] are listed in Tables 6 and 7.

Table 6 Ion interaction coefficients $\varepsilon(j,k)$ ($kg\cdot mol^{-1}$) for cations j with k = Cl^-, ClO_4^- and NO_3^- not selected by the NEA or different from those selected by the NEA.
The uncertainties are 95 % confidence level.

j	k	$\varepsilon(j,k)$	Comment
$Co(OH)^+$	Cl^-	-0.01 ± 0.07	Taken from ε($Ni(OH)^+$, Cl^-) [11,16]
$Co(OH)^+$	ClO_4^-	0.14 ± 0.07	Taken from ε($Ni(OH)^+$, ClO_4^-) [11,16]
$CoCl^+$	ClO_4^-	0.41 ± 0.04	Determined in Reference 26
$CoNO_3^+$	ClO_4^-	0.33 ± 0.04	Taken from ε($UO_2NO_3^+$, ClO_4^-) [26]
$CoHCO_3^+$	ClO_4^-	0.2 ± 0.2	Taken from ε($ZnHCO_3^+$, ClO_4^-) with uncertainties of ± 0.2 [26]
$ZrCl_3^+$	ClO_4^-	0.88 ± 0.45	Determined in Reference 27
$Zr(NO_3)_3^+$	ClO_4^-	0.22 ± 1.24	Average value of ε(M^+,ClO_4^-) in NEA-TDB [16]
$TcOOH^+$	Cl^-	0.11 ± 0.01	Determined in Reference 1
$PdCl^+$	ClO_4^-	0.25 ± 0.02	Determined in Reference 9
Sn^{4+}	Cl^-	0.25 ± 0.03	Determined in Reference 10
Sn^{4+}	ClO_4^-	0.78	Determined in Reference 10
$SnOH^{3+}$	Cl^-	0.19 ± 0.05	Determined in Reference 10
$PbOH^+$	ClO_4^-	0.13 ± 0.25	Determined in Reference 28
$PbCl^+$	ClO_4^-	0.04 ± 0.14	Determined in Reference 28
$BiCl_2^+$	ClO_4^-	0.13	Determined in Reference 29
$PaO(OH)_2^+$	ClO_4^-	-0.23 ± 0.10	Determined from $\Delta\varepsilon$ in Reference 30 and ε(H^+,ClO_4^-) in Reference 16
$PaOOH^{2+}$	ClO_4^-	-0.03 ± 0.02	Determined from $\Delta\varepsilon$ in Reference 30 and ε(H^+,ClO_4^-) in Reference 16
$PaOOHCl^+$	ClO_4^-	0.19 ± 0.64	average value among that for hydroxide and chloride complexes of metal ions with positive net charge of 1 listed in NEA-TDB [16], i.e. $CdCl^+$, $HgCl^+$, $NiCl^+$, PuO_2Cl^+, NpO_2Cl^+, UO_2Cl^+, $NiOH^+$, $Am(OH)_2^+$, NpO_2OH^+, UO_2OH^+, $Th(OH)_3^+$
$PaOSO_4^+$	ClO_4^-	0.80 ± 0.20	Determined from $\Delta\varepsilon$ in Reference 32, ε(H^+,ClO_4^-) and ε(SO_4^-,Na^+) in Reference 16
$U(OH)_3^+$	ClO_4^-	0.23 ± 0.39	Determined in Reference 31
$Np(OH)_3^+$	ClO_4^-	0.29 ± 0.15	Determined in Reference 32
$Pu(OH)_3^+$	Cl^-	0.05 ± 0.10	Determined in Reference 34
Co^{2+}	F^-	0.31 ± 0.04	Determined in Reference 26
Pd^{2+}	ClO_4^-	0.22	Determined in Reference 9
$BiCl^{2+}$	ClO_4^-	0.34	Determined in Reference 29
$U(OH)_2^{2+}$	ClO_4^-	0.52 ± 0.31	Determined in Reference 31
$Np(OH)_2^{2+}$	ClO_4^-	0.35 ± 0.11	Determined in Reference 32
$Pu(OH)_2^{2+}$	Cl^-	0.10 ± 0.10	Determined in Reference 34
Bi^{3+}	ClO_4^-	0.30	Determined in Reference 29
UOH^{3+}	ClO_4^-	0.54 ± 0.34	Determined in Reference 31
$NpOH^{3+}$	ClO_4^-	0.49 ± 0.15	Determined in Reference 33
$PuOH^{3+}$	Cl^-	0.20 ± 0.10	Determined in Reference 34
$Ca_4[Th(OH)_8]^{4+}$	Cl^-	-0.01 ± 0.10	Determined in ref. 35
$Ca_4[Th(OH)_8]^{4+}$	ClO_4^-	0.21 ± 0.17	Determined in ref. 35
U^{4+}	ClO_4^-	0.29 ± 0.17	Determined in Reference 31
Pu^{4+}	Cl^-	0.40 ± 0.10	Determined in Reference 34

Table 7 Ion interation coefficients $\varepsilon(j,k)$ (kg·mol^{-1}) for anions j with k = H^+, Li^+, Na^+ and K^+ not selected by the NEA or different from those selected by the NEA.
The uncertainties are 95 % confidence level.

j	k	$\varepsilon(j,k)$	Comment
isa^-	Na^+	-0.07	Determined in Reference 27
$Nb(OH)_6^-$	Na^+	-0.07 ± 0.11	average value among hydrolysis species with net charge of -1, i.e. $\varepsilon(SiO(OH)_3^-,Na^+)$, $\varepsilon(Si_2O_2(OH)_5^-,Na^+)$, $\varepsilon(B(OH)_4^-,Na^+)$, $\varepsilon(NpO_2(OH)_2^-,Na^+)$ and $\varepsilon(UO_2(OH)_3^-,Na^+)$ in NEA-TDB [16]
$Pd(OH)_3^-$	Na^+	0.11	Determined in Reference 9
$PdCl_3^-$	Na^+	0.03 ± 0.01	Determined in Reference 9
$PdCl_3^-$	K^+	0.00 ± 0.01	Determined in Reference 9
$Sn(OH)_5^-$	Na^+	-0.08	Determined in Reference 10
$Sn(OH)_6^{2-}$	Na^+	-0.125	Determined in Reference 10
$PbCl_3^-$	Li^+	-0.07 ± 0.61	Determined in Reference 9
$PbCl_3^-$	Na^+	-0.22 ± 0.22	Determined in Reference 9
$Pb(OH)_3^-$	Na^+	0.42 ± 0.80	Determined in Reference 9
$Bi(OH)_4^-$	Na^+	0.07	Determined in Reference 29
$BiCl_4^-$	H^+	-0.09	Determined in Reference 29
$BiCl_4^-$	Na^+	0.03	Determined in Reference 29
$BiCl_4^-$	Li^+	0.15	Determined in Reference 29
$Th(OH)_3(isa)_2^-$	Na^+	-0.07	Determined in Reference 27
$Co(SO_4)_2^{2-}$	Na^+	-0.12 ± 0.06	Taken from $\varepsilon(UO_2(SO_4)_2^{2-},Na^+)$ [16]
$PdCl_4^{2-}$	K^+	-0.06	Determined in Reference 9
$PdCl_4^{2-}$	Na^+	-0.044	Determined in Reference 9
$PdCl_3OH^{2-}$	Na^+	-0.044	Determined in Reference 9
$BiCl_5^{2-}$	H^+	-0.10	Determined in Reference 29
$BiCl_5^{2-}$	Li^+	-0.10	Determined in Reference 29
$BiCl_5^{2-}$	Na^+	-0.10	Determined in Reference 29
$PaO(SO_4)_2^-$	Na^+	0.40 ± 0.10	Determined from $\Delta\varepsilon$ in Reference 32, $\varepsilon(H^+,ClO_4^-)$ and $\varepsilon(SO_4^-,Na^+)$ in Reference 16
$Th(OH)_4(isa)_2^{2-}$	Na^+	-0.12	Determined in Reference 27
$PaO(SO_4)_3^{3-}$	Na^+	0.20 ± 0.10	Determined from $\Delta\varepsilon$ in Reference 32, $\varepsilon(H^+,ClO_4^-)$ and $\varepsilon(SO_4^-,Na^+)$ in Reference 16

3.5 Errata

3.5.1 Correction of Actinide(III/IV) Isosaccharinate System

Equilibrium constants for actinide(III/IV) isosaccharinate (ISA) system were selected in JAEA-TDB (2010) [1] and JAEA-2012 [3]. The values of equilibrium constants were not correctly recorded from Gaona *et al.*[36] and Rai *et al.* [37] and they were extremely underestimated. Therefore for the current TDB, we corrected these errors in the values of equilibrium constants for the following reactions.

$$Am^{3+} + 3\ H_2O(l) + isa^- \Leftrightarrow Am(OH)_3(isa)^- . \quad (14)$$

$$An(OH)_4(am) + n\ isa^- \Leftrightarrow An(OH)_4(isa)_n^{n-}\ \text{(An: U(IV), Np(IV), Pu(IV))}\ , \quad (15)$$

The selected equilibrium constants for Th-ISA reactions are from Rai *et al.* [37] and for all other actinides are Gaona *et al.* [36]

The equilibrium constant for reaction (14) at standard state can be directly taken from Tits *et al.* [38] (-21.4 ± 1). Because of restrictions of database files for use of the geochemical calculation programs, the log $K°$ values of following reaction for actinide(IV)-ISA system should be selected:

$$An^{4+} + m\ H_2O(l) + n\ isa^- \Leftrightarrow An(OH)_m(isa)_n^{(-4+m+n)-} + m\ H^+$$
$$\text{(An: Th, U(IV), Np(IV), Pu(IV))}\ . \quad (16)$$

The $\log_{10} K°$ values for reaction (16) can be obtained by subtracting the solubility products of actinide(IV) hydrous oxide (already selected in JAEA-TDB) from those for reaction (15).

The refined thermodynamic data for actinide(III/IV)-ISA system are listed in Table 8. The $\log_{10} K°$ values for $M(OH)_3(isa)^-$ (M: Sm, Ac, Pu and Cm) were taken from that for $Am(OH)_3(isa)^-$ based on a chemical analogue among trivalent lanthanides and actinides as discussed previously [39].

Table 8 Refined thermodynamic data for actinide(III/IV) isosaccharinate system

reaction	$\log_{10} K°$	
	present	JAEA-2012 [3]
$M^{3+} + 3\ H_2O(l) + isa^- \Leftrightarrow M(OH)_3(isa)^- + 3\ H^+$ (M: Sm, Ac, Pu, Am and Cm)	-21.400 ± 1.000	-47.700 (only for Am)
$Th^{4+} + H_2O(l) + isa^- \Leftrightarrow ThOH(isa)^{2+} + H^+$	3.200 ± 0.500	-6.200
$Th^{4+} + 3\ H_2O(l) + 2\ isa^- \Leftrightarrow Th(OH)_3(isa)_2^- + 3\ H^+$	-4.900 ± 0.500	-70.300
$Th^{4+} + 4\ H_2O(l) + 2\ isa^- \Leftrightarrow Th(OH)_4(isa)_2^{2-} + 4\ H^+$	-12.500 ± 0.500	-105.900
$U^{4+} + 4\ H_2O(l) + isa^- \Leftrightarrow U(OH)_4(isa)^- + 4\ H^+$	-6.800 ± 0.900	-17.600
$U^{4+} + 4\ H_2O(l) + 2\ isa^- \Leftrightarrow U(OH)_4(isa)_2^{2-} + 4\ H^+$	-4.900 ± 1.000	-15.700
$Np^{4+} + 4\ H_2O(l) + isa^- \Leftrightarrow Np(OH)_4(isa)^- + 4\ H^+$	-4.060 ± 0.620	-13.660
$Np^{4+} + 4\ H_2O(l) + 2\ isa^- \Leftrightarrow Np(OH)_4(isa)_2^{2-} + 4\ H^+$	-2.200 ± 0.620	-11.800
$Pu^{4+} + 4\ H_2O(l) + isa^- \Leftrightarrow Pu(OH)_4(isa)^- + 4\ H^+$	-1.474 ± 1.588	-12.300
$Pu^{4+} + 4\ H_2O(l) + 2\ isa^- \Leftrightarrow Pu(OH)_4(isa)_2^{2-} + 4\ H^+$	2.726 ± 1.127	-8.100

Thermodynamic calculations were performed to estimate ISA contributions to solubility values using the updated JAEA-TDB. Two water compositions were selected; one was the reference porewater of fresh-reducing-high pH type (FRHP) [40] and the other was cement-equilibrated FRHP groundwater at pH = 12.5 (Region II) [41]. The estimated solubility values and contribution of actinide(III/IV)-ISA complexes for thorium, uranium, neptunium, plutonium and americium are shown in Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8, respectively. Major ISA contributions below 10^{-3} molal (mol·(kg $H_2O)^{-1}$) were found in neptunium and plutonium calculations and americium calculation for cement-equilibrated water. These results imply that ISA has no significant effect on actinide(III/IV) solubility because the maximum ISA concentration in porewater around a TRU disposal facility is assumed to be 5×10^{-6} mol·dm^{-3}.

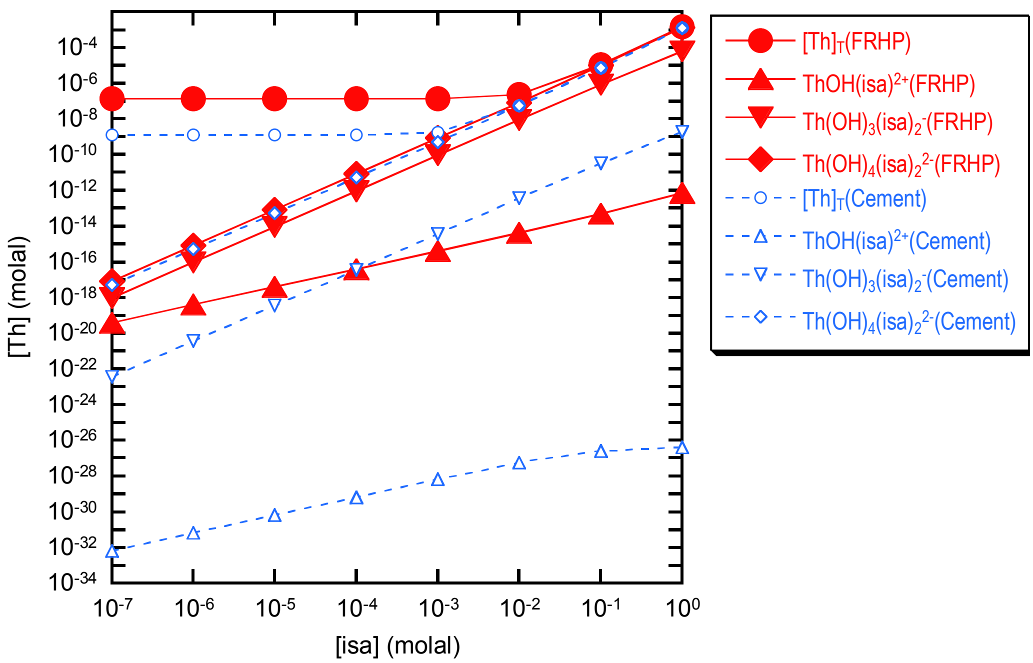

Figure 4 Calculated thorium solubilities and ISA contributions as a function of ISA concentration in FRHP porewater and cement-equilibrated water

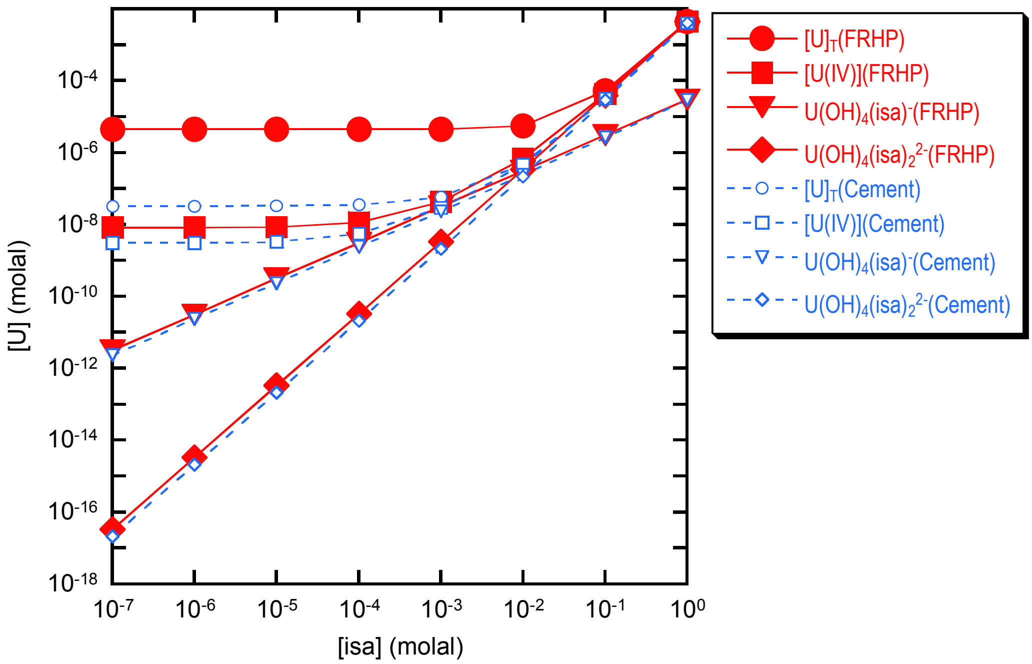

Figure 5 Calculated uranium solubilities and ISA contributions as a function of ISA concentration in FRHP porewater and cement-equilibrated water

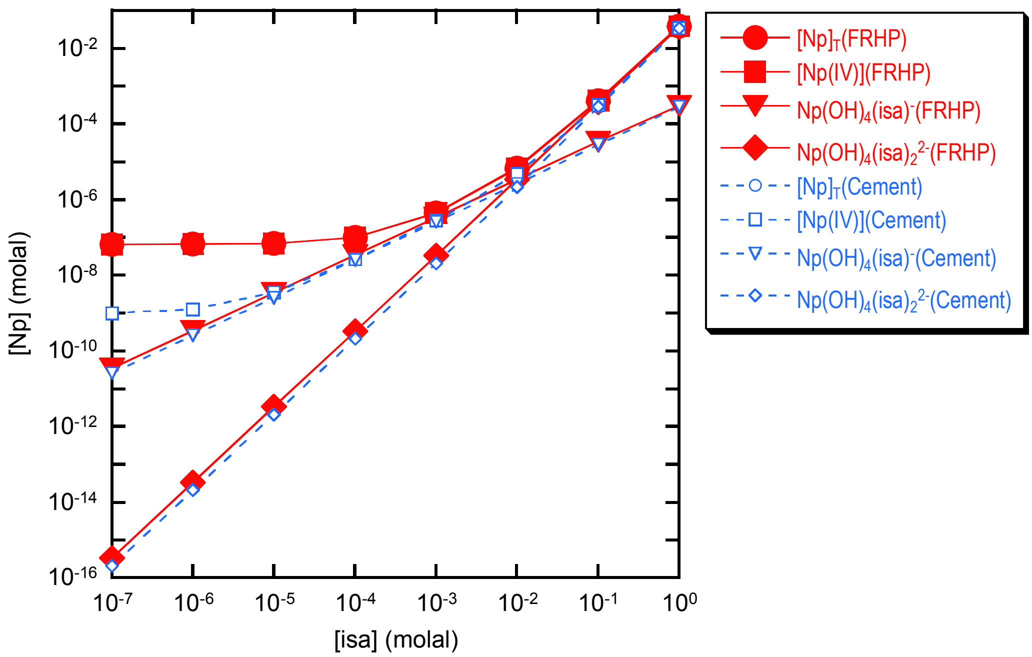

Figure 6 Calculated neptunium solubilities and ISA contributions as a function of ISA concentration in FRHP porewater and cement-equilibrated water

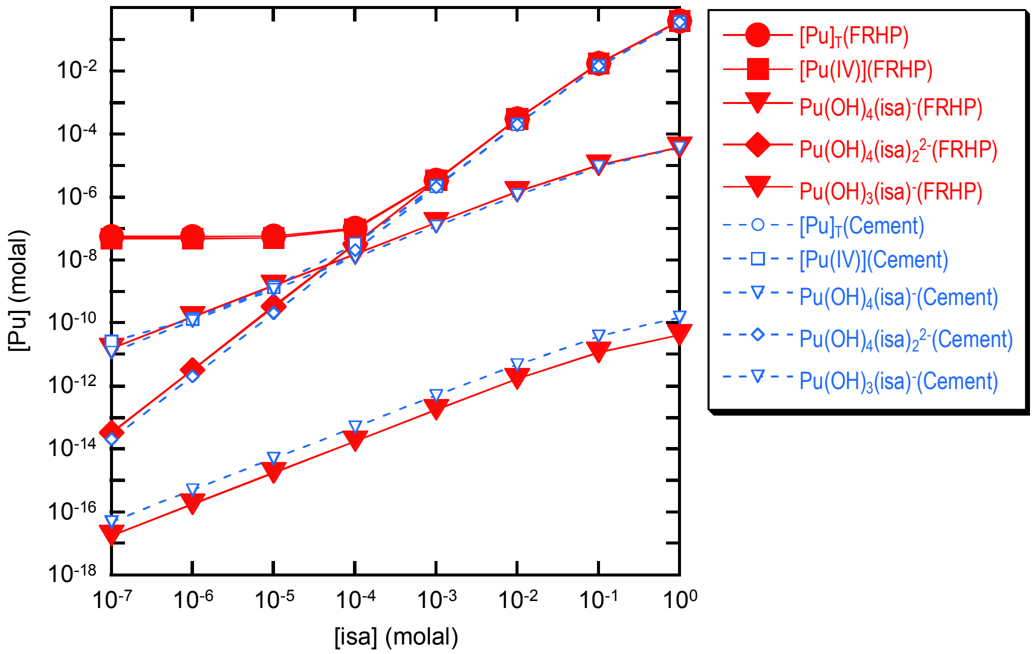

Figure 7 Calculated plutonium solubilities and ISA contributions as a function of ISA concentration in FRHP porewater and cement-equilibrated water

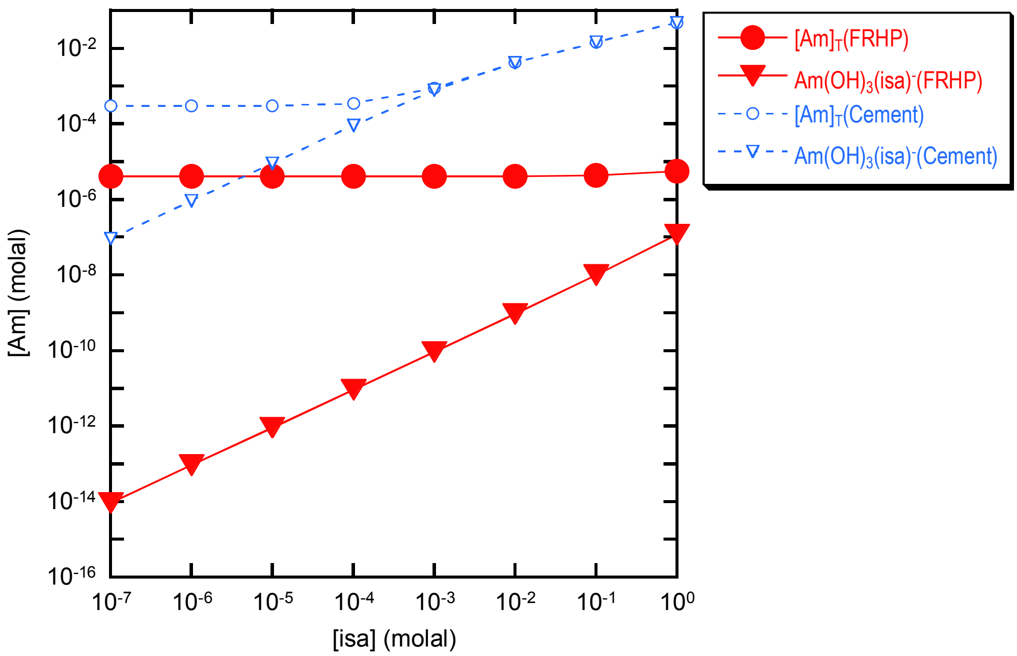

Figure 8 Calculated americium solubilities and ISA contributions as a function of ISA concentration in FRHP porewater and cement-equilibrated water

3.5.2 Refinement of Thermodynamic Data

(1) Cyanate, Thiocyanate and Selenocyanate Systems

The NEA selected the $\log_{10} K°$ values of thiocyanate complexes of thorium for the following reactions and JAEA-2012 [3] took the $\log_{10} K°$ values without any modifications:

$$Th^{4+} + SCN^- \Leftrightarrow ThSCN^{3+} \quad \log_{10} K° = 2.000 \pm 0.500 , \quad (17)$$

$$Th^{4+} + 2\ SCN^- \Leftrightarrow Th(SCN)_2^{2+} \quad \log_{10} K° = 3.400 \pm 0.800 . \quad (18)$$

Species containing multiple elements of which master species have the same positive or negative charge (except H and O), e.g. cyanate (CN^-), thiocyanate (SCN^-) and selenocyanate ($SeCN^-$) ions, are compatible for use with PHREEQC [6] after definition of the reaction of species, but not acceptable as a counter-ion in the EQ3/6 [7] and the Geochemist's Workbench [8]. The SCN^- should be divided to master species of each element (i.e. SO_4^-, CO_3^{2-} and NO_3^-) using the following reaction and $\log_{10} K°$ value already selected in JAEA-TDB:

$$SO_4^{2-} + CO_3^{2-} + NO_3^- + 20\ H^+ + 16\ e^- \Leftrightarrow SCN^- + 10\ H_2O(l)$$
$$\log_{10} K° = 156.972 \pm 0.715 . \quad (19)$$

Therefore we redefined the $\log_{10} K°$ values of thiocyanate complexes for the following reactions:

$$Th^{4+} + SO_4^{2-} + CO_3^{2-} + NO_3^- + 20\ H^+ + 16\ e^- \Leftrightarrow ThSCN^{3+} + 10\ H_2O(l)$$
$$\log_{10} K° = 158.972 \pm 0.872 , \quad (20)$$

$$Th^{4+} + 2\ SO_4^{2-} + 2\ CO_3^{2-} + 2\ NO_3^- + 40\ H^+ + 32\ e^- \Leftrightarrow Th(SCN)_2^{2+} + 20\ H_2O(l)$$
$$\log_{10} K° = 317.344 \pm 1.639 . \quad (21)$$

It should be noted that the use of reactions (20) and (21) enlarges uncertainty of these $\log_{10} K°$ values.

In contrast, the uncertainty of $\log_{10} K°$ values of cyanate, thiocyanate and selenocyanate complexes can be reduced after the use of CN^-, SCN^- and $SeCN^-$ in formation reactions. Refined reactions and $\log_{10} K°$ values for cyanate, thiocyanate and selenocyanate systems are listed in Table 9. Formation constant of $SeCN^-$ was defined in the present study using $\Delta_f G°_m$ values selected by the NEA [42].

(2) Iodate and Selenide Systems

Some thermodynamic data for iodate and selenide systems involved redox reactions where master species of different oxidation states were defined. We refined the $\log_{10} K^\circ$ values for some compounds listed in Table 10.

Table 9 Refined equilibrium constants for cyanate, thiocyanate and selenocyanate systems (1/2)

Reaction	$\log_{10} K°$
$Co^{2+} + 4 CN^- \Leftrightarrow Co(CN)_4^{2-}$	**30.017 ± 0.533**
$Co^{2+} + 4 CO_3^{2-} + 4 NO_3^- + 48 H^+ + 40 e^- \Leftrightarrow Co(CN)_4^{2-} + 24 H_2O(l)$	462.533 ± 1.896
$Co^{2+} + 5 CN^- \Leftrightarrow Co(CN)_5^{3-}$	**28.327 ± 0.888**
$Co^{2+} + 5 CO_3^{2-} + 5 NO_3^- + 60 H^+ + 50 e^- \Leftrightarrow Co(CN)_5^{3-} + 30 H_2O(l)$	568.972 ± 2.442
$Co^{2+} + SCN^- \Leftrightarrow CoSCN^+$	**1.790 ± 0.073**
$Co^{2+} + SO_4^{2-} + CO_3^{2-} + NO_3^- + 20 H^+ + 16 e^- \Leftrightarrow CoSCN^+ + 10 H_2O(l)$	158.762 ± 0.719
$Co^{2+} + 2 SCN^- \Leftrightarrow Co(SCN)_2(aq)$	**2.665 ± 0.115**
$Co^{2+} +2 SO_4^{2-} +2 CO_3^{2-} +2 NO_3^- +40 H^+ +32 e^- \Leftrightarrow Co(SCN)_2(aq) +20 H_2O(l)$	316.609 ± 1.435
$Co^{2+} + 3 SCN^- \Leftrightarrow Co(SCN)_3^-$	**2.993 ± 0.229**
$Co^{2+} +3 SO_4^{2-} +3 CO_3^{2-} +3 NO_3^- +60 H^+ +48 e^- \Leftrightarrow Co(SCN)_3^- +30 H_2O(l)$	473.909 ± 2.157
$Ni^{2+} + 4 CN^- \Leftrightarrow Ni(CN)_4^{2-}$	**30.200 ± 0.120**
$Ni^{2+} + 4 NO_3^- + 4 CO_3^{2-} + 48 H^+ + 40 e^- \Leftrightarrow Ni(CN)_4^{2-} + 24 H_2O(l)$	462.716 ± 1.824
$Ni^{2+} + 5 CN^- \Leftrightarrow Ni(CN)_5^{3-}$	**28.500 ± 0.500**
$Ni^{2+} + 5 NO_3^- + 5 CO_3^{2-} + 60 H^+ + 50 e^- \Leftrightarrow Ni(CN)_5^{3-} + 30 H_2O(l)$	569.145 ± 2.329
$Ni^{2+} + SCN^- \Leftrightarrow NiSCN^+$	**1.810 ± 0.040**
$Ni^{2+} + NO_3^- + CO_3^{2-} + SO_4^{2-} + 20 H^+ + 16 e^- \Leftrightarrow NiSCN^+ + 10 H_2O(l)$	158.782 ± 0.716
$Ni^{2+} + 2 SCN^- \Leftrightarrow Ni(SCN)_2(aq)$	**2.690 ± 0.070**
$Ni^{2+} +2 NO_3^- +2 CO_3^{2-} +2 SO_4^{2-} +40 H^+ +32 e^- \Leftrightarrow Ni(SCN)_2(aq) +20 H_2O(l)$	316.634 ± 1.432
$Ni^{2+} + 3 SCN^- \Leftrightarrow Ni(SCN)_3^-$	**3.020 ± 0.180**
$Ni^{2+} + 3 NO_3^- + 3 CO_3^{2-} + 3 SO_4^{2-} + 60 H^+ + 48 e^- \Leftrightarrow Ni(SCN)_3^- + 30 H_2O(l)$	473.936 ± 2.153
$SeCN^- + Tl^+ \Leftrightarrow TlSeCN(aq)$	**1.750 ± 0.290**
$SeO_4^{2-} + 20 H^+ + 16 e^- + CO_3^{2-} + NO_3^- + Tl^+ \Leftrightarrow TlSeCN(aq) + 10 H_2O(l)$	204.476 ± 0.778
$SeCN^- + Zn^{2+} \Leftrightarrow ZnSeCN^+$	**1.210 ± 0.060**
$SeO_4^{2-} + 20 H^+ + 16 e^- + CO_3^{2-} + NO_3^- + Zn^{2+} \Leftrightarrow ZnSeCN^+ + 10 H_2O(l)$	203.936 ± 0.724
$SeCN^- + Zn^{2+} \Leftrightarrow Zn(SeCN)_2(aq)$	**1.680 ± 0.110**
$2 SeO_4^{2-}+40 H^+ +32 e^- +2 CO_3^{2-}+2 NO_3^-+Zn^{2+} \Leftrightarrow Zn(SeCN)_2(aq)+20 H_2O(l)$	407.133 ± 1.448
$SeCN^- + Cd^{2+} \Leftrightarrow CdSeCN^+$	**2.240 ± 0.060**
$SeO_4^{2-} + 20 H^+ + 16 e^- + CO_3^{2-} + NO_3^- + Cd^{2+} \Leftrightarrow CdSeCN^+ + 10 H_2O(l)$	204.966 ± 0.724
$2 SeCN^- + Cd^{2+} \Leftrightarrow Cd(SeCN)_2(aq)$	**3.340 ± 0.120**
$2 SeO_4^{2-}+40 H^+ +32 e^- +2 CO_3^{2} +2 NO_3^-+Cd^{2+} \Leftrightarrow Cd(SeCN)_2(aq)+20 H_2O(l)$	408.793 ± 1.449
$3 SeCN^- + Cd^{2+} \Leftrightarrow Cd(SeCN)_3^-$	**3.810 ± 0.210**
$3 SeO_4^{2-}+60 H^+ +48 e^- +3 CO_3^{2-}+3 NO_3^-+Cd^{2+} \Leftrightarrow Cd(SeCN)_3^-+30 H_2O(l)$	611.989 ± 2.176
$4 SeCN^- + Cd^{2+} \Leftrightarrow Cd(SeCN)_4^{2-}$	**4.600 ± 0.110**
$4 SeO_4^{2-}+80 H^+ +64 e^- +4 CO_3^{2-}+4 NO_3^-+Cd^{2+} \Leftrightarrow Cd(SeCN)_4^{2-}+40 H_2O(l)$	815.505 ± 2.890
$2 SeCN^- + Hg^{2+} \Leftrightarrow Hg(SeCN)_2(aq)$	**22.300 ± 1.000**
$2 SeO_4^{2-}+40 H^+ +32 e^- +2 CO_3^{2-}+2 NO_3^-+Hg^{2+} \Leftrightarrow Hg(SeCN)_2(aq)+20 H_2O(l)$	427.753 ± 1.756
$3 SeCN^- + Hg^{2+} \Leftrightarrow Hg(SeCN)_3^-$	**26.800 ± 1.000**
$3 SeO_4^{2-}+60 H^+ +48 e^- +3 CO_3^{2-}+3 NO_3^-+Hg^{2+} \Leftrightarrow Hg(SeCN)_3^-+30 H_2O(l)$	634.979 ± 2.386
$4 SeCN^- + Hg^{2+} \Leftrightarrow Hg(SeCN)_4^{2-}$	**29.300 ± 0.500**
$4 SeO_4^{2-}+80 H^+ +64 e^- +4 CO_3^{2-}+4 NO_3^-+Hg^{2+} \Leftrightarrow Hg(SeCN)_4^{2-}+40 H_2O(l)$	840.205 ± 2.931
$3 SeCN^- + Ag^+ \Leftrightarrow Ag(SeCN)_3^{2-}$	**13.850 ± 0.300**
$3 SeO_4^{2-}+60 H^+ +48 e^- +3 CO_3^{2-}+3 NO_3^-+Ag^+ \Leftrightarrow Ag(SeCN)_3^{2-}+30 H_2O(l)$	622.029 ± 2.187
$SeCN^- + Ni^{2+} \Leftrightarrow NiSeCN^+$	**1.770 ± 0.060**
$SeO_4^{2-} + 20 H^+ + 16 e^- + CO_3^{2-} + NO_3^- + Ni^{2+} \Leftrightarrow NiSeCN^+ + 10 H_2O(l)$	204.496 ± 0.724
$2 SeCN^- + Ni^{2+} \Leftrightarrow Ni(SeCN)_2(aq)$	**2.240 ± 0.140**
$2 SeO_4^{2-}+40 H^+ +32 e^- +2 CO_3^{2-}+2 NO_3^-+Ni^{2+} \Leftrightarrow Ni(SeCN)_2(aq)+20 H_2O(l)$	407.693 ± 1.451

Table 9 Refined equilibrium constants for cyanate, thiocyanate and selenocyanate systems (2/2)

Reaction	$\log_{10} K°$
$Sm^{3+} + SCN^- \Leftrightarrow SmSCN^{2+}$	**1.300 ± 0.300**
$Sm^{3+} + NO_3^- + CO_3^{2-} + SO_4^{2-} + 20\ H^+ + 16\ e^- \Leftrightarrow SmSCN^{2+} + 10\ H_2O(l)$	158.272 ± 0.775
$Ac^{3+} + SCN^- \Leftrightarrow AcSCN^{2+}$	**1.300 ± 0.500**
$Ac^{3+} + NO_3^- + CO_3^{2-} + SO_4^{2-} + 20\ H^+ + 16\ e^- \Leftrightarrow AcSCN^{2+} + 10\ H_2O(l)$	158.272 ± 0.872
$U^{4+} + SCN^- \Leftrightarrow USCN^{3+}$	**2.970 ± 0.060**
$U^{4+} + SO_4^{2-} + CO_3^{2-} + NO_3^- + 20\ H^+ + 16\ e^- \Leftrightarrow USCN^{3+} + 10\ H_2O(l)$	159.942 ± 0.718
$U^{4+} + 2\ SCN^- \Leftrightarrow U(SCN)_2^{2+}$	**4.260 ± 0.180**
$U^{4+} + 2\ SO_4^{2-} + 2\ CO_3^{2-} + 2\ NO_3^- + 40\ H^+ + 32\ e^- \Leftrightarrow U(SCN)_2^{2+} + 20\ H_2O(l)$	318.204 ± 1.441
$UO_2^{2+} + SCN^- \Leftrightarrow UO_2SCN^+$	**1.400 ± 0.230**
$UO_2^{2+} + SO_4^{2-} + CO_3^{2-} + NO_3^- + 20\ H^+ + 16\ e^- \Leftrightarrow UO_2SCN^+ + 10\ H_2O(l)$	158.372 ± 0.751
$UO_2^{2+} + 2\ SCN^- \Leftrightarrow UO_2(SCN)_2(aq)$	**1.240 ± 0.550**
$UO_2^{2+}+2\ SO_4^{2-}+2\ CO_3^{2-}+2\ NO_3^-+40\ H^++32\ e^- \Leftrightarrow UO_2(SCN)_2(aq)+20\ H_2O(l)$	315.184 ± 1.532
$UO_2^{2+} + 3\ SCN^- \Leftrightarrow UO_2(SCN)_3^-$	**2.100 ± 0.500**
$UO_2^{2+} +3\ SO_4^{2-} +3\ CO_3^{2-} +3\ NO_3^- +60\ H^+ +48\ e^- \Leftrightarrow UO_2(SCN)_3^- +30\ H_2O(l)$	473.016 ± 2.203
$Np^{4+} + SCN^- \Leftrightarrow NpSCN^{3+}$	**3.000 ± 0.300**
$Np^{4+} + SO_4^{2-} + CO_3^{2-} + NO_3^- + 20\ H^+ + 16\ e^- \Leftrightarrow NpSCN^{3+} + 10\ H_2O(l)$	159.972 ± 0.775
$Np^{4+} + 2\ SCN^- \Leftrightarrow Np(SCN)_2^{2+}$	**4.100 ± 0.500**
$Np^{4+} +2\ SO_4^{2-} +2\ CO_3^{2-} +2\ NO_3^- +40\ H^+ +32\ e^- \Leftrightarrow Np(SCN)_2^{2+} +20\ H_2O(l)$	318.044 ± 1.515
$Np^{4+} + 3\ SCN^- \Leftrightarrow Np(SCN)_3^+$	**4.800 ± 0.500**
$Np^{4+} +3\ SO_4^{2-} +3\ CO_3^{2-} +3\ NO_3^- +60\ H^+ +48\ e^- \Leftrightarrow Np(SCN)_3^+ +30\ H_2O(l)$	475.716 ± 2.203
$Pu^{3+} + SCN^- \Leftrightarrow PuSCN^{2+}$	**1.300 ± 0.300**
$Pu^{3+} + NO_3^- + CO_3^{2-} + SO_4^{2-} + 20\ H^+ + 16\ e^- \Leftrightarrow PuSCN^{2+} + 10\ H_2O(l)$	158.272 ± 0.775
$Am^{3+} + SCN^- \Leftrightarrow AmSCN^{2+}$	**1.300 ± 0.300**
$Am^{3+} + NO_3^- + CO_3^{2-} + SO_4^{2-} + 20\ H^+ + 16\ e^- \Leftrightarrow AmSCN^{2+} + 10\ H_2O(l)$	158.272 ± 0.775
$Cm^{3+} + SCN^- \Leftrightarrow CmSCN^{2+}$	**1.300 ± 0.300**
$Cm^{3+} + NO_3^- + CO_3^{2-} + SO_4^{2-} + 20\ H^+ + 16\ e^- \Leftrightarrow CmSCN^{2+} + 10\ H_2O(l)$	158.272 ± 0.775
$HCN(g) \Leftrightarrow CN^- + H^+$	**-8.308 ± 0.054**
$HCN(g) + 6\ H_2O(l) \Leftrightarrow CO_3^{2-} + NO_3^- + 13\ H^+ + 10\ e^-$	-116.437 ± 0.451
$Cd(SeCN)_2(cr) \Leftrightarrow Cd^{2+} + 2\ SCN^-$	**-5.700 ± 0.500**
$Cd(SeCN)_2(cr)+20\ H_2O(l) \Leftrightarrow Cd^{2+}+2\ SeO_4^{2-}+40\ H^++32\ e^-+2\ CO_3^{2-}+2\ NO_3^-$	-411.153 ± 1.528
$AgSeCN(cr) \Leftrightarrow SCN^- + Ag^+$	**-13.998 ± 0.508**
$AgSeCN(cr) + 10\ H_2O(l) \Leftrightarrow SeO_4^{2-} + 20\ H^+ + 16\ e^- + CO_3^{2-} + NO_3^- + Ag^+$	-216.724 ± 0.883

Table 10 Refinement of thermodynamic data for iodate and selenide systems

Reaction	$\log_{10} K°$
$\beta\text{-}Co(IO_3)_2 + 12\ H^+ + 12\ e^- \Leftrightarrow Co^{2+} + 2\ I^- + 6\ H_2O(l)$	218.731 ± 0.293
$\beta\text{-}Co(IO_3)_2 \Leftrightarrow Co^{2+} + 2\ IO_3^-$	**-4.395 ± 0.088**
$Co(IO_3)_2\cdot 2H_2O(cr) + 12\ H^+ + 12\ e^- \Leftrightarrow Co^{2+} + 8\ H_2O(l) + 2\ I^-$	218.025 ± 0.328
$Co(IO_3)_2\cdot 2H_2O(cr) \Leftrightarrow Co^{2+} + 2\ IO_3^- + 8\ H_2O(l)$	**-5.101 ± 0.177**
$\beta\text{-}Ni(IO_3)_2 + 12\ H^+ + 12\ e^- \Leftrightarrow Ni^{2+} + 2\ I^- + 6\ H_2O(l)$	218.696 ± 0.277
$\beta\text{-}Ni(IO_3)_2 \Leftrightarrow Ni^{2+} + 2\ IO_3^-$	**-4.430 ± 0.020**
$Ni(IO_3)_2\cdot 2H_2O(cr) + 12\ H^+ + 12\ e^- \Leftrightarrow Ni^{2+} + 8\ H_2O(l) + 2\ I^-$	217.986 ± 0.294
$Ni(IO_3)_2\cdot 2H_2O(cr) \Leftrightarrow Ni^{2+} + 2\ IO_3^- + 8\ H_2O(l)$	**5.140 ± 0.100**
$NH_4HSe(cr) + 7\ H_2O(l) \Leftrightarrow SeO_4^{2-} + NO_3^- + 19\ H^+ + 16\ e^-$	-198.643 ± 0.973
$NH_4HSe(cr) \Leftrightarrow HSe^- + NH_4^+$	**2.061 ± 1.002**

3.5.3 Correction of Thermodynamic Data for Amorphous Selenium in PHREEQC Database

We did not put a minus sign for the equilibrium constant for amorphous selenium (Se(am)) in the PHREEQC database of previous JAEA-TDB (JAEA-2012) [3]. The $\log_{10} K°$ for Se(am) was corrected from 6.570 to -6.570 (±0.150).

The master species of the reaction ZrO_2(mono) +4 $H^+ \Leftrightarrow Zr^{4+}$ + 2 H_2O(l) was wrong (as $Zr(OH)_4$(aq)) and the reaction did not work in the PHREEQC database of previous JAEA-TDB (JAEA-2012) [3]. The master species was replaced to Zr^{4+}.

There are no errata in the text and other database files of JAEA-2012 [3].

Acknowledgements

We acknowledge Dr. Dhanpat Rai of Rai Enviro-Chem LLC and Dr. Tetsuji Yamaguchi of Nuclear Safety Research Center, Japan Atomic Energy Agency, for reviewing and giving advice regarding the present paper.

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Appendix 1　Revised Thermodynamic Data Compiled for JAEA-TDB

Selected equilibrium constants for JAEA-TDB are shown in Table A1 and Table A2.

Table A1　Selected equilibrium constants of aqueous species for JAEA-TDB ready to use for the geochemical calculation programs (revised from Table A1 in the previous TDB report [3)])

Reactions and $\log_{10} K°$ values written with bold letters are additionally selected or revised in the present report.

Reaction	$\log_{10} K°$	Ref.	T.v.*
$2\ H^+ + 2\ e^- \Leftrightarrow H_2(aq)$	-3.150	5	
$H_2O(l) \Leftrightarrow H^+ + OH^-$	-14.001 ± 0.015	4	
$2\ H_2O(l) \Leftrightarrow O_2(aq) + 4\ H^+ + 4\ e^-$	-86.080	5	
$Li^+ + SO_4^{2-} \Leftrightarrow LiSO_4^-$	0.640	5	
$B(OH)_3(aq) \Leftrightarrow H_2BO_3^- + H^+$	-9.240	5	
$B(OH)_3(aq) + F^- \Leftrightarrow BF(OH)_3^-$	-0.400	5	
$B(OH)_3(aq) + 2\ F^- + H^+ \Leftrightarrow BF_2(OH)_2^- + H_2O(l)$	7.628	5	
$B(OH)_3(aq) + 2\ H^+ + 3\ F^- \Leftrightarrow BF_3OH^- + 2\ H_2O(l)$	13.666	5	
$B(OH)_3(aq) + 3\ H^+ + 4\ F^- \Leftrightarrow BF_4^- + 3\ H_2O(l)$	20.274	5	
$CO_3^{2-} + H^+ \Leftrightarrow HCO_3^-$	10.329 ± 0.020	4	
$CO_3^{2-} + 2\ H^+ \Leftrightarrow CO_2(aq) + H_2O(l)$	16.683 ± 0.028	4	
$CO_3^{2-} + 10\ H^+ + 8\ e^- \Leftrightarrow CH_4(aq) + 3\ H_2O(l)$	41.071	5	
$CO_3^{2-} + NO_3^- + 12\ H^+ + 10\ e^- \Leftrightarrow CN^- + 6\ H_2O(l)$	108.129 ± 0.455	4	
$CN^- + H^+ \Leftrightarrow HCN(aq)$	117.339 ± 0.454	3	
$NO_3^- + 10\ H^+ + 8\ e^- \Leftrightarrow NH_4^+ + 3\ H_2O(l)$	119.134 ± 0.089	4	
$NO_3^- + 2\ H^+ + 2\ e^- \Leftrightarrow NO_2^- + H_2O(l)$	27.776 ± 0.075	4, 43	
$NO_2^- + H^+ \Leftrightarrow HNO_2(aq)$	3.210 ± 0.160	4	
$3\ NO_3^- + 18\ H^+ + 16\ e^- \Leftrightarrow N_3^- + 9\ H_2O(l)$	254.672 ± 0.418	4	
$3\ NO_3^- + 19\ H^+ + 16\ e^- \Leftrightarrow HN_3(aq) + 9\ H_2O(l)$	259.372 ± 0.382	4	
$NH_4^+ \Leftrightarrow H^+ + NH_3(aq)$	-9.237 ± 0.022	4	
$NH_4^+ + SO_4^{2-} \Leftrightarrow NH_4SO_4^-$	1.052	5	
$F^+ + H^- \Leftrightarrow HF(aq)$	3.180 ± 0.020	4	
$2\ F^- + H^+ \Leftrightarrow HF_2^-$	3.620 ± 0.122	4	
$Na^+ + CO_3^{2-} \Leftrightarrow NaCO_3^-$	1.268	5	
$Na^+ + CO_3^{2-} + H^+ \Leftrightarrow NaHCO_3(aq)$	10.080	5	
$Na^+ + SO_4^{2-} \Leftrightarrow NaSO_4^-$	0.700 ± 0.050	5, 43	
$Na^+ + H^+ + PO_4^{3-} \Leftrightarrow NaHPO_4^-$	12.636	5	
$Mg^{2+} + H_2O(l) \Leftrightarrow MgOH^+ + H^+$	-11.794	5	
$Mg^{2+} + CO_3^{2-} \Leftrightarrow MgCO_3(aq)$	2.981 ± 0.030	5, 43	
$Mg^{2+} + SO_4^{2-} \Leftrightarrow MgSO_4(aq)$	2.250	5	
$Mg^{2+} + PO_4^{3-} \Leftrightarrow MgPO_4^-$	6.589	5	
$Mg^{2+} + H^+ + PO_4^{3-} \Leftrightarrow MgHPO_4(aq)$	15.216	5	
$Mg^{2+} + 2\ H^+ + PO_4^{3-} \Leftrightarrow MgH_2PO_4^+$	21.066	5	
$Mg^{2+} + F^- \Leftrightarrow MgF^+$	1.820	5	
$Al^{3+} + H_2O(l) \Leftrightarrow AlOH^{2+} + H^+$	-4.990 ± 0.020	5, 43	
$Al^{3+} + 2\ H_2O(l) \Leftrightarrow Al(OH)_2^+ + 2\ H^+$	-10.100 ± 0.200	5, 43	
$Al^{3+} + 3\ H_2O(l) \Leftrightarrow Al(OH)_3(aq) + 3\ H^+$	-16.000	5	
$Al^{3+} + 4\ H_2O(l) \Leftrightarrow Al(OH)_4^- + 4\ H^+$	-23.000	5	
$Al^{3+} + F^- \Leftrightarrow AlF^{2+}$	7.010	5	
$Al^{3+} + 2\ F^- \Leftrightarrow AlF_2^+$	12.750	5	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Al^{3+} + 3 F^- \Leftrightarrow AlF_3(aq)$	17.020	5	
$Al^{3+} + 4 F^- \Leftrightarrow AlF_4^-$	19.720	5	
$Al^{3+} + SO_4^{2-} \Leftrightarrow AlSO_4^+$	3.020	5	
$Al^{3+} + 2 SO_4^{2-} \Leftrightarrow Al(SO_4)_2^-$	4.920	5	
$H_4SiO_4(aq) \Leftrightarrow H_2SiO_4^{2-} + 2 H^+$	-23.140 ± 0.090	4	
$H_4SiO_4(aq) \Leftrightarrow H_3SiO_4^- + H^+$	-9.810 ± 0.020	4	
$2 H_4SiO_4(aq) \Leftrightarrow H_4Si_2O_7^{2-} + H_2O(l) + 2 H^+$	-19.000 ± 0.300	4	
$2 H_4SiO_4(aq) \Leftrightarrow H_5Si_2O_7^- + H_2O(l) + H^+$	-8.100 ± 0.300	4	
$3 H_4SiO_4(aq) \Leftrightarrow H_3Si_3O_9^{3-} + 3 H_2O(l) + 3 H^+$	-28.600 ± 0.300	4	
$3 H_4SiO_4(aq) \Leftrightarrow H_5Si_3O_{10}^{3-} + 2 H_2O(l) + 3 H^+$	-27.500 ± 0.300	4	
$4 H_4SiO_4(aq) \Leftrightarrow H_4Si_4O_{12}^{4-} + 4 H_2O(l) + 4 H^+$	-36.300 ± 0.500	4	
$4 H_4SiO_4(aq) \Leftrightarrow H_5Si_4O_{12}^{3-} + 4 H_2O(l) + 3 H^+$	-25.500 ± 0.300	4	
$4 H_4SiO_4(aq) \Leftrightarrow H_{13}Si_4O_{16}^{3-} + 3 H^+$	-34.901	5	
$H_4SiO_4(aq) + 4 H^+ + 6 F^- \Leftrightarrow F_6Si^{2-} + 4 H_2O(l)$	30.180	5	
$2 PO_4^{3-} + 2 H^+ \Leftrightarrow P_2O_7^{4-} + H_2O(l)$	21.314 ± 0.890	4	
$PO_4^{3-} + H^+ \Leftrightarrow HPO_4^{2-}$	12.350 ± 0.030	4	
$PO_4^{3-} + 2 H^+ \Leftrightarrow H_2PO_4^-$	19.562 ± 0.033	4	
$PO_4^{3-} + 3 H^+ \Leftrightarrow H_3PO_4(aq)$	21.702 ± 0.176	4	
$2 PO_4^{3-} + 3 H^+ \Leftrightarrow HP_2O_7^{3-} + H_2O(l)$	30.714 ± 0.660	4	
$2 PO_4^{3-} + 4 H^+ \Leftrightarrow H_2P_2O_7^{2-} + H_2O(l)$	37.364 ± 0.652	4	
$2 PO_4^{3-} + 5 H^+ \Leftrightarrow H_3P_2O_7^- + H_2O(l)$	39.614 ± 0.635	4	
$2 PO_4^{3-} + 6 H^+ \Leftrightarrow H_4P_2O_7(aq) + H_2O(l)$	40.614 ± 0.391	4	
$HS^- \Leftrightarrow S^{2-} + H^+$	-19.000 ± 2.000	4	
$SO_4^{2-} + 2 H^+ + 2 e^- \Leftrightarrow SO_3^{2-} + H_2O(l)$	-3.397 ± 0.701	4	
$2 SO_4^{2-} + 10 H^+ + 8 e^- \Leftrightarrow S_2O_3^{2-} + 5 H_2O(l)$	38.013 ± 1.985	4	
$SO_4^{2-} + 9 H^+ + 8 e^- \Leftrightarrow HS^- + 4 H_2O(l)$	33.692 ± 0.378	4	
$HS^- + H^+ \Leftrightarrow H_2S(aq)$	6.990 ± 0.170	4	
$SO_3^{2-} + H^+ \Leftrightarrow HSO_3^-$	7.220 ± 0.080	4	
$S_2O_3^{2-} + H^+ \Leftrightarrow HS_2O_3^-$	1.590 ± 0.150	4	
$0.5 S_2O_3^{2-} + 1.5 H_2O(l) \Leftrightarrow H_2SO_3(aq) + H^+ + 2 e^-$	-13.344 ± 0.710	4	
$SO_4^{2-} + H^+ \Leftrightarrow HSO_4^-$	1.980 ± 0.050	4	
$SO_4^{2-} + CO_3^{2-} + NO_3^- + 20 H^+ + 16 e^- \Leftrightarrow SCN^- + 10 H_2O(l)$	156.972 ± 0.715	4	
$Cl^- + H_2O(l) \Leftrightarrow ClO^- + 2 H^+ + 2 e^-$	-57.933 ± 0.170	4	
$Cl^- + 2 H_2O(l) \Leftrightarrow ClO_2^- + 4 H^+ + 4 e^-$	-107.874 ± 0.709	4	
$Cl^- + 3 H_2O(l) \Leftrightarrow ClO_3^- + 6 H^+ + 6 e^-$	-146.238 ± 0.236	4	
$Cl^- + 4 H_2O(l) \Leftrightarrow ClO_4^- + 8 H^+ + 8 e^-$	-187.785 ± 0.108	4	
$Cl^- + H_2O(l) \Leftrightarrow HClO(aq) + H^+ + 2 e^-$	-50.513 ± 0.109	4	
$Cl^- + 2 H_2O(l) \Leftrightarrow HClO_2(aq) + 3 H^+ + 4 e^-$	-105.913 ± 0.708	4	
$K^+ + SO_4^{2-} \Leftrightarrow KSO_4^-$	0.850 ± 0.050	5, 43	
$K^+ + H^+ + PO_4^{3-} \Leftrightarrow KHPO_4^-$	12.636	5	
$Ca^{2+} + H_2O(l) \Leftrightarrow CaOH^+ + H^+$	-12.850 ± 0.500	44	
$Ca^{2+} + SO_4^{2-} \Leftrightarrow CaSO_4(aq)$	2.309	5	
$Ca^{2+} + PO_4^{3-} \Leftrightarrow CaPO_4^-$	6.459	5	
$Ca^{2+} + H^+ + PO_4^{3-} \Leftrightarrow CaHPO_4(aq)$	15.085	5	
$Ca^{2+} + 2 H^+ + PO_4^{3-} \Leftrightarrow CaH_2PO_4^+$	20.961	5	
$Ca^{2+} + F^- \Leftrightarrow CaF^+$	0.940	5	
$Mn^{2+} + H_2O(l) \Leftrightarrow MnOH^+ + H^+$	-10.590 ± 0.040	5, 43	
$Mn^{2+} + 3 H_2O(l) \Leftrightarrow Mn(OH)_3^- + 3 H^+$	-34.800	5	
$Mn^{2+} \Leftrightarrow Mn^{3+} + e^-$	-25.507	5	
$Mn^{2+} + 4 H_2O(l) \Leftrightarrow MnO_4^{2-} + 8 H^+ + 4 e^-$	-118.440	5	
$Mn^{2+} + 4 H_2O(l) \Leftrightarrow MnO_4^- + 8 H^+ + 5 e^-$	-127.824	5	
$Mn^{2+} + F^- \Leftrightarrow MnF^+$	0.850	5	
$Mn^{2+} + Cl^- \Leftrightarrow MnCl^+$	0.607	5	
$Mn^{2+} + 2 Cl^- \Leftrightarrow MnCl_2(aq)$	0.041	5	
$Mn^{2+} + 3 Cl^- \Leftrightarrow MnCl_3^-$	-0.305	5	
$Mn^{2+} + 2 NO_3^- \Leftrightarrow Mn(NO_3)_2(aq)$	0.600	5	
$Mn^{2+} + SO_4^{2-} \Leftrightarrow MnSO_4(aq)$	2.260	5	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Mn^{2+} + CO_3^{2-} + H^+ \Leftrightarrow MnHCO_3^+$	11.600	5	
$Fe^{2+} + H_2O(l) \Leftrightarrow FeOH^+ + H^+$	-9.500 ± 0.100	5, 43	
$Fe^{2+} + 2\ H_2O(l) \Leftrightarrow Fe(OH)_2(aq) + 2\ H^+$	-20.570 ± 1.000	5, 43	
$Fe^{2+} + 3\ H_2O(l) \Leftrightarrow Fe(OH)_3^- + 3\ H^+$	-31.000 ± 1.500	5, 43	
$Fe^{2+} + SO_4^{2-} \Leftrightarrow FeSO_4(aq)$	2.250	5	
$Fe^{2+} + 2\ HS^- \Leftrightarrow Fe(HS)_2(aq)$	8.864	5	
$Fe^{2+} + 3\ HS^- \Leftrightarrow Fe(HS)_3^-$	10.858	5	
$Fe^{2+} + H^+ + PO_4^{3-} \Leftrightarrow FeHPO_4(aq)$	15.946	5	
$Fe^{2+} + 2\ H^+ + PO_4^{3-} \Leftrightarrow FeH_2PO_4^+$	22.253	5	
$Fe^{2+} \Leftrightarrow Fe^{3+} + e^-$	-13.032 ± 0.010	5, 43	
$Fe^{3+} + H_2O(l) \Leftrightarrow FeOH^{2+} + H^+$	-2.188 ± 0.020	5, 43	
$Fe^{3+} + 2\ H_2O(l) \Leftrightarrow Fe(OH)_2^+ + 2\ H^+$	-5.668 ± 0.100	5, 43	
$Fe^{3+} + 3\ H_2O(l) \Leftrightarrow Fe(OH)_3(aq) + 3\ H^+$	-13.598	5	
$Fe^{3+} + 4\ H_2O(l) \Leftrightarrow Fe(OH)_4^- + 4\ H^+$	-21.598 ± 0.200	5, 43	
$2\ Fe^{3+} + 2\ H_2O(l) \Leftrightarrow Fe_2(OH)_2^{4+} + 2\ H^+$	-2.946 ± 0.050	5, 43	
$3\ Fe^{3+} + 4\ H_2O(l) \Leftrightarrow Fe_3(OH)_4^{5+} + 4\ H^+$	-6.304 ± 0.100	5, 43	
$Fe^{3+} + Cl^- \Leftrightarrow FeCl^{2+}$	1.482	5	
$Fe^{3+} + 2\ Cl^- \Leftrightarrow FeCl_2^+$	2.132	5	
$Fe^{3+} + 3\ Cl^- \Leftrightarrow FeCl_3(aq)$	1.132	5	
$Fe^{3+} + SO_4^{2-} \Leftrightarrow FeSO_4^+$	3.922	5	
$Fe^{3+} + 2\ SO_4^{2-} \Leftrightarrow Fe(SO_4)_2^-$	5.422	5	
$Fe^{3+} + H^+ + PO_4^{3-} \Leftrightarrow FeHPO_4^+$	17.772	5	
$Fe^{3+} + 2\ H^+ + PO_4^{3-} \Leftrightarrow FeH_2PO_4^{2+}$	24.982	5	
$Fe^{3+} + F^- \Leftrightarrow FeF^{2+}$	6.232	5	
$Fe^{3+} + 2\ F^- \Leftrightarrow FeF_2^+$	10.832	5	
$Fe^{3+} + 3\ F^- \Leftrightarrow FeF_3(aq)$	14.002	5	
$Co^{2+} + H_2O(l) \Leftrightarrow H^+ + CoOH^+$	-9.470 ± 0.020	45	
$Co^{2+} + 2\ H_2O(l) \Leftrightarrow 2\ H^+ + Co(OH)_2(aq)$	-18.000 ± 1.100	45	
$Co^{2+} + 3\ H_2O(l) \Leftrightarrow 3\ H^+ + Co(OH)_3^-$	-31.500 ± 0.500	45	
$2\ Co^{2+} + H_2O(l) \Leftrightarrow H^+ + Co_2OH^{3+}$	-10.548 ± 0.861	45	*
$4\ Co^{2+} + 4\ H_2O(l) \Leftrightarrow 4\ H^+ + Co_4(OH)_4^{4+}$	-27.371 ± 0.211	45	*
$Co^{2+} + F^- \Leftrightarrow CoF^+$	1.470 ± 0.040	45	
$Co^{2+} + Cl^- \Leftrightarrow CoCl^+$	0.810 ± 0.070	45	
$Co^{2+} + HS^{2-} \Leftrightarrow CoS(aq) + H^+$	0.600 ± 2.062	45	
$Co^{2+} + HS^- \Leftrightarrow CoHS^+$	5.141 ± 0.277	45	*
$Co^{2+} + SO_4^{2-} \Leftrightarrow CoSO_4(aq)$	2.200 ± 0.050	45	
$Co^{2+} + 2\ SO_4^{2-} \Leftrightarrow Co(SO_4)_2^{2-}$	2.870 ± 0.050	45	
$Co^{2+} + NO_3^- \Leftrightarrow CoNO_3^+$	-1.020 ± 0.060	45	
$Co^{2+} + NH_4^+ \Leftrightarrow CoNH_3^{2+} + H^+$	-7.037 ± 0.102	45, 4	
$Co^{2+} + 2\ NH_4^+ \Leftrightarrow Co(NH_3)_2^{2+} + 2\ H^+$	-14.574 ± 0.205	45, 4	
$Co^{2+} + 3\ NH_4^+ \Leftrightarrow Co(NH_3)_3^{2+} + 3\ H^+$	-22.311 ± 0.405	45, 4	
$Co^{2+} + 4\ NH_4^+ \Leftrightarrow Co(NH_3)_4^{2+} + 4\ H^+$	-30.548 ± 0.410	45, 4	
$Co^{2+} + 5\ NH_4^+ \Leftrightarrow Co(NH_3)_5^{2+} + 5\ H^+$	-39.485 ± 0.415	45, 4	
$Co^{2+} + 6\ NH_4^+ \Leftrightarrow Co(NH_3)_6^{2+} + 6\ H^+$	-49.522 ± 0.421	45, 4	
$Co^{2+} + H^+ + PO_4^{3-} \Leftrightarrow CoHPO_4(aq)$	15.300 ± 0.143	45, 4	
$Co^{2+} + 2\ H^+ + 2\ PO_4^{3-} \Leftrightarrow CoP_2O_7^{2-} + H_2O(l)$	29.985 ± 0.966	45, 4	*
$Co^{2+} + 3\ H^+ + 2\ PO_4^{3-} \Leftrightarrow HCoP_2O_7^- + H_2O(l)$	35.815 ± 0.737	45, 4	*
$Co^{2+} + H^+ + AsO_4^{3-} \Leftrightarrow CoHAsO_4(aq)$	14.477 ± 1.052	45, 4	*
$Co^{2+} + CO_3^{2-} \Leftrightarrow CoCO_3(aq)$	4.400 ± 0.100	45	
$Co^{2+} + H^+ + CO_3^{2-} \Leftrightarrow CoHCO_3^+$	11.729 ± 0.201	45, 4	
$Co^{2+} + 4\ CN^- \Leftrightarrow Co(CN)_4^{2-}$	**30.017 ± 0.533**	**45**	*
$Co^{2+} + 4\ CO_3^{2-} + 4\ NO_3^- + 48\ H^+ + 40\ e^- \Leftrightarrow Co(CN)_4^{2-} + 24\ H_2O(l)$	462.533 ± 1.896	45, 4	
$Co^{2+} + 5\ CN^- \Leftrightarrow Co(CN)_5^{3-}$	**28.327 ± 0.888**	**45**	*
$Co^{2+} + 5\ CO_3^{2-} + 5\ NO_3^- + 60\ H^+ + 50\ e^- \Leftrightarrow Co(CN)_5^{3-} + 30\ H_2O(l)$	568.972 ± 2.442	45, 4	
$Co^{2+} + SCN^- \Leftrightarrow CoSCN^+$	**1.790 ± 0.073**	**45**	*
$Co^{2+} + SO_4^{2-} + CO_3^{2-} + NO_3^- + 20\ H^+ + 16\ e^- \Leftrightarrow CoSCN^+ + 10\ H_2O(l)$	158.762 ± 0.719	45, 4	
$Co^{2+} + 2\ SCN^- \Leftrightarrow Co(SCN)_2(aq)$	**2.665 ± 0.115**	**45**	*

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Co^{2+} + 2 SO_4^{2-} + 2 CO_3^{2-} + 2 NO_3^- + 40 H^+ + 32 e^- \Leftrightarrow Co(SCN)_2(aq) + 20 H_2O(l)$	316.609 ± 1.435	45, 4	
$Co^{2+} + 3 SCN^- \Leftrightarrow Co(SCN)_3^-$	**2.993 ± 0.229**	**45**	*
$Co^{2+} + 3 SO_4^{2-} + 3 CO_3^{2-} + 3 NO_3^- + 60 H^+ + 48 e^- \Leftrightarrow Co(SCN)_3^- + 30 H_2O(l)$	473.909 ± 2.157	45, 4	
$Ni^{2+} + H_2O(l) \Leftrightarrow H^+ + NiOH^+$	-9.540 ± 0.140	46	
$Ni^{2+} + 2 H_2O(l) \Leftrightarrow 2 H^+ + Ni(OH)_{2(}aq)$	< -18.029	46	
$Ni^{2+} + 3 H_2O(l) \Leftrightarrow 3 H^+ + Ni(OH)_3^-$	-29.200 ± 1.700	46	
$2 Ni^{2+} + H_2O(l) \Leftrightarrow H^+ + Ni_2OH^{3+}$	-10.600 ± 1.000	46	
$4 Ni^{2+} + 4 H_2O(l) \Leftrightarrow 4 H^+ + Ni_4(OH)_4^{4+}$	-27.520 ± 0.150	46	
$Ni^{2+} + F^- \Leftrightarrow NiF^+$	1.430 ± 0.080	46	
$Ni^{2+} + Cl^- \Leftrightarrow NiCl^+$	0.080 ± 0.600	46	
$Ni^{2+} + HS^{2-} \Leftrightarrow NiS(aq) + H^+$	0.723 ± 2.013	45, 4	*
$Ni^{2+} + HS^- \Leftrightarrow NiHS^+$	5.180 ± 0.200	46	
$Ni^{2+} + SO_4^{2-} \Leftrightarrow NiSO_4(aq)$	2.350 ± 0.030	46	
$Ni^{2+} + 2 SO_4^{2-} \Leftrightarrow Ni(SO_4)_2^{2-}$	2.896 ± 0.002	46	*
$Ni^{2+} + NO_3^- \Leftrightarrow NiNO_3^+$	0.500 ± 1.000	46	
$Ni^{2+} + NH_4^+ \Leftrightarrow NiNH_3^{2+} + H^+$	-7.015 ± 0.065	45, 4	*
$Ni^{2+} + 2 NH_4^+ \Leftrightarrow Ni(NH_3)_2^{2+} + 2 H^+$	-14.542 ± 0.146	45, 4	*
$Ni^{2+} + 3 NH_4^+ \Leftrightarrow Ni(NH_3)_3^{2+} + 3 H^+$	-22.271 ± 0.327	45, 4	*
$Ni^{2+} + 4 NH_4^+ \Leftrightarrow Ni(NH_3)_4^{2+} + 4 H^+$	-30.502 ± 0.318	45, 4	*
$Ni^{2+} + 5 NH_4^+ \Leftrightarrow Ni(NH_3)_5^{2+} + 5 H^+$	-39.437 ± 0.321	45, 4	*
$Ni^{2+} + 6 NH_4^+ \Leftrightarrow Ni(NH_3)_6^{2+} + 6 H^+$	-49.479 ± 0.340	45, 4	*
$Ni^{2+} + H^+ + PO_4^{3-} \Leftrightarrow NiHPO_4(aq)$	15.400 ± 0.095	46, 4	
$Ni^{2+} + 2 H^+ + 2 PO_4^{3-} \Leftrightarrow NiP_2O_7^{2-} + H_2O(l)$	30.044 ± 0.924	46, 4	
$Ni^{2+} + 3 H^+ + 2 PO_4^{3-} \Leftrightarrow HNiP_2O_7^- + H_2O(l)$	35.854 ± 0.706	46, 4	
$Ni^{2+} + H^+ + AsO_4^{3-} \Leftrightarrow NiHAsO_4(aq)$	14.503 ± 1.037	46, 4	
$Ni^{2+} + CO_3^{2-} \Leftrightarrow NiCO_3(aq)$	4.200 ± 0.400	46	
$Ni^{2+} + H^+ + CO_3^{2-} \Leftrightarrow NiHCO_3^+$	11.746 ± 0.174	45, 4	*
$Ni^{2+} + 4 CN^- \Leftrightarrow Ni(CN)_4^{2-}$	**30.200 ± 0.120**	**46**	
$Ni^{2+} + 4 NO_3^- + 4 CO_3^{2-} + 48 H^+ + 40 e^- \Leftrightarrow Ni(CN)_4^{2-} + 24 H_2O(l)$	462.716 ± 1.824	46, 4	
$Ni^{2+} + 5 CN^- \Leftrightarrow Ni(CN)_5^{3-}$	**28.500 ± 0.500**	**46**	
$Ni^{2+} + 5 NO_3^- + 5 CO_3^{2-} + 60 H^+ + 50 e^- \Leftrightarrow Ni(CN)_5^{3-} + 30 H_2O(l)$	569.145 ± 2.329	46, 4	
$Ni^{2+} + SCN^- \Leftrightarrow NiSCN^+$	**1.810 ± 0.040**	**46**	
$Ni^{2+} + NO_3^- + CO_3^{2-} + SO_4^{2-} + 20 H^+ + 16 e^- \Leftrightarrow NiSCN^+ + 10 H_2O(l)$	158.782 ± 0.716	46, 4	
$Ni^{2+} + 2 SCN^- \Leftrightarrow Ni(SCN)_2(aq)$	**2.690 ± 0.070**	**46**	
$Ni^{2+} + 2 NO_3^- + 2 CO_3^{2-} + 2 SO_4^{2-} + 40 H^+ + 32 e^- \Leftrightarrow Ni(SCN)_2(aq) + 20 H_2O(l)$	316.634 ± 1.432	46, 4	
$Ni^{2+} + 3 SCN^- \Leftrightarrow Ni(SCN)_3^-$	**3.020 ± 0.180**	**46**	
$Ni^{2+} + 3 NO_3^- + 3 CO_3^{2-} + 3 SO_4^{2-} + 60 H^+ + 48 e^- \Leftrightarrow Ni(SCN)_3^- + 30 H_2O(l)$	473.936 ± 2.153	46, 4	
$AsO_4^{3-} + 4 H^+ + 2 e^- \Leftrightarrow AsO_2^- + 2 H_2O(l)$	30.859 ± 0.993	4	
$AsO_4^{3-} + 5 H^+ + 2 e^- \Leftrightarrow HAsO_2(aq) + 2 H_2O(l)$	40.092 ± 0.993	4	
$AsO_4^{3-} + 4 H^+ + 2 e^- \Leftrightarrow H_2AsO_3^- + H_2O(l)$	30.809 ± 0.993	4	
$AsO_4^{3-} + 5 H^+ + 2 e^- \Leftrightarrow H_3AsO_3(aq) + H_2O(l)$	40.024 ± 0.994	4	
$AsO_4^{3-} + H^+ \Leftrightarrow HAsO_4^{2-}$	11.603 ± 0.993	4	
$AsO_4^{3-} + 2 H^+ \Leftrightarrow H_2AsO_4^-$	18.368 ± 0.994	4	
$AsO_4^{3-} + 3 H^+ \Leftrightarrow H_3AsO_4(aq)$	20.630 ± 0.994	4	
$2 SeO_4^{2-} + 16 H^+ + 14 e^- \Leftrightarrow Se_2^{2-} + 8 H_2O(l)$	158.632 ± 1.213	42	
$3 SeO_4^{2-} + 24 H^+ + 20 e^- \Leftrightarrow Se_3^{2-} + 12 H_2O(l)$	249.934 ± 1.780	42	
$4 SeO_4^{2-} + 32 H^+ + 26 e^- \Leftrightarrow Se_4^{2-} + 16 H_2O(l)$	340.074 ± 0.562	42, 3	
$SeO_4^{2-} + 2 H^+ + 2 e^- \Leftrightarrow SeO_3^{2-} + H_2O(l)$	28.039 ± 0.397	42	
$SeO_4^{2-} + 9 H^+ + 8 e^- \Leftrightarrow HSe^- + 4 H_2O(l)$	81.570 ± 0.435	42	
$HSe^- + H^+ \Leftrightarrow H_2Se(aq)$	3.850 ± 0.050	42	
$HSe^- \Leftrightarrow Se^{2-} + H^+$	-14.914 ± 0.634	3	
$SeO_3^{2-} + H^+ \Leftrightarrow HSeO_3^-$	8.360 ± 0.230	42	
$SeO_4^{2-} + H^+ \Leftrightarrow HSeO_4^-$	1.750 ± 0.100	42	
$SeO_3^{2-} + 2 H^+ \Leftrightarrow H_2SeO_3(aq)$	11.000 ± 0.269	42	
$2 SeO_4^{2-} + 16 H^+ + 10 e^- + 2 Cl^- \Leftrightarrow Se_2Cl_2(aq) + 8 H_2O(l)$	140.427 ± 0.904	42	
$SeO_4^{2-} + 20 H^+ + 16 e^- + CO_3^{2-} + NO_3^- \Leftrightarrow SeCN^- + 10 H_2O(l)$	202.726 ± 0.722	42	
$SeCN^- + Tl^+ \Leftrightarrow TlSeCN(aq)$	**1.750 ± 0.290**	**42**	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$SeO_4^{2-} + 20\ H^+ + 16\ e^- + CO_3^{2-} + NO_3^- + Tl^+ \Leftrightarrow TlSeCN(aq) + 10\ H_2O(l)$	204.476 ± 0.778		
$SeO_4^{2-} + Zn^{2+} \Leftrightarrow ZnSeO_4(aq)$	2.160 ± 0.060	42	
$SeCN^- + Zn^{2+} \Leftrightarrow ZnSeCN^+$ $SeO_4^{2-} + 20\ H^+ + 16\ e^- + CO_3^{2-} + NO_3^- + Zn^{2+} \Leftrightarrow ZnSeCN^+ + 10\ H_2O(l)$	**1.210 ± 0.060** 203.936 ± 0.724	**42**	
$SeCN^- + Zn^{2+} \Leftrightarrow Zn(SeCN)_2(aq)$ $2\ SeO_4^{2-}+40\ H^++32\ e^-+2\ CO_3^{2-}+2\ NO_3^-+Zn^{2+} \Leftrightarrow Zn(SeCN)_2(aq)+20\ H_2O(l)$	**1.680 ± 0.110** 407.133 ± 1.448	**42**	
$Cd^{2+} + SeO_4^{2-} \Leftrightarrow CdSeO_4(aq)$	2.270 ± 0.060	42	
$SeCN^- + Cd^{2+} \Leftrightarrow CdSeCN^+$ $SeO_4^{2-} + 20\ H^+ + 16\ e^- + CO_3^{2-} + NO_3^- + Cd^{2+} \Leftrightarrow CdSeCN^+ + 10\ H_2O(l)$	**2.240 ± 0.060** 204.966 ± 0.724	**42**	
$2\ SeCN^- + Cd^{2+} \Leftrightarrow Cd(SeCN)_2(aq)$ $2\ SeO_4^{2-}+40\ H^++32\ e^-+2\ CO_3^{2}\ +2\ NO_3^-+Cd^{2+} \Leftrightarrow Cd(SeCN)_2(aq)+20\ H_2O(l)$	**3.340 ± 0.120** 408.793 ± 1.449	**42**	
$3\ SeCN^- + Cd^{2+} \Leftrightarrow Cd(SeCN)_3^-$ $3\ SeO_4^{2-}+60\ H^++48\ e^-+3\ CO_3^{2-}+3\ NO_3^-+Cd^{2+} \Leftrightarrow Cd(SeCN)_3^-+30\ H_2O(l)$	**3.810 ± 0.210** 611.989 ± 2.176	**42**	
$4\ SeCN^- + Cd^{2+} \Leftrightarrow Cd(SeCN)_4^{2-}$ $4\ SeO_4^{2-}+80\ H^++64\ e^-+4\ CO_3^{2-}+4\ NO_3^-+Cd^{2+} \Leftrightarrow Cd(SeCN)_4^{2-}+40\ H_2O(l)$	**4.600 ± 0.110** 815.505 ± 2.890	**42**	
$2\ SeO_4^{2-} + 16\ H^+ + 16\ e^- + Hg^{2+} \Leftrightarrow HgSe_2^{2-} + 8\ H_2O(l)$	195.773 ± 1.111	42	
$2\ SeO_3^{2-} + Hg^{2+} \Leftrightarrow Hg(SeO_3)_2^{2-}$	14.850 ± 1.011	42	
$2\ SeCN^- + Hg^{2+} \Leftrightarrow Hg(SeCN)_2(aq)$ $2\ SeO_4^{2-}+40\ H^++32\ e^-+2\ CO_3^{2-}+2\ NO_3^-+Hg^{2+} \Leftrightarrow Hg(SeCN)_2(aq)+20\ H_2O(l)$	**22.300 ± 1.000** 427.753 ± 1.756	**42**	
$3\ SeCN^- + Hg^{2+} \Leftrightarrow Hg(SeCN)_3^-$ $3\ SeO_4^{2-}+60\ H^++48\ e^-+3\ CO_3^{2-}+3\ NO_3^-+Hg^{2+} \Leftrightarrow Hg(SeCN)_3^-+30\ H_2O(l)$	**26.800 ± 1.000** 634.979 ± 2.386	**42**	
$4\ SeCN^- + Hg^{2+} \Leftrightarrow Hg(SeCN)_4^{2-}$ $4\ SeO_4^{2-}+80\ H^++64\ e^-+4\ CO_3^{2-}+4\ NO_3^-+Hg^{2+} \Leftrightarrow Hg(SeCN)_4^{2-}+40\ H_2O(l)$	**29.300 ± 0.500** 840.205 ± 2.931	**42**	
$3\ SeCN^- + Ag^+ \Leftrightarrow Ag(SeCN)_3^{2-}$ $3\ SeO_4^{2-}+60\ H^++48\ e^-+3\ CO_3^{2-}+3\ NO_3^-+Ag^+ \Leftrightarrow Ag(SeCN)_3^{2-}+30\ H_2O(l)$	**13.850 ± 0.300** 622.029 ± 2.187	**42**	
$SeO_4^{2-} + Ni^{2+} \Leftrightarrow NiSeO_4(aq)$	2.670 ± 0.050	42	
$SeCN^- + Ni^{2+} \Leftrightarrow NiSeCN^+$ $SeO_4^{2-} + 20\ H^+ + 16\ e^- + CO_3^{2-} + NO_3^- + Ni^{2+} \Leftrightarrow NiSeCN^+ + 10\ H_2O(l)$	**1.770 ± 0.060** 204.496 ± 0.724	**42**	
$2\ SeCN^- + Ni^{2+} \Leftrightarrow Ni(SeCN)_2(aq)$ $2\ SeO_4^{2-}+40\ H^++32\ e^-+2\ CO_3^{2-}+2\ NO_3^-+Ni^{2+} \Leftrightarrow Ni(SeCN)_2(aq)+20\ H_2O(l)$	**2.240 ± 0.140** 407.693 ± 1.451	**42**	
$SeO_4^{2-} + UO_2^{2+} \Leftrightarrow UO_2SeO_4(aq)$	2.740 ± 0.250	42	
$SeO_4^{2-} + Mg^{2+} \Leftrightarrow MgSeO_4(aq)$	2.200 ± 0.200	42	
$SeO_4^{2-} + Ca^{2+} \Leftrightarrow CaSeO_4(aq)$	2.000 ± 0.100	42	
$SeO_4^{2-} + Mn^{2+} \Leftrightarrow MnSeO_4(aq)$	2.430 ± 0.050	42	
$SeO_4^{2-} + Co^{2+} \Leftrightarrow CoSeO_4(aq)$	2.700 ± 0.050	42	
$FeSeO_3^+ \Leftrightarrow SeO_3^{2-} + Fe^{3+}$	-11.150 ± 0.110	3	
$2\ Br^- \Leftrightarrow Br_2(aq) + 2\ e^-$	-37.246 ± 0.180	4	
$Br^- + H_2O(l) \Leftrightarrow BrO^- + 2\ H^+ + 2\ e^-$	-54.116 ± 0.271	4	
$Br^- + 3\ H_2O(l) \Leftrightarrow BrO_3^- + 6\ H^+ + 6\ e^-$	-146.169 ± 0.116	4	
$Br^- + H_2O(l) \Leftrightarrow HBrO(aq) + H^+ + 2\ e^-$	-45.486 ± 0.269	4	
$Sr^{2+} + H_2O(l) \Leftrightarrow SrOH^+ + H^+$	-13.290 ± 0.500	44	
$Sr^{2+} + SO_4^{2-} \Leftrightarrow SrSO_4(aq)$	1.860 ± 0.030	44	
$Sr^{2+} + NO_3^- \Leftrightarrow SrNO_3^+$	0.800	5	
$Sr^{2+} + PO_4^{3-} \Leftrightarrow SrPO_4^-$	4.200	5	
$Zr^{4+} + H_2O(l) \Leftrightarrow ZrOH^{3+} + H^+$	0.320 ± 0.220	47	
$Zr^{4+} + 2\ H_2O(l) \Leftrightarrow ZrOH)_2^{2+} + 2\ H^+$	0.980 ± 1.060	47	
$Zr^{4+} + 4\ H_2O(l) \Leftrightarrow Zr(OH)_4(aq) + 4\ H^+$	-2.190 ± 1.700	47	
$Zr^{4+} + 6\ H_2O(l) \Leftrightarrow Zr(OH)_6^{2-} + 6\ H^+$	-29.000 ± 0.700	47	
$3\ Zr^{4+} + 4\ H_2O(l) \Leftrightarrow Zr_3(OH)_4^{8+} + 4\ H^+$	0.400 ± 0.300	47	
$3\ Zr^{4+} + 9\ H_2O(l) \Leftrightarrow Zr_3(OH)_9^{3+} + 9\ H^+$	12.190 ± 0.080	47	
$4\ Zr^{4+} + 8\ H_2O(l) \Leftrightarrow Zr_4(OH)_8^{8+} + 8\ H^+$	6.520 ± 0.650	47	
$4\ Zr^{4+} + 15\ H_2O(l) \Leftrightarrow Zr_4(OH)_{15}^+ + 15\ H^+$	12.580 ± 0.240	47	
$4\ Zr^{4+} + 16\ H_2O(l) \Leftrightarrow Zr_4(OH)_{16}(aq) + 16\ H^+$	8.390 ± 0.800	47	
$Zr^{4+} + F^- \Leftrightarrow ZrF^{3+}$	10.120 ± 0.070	47	
$Zr^{4+} + 2\ F^- \Leftrightarrow ZrF_2^{2+}$	18.550 ± 0.310	47	
$Zr^{4+} + 3\ F^- \Leftrightarrow ZrF_3^+$	24.720 ± 0.380	47	
$Zr^{4+} + 4\ F^- \Leftrightarrow ZrF_4(aq)$	30.110 ± 0.400	47	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Zr^{4+} + 5 F^- \Leftrightarrow ZrF_5^-$	34.600 ± 0.420	47	
$Zr^{4+} + 6 F^- \Leftrightarrow ZrF_6^{2-}$	38.110 ± 0.430	47	
$Zr^{4+} + Cl^- \Leftrightarrow ZrCl^{3+}$	1.590 ± 0.060	47	
$Zr^{4+} + 2 Cl^- \Leftrightarrow ZrCl_2^{2+}$	2.170 ± 0.240	47	
$Zr^{4+} + 3 Cl^- \Leftrightarrow ZrCl_3^+$	3.000 ± 0.450	27	
$Zr^{4+} + 4 Cl^- \Leftrightarrow ZrCl_4(aq)$	-1.230 ± 0.500	27	
$Zr^{4+} + SO_4^{2-} \Leftrightarrow ZrSO_4^{2+}$	7.040 ± 0.090	47	
$Zr^{4+} + 2 SO_4^{2-} \Leftrightarrow Zr(SO_4)_2(aq)$	11.540 ± 0.210	47	
$Zr^{4+} + 3 SO_4^{2-} \Leftrightarrow Zr(SO_4)_3^{2-}$	14.300 ± 0.500	47	
$Zr^{4+} + NO_3^- \Leftrightarrow ZrNO_3^{3+}$	1.590 ± 0.080	47	
$Zr^{4+} + 2 NO_3^- \Leftrightarrow Zr(NO_3)_2^{2+}$	2.640 ± 0.170	47	
$Zr^{4+} + 3 NO_3^- \Leftrightarrow Zr(NO_3)_3^+$	1.040 ± 1.500	27	*
$Zr^{4+} + 4 CO_3^{2-} \Leftrightarrow Zr(CO_3)_4^{4-}$	42.900 ± 1.000	47	
$Zr^{4+} + 2 Ca^{2+} + 6 H_2O(l) \Leftrightarrow Ca_2[Zr(OH)_6]^{2+} + 6 H^+$	-22.606 ± 0.313	35	
$Zr^{4+} + 3 Ca^{2+} + 6 H_2O(l) \Leftrightarrow Ca_3[Zr(OH)_6]^{4+} + 6 H^+$	-23.206 ± 0.313	35	
$Nb(OH)_5(aq) + H_2O(l) \Leftrightarrow Nb(OH)_6^- + H^+$	> -6.758	1	
$MoO_4^{2-} + 8 H^+ + 3 e^- \Leftrightarrow Mo^{3+} + 4 H_2O(l)$	29.390	49	
$MoO_4^{2-} + H^+ \Leftrightarrow HMoO_4^-$	4.100 ± 0.100	49	
$MoO_4^{2-} + 2 H^+ \Leftrightarrow H_2MoO_4(aq)$	6.700 ± 0.200	49	
$7 MoO_4^{2-} + 8 H^+ \Leftrightarrow Mo_7O_{24}^{6-} + 4 H_2O(l)$	53.000 ± 0.200	49	
$7 MoO_4^{2-} + 9 H^+ \Leftrightarrow HMo_7O_{24}^{5-} + 4 H_2O(l)$	59.800 ± 0.500	49	
$Sm^{3+} + 2 MoO_4^{2-} \Leftrightarrow Sm(MoO_4)_2^-$	11.200 ± 0.300	50	
$TcO_4^- + e^- \Leftrightarrow TcO_4^{2-}$	-10.800 ± 0.500	51	
$TcO_4^- + 6 H^+ + 3 e^- \Leftrightarrow TcO^{2+} + 3 H_2O(l)$	< 33.414	3	
$TcO(OH)_2(aq) + H^+ \Leftrightarrow TcO(OH)^+ + H_2O(l)$	4.563 ± 0.216	3	
$TcO(OH)_2(aq) + 2 H^+ \Leftrightarrow TcO^{2+} + 2 H_2O(l)$	< 4.000	3	
$TcO(OH)_2(aq) + H_2O(l) \Leftrightarrow TcO(OH)_3^- + H^+$	-10.900 ± 0.400	3	
$TcO(OH)_2(aq) + 2 H^+ + CO_3^{2-} \Leftrightarrow TcCO_3(OH)_2(aq) + H_2O(l)$	19.255 ± 0.302	3	
$TcO(OH)_2(aq) + H^+ + CO_3^{2-} \Leftrightarrow TcCO_3(OH)_3^-$	10.955 ± 0.601	3	
$Pd^{2+} + 2 H_2O(l) \Leftrightarrow Pd(OH)_2(aq) + 2 H^+$	**< -3.490**	9	
$Pd^{2+} + 3 H_2O(l) \Leftrightarrow Pd(OH)_3^- + 3 H^+$	**-15.480 ± 0.350**	9	
$Pd^{2+} + Cl^- \Leftrightarrow PdCl^+$	**5.000 ± 0.240**	9	
$Pd^{2+} + 2 Cl^- \Leftrightarrow PdCl_2(aq)$	**8.420 ± 0.310**	9	
$Pd^{2+} + 3 Cl^- \Leftrightarrow PdCl_3^-$	**10.930 ± 0.380**	9	
$Pd^{2+} + 4 Cl^- \Leftrightarrow PdCl_4^{2-}$	**13.050 ± 0.590**	9	
$Pd^{2+} + NO_3^- \Leftrightarrow PdNO_3^+$	0.167 ± 0.024	1	*
$Pd^{2+} + 2 NO_3^- \Leftrightarrow Pd(NO_3)_2(aq)$	-0.762 ± 0.039	1	*
$Pd^{2+} + 2 NO_3^- + H_2O(l) \Leftrightarrow PdOHNO_3(aq) + H^+$	-0.650 ± 0.036	1	*
$Pd^{+2} + 3 Cl^- + H_2O(l) \Leftrightarrow PdCl_3OH^{2-} + H^+$	2.500	12	
$Pd^{+2} + 2 Cl^- + 2 H_2O(l) \Leftrightarrow PdCl_2(OH)_2^{2-} + 2 H^+$	-7.000	12	
$Pd^{+2} + NH_4^+ \Leftrightarrow PdNH_3^{2+} + H^+$	0.363	12	
$Pd^{+2} + 2 NH_4^+ \Leftrightarrow Pd(NH_3)_2^{2+} + 2 H^+$	0.026	12	
$Pd^{+2} + 3 NH_4^+ \Leftrightarrow Pd(NH_3)_3^{2+} + 3 H^+$	-1.711	12	
$Pd^{+2} + 4 NH_4^+ \Leftrightarrow Pd(NH_3)_4^{2+} + 4 H^+$	-4.148	12	
$Sn^{2+} + H_2O(l) \Leftrightarrow SnOH^+ + H^+$	**-3.530 ± 0.400**	**11**	
$3 Sn^{2+} + 4 H_2O(l) \Leftrightarrow Sn_3(OH)_4^{2+} + 4 H^+$	**-5.600 ± 0.470**	**11**	
$Sn^{2+} + 2 H_2O(l) \Leftrightarrow Sn(OH)_2(aq) + 2 H^+$	**-7.680 ± 0.400**	**11**	
$Sn^{2+} + 3 H_2O(l) \Leftrightarrow Sn(OH)_3^- + 3 H^+$	**-17.000 ± 0.600**	**11**	
$Sn^{2+} + F^- \Leftrightarrow SnF^+$	**5.250 ± 0.190**	**11**	
$Sn^{2+} + 2 F^- \Leftrightarrow SnF_2(aq)$	**8.890 ± 0.210**	**11**	
$Sn^{2+} + 3 F^- \Leftrightarrow SnF_3^-$	**11.500 ± 1.000**	**11**	
$Sn^{2+} + Cl^- \Leftrightarrow SnCl^+$	**1.520 ± 0.200**	**11**	
$Sn^{2+} + 2 Cl^- \Leftrightarrow SnCl_2(aq)$	**2.170 ± 0.170**	**11**	
$Sn^{2+} + 3 Cl^- \Leftrightarrow SnCl_3^-$	**2.132 ± 0.190**	**11**	
$Sn^{2+} + 4 Cl^- \Leftrightarrow SnCl_4^{2-}$	**2.030 ± 0.400**	**11**	
$Sn^{2+} + Br^- \Leftrightarrow SnBr^+$	**1.330 ± 0.180**	**11**	
$Sn^{2+} + 2 Br^- \Leftrightarrow SnBr_2(aq)$	**1.970 ± 0.210**	**11**	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Sn^{2+} + 3\ Br^- \Leftrightarrow SnBr_3^-$	**1.930 ± 0.270**	**11**	
$Sn^{2+} + SO_4^{2-} \Leftrightarrow SnSO_4(aq)$	**3.430 ± 0.250**	**11**	
$Sn^{2+} + 2\ SO_4^{2-} \Leftrightarrow Sn(SO_4)_2^{2-}$	**3.300 ± 0.500** *	**11**	
$Sn^{2+} + SCN^- \Leftrightarrow SnSCN^+$ **$Sn^{2+} + SO_4^{2-} + CO_3^{2-} + NO_3^- + 20\ H^+ + 16\ e^- \Leftrightarrow SnSCN^+ + 10\ H_2O(l)$**	**1.500 ± 0.700** **158.472 ± 1.004**	**11**	
$Sn^{2+} + NO_3^- \Leftrightarrow SnNO_3^+$	**1.270 ± 0.310**	**11**	
$Sn^{2+} + 2\ NO_3^- \Leftrightarrow Sn(NO_3)_2(aq)$	**1.390 ± 0.530**	**11**	
$Sn^{2+} + 5\ H_2O(l) \Leftrightarrow Sn(OH)_5^- + 5\ H^+ + 2\ e^-$	**-14.037 ± 0.422**	**11**	
$Sn(OH)_5^- + 5\ H+ \Leftrightarrow Sn^{4+} + 5\ H_2O(l)$	**9.200 ± 0.340**	**10**	
$Sn(OH)_5^- + 4\ H^+ \Leftrightarrow SnOH^{3+} + 4\ H_2O(l)$	**11.060 ± 0.467**	**10**	
$Sn(OH)_5^- + H^+ \Leftrightarrow Sn(OH)_4(aq) + H_2O(l)$	**≤ 8.580**	**10**	
$Sn(OH)_5^- + H_2O(l) \Leftrightarrow Sn(OH)_6^{2-} + H^+$	**-11.080 ± 0.481**	**10**	
$Sb(OH)_3(aq) + 3\ H^+ \Leftrightarrow Sb^{3+} + 3\ H_2O(l)$	-0.730	12	
$Sb(OH)_3(aq) + 2\ H^+ \Leftrightarrow SbOH^{2+} + 2\ H_2O(l)$	0.830	12	
$Sb(OH)_3(aq) + H^+ \Leftrightarrow Sb(OH)_2^+ + H_2O(l)$	1.300	12	
$Sb(OH)_3(aq) + H_2O(l) \Leftrightarrow Sb(OH)_4^- + H^+$	-11.930	12	
$2\ Sb(OH)_3(aq) + 2\ H^+ + 4\ HS^- \Leftrightarrow Sb_2S_4^{2-} + 6\ H_2O(l)$	42.530	12	
$2\ Sb(OH)_3(aq) + 3\ H^+ + 4\ HS^- \Leftrightarrow HSb_2S_4^- + 6\ H_2O(l)$	52.180	12	
$2\ Sb(OH)_3(aq) + 4\ H^+ + 4\ HS^- \Leftrightarrow H_2Sb_2S_4(aq) + 6\ H_2O(l)$	57.000	12	
$2\ Sb(OH)_3(aq) \Leftrightarrow Sb_2(OH)_6(aq)$	0.080	12	
$Sb(OH)_3(aq) + 3\ H^+ + Cl^- \Leftrightarrow SbCl^{2+} + 3\ H_2O(l)$	2.780	12	
$Sb(OH)_3(aq) + 3\ H^+ + 2\ Cl^- \Leftrightarrow SbCl_2^+ + 3\ H_2O(l)$	3.270	12	
$Sb(OH)_3(aq) + 3\ H^+ + F^- \Leftrightarrow SbF^{2+} + 3\ H_2O(l)$	6.480	12	
$Sb(OH)_3(aq) + 3\ H^+ + 2\ F^- \Leftrightarrow SbF_2^+ + 3\ H2O(l)$	12.650	12	
$Sb(OH)_3(aq) + 3\ H^+ + 3\ F^- \Leftrightarrow SbF_3(aq) + 3\ H_2O(l)$	18.360	12	
$Sb(OH)_3(aq) + 2\ H_2O(l) \Leftrightarrow Sb(OH)_5(aq) + 2\ H^+ + 2\ e^-$	-21.840	12	
$Sb(OH)_5(aq) + H_2O(l) \Leftrightarrow Sb(OH)_6^- + H^+$	-2.720	12	
$12\ Sb(OH)_5(aq) + 4\ H_2O(l) \Leftrightarrow Sb_{12}(OH)_{64}^{4-} + 4\ H^+$	20.340	12	
$12\ Sb(OH)_5(aq) + 5\ H_2O(l) \Leftrightarrow Sb_{12}(OH)_{65}^{5-} + 5\ H^+$	16.720	12	
$12\ Sb(OH)_5(aq) + 6\ H_2O(l) \Leftrightarrow Sb_{12}(OH)_{66}^{6-} + 6\ H^+$	11.890	12	
$12\ Sb(OH)_5(aq) + 7\ H_2O(l) \Leftrightarrow Sb_{12}(OH)_{67}^{7-} + 7\ H^+$	6.070	12	
$I^- + 3\ H_2O(l) \Leftrightarrow IO_3^- + 6\ H^+ + 6\ e^-$	-111.563 ± 0.138	3	
$IO_3^- + H^+ \Leftrightarrow HIO_3(aq)$	0.788 ± 0.029	4	
$2\ I^- \Leftrightarrow I_2(aq) + 2\ e^-$	-20.996	3	*
$3\ I^- \Leftrightarrow I_3^- + 2\ e^-$	-18.180	3	*
$I^- + H_2O(l) \Leftrightarrow IO^- + 2\ H^+ + 2\ e^-$	-43.862	3	*
$I^- + 4\ H_2O(l) \Leftrightarrow IO_4^- + 8\ H^+ + 8\ e^-$	-164.992	3	*
$2\ I^- + H_2O(l) \Leftrightarrow I_2O^{2-} + 2\ H^+ + 2\ e^-$	-45.232	3	*
$I^- + H^+ \Leftrightarrow HI(aq)$	-0.027	3	*
$I^- + H_2O(l) \Leftrightarrow HIO(aq) + H^+ + 2\ e^-$	-33.245	3	*
$I^- + H_2O(l) \Leftrightarrow H_2OI^+ + 2\ e^-$	-31.914	3	*
$2\ I^- + H_2O(l) \Leftrightarrow I_2OH^- + H^+ + 2\ e^-$	-19.357	3	*
$I^- + 2\ Cl^- \Leftrightarrow ICl_2^- + 2\ e^-$	-26.832	3	*
$2\ I^- + Cl^- \Leftrightarrow I_2Cl^- + 2\ e^-$	-20.737	3	*
$I^- + Br^- \Leftrightarrow IBr(aq) + 2\ e^-$	-26.519	3	*
$I^- + 2\ Br^- \Leftrightarrow IBr_2^- + 2\ e^-$	-23.900	3	*
$2\ I^- + Br^- \Leftrightarrow BrI_2^- + 2\ e^-$	-17.046	3	*
$2\ I^- + H^+ + Br^- \Leftrightarrow HBrI_2(aq) + 2\ e^-$	-17.046	3	*
$I^- + Cl^- + Br^- \Leftrightarrow IBrCl^- + 2\ e^-$	-24.595	3	*
$Ba^{2+} + H_2O(l) \Leftrightarrow BaOH^+ + H^+$	-13.470 ± 0.500	44	
$Ba^{2+} + SO_4^{2-} \Leftrightarrow BaSO_4(aq)$	2.720 ± 0.090	44	
$Sm^{3+} + H_2O(l) \Leftrightarrow SmOH^{2+} + H^+$	-7.200 ± 0.500	39	
$Sm^{3+} + 2\ H_2O(l) \Leftrightarrow Sm(OH)_2^+ + 2\ H^+$	-15.100 ± 0.700	39	
$Sm^{3+} + 3\ H_2O(l) \Leftrightarrow Sm(OH)_3(aq) + 3\ H^+$	-26.200 ± 0.500	39	
$Sm^{3+} + F^- \Leftrightarrow SmF^{2+}$	3.400 ± 0.400	39	
$Sm^{3+} + 2\ F^- \Leftrightarrow SmF_2^+$	5.800 ± 0.200	39	
$Sm^{3+} + Cl^- \Leftrightarrow SmCl^{2+}$	0.240 ± 0.030	39	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Sm^{3+} + 2\ Cl^- \Leftrightarrow SmCl_2^+$	-0.740 ± 0.050	39	
$Sm^{3+} + SO_4^{2-} \Leftrightarrow SmSO_4^+$	3.300 ± 0.150	39	
$Sm^{3+} + 2\ SO_4^{2-} \Leftrightarrow Sm(SO_4)_2^-$	3.700 ± 0.150	39	
$Sm^{3+} + 3\ NO_3^- + 18\ H^+ + 16\ e^- \Leftrightarrow SmN_3^{2+} + 9\ H_2O(l)$	256.342 ± 0.430	39	
$Sm^{3+} + NO_2^- \Leftrightarrow SmNO_2^{2+}$	2.100 ± 0.200	39	
$Sm^{3+} + NO_3^- \Leftrightarrow SmNO_3^{2+}$	1.330 ± 0.200	39	
$Sm^{3+} + 2\ H^+ + PO_4^{3-} \Leftrightarrow SmH_2PO_4^{2+}$	22.562 ± 0.501	39	
$Sm^{3+} + CO_3^{2-} \Leftrightarrow SmCO_3^+$	8.000 ± 0.400	39	
$Sm^{3+} + 2\ CO_3^{2-} \Leftrightarrow Sm(CO_3)_2^-$	12.900 ± 0.600	39	
$Sm^{3+} + 3\ CO_3^{2-} \Leftrightarrow Sm(CO_3)_3^{3-}$	15.000 ± 1.000	39	
$Sm^{3+} + H^+ + CO_3^{2-} \Leftrightarrow SmHCO_3^{2+}$	13.429 ± 0.301	39	
$Sm^{3+} + H_4SiO_4(aq) \Leftrightarrow SmSiO(OH)_3^{2+} + H^+$	-1.680 ± 0.180	39	
$Sm^{3+} + SCN^- \Leftrightarrow SmSCN^{2+}$ $Sm^{3+} + NO_3^- + CO_3^{2-} + SO_4^{2-} + 20\ H^+ + 16\ e^- \Leftrightarrow SmSCN^{2+} + 10\ H_2O(l)$	**1.300 ± 0.300** 158.272 ± 0.775	**39**	
$2\ Hg^{2+} + 2\ e^- \Leftrightarrow Hg_2^{2+}$	3.889 ± 0.224	4	
$Pb^{2+} + H_2O(l) \Leftrightarrow PbOH^+ + H^+$	-6.910 ± 0.360	28	
$Pb^{2+} + 2\ H_2O(l) \Leftrightarrow Pb(OH)2(aq) + 2\ H^+$	-16.110 ± 0.710	28	
$Pb^{2+} + 3\ H_2O(l) \Leftrightarrow Pb(OH)_3^- + 3\ H^+$	-26.270 ± 1.180	28	
$Pb^{2+} + 4\ H_2O(l) \Leftrightarrow Pb(OH)_4^{2-} + 4\ H^+$	-38.780 ± 0.390	28	
$2\ Pb^{2+} + H_2O(l) \Leftrightarrow Pb_2OH^{3+} + H^+$	-7.180	12	
$4\ Pb^{2+} + 4\ H_2O(l) \Leftrightarrow Pb_4(OH)_4^{4+} + 4\ H^+$	-20.630	12	
$3\ Pb^{2+} + 4\ H_2O(l) \Leftrightarrow Pb_3(OH)_4^{2+} + 4\ H^+$	-22.480	12	
$3\ Pb^{2+} + 5\ H_2O(l) \Leftrightarrow Pb_3(OH)_5^+ + 5\ H^+$	-30.720	12	
$6\ Pb^{2+} + 8\ H_2O(l) \Leftrightarrow Pb_6(OH)_8^{4+} + 8\ H^+$	-42.680	12	
$Pb^{2+} + CO_3^{2-} \Leftrightarrow PbCO_3(aq)$	7.300	12	
$Pb^{2+} + 2\ CO_3^{2-} \Leftrightarrow Pb(CO_3)_2^{-2}$	10.130	12	
$Pb^{2+} + NO_3^- \Leftrightarrow PbNO_3^+$	1.060	12	
$Pb^{2+} + 2\ NO_3^- \Leftrightarrow Pb(NO_3)_2(aq)$	1.480	12	
$Pb^{2+} + 3\ NO_3^- \Leftrightarrow Pb(NO_3)_3^-$	0.760	12	
$Pb^{2+} + PO_4^{-3} + H^+ \Leftrightarrow PbHPO_4(aq)$	15.450	12	
$Pb^{2+} + PO_4^{-3} + 2\ H^+ \Leftrightarrow PbH_2PO_4^+$	21.050	12	
$Pb^{2+} + SO_4^{2-} \Leftrightarrow PbSO_4(aq)$	2.820	12	
$Pb^{2+} + 2\ SO_4^{2-} \Leftrightarrow Pb(SO_4)_2^{2-}$	2.370	12	
$Pb^{2+} + 2\ HS^- \Leftrightarrow Pb(HS)_2(aq)$	12.340	12	
$Pb^{2+} + 3\ HS^- \Leftrightarrow Pb(HS)_3^-$	13.590	12	
$Pb^{2+} + Cl^- \Leftrightarrow PbCl^+$	1.480 ± 0.100	28	
$Pb^{2+} + 2\ Cl^- \Leftrightarrow PbCl_2(aq)$	2.070 ± 0.170	28	
$Pb^{2+} + 3\ Cl^- \Leftrightarrow PbCl_3^-$	1.800 ± 0.320	28	
$Pb^{2+} + 4\ Cl^- \Leftrightarrow PbCl_4^{2-}$	1.330 ± 0.830	28	*
$Pb^{2+} + F^- \Leftrightarrow PbF^+$	2.270	12	
$Pb^{2+} + 2\ F^- \Leftrightarrow PbF_2(aq)$	3.010	12	
$Pb^{2+} + F^- + Cl^- \Leftrightarrow PbFCl(aq)$	3.550	12	
$Bi^{3+} + H_2O \Leftrightarrow BiOH^{2+} + H^+$	-0.920	12	
$Bi^{3+} + 2\ H_2O \Leftrightarrow Bi(OH)_2^+ + 2\ H^+$	-2.560 ± 1.000	29	
$Bi^{3+} + 3\ H_2O \Leftrightarrow Bi(OH)_3(aq) + 3\ H^+$	-8.940 ± 0.500	29	
$Bi^{3+} + 4\ H_2O \Leftrightarrow Bi(OH)_4^- + 4\ H^+$	-21.660 ± 0.870	29	
$6\ Bi^{3+} + 12\ H_2O \Leftrightarrow Bi_6(OH)_{12}^{6+} + 12\ H^+$	1.340	12	
$9\ Bi^{3+} + 20\ H_2O \Leftrightarrow Bi_9(OH)_{20}^{7+} + 20\ H^+$	-1.360	12	
$9\ Bi^{3+} + 21\ H_2O \Leftrightarrow Bi_9(OH)_{21}^{6+} + 21\ H^+$	-3.250	12	
$9\ Bi^{3+} + 22\ H_2O \Leftrightarrow Bi_9(OH)_{22}^{5+} + 22\ H^+$	-4.860	12	
$3\ Bi^{3+} + 4\ H_2O \Leftrightarrow Bi_3(OH)_4^{5+} + 4\ H^+$	-0.800	12	
$Bi^{3+} + Cl^- \Leftrightarrow BiCl^{2+}$	3.610 ± 0.180	29	
$Bi^{3+} + 2\ Cl^- \Leftrightarrow BiCl_2^+$	5.560 ± 0.240	29	
$Bi^{3+} + 3\ Cl^- \Leftrightarrow BiCl_3(aq)$	6.980 ± 0.370	29	
$Bi^{3+} + 4\ Cl^- \Leftrightarrow BiCl_4^-$	8.040 ± 0.200	29	
$Bi^{3+} + 5\ Cl^- \Leftrightarrow BiCl_5^{2-}$	7.360 ± 0.370	29	
$Bi^{3+} + PO_4^{3-} \Leftrightarrow BiPO_4(aq)$	≤ 21.850	29	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Bi^{3+} + NO_3^- \Leftrightarrow BiNO_3^{2+}$	1.970	12	
$Bi^{3+} + 2\ NO_3^- \Leftrightarrow Bi(NO_3)_2^+$	2.950	12	
$Bi^{3+} + 3\ NO_3^- \Leftrightarrow Bi(NO_3)_3(aq)$	3.620	12	
$Bi^{3+} + 4\ NO_3^- \Leftrightarrow Bi(NO_3)_4^-$	3.090	12	
$Bi^{3+} + Cl^- + NO_3^- \Leftrightarrow BiClNO_3^+$	5.160	12	
$Bi^{3+} + Cl^- + 2\ NO_3^- \Leftrightarrow BiCl(NO_3)_2(aq)$	5.280	12	
$Bi^{3+} + 2\ Cl^- + NO_3^- \Leftrightarrow BiCl_2NO_3(aq)$	6.860	12	
$Bi^{3+} + 2\ Cl^- + 2\ NO_3^- \Leftrightarrow BiCl_2(NO_3)_2^-$	5.750	12	
$Bi^{3+} + 3\ Cl^- + NO_3^- \Leftrightarrow BiCl_3NO_3^-$	8.090	12	
$Ra^{2+} + H_2O \Leftrightarrow RaOH^+ + H^+$	-13.470 ± 0.500	44	
$Ra^{2+} + SO_4^{2-} \Leftrightarrow RaSO_4(aq)$	2.720 ± 0.090	44	
$Ac^{3+} + H_2O(l) \Leftrightarrow AcOH^{2+} + H^+$	-7.200 ± 0.700	39	*
$Ac^{3+} + 2\ H_2O(l) \Leftrightarrow Ac\ OH)_2^+ + 2\ H^+$	-15.100 ± 0.900	39	*
$Ac^{3+} + 3\ H_2O(l) \Leftrightarrow Ac(OH)_3(aq) + 3\ H^+$	-26.200 ± 0.700	39	*
$Ac^{3+} + F^- \Leftrightarrow AcF^{2+}$	3.400 ± 0.600	39	*
$Ac^{3+} + 2\ F^- \Leftrightarrow AcF_2^+$	5.800 ± 0.400	39	*
$Ac^{3+} + Cl^- \Leftrightarrow AcCl^{2+}$	0.240 ± 0.230	39	*
$Ac^{3+} + 2\ Cl^- \Leftrightarrow AcCl_2^+$	-0.740 ± 0.250	39	*
$Ac^{3+} + SO_4^{2-} \Leftrightarrow AcSO_4^+$	3.300 ± 0.350	39	*
$Ac^{3+} + 2\ SO_4^{2-} \Leftrightarrow Ac(SO_4)_2^-$	3.700 ± 0.350	39	*
$Ac^{3+} + 3\ NO_3^- + 18\ H^+ + 16\ e^- \Leftrightarrow AcN_3^{2+} + 9\ H_2O(l)$	256.342 ± 0.515	39, 4	*
$Ac^{3+} + NO_2^- \Leftrightarrow AcNO_2^{2+}$	2.100 ± 0.400	39	*
$Ac^{3+} + NO_3^- \Leftrightarrow AcNO_3^{2+}$	1.330 ± 0.400	39	*
$Ac^{3+} + 2\ H^+ + PO_4^{3-} \Leftrightarrow AcH_2PO_4^{2+}$	22.562 ± 0.701	39, 4	*
$Ac^{3+} + CO_3^{2-} \Leftrightarrow AcCO_3^+$	8.000 ± 0.600	39	*
$Ac^{3+} + 2\ CO_3^{2-} \Leftrightarrow Ac(CO_3)_2^-$	12.900 ± 0.800	39	*
$Ac^{3+} + 3\ CO_3^{2-} \Leftrightarrow Ac(CO_3)_3^{3-}$	15.000 ± 1.200	39	*
$Ac^{3+} + H^+ + CO_3^{2-} \Leftrightarrow AcHCO_3^{2+}$	13.429 ± 0.500	39, 4	*
$Ac^{3+} + H_4SiO_4(aq) \Leftrightarrow AcSiO(OH)_3^{2+} + H^+$	-1.680 ± 0.380	39	*
$Ac^{3+} + SCN^- \Leftrightarrow AcSCN^{2+}$ $Ac^{3+} + NO_3^- + CO_3^{2-} + SO_4^{2-} + 20\ H^+ + 16\ e^- \Leftrightarrow AcSCN^{2+} + 10\ H_2O(l)$	**1.300 ± 0.500** 158.272 ± 0.872	**39**	 *
$Th^{4+} + H_2O(l) \Leftrightarrow ThOH^{3+} + H^+$	-2.500 ± 0.500	4	
$Th^{4+} + 2\ H_2O(l) \Leftrightarrow Th(OH)_2^{2+} + 2\ H^+$	-6.200 ± 0.500	4	
$Th^{4+} + 4\ H_2O(l) \Leftrightarrow Th(OH)_4(aq) + 4\ H^+$	-17.400 ± 0.700	4	
$2\ Th^{4+} + 2\ H_2O(l) \Leftrightarrow Th_2(OH)_2^{6+} + 2\ H^+$	-5.900 ± 0.500	4	
$2\ Th^{4+} + 3\ H_2O(l) \Leftrightarrow Th_2(OH)_3^{5+} + 3\ H^+$	-6.800 ± 0.200	4	
$4\ Th^{4+} + 8\ H_2O(l) \Leftrightarrow Th_4(OH)_8^{8+} + 8\ H^+$	-20.400 ± 0.400	4	
$4\ Th^{4+} + 12\ H_2O(l) \Leftrightarrow Th_4(OH)_{12}^{4+} + 12\ H^+$	-26.600 ± 0.200	4	
$6\ Th^{4+} + 14\ H_2O(l) \Leftrightarrow Th_6(OH)_{14}^{10+} + 14\ H^+$	-36.800 ± 1.200	4	
$6\ Th^{4+} + 15\ H_2O(l) \Leftrightarrow Th_6(OH)_{15}^{9+} + 15\ H^+$	-36.800 ± 1.500	4	
$Th^{4+} + F^- \Leftrightarrow ThF^{3+}$	8.870 ± 0.150	4	
$Th^{4+} + 2\ F^- \Leftrightarrow ThF_2^{2+}$	15.630 ± 0.230	4	
$Th^{4+} + 3\ F^- \Leftrightarrow ThF_3^+$	20.670 ± 0.160	4	
$Th^{4+} + 4\ F^- \Leftrightarrow ThF_4(aq)$	25.580 ± 0.180	4	
$Th^{4+} + Cl^- \Leftrightarrow ThCl^{3+}$	1.700 ± 0.100	4	
$Th^{4+} + ClO_3^- \Leftrightarrow ThClO_3^{3+}$	1.550 ± 0.130	4	
$Th^{4+} + Br^- \Leftrightarrow ThBr^{3+}$	1.380 ± 0.130	4	
$Th^{4+} + BrO_3^- \Leftrightarrow ThBrO_3^{3+}$	1.900 ± 0.100	4	
$Th^{4+} + IO_3^- \Leftrightarrow ThIO_3^{3+}$	4.140 ± 0.100	4	
$Th^{4+} + 2\ IO_3^- \Leftrightarrow Th(IO_3)_2^{2+}$	6.970 ± 0.120	4	
$Th^{4+} + 3\ IO_3^- \Leftrightarrow Th(IO_3)_3^+$	9.870 ± 0.110	4	
$Th^{4+} + SO_4^{2-} \Leftrightarrow ThSO_4^{2+}$	6.170 ± 0.320	4	
$Th^{4+} + 2\ SO_4^{2-} \Leftrightarrow Th(SO_4)_2(aq)$	9.690 ± 0.270	4	
$Th^{4+} + 3\ SO_4^{2-} \Leftrightarrow Th(SO_4)_3^{2-}$	10.748 ± 0.076	4	
$Th^{4+} + N_3^- \Leftrightarrow ThN_3^{3+}$	4.440 ± 0.640	4	
$Th^{4+} + 2\ N_3^- \Leftrightarrow Th(N_3)_2^{2+}$	8.590 ± 0.640	4	
$Th^{4+} + NO_3^- \Leftrightarrow ThNO_3^{3+}$	1.300 ± 0.200	4	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Th^{4+} + 2\ NO_3^- \Leftrightarrow Th(NO_3)_2^{2+}$	2.300 ± 0.400	4	
$Th^{4+} + 2\ H^+ + PO_4^{3-} \Leftrightarrow ThH_2PO_4^{3+}$	25.152 ± 0.365	4	
$Th^{4+} + 3\ H^+ + PO_4^{3-} \Leftrightarrow ThH_3PO_4^{4+}$	23.592 ± 0.356	4	
$Th^{4+} + 4\ H^+ + 2\ PO_4^{3-} \Leftrightarrow Th(H_2PO_4)_2^{2+}$	49.604 ± 0.476	4	
$Th^{4+} + 5\ H^+ + 2\ PO_4^{3-} \Leftrightarrow Th(H_3PO_4)(H_2PO_4)^{3+}$	48.824 ± 0.476	4	
$Th^{4+} + 5\ CO_3^{2-} \Leftrightarrow Th(CO_3)_5^{6-}$	31.000 ± 0.700	4	
$Th^{4+} + 2\ CO_3^{2-} + 2\ H_2O(l) \Leftrightarrow Th(CO_3)_2(OH)_2^{2-} + 2\ H^+$	8.798 ± 0.501	4	
$Th^{4+} + 4\ CO_3^{2-} + H_2O(l) \Leftrightarrow Th(CO_3)_4OH^{5-} + H^+$	21.599 ± 0.500	4	
$Th^{4+} + CO_3^{2-} + 4\ H_2O(l) \Leftrightarrow ThCO_3(OH)_4^{2-} + 4\ H^+$	-15.605 ± 0.603	4	
$Th^{4+} + SCN^- \Leftrightarrow ThSCN^{3+}$ **$Th^{4+} + SO_4^{2-} + CO_3^{2-} + NO_3^- + 20\ H^+ + 16\ e^- \Leftrightarrow ThSCN^{3+} + 10\ H_2O(l)$**	2.000 ± 0.500 **158.972 ± 0.872**	4	
$Th^{4+} + 2\ SCN^- \Leftrightarrow Th(SCN)_2^{2+}$ **$Th^{4+} +2\ SO_4^{2-} +2\ CO_3^{2-} +2\ NO_3^- +40\ H^+ +32\ e^- \Leftrightarrow Th(SCN)_2^{2+} +20\ H_2O(l)$**	3.400 ± 0.800 **317.344 ± 1.639**	4	
$Th^{4+} + 3\ H_4SiO_4(aq) + 3\ H_2O(l) \Leftrightarrow Th(OH)_3(H_3SiO_4)_3^{2-} + 6\ H^+$	-27.800 ± 0.700	35	
$Th^{4+} + 8\ H_2O(l) + 4\ Ca^{2+} \Leftrightarrow Ca_4[Th(OH)_8]^{4+} + 8\ H^+$	-62.708 ± 0.908	52	
$Pa^{4+} + H_2O(l) \Leftrightarrow PaOH^{3+} + H^+$	0.840	24	
$Pa^{4+} + 2\ H_2O(l) \Leftrightarrow Pa(OH)_2^{2+} + 2\ H^+$	-0.020	24	
$Pa^{4+} + 3\ H_2O(l) \Leftrightarrow Pa(OH)_3^+ + 3\ H^+$	-1.500	24	
$Pa^{4+} + 2\ H_2O(l) \Leftrightarrow PaOOH^{2+} + e^- + 3\ H^+$	1.860	24	
$PaOOH^{2+} + H_2O(l) \Leftrightarrow PaO(OH)_2^+ + H^+$	-1.240 ± 0.020	23,30	
$PaOOH^{2+} + 3\ H_2O(l) \Leftrightarrow Pa(OH)_5(aq) + 2\ H^+$	-8.270 ± 0.151	23,30	
$PaOOH^{2+} + Cl^- \Leftrightarrow PaOOHCl^+$	1.922 ± 0.020	32	
$PaOOH^{2+} + SO_4^{2-} + H^+ \Leftrightarrow PaOSO_4^+ + H_2O(l)$	3.890 ± 0.180	32	
$PaOOH^{2+} + 2\ SO_4^{2-} + H^+ \Leftrightarrow PaO(SO_4)_2^- + H_2O(l)$	7.000 ± 0.200	32	
$PaOOH^{2+} + 3\ SO_4^{2-} + H^+ \Leftrightarrow PaO(SO_4)_3^{3-} + H_2O(l)$	8.590 ± 0.230	32	
$U^{4+} + e^- \Leftrightarrow U^{3+}$	-9.353 ± 0.070	51	
$U^{4+} + H_2O(l) \Leftrightarrow UOH^{3+} + H^+$	-0.290 ± 0.310	53	
$U^{4+} + 2\ H_2O(l) \Leftrightarrow U(OH)_2^{2+} + 2\ H^+$	-1.780 ± 0.210	53	
$U^{4+} + 3\ H_2O(l) \Leftrightarrow U(OH)_3^+ + 3\ H^+$	-5.150 ± 0.210	53	
$U^{4+} + 4\ H_2O(l) \Leftrightarrow U(OH)_4(aq) + 4\ H^+$	-10.800 ± 1.400	53	
$U^{4+} + F^- \Leftrightarrow UF^{3+}$	9.420 ± 0.510	51	
$U^{4+} + 2\ F^- \Leftrightarrow UF_2^{2+}$	16.560 ± 0.710	51	
$U^{4+} + 3\ F^- \Leftrightarrow UF_3^+$	21.890 ± 0.830	51	
$U^{4+} + 4\ F^- \Leftrightarrow UF_4$	26.340 ± 0.960	51	
$U^{4+} + 5\ F^- \Leftrightarrow UF_5^-$	27.730 ± 0.740	51	
$U^{4+} + 6\ F^- \Leftrightarrow UF_6^{2-}$	29.800 ± 0.700	51	
$U^{4+} + Cl^- \Leftrightarrow UCl^{3+}$	1.720 ± 0.130	51	
$U^{4+} + Br^- \Leftrightarrow UBr^{3+}$	1.460 ± 0.200	51	
$U^{4+} + I^- \Leftrightarrow UI^{3+}$	1.250 ± 0.300	51	
$U^{4+} + SO_4^{2-} \Leftrightarrow USO_4^{2+}$	6.580 ± 0.190	51	
$U^{4+} + 2\ SO_4^{2-} \Leftrightarrow U(SO_4)_2(aq)$	10.510 ± 0.200	51	
$U^{4+} + NO_3^- \Leftrightarrow UNO_3^{3+}$	1.470 ± 0.130	51	
$U^{4+} + 2\ NO_3^- \Leftrightarrow U(NO_3)_2^{2+}$	2.300 ± 0.350	51	
$U^{4+} + 4\ CO_3^{2-} \Leftrightarrow U(CO_3)_4^{4-}$	35.120 ± 0.934	51	
$U^{4+} + 5\ CO_3^{2-} \Leftrightarrow U(CO_3)_5^{6-}$	31.500 ± 1.000	51	
$U^{4+} + 2\ CO_3^{2-} + 2\ H_2O(l) \Leftrightarrow U(CO_3)_2(OH)_2^{2-} + 2\ H^+$	13.557 ± 1.000	51	
$U^{4+} + SCN^- \Leftrightarrow USCN^{3+}$ $U^{4+} + SO_4^{2-} + CO_3^{2-} + NO_3^- + 20\ H^+ + 16\ e^- \Leftrightarrow USCN^{3+} + 10\ H_2O(l)$	**2.970 ± 0.060** 159.942 ± 0.718	**51**	
$U^{4+} + 2\ SCN^- \Leftrightarrow U(SCN)_2^{2+}$ $U^{4+} + 2\ SO_4^{2-} + 2\ CO_3^{2-} + 2\ NO_3^- + 40\ H^+ + 32\ e^- \Leftrightarrow U(SCN)_2^{2+} + 20\ H_2O(l)$	**4.260 ± 0.180** 318.204 ± 1.441	**51**	
$U^{4+} + 2\ H_2O(l) \Leftrightarrow UO_2^+ + 4\ H^+ + e^-$	-7.554 ± 0.047	51	
$UO_2^+ + 3\ CO_3^{2-} \Leftrightarrow UO_2(CO_3)_3^{5-}$	6.950 ± 0.360	51	
$U^{4+} + 2\ H_2O(l) \Leftrightarrow UO_2^{2+} + 4\ H^+ + 2\ e^-$	-9.038 ± 0.041	51	
$UO_2^{2+} + H_2O(l) \Leftrightarrow UO_2OH^+ + H^+$	-5.250 ± 0.240	51	
$UO_2^{2+} + 2\ H_2O(l) \Leftrightarrow UO_2(OH)_2(aq) + 2\ H^+$	-12.150 ± 0.070	51	
$UO_2^{2+} + 3\ H_2O(l) \Leftrightarrow UO_2(OH)_3^- + 3\ H^+$	-20.250 ± 0.420	51	
$UO_2^{2+} + 4\ H_2O(l) \Leftrightarrow UO_2(OH)_4^{2-} + 4\ H^+$	-32.400 ± 0.680	51	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$2\ UO_2^{2+} + H_2O(l) \Leftrightarrow (UO_2)_2OH^{3+} + H^+$	-2.700 ± 1.000	51	
$2\ UO_2^{2+} + 2\ H_2O(l) \Leftrightarrow (UO_2)_2OH_2^{2+} + 2\ H^+$	-5.620 ± 0.040	51	
$3\ UO_2^{2+} + 4\ H_2O(l) \Leftrightarrow (UO_2)_3(OH)_4^{2+} + 4\ H^+$	-11.900 ± 0.300	51	
$3\ UO_2^{2+} + 5\ H_2O(l) \Leftrightarrow (UO_2)_3(OH)_5^{+} + 5\ H^+$	-15.550 ± 0.120	51	
$3\ UO_2^{2+} + 7\ H_2O(l) \Leftrightarrow (UO_2)_3(OH)_7^{-} + 7\ H^+$	-32.200 ± 0.800	51	
$4\ UO_2^{2+} + 7\ H_2O(l) \Leftrightarrow (UO_2)_4(OH)_7^{+} + 7\ H^+$	-21.900 ± 1.000	51	
$UO_2^{2+} + F^- \Leftrightarrow UO_2F^+$	5.160 ± 0.060	51	
$UO_2^{2+} + 2\ F^- \Leftrightarrow UO_2F_2(aq)$	8.830 ± 0.080	51	
$UO_2^{2+} + 3\ F^- \Leftrightarrow UO_2F_3^-$	10.900 ± 0.100	51	
$UO_2^{2+} + 4\ F^- \Leftrightarrow UO_2F_4^{2-}$	11.840 ± 0.110	51	
$UO_2^{2+} + Cl^- \Leftrightarrow UO_2Cl^+$	0.170 ± 0.020	51	
$UO_2^{2+} + 2\ Cl^- \Leftrightarrow UO_2Cl_2(aq)$	-1.100 ± 0.400	51	
$UO_2^{2+} + Cl^- + 3\ H_2O(l) \Leftrightarrow UO_2ClO_3^+ + 6\ H^+ + 6\ e^-$	-145.738 ± 0.246	51	
$UO_2^{2+} + Br^- \Leftrightarrow UO_2Br^+$	0.220 ± 0.020	51	
$UO_2^{2+} + Br^- + 3\ H_2O(l) \Leftrightarrow UO_2BrO_3^+ + 6\ H^+ + 6\ e^-$	-145.539 ± 0.141	51	
$UO_2^{2+} + 2\ IO_3^- \Leftrightarrow UO_2(IO_3)_2(aq)$	3.590 ± 0.150	51	
$UO_2(IO_3)_2(cr) \Leftrightarrow UO_2^{2+} + 2\ IO_3^-$	-7.880 ± 0.100	51	
$UO_2^{2+} + SO_3^{2-} \Leftrightarrow UO_2SO_3(aq)$	6.600 ± 0.600	51	
$UO_2^{2+} + S_2O_3^{2-} \Leftrightarrow UO_2S_2O_3(aq)$	2.800 ± 0.300	51	
$UO_2^{2+} + SO_4^{2-} \Leftrightarrow UO_2SO_4(aq)$	3.150 ± 0.020	51	
$UO_2^{2+} + 2\ SO_4^{2-} \Leftrightarrow UO_2(SO_4)_2^{2-}$	4.140 ± 0.070	51	
$UO_2^{2+} + 3\ SO_4^{2-} \Leftrightarrow UO_2(SO_4)_3^{4-}$	3.020 ± 0.380	51	
$UO_2^{2+} + 3\ NO_3^- + 18\ H^+ + 16\ e^- \Leftrightarrow UO_2N_3^+ + 9\ H_2O(l)$	257.252 ± 0.428	51	
$UO_2^{2+} + 6\ NO_3^- + 36\ H^+ + 32\ e^- \Leftrightarrow UO_2(N_3)_2(aq) + 18\ H_2O(l)$	513.674 ± 0.867	51	
$UO_2^{2+} + 9\ NO_3^- + 54\ H^+ + 48\ e^- \Leftrightarrow UO_2(N_3)_3^- + 27\ H_2O(l)$	769.756 ± 1.273	51	
$UO_2^{2+} + 12\ NO_3^- + 72\ H^+ + 64\ e^- \Leftrightarrow UO_2(N_3)_4^{2-} + 36\ H_2O(l)$	1023.608 ± 1.689	51	
$UO_2^{2+} + NO_3^- \Leftrightarrow UO_2NO_3^+$	0.300 ± 0.150	51	
$UO_2^{2+} + PO_4^{3-} \Leftrightarrow UO_2PO_4^-$	13.230 ± 0.150	51	
$UO_2^{2+} + H^+ + PO_4^{3-} \Leftrightarrow UO_2HPO_4(aq)$	19.590 ± 0.262	51	
$UO_2^{2+} + 2\ H^+ + PO_4^{3-} \Leftrightarrow UO_2H_2PO_4^+$	20.682 ± 0.068	51	
$UO_2^{2+} + 3\ H^+ + PO_4^{3-} \Leftrightarrow UO_2H_3PO_4^{2+}$	22.462 ± 0.231	51	
$UO_2^{2+} + 4\ H^+ + 2\ PO_4^{3-} \Leftrightarrow UO_2(H_2PO_4)_2(aq)$	44.044 ± 0.369	51	
$UO_2^{2+} + 5\ H^+ + 2\ PO_4^{3-} \Leftrightarrow UO_2(H_2PO_4)(H_3PO_4)^+$	45.054 ± 0.369	51	
$UO_2^{2+} + AsO_4^{3-} + H^+ \Leftrightarrow UO_2HAsO_4(aq)$	18.760 ± 0.310	51	
$UO_2^{2+} + AsO_4^{3-} + 2\ H^+ \Leftrightarrow UO_2H_2AsO_4^+$	21.960 ± 0.240	51	
$UO_2^{2+} + 2\ AsO_4^{3-} + 4\ H^+ \Leftrightarrow UO_2(H_2AsO_4)_2(aq)$	41.530 ± 0.200	51	
$UO_2^{2+} + CO_3^{2-} \Leftrightarrow UO_2CO_3(aq)$	9.940 ± 0.030	51	
$UO_2^{2+} + 2\ CO_3^{2-} \Leftrightarrow UO_2(CO_3)_2^{2-}$	16.610 ± 0.090	51	
$UO_2^{2+} + 3\ CO_3^{2-} \Leftrightarrow UO_2(CO_3)_3^{4-}$	21.840 ± 0.040	51	
$3\ UO_2^{2+} + 6\ CO_3^{2-} \Leftrightarrow (UO_2)_3(CO_3)_6^{6-}$	54.000 ± 1.000	51	
$2\ UO_2^{2+} + CO_3^{2-} + 3\ H_2O(l) \Leftrightarrow (UO_2)_2CO_3(OH)_3^- + 3\ H^+$	-0.855 ± 0.501	51	
$3\ UO_2^{2+} + CO_3^{2-} + 3\ H_2O(l) \Leftrightarrow (UO_2)_3O(OH)_2(HCO_3)^+ + 3\ H^+$	0.655 ± 0.501	51	
$11\ UO_2^{2+} + 6\ CO_3^{2-} + 12\ H_2O(l) \Leftrightarrow (UO_2)_{11}(CO_3)_6(OH)_{12}^{2-} + 12\ H^+$	36.430 ± 2.011	51	
$UO_2^{2+} + CO_3^{2-} + F^- \Leftrightarrow UO_2CO_3F^-$	13.750 ± 0.090	51	
$UO_2^{2+} + CO_3^{2-} + 2\ F^- \Leftrightarrow UO_2CO_3F_2^{2-}$	15.570 ± 0.140	51	
$UO_2^{2+} + CO_3^{2-} + 3\ F^- \Leftrightarrow UO_2CO_3F_3^{3-}$	16.380 ± 0.110	51	
$UO_2^{2+} + SCN^- \Leftrightarrow UO_2SCN^+$ $UO_2^{2+} + SO_4^{2-} + CO_3^{2-} + NO_3^- + 20\ H^+ + 16\ e^- \Leftrightarrow UO_2SCN^+ + 10\ H_2O(l)$	**1.400 ± 0.230** 158.372 ± 0.751	**51**	
$UO_2^{2+} + 2\ SCN^- \Leftrightarrow UO_2(SCN)_2(aq)$ $UO_2^{2+} + 2\ SO_4^{2-} + 2\ CO_3^{2-} + 2\ NO_3^- + 40\ H^+ + 32\ e^- \Leftrightarrow UO_2(SCN)_2(aq) + 20\ H_2O(l)$	**1.240 ± 0.550** 315.184 ± 1.532	**51**	
$UO_2^{2+} + 3\ SCN^- \Leftrightarrow UO_2(SCN)_3^-$ $UO_2^{2+} + 3\ SO_4^{2-} + 3\ CO_3^{2-} + 3\ NO_3^- + 60\ H^+ + 48\ e^- \Leftrightarrow UO_2(SCN)_3^- + 30\ H_2O(l)$	**2.100 ± 0.500** 473.016 ± 2.203	**51**	
$UO_2^{2+} + H_4SiO_4(aq) \Leftrightarrow UO_2SiO(OH)_3^+ + H^+$	-1.840 ± 0.100	51	
$UO_2^{2+} + PuO_2^{2+-} + 6\ CO_3^{2-} \Leftrightarrow (UO_2)_2PuO_2(CO_3)_6^{6-}$	53.480 ± 1.395	51	
$UO_2^{2+} + NpO_2^{2+} + 6\ CO_3^{2-} \Leftrightarrow (UO_2)_2NpO_2(CO_3)_6^{6-}$	54.053 ± 3.336	51	
$Np^{4+} + e^- \Leftrightarrow Np^{3+}$	3.695 ± 0.169	51	
$Np^{4+} + 3\ CO_3^{2-} + e^- \Leftrightarrow Np(CO_3)_3^{3-}$	20.279 ± 2.385	51,53	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Np^{3+} + H_2O(l) \Leftrightarrow NpOH^{2+} + H^+$	-6.800 ± 0.300	51	
$Np^{4+} + H_2O(l) \Leftrightarrow NpOH^{3+} + H^+$	-0.090 ± 0.300	53	
$Np^{4+} + 2\ H_2O(l) \Leftrightarrow Np(OH)_2^{2+} + 2\ H^+$	-0.870 ± 0.150	53	
$Np^{4+} + 3\ H_2O(l) \Leftrightarrow Np(OH)_3^{+} + 3\ H^+$	-4.300 ± 0.300	53	
$Np^{4+} + 4\ H_2O(l) \Leftrightarrow Np(OH)_4(aq) + 4\ H^+$	-9.600 ± 1.100	53	
$Np^{4+} + F^- \Leftrightarrow NpF^{3+}$	8.960 ± 0.140	51	
$Np^{4+} + 2\ F^- \Leftrightarrow NpF_2^{2+}$	15.700 ± 0.300	51	
$Np^{4+} + Cl^- \Leftrightarrow NpCl^{3+}$	1.500 ± 0.300	51	
$Np^{4+} + I^- \Leftrightarrow NpI^{3+}$	1.500 ± 0.400	51	
$Np^{4+} + SO_4^{2-} \Leftrightarrow NpSO_4^{2+}$	6.850 ± 0.158	51	
$Np^{4+} + 2\ SO_4^{2-} \Leftrightarrow Np(SO_4)_2(aq)$	11.050 ± 0.269	51	
$Np^{4+} + NO_3^- \Leftrightarrow NpNO_3^{3+}$	1.900 ± 0.150	51	
$Np^{4+} + 4\ CO_3^{2-} \Leftrightarrow Np(CO_3)_4^{4-}$	37.610 ± 0.686	51,53	
$Np^{4+} + 5\ CO_3^{2-} \Leftrightarrow Np(CO_3)_5^{6-}$	36.540 ± 0.748	51,53	
$Np^{4+} + 2\ CO_3^{2-} + 2\ H_2O(l) \Leftrightarrow Np(CO_3)_2(OH)_2^{2-} + H^+$	16.387 ± 1.210	53	
$Np^{4+} + SCN^- \Leftrightarrow NpSCN^{3+}$ $Np^{4+} + SO_4^{2-} + CO_3^{2-} + NO_3^- + 20\ H^+ + 16\ e^- \Leftrightarrow NpSCN^{3+} + 10\ H_2O(l)$	**3.000 ± 0.300** 159.972 ± 0.775	**51**	
$Np^{4+} + 2\ SCN^- \Leftrightarrow Np(SCN)_2^{2+}$ $Np^{4+} +2\ SO_4^{2-} +2\ CO_3^{2-} +2\ NO_3^- +40\ H^+ +32\ e^- \Leftrightarrow Np(SCN)_2^{2+} +20\ H_2O(l)$	**4.100 ± 0.500** 318.044 ± 1.515	**51**	
$Np^{4+} + 3\ SCN^- \Leftrightarrow Np(SCN)_3^{+}$ $Np^{4+} +3\ SO_4^{2-} +3\ CO_3^{2-} +3\ NO_3^- +60\ H^+ +48\ e^- \Leftrightarrow Np(SCN)_3^{+} +30\ H_2O(l)$	**4.800 ± 0.500** 475.716 ± 2.203	**51**	
$Np^{4+} + 2\ H_2O(l) \Leftrightarrow NpO_2^{+} + 4\ H^+ + e^-$	-10.212 ± 1.389	51	
$NpO_2^{+} + H_2O(l) \Leftrightarrow NpO_2OH(aq) + H^+$	-11.300 ± 0.700	51	
$NpO_2^{+} + 2\ H_2O(l) \Leftrightarrow NpO_2(OH)_2^{-} + 2\ H^+$	-23.600 ± 0.500	51	
$NpO_2^{+} + F^- \Leftrightarrow NpO_2F(aq)$	1.200 ± 0.300	51	
$NpO_2^{+} + IO_3^- \Leftrightarrow NpO_2IO_3(aq)$	0.500 ± 0.300	51	
$NpO_2^{+} + SO_4^{2-} \Leftrightarrow NpO_2SO_4^{-}$	0.440 ± 0.270	51	
$NpO_2^{+} + H^+ + PO_4^{3-} \Leftrightarrow NpO_2HPO_4^{-}$	15.300 ± 0.104	51	
$NpO_2^{+} + CO_3^{2-} \Leftrightarrow NpO_2CO_3^{-}$	4.962 ± 0.061	51	
$NpO_2^{+} + 2\ CO_3^{2-} \Leftrightarrow NpO_2(CO_3)_2^{3-}$	6.534 ± 0.103	51	
$NpO_2^{+} + 3\ CO_3^{2-} \Leftrightarrow NpO_2(CO_3)_3^{5-}$	5.500 ± 0.151	51	
$3\ NpO_2^{+} + 6\ CO_3^{2-} \Leftrightarrow (NpO_2)_3(CO_3)_6^{6-} + 3\ e^-$	-8.492 ± 1.458	51	
$NpO_2^{+} + 2\ CO_3^{2-} + H_2O(l) \Leftrightarrow NpO_2(CO_3)_2OH^{4-} + H^+$	-5.306 ± 1.174	51	
$Np^{4+} + 2\ H_2O(l) \Leftrightarrow NpO_2^{2+} + 4\ H^+ + 2\ e^-$	-29.803 ± 1.388	51	
$NpO_2^{2+} + H_2O(l) \Leftrightarrow NpO_2OH^{+} + H^+$	-5.100 ± 0.400	51	
$2\ NpO_2^{2+} + 2\ H_2O(l) \Leftrightarrow (NpO_2)_2(OH)_2^{2+} + 2\ H^+$	-6.270 ± 0.210	51	
$3\ NpO_2^{2+} + 5\ H_2O(l) \Leftrightarrow (NpO_2)_3(OH)_5^{+} + 5\ H^+$	-17.120 ± 0.220	51	
$NpO_2^{2+} + F^- \Leftrightarrow NpO_2F^{+}$	4.570 ± 0.070	51	
$NpO_2^{2+} + 2\ F^- \Leftrightarrow NpO_2F_2(aq)$	7.600 ± 0.080	51	
$NpO_2^{2+} + Cl^- \Leftrightarrow NpO_2Cl^{+}$	0.400 ± 0.170	51	
$NpO_2^{2+} + IO_3^- \Leftrightarrow NpO_2IO_3^{+}$	1.200 ± 0.300	51	
$NpO_2^{2+} + SO_4^{2-} \Leftrightarrow NpO_2SO_4(aq)$	3.280 ± 0.060	51	
$NpO_2^{2+} + 2\ SO_4^{2-} \Leftrightarrow NpO_2(SO_4)_2^{2-}$	4.700 ± 0.100	51	
$NpO_2^{2+} + H^+ + PO_4^{3-} \Leftrightarrow NpO_2HPO_4(aq)$	18.550 ± 0.701	51	
$NpO_2^{2+} + 2\ H^+ + PO_4^{3-} \Leftrightarrow NpO_2H_2PO_4^{+}$	22.882 ± 0.501	51	
$NpO_2^{2+} + 2\ H^+ + 2\ PO_4^{3-} \Leftrightarrow NpO_2(HPO_4)_2^{2-}$	34.200 ± 1.001	51	
$NpO_2^{2+} + CO_3^{2-} \Leftrightarrow NpO_2CO_3(aq)$	9.320 ± 0.610	51	
$NpO_2^{2+} + 2\ CO_3^{2-} \Leftrightarrow NpO_2(CO_3)_2^{2-}$	16.516 ± 0.729	51	
$NpO_2^{2+} + 3\ CO_3^{2-} \Leftrightarrow NpO_2(CO_3)_3^{4-}$	19.371 ± 1.972	51	
$NpO_2^{2+} + CO_3^{2-} + 3\ H_2O(l) \Leftrightarrow (NpO_2)_2\ CO_3\ (OH)_3^{-}$	2.867 ± 4.254	51	
$Pu^{4+} + e^- \Leftrightarrow Pu^{3+}$	17.694 ± 0.668	51	
$Pu^{3+} + H_2O(l) \Leftrightarrow PuOH^{2+} + H^+$	-7.200 ± 0.500	39	
$Pu^{3+} + 2\ H_2O(l) \Leftrightarrow Pu(OH)_2^{+} + 2\ H^+$	-15.100 ± 0.700	39	
$Pu^{3+} + 3\ H_2O(l) \Leftrightarrow Pu(OH)_3(aq) + 3\ H^+$	-26.200 ± 0.500	39	
$Pu^{3+} + F^- \Leftrightarrow PuF^{2+}$	3.400 ± 0.400	39	
$Pu^{3+} + 2\ F^- \Leftrightarrow PuF_2^{+}$	5.800 ± 0.200	39	
$Pu^{3+} + Cl^- \Leftrightarrow PuCl^{2+}$	0.240 ± 0.030	39	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Pu^{3+} + 2\ Cl^- \Leftrightarrow PuCl_2^+$	-0.740 ± 0.050	39	
$Pu^{3+} + SO_4^{2-} \Leftrightarrow PuSO_4^+$	3.300 ± 0.150	39	
$Pu^{3+} + 2\ SO_4^{2-} \Leftrightarrow Pu(SO_4)_2^-$	3.700 ± 0.150	39	
$Pu^{3+} + 3\ NO_3^- + 18\ H^+ + 16\ e^- \Leftrightarrow PuN_3^{2+} + 9\ H_2O(l)$	256.342 ± 0.430	39,4	
$Pu^{3+} + NO_2^- \Leftrightarrow PuNO_2^{2+}$	2.100 ± 0.200	39	
$Pu^{3+} + NO_3^- \Leftrightarrow PuNO_3^{2+}$	1.330 ± 0.200	39	
$Pu^{3+} + 2\ H^+ + PO_4^{3-} \Leftrightarrow PuH_2PO_4^{2+}$	22.562 ± 0.501	39,4	
$Pu^{3+} + CO_3^{2-} \Leftrightarrow PuCO_3^+$	8.000 ± 0.400	39	
$Pu^{3+} + 2\ CO_3^{2-} \Leftrightarrow Pu(CO_3)_2^-$	12.900 ± 0.600	39	
$Pu^{3+} + 3\ CO_3^{2-} \Leftrightarrow Pu(CO_3)_3^{3-}$	15.000 ± 1.000	39	
$Pu^{3+} + H^+ + CO_3^{2-} \Leftrightarrow PuHCO_3^{2+}$	13.429 ± 0.301	39,4	
$Pu^{3+} + H_4SiO_4(aq) \Leftrightarrow PuSiO(OH)_3^{2+} + H^+$	-1.680 ± 0.180	39	
$Pu^{3+} + SCN^- \Leftrightarrow PuSCN^{2+}$	**1.300 ± 0.300**	**39**	
$Pu^{3+} + NO_3^- + CO_3^{2-} + SO_4^{2-} + 20\ H^+ + 16\ e^- \Leftrightarrow PuSCN^{2+} + 10\ H_2O(l)$	158.272 ± 0.775	39,4	
$Pu^{4+} + H_2O(l) \Leftrightarrow PuOH^{3+} + H^+$	0.000 ± 0.200	51	
$Pu^{4+} + 2\ H_2O(l) \Leftrightarrow Pu(OH)_2^{2+} + 2\ H^+$	-1.200 ± 0.600	53	
$Pu^{4+} + 3\ H_2O(l) \Leftrightarrow Pu(OH)_3^+ + 3\ H^+$	-3.100 ± 0.900	53	
$Pu^{4+} + 4\ H_2O(l) \Leftrightarrow Pu(OH)_4(aq) + 4\ H^+$	-8.500 ± 0.500	53	
$Pu^{4+} + F^- \Leftrightarrow PuF^{3+}$	8.840 ± 0.100	51	
$Pu^{4+} + 2\ F^- \Leftrightarrow PuF_2^{2+}$	15.700 ± 0.200	51	
$Pu^{4+} + Cl^- \Leftrightarrow PuCl^{3+}$	1.800 ± 0.300	51	
$Pu^{4+} + Br^- \Leftrightarrow PuBr^{3+}$	1.600 ± 0.300	51	
$Pu^{4+} + SO_4^{2-} \Leftrightarrow PuSO_4^{2+}$	6.890 ± 0.226	51	
$Pu^{4+} + 2\ SO_4^{2-} \Leftrightarrow Pu(SO_4)_2(aq)$	11.140 ± 0.335	51	
$Pu^{4+} + NO_3^- \Leftrightarrow PuNO_3^{3+}$	1.950 ± 0.150	51	
$Pu^{4+} + 3\ H^+ + PO_4^{3-} \Leftrightarrow PuH_3PO_4^{4+}$	24.102 ± 0.348	51	
$Pu^{4+} + 4\ CO_3^{2-} \Leftrightarrow Pu(CO_3)_4^{4-}$	37.000 ± 1.100	51	
$Pu^{4+} + 5\ CO_3^{2-} \Leftrightarrow Pu(CO_3)_5^{6-}$	35.650 ± 1.130	51	
$Pu^{4+} + 2\ CO_3^{2-} + 2\ H_2O(l) \Leftrightarrow Pu(CO_3)_2(OH)_2^{2-} + 2\ H^+$	19.177 ± 1.250	51	
$Pu^{4+} + 2\ H_2O(l) \Leftrightarrow PuO_2^+ + 4\ H^+ + e^-$	-17.453 ± 0.691	51	
$PuO_2^+ + H_2O(l) \Leftrightarrow PuO_2OH(aq) + H^+$	≤ -9.730	51	
$PuO_2^+ + CO_3^{2-} \Leftrightarrow PuO_2CO_3^-$	5.120 ± 0.140	51	
$PuO_2^+ + 3\ CO_3^{2-} \Leftrightarrow PuO_2(CO_3)_3^{5-}$	5.025 ± 0.920	51	
$Pu^{4+} + 2\ H_2O(l) \Leftrightarrow PuO_2^{2+} + 4\ H^+ + 2\ e^-$	-33.272 ± 0.697	51	
$PuO_2^{2+} + H_2O(l) \Leftrightarrow PuO_2OH^+ + H^+$	-5.500 ± 0.500	51	
$PuO_2^{2+} + 2\ H_2O(l) \Leftrightarrow PuO_2OH_2(aq) + 2\ H^+$	-13.200 ± 1.500	51	
$2\ PuO_2^{2+} + 2\ H_2O(l) \Leftrightarrow (PuO_2)_2(OH)_2^{2+} + 2\ H^+$	-7.500 ± 1.000	51	
$PuO_2^{2+} + F^- \Leftrightarrow PuO_2F^+$	4.560 ± 0.200	51	
$PuO_2^{2+} + 2\ F^- \Leftrightarrow PuO_2F_2(aq)$	7.250 ± 0.450	51	
$PuO_2^{2+} + Cl^- \Leftrightarrow PuO_2Cl^+$	0.230 ± 0.030	51	
$PuO_2^{2+} + 2\ Cl^- \Leftrightarrow PuO_2Cl_2(aq)$	-1.150 ± 0.300	51	
$PuO_2^{2+} + SO_4^{2-} \Leftrightarrow PuO_2SO_4(aq)$	3.380 ± 0.200	51	
$PuO_2^{2+} + 2\ SO_4^{2-} \Leftrightarrow PuO_2(SO_4)_2^{2-}$	4.400 ± 0.200	51	
$PuO_2^{2+} + CO_3^{2-} \Leftrightarrow PuO_2CO_3(aq)$	9.500 ± 0.500	51	
$PuO_2^{2+} + 2\ CO_3^{2-} \Leftrightarrow PuO_2(CO_3)_2^{2-}$	14.700 ± 0.500	51	
$PuO_2^{2+} + 3\ CO_3^{2-} \Leftrightarrow PuO_2(CO_3)_3^{4-}$	18.000 ± 0.500	51	
$Am^{3+} + e^- \Leftrightarrow Am^{2+}$	-38.878 ± 2.536	51	
$Am^{3+} + H_2O(l) \Leftrightarrow AmOH^{2+} + H^+$	-7.200 ± 0.500	51	
$Am^{3+} + 2\ H_2O(l) \Leftrightarrow Am(OH)_2^+ + 2\ H^+$	-15.100 ± 0.700	51	
$Am^{3+} + 3\ H_2O(l) \Leftrightarrow Am(OH)_3(aq) + 3\ H^+$	-26.200 ± 0.500	51	
$Am^{3+} + F^- \Leftrightarrow AmF^{2+}$	3.400 ± 0.400	51	
$Am^{3+} + 2\ F^- \Leftrightarrow AmF_2^+$	5.800 ± 0.200	51	
$Am^{3+} + Cl^- \Leftrightarrow AmCl^{2+}$	0.240 ± 0.030	51	
$Am^{3+} + 2\ Cl^- \Leftrightarrow AmCl_2^+$	-0.740 ± 0.050	51	
$Am^{3+} + SO_4^{2-} \Leftrightarrow AmSO_4^+$	3.300 ± 0.150	51	
$Am^{3+} + 2\ SO_4^{2-} \Leftrightarrow Am(SO_4)_2^-$	3.700 ± 0.150	51	
$Am^{3+} + 3\ NO_3^- + 18\ H^+ + 16\ e^- \Leftrightarrow AmN_3^{2+} + 9\ H_2O(l)$	256.342 ± 0.430	51	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Am^{3+} + NO_2^- \Leftrightarrow AmNO_2^{2+}$	2.100 ± 0.200	51	
$Am^{3+} + NO_3^- \Leftrightarrow AmNO_3^{2+}$	1.330 ± 0.200	51	
$Am^{3+} + 2\ H^+ + PO_4^{3-} \Leftrightarrow AmH_2PO_4^{2+}$	22.562 ± 0.501	51	
$Am^{3+} + CO_3^{2-} \Leftrightarrow AmCO_3^+$	8.000 ± 0.400	51	
$Am^{3+} + 2\ CO_3^{2-} \Leftrightarrow Am(CO_3)_2^-$	12.900 ± 0.600	51	
$Am^{3+} + 3\ CO_3^{2-} \Leftrightarrow Am(CO_3)_3^{3-}$	15.000 ± 1.000	51	
$Am^{3+} + H^+ + CO_3^{2-} \Leftrightarrow AmHCO_3^{2+}$	13.429 ± 0.301	51	
$Am^{3+} + H_4SiO_4(aq) \Leftrightarrow AmSiO(OH)_3^{2+} + H^+$	-1.680 ± 0.180	51	
$Am^{3+} + SCN^- \Leftrightarrow AmSCN^{2+}$ $Am^{3+} + NO_3^- + CO_3^{2-} + SO_4^{2-} + 20\ H^+ + 16\ e^- \Leftrightarrow AmSCN^{2+} + 10\ H_2O(l)$	**1.300 ± 0.300** 158.272 ± 0.775	**51**	
$Am^{3+} \Leftrightarrow Am^{4+} + e^-$	-44.208 ± 1.736	3	
$Am^{4+} + 5\ CO_3^{2-} \Leftrightarrow Am(CO_3)_5^{6-}$	39.308 ± 2.088	3	
$Am^{3+} + 2\ H_2O(l) \Leftrightarrow AmO_2^+ + 4\ H^+ + 2\ e^-$	-58.371 ± 1.370	3	
$AmO_2^+ + CO_3^{2-} \Leftrightarrow AmO_2CO_3^-$	5.100 ± 0.500	51	*
$AmO_2^+ + 2\ CO_3^{2-} \Leftrightarrow AmO_2(CO_3)_2^{3-}$	6.700 ± 0.800	51	*
$AmO_2^+ + 3\ CO_3^{2-} \Leftrightarrow AmO_2(CO_3)_3^{5-}$	5.100 ± 1.000	51	*
$Am^{3+} + 2\ H_2O(l) \Leftrightarrow AmO_2^{2+} + 4\ H^+ + 3\ e^-$	-85.349 ± 1.303	3	
$AmO_2^{2+} + 3\ CO_3^{2-} \Leftrightarrow AmO_2(CO_3)_3^{4-}$	18.978 ± 1.905	3	
$Cm^{3+} + H_2O(l) \Leftrightarrow CmOH^{2+} + H^+$	-7.200 ± 0.500	39	
$Cm^{3+} + 2\ H_2O(l) \Leftrightarrow Cm(OH)_2^+ + 2\ H^+$	-15.100 ± 0.700	39	
$Cm^{3+} + 3\ H_2O(l) \Leftrightarrow Cm(OH)_3(aq) + 3\ H^+$	-26.200 ± 0.500	39	
$Cm^{3+} + F^- \Leftrightarrow CmF^{2+}$	3.400 ± 0.400	39	
$Cm^{3+} + 2\ F^- \Leftrightarrow CmF_2^+$	5.800 ± 0.200	39	
$Cm^{3+} + Cl^- \Leftrightarrow CmCl^{2+}$	0.240 ± 0.030	39	
$Cm^{3+} + 2\ Cl^- \Leftrightarrow CmCl_2^+$	-0.740 ± 0.050	39	
$Cm^{3+} + SO_4^{2-} \Leftrightarrow CmSO_4^+$	3.300 ± 0.150	39	
$Cm^{3+} + 2\ SO_4^{2-} \Leftrightarrow Cm(SO_4)_2^-$	3.700 ± 0.150	39	
$Cm^{3+} + 3\ NO_3^- + 18\ H^+ + 16\ e^- \Leftrightarrow CmN_3^{2+} + 9\ H_2O(l)$	256.342 ± 0.430	39, 4	
$Cm^{3+} + NO_2^- \Leftrightarrow CmNO_2^{2+}$	2.100 ± 0.200	39	
$Cm^{3+} + NO_3^- \Leftrightarrow CmNO_3^{2+}$	1.330 ± 0.200	39	
$Cm^{3+} + 2\ H^+ + PO_4^{3-} \Leftrightarrow CmH_2PO_4^{2+}$	22.562 ± 0.501	39, 4	
$Cm^{3+} + CO_3^{2-} \Leftrightarrow CmCO_3^+$	8.000 ± 0.400	39	
$Cm^{3+} + 2\ CO_3^{2-} \Leftrightarrow Cm(CO_3)_2^-$	12.900 ± 0.600	39	
$Cm^{3+} + 3\ CO_3^{2-} \Leftrightarrow Cm(CO_3)_3^{3-}$	15.000 ± 1.000	39	
$Cm^{3+} + H^+ + CO_3^{2-} \Leftrightarrow CmHCO_3^{2+}$	13.429 ± 0.301	39, 4	
$Cm^{3+} + H_4SiO_4(aq) \Leftrightarrow CmSiO(OH)_3^{2+} + H^+$	-1.680 ± 0.180	39	
$Cm^{3+} + SCN^- \Leftrightarrow CmSCN^{2+}$ $Cm^{3+} + NO_3^- + CO_3^{2-} + SO_4^{2-} + 20\ H^+ + 16\ e^- \Leftrightarrow CmSCN^{2+} + 10\ H_2O(l)$	**1.300 ± 0.300** 158.272 ± 0.775	**39** 39, 4	
$H^+ + ox^{2-} \Leftrightarrow Hox^-$	4.250 ± 0.010	54	
$2\ H^+ + ox^{2-} \Leftrightarrow H_2ox(aq)$	5.650 ± 0.032	54	
$Ni^{2+} + ox^{2-} \Leftrightarrow Ni(ox)(aq)$	5.190 ± 0.040	54	
$Ni^{2+} + 2\ ox^{2-} \Leftrightarrow Ni(ox)_2^{2-}$	7.640 ± 0.070	54	
$Am^{3+} + ox^{2-} \Leftrightarrow Am(ox)^+$	6.510 ± 0.150	54	
$Am^{3+} + 2\ ox^{2-} \Leftrightarrow Am(ox)_2^-$	10.710 ± 0.200	54	
$Am^{3+} + 3\ ox^{2-} \Leftrightarrow Am(ox)_3^{3-}$	13.000 ± 1.000	54	
$NpO_2^+ + ox^{2-} \Leftrightarrow NpO_2ox^-$	3.900 ± 0.100	54	
$NpO_2^+ + 2\ ox^{2-} \Leftrightarrow NpO_2(ox)_2^{3-}$	5.800 ± 0.200	54	
$UO_2^{2+} + ox^{2-} \Leftrightarrow UO_2ox(aq)$	7.130 ± 0.160	54	
$UO_2^{2+} + 2\ ox^{2-} \Leftrightarrow UO_2(ox)_2^{2-}$	11.650 ± 0.150	54	
$UO_2^{2+} + 3\ ox^{2-} \Leftrightarrow UO_2(ox)_3^{4-}$	13.800 ± 1.500	54	
$Mg^{2+} + ox^{2-} \Leftrightarrow Mg(ox)(aq)$	3.560 ± 0.040	54	
$Mg^{2+} + 2\ ox^{2-} \Leftrightarrow Mg(ox)_2^{2-}$	5.170 ± 0.080	54	
$Ca^{2+} + ox^{2-} \Leftrightarrow Ca(ox)(aq)$	3.190 ± 0.060	54	
$Ca^{2+} + 2\ ox^{2-} \Leftrightarrow Ca(ox)_2^{2-}$	4.020 ± 0.199	54	
$cit^{3-} + H^+ \Leftrightarrow Hcit^{2-}$	6.360 ± 0.020	54	
$cit^{3-} + 2\ H^+ \Leftrightarrow H_2cit^-$	11.140 ± 0.022	54	
$cit^{3-} + 3\ H^+ \Leftrightarrow H_3cit(aq)$	14.270 ± 0.024	54	

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Ni^{2+} + cit^{3-} \Leftrightarrow Ni(cit)^{-}$	6.760 ± 0.080	54	
$Ni^{2+} + 2\ cit^{3-} \Leftrightarrow Ni(cit)_2^{4-}$	8.500 ± 0.400	54	
$Ni^{2+} + H^{+} + cit^{3-} \Leftrightarrow Ni(Hcit)(aq)$	10.520 ± 0.102	54	
$Ni^{2+} + 2\ H^{+} + cit^{3-} \Leftrightarrow Ni(H_2cit)^{+}$	13.190 ± 0.251	54	
$Am^{3+} + cit^{3-} \Leftrightarrow Am(cit)(aq)$	8.550 ± 0.200	54	
$Am^{3+} + 2\ cit^{3-} \Leftrightarrow Am(cit)_2^{3-}$	13.900 ± 1.000	54	
$Am^{3+} + H^{+} + cit^{3-} \Leftrightarrow Am(Hcit)^{+}$	12.860 ± 1.000	54	
$Am^{3+} + 2\ H^{+} + 2\ cit^{3-} \Leftrightarrow Am(Hcit)_2^{-}$	23.520 ± 1.001	54	
$NpO_2^{+} + cit^{3-} \Leftrightarrow NpO_2cit^{2-}$	3.680 ± 0.050	54	
$UO_2^{2+} + cit^{3-} \Leftrightarrow UO_2cit^{-}$	8.960 ± 0.170	54	
$2\ UO_2^{2+} + 2\ cit^{3-} \Leftrightarrow (UO_2)_2(cit)_2^{2-}$	21.300 ± 0.500	54	
$UO_2^{2+} + H^{+} + cit^{3-} \Leftrightarrow UO_2(Hcit)(aq)$	11.360 ± 1.000	54	
$Mg^{2+} + cit^{3-} \Leftrightarrow Mg(cit)^{-}$	4.810 ± 0.030	54	
$Mg^{2+} + H^{+} + cit^{3-} \Leftrightarrow Mg(Hcit)(aq)$	8.960 ± 0.073	54	
$Mg^{2+} + 2\ H^{+} + cit^{3-} \Leftrightarrow Mg(H_2cit)^{+}$	12.450 ± 0.162	54	
$Ca^{2+} + cit^{3-} \Leftrightarrow Ca(cit)^{-}$	4.800 ± 0.030	54	
$Ca^{2+} + H^{+} + cit^{3-} \Leftrightarrow Ca(Hcit)(aq)$	9.280 ± 0.073	54	
$Ca^{2+} + 2\ H^{+} + cit^{3-} \Leftrightarrow Ca(H_2cit)^{+}$	12.670 ± 0.162	54	
$edta^{4-} + H^{+} \Leftrightarrow Hedta^{3-}$	11.240 ± 0.030	54	
$edta^{4-} + 2\ H^{+} \Leftrightarrow H_2edta^{2-}$	18.040 ± 0.036	54	
$edta^{4-} + 3\ H^{+} \Leftrightarrow H_3edta^{-}$	21.190 ± 0.041	54	
$edta^{4-} + 4\ H^{+} \Leftrightarrow H_4edta(aq)$	23.420 ± 0.065	54	
$edta^{4-} + 5\ H^{+} \Leftrightarrow H_5edta^{+}$	24.720 ± 0.119	54	
$edta^{4-} + 6\ H^{+} \Leftrightarrow H_6edta^{2+}$	24.220 ± 0.233	54	
$Ni^{2+} + edta^{4-} \Leftrightarrow Ni(edta)^{2-}$	20.540 ± 0.130	54	
$Ni^{2+} + edta^{4-} + H^{+} \Leftrightarrow Ni(Hedta)^{-}$	24.200 ± 0.206	54	
$Am^{3+} + edta^{4-} \Leftrightarrow Am(edta)^{-}$	19.670 ± 0.110	54	
$Am^{3+} + edta^{4-} + H^{+} \Leftrightarrow Am(Hedta)(aq)$	21.840 ± 0.273	54	
$Pu^{3+} + edta^{4-} \Leftrightarrow Pu(edta)^{-}$	20.180 ± 0.370	54	
$Pu^{3+} + edta^{4-} + H^{+} \Leftrightarrow Pu(Hedta)(aq)$	22.020 ± 0.454	54	
$Np^{4+} + edta^{4-} \Leftrightarrow Np(edta)(aq)$	31.200 ± 0.600	54	
$NpO_2^{+} + edta^{4-} \Leftrightarrow NpO_2edta^{3-}$	9.230 ± 0.130	54	
$NpO_2^{+} + edta^{4-} + H^{+} \Leftrightarrow NpO_2(Hedta)^{2-}$	17.060 ± 0.114	54	
$NpO_2^{+} + edta^{4-} + 2\ H^{+} \Leftrightarrow NpO_2(H_2edta)^{-}$	22.510 ± 0.145	54	
$U^{4+} + edta^{4-} \Leftrightarrow Uedta(aq)$	29.500 ± 0.200	54	
$UO_2^{2+} + edta^{4-} \Leftrightarrow UO_2edta^{2-}$	13.700 ± 0.200	54	
$2\ UO_2^{2+} + edta^{4-} \Leftrightarrow (UO_2)_2edta(aq)$	20.600 ± 0.400	54	
$UO_2^{2+} + edta^{4-} + H^{+} \Leftrightarrow UO_2(Hdta)^{-}$	19.610 ± 0.104	54	
$Mg^{2+} + edta^{4-} \Leftrightarrow Mg(edta)^{2-}$	10.900 ± 0.100	54	
$Mg^{2+} + edta^{4-} + H^{+} \Leftrightarrow Mg(Hedta)^{-}$	15.400 ± 0.224	54	
$Ca^{2+} + edta^{4-} \Leftrightarrow Ca(edta)^{2-}$	12.690 ± 0.060	54	
$Ca^{2+} + edta^{4-} + H^{+} \Leftrightarrow Ca(Hedta)^{-}$	16.230 ± 0.108	54	
$Na^{+} + edta^{4-} \Leftrightarrow Na(edta)^{3-}$	2.800 ± 0.200	54	
$K^{+} + edta^{4-} \Leftrightarrow Na(edta)^{3-}$	1.800 ± 0.300	54	
$H^{+} + isa^{-} \Leftrightarrow Hisa(aq)$	4.000 ± 0.500	54	
$Ca^{2+} + isa^{-} \Leftrightarrow Ca(isa)^{+}$	1.700 ± 0.300	54	
$Na^{+} + (ox)^{2-} \Leftrightarrow Na(ox)^{-}$	1.000	55	*
$K^{+} + (ox)^{2-} \Leftrightarrow K(ox)^{-}$	0.900	55	*
$Sr^{2+} + (ox)^{2-} \Leftrightarrow Sr(ox)$	2.330	56	*
$Sr^{2+} + 2\ (ox)^{2-} \Leftrightarrow Sr(ox)_2^{2-}$	2.980	56	*
$Ra^{2+} + (ox)^{2-} \Leftrightarrow Ra(ox)$	2.780	57	*
$Ra^{2+} + 2\ (ox)^{2-} \Leftrightarrow Ra(ox)_2^{2-}$	3.440	57	*
$Fe^{2+} + (ox)^{2-} \Leftrightarrow Fe(ox)$	4.130	56	*
$Fe^{2+} + 2\ (ox)^{2-} \Leftrightarrow Fe(ox)_2^{2-}$	6.230	56	*
$Co^{2+} + (ox)^{2-} \Leftrightarrow Co(ox)$	4.720	56	*
$Co^{2+} + 2\ (ox)^{2-} \Leftrightarrow Co(ox)_2^{2-}$	7.000	56	*
$Pb^{+} + 2\ (ox)^{2-} \Leftrightarrow Pb(ox)$	4.910	56	*

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Pb + 2\ (ox)^{2-} \Leftrightarrow Pb(ox)_2^{2-}$	6.760	56	*
$Al^{3+} + (ox)^{2-} \Leftrightarrow Al(ox)^{+}$	7.720	56	*
$Al^{3+} + 2\ (ox)^{2-} \Leftrightarrow Al(ox)_2^{-}$	13.200	56	*
$Al^{3+} + 3\ (ox)^{2-} \Leftrightarrow Al(ox)_3^{3-}$	16.740	56	*
$Zr^{4+} + (ox)^{2-} \Leftrightarrow Zr(ox)^{2+}$	10.520	57	*
$Zr^{4+} + 2\ (ox)^{2-} \Leftrightarrow Zr(ox)_2$	18.150	57	*
$TcO(OH)_2(aq) + 2\ H^{+} + (cit)^{3-} \Leftrightarrow TcO(cit)^{-} + 2\ H_2O(l)$	< 15.999	3, 57	*
$TcO(OH)_2(aq) + 3\ H^{+} + (cit)^{3-} \Leftrightarrow TcOH(cit)(aq) + 2\ H_2O(l)$	< 18.110	3, 57	*
$Sm^{3+} + (ox)^{2-} \Leftrightarrow Sm(ox)^{+}$	6.300	57	*
$Sm^{3+} + 2\ (ox)^{2-} \Leftrightarrow Sm(ox)_2^{-}$	10.130	57	*
$Ac^{3+} + (ox)^{2-} \Leftrightarrow Ac(ox)^{+}$	5.650	56	*
$Ac^{3+} + 2\ (ox)^{2-} \Leftrightarrow Ac(ox)_2^{-}$	8.800	56	*
$Cm^{3+} + (ox)^{2-} \Leftrightarrow Cm(ox)^{+}$	6.540	56	*
$Cm^{3+} + 2\ (ox)^{2-} \Leftrightarrow Cm(ox)_2^{-}$	10.570	56	*
$Th^{4+} + (ox)^{2-} \Leftrightarrow Th(ox)^{2+}$	10.600	56	*
$Th^{4+} + 2\ (ox)^{2-} \Leftrightarrow Th(ox)_2(aq)$	20.200	56	*
$Th^{4+} + 3\ (ox)^{2-} \Leftrightarrow Th(ox)_3^{2-}$	26.400	56	*
$Pu^{4+} + (ox)^{2-} \Leftrightarrow Pu(ox)^{2+}$	10.340	57	*
$Pu^{4+} + 2\ (ox)^{2-} \Leftrightarrow Pu(ox)_2(aq)$	17.800	57	*
$U^{4+} + (ox)^{2-} \Leftrightarrow U(ox)^{2+}$	10.180	57	*
$U^{4+} + 2\ (ox)^{2-} \Leftrightarrow U(ox)_2(aq)$	17.500	57	*
$Np^{4+} + (ox)^{2-} \Leftrightarrow Np(ox)^{2+}$	10.290	57	*
$Np^{4+} + 2\ (ox)^{2-} \Leftrightarrow Np(ox)_2(aq)$	17.710	57	*
$PuO_2^{2+} + (ox)^{2-} \Leftrightarrow PuO_2(ox)\ (aq)$	7.250	57	*
$PuO_2^{2+} + 2\ (ox)^{2-} \Leftrightarrow PuO_2(ox)_2^{2-}$	11.940	57	*
$Na^{+} + (cit)^{3-} \Leftrightarrow Na(cit)^{2-}$	1.340	56	*
$K^{+} + (cit)^{3-} \Leftrightarrow K(cit)^{2-}$	1.230	56	*
$Sr^{2+} + (cit)^{3-} \Leftrightarrow Sr(cit)^{-}$	4.110	56	*
$Sr^{2+} + H^{+} + (cit)^{3-} \Leftrightarrow SrH(cit)(aq)$	9.080	57	*
$Ra^{2+} + (cit)^{3-} \Leftrightarrow Ra(cit)^{-}$	3.590	57	*
$Ra^{2+} + H^{+} + (cit)^{3-} \Leftrightarrow Ra(H(cit)(aq)$	9.000	57	*
$Fe^{2+} + (cit)^{3-} \Leftrightarrow Fe(cit)^{-}$	5.690	56	*
$Fe^{2+} + H^{+} + (cit)^{3-} \Leftrightarrow FeH(cit)(aq)$	9.870	56	*
$Co^{2+} + (cit)^{3-} \Leftrightarrow Co(cit)^{-}$	6.290	56	*
$Co^{2+} + H^{+} + (cit)^{3-} \Leftrightarrow CoH(cit)(aq)$	10.270	56	*
$Pb^{2+} + (cit)^{3-} \Leftrightarrow Pb(cit)^{-}$	5.700	56	*
$Pb^{2+} + 2\ (cit)^{3-} \Leftrightarrow Pb(cit)_2^{4-}$	9.910	56	*
$Pb^{2+} + 3\ (cit)^{3-} \Leftrightarrow Pb(cit)_3^{7-}$	4.550	56	*
$Pb^{2+} + H^{+} + (cit)^{3-} \Leftrightarrow PbH(cit)(aq)$	10.410	56	*
$Al^{3+} + (cit)^{3-} \Leftrightarrow Al(cit)$	9.910	55	*
$Al^{3+} + 2\ (cit)^{3-} \Leftrightarrow Al(cit)_2^{3-}$	14.120	55	*
$Al^{3+} + H^{+} + (cit)^{3-} \Leftrightarrow AlH(cit)^{+}$	12.860	55	*
$Zr^{4+} + (cit)^{3-} \Leftrightarrow Zr(cit)^{+}$	13.270	57	*
$Zr^{4+} + H^{+} + (cit)^{3-} \Leftrightarrow ZrH(cit)^{2+}$	14.880	57	*
$TcO^{2+} + (cit)^{3-} \Leftrightarrow TcO(cit)^{-}$	11.990	57	*
$TcO^{2+} + H^{+} + (cit)^{3-} \Leftrightarrow TcOH(cit)(aq)$	14.110	57	*
$Sm^{3+} + (cit)^{3-} \Leftrightarrow Sm(cit)(aq)$	7.990	57	*
$Sm^{3+} + H^{+} + (cit)^{3-} \Leftrightarrow SmH(cit)^{+}$	11.670	57	*
$Ac^{3+} + (cit)^{3-} \Leftrightarrow Ac(cit)(aq)$	7.990	57	*
$Ac^{3+} + H^{+} + (cit)^{3-} \Leftrightarrow AcH(cit)^{+}$	11.670	57	*
$Cm^{3+} + (cit)^{3-} \Leftrightarrow Cm(cit)(aq)$	7.990	57	*
$Cm^{3+} + H^{+} + (cit)^{3-} \Leftrightarrow CmH(cit)^{+}$	11.670	57	*
$Pu^{3+} + (cit)^{3-} \Leftrightarrow Pu(cit)(aq)$	7.990	57	*
$Pu^{3+} + H^{+} + (cit)^{3-} \Leftrightarrow PuH(cit)^{+}$	11.670	57	*
$Th^{4+} + (cit)^{3-} \Leftrightarrow Th(cit)^{+}$	11.290	57	*
$Th^{4+} + H^{+} + (cit)^{3-} \Leftrightarrow ThH(cit)^{2+}$	13.680	57	*
$Pu^{4+} + (cit)^{3-} \Leftrightarrow Pu(cit)^{+}$	13.040	57	*

Reaction	$\log_{10} K°$	Ref.	T.v.*
$Pu^{4+} + H^+ + (cit)^{3-} \Leftrightarrow PuH(cit)^{2+}$	14.750	57	*
$U^{4+} + (cit)^{3-} \Leftrightarrow U(cit)^+$	12.840	57	*
$U^{4+} + H^+ + (cit)^{3-} \Leftrightarrow UH(cit)^{2+}$	14.620	57	*
$Np^{4+} + (cit)^{3-} \Leftrightarrow Np(cit)^+$	12.980	57	*
$Np^{4+} + H^+ + (cit)^{3-} \Leftrightarrow NpH(cit)^{2+}$	14.710	57	*
$NpO_2^+ + H^+ + (cit)^{3-} \Leftrightarrow NpH(cit)^-$	9.920	57	*
$PuO_2^{2+} + (cit)^{3-} \Leftrightarrow PuO_2(cit)^-$	9.180	57	*
$PuO_2^{2+} + H^+ + (cit)^{3-} \Leftrightarrow PuO_2H(cit)(aq)$	12.400	57	*
$Sr^{2+} + (edta)^{4-} \Leftrightarrow Sr(edta)^{2-}$	10.460	55	*
$Sr^{2+} + H^+ + (edta)^{4-} \Leftrightarrow SrH(edta)^-$	14.820	55	*
$Fe^{2+} + (edta)^{4-} \Leftrightarrow Fe(edta)^{2-}$	16.020	55	*
$Fe^{2+} + H^+ + (edta)^{4-} \Leftrightarrow FeH(edta)^-$	19.250	55	*
$Co^{2+} + (edta)^{4-} \Leftrightarrow Co(edta)^{2-}$	18.170	55	*
$Co^{2+} + H^+ + (edta)^{4-} \Leftrightarrow CoH(edta)^-$	21.600	55	*
$Co^{2+} + 2\ H^+ + (edta)^{4-} \Leftrightarrow CoH_2(edta)(aq)$	23.570	55	*
$Pb^{2+} + (edta)^{4-} \Leftrightarrow Pb(edta)^{2-}$	19.680	55	*
$Pb^{2+} + H^+ + (edta)^{4-} \Leftrightarrow PbH(edta)^-$	22.610	55	*
$Pb^{2+} + 2\ H^+ + (edta)^{4-} \Leftrightarrow PbH_2(edta)(aq)$	24.570	55	*
$Pb^{2+} + 3\ H^+ + (edta)^{4-} \Leftrightarrow PbH_3(edta)^+$	25.770	55	*
$Th^{4+} + (edta)^{4-} \Leftrightarrow Th(edta)(aq)$	26.630	55	*
$Th^{4+} + H^+ + (edta)^{4-} \Leftrightarrow ThH(edta)^+$	28.610	55	*
$Pu^{4+} + (edta)^{4-} + H_2O \Leftrightarrow PuOH(edta)^- + H^+$	24.200	58	*
$Pu^{4+} + (edta)^{4-} + 2\ H_2O \Leftrightarrow Pu(OH)_2(edta)^{2-} + 2\ H^+$	19.220	58	*
$Pu^{4+} + (edta)^{4-} + 3\ H_2O \Leftrightarrow Pu(OH)_3(edta)^{3-} + 3\ H^+$	9.710	58	*
$Mg^{2+} + (isa)^- \Leftrightarrow Mg(isa)^+$	0.600	57	*
$Sr^{2+} + (isa)^- \Leftrightarrow Sr(isa)^+$	0.910	57	*
$Fe^{2+} + (isa)^- \Leftrightarrow Fe(isa)^+$	0.940	57	*
$Ni^{2+} + (isa)^- \Leftrightarrow Ni(isa)^+$	2.200	57	*
$Sm^{3+} + 3\ H_2O(l) + (isa)^- \Leftrightarrow Sm(OH)_3(isa)^- + 3\ H^+$	**-21.400 ± 1.000**	**36**	*
$Pb^{2+} + (isa)^- \Leftrightarrow Pb(isa)^+$	2.440	57	*
$Ac^{3+} + 3\ H_2O(l) + (isa)^- \Leftrightarrow Ac(OH)_3(isa)^- + 3\ H^+$	**-21.400 ± 1.000**	**36**	*
$Th^{4+} + H_2O(l) + (isa)^- \Leftrightarrow ThOH(isa)^{2+} + H^+$	**3.200 ± 0.500**	**37**	*
$Th^{4+} + 3\ H_2O(l) + 2\ (isa)^- \Leftrightarrow Th(OH)_3(isa)_2^- + 3\ H^+$	**-4.900 ± 0.500**	**37**	*
$Th^{4+} + 4\ H_2O(l) + 2\ (isa)^- \Leftrightarrow Th(OH)_4(isa)_2^{2-} + 4\ H^+$	**-12.500 ± 0.500**	**37**	*
$U^{4+} + 4\ H_2O(l) + (isa)^- \Leftrightarrow U(OH)_4(isa)^- + 4\ H^+$	**-6.800 ± 0.900**	**36**	*
$U^{4+} + 4\ H_2O(l) + 2(isa)^- \Leftrightarrow U(OH)_4(isa)_2^{2-} + 4\ H^+$	**-4.900 ± 1.000**	**36**	*
$Np^{4+} + 4\ H_2O(l) + (isa)^- \Leftrightarrow Np(OH)_4(isa)^- + 4\ H^+$	**-4.060 ± 0.620**	**36**	*
$Np^{4+} + 4\ H_2O(l) + 2\ (isa)^- \Leftrightarrow Np(OH)_4(isa)_2^{2-} + 4\ H^+$	**-2.200 ± 0.620**	**36**	*
$Pu^{3+} + 3\ H_2O(l) + (isa)^- \Leftrightarrow Pu(OH)_3(isa)^- + 3\ H^+$	**-21.400 ± 1.000**	**36**	*
$Pu^{4+} + 4\ H_2O(l) + (isa)^- \Leftrightarrow Pu(OH)_4(isa)^- + 4\ H^+$	**-1.474 ± 1.588**	**36**	*
$Pu^{4+} + 4\ H_2O(l) + 2\ (isa)^- \Leftrightarrow Pu(OH)_4(isa)_2^{2-} + 4\ H^+$	**2.726 ± 1.127**	**36**	*
$Am^{3+} + 3\ H_2O(l) + (isa)^- \Leftrightarrow Am(OH)_3(isa)^- + 3\ H^+$	**-21.400 ± 1.000**	**36**	*
$Cm^{3+} + 3\ H_2O(l) + (isa)^- \Leftrightarrow Cm(OH)_3(isa)^- + 3\ H^+$	**-21.400 ± 1.000**	**36**	*

* Tentative values.

Table A2 Selected equilibrium constants of solid phases for JAEA-TDB ready to use for the geochemical calculation programs (revised from Table A2 in the previous TDB report [3)])

Reactions and $\log_{10} K°$ values written with bold letters are additionally selected or revised in the present report.

Reaction	$\log_{10} K°$	ref.	T.v.*
$H(g) \Leftrightarrow H^+ + e^-$	35.612 ± 0.001	4	
$H_2(g) \Leftrightarrow 2\ H^+ + 2\ e^-$	0.000	4, 5	
$H_2O(g) \Leftrightarrow H_2O(l)$	1.499 ± 0.010	4	
$Li(cr) \Leftrightarrow Li^+ + e^-$	51.317 ± 0.019	3	
$Li(g) \Leftrightarrow Li^+ + e^-$	73.497 ± 0.177	3	
$B(cr) + 3\ H_2O(l) \Leftrightarrow B(OH)_3(aq) + 3\ H^+ + 3\ e^-$	45.173 ± 0.145	4	
$B(g) + 3\ H_2O(l) \Leftrightarrow B(OH)_3(aq) + 3\ H^+ + 3\ e^-$	136.450 ± 0.888	4	
$B_2O_3(cr) + 3\ H_2O(l) \Leftrightarrow 2\ B(OH)_3(aq)$	5.745 ± 0.379	4	
$B(OH)_3(cr) \Leftrightarrow B(OH)_3(aq)$	-0.070 ± 0.203	4	
$BF_3(g) + 3\ H_2O(l) \Leftrightarrow B(OH)_3(aq) + 3\ F^- + 3\ H^+$	-2.976 ± 0.416	4	
$C(cr) + 3\ H_2O(l) \Leftrightarrow CO_3^{2-} + 6\ H^+ + 4\ e^-$	-32.151 ± 0.069	4	
$C(g) + 3\ H_2O(l) \Leftrightarrow CO_3^{2-} + 6\ H^+ + 4\ e^-$	85.447 ± 0.105	4	
$CO(g) + 2\ H_2O(l) \Leftrightarrow CO_3^{2-} + 4\ H^+ + 2\ e^-$	-14.637 ± 0.075	4	
$CO_2(g) + H_2O(l) \Leftrightarrow CO_3^{2-} + 2\ H^+$	-18.155 ± 0.035	4	
$CH_4(g) + 3\ H_2O(l) \Leftrightarrow CO_3^{2-} + 10\ H^+ + 8\ e^-$	-43.931	1	
$HCN(g) \Leftrightarrow CN^- + H^+$ $HCN(g) + 6\ H_2O(l) \Leftrightarrow CO_3^{2-} + NO_3^- + 13\ H^+ + 10\ e^-$	**-8.308 ± 0.054** -116.437 ± 0.451	3	
$N(g) + 3\ H_2O(l) \Leftrightarrow NO_3^- + 6\ H^+ +5\ e^-$	-25.418 ± 0.102	4	
$N_2(g) + 6\ H_2O(l) \Leftrightarrow 2\ NO_3^- + 12\ H^+ + 10\ e^-$	-210.449 ± 0.105	4	
$NH_3(g) + 3\ H_2O(l) \Leftrightarrow NO_3^- + 9\ H^+ + 8\ e^-$	-108.099 ± 0.096	4	
$O(g) + 2\ H^+ + 2\ e^- \Leftrightarrow H_2O(l)$	82.144 ± 0.019	4	
$O_2(g) + 4\ H^+ + 4\ e^- \Leftrightarrow 2\ H_2O(l)$	83.090 ± 0.010	4	
$F(g) + e^- \Leftrightarrow F^-$	60.231 ± 0.132	4	
$F_2(g) + 2\ e^- \Leftrightarrow 2\ F^-$	98.641 ± 0.171	4	
$HF(g) \Leftrightarrow F^- + H^+$	1.073 ± 0.172	4	
$Na(cr) \Leftrightarrow Na^+ + e^-$	45.892 ± 0.017	4	
$Na(g) \Leftrightarrow Na^+ + e^-$	59.375 ± 0.124	4	
$NaCl(cr) \Leftrightarrow Na^+ + Cl^-$	1.568 ± 0.037	3	
$NaF(cr) \Leftrightarrow Na^+ + F^-$	-0.499 ± 0.174	3	
$Na_2Al_{14}Si_{22}O_{60}(OH)_{12}$(montmorillonite,Na) + $16\ H_2O(l) + 44\ H^+$ $\Leftrightarrow 2\ Na^+ + 14\ Al^{3+} + 22\ H_4SiO_4(aq)$	58.540	5	
$NaAl_3Si_3O_{10}(OH)_2$(plagioclase) + $10\ H^+ \Leftrightarrow Na^+ + 3\ Al^{3+} + 3\ H_4SiO_4(aq)$	18.870	5	
$NaAlSi_3O_8$(albite) + $4\ H_2O(l) + 4\ H^+ \Leftrightarrow Na^+ + Al^{3+} + 3\ H_4SiO_4(aq)$	3.540	5	
$Mg(cr) \Leftrightarrow Mg^{2+} + 2\ e^-$	79.778 ± 0.234	3	
$Mg(g) \Leftrightarrow Mg^{2+} + 2\ e^-$	99.491 ± 0.273	3	
$Mg_{26}Fe_8Al_{20}Si_{24}O_{80}(OH)_{64}$(clinochlore) + $128\ H^+$ $\Leftrightarrow 26\ Mg^{2+} + 20\ Al^{3+} + 24\ H_4SiO_4(aq) + 8\ Fe^{2+} + 48\ H_2O(l)$	447.610	5	
$Mg_2Si_2O_6(s) + 2\ H_2O(l) + 4\ H^+ \Leftrightarrow 2\ Mg^{2+} +2\ H_4SiO_4(aq)$	23.260	5	
$Mg_3Si_4O_{10}(OH)_2$(talc) + $4\ H_2O(l) + 6\ H^+ \Leftrightarrow 3\ Mg^{2+} +4\ H_4SiO_4(aq)$	20.600 ± 2.000	5, 43	
$Mg_{40}Al_{16}Si_{24}O_{80}(OH)_{64}$(clinochlore,Mg-rich) + $128\ H^+$ $\Leftrightarrow 40\ Mg^{2+} + 16\ Al^{3+} + 24\ H_4SiO_4(aq) + 48\ H_2O(l)$	546.830	5	
$Mg_4Si_6O_9(OH)_{14}$(sepiolite) + $H_2O(l) + 8\ H^+ \Leftrightarrow 4\ Mg^{2+} + 6\ H_4SiO_4(aq)$	32.830	5	
$Mg_8Fe_{26}Al_{25}Si_{20}O_{80}(OH)_{64}$(clinochlore,Fe-rich) + $144\ H^+ + e^-$ $\Leftrightarrow 8\ Mg^{2+} + 25\ Al^{3+} + 20\ H_4SiO_4(aq) + 26\ Fe^{2+} + 64\ H_2O(l)$	178.370	5	
$MgAl_{14}Si_{22}O_{60}(OH)_{12}$(montmorillonite,Mg) +$16\ H_2O(l) + 44\ H^+$ $\Leftrightarrow Mg^{2+} + 14\ Al^{3+} + 22\ H_4SiO_4(aq)$	57.040	5	
$MgFe_2O_4$(magnesio-ferrite) + $8\ H^+ + 2\ e^- \Leftrightarrow Mg^{2+} + 2\ Fe^{2+} + 4\ H_2O(l)$	42.820	5	
MgO(periclase) + $2\ H^+ \Leftrightarrow Mg^{2+} + H_2O(l)$	21.580	5	
$Al(OH)_3$(gibbsite) + $3\ H^+ \Leftrightarrow Al^{3+} + 3\ H_2O(l)$	8.770	5	

Reaction	$\log_{10} K°$	ref.	T.v.*
$Al_2SiO_4(OH)_2$(topaz,O) + 6 H^+ ⇔ 2 Al^{3+} + H_4SiO_4(aq) + 2 H_2O(l)	12.810	5	
$Al_2Si_2O_5(OH)_4$(kaolinite) 6 H^+ ⇔ + 2 H_4SiO_4(aq) + 2 Al^{3+} + H_2O(l)	9.080	5	
Al(cr) ⇔ Al^{3+} + 3 e^-	86.108 ± 0.585	3	
Al(g) ⇔ Al^{3+} + 3 e^-	136.804 ± 0.913	3	
Al_2O_3(corundum) + 6 H^+ ⇔ 2 Al^{3+} + 3 H_2O(l)	19.652 ± 1.192	3	
AlF_3(cr) ⇔ Al^{3+} + 3 F^-	-16.647 ± 0.726	3	
SiO_2(chalcedony) + 2 H_2O(l) ⇔ H_4SiO_4(aq)	-3.490	5	
SiO_2(quartz) + 2 H_2O(l) ⇔ H_4SiO_4(aq)	-3.780	5	
SiO_2(silica-gel) + 2 H_2O(l) ⇔ H_4SiO_4(aq)	-2.700	5	
$SiO_2 \cdot H_2O$(silica-glass) + H_2O(l) ⇔ H_4SiO_4(aq)	-3.020	5	
SiO_2(am) + 2 H_2O(l) ⇔ H_4SiO_4(aq)	-2.710	5	
Si(cr) + 4 H_2O(l) ⇔ H_4SiO_4(aq) + 4 H^+ + 4 e^-	62.924 ± 0.205	4	
Si(g) + 4 H_2O(l) ⇔ H_4SiO_4(aq) + 4 H^+ + 4 e^-	133.969 ± 1.416	4	
SiO_2(α-quartz) + 2 H_2O(l) ⇔ H_4SiO_4(aq)	-4.000 ± 0.268	4	
SiF_4(g) + 4 H_2O(l) ⇔ H_4SiO_4(aq) + 4 F^- + 4 H^+	-15.330 ± 0.545	4	
P(am) + 4 H_2O(l) ⇔ PO_4^{3-} + 8 H^+ + 5 e^-	13.478 ± 0.276	4	
P(cr) + 4 H_2O(l) ⇔ PO_4^{3-} + 8 H^+ + 5 e^-	13.478 ± 0.276	4	
P(g) + 4 H_2O(l) ⇔ PO_4^{3-} + 8 H^+ + 5 e^-	62.548 ± 0.328	4	
P_2(g) + 8 H_2O(l) ⇔ 2 PO_4^{3-} + 16 H^+ + 10 e^-	45.082 ± 0.526	4	
P_4(g) + 16 H_2O(l) ⇔ 4 PO_4^{3-} + 32 H^+ + 20 e^-	58.189 ± 0.558	4	
S(cr) + 4 H_2O(l) ⇔ SO_4^{2-} + 8 H^+ + 6 e^-	-35.836 ± 0.075	4	
S(g) + 4 H_2O(l) ⇔ SO_4^{2-} + 8 H^+ + 6 e^-	5.629 ± 0.079	4	
S_2(g) + 8 H_2O(l) ⇔ 2 SO_4^{2-} + 16 H^+ + 12 e^-	-57.713 ± 0.118	4	
SO_2(g) + 2 H_2O(l) ⇔ SO_4^{2-} + 4 H^+ + 2 e^-	-5.321 ± 0.082	4	
H_2S(g) + 4 H_2O(l) ⇔ SO_4^{2-} + 10 H^+ + 8 e^-	-41.695 ± 0.115	4	
Cl(g) + e^- ⇔ Cl^-	41.437 ± 0.021	4	
Cl_2(g) + 2 e^- ⇔ 2 Cl^-	45.976 ± 0.029	4	
HCl(g) ⇔ Cl^- + H^+	6.293 ± 0.027	4	
K(cr) ⇔ K^+ + e^-	49.493 ± 0.020	4	
K(g) ⇔ K^+ + e^-	60.089 ± 0.142	4	
$KAl_2(AlSi_3O_{10})(OH)_2$(muscovite) + H^+ ⇔ 3 Al^{3+} + 3 H_4SiO_4(aq) + K^+	14.600	5	
$K_2Al_{10}Si_{14}O_{40}(OH)_8$(illite,idealized2) + 8 H_2O(l) + 32 H^+ ⇔ 10 Al^{3+} + 14 H_4SiO_4(aq) + 2 K^+	28.540	5	
$K_2Al_{14}Si_{22}O_{60}(OH)_{12}$(montmorillonite,K) + 16 H_2O(l) + 44 H^+ ⇔ 14 Al^{3+} + 22 H_4SiO_4(aq) + 2 K^+	57.510	5	
$KAl_3(SO_4)_2(OH)_6$(alunite) + 6 H^+ ⇔ 3 Al^{3+} + 2 SO_4^{2-} + K^+ + 6 H_2O(l)	1.610	5	
$KAlSi_3O_8$(microcline) + 4 H_2O(l) + 4 H^+ ⇔ Al^{3+} +3 H_4SiO_4(aq) + K^+	1.780	5	
$KAlSi_3O_8$(orthoclase) + 4 H_2O(l) + 4 H^+ ⇔ Al^{3+} +3 H_4SiO_4(aq) + K^+	0.860	5	
$KFe_3AlSi_3O_{10}(OH)_2$(annite) + 10 H^+ ⇔ Al^{3+} + 3 H_4SiO_4(aq) + K^+ + 3 Fe^{2+}	22.330	5	
$K_3MgAl_9Si_{14}O_{40}(OH)_8$(illite,idealized) + 8 H_2O(l) + 32 H^+ ⇔ Mg^{2+} + 9 Al^{3+} + 14 H_4SiO_4(aq) + 3 K^+	67.150	5	
$KMg_3AlSi_3O_{10}(OH)_2$(phlogopite)+10 H^+ ⇔ 3 Mg^{2+}+Al^{3+}+3 H_4SiO_4(aq)+K^+	36.330	5	
$KAlSi_3O_8$(feldspar,K) + 4 H_2O(l) + 4 H^+ ⇔ 3 H_4SiO_4(aq) + K^+ + Al^{3+}	0.0832	5	
Ca(cr) ⇔ Ca^{2+} + 2 e^-	96.847 ± 0.184	4	
Ca(g) ⇔ Ca^{2+} + 2 e^-	122.078 ± 0.232	4	
CaO(cr) + 2 H^+ ⇔ Ca^{2+} + H_2O(l)	32.699 ± 0.244	4	
CaCl(g) ⇔ Ca^{2+} + Cl^- + e^-	97.097 ± 0.895	3	
CaF(g) ⇔ Ca^{2+} + F^- + e^-	93.239 ± 0.921	3	
$CaCO_3$(calcite) ⇔ Ca^{2+} + CO_3^{2-}	-8.460 ± 0.010	44	
$CaCO_3$(aragonite) ⇔ Ca^{2+} + CO_3^{2-}	-8.340 ± 0.020	5, 43	
$CaMg(CO_3)_2$(dolomite) ⇔ Ca^{2+} + Mg^{2+} + 2 CO_3^{2-}	-17.090	5	
$CaSO_4 \cdot 2H_2O$(gypsum) ⇔ Ca^{2+} + SO_4^{2-} + 2 H_2O(l)	-4.600 ± 0.020	5, 43	
$CaSO_4$(anhydrite) ⇔ Ca^{2+} + SO_4^{2-}	-4.380	5	
$Ca_5(PO_4)_3(OH)$(hydroxyapatite) + H^+ ⇔ H_2O(l) + 3 PO_4^{3-} + 5 Ca^{2+}	-40.470	5	
CaF_2(fluorite) ⇔ Ca^{2+} + 2 F^-	-10.960	5	
$Ca_2Al_3(SiO_4)_3OH$(clinozoisite)+13H^+ ⇔ 3Al^{3+}+3H_4SiO_4(aq)+2Ca^{2+}+H_2O(l)	43.610	5	
$Ca_2Al_2Fe(SiO_4)(Si_2O_7)OOH$(epidote) + 13 H^+ + e^-	45.430	5	

Reaction	$\log_{10} K°$	ref.	T.v.*
$\Leftrightarrow$ 2 Al^{3+} +3 H_4SiO_4(aq) +2 Ca^{2+} + Fe^{2+} + H_2O(l)			
$Ca_2Mg_5Si_8O_{22}(OH)_2$(tremolite)+8H_2O(l)+14$H^+$$\Leftrightarrow$5$Mg^{2+}$+8$H_4SiO_4$(aq)+2$Ca^{2+}$	57.700	5	
$Ca_3Fe_2(SiO_4)_3$(andradite) + 12 H^+ + 2 e^- $\Leftrightarrow$ 3 H_4SiO_4(aq) +3 Ca^{2+} +2 Fe^{2+}	55.100	5	
$CaAl_{14}Si_{22}O_{60}(OH)_{12}$ (montmorillonite,Ca) + 16 H_2O(l) + 44 H^+ $\Leftrightarrow$ 14 Al^{3+} + 22 H_4SiO_4(aq) + Ca^{2+}	41.880	5	
$CaAl_2Si_2O_8$(anorthite,hexagonal) + 8 H^+ $\Leftrightarrow$ 2 Al^{3+} + 2 H_4SiO_4(aq) + Ca^{2+}	26.700	5	
$CaAl_2Si_2O_8$(anorthite,triclinic) + 8 H^+ $\Leftrightarrow$ 2 Al^{3+} + 2 H_4SiO_4(aq) + Ca^{2+}	26.370	5	
CaO(s) + 2 H^+ $\Leftrightarrow$ Ca^{2+} + H_2O(l)	32.700	5	
MnO_2(birnessite-type) + 2 e^- + 4 H^+ $\Leftrightarrow$ Mn^{2+} + 2 H_2O(l)	43.597	5	
MnOOH(manganite) + e^- + 3 H^+ $\Leftrightarrow$ Mn^{2+} + 2 H_2O(l)	25.267	5	
$MnCO_3$(rhodochrosite) $\Leftrightarrow$ CO_3^{2-} + Mn^{2+}	-10.540	5	
MnO_2(pyrolusite) + 4 H^+ + 2 e^- $\Leftrightarrow$ Mn^{2+} +2 H_2O(l)	41.550	5	
MnS(alabandite) + 4 H_2O(l) $\Leftrightarrow$ SO_4^{2-} + Mn^{2+} + 8 H^+ + 8 e^-	-34.110	5	
$Fe(OH)_3$(s) + 3 H^+ $\Leftrightarrow$ Fe^{3+} + 3 H_2O(l)	4.890	5	
$FeCO_3$(siderite) $\Leftrightarrow$ Fe^{2+} + CO_3^{2-}	-10.570	5	
Fe_2O_3(hematite) + 6 H^+ + 2 e^- $\Leftrightarrow$ 2 Fe^{2+} + 3 H_2O(l)	22.400	5	
FeS(mackinawite) + 4 H_2O(l) $\Leftrightarrow$ Fe^{2+} + SO_4^{2-} + H^+ + 8 e^-	-38.323	5	
FeS(s) + 4 H_2O(l) $\Leftrightarrow$ Fe^{2+} +SO_4^{2-}+8 H^+ +8 e^-	-37.603	5	
$Fe_3(PO_4)_2\cdot8H_2O$ (vivianite) $\Leftrightarrow$ 3 Fe^{2+} + 2 PO_4^{3-} + 8 H_2O(l)	-36.000	5, 43	
$Fe_2Si_2O_6$(s) + 2 H_2O(l) + 4 H^+ $\Leftrightarrow$ 2 H_4SiO_4(aq) + 2 Fe^{2+}	10.600	5	
$Fe_3Al_2(SiO_4)_3$(almandine) + 12 H^+ $\Leftrightarrow$ 2 Al^{3+} + 3 H_4SiO_4(aq) +3 Fe^{2+}	33.410	5	
Fe_3O_4(magnetite) + 8 H^+ + 2 e^- $\Leftrightarrow$ 3 Fe^{2+} + 4 H_2O(l)	30.650	5	
Fe_7S_8(pyrrhotite) + 32 H_2O(l) $\Leftrightarrow$ 8 SO_4^{-2} + 7 Fe^{2+} + 64 H^+ + 62 e^-	-321.280	5	
$FeCl_2$(lawrencite) $\Leftrightarrow$ 2 Cl^- + Fe^{2+}	6.820	5	
$FeCl_3$(molysite) + e^- $\Leftrightarrow$ 3 Cl^- + Fe^{2+}	24.560	5	
FeOOH(goethite) + 3 H^+ + e^- $\Leftrightarrow$ Fe^{2+} + 2 H_2O(l)	11.290	5	
FeS_2(pyrite) + 8 H_2O(l) $\Leftrightarrow$ 2 SO_4^{2-} + Fe^{2+} + 16 H^+ + 14 e^-	-85.950	5	
$FeSiO_3$(ferrosilite) + H_2O(l) + 2 H^+ $\Leftrightarrow$ Fe^{2+} + H_4SiO_4(aq)	7.420	5	
$Fe_3Si_2O_5(OH)_4$(greenalite) + 6 H^+ $\Leftrightarrow$ 3 Fe^{2+} + 2 H_4SiO_4(aq) + H_2O(l)	22.590	5	
Fe_2SiO_4(fayalite) + 4 H^+ $\Leftrightarrow$ 2 Fe^{2+} + H_4SiO_4(aq)	19.050	5	
Co(cr) $\Leftrightarrow$ Co^{2+} + 2 e^-	9.530 ± 0.175	45	
CoO(cr) + 2 H^+ $\Leftrightarrow$ Co^{2+} + H_2O(l)	12.399 ± 0.326	45	*
β-$Co(OH)_2$ +2 H^+ $\Leftrightarrow$ Co^{2+} + 2 H_2O(l)	12.430 ± 0.170	45	
$CoCl_2\cdot6H_2O$(cr) $\Leftrightarrow$ 2 Co^{2+} + 2 Cl^- + 6 H_2O(l)	3.037 ± 0.018	45	*
β-$Co(IO_3)_2$ $\Leftrightarrow$ Co^{2+} + 2 IO_3^-	**-4.395 ± 0.088**	**45**	*
$Co(IO_3)_2\cdot2H_2O$(cr) $\Leftrightarrow$ Co^{2+} + 2 IO_3^- + 8 H_2O(l)	**-5.101 ± 0.177**	**45**	*
α-CoS + H^+ $\Leftrightarrow$ Co^{2+} + HS^-	-7.440 ± 0.120	45	
β-CoS + H^+ $\Leftrightarrow$ Co^{2+} + HS^-	-11.100 ± 1.700	45	
α-$CoSO_4\cdot6H_2O$ $\Leftrightarrow$ Co^{2+} + 6 H_2O(l) + SO_4^{2-}	-2.229 ± 0.279	45	*
β-$CoSO_4\cdot6H_2O$ $\Leftrightarrow$ Co^{2+} + 6 H_2O(l) + SO_4^{2-}	-2.124 ± 0.467	45	*
$CoSO_4\cdot7H_2O$(cr) $\Leftrightarrow$ Co^{2+} + 7 H_2O(l) + SO_4^{2-}	-2.245 ± 0.058	45	
$Co_3(AsO_3)_2$(cr,hyd) + 2 H_2O(l) + 4 e^- $\Leftrightarrow$ 3 Co^{2+} + 4 H^+ + 2 AsO_4^{3-}	-51.640 ± 2.012	45	*
$Co_3(AsO_4)_2\cdot8H_2O$(cr) $\Leftrightarrow$ 3 Co^{2+} + 2 AsO_4^{3-} + 8 H_2O(l)	-27.929 ± 0.883	45	*
$CoCO_3$(cr) $\Leftrightarrow$ Co^{2+} + CO_3^{2-}	-11.027 ± 0.098	45	*
$CoCO_3\cdot5.5H_2O$(cr) $\Leftrightarrow$ Co^{2+} + CO_3^{2-} + 5.5 H_2O(l)	-7.577 ± 0.049	45	*
Ni(cr) $\Leftrightarrow$ Ni^{2+} + 2 e^-	8.019 ± 0.135	46	
NiO(cr) + 2 H^+ $\Leftrightarrow$ Ni^{2+} + H_2O(l)	12.483 ± 0.154	45	*
β-$Ni(OH)_2$ + 2 H^+ $\Leftrightarrow$ Ni^{2+} + 2 H_2O(l)	11.029 ± 0.280	45	*
$NiCl_2\cdot6H_2O$(cr) $\Leftrightarrow$ 2 Ni^{2+} + 2 Cl^- + 6 H_2O(l)	3.045 ± 0.014	46	
β-$Ni(IO_3)_2$ $\Leftrightarrow$ Ni^{2+} + 2 IO_3^-	**-4.430 ± 0.020**	**46**	
$Ni(IO_3)_2\cdot2H_2O$(cr) $\Leftrightarrow$ Ni^{2+} + 2 IO_3^- + 8 H_2O(l)	**5.140 ± 0.100**	**46**	
α-NiS + H^+ $\Leftrightarrow$ Ni^{2+} + HS^-	-9.508 ± 0.464	45	*
β-NiS + H^+ $\Leftrightarrow$ Ni^{2+} + HS^-	-10.128 ± 0.464	45	*
$NiSO_4\cdot7H_2O$(cr) $\Leftrightarrow$ Ni^{2+} + 7 H_2O(l) + SO_4^{2-}	-2.267 ± 0.019	46	
$Ni_3(AsO_3)_2$(cr,hyd) + 2 H_2O(l) + 4 e^- $\Leftrightarrow$ 3 Ni^{2+} + 4 H^+ + 2 $HAsO_4^{3-}$	-51.484 ± 2.106	46	
$Ni_3(AsO_4)_2\cdot8H_2O$(cr) $\Leftrightarrow$ 3 Ni^{2+} + 2 AsO_4^{3-} + 8 H_2O(l)	-28.100 ± 0.500	46	
$NiCO_3$(cr) $\Leftrightarrow$ Ni^{2+} + CO_3^{2-}	-10.995 ± 0.183	46	

Reaction	$\log_{10} K°$	ref.	T.v.*
$NiCO_3 \cdot 5.5H_2O(cr) \Leftrightarrow Ni^{2+} + CO_3^{2-} + 5.5\ H_2O(l)$	-7.525 ± 0.106	46	
$Ni(g) \Leftrightarrow Ni^{2+} + 2\ e^-$	75.413 ± 1.478	3	
$NiF_2(cr) \Leftrightarrow Ni^{2+} + 2\ F^-$	-0.181 ± 1.429	3	
$NiCl_2(cr) \Leftrightarrow Ni^{2+} + 2\ Cl^-$	8.666 ± 0.144	3	
$NiCl_2 \cdot 2H_2O(cr) \Leftrightarrow Ni^{2+} + 2\ Cl^- + 2\ H_2O(l)$	4.924 ± 0.262	3	
$NiCl_2 \cdot 4H_2O(cr) \Leftrightarrow Ni^{2+} + 2\ Cl^- + 4\ H_2O(l)$	3.823 ± 0.232	3	
$NiBr_2(cr) \Leftrightarrow Ni^{2+} + 2\ Br^-$	10.172 ± 0.449	3	
$NiI_2(cr) \Leftrightarrow Ni^{2+} + 2\ I^-$	9.611 ± 0.211	3	
$NiS_2(cr) + 2\ H^+ + 2\ e^- \Leftrightarrow Ni^{2+} + 2\ HS^-$	-17.965 ± 1.499	3	
$Ni_3S_2(cr) + 2\ H^+ \Leftrightarrow 3\ Ni^{2+} + 2\ HS^- + 2\ e^-$	-17.228 ± 0.891	3	
$Ni_9S_8(cr) + 8\ H^+ \Leftrightarrow 9\ Ni^{2+} + 8\ HS^- + 2\ e^-$	-75.821 ± 3.591	3	
$NiSO_4(cr) \Leftrightarrow Ni^{2+} + SO_4^{2-}$	4.746 ± 0.315	3	
$\alpha\text{-}NiSO_4 \cdot 6H_2O \Leftrightarrow Ni^{2+} + SO_4^{2-} + 6\ H_2O(l)$	-2.251 ± 0.245	3	
$\beta\text{-}NiSO_4 \cdot 6H_2O \Leftrightarrow Ni^{2+} + SO_4^{2-} + 6\ H_2O(l)$	-2.155 ± 0.356	3	
$NiAs(cr) + 4\ H_2O(l) \Leftrightarrow Ni^{2+} + AsO_4^{3-} + 8\ H^+ + 7\ e^-$	-56.238 ± 1.079	3	
$Ni_5As_2(cr) + 8\ H_2O(l) \Leftrightarrow 5\ Ni^{2+} + 2\ AsO_4^{3-} + 6\ H^+ + 20\ e^-$	-106.722 ± 4.144	3	
$Ni_{11}As_8(cr) + 32\ H_2O(l) \Leftrightarrow 11\ Ni^{2+} + 8\ AsO_4^{3-} + 64\ H^+ + 62\ e^-$	-457.925 ± 9.017	3	
$Ni_2SiO_4(oliv) + 4\ H^+ \Leftrightarrow 2\ Ni^{2+} + H_4SiO_4(aq)$	19.418 ± 0.939	3	
$Cu(cr) \Leftrightarrow Cu^{2+} + 2\ e^-$	-11.394 ± 0.273	3	
$Cu(g) \Leftrightarrow Cu^{2+} + 2\ e^-$	40.755 ± 0.344	3	
$CuSO_4(cr) \Leftrightarrow Cu^{2+} + SO_4^{2-}$	2.940 ± 0.353	3	
$Zn(cr) \Leftrightarrow Zn^{2+} + 2\ e^-$	25.789 ± 0.044	3	
$Zn(g) \Leftrightarrow Zn^{2+} + 2\ e^-$	42.399 ± 0.083	3	
$ZnO(cr) + 2\ H^+ \Leftrightarrow Zn^{2+} + H_2O(l)$	11.188 ± 0.069	3	
$As(cr) + 4\ H_2O(l) \Leftrightarrow AsO_4^{3-} + 8\ H^+ + 5\ e^-$	-52.592 ± 0.703	4	
$As_2O_5(cr) + 3\ H_2O(l) \Leftrightarrow 2\ AsO_4^{3--} + 6\ H^+$	-34.539 ± 1.986	4	
$As_4O_6(cubic) + 10\ H_2O(l) \Leftrightarrow 4\ AsO_4^{3-} + 20\ H^+ + 8\ e^-$	-162.999 ± 3.973	4	
$As_4O_6(monoclinic) + 10\ H_2O(l) \Leftrightarrow 4\ AsO_4^{3-} + 20\ H^+ + 8\ e^-$	-163.273 ± 3.974	4	
$As_4O_6(g) + 10\ H_2O(l) \Leftrightarrow 4\ AsO_4^{3-} + 20\ H^+ + 8\ e^-$	-152.535 ± 3.983	3	
$Se(cr,trigonal) + H^+ + 2\ e^- \Leftrightarrow HSe^-$	-7.616 ± 0.355	42	
$Se(mono) + H^+ + 2\ e^- \Leftrightarrow HSe^-$	-7.391 ± 0.356	3	
$Se(am) + H^+ + 2\ e^- \Leftrightarrow HSe^-$	-6.570 ± 0.150	59	
$PbSeO_3(cr) \Leftrightarrow Pb^{2+} + SeO_3^{2-}$	-12.500 ± 1.000	42	
$PbSeO_4(cr) \Leftrightarrow Pb^{2+} + SeO_4^{2-}$	-6.900 ± 0.250	42	
$Tl_2SeO_4(cr) \Leftrightarrow 2\ Tl^+ + SeO_4^{2-}$	-3.900 ± 0.150	42	
$ZnSeO_4 \cdot 6H_2O(cr) \Leftrightarrow Zn^{2+} + 6H_2O(l) + SeO_4^{2-}$	-1.538 ± 0.068	42	
$Cd(SeCN)_2(cr) \Leftrightarrow Cd^{2+} + 2\ SCN^-$ $Cd(SeCN)_2(cr)+20\ H_2O(l) \Leftrightarrow Cd^{2+}+2\ SeO_4^{2-}+40\ H^+ +32\ e^- +2\ CO_3^{2-}+2\ NO_3^-$	**-5.700 ± 0.500** -411.153 ± 1.528	**42**	
$Ag_2SeO_3(cr) \Leftrightarrow 2\ Ag^+ + SeO_3^{2-}$	-15.800 ± 0.300	42	
$Ag_2SeO_4(cr) \Leftrightarrow 2\ Ag^+ + SeO_4^{2-}$	-7.860 ± 0.500	42	
$AgSeCN(cr) \Leftrightarrow SCN^- + Ag^+$ $AgSeCN(cr) + 10\ H_2O(l) \Leftrightarrow SeO_4^{2-} + 20\ H^+ + 16\ e^- + CO_3^{2-} + NO_3^- + Ag^+$	**-13.998 ± 0.508** -216.724 ± 0.883	**42**	
$NiSeO_3 \cdot 2H_2O(cr) \Leftrightarrow Ni^{2+} + 2\ H_2O(l) + SeO_3^{2-}$	-5.800 ± 1.000	42	
$NiSeO_4 \cdot 6H_2O(cr) \Leftrightarrow Ni^{2+} + 6\ H_2O(l) + SeO_4^{2-}$	-1.381 ± 0.045	42	
$CuSeO_4 \cdot 5H_2O(cr) \Leftrightarrow Cu^{2+} + 5\ H_2O(l) + SeO_4^{2-}$	-2.440 ± 0.200	42	
$MgSeO_3 \cdot 6H_2O(cr) \Leftrightarrow Mg^{2+} + 6\ H_2O(l) + SeO_3^{2-}$	-5.820 ± 0.250	42	
$MgSeO_4 \cdot 6H_2O(cr) \Leftrightarrow Mg^{2+} + 6\ H_2O(l) + SeO_4^{2-}$	-1.133 ± 0.044	42	
$CaSeO_3 \cdot H_2O(cr) \Leftrightarrow Ca^{2+} + H_2O(l) + SeO_3^{2-}$	-6.400 ± 0.250	42	
$CaSeO_4 \cdot 2H_2O(cr) \Leftrightarrow Ca^{2+} + 2\ H_2O(l) + SeO_4^{2-}$	-2.680 ± 0.250	42	
$SrSeO_3(cr) \Leftrightarrow Sr^{2+} + SeO_3^{2-}$	-6.300 ± 0.500	42	
$BaSeO_3(cr) \Leftrightarrow Ba^{2+} + SeO_3^{2-}$	-6.500 ± 0.250	42	
$BaSeO_4(cr) \Leftrightarrow Ba^{2+} + SeO_4^{2-}$	-7.560 ± 0.100	42	
$NH_4HSe(cr) \Leftrightarrow HSe^- + NH_4^+$	**2.061 ± 1.002**	**42**	
$(NH_4)_2SeO_4(cr) \Leftrightarrow 2\ NH_4^+ + SeO_4^{2-}$	0.911 ± 0.065	42	
$Li_2SeO_4 \cdot H_2O(cr) \Leftrightarrow 2\ Li^+ + H_2O(l) + SeO_4^{2-}$	1.762 ± 0.065	42	
$Na_2SeO_4 \cdot 10H_2O(cr) \Leftrightarrow 2\ Na^+ + 10H_2O(l) + SeO_4^{2-}$	-0.681 ± 0.087	42	
$K_2SeO_4(cr) \Leftrightarrow 2\ K^+ + SeO_4^{2-}$	0.904 ± 0.065	42	

Reaction	$\log_{10} K°$	ref.	T.v.*
$Cs_2SeO_4(cr) \Leftrightarrow 2\ Cs^+ + SeO_4^{2-}$	0.636 ± 0.065	42	
$FeSe_2(cr) + 2\ H^+ + 2\ e^- \Leftrightarrow Fe^{2+} + 2\ HSe^-$	-17.220 ± 2.754	60	*
$\beta\text{-}Fe_{1.04}Se + H^+ \Leftrightarrow 1.04\ Fe^{2+} + HSe^- + 0.08\ e^-$	-3.503 ± 0.870	60	*
$\gamma\text{-}Fe_3Se_4 + 4\ H^+ + 2\ e^- \Leftrightarrow 3\ Fe^{2+} + 4\ HSe^-$	-25.908 ± 5.547	60	*
$\alpha\text{-}Fe_7Se_8 + 8\ H^+ + 2\ e^- \Leftrightarrow 7\ Fe^{2+} + 8\ HSe^-$	-36.274 ± 5.175	60	*
$HgSeO_3(cr) \Leftrightarrow Hg^{2+} + SeO_3^{2-}$	-16.200 ± 1.000	42	
$Hg_2SeO_3(cr) \Leftrightarrow Hg_2^{2+} + SeO_3^{2-}$	-15.200 ± 1.000	42	
$SeO_2(cr) + H_2O(l) \Leftrightarrow SeO_3^{2-} + 2\ H^+$	-8.154 ± 0.326	3	
$SeO_3(cr) + H_2O(l) \Leftrightarrow SeO_4^{2-} + 2\ H^+$	20.356 ± 0.463	3	
$SeCl_4(cr) + 3\ H_2O(l) \Leftrightarrow SeO_3^{2-} + 4\ Cl^- + 6\ H^+$	15.756 ± 0.632	3	
$PbSe(cr) + H^+ \Leftrightarrow HSe^- + Pb^{2+}$	-20.527 ± 1.396	3	
$\alpha\text{-}ZnSe + H^+ \Leftrightarrow HSe^- + Zn^{2+}$	-12.045 ± 0.789	3	
$\alpha\text{-}CdSe + H^+ \Leftrightarrow HSe^- + Cd^{2+}$	-18.682 ± 0.506	3	
$CdSeO_3(cr) \Leftrightarrow SeO_3^{2-} + Cd^{2+}$	-9.339 ± 1.181	3	
$\alpha\text{-}HgSe + H^+ \Leftrightarrow HSe^- + Hg^{2+}$	-45.434 ± 0.787	3	
$\alpha\text{-}CuSe + H^+ \Leftrightarrow HSe^- + Cu^{2+}$	-25.463 ± 0.458	3	
$\beta\text{-}CuSe + H^+ \Leftrightarrow HSe^- + Cu^{2+}$	-25.126 ± 0.458	3	
$\alpha\text{-}Ag_2Se + H^+ \Leftrightarrow HSe^- + 2\ Ag^+$	-42.845 ± 0.425	3	
$Ni_{0.88}Se(cr) + H^+ + 0.24\ e^- \Leftrightarrow HSe^- + 0.88\ Ni^{2+}$	-12.757 ± 0.470	3	
$NiSe_2(cr) + 2\ H^+ + 2\ e^- \Leftrightarrow 2\ HSe^- + Ni^{2+}$	-26.896 ± 1.426	3	
$Co_{0.84}Se(cr) + H^+ + 0.32\ e^- \Leftrightarrow HSe^- + 0.84\ Co^{2+}$	-9.473 ± 1.202	3	
$USe(cr) + H^+ \Leftrightarrow HSe^- + U^{4+} + 2\ e^-$	37.339 ± 3.189	3	
$Na_2SeO_3(cr) \Leftrightarrow SeO_3^{2-} + 2\ Na^+$	3.087 ± 0.353	3	
$Rb_2SeO_4(cr) \Leftrightarrow SeO_4^{2-} + 2\ Rb^+$	0.421 ± 0.367	3	
$Ga_2(SeO_3)_3 \cdot 6H_2O(cr) \Leftrightarrow 3\ SeO_3^{2-} + 2\ Ga^{3+} + 6\ H_2O(l)$	-37.000 ± 2.000	3	
$In_2(SeO_3)_3 \cdot 6H_2O(cr) \Leftrightarrow 3\ SeO_3^{2-} + 2\ In^{3+} + 6\ H_2O(l)$	-39.000 ± 2.000	3	
$CoSeO_3 \cdot 2H_2O(cr) \Leftrightarrow SeO_3^{2-} + Co^{2+} + 2\ H_2O(l)$	-7.900 ± 0.400	3	
$CoSeO_4 \cdot 6H_2O(cr) \Leftrightarrow SeO_4^{2-} + Co^{2+} + 6\ H_2O(l)$	-1.759 ± 0.043	3	
$Fe_2(SeO_3)_3 \cdot 6H_2O(cr) \Leftrightarrow 3\ SeO_3^{2-} + 2\ Fe^{3+} + 6\ H_2O(l)$	-41.580 ± 0.110	3	
$MnSeO_3 \cdot 2H_2O(cr) \Leftrightarrow SeO_3^{2-} + Mn^{2+} + 2\ H_2O(l)$	-7.600 ± 1.000	3	
$Se(g) + H^+ + 2\ e^- \Leftrightarrow HSe^-$	26.709 ± 0.444	3	
$Se_2(g) + 2\ H^+ + 4\ e^- \Leftrightarrow 2\ HSe^-$	0.964 ± 0.884	3	
$Se_3(g) + 3\ H^+ + 6\ e^- \Leftrightarrow 3\ HSe^-$	-1.203 ± 2.116	3	
$Se_4(g) + 4\ H^+ + 8\ e^- \Leftrightarrow 4\ HSe^-$	-10.903 ± 2.744	3	
$Se_5(g) + 5\ H^+ + 10\ e^- \Leftrightarrow 5\ HSe^-$	-22.593 ± 1.998	3	
$Se_6(g) + 6\ H^+ + 12\ e^- \Leftrightarrow 6\ HSe^-$	-31.042 ± 2.292	3	
$Se_7(g) + 7\ H^+ + 14\ e^- \Leftrightarrow 7\ HSe^-$	-37.045 ± 2.626	3	
$Se_8(g) + 8\ H^+ + 16\ e^- \Leftrightarrow 8\ HSe^-$	-43.353 ± 2.905	3	
$SeO(g) + 2\ H_2O(l) \Leftrightarrow SeO_3^{2-} + 4\ H^+ + 2\ e^-$	-14.196 ± 1.132	3	
$SeO_2(g) + H_2O(l) \Leftrightarrow SeO_3^{2-} + 2\ H^+$	1.767 ± 0.550	3	
$H_2Se(g) \Leftrightarrow HSe^- + H^+$	-4.950 ± 0.051	3	
$SeF_4(g) + 3\ H_2O(l) \Leftrightarrow SeO_3^{2-} + 4\ F^- + 6\ H^+$	2.017 ± 4.252	3	
$SeF_6(g) + 4\ H_2O(l) \Leftrightarrow SeO_4^{2-} + 6\ F^- + 8\ H^+$	28.489 ± 0.774	3	
$SeOF_2(g) + 2\ H_2O(l) \Leftrightarrow SeO_3^{2-} + 2\ F^- + 4\ H^+$	-11.258 ± 2.836	3	
$SeCl_2(g) + 3\ H_2O(l) \Leftrightarrow SeO_3^{2-} + 2\ Cl^- + 6\ H^+ + 2\ e^-$	-19.716 ± 0.843	3	
$Se_2Cl_2(g) + 6\ H_2O(l) \Leftrightarrow 2\ SeO_3^{2-} + 2\ Cl^- + 12\ H^+ + 6\ e^-$	-82.438 ± 1.858	3	
$SeOCl_2(g) + 2\ H_2O(l) \Leftrightarrow SeO_3^{2-} + 2\ Cl^- + 4\ H^+$	6.363 ± 0.537	3	
$SeBr_2(g) + 3\ H_2O(l) \Leftrightarrow SeO_3^{2-} + 2\ Br^- + 6\ H^+ + 2\ e^-$	-25.562 ± 3.557	3	
$SeS(g) + 3\ H_2O(l) \Leftrightarrow SeO_3^{2-} + HS^- + 5\ H^+ + 2\ e^-$	-47.112 ± 1.297	3	
$CSe(g) + 3\ H_2O(l) \Leftrightarrow HSe^- + CO_3^{2-} + 5\ H^+ + 2\ e^-$	14.516 ± 1.652	3	
$CSe_2(g) + 3\ H_2O(l) \Leftrightarrow 2\ HSe^- + CO_3^{2-} + 4\ H^+$	-11.655 ± 1.512	3	
$SiSe(g) + 4\ H_2O(l) \Leftrightarrow HSe^- + H_4SiO_4(aq) + 3\ H^+ + 2\ e^-$	72.498 ± 1.885	3	
$SnSe(g) + H^+ \Leftrightarrow HSe^- + Sn^{2+}$	8.061 ± 2.785	3	
$PbSe(g) + H^+ \Leftrightarrow HSe^- + Pb^{2+}$	11.148 ± 1.565	3	
$BSe_2(g) + 3\ H_2O(l) + e^- \Leftrightarrow 2\ HSe^- + B(OH)_3(aq) + H^+$	52.961 ± 3.727	3	
$AlSe(g) + H^+ \Leftrightarrow HSe^- + Al^{3+} + e^-$	114.681 ± 6.170	3	

Reaction	$\log_{10} K°$	ref.	T.v.*
$Br(g) + e^- \Leftrightarrow Br^-$	32.626 ± 0.037	4	
$Br_2(g) + 2\ e^- \Leftrightarrow 2\ Br^-$	36.931 ± 0.048	4	
$HBr(g) \Leftrightarrow Br^- + H^+$	8.845 ± 0.041	4	
$Br_2(l) + 2\ e^- \Leftrightarrow 2\ Br^-$	36.387 ± 0.059	3	
$Rb(cr) \Leftrightarrow Rb^+ + e^-$	49.756 ± 0.027	3	
$Rb(g) \Leftrightarrow Rb^+ + e^-$	59.055 ± 0.144	3	
$Sr(cr) \Leftrightarrow Sr^{2+} +2\ e^-$	98.784 ± 0.137	4	
$SrO(cr) + 2\ H^+ \Leftrightarrow Sr^{2+} + H_2O(l)$	42.233 ± 0.211	4	
$SrCl_2(cr) \Leftrightarrow Sr^{2+} + 2\ Cl^-$	7.240 ± 0.190	3	
$SrCO_3$(strontianite) $\Leftrightarrow Sr^{2+} + CO_3^{2-}$	-9.250 ± 0.010	44	
$SrSO_4$(celestite) $\Leftrightarrow Sr^{2+} + SO_4^{2-}$	-6.620 ± 0.020	44	
$Sr_3(PO_4)_2(s) \Leftrightarrow 3\ Sr^{2+} + 2\ PO_4^{3-}$	-27.800	5	
$SrHPO_4(s) \Leftrightarrow Sr^{2+} +P\ O_4^{3-} + H^+$	-19.310	5	
$Sr(OH)_2(s) + 2\ H^+ \Leftrightarrow Sr^{2+} +2\ H_2O(l)$	24.980	5	
$Sr(NO_3)_2(cr) \Leftrightarrow Sr^{2+} +2\ NO_3^-$	0.404 ± 0.268	4	
ZrO_2(mono) $+4\ H^+ \Leftrightarrow Zr^{4+} + 2\ H_2O(l)$	-7.000 ± 1.600	47	
$Zr(OH)_4$(am,fresh) $+ 4\ H^+ \Leftrightarrow Zr^{4+} + 4\ H_2O(l)$	-3.240 ± 0.100	47	
β-$ZrF_4 \Leftrightarrow Zr^{4+} + 4\ F^-$	-31.830 ± 0.408	47	
$Zr(SO_4)_2$•$9H_2O(cr) \Leftrightarrow Zr^{4+} + 9\ H_2O(l) +\ 2\ SO_4^{2-}$	-11.250 ± 0.096	47	
$ZrSiO_4(cr) + 4\ H^+ \Leftrightarrow Zr^{4+} + H_4SiO_4(aq)$	-14.623 ± 1.718	47	
$Zr(cr) \Leftrightarrow Zr^{4+} + 4\ e^-$	92.590 ± 1.616	3	
$Zr(g) \Leftrightarrow Zr^{4+} + 4\ e^-$	191.903 ± 1.635	3	
$ZrO(g) + 2\ H^+ \Leftrightarrow Zr^{4+} + H_2O(l) + 2\ e^-$	139.492 ± 5.019	3	
$ZrO_2(g) + 4\ H^+ \Leftrightarrow Zr^{4+} + 2\ H_2O(l)$	123.405 ± 8.398	3	
$ZrH(cr) \Leftrightarrow Zr^{4+} + H^+ + 5\ e^-$	81.258 ± 1.623	3	
ε-$ZrH_2 \Leftrightarrow Zr^{4+} + 2\ H^+ + 6\ e^-$	70.817 ± 1.644	3	
$ZrF(g) \Leftrightarrow Zr^{4+} + F^- + 3\ e^-$	149.155 ± 1.634	3	
$ZrF_2(g) \Leftrightarrow Zr^{4+} + 2\ F^- + 2\ e^-$	104.902 ± 1.654	3	
$ZrF_3(g) \Leftrightarrow Zr^{4+} + 3\ F^- + e^-$	53.848 ± 1.683	3	
$ZrF_4(g) \Leftrightarrow Zr^{4+} + 4\ F^-$	3.508 ± 1.698	3	
$ZrCl(cr) \Leftrightarrow Zr^{4+} + Cl^- + 3\ e^-$	69.244 ± 1.655	3	
$ZrCl(g) \Leftrightarrow Zr^{4+} + Cl^- + 3\ e^-$	150.690 ± 4.436	3	
$ZrCl_2(cr) \Leftrightarrow Zr^{4+} + 2\ Cl^- + 2\ e^-$	51.645 ± 2.796	3	
$ZrCl_2(g) \Leftrightarrow Zr^{4+} + 2\ Cl^- + 2\ e^-$	111.532 ± 3.838	3	
$ZrCl_3(cr) \Leftrightarrow Zr^{4+} + 3\ Cl^- + e^-$	40.718 ± 1.702	3	
$ZrCl_3(g) \Leftrightarrow Zr^{4+} + 3\ Cl^- + e^-$	72.107 ± 2.283	3	
$ZrCl_4(cr) \Leftrightarrow Zr^{4+} + 4\ Cl^-$	28.596 ± 1.632	3	
$ZrCl_4(g) \Leftrightarrow Zr^{4+} + 4\ Cl^-$	38.008 ± 1.627	3	
$ZrBr_4(g) \Leftrightarrow Zr^{4+} + 4\ Br^-$	48.920 ± 1.750	3	
$ZrI(cr) \Leftrightarrow Zr^{4+} + I^- + 3\ e^-$	75.300 ± 1.630	3	
$ZrI(g) \Leftrightarrow Zr^{4+} + I^- + 3\ e^-$	162.849 ± 2.520	3	
$ZrI_2(cr) \Leftrightarrow Zr^{4+} + 2\ I^- + 2\ e^-$	62.746 ± 2.384	3	
$ZrI_2(g) \Leftrightarrow Zr^{4+} + 2\ I^- + 2\ e^-$	124.337 ± 3.247	3	
$ZrI_3(cr) \Leftrightarrow Zr^{4+} + 3\ I^- + e^-$	52.225 ± 3.086	3	
$ZrI_3(g) \Leftrightarrow Zr^{4+} + 3\ I^- + e^-$	87.211 ± 1.789	3	
$ZrI_4(cr) \Leftrightarrow Zr^{4+} + 4\ I^-$	44.594 ± 1.744	3	
$ZrI_4(g) \Leftrightarrow Zr^{4+} + 4\ I^-$	57.716 ± 1.745	3	
$ZrS_{1.5}(cr) + 1.5\ H^+ \Leftrightarrow 1.5\ HS^-$	-91.182 ± 0.879	3	
$ZrS_2(cr) + 2\ H^+ \Leftrightarrow 2\ HS^-$	-103.404 ± 2.232	3	
$ZrS_3(cr) + 3\ H^+ \Leftrightarrow 3\ HS^-$	-111.886 ± 1.398	3	
$Zr(SO_3)_2(cr) \Leftrightarrow Zr^{4+} + 2\ SO_3^{2-}$	-58.061 ± 2.772	3	
$Zr(SO_4)_2(cr) \Leftrightarrow Zr^{4+} + 2\ SO_4^{2-}$	1.237 ± 1.668	3	
$Zr(SO_4)_2 \cdot 4H_2O(cr) \Leftrightarrow Zr^{4+} + 2\ SO_4^{2-} + 4\ H_2O(l)$	-7.653 ± 1.686	3	
$ZrN(cr) + 3\ H_2O(l) \Leftrightarrow Zr^{4+} + NO_3^- + 6\ H^+ + 9\ e^-$	-72.524 ± 1.654	3	
α-$Zr(HPO_4)_2 \Leftrightarrow Zr^{4+} + 2\ PO_4^{3-} + 2\ H^+$	-71.392 ± 4.377	3	
$Zr(HPO_4)_2 \cdot H_2O(cr) \Leftrightarrow Zr^{4+} + 2\ PO_4^{3-} + 2\ H^+ + H_2O(l)$	-66.204 ± 3.930	3	
$ZrC(cr) + 3\ H_2O(l) \Leftrightarrow Zr^{4+} + CO_3^{2-} + 6\ H^+ + 8\ e^-$	24.792 ± 1.680	3	

Reaction	$\log_{10} K°$	ref.	T.v.*
$Ca_2ZrSi_3O_{12}$(cr) + 12 H^+ + 4 e^- ⇔ 2 Ca^{2+} + Zr^{4+} + 3 H_4SiO_4(aq)	-69.048 ± 3.177	3	
$Ca_3ZrSi_2O_9$(cr) + 10 H^+ ⇔ 3 Ca^{2+} + Zr^{4+} + 2 H_4SiO_4(aq) + H_2O(l)	47.344 ± 2.486	3	
$SrZrSi_2O_7$(cr) + H_2O(l) + 6 H^+ ⇔ Sr^{2+} + Zr^{4+} + 2 H_4SiO_4(aq)	4.680 ± 1.827	3	
Na_2ZrSiO_5(cr) + 6 H^+ ⇔ 2 Na^+ + Zr^{4+} + H_4SiO_4(aq) + H_2O(l)	12.928 ± 3.865	3	
$Na_2ZrSi_2O_7$(cr) + H_2O(l) + 6 H^+ ⇔ 2 Na^+ + Zr^{4+} + 2 H_4SiO_4(aq)	3.214 ± 2.421	3	
$Na_2ZrSi_3O_9\cdot 2H_2O$(cr) + H_2O(l) + 6 H^+ ⇔ 2 Na^+ + Zr^{4+} + 3 H_4SiO_4(aq)	14.800 ± 3.906	3	
$Na_2ZrSi_4O_{11}$(cr) + 5 H_2O(l) + 6 H^+ ⇔ 2 Na^+ + Zr^{4+} + 4 H_4SiO_4(aq)	-14.601 ± 3.943	3	
$Na_2ZrSi_6O_{15}\cdot 3H_2O$(cr) + 6 H_2O(l) + 6 H^+ ⇔ 2 Na^+ + Zr^{4+} + 6 H_4SiO_4(aq)	14.889 ± 5.632	3	
$Na_4Zr_2Si_3O_{12}$(cr) + 2 H^+ ⇔ 4 Na^+ + 2 Zr^{4+} + 3 H_4SiO_4(aq)	14.721 ± 4.814	3	
$NaZr_2P_3O_{12}$(cr) ⇔ Na^+ + 2 Zr^{4+} + 3 PO_4^{3-}	-28.298 ± 4.867	3	
Nb_2O_5(s) + 7 H_2O ⇔ 2 $Nb(OH)_6^-$ + 2 H^+	-28.913 ± 0.507	1	
Mo(metal) + 4 H_2O(l) ⇔ MoO_4^{2-} + 8 H^+ + 6 e^-	-19.280	49	
MoO_2(cr) + 2 H_2O(l) ⇔ MoO_4^{2-} + 4 H^+ + 2 e^-	-29.570	49	
$PbMoO_4$(cr) ⇔ MoO_4^{2-} + Pb^{2+}	-12.980 ± 0.050	49	
$CaMoO_4$(cr) ⇔ MoO_4^{2-} + Ca^{2+}	-7.950 ± 0.050	49	
$Sm_2(MoO_4)_3\cdot xH_2O$(cr) ⇔ 3 MoO_4^{2-} + 2 Sm^{3+}	-26.100 ± 0.300	50	
NH_4TcO_4(cr) ⇔ TcO_4^- + NH_4^+	-0.910 ± 0.070	51	
$TlTcO_4$(cr) ⇔ TcO_4^- + Tl^+	-5.320 ± 0.120	51	
$AgTcO_4$(cr) ⇔ TcO_4^- + Ag^+	-3.270 ± 0.130	51	
$NaTcO_4\cdot 4H_2O$(s) ⇔ TcO_4^- + 4 H_2O(l) + Na^+	0.790 ± 0.040	51	
$KTcO_4$(cr) ⇔ TcO_4^- + K^+	-2.288 ± 0.026	51	
$TcO_2\cdot 1.6H_2O$(s) ⇔ $TcO(OH)_2$(aq) + 0.6 H_2O(l)	-8.415 ± 0.180	1	
$TcO_2\cdot 1.6H_2O$(s) + 0.4 H_2O(l) ⇔ TcO_4^- + 4 H^+ + 3 e^-	-37.829 ± 0.609	51	
Tc(cr) + 4 H_2O(l) ⇔ TcO_4^- + 8 H^+ + 7 e^-	-54.512 ± 1.335	3	
Tc(g) + 4 H_2O(l) ⇔ TcO_4^- + 8 H^+ + 7 e^-	55.984 ± 4.579	3	
TcO(g) + 3 H_2O(l) ⇔ TcO_4^- + 6 H^+ + 5 e^-	49.663 ± 10.075	3	
TcO_2(cr) + 2 H_2O(l) ⇔ TcO_4^- + 4 H^+ + 3 e^-	-41.822 ± 2.455	3	
Tc_2O_7(cr) + H_2O(l) ⇔ 2 TcO_4^- + 2 H^+	15.310 ± 3.815	3	
Tc_2O_7(g) + H_2O(l) ⇔ 2 TcO_4^- + 2 H^+	23.275 ± 3.929	3	
$Tc_2O_7\cdot H_2O$(s) ⇔ 2 TcO_4^- + 2 H^+	14.105 ± 3.807	3	
TcS(g) + 4 H_2O(l) ⇔ TcO_4^- + HS^- + 7 H^+ + 5 e^-	29.525 ± 11.472	3	
TcC(g) + 7 H_2O(l) ⇔ TcO_4^- + CO_3^{2-} + 14 H^+ + 11 e^-	47.464 ± 7.177	3	
$CsTcO_4$(cr) ⇔ TcO_4^- + Cs^+	-3.617 ± 0.047	3	
Pd(cr) ⇔ Pd^{2+} + 2 e^-	-32.860	12	
Pd(s) ⇔ Pd^{2+} + 2 e^-	-29.570 ± 1.120	15	
$Pd(OH)_2$(am) + 2 H^+ ⇔ Pd^{2+} + 2 H_2O(l)	**-3.580 ± 0.360**	9	
$Pd(OH)_2$(colloidal) + 2 H^+ ⇔ Pd^{2+} + 2 H_2O(l)	**-2.410**	9	
Ag(cr) ⇔ Ag^+ + e^-	-13.507 ± 0.027	3	
Ag(g) ⇔ Ag^+ + e^-	29.592 ± 0.143	3	
AgCl(cr) ⇔ Ag^+ + Cl^-	-9.748 ± 0.038	3	
Cd(cr) ⇔ Cd^{2+} + 2 e^-	13.618 ± 0.131	3	
Cd(g) ⇔ Cd^{2+} + 2 e^-	27.148 ± 0.136	3	
CdO(cr) + 2 H^+ ⇔ Cd^{2+} + H_2O(l)	15.104 ± 0.169	3	
$CdSO_4\cdot 2.667H_2O$(cr) ⇔ Cd^{2+} + SO_4^{2-} + 2.667 H_2O(l)	-1.887 ± 0.208	3	
α-Sn ⇔ Sn^{2+} + 2 e^-	**4.819 ± 0.060**	**11**	
β-Sn ⇔ Sn^{2+} + 2 e^-	**4.798 ± 0.053**	**11**	
SnO(cr) + 2 H^+ ⇔ Sn^{2+} + H_2O(l)	**1.591 ± 0.144**	**11**	
$Sn_{21}Cl_{16}(OH)_{14}O_6$(cr) + 26 H^+ ⇔ 21 Sn^{2+} + 16 Cl^- + 20 H_2O(l)	**-34.020 ± 3.360**	**11**	
Sn^{2+} + 4 H_2O(l) ⇔ $Sn(OH)_4$(aq) + 4 H^+ + 2 e^-	**-5.437 ± 0.131**	**11**	
SnO_2(cass) + 2 H_2O(l) ⇔ $Sn(OH)_5^-$ + H^+	**-17.586 ± 0.454**	**10**	
SnO_2(am) + 2 H_2O(l) ⇔ $Sn(OH)_5^-$ + H^+	**-14.996 ± 0.448**	**10**	
I(g) + e^- ⇔ I^-	21.355 ± 0.022	4	
I_2(cr) + 2 e^- ⇔ 2 I^-	18.123 ± 0.028	4	
I_2(g) + 2 e^- ⇔ 2 I^-	21.508 ± 0.035	3	
HI(g) ⇔ I^- + H^+	9.359 ± 0.028	3	
IO(g) + 2 H^+ + 3 e^- ⇔ I^- + H_2O(l)	68.564	3	*
IF(g) + 2 e^- ⇔ I^- + F^-	37.620	3	*

Reaction	$\log_{10} K°$	ref.	T.v.[*]
$IF_7(g) + 8 e^- \Leftrightarrow I^- + 7 F^-$	210.945	3	*
$ICl(g) + 2 e^- \Leftrightarrow I^- + Cl^-$	31.093	3	*
$ICl_3(cr) + 4 e^- \Leftrightarrow I^- + 3 Cl^-$	74.121	3	*
$IBr(g) + 2 e^- \Leftrightarrow I^- + Br^-$	27.902	3	*
$AgI(cr) \Leftrightarrow I^- + Ag^+$	-16.043	3	*
$AgIO_3(cr) \Leftrightarrow IO_3^- + Ag^+$	-7.789	3	*
$KI(cr) \Leftrightarrow I^- + K^+$	1.635	3	*
$KIO_3(cr) \Leftrightarrow IO_3^- + K^+$	-1.673	3	*
$KIO_4(cr) + 2 H^+ + 2 e^- \Leftrightarrow IO_3^- + K^+ + H_2O(l)$	49.857	3	*
$NaI(cr) \Leftrightarrow I^- + Na^+$	4.831	3	*
$NaIO_4(cr) + 2 H^+ + 2 e^- \Leftrightarrow IO_3^- + Na^+ + H_2O(l)$	52.983	3	*
$CsI(cr) \Leftrightarrow I^- + Cs^+$	0.452	3	*
$BI_3(g) + 3 H_2O(l) \Leftrightarrow 3 I^- + B(OH)_3(aq) + 3 H^+$	75.993	3	*
$BaI_2(cr) \Leftrightarrow 2 I^- + Ba^{2+}$	11.110	3	*
$CaI_2(cr) \Leftrightarrow 2 I^- + Ca^{2+}$	22.311	3	*
$CdI_2(cr) \Leftrightarrow 2 I^- + Cd^{2+}$	-3.539	3	*
$CoI_2(cr) \Leftrightarrow 2 I^- + Co^{2+}$	11.751	3	*
$CuI(cr) \Leftrightarrow I^- + Cu^{2+} + e^-$	-14.509	3	*
$HgI_2(cr) \Leftrightarrow 2 I^- + Hg^{2+}$	-28.542	3	*
$Hg_2I_2(cr) \Leftrightarrow 2 I^- + Hg_2^{2+}$	-28.227	3	*
$LiI(cr) \Leftrightarrow I^- + Li^+$	13.024	3	*
$MgI_2(cr) \Leftrightarrow 2 I^- + Mg^{2+}$	35.147	3	*
$NH_4I(cr) \Leftrightarrow I^- + NH_4^+$	3.262	3	*
$PbI_2(cr) \Leftrightarrow 2 I^- + Pb^{2+}$	-8.044	3	*
$RbI(cr) \Leftrightarrow I^- + Rb^+$	1.197	3	*
$SiI_4(cr) + 4 H_2O(l) \Leftrightarrow 4 I^- + H_4SiO_4(aq) + 4 H^+$	65.604	3	*
$SrI_2(cr) \Leftrightarrow 2 I^- + Sr^{2+}$	18.678	3	*
$TlI(cr) \Leftrightarrow I^- + Tl^+$	-7.231	3	*
$ZnI_2(cr) \Leftrightarrow 2 I^- + Zn^{2+}$	7.297	3	*
$AlI_3(cr) \Leftrightarrow 3 I^- + Al^{3+}$	60.595	3	*
$AsI_3(cr) + 4 H_2O(l) \Leftrightarrow 3 I^- + AsO_4^{3-} + 8 H^+ + 2 e^-$	-35.814	3	*
$Sb(cr) + 3 H_2O(l) \Leftrightarrow Sb(OH)_3(aq) + 3 H^+ + 3 e^-$	-11.990	9	
Sb_2O_3(valentinite) $+ 3 H_2O(l) \Leftrightarrow 2 Sb(OH)_3(aq)$	-8.720	9	
Sb_2S_3(stibnite) $+ 18 H_2O(l) \Leftrightarrow 2 Sb(OH)_3(aq) + 3 SO_4^{2-} + 30 H^+ + 24 e^-$	-156.219	9	
$Sb_2O_5(am) + 5 H_2O(l) \Leftrightarrow 2 Sb(OH)_5(aq)$	-7.400	9	
$Cs(cr) \Leftrightarrow Cs^+ + e^-$	51.061 ± 0.094	4	
$Cs(g) \Leftrightarrow Cs^+ + e^-$	59.742 ± 0.200	4	
$CsNO_3(s) \Leftrightarrow Cs^+ + NO_3^-$	-0.410	5	
$Cs_2O(s) + 2 H^+ \Leftrightarrow 2 Cs^+ + H_2O(l)$	89.890	5	
$CsOH(s) + H^+ \Leftrightarrow Cs^+ + H_2O(l)$	27.420	5	
$Cs_2SO_4(s) \Leftrightarrow 2 Cs^+ + SO_4^{2-}$	0.870	5	
$Cs_2CO_3(s) \Leftrightarrow 2 Cs^+ + CO_3^{2-}$	10.070	5	
$CsBr(cr) \Leftrightarrow Cs^+ + Br^-$	0.724 ± 0.112	3	
$CsCl(cr) \Leftrightarrow Cs^+ + Cl^-$	1.553 ± 0.103	3	
$Ba(cr) \Leftrightarrow Ba^{2+} + 2 e^-$	97.697 ± 0.452	4	
$BaO(cr) + 2 H^+ \Leftrightarrow Ba^{2+} + H_2O(l)$	48.073 ± 0.632	4	
$BaCO_3$(witherite) $\Leftrightarrow Ba^{2+} + CO_3^{2-}$	-8.540 ± 0.030	44	
$BaSO_4$(barite) $\Leftrightarrow Ba^{2+} + SO_4^{2-}$	-10.050 ± 0.050	44	
$Ba(g) \Leftrightarrow Ba^{2+} + 2 e^-$	124.475 ± 0.987	3	
$BaCl_2(cr) \Leftrightarrow Ba^{2+} + 2 Cl^-$	2.301 ± 0.633	3	
$BaF(g) \Leftrightarrow Ba^{2+} + F^- + e^-$	85.775 ± 1.265	3	
$Sm(OH)_3(am) + 3 H^+ \Leftrightarrow Sm^{3+} + 3 H_2O(l)$	16.900 ± 0.800	39	
$Sm(OH)_3(cr) + 3 H^+ \Leftrightarrow Sm^{3+} + 3 H_2O(l)$	15.600 ± 0.600	39	
$Sm_2(CO_3)_3(am) \Leftrightarrow 2 Sm^{3+} + 3 CO_3^{2-}$	-33.400 ± 2.200	39	
$SmCO_3OH(am) + H^+ \Leftrightarrow Sm^{3+} + CO_3^{2-} + H_2O(l)$	-6.199 ± 1.000	39	
$SmCO_3OH \cdot 0.5H_2O(cr) + H^+ \Leftrightarrow Sm^{3+} + CO_3^{2-} + 1.5 H_2O(l)$	-8.399 ± 0.500	39	
$NaSm(CO_3)_2 \cdot 5H_2O(cr) \Leftrightarrow Sm^{3+} + 2 CO_3^{2-} + 5 H_2O(l) + Na^+$	-21.000 ± 0.500	39	

Reaction	$\log_{10} K°$	ref.	T.v.*
$SmPO_4$(am,hydr) ⇔ Sm^{3+} + PO_4^{3-}	-24.790 ± 0.600	39	
Hg(g) ⇔ Hg^{2+} + 2 e^-	-23.270 ± 0.056	3	
Hg(l) ⇔ Hg^{2+} + 2 e^-	-28.848 ± 0.055	3	
Hg_2Cl_2(cr) ⇔ 2 Hg^{2+} + 2 e^- + 2 Cl^-	-48.638 ± 0.143	3	
Hg_2SO_4(cr) ⇔ 2 Hg^{2+} + SO_4^{2-} + 2 e^-	-36.985 ± 0.150	3	
HgO(montroydite,red) + 2 H^+ ⇔ Hg^{2+} + H_2O(l)	2.444 ± 0.062	3	
Pb(cr) ⇔ Pb^{2+} + 2 e^-	4.250	9	
Pb(g) ⇔ Pb^{2+} + 2 e^-	32.668 ± 0.157	3	
PbO(red,litharge) + 2 H^+ ⇔ Pb^{2+} + H_2O(l)	12.680	9	
PbO(yellow,massicot) + 2 H^+ ⇔ Pb^{2+} + H_2O(l)	12.960	9	
$Pb(OH)_2$(am) + 2 H^+ ⇔ Pb^{2+} + 2 H_2O(l)	13.050	9	
$PbSO_4$(anglesite) ⇔ Pb^{2+} + SO_4^{2-}	-7.810	9	
$PbCl_2$(s) ⇔ Pb^{2+} + 2 Cl^-	-4.810	9	
PbClOH(cr) + H^+ ⇔ Pb^{2+} + Cl^- + H_2O(l)	0.620	9	
PbF_2(s) ⇔ Pb^{2+} + 2 F^-	-7.520	9	
PbFCl(matlockite) ⇔ Pb^{2+} + F^- + Cl^-	-8.820	9	
$PbCO_3$(cerrusite) ⇔ Pb^{2+} +CO_3^{2-}	-13.230	9	
$Pb_3(CO_3)_2(OH)_2$(hydrocerrusite) + 2 H^+ ⇔ 3 Pb^{2+} + 2 CO_3^{2-} + 2 H_2O(l)	-17.640	9	
$Pb_{10}(CO_3)_6(OH)_6$(plumbonacrite) + 8 H^+ ⇔ 10 Pb^{2+} + 6 CO_3^{2-} + 7 H_2O(l)	-41.210	9	
$PbOHNO_3$(cr) + H^+ ⇔ Pb^{2+} + NO_3^- + H_2O(l)	2.940	9	
$PbHPO_4$(s) ⇔ Pb^{2+} + PO_4^{3-} + H^+	-23.780	9	
$Pb(H_2PO_4)_2$(s) ⇔ Pb^{2+} + 2 PO_4^{3-} + 4 H^+	-48.940	9	
$Pb_3(PO)_4$(s) ⇔ 3 Pb^{2+} + 2 PO_4^{3-}	-44.400	9	
$Pb_4(PO_4)_2O$(s) + 2 H^+ ⇔ 4 Pb^{2+} + 2 PO_4^{3-} + H_2O(l)	-37.090	9	
$Pb_5(PO_4)_3OH$(hydroxyl pyromorphite) + H^+ ⇔ 5 Pb^{2+} + 3 PO_4^{3-} + H_2O(l)	-62.800	9	
$Pb_5(PO_4)_3Cl$(chloro pyromorphite) ⇔ 5 Pb^{2+} +3 PO_4^{3-} + Cl^-	-84.400	9	
$Pb_5(PO_4)_3F$(fluoro pyromorphite) ⇔ 5 Pb^{2+} +3 PO_4^{3-} + F^-	-71.600	9	
PbS(galena) + 4 H_2O(l) ⇔ Pb^{2+} + SO_4^{2-} + 8 H^+ + 8 e^-	-45.863	9	
PbO_2(s) + 4 H^+ + 2 e^- ⇔ Pb^{2+} +2 H_2O(l)	48.980	9	
Pb_3O_4(s) + 8 H^+ + 2 e^- ⇔ 3 Pb^{2+} +4 H_2O(l)	70.980	9	
$Bi(OH)_3$(am) + 3 H^+ ⇔ Bi^{3+} + 3 H_2O(l)	31.501 ± 0.927	29	
0.5 α-Bi_2O_3(c) + 3 H^+ ⇔ Bi^{3+} + 1.5 H_2O(l)	31.501 ± 0.927	29	
$BiPO_4$(c) ⇔ Bi^{3+} + PO_4^{3-}	-30.350 ± 0.540	29	
Bi(cr) ⇔ Bi^{3+} + 3 e^-	-16.740	9	
BiOCl(s) + 2 H^+ ⇔ Bi^{3+} + H_2O + Cl^-	-8.470	9	
$(BiO)_2CO_3$(cr) + 4 H^+ ⇔ 2 Bi^{3+}+ 2 H_2O + CO_3^{2-}	-14.270	9	
$(BiO)_4(OH)_2CO_3$(cr) + 10 H^+⇔ 4 Bi^{3+}+ 6 H_2O + CO_3^{2-}	-8.680	9	
$BiONO_3$(s) + 2 H^+ ⇔ Bi^{3+}+ H_2O + NO_3^-	-2.750	9	
$Po(OH)_4$(s) + 4 H^+ ⇔ Po^{4+} + 4 H_2O(l)	19.520	5	
$RaSO_4$(cr) ⇔ Ra^{2+} + SO_4^{2-}	-10.050 ± 0.390	44	
$RaCO_3$(cr) ⇔ Ra^{2+} + CO_3^{2-}	-8.540 ± 0.200	44	
$Ac(OH)_3$(am) + 3 H^+ ⇔ Ac^{3+} + 3 H_2O(l)	16.900 ± 4.800	39	*
$Ac_2(CO_3)_3$(am) ⇔ 2 Ac^{3+} + 3 CO_3^{2-}	-33.400 ± 5.100	39	*
$AcCO_3OH$(am) + H^+ ⇔ Ac^{3+} + CO_3^{2-} + H_2O(l)	-6.199 ± 5.000	39	*
$AcPO_4$(am,hydr) ⇔ Ac^{3+} + PO_4^{3-}	-24.790 ± 4.600	39	*
ThO_2(am,fresh) + 4 H^+ ⇔ Th^{4+} + 2 H_2O(l)	9.304 ± 0.900	4	
ThO_2(am,aged) + 4 H^+ ⇔ Th^{4+} + 2 H_2O(l)	8.504 ± 0.900	4	
ThO_2(cr) + 4 H^+ ⇔ Th^{4+} + 2 H_2O(l)	1.765 ± 1.113	4	
ThF_4(cr, hyd) + 4 H^+ ⇔ Th^{4+} + 4 HF(aq)	-19.110 ± 0.400	4	
$Th(SO_4)_2$•$9H_2O$(cr) ⇔ Th^{4+} + 9 H_2O(l) + 2 SO_4^{2-}	-11.250 ± 0.096	4	
$Na_6Th(CO_3)_5$•$12H_2O$(cr) ⇔ Th^{4+} + 5 CO_3^{2-} + 12 H_2O(l) + 6 Na^+	-42.200 ± 0.800	4	
Th(cr) ⇔ Th^{4+} + 4 e^-	123.472 ± 0.928	3	
Th(g) ⇔ Th^{4+} + 4 e^-	221.753 ± 1.403	3	
ThO(g) + 2 H^+ ⇔ Th^{4+} + H_2O(l) + 2 e^-	156.030 ± 1.403	3	
ThO_2(g) + 4 H^+ ⇔ Th^{4+} + 2 H_2O(l)	125.601 ± 2.858	3	
ThH_2(cr) ⇔ Th^{4+} + 2 H^+ + 6 e^-	104.995 ± 0.992	3	
$ThH_{3.75}$(cr) ⇔ Th^{4+} + 3.75 H^+ + 7.75 e^-	98.441 ± 1.681	3	

Reaction	$\log_{10} K°$	ref.	T.v.*
$ThF(g) \Leftrightarrow Th^{4+} + F^- + 3 e^-$	172.654 ± 2.859	3	
$ThF_2(g) \Leftrightarrow Th^{4+} + 2 F^- + 2 e^-$	116.673 ± 3.670	3	
$ThF_3(g) \Leftrightarrow Th^{4+} + 3 F^- + e^-$	68.251 ± 2.859	3	
$ThF_4(g) \Leftrightarrow Th^{4+} + 4 F^-$	19.542 ± 2.074	3	
$ThOF(g) + 2 H^+ \Leftrightarrow Th^{4+} + F^- + H_2O(l) + e^-$	115.146 ± 2.360	3	
$ThOF_2(cr) + 2 H^+ \Leftrightarrow Th^{4+} + 2 F^- + H_2O(l)$	-14.751 ± 1.691	3	
$ThCl(g) \Leftrightarrow Th^{4+} + Cl^- + 3 e^-$	184.247 ± 3.679	3	
$ThCl_2(g) \Leftrightarrow Th^{4+} + 2 Cl^- + 2 e^-$	135.928 ± 3.999	3	
$ThCl_3(g) \Leftrightarrow Th^{4+} + 3 Cl^- + e^-$	93.670 ± 4.508	3	
$\beta\text{-}ThCl_4 \Leftrightarrow Th^{4+} + 4 Cl^-$	24.064 ± 0.994	3	
$ThCl_4(g) \Leftrightarrow Th^{4+} + 4 Cl^-$	53.730 ± 1.316	3	
$ThOCl_2(cr) + 2 H^+ \Leftrightarrow Th^{4+} + 2 F^- + H_2O(l)$	61.563 ± 1.039	3	
$ThBr(g) \Leftrightarrow Th^{4+} + Br^- + 3 e^-$	197.652 ± 3.679	3	
$ThBr_2(g) \Leftrightarrow Th^{4+} + 2 Br^- + 2 e^-$	159.854 ± 3.663	3	
$ThBr_3(g) \Leftrightarrow Th^{4+} + 3 Br^- + e^-$	113.044 ± 2.837	3	
$\beta\text{-}ThBr_4 \Leftrightarrow Th^{4+} + 4 Br^-$	34.190 ± 1.033	3	
$ThBr_4(g) \Leftrightarrow Th^{4+} + 4 Br^-$	61.519 ± 1.355	3	
$ThI_4(g) \Leftrightarrow Th^{4+} + 4 I^-$	68.914 ± 1.372	3	
$ThI_4(cr) \Leftrightarrow Th^{4+} + 4 I^-$	44.182 ± 1.042	3	
$Th^{4+} + IO_3^- \Leftrightarrow ThIO_3^{3+}$	4.140 ± 0.100	4	
$Th^{4+} + 2 IO_3^- \Leftrightarrow Th(IO_3)_2^{2+}$	6.970 ± 0.120	4	
$Th^{4+} + 3 IO_3^- \Leftrightarrow Th(IO_3)_3^{+}$	9.870 ± 0.110	4	
$ThS(cr) + H^+ \Leftrightarrow Th^{4+} + HS^- + 2 e^-$	52.676 ± 1.477	3	
$ThN(cr) + 3 H_2O(l) \Leftrightarrow Th^{4+} + NO_3^- + 6 H^+ + 9 e^-$	-43.707 ± 1.986	3	
$Th_3N_4(cr) + 12 H_2O(l) \Leftrightarrow 3 Th^{4+} + 4 NO_3^- + 24 H^+ + 32 e^-$	-260.721 ± 3.921	3	
$Th(NO_3)_4 \cdot 5H_2O(cr) \Leftrightarrow Th^{4+} + 4 NO_3^- + 5 H_2O(l)$	1.929 ± 1.091	3	
$ThC_{0.97}(cr) + 2.91 H_2O(l) \Leftrightarrow Th^{4+} + 0.97 CO_3^{2-} + 5.82 H^+ + 7.88 e^-$	70.480 ± 1.445	3	
$ThC_{1.94}(s) + 5.82 H_2O(l) \Leftrightarrow Th^{4+} + 1.94 CO_3^{2-} + 11.64 H^+ + 11.76 e^-$	38.901 ± 1.615	3	
$PaO_2(cr) + 4 H^+ \Leftrightarrow Pa^{4+} + 2 H_2O(l)$	0.600	61	
$PaCl_4(s) \Leftrightarrow Pa^{4+} + 4 Cl^-$	24.010	24	
$Pa_2O_5(s) + 4 H^+ \Leftrightarrow 2 PaOOH^{2+} + H_2O(l)$	**≤ -1.520**	**present**	
$PaCl_5(cr) - e^- \Leftrightarrow Pa^{4+} + 5 Cl^-$	32.850	24	
$UO_2(am) + 4 H^+ \Leftrightarrow U^{4+} + 2 H_2O(l)$	2.304 ± 1.000	53	
$UO_2(cr) + 4 H^+ \Leftrightarrow U^{4+} + 2 H_2O(l)$	-4.852 ± 0.365	51	
$\alpha\text{-}UO_3 + 2 H^+ \Leftrightarrow UO_2^{2+} + H_2O(l)$	9.524 ± 0.401	51	
$\beta\text{-}UO_3 + 2 H^+ \Leftrightarrow UO_2^{2+} + H_2O(l)$	8.302 ± 0.382	51	
$\gamma\text{-}UO_3 + 2 H^+ \Leftrightarrow UO_2^{2+} + H_2O(l)$	7.700 ± 0.372	51	
$\alpha\text{-}UO_3 \cdot 0.9H_2O(cr) + 2 H^+ \Leftrightarrow UO_2^{2+} + 1.9 H_2O(l)$	5.003 ± 0.529	51	
$UO_3 \cdot 2H_2O(cr) + 2 H^+ \Leftrightarrow UO_2^{2+} + 3 H_2O(l)$	4.812 ± 0.428	51	
$\beta\text{-}UO_2(OH)_2 + 4 H^+ \Leftrightarrow UO_2^{2+} + 2 H_2O(l)$	4.931 ± 0.435	51	
$U(OH)_2SO_4(cr) + 2 H^+ \Leftrightarrow U^{4+} + 2 H_2O(l) + SO_4^{2-}$	-3.168 ± 0.500	51	
$U(HPO_4)_2 \cdot 4H_2O(cr) \Leftrightarrow U^{4+} + 2 PO_4^{3-} + 2 H^+ + 4 H_2O(l)$	-55.194 ± 0.383	51	
$UF_6(cr) + 2 H_2O(l) \Leftrightarrow UO_2^{2+} + 6 F^- + 4 H^+$	17.204 ± 0.853	51	
$UO_2(IO_3)_2(cr) + 12 H^+ + 12 e^- \Leftrightarrow UO_2^{2+} + 2 I^- + 6 H_2O(l)$	215.246 ± 0.294	51	
$UO_2SO_4(cr) \Leftrightarrow UO_2^{2+} + SO_4^{2-}$	1.889 ± 0.560	51	
$UO_2SO_4 \cdot 2.5H_2O(cr) \Leftrightarrow UO_2^{2+} + SO_4^{2-} + 2.5 H_2O(l)$	-1.589 ± 0.019	51	
$UO_2SO_4 \cdot 3.5H_2O(cr) \Leftrightarrow UO_2^{2+} + SO_4^{2-} + 3.5 H_2O(l)$	-1.585 ± 0.019	51	
$UO_2HPO_4 \cdot 4H_2O(cr) + 2 H^+ \Leftrightarrow UO_2^{2+} + PO_4^{3-} + H^+ + 4 H_2O(l)$	-24.202 ± 0.198	51	
$(UO_2)_3(PO_4)_2 \cdot 4H_2O(cr) \Leftrightarrow 3 UO_2^{2+} + 2 PO_4^{3-} + 4 H_2O(l)$	-48.364 ± 0.462	51	
$UO_2CO_3(cr) \Leftrightarrow UO_2^{2+} + CO_3^{2-}$	-14.760 ± 0.020	51	
$CaU_6O_{19} \cdot 11H_2O(cr) + 14 H^+ \Leftrightarrow 6 UO_2^{2+} + Ca^{2+} + 18 H_2O(l)$	-40.500 ± 1.600	51	
$Na_4UO_2(CO_3)_3(cr) \Leftrightarrow UO_2^{2+} + 3 CO_3^{2-} + 4 Na^+$	-27.180 ± 0.165	51	
$K_2U_6O_{19} \cdot 11H_2O(cr) + 14 H^+ \Leftrightarrow 6 UO_2^{2+} + 2 K^+ + 18 H_2O(l)$	-37.100 ± 0.540	51	
$UO(g) + 2 H^+ \Leftrightarrow U^{4+} + H_2O(l) + 2 e^-$	135.305 ± 1.782	3	
$UO_2(g) + 4 H^+ \Leftrightarrow U^{4+} + 2 H_2O(l)$	91.638 ± 3.524	3	
$\beta\text{-}UO_{2.25} + 4.5 H^+ + 0.5 e^- \Leftrightarrow U^{4+} + 2.25 H_2O(l)$	-0.991 ± 0.430	3	
$UO_{2.25}(cr) + 4.5 H^+ + 0.5 e^- \Leftrightarrow U^{4+} + 2.25 H_2O(l)$	-0.999 ± 0.430	3	

Reaction	$\log_{10} K°$	ref.	T.v.*
β-$UO_{2.3333}$ + 4.6666 H^+ + 0.6666 e^- ⇔ U^{4+} + 2.3333 $H_2O(l)$	0.632 ± 0.468	3	
$UO_{2.6667}(cr)$ + 5.3334 H^+ + 1.3334 e^- ⇔ U^{4+} + 2.6667 $H_2O(l)$	6.847 ± 0.340	3	
$UO_3(g)$ + 2 H^+ ⇔ UO_2^{2+} + $H_2O(l)$	70.940 ± 2.648	3	
β-UH_3 ⇔ U^{3+} + 3 H^+ + 6 e^-	70.763 ± 0.318	3	
$UF(g)$ ⇔ U^{4+} + F^- + 3 e^-	128.679 ± 3.523	3	
$UF_2(g)$ ⇔ U^{4+} + 2 F^- + 2 e^-	93.589 ± 4.428	3	
$UF_3(cr)$ ⇔ U^{3+} + 3 F^-	-19.532 ± 0.955	3	
$UF_3(g)$ ⇔ U^{3+} + 3 F^-	45.216 ± 3.575	3	
$UF_4(cr)$ ⇔ U^{4+} + 4 F^-	-29.360 ± 0.934	3	
$UF_4(g)$ ⇔ U^{4+} + 4 F^-	13.858 ± 1.307	3	
$UF_4\cdot 2.5H_2O(cr)$ ⇔ U^{4+} + 4 F^- + 2.5 $H_2O(l)$	-33.546 ± 1.227	3	
α-UF_5 + 2 $H_2O(l)$ ⇔ UO_2^+ + 5 F^- + 4 H^+	-13.022 ± 1.401	3	
β-UF_5 + 2 $H_2O(l)$ ⇔ UO_2^+ + 5 F^- + 4 H^+	-13.356 ± 1.199	3	
$UF_5(g)$ + 2 $H_2O(l)$ ⇔ UO_2^+ + 5 F^- + 4 H^+	5.654 ± 2.764	3	
$UF_6(g)$ + 2 $H_2O(l)$ ⇔ UO_2^{2+} + 6 F^- + 4 H^+	18.039 ± 0.856	3	
$U_2F_9(cr)$ + e^- ⇔ 2 U^{4+} + 9 F^-	-38.292 ± 3.232	3	
$U_4F_{17}(cr)$ + e^- ⇔ 4 U^{4+} + 17 F^-	-97.874 ± 5.779	3	
$UOF_2(cr)$ + 2 H^+ ⇔ U^{4+} + 2 F^- + $H_2O(l)$	-18.234 ± 1.192	3	
$UOF_4(cr)$ + $H_2O(l)$ ⇔ UO_2^{2+} + 4 F^- + 2 H^+	4.422 ± 0.942	3	
$UOF_4(g)$ + $H_2O(l)$ ⇔ UO_2^{2+} + 4 F^- + 2 H^+	23.947 ± 3.575	3	
$UO_2F_2(cr)$ ⇔ UO_2^{2+} + 2 F^-	-7.310 ± 0.453	3	
$UO_2F_2(g)$ ⇔ UO_2^{2+} + 2 F^-	34.603 ± 1.836	3	
$U_2O_3F_6(cr)$ + $H_2O(l)$ ⇔ 2 UO_2^{2+} + 6 F^- + 2 H^+	-2.738 ± 2.762	3	
$U_3O_5F_8(cr)$ + $H_2O(l)$ ⇔ 3 UO_2^{2+} + 8 F^- + 2 H^+	-3.055 ± 2.171	3	
$UOFOH(cr)$ ⇔ UO_2^{2+} + F^- + H^+	-18.019 ± 2.292	3	
$UOFOH\cdot 0.5H_2O(cr)$ ⇔ UO_2^{2+} + F^- + H^+ + 0.5 $H_2O(l)$	-18.478 ± 1.265	3	
$UOF_2\cdot H_2O(cr)$ + 2 H^+ ⇔ U^{4+} + 2 F^- + 2 $H_2O(l)$	-18.796 ± 0.825	3	
$UO_2FOH\cdot H_2O(cr)$ + H^+ ⇔ UO_2^{2+} + F^- + 2 $H_2O(l)$	-2.338 ± 1.355	3	
$UO_2FOH\cdot 2H_2O(cr)$ + H^+ ⇔ UO_2^{2+} + F^- + 3 $H_2O(l)$	-2.722 ± 1.510	3	
$UO_2F_2\cdot 3H_2O(cr)$ ⇔ UO_2^{2+} + 2 F^- + 3 $H_2O(l)$	-7.470 ± 1.277	3	
$UCl(g)$ ⇔ U^{4+} + Cl^- + 3 e^-	143.135 ± 3.521	3	
$UCl_2(g)$ ⇔ U^{4+} + 2 Cl^- + 2 e^-	108.210 ± 3.556	3	
$UCl_3(cr)$ ⇔ U^{3+} + 3 Cl^-	12.968 ± 0.477	3	
$UCl_3(g)$ ⇔ U^{3+} + 3 Cl^-	61.049 ± 3.557	3	
$UCl_4(cr)$ ⇔ U^{4+} + 4 Cl^-	21.920 ± 0.544	3	
$UCl_4(g)$ ⇔ U^{4+} + 4 Cl^-	46.476 ± 0.924	3	
$UCl_5(cr)$ + 2 $H_2O(l)$ ⇔ UO_2^+ + 5 Cl^- + 4 H^+	37.265 ± 0.757	3	
$UCl_5(g)$ + 2 $H_2O(l)$ ⇔ UO_2^+ + 5 Cl^- + 4 H^+	51.379 ± 2.661	3	
$UCl_6(cr)$ + 2 $H_2O(l)$ ⇔ UO_2^{2+} + 6 Cl^- + 4 H^+	57.542 ± 0.627	3	
$UCl_6(g)$ + 2 $H_2O(l)$ ⇔ UO_2^{2+} + 6 Cl^- + 4 H^+	63.767 ± 0.972	3	
$UOCl(cr)$ + 2 H^+ ⇔ U^{3+} + Cl^- + $H_2O(l)$	10.367 ± 0.914	3	
$UOCl_2(cr)$ + 2 H^+ ⇔ U^{4+} + 2 Cl^- + $H_2O(l)$	5.423 ± 0.567	3	
$UOCl_3(cr)$ + $H_2O(l)$ ⇔ UO_2^+ + 3 Cl^- + 2 H^+	12.606 ± 1.502	3	
$UO_2Cl(cr)$ ⇔ UO_2^+ + Cl^-	-0.528 ± 1.501	3	
$UO_2Cl_2(cr)$ ⇔ UO_2^{2+} + 2 Cl^-	12.114 ± 0.384	3	
$UO_2Cl_2(g)$ ⇔ UO_2^{2+} + 2 Cl^-	48.353 ± 2.664	3	
$U_2O_2Cl_5(cr)$ + 2 $H_2O(l)$ ⇔ 2 UO_2^{2+} + 5 Cl^- + 4 H^+ + e^-	8.690 ± 1.058	3	
$(UO_2)_2Cl_3(cr)$ + e^- ⇔ 2 UO_2^{2+} + 3 Cl^-	11.212 ± 0.801	3	
$U_5O_{12}Cl(cr)$ + 4 H^+ ⇔ 5 UO_2^{2+} + Cl^- + 2 $H_2O(l)$ + 5 e^-	-26.226 ± 2.659	3	
$UO_2Cl_2\cdot H_2O(cr)$ ⇔ UO_2^{2+} + 2 Cl^- + $H_2O(l)$	8.255 ± 0.651	3	
$UO_2ClOH\cdot 2H_2O(cr)$ + H^+ ⇔ UO_2^{2+} + Cl^- + 3 $H_2O(l)$	2.272 ± 0.847	3	
$UO_2Cl_2\cdot 3H_2O(cr)$ ⇔ UO_2^{2+} + 2 Cl^- + 3 $H_2O(l)$	5.569 ± 0.614	3	
$UCl_3F(cr)$ ⇔ U^{4+} + 3 Cl^- + F^-	10.242 ± 0.964	3	
$UCl_2F_2(cr)$ ⇔ U^{4+} + 2 Cl^- + 2 F^-	-3.614 ± 1.056	3	
$UClF_3(cr)$ ⇔ U^{4+} + Cl^- + 3 F^-	-17.644 ± 1.022	3	
$UBr(g)$ ⇔ U^{4+} + Br^- + 3 e^-	145.993 ± 2.651	3	
$UBr_2(g)$ ⇔ U^{4+} + 2 Br^- + 2 e^-	113.991 ± 2.698	3	

Reaction	$\log_{10} K°$	ref.	T.v.*
$UBr_3(cr) \Leftrightarrow U^{3+} + 3\ Br^-$	20.116 ± 0.807	3	
$UBr_3(g) \Leftrightarrow U^{3+} + 3\ Br^-$	66.557 ± 3.605	3	
$UBr_4(cr) \Leftrightarrow U^{4+} + 4\ Br^-$	31.146 ± 0.703	3	
$UBr_4(g) \Leftrightarrow U^{4+} + 4\ Br^-$	54.424 ± 0.928	3	
$UBr_5(cr) + 2\ H_2O(l) \Leftrightarrow UO_2^+ + 5\ Br^- + 4\ H^+$	41.465 ± 1.648	3	
$UBr_5(g) + 2\ H_2O(l) \Leftrightarrow UO_2^+ + 5\ Br^- + 4\ H^+$	59.176 ± 2.701	3	
$UOBr_2(cr) + 2\ H^+ \Leftrightarrow U^{4+} + 2\ Br^- + H_2O(l)$	7.893 ± 1.505	3	
$UOBr_3(cr) + H_2O(l) \Leftrightarrow UO_2^+ + 3\ Br^- + 2\ H^+$	23.464 ± 3.751	3	
$UO_2Br_2(cr) \Leftrightarrow UO_2^{2+} + 2\ Br^-$	16.438 ± 0.444	3	
$UO_2Br_2 \cdot H_2O(cr) \Leftrightarrow UO_2^{2+} + 2\ Br^- + H_2O(l)$	12.044 ± 0.540	3	
$UO_2BrOH \cdot 2H_2O(cr) + H^+ \Leftrightarrow UO_2^{2+} + Br^- + 3\ H_2O(l)$	4.145 ± 0.826	3	
$UO_2Br_2 \cdot 3H_2O(cr) \Leftrightarrow UO_2^{2+} + 2\ Br^- + 3\ H_2O(l)$	9.318 ± 1.025	3	
$UBr_2Cl(cr) \Leftrightarrow U^{3+} + 2\ Br^- + Cl^-$	17.695 ± 1.741	3	
$UBr_3Cl(cr) \Leftrightarrow U^{4+} + 3\ Br^- + Cl^-$	28.996 ± 1.741	3	
$UBrCl_2(cr) \Leftrightarrow U^{3+} + Br^- + 2\ Cl^-$	14.443 ± 1.741	3	
$UBr_2Cl_2(cr) \Leftrightarrow U^{4+} + 2\ Br^- + 2\ Cl^-$	26.121 ± 1.740	3	
$UBrCl_3(cr) \Leftrightarrow U^{4+} + Br^- + 3\ Cl^-$	23.451 ± 1.643	3	
$UI(g) \Leftrightarrow U^{4+} + I^- + 3\ e^-$	152.494 ± 4.399	3	
$UI_2(g) \Leftrightarrow U^{4+} + 2\ I^- + 2\ e^-$	118.018 ± 4.422	3	
$UI_3(cr) \Leftrightarrow U^{3+} + 3\ I^-$	28.998 ± 0.916	3	
$UI_3(g) \Leftrightarrow U^{3+} + 3\ I^-$	75.856 ± 4.423	3	
$UI_4(cr) \Leftrightarrow U^{4+} + 4\ I^-$	39.258 ± 0.732	3	
$UI_4(g) \Leftrightarrow U^{4+} + 4\ I^-$	64.325 ± 1.134	3	
$UO_2(IO_3)_2(cr) \Leftrightarrow UO_2^{2+} + 2\ IO_3^-$	-7.880 ± 0.100	51	
$UClI_3(cr) \Leftrightarrow U^{4+} + Cl^- + 3\ I^-$	35.119 ± 2.013	3	
$UCl_2I_2(cr) \Leftrightarrow U^{4+} + 2\ Cl^- + 2\ I^-$	30.201 ± 2.013	3	
$UCl_3I(cr) \Leftrightarrow U^{4+} + 3\ Cl^- + I^-$	25.465 ± 1.568	3	
$US(cr) + H^+ \Leftrightarrow U^{4+} + HS^- + 2\ e^-$	34.458 ± 2.260	3	
$US_{1.90}(cr) + 1.9\ H^+ \Leftrightarrow U^{4+} + 1.9\ HS^- + 0.2\ e^-$	-0.503 ± 3.741	3	
$US_2(cr) + 2\ H^+ \Leftrightarrow U^{4+} + 2\ HS^-$	-2.429 ± 1.615	3	
$US_3(cr) + 2\ H_2O(l) \Leftrightarrow UO_2^{2+} + 3\ HS^- + H^+$	-16.768 ± 2.490	3	
$U_2S_3(cr) + 3\ H^+ \Leftrightarrow 2\ U^{3+} + 3\ HS^-$	6.382 ± 11.808	3	
$U_3S_5(cr) + 5\ H^+ \Leftrightarrow 3\ U^{4+} + 5\ HS^- + 2\ e^-$	18.095 ± 17.690	3	
$UO_2SO_3(cr) \Leftrightarrow UO_2^{2+} + SO_3^{2-}$	-15.828 ± 2.358	3	
$U(SO_3)_2(cr) \Leftrightarrow U^{4+} + 2\ SO_3^{2-}$	-36.444 ± 3.979	3	
$U(SO_4)_2(cr) \Leftrightarrow U^{4+} + 2\ SO_4^{2-}$	-11.677 ± 2.489	3	
$U(OH)_2SO_4(cr) + 2\ H^+ \Leftrightarrow U^{4+} + SO_4^{2-} + 2\ H_2O(l)$	-3.167 ± 0.673	3	
$UO_2SO_4 \cdot 3H_2O(cr) \Leftrightarrow UO_2^{2+} + SO_4^{2-} + 3\ H_2O(l)$	-1.504 ± 0.447	3	
$U(SO_4)_2 \cdot 4H_2O(cr) \Leftrightarrow U^{4+} + 2\ SO_4^{2-} + 4\ H_2O(l)$	-11.717 ± 2.032	3	
$U(SO_4)_2 \cdot 8H_2O(cr) \Leftrightarrow U^{4+} + 2\ SO_4^{2-} + 8\ H_2O(l)$	-12.773 ± 2.952	3	
$USe(cr) + H^+ \Leftrightarrow U^{4+} + HSe^- + 2\ e^-$	37.339 ± 3.189	3	
$\alpha\text{-}USe_2 + 2\ H^+ \Leftrightarrow U^{4+} + 2\ HSe^-$	2.776 ± 7.399	3	
$\beta\text{-}USe_2 + 2\ H^+ \Leftrightarrow U^{4+} + 2\ HSe^-$	2.618 ± 7.430	3	
$USe_3(cr) + 2\ H_2O(l) \Leftrightarrow UO_2^{2+} + 3\ HSe^- + H^+$	-18.244 ± 7.494	3	
$U_2Se_3(cr) + 3\ H^+ \Leftrightarrow 2\ U^{3+} + 3\ HSe^-$	17.754 ± 13.198	3	
$U_3Se_4(cr) + 4\ H^+ \Leftrightarrow 3\ U^{4+} + 4\ HSe^- + 4\ e^-$	74.796 ± 15.118	3	
$U_3Se_5(cr) + 5\ H^+ \Leftrightarrow 3\ U^{4+} + 5\ HSe^- + 2\ e^-$	42.329 ± 19.996	3	
$UN(cr) + 3\ H_2O(l) \Leftrightarrow U^{4+} + NO_3^- + 6\ H^+ + 9\ e^-$	-58.838 ± 0.615	3	
$\alpha\text{-}UN_{1.59} + 4.77\ H_2O(l) \Leftrightarrow U^{4+} + 1.59\ NO_3^- + 9.54\ H^+ + 11.95\ e^-$	-133.730 ± 0.970	3	
$\alpha\text{-}UN_{1.73} + 5.19\ H_2O(l) \Leftrightarrow U^{4+} + 1.73\ NO_3^- + 10.38\ H^+ + 12.65\ e^-$	-151.186 ± 1.356	3	
$UO_2(NO_3)_2(cr) \Leftrightarrow UO_2^{2+} + 2\ NO_3^-$	11.921 ± 1.050	3	
$UO_2(NO_3)_2 \cdot H_2O(cr) \Leftrightarrow UO_2^{2+} + 2\ NO_3^- + H_2O(l)$	8.464 ± 1.875	3	
$UO_2(NO_3)_2 \cdot 2H_2O(cr) \Leftrightarrow UO_2^{2+} + 2\ NO_3^- + 2\ H_2O(l)$	4.891 ± 0.488	3	
$UO_2(NO_3)_2 \cdot 3H_2O(cr) \Leftrightarrow UO_2^{2+} + 2\ NO_3^- + 3\ H_2O(l)$	3.655 ± 0.484	3	
$UO_2(NO_3)_2 \cdot 6H_2O(cr) \Leftrightarrow UO_2^{2+} + 2\ NO_3^- + 6\ H_2O(l)$	2.236 ± 0.444	3	
$UP(cr) + 4\ H_2O(l) \Leftrightarrow U^{4+} + PO_4^{3-} + 8\ H^+ + 9\ e^-$	59.718 ± 1.989	3	
$UP_2(cr) + 8\ H_2O(l) \Leftrightarrow U^{4+} + 2\ PO_4^{3-} + 16\ H^+ + 14\ e^-$	68.179 ± 2.709	3	

Reaction	$\log_{10} K°$	ref.	T.v.*
$U_3P_4(cr) + 16\ H_2O(l) \Leftrightarrow U^{4+} + 4\ PO_4^{3-} + 32\ H^+ + 32\ e^-$	187.607 ± 4.782	3	
$UPO_5(cr) + H_2O(l) \Leftrightarrow UO_2^+ + PO_4^{3-} + 2\ H^+$	-30.718 ± 0.967	3	
$UP_2O_7(cr) + 3\ H_2O(l) \Leftrightarrow UO_2^{2+} + 2\ PO_4^{3-} + 6\ H^+ + 2\ e^-$	-64.323 ± 1.133	3	
$(UO_2)_2P_2O_7(cr) + H_2O(l) \Leftrightarrow 2\ UO_2^{2+} + 2\ PO_4^{3-} + 2\ H^+$	-36.976 ± 1.458	3	
$(UO_2)_3(PO_4)_2(cr) \Leftrightarrow 3\ UO_2^{2+} + 2\ PO_4^{3-}$	-36.324 ± 1.435	3	
$U(HPO_4)_2 \cdot 4H_2O(cr) \Leftrightarrow U^{4+} + 2\ PO_4^{3-} + 4\ H_2O(l) + 2\ H^+$	-55.194 ± 0.909	3	
$(UO_2)_3(PO_4)_2 \cdot 6H_2O(cr) \Leftrightarrow 3\ UO_2^{2+} + 2\ PO_4^{3-} + 6\ H_2O(l)$	-49.325 ± 2.580	3	
$UAs(cr) + 4\ H_2O(l) \Leftrightarrow U^{4+} + AsO_4^{3-} + 8\ H^+ + 9\ e^-$	-1.445 ± 1.602	3	
$UAs_2(cr) + 8\ H_2O(l) \Leftrightarrow U^{4+} + 2\ AsO_4^{3-} + 16\ H^+ + 14\ e^-$	-56.645 ± 2.695	3	
$U_3As_4(cr) + 16\ H_2O(l) \Leftrightarrow 3\ U^{4+} + 4\ AsO_4^{3-} + 32\ H^+ + 32\ e^-$	-58.971 ± 4.327	3	
$UO_2(AsO_3)_2(cr) + 2\ H_2O(l) \Leftrightarrow UO_2^{2+} + 2\ AsO_4^{3-} + 4\ H^+$	-29.769 ± 2.548	3	
$(UO_2)_2As_2O_7(cr) + H_2O(l) \Leftrightarrow 2\ UO_2^{2+} + 2\ AsO_4^{3-} + 2\ H^+$	-29.007 ± 2.602	3	
$(UO_2)_3(AsO_4)_2(cr) \Leftrightarrow 3\ UO_2^{2+} + 2\ AsO_4^{3-}$	-27.403 ± 2.691	3	
$UC(cr) + 3\ H_2O(l) \Leftrightarrow U^{4+} + CO_3^{2-} + 6\ H^+ + 8\ e^-$	43.349 ± 0.614	3	
$\alpha\text{-}UC_{1.94} + 5.82\ H_2O(l) \Leftrightarrow U^{4+} + 1.94\ CO_3^{2-} + 11.64\ H^+ + 11.76\ e^-$	15.142 ± 0.500	3	
$U_2C_3(cr) + 9\ H_2O(l) \Leftrightarrow 2\ U^{4+} + 3\ CO_3^{2-} + 18\ H^+ + 20\ e^-$	56.034 ± 1.871	3	
$USiO_4(cr) + 4\ H^+ \Leftrightarrow U^{4+} + H_4SiO_4(aq)$	-8.060 ± 0.792	3	
$MgUO_4(cr) + 4\ H^+ \Leftrightarrow UO_2^{2+} + Mg^{2+} + 2\ H_2O(l)$	23.231 ± 0.467	3	
$CaUO_4(cr) + 4\ H^+ \Leftrightarrow UO_2^{2+} + Ca^{2+} + 2\ H_2O(l)$	15.930 ± 0.555	3	
$\alpha\text{-}SrUO_4 + 4\ H^+ \Leftrightarrow UO_2^{2+} + Sr^{2+} + 2\ H_2O(l)$	19.155 ± 0.595	3	
$BaUO_4(cr) + 4\ H^+ \Leftrightarrow UO_2^{2+} + Ba^{2+} + 2\ H_2O(l)$	17.639 ± 0.807	3	
$Ba_3UO_6(cr) + 8\ H^+ \Leftrightarrow UO_2^{2+} + 3\ Ba^{2+} + 4\ H_2O(l)$	92.699 ± 2.129	3	
$BaU_2O_7(cr) + 6\ H^+ \Leftrightarrow 2\ UO_2^{2+} + Ba^{2+} + 3\ H_2O(l)$	21.388 ± 1.401	3	
$Ba_2U_2O_7(cr) + 6\ H^+ \Leftrightarrow 2\ UO_2^+ + 2\ Ba^{2+} + 3\ H_2O(l)$	35.346 ± 1.742	3	
$Li_2UO_4(cr) + 4\ H^+ \Leftrightarrow UO_2^{2+} + 2\ Li^+ + 2\ H_2O(l)$	27.939 ± 0.496	3	
$NaUO_3(cr) + 2\ H^+ \Leftrightarrow UO_2^+ + Na^+ + H_2O(l)$	8.342 ± 1.779	3	
$\alpha\text{-}Na_2UO_4 + 4\ H^+ \Leftrightarrow UO_2^{2+} + 2\ Na^+ + 2\ H_2O(l)$	30.034 ± 0.687	3	
$Na_3UO_4(cr) + 4\ H^+ \Leftrightarrow UO_2^+ + 3\ Na^+ + 2\ H_2O(l)$	56.280 ± 1.436	3	
$Na_2U_2O_7(cr) + 6\ H^+ \Leftrightarrow 2\ UO_2^{2+} + 2\ Na^+ + 3\ H_2O(l)$	22.595 ± 0.933	3	
$K_2UO_4(cr) + 4\ H^+ \Leftrightarrow UO_2^{2+} + 2\ K^+ + 2\ H_2O(l)$	33.874 ± 0.648	3	
$Rb_2UO_4(cr) + 4\ H^+ \Leftrightarrow UO_2^{2+} + 2\ Rb^+ + 2\ H_2O(l)$	34.111 ± 0.649	3	
$Cs_2UO_4(cr) + 4\ H^+ \Leftrightarrow UO_2^{2+} + 2\ Cs^+ + 2\ H_2O(l)$	35.804 ± 0.419	3	
$Cs_2U_2O_7(cr) + 6\ H^+ \Leftrightarrow 2\ UO_2^{2+} + 2\ Cs^+ + 3\ H_2O(l)$	30.931 ± 1.866	3	
$Cs_2U_4O_{12}(cr) + 8\ H^+ \Leftrightarrow 4\ UO_2^{2+} + 2\ Cs^+ + 4\ H_2O(l) + 2\ e^-$	15.875 ± 1.392	3	
$Na_4UO_2(CO_3)_3(cr) \Leftrightarrow UO_2^{2+} + 4\ Na^+ + 3\ CO_3^{2-}$	-27.180 ± 0.555	3	
$NpO_2(am) + 4\ H^+ \Leftrightarrow Np^{4+} + 2\ H_2O(l)$	0.604 ± 1.000	53	
$NpO_2OH(am,\ aged) + H^+ \Leftrightarrow NpO_2^+ + H_2O(l)$	4.700 ± 0.500	51	
$NpO_2OH(am,\ fresh) + H^+ \Leftrightarrow NpO_2^+ + H_2O(l)$	5.300 ± 0.200	51	
$Na_3NpO_2(CO_3)_2(cr) \Leftrightarrow NpO_2^+ + 2\ CO_3^{2-} + 3\ Na^+$	-14.220 ± 0.500	51	
$NaNpO_2CO_3 \bullet 3.5H_2O(cr) \Leftrightarrow NpO_2^+ + CO_3^{2-} + 3.5\ H_2O + Na^+$	-11.000 ± 0.240	51	
$KNpO_2CO_3(s) \Leftrightarrow NpO_2^+ + CO_3^{2-} + K^+$	-13.150 ± 0.190	51	
$K_3NpO_2(CO_3)_2(s) \Leftrightarrow NpO_2^+ + 2\ CO_3^{2-} + 3\ K^+$	-15.460 ± 0.160	51	
$NpO_3 \bullet H_2O(cr) + 2\ H^+ \Leftrightarrow NpO_2^{2+} + 2\ H_2O(l)$	5.470 ± 0.400	51	
$NpO_2CO_3(s) \Leftrightarrow NpO_2^{2+} + CO_3^{2-}$	-14.596 ± 0.469	51	
$(NH_4)_4NpO_2(CO_3)_3(s) + e^- \Leftrightarrow NpO_2^+ + 3\ CO_3^{2-} + 4\ NH_4^+$	-7.223 ± 0.346	51	
$K_4NpO_2(CO_3)_3(s) + e^- \Leftrightarrow NpO_2^+ + 3\ CO_3^{2-} + 4\ K^+$	-6.813 ± 0.894	51	
$Np(cr) \Leftrightarrow Np^{4+} + 4\ e^-$	86.155 ± 0.979	3	
$Np(g) \Leftrightarrow Np^{4+} + 4\ e^-$	159.944 ± 1.112	3	
$NpO_2(cr) + 4\ H^+ \Leftrightarrow Np^{4+} + 2\ H_2O(l)$	-9.754 ± 1.073	3	
$Np_2O_5(cr) + 2\ H^+ \Leftrightarrow 2\ NpO_2^+ + H_2O(l)$	3.696 ± 2.785	3	
$NpO_2(OH)_2(cr) + 2\ H^+ \Leftrightarrow NpO_2^{2+} + 2\ H_2O(l)$	5.469 ± 1.492	3	
$NpF(g) \Leftrightarrow Np^{4+} + F^- + 3\ e^-$	116.281 ± 4.497	3	
$NpF_2(g) \Leftrightarrow Np^{4+} + 2\ F^- + 2\ e^-$	81.410 ± 5.377	3	
$NpF_3(cr) \Leftrightarrow Np^{3+} + 3\ F^-$	-18.056 ± 1.802	3	
$NpF_3(g) \Leftrightarrow Np^{3+} + 3\ F^-$	43.734 ± 4.536	3	
$NpF_4(cr) \Leftrightarrow Np^{4+} + 4\ F^-$	-29.070 ± 3.016	3	
$NpF_4(g) \Leftrightarrow Np^{4+} + 4\ F^-$	14.467 ± 4.040	3	

Reaction	$\log_{10} K°$	ref.	T.v.*
$NpF_5(cr) + 2 H_2O(l) \Leftrightarrow NpO_2^+ + 5 F^- + 4 H^+$	1.169 ± 4.598	3	
$NpF_6(cr) + 2 H_2O(l) \Leftrightarrow NpO_2^{2+} + 6 F^- + 4 H^+$	29.594 ± 3.712	3	
$NpF_6(g) + 2 H_2O(l) \Leftrightarrow NpO_2^{2+} + 6 F^- + 4 H^+$	30.356 ± 3.712	3	
$NpCl_3(cr) \Leftrightarrow Np^{3+} + 3 Cl^-$	13.438 ± 1.145	3	
$NpCl_3(g) \Leftrightarrow Np^{3+} + 3 Cl^-$	56.790 ± 2.141	3	
$NpCl_4(cr) \Leftrightarrow Np^{4+} + 4 Cl^-$	21.212 ± 1.114	3	
$NpCl_4(g) \Leftrightarrow Np^{4+} + 4 Cl^-$	44.077 ± 1.374	3	
$NpOCl_2(cr) + 2 H^+ \Leftrightarrow Np^{4+} + 2 Cl^- + H_2O(l)$	5.379 ± 1.730	3	
$NpBr_3(cr) \Leftrightarrow Np^{3+} + 3 Br^-$	20.829 ± 1.195	3	
$NpBr_4(cr) \Leftrightarrow Np^{4+} + 4 Br^-$	29.665 ± 1.160	3	
$NpOBr_2(cr) + 2 H^+ \Leftrightarrow Np^{4+} + 2 Br^- + H_2O(l)$	5.200 ± 2.173	3	
$NpI_3(cr) \Leftrightarrow Np^{3+} + 3 I^-$	27.249 ± 1.189	3	
$NpN(cr) + 3 H_2O(l) \Leftrightarrow Np^{4+} + NO_3^- + 6 H^+ + 9 e^-$	-68.201 ± 2.010	3	
$NpO_2(NO_3)_2 \cdot 6H_2O(cr) \Leftrightarrow NpO_2^{2+} + 2 NO_3^- + 6 H_2O(l)$	2.155 ± 1.393	3	
$NpC_{0.91}(cr) + 2.73 H_2O(l) \Leftrightarrow Np^{4+} + 0.91 CO_3^{2-} + 5.46 H^+ + 7.64 e^-$	43.578 ± 2.012	3	
$Np_2C_3(cr) + 9 H_2O(l) \Leftrightarrow 2 Np^{4+} + 3 CO_3^{2-} + 18 H^+ + 20 e^-$	42.144 ± 3.933	3	
$Na_3NpF_8(cr) + e^- \Leftrightarrow 3 Na^+ + Np^{4+} + 8 F^-$	1.503 ± 3.979	3	
$K_4NpO_2(CO_3)_3(s) \Leftrightarrow 4 K^+ + NpO_2^{2+} + 3 CO_3^{2-}$	-26.404 ± 1.676	3	
$Cs_2NpCl_6(cr) \Leftrightarrow 2 Cs^+ + Np^{4+} + 6 Cl^-$	5.072 ± 1.318	3	
$Cs_2NpBr_6(cr) \Leftrightarrow 2 Cs^+ + Np^{4+} + 6 Br^-$	13.606 ± 1.194	3	
$Pu(OH)_3(am) + 3 H^+ \Leftrightarrow Pu^{3+} + 3 H_2O(l)$	16.900 ± 0.800	39	
$PuCO_3OH(am) + H^+ \Leftrightarrow Pu^{3+} + CO_3^{2-} + H_2O(l)$	-6.199 ± 1.000	39	
$PuCO_3OH•0.5H_2O(cr) + H^+ \Leftrightarrow Pu^{3+} + CO_3^{2-} + 1.5 H_2O(l)$	-8.399 ± 0.500	39	
$Pu(OH)_3(cr) + 3 H^+ \Leftrightarrow Pu^{3+} + 3 H_2O(l)$	15.600 ± 0.600	39	
$Pu_2(CO_3)_3(am) \Leftrightarrow 2 Pu^{3+} + 3 CO_3^{2-}$	-33.400 ± 2.200	39	
$PuPO_4(am,hydr) \Leftrightarrow Pu^{3+} + PO_4^{3-}$	-24.790 ± 0.600	39	
$PuO_2(am) + 4 H^+ \Leftrightarrow Pu^{4+} + 2 H_2O(l)$	-2.326 ± 0.520	51	
$PuO_2OH(am) + H^+ \Leftrightarrow PuO_2^+ + H_2O(l)$	5.000 ± 0.500	51	
$PuO_2(OH)_2 \cdot H_2O(cr) + 2 H^+ \Leftrightarrow PuO_2^{2+} + 3 H_2O(l)$	5.500 ± 1.000	51	
$Pu(HPO_4)_2(am) \Leftrightarrow Pu^{4+} + 2 H^+ + 2 PO_4^{3-}$	5.750 ± 0.514	51	
$PuO_2CO_3(s) \Leftrightarrow PuO_2^{2+} + CO_3^{2-}$	-14.650 ± 0.470	51	
$Pu(cr) \Leftrightarrow Pu^{4+} + 4 e^-$	83.739 ± 0.474	3	
$Pu(g) \Leftrightarrow Pu^{4+} + 4 e^-$	138.472 ± 0.709	3	
$PuO_{1.61}(bcc) + 3.22 H^+ \Leftrightarrow Pu^{4+} + 1.61 H_2O(l) + 0.78 e^-$	4.382 ± 1.834	3	
$PuO_2(cr) + 4 H^+ \Leftrightarrow Pu^{4+} + 2 H_2O(l)$	-8.032 ± 0.507	3	
$Pu_2O_3(cr) + 6 H^+ \Leftrightarrow 2 Pu^{3+} + 3 H_2O(l)$	50.633 ± 1.991	3	
$Pu(OH)_3(cr) + 3 H^+ \Leftrightarrow Pu^{3+} + 3 H_2O(l)$	15.800 ± 1.641	3	
$PuF(g) \Leftrightarrow Pu^{4+} + F^- + 3 e^-$	108.364 ± 1.838	3	
$PuF_2(g) \Leftrightarrow Pu^{4+} + 2 F^- + 2 e^-$	72.684 ± 1.289	3	
$PuF_3(cr) \Leftrightarrow Pu^{3+} + 3 F^-$	-16.436 ± 0.881	3	
$PuF_3(g) \Leftrightarrow Pu^{3+} + 3 F^-$	45.983 ± 1.024	3	
$PuF_4(cr) \Leftrightarrow Pu^{4+} + 4 F^-$	-26.745 ± 3.569	3	
$PuF_4(g) \Leftrightarrow Pu^{4+} + 4 F^-$	15.103 ± 3.948	3	
$PuF_6(cr) + 2 H_2O(l) \Leftrightarrow PuO_2^{2+} + 6 F^- + 4 H^+$	43.334 ± 3.642	3	
$PuF_6(g) + 2 H_2O(l) \Leftrightarrow PuO_2^{2+} + 6 F^- + 4 H^+$	44.174 ± 3.630	3	
$PuOF(cr) + 2 H^+ \Leftrightarrow Pu^{3+} + F^- + H_2O(l)$	1.064 ± 3.576	3	
$PuCl_3(cr) \Leftrightarrow Pu^{3+} + 3 Cl^-$	14.161 ± 0.593	3	
$PuCl_3(g) \Leftrightarrow Pu^{3+} + 3 Cl^-$	58.047 ± 0.789	3	
$PuCl_4(cr) \Leftrightarrow Pu^{4+} + 4 Cl^-$	21.634 ± 1.128	3	
$PuCl_4(g) \Leftrightarrow Pu^{4+} + 4 Cl^-$	41.726 ± 1.891	3	
$PuOCl(cr) + 2 H^+ \Leftrightarrow Pu^{3+} + Cl^- + H_2O(l)$	11.376 ± 0.581	3	
$PuCl_3 \cdot 6H_2O(cr) \Leftrightarrow Pu^{3+} + 3 Cl^- + 6 H_2O(l)$	5.278 ± 0.658	3	
$PuBr_3(cr) \Leftrightarrow Pu^{3+} + 3 Br^-$	21.585 ± 0.673	3	
$PuBr_3(g) \Leftrightarrow Pu^{3+} + 3 Br^-$	63.196 ± 2.784	3	
$PuOBr(cr) + 2 H^+ \Leftrightarrow Pu^{3+} + Br^- + H_2O(l)$	14.299 ± 1.569	3	
$PuI_3(cr) \Leftrightarrow Pu^{3+} + 3 I^-$	27.182 ± 0.928	3	
$PuI_3(g) \Leftrightarrow Pu^{3+} + 3 I^-$	64.407 ± 2.783	3	

Reaction	$\log_{10} K°$	ref.	T.v.*
$PuOI(cr) + 2 H^+ \Leftrightarrow Pu^{3+} + I^- + H_2O(l)$	15.981 ± 3.621	3	
$PuN(cr) + 3 H_2O(l) \Leftrightarrow Pu^{4+} + NO_3^- + 6 H^+ + 9 e^-$	-69.438 ± 0.656	3	
$PuP(cr) + 4 H_2O(l) \Leftrightarrow Pu^{4+} + PO_4^{3-} + 8 H^+ + 9 e^-$	42.250 ± 3.733	3	
$PuPO_4(s, hyd) \Leftrightarrow Pu^{3+} + 3 PO_4^{3-}$	-24.600 ± 1.112	3	
$PuAs(cr) + 4 H_2O(l) \Leftrightarrow Pu^{4+} + AsO_4^{3-} + 8 H^+ + 9 e^-$	-11.147 ± 3.624	3	
$PuC_{0.84}(cr) + 2.52 H_2O(l) \Leftrightarrow Pu^{4+} + 0.84 CO_3^{2-} + 5.04 H^+ + 7.36 e^-$	48.003 ± 1.485	3	
$Pu_3C_2(cr) + 6 H_2O(l) \Leftrightarrow 3 Pu^{4+} + 2 CO_3^{2-} + 12 H^+ + 20 e^-$	165.284 ± 5.454	3	
$Pu_2C_3(cr) + 9 H_2O(l) \Leftrightarrow 2 Pu^{4+} + 3 CO_3^{2-} + 18 H^+ + 20 e^-$	43.605 ± 3.088	3	
$Cs_2PuCl_6(cr) \Leftrightarrow 2 Cs^+ + Pu^{4+} + 6 Cl^-$	1.745 ± 1.288	3	
$Cs_3PuCl_6(cr) \Leftrightarrow 3 Cs^+ + Pu^{3+} + 6 Cl^-$	5.713 ± 1.755	3	
$CsPu_2Cl_7(cr) \Leftrightarrow Cs^+ + 2 Pu^{3+} + 7 Cl^-$	23.270 ± 1.332	3	
$Cs_2PuBr_6(cr) \Leftrightarrow 2 Cs^+ + Pu^{4+} + 6 Br^-$	8.702 ± 1.205	3	
$Cs_2NaPuCl_6(cr) \Leftrightarrow Na^+ + 2 Cs^+ + Pu^{3+} + 6 Cl^-$	11.853 ± 1.047	3	
$Am(OH)_3(am) + 3 H^+ \Leftrightarrow Am^{3+} + 3 H_2O(l)$	16.900 ± 0.800	51	
$Am(OH)_3(cr) + 3 H^+ \Leftrightarrow Am^{3+} + 3 H_2O(l)$	15.600 ± 0.600	51	
$Am_2(CO_3)_3(am) \Leftrightarrow 2 Am^{3+} + 3 CO_3^{2-}$	-33.400 ± 2.200	51	
$AmCO_3OH(am) + H^+ \Leftrightarrow Am^{3+} + CO_3^{2-} + H_2O(l)$	-6.199 ± 1.000	51	
$AmCO_3OH{\bullet}0.5H_2O(cr) + H^+ \Leftrightarrow Am^{3+} + CO_3^{2-} + 1.5 H_2O(l)$	-8.399 ± 0.500	51	
$NaAm(CO_3)_2{\bullet}5H_2O(cr) \Leftrightarrow Am^{3+} + 2 CO_3^{2-} + 5 H_2O(l) + Na^+$	-21.000 ± 0.500	51	
$AmPO_4(am,hydr) \Leftrightarrow Am^{3+} + PO_4^{3-}$	-24.790 ± 0.600	51	
$AmO_2OH(am) + H^+ \Leftrightarrow AmO_2^+ + H_2O(l)$	5.300 ± 0.500	51	
$NaAmO_2CO_3(s) \Leftrightarrow AmO_2^+ + CO_3^{2-} + Na^+$	-10.900 ± 0.400	51	
$Am(cr) \Leftrightarrow Am^{3+} + 3 e^-$	104.887 ± 0.833	3	
$Am(g) \Leftrightarrow Am^{3+} + 3 e^-$	147.338 ± 0.880	3	
$AmO_2(cr) + 4 H^+ \Leftrightarrow Am^{4+} + 2 H_2O(l)$	-9.994 ± 1.697	3	
$Am_2O_3(cr) + 6 H^+ \Leftrightarrow 2 Am^{3+} + 3 H_2O(l)$	53.147 ± 2.210	3	
$AmH_2(cr) \Leftrightarrow Am^{2+} + 2 H^+$	42.417 ± 3.752	3	
$AmF_3(cr) \Leftrightarrow Am^{3+} + 3 F^-$	-13.402 ± 2.636	3	
$AmF_3(g) \Leftrightarrow Am^{3+} + 3 F^-$	51.764 ± 3.076	3	
$AmF_4(cr) \Leftrightarrow Am^{4+} + 4 F^-$	-28.040 ± 3.407	3	
$AmCl_3(cr) \Leftrightarrow Am^{3+} + 3 Cl^-$	15.284 ± 0.927	3	
$AmBr_3(cr) \Leftrightarrow Am^{3+} + 3 Br^-$	23.927 ± 1.446	3	
$AmOCl(cr) + 2 H^+ \Leftrightarrow Am^{3+} + Cl^- + H_2O(l)$	12.264 ± 1.443	3	
$AmOBr(cr) + 2 H^+ \Leftrightarrow Am^{3+} + Br^- + H_2O(l)$	15.978 ± 1.908	3	
$AmI_3(cr) \Leftrightarrow Am^{3+} + 3 I^-$	25.301 ± 1.952	3	
$Am_2C_3(cr) + 9 H_2O(l) \Leftrightarrow 2 Am^{3+} + 8 H^+ + 8 e^- + 3 CO_3^{2-}$	85.979 ± 7.622	3	
$Cs_2NaAmCl_6(cr) \Leftrightarrow Am^{3+} + 2 Cs^+ + Na^+ + 6 Cl^-$	12.564 ± 1.213	3	
$Cm(OH)_3(am) + 3 H^+ \Leftrightarrow Cm^{3+} + 3 H_2O(l)$	16.900 ± 0.800	39	
$Cm(OH)_3(cr) + 3 H^+ \Leftrightarrow Cm^{3+} + 3 H_2O(l)$	15.600 ± 0.600	39	
$Cm_2(CO_3)_3(am) \Leftrightarrow 2 Cm^{3+} + 3 CO_3^{2-}$	-33.400 ± 2.200	39	
$CmCO_3OH(am) + H^+ \Leftrightarrow Cm^{3+} + CO_3^{2-} + H_2O(l)$	-6.199 ± 1.000	39	
$CmCO_3OH{\bullet}0.5H_2O(cr) + H^+ \Leftrightarrow Cm^{3+} + CO_3^{2-} + 1.5 H_2O(l)$	-8.399 ± 0.500	39	
$NaCm(CO_3)_2{\bullet}5H_2O(cr) \Leftrightarrow Cm^{3+} + 2 CO_3^{2-} + 5 H_2O(l) + Na^+$	-21.000 ± 0.500	39	
$CmPO_4(am,hydr) \Leftrightarrow Cm^{3+} + PO_4^{3-}$	-24.790 ± 0.600	39	
$UO_2ox{\cdot}3H_2O(cr) \Leftrightarrow UO_2^{2+} + ox^{2-} + 3 H_2O(l)$	-8.930 ± 0.314	54	
$Ca(ox){\cdot}H_2O(cr) \Leftrightarrow Ca^{2+} + H_2O(l) + ox^{2-}$	-8.730 ± 0.060	54	
$Ca(ox){\cdot}2H_2O(cr) \Leftrightarrow Ca^{2+} + 2 H_2O(l) + ox^{2-}$	-8.300 ± 0.060	54	
$Ca(ox){\cdot}3H_2O(cr) \Leftrightarrow Ca^{2+} + 3 H_2O(l) + ox^{2-}$	-8.190 ± 0.040	54	
$H_3cit(cr) \Leftrightarrow cit^{3-} + 3 H^+$	-13.041 ± 0.500	54	
$H_3cit{\cdot}H_2O(cr) \Leftrightarrow cit^{3-} + 3 H^+ + H_2O(l)$	-12.950 ± 0.024	54	
$Ca_3(cit)_2{\cdot}4H_2O(cr) \Leftrightarrow 3 Ca^{2+} 4 H_2O(l) + 2 cit^{3-}$	-17.900 ± 0.100	54	
$H_4edta(cr) \Leftrightarrow edta^{4-} + 4 H^+$	-27.220 ± 0.201	54	
$Ca(isa)_2(cr) \Leftrightarrow Ca^{2+} + 2 isa^-$	-6.400 ± 0.200	54	

* Tentative values.

Appendix 2 Text Files of JAEA-TDB for Geochemical Calculation Programs

Enclosed CD-ROM contains four text files of JAEA-TDB for geochemical calculation programs. Correspondence between file name and its corresponding geochemical calculation program is shown in Table A3.

Table A3 Correspondence between file name and its corresponding geochemical calculation program

file name	corresponding geochemical calculation program
140331c0.tdb	PHREEQC [6] without using SIT
140331s0.tdb	PHREEQC [6] using SIT
140331e0.tdb	EQ3/6 Ver. 7.2c [7]
140331g0.tdb	Geochemist’s Workbench [8]

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国際単位系（SI）

表１．SI 基本単位

基本量	SI 基本単位	
	名称	記号
長さ	メートル	m
質量	キログラム	kg
時間	秒	s
電流	アンペア	A
熱力学温度	ケルビン	K
物質量	モル	mol
光度	カンデラ	cd

表２．基本単位を用いて表されるSI組立単位の例

組立量	SI 基本単位	
	名称	記号
面積	平方メートル	m^2
体積	立法メートル	m^3
速さ，速度	メートル毎秒	m/s
加速度	メートル毎秒毎秒	m/s^2
波数	毎メートル	m^{-1}
密度，質量密度	キログラム毎立方メートル	kg/m^3
面積密度	キログラム毎平方メートル	kg/m^2
比体積	立方メートル毎キログラム	m^3/kg
電流密度	アンペア毎平方メートル	A/m^2
磁界の強さ	アンペア毎メートル	A/m
量濃度(a)，濃度	モル毎立方メートル	mol/m^3
質量濃度	キログラム毎立法メートル	kg/m^3
輝度	カンデラ毎平方メートル	cd/m^2
屈折率(b)	（数字の）　1	1
比透磁率(b)	（数字の）　1	1

（a）量濃度（amount concentration）は臨床化学の分野では物質濃度（substance concentration）ともよばれる。
（b）これらは無次元量あるいは次元１をもつ量であるが、そのことを表す単位記号である数字の１は通常は表記しない。

表５．SI 接頭語

乗数	接頭語	記号	乗数	接頭語	記号
10^{24}	ヨタ	Y	10^{-1}	デシ	d
10^{21}	ゼタ	Z	10^{-2}	センチ	c
10^{18}	エクサ	E	10^{-3}	ミリ	m
10^{15}	ペタ	P	10^{-6}	マイクロ	µ
10^{12}	テラ	T	10^{-9}	ナノ	n
10^{9}	ギガ	G	10^{-12}	ピコ	p
10^{6}	メガ	M	10^{-15}	フェムト	f
10^{3}	キロ	k	10^{-18}	アト	a
10^{2}	ヘクト	h	10^{-21}	ゼプト	z
10^{1}	デカ	da	10^{-24}	ヨクト	y

表６．SIに属さないが、SIと併用される単位

名称	記号	SI 単位による値
分	min	1 min=60s
時	h	1h =60 min=3600 s
日	d	1 d=24 h=86 400 s
度	°	1°=(π/180) rad
分	’	1’=(1/60)°=(π/10800) rad
秒	”	1”=(1/60)’=(π/648000) rad
ヘクタール	ha	$1ha=1hm^2=10^4m^2$
リットル	L，l	$1L=1l=1dm^3=10^3cm^3=10^{-3}m^3$
トン	t	$1t=10^3$ kg

表７．SIに属さないが、SIと併用される単位で、SI単位で表される数値が実験的に得られるもの

名称	記号	SI 単位で表される数値
電子ボルト	eV	$1eV=1.602\ 176\ 53(14)\times10^{-19}J$
ダルトン	Da	$1Da=1.660\ 538\ 86(28)\times10^{-27}kg$
統一原子質量単位	u	1u=1 Da
天文単位	ua	$1ua=1.495\ 978\ 706\ 91(6)\times10^{11}m$

表３．固有の名称と記号で表されるSI組立単位

組立量	SI 組立単位			
	名称	記号	他のSI単位による表し方	SI基本単位による表し方
平面角	ラジアン(b)	rad	1 (b)	m/m
立体角	ステラジアン(b)	sr(c)	1 (b)	m^2/m^2
周波数	ヘルツ(d)	Hz		s^{-1}
力	ニュートン	N		$m\ kg\ s^{-2}$
圧力，応力	パスカル	Pa	N/m^2	$m^{-1}\ kg\ s^{-2}$
エネルギー，仕事，熱量	ジュール	J	N m	$m^2\ kg\ s^{-2}$
仕事率，工率，放射束	ワット	W	J/s	$m^2\ kg\ s^{-3}$
電荷，電気量	クーロン	C		s A
電位差（電圧），起電力	ボルト	V	W/A	$m^2\ kg\ s^{-3}\ A^{-1}$
静電容量	ファラド	F	C/V	$m^{-2}\ kg^{-1}\ s^4\ A^2$
電気抵抗	オーム	Ω	V/A	$m^2\ kg\ s^{-3}\ A^{-2}$
コンダクタンス	ジーメンス	S	A/V	$m^{-2}\ kg^{-1}\ s^3\ A^2$
磁束	ウエーバ	Wb	Vs	$m^2\ kg\ s^{-2}\ A^{-1}$
磁束密度	テスラ	T	Wb/m^2	$kg\ s^{-2}\ A^{-1}$
インダクタンス	ヘンリー	H	Wb/A	$m^2\ kg\ s^{-2}\ A^{-2}$
セルシウス温度	セルシウス度(e)	℃		K
光束	ルーメン	lm	cd sr(c)	cd
照度	ルクス	lx	lm/m^2	$m^{-2}\ cd$
放射性核種の放射能(f)	ベクレル(d)	Bq		s^{-1}
吸収線量, 比エネルギー分与, カーマ	グレイ	Gy	J/kg	$m^2\ s^{-2}$
線量当量, 周辺線量当量, 方向性線量当量, 個人線量当量	シーベルト(g)	Sv	J/kg	$m^2\ s^{-2}$
酸素活性	カタール	kat		$s^{-1}\ mol$

(a)SI接頭語は固有の名称と記号を持つ組立単位と組み合わせても使用できる。しかし接頭語を付した単位はもはやコヒーレントではない。
(b)ラジアンとステラジアンは数字の１に対する単位の特別な名称で、量についての情報をつたえるために使われる。実際には、使用する時には記号rad及びsrが用いられるが、習慣として組立単位としての記号である数字の１は明示されない。
(c)測光学ではステラジアンという名称と記号srを単位の表し方の中に、そのまま維持している。
(d)ヘルツは周期現象についてのみ、ベクレルは放射性核種の統計的過程についてのみ使用される。
(e)セルシウス度はケルビンの特別な名称で、セルシウス温度を表すために使用される。セルシウス度とケルビンの単位の大きさは同一である。したがって、温度差や温度間隔を表す数値はどちらの単位で表しても同じである。
(f)放射性核種の放射能（activity referred to a radionuclide）は、しばしば誤った用語で”radioactivity”と記される。
(g)単位シーベルト（PV,2002,70,205）についてはCIPM勧告2（CI-2002）を参照。

表４．単位の中に固有の名称と記号を含むSI組立単位の例

組立量	SI 組立単位		
	名称	記号	SI 基本単位による表し方
粘度	パスカル秒	Pa s	$m^{-1}\ kg\ s^{-1}$
力のモーメント	ニュートンメートル	N m	$m^2\ kg\ s^{-2}$
表面張力	ニュートン毎メートル	N/m	$kg\ s^{-2}$
角速度	ラジアン毎秒	rad/s	$m\ m^{-1}\ s^{-1}=s^{-1}$
角加速度	ラジアン毎秒毎秒	rad/s^2	$m\ m^{-1}\ s^{-2}=s^{-2}$
熱流密度，放射照度	ワット毎平方メートル	W/m^2	$kg\ s^{-3}$
熱容量，エントロピー	ジュール毎ケルビン	J/K	$m^2\ kg\ s^{-2}\ K^{-1}$
比熱容量，比エントロピー	ジュール毎キログラム毎ケルビン	J/(kg K)	$m^2\ s^{-2}\ K^{-1}$
比エネルギー	ジュール毎キログラム	J/kg	$m^2\ s^{-2}$
熱伝導率	ワット毎メートル毎ケルビン	W/(m K)	$m\ kg\ s^{-3}\ K^{-1}$
体積エネルギー	ジュール毎立方メートル	J/m^3	$m^{-1}\ kg\ s^{-2}$
電界の強さ	ボルト毎メートル	V/m	$m\ kg\ s^{-3}\ A^{-1}$
電荷密度	クーロン毎立方メートル	C/m^3	$m^{-3}\ sA$
表面電荷	クーロン毎平方メートル	C/m^2	$m^{-2}\ sA$
電束密度，電気変位	クーロン毎平方メートル	C/m^2	$m^{-2}\ sA$
誘電率	ファラド毎メートル	F/m	$m^{-3}\ kg^{-1}\ s^4\ A^2$
透磁率	ヘンリー毎メートル	H/m	$m\ kg\ s^{-2}\ A^{-2}$
モルエネルギー	ジュール毎モル	J/mol	$m^2\ kg\ s^{-2}\ mol^{-1}$
モルエントロピー, モル熱容量	ジュール毎モル毎ケルビン	J/(mol K)	$m^2\ kg\ s^{-2}\ K^{-1}\ mol^{-1}$
照射線量（X線及びγ線）	クーロン毎キログラム	C/kg	$kg^{-1}\ sA$
吸収線量率	グレイ毎秒	Gy/s	$m^2\ s^{-3}$
放射強度	ワット毎ステラジアン	W/sr	$m^4\ m^{-2}\ kg\ s^{-3}=m^2\ kg\ s^{-3}$
放射輝度	ワット毎平方メートル毎ステラジアン	$W/(m^2\ sr)$	$m^2\ m^{-2}\ kg\ s^{-3}=kg\ s^{-3}$
酵素活性濃度	カタール毎立方メートル	kat/m^3	$m^{-3}\ s^{-1}\ mol$

表８．SIに属さないが、SIと併用されるその他の単位

名称	記号	SI 単位で表される数値
バール	bar	$1\ bar=0.1MPa=100kPa=10^5Pa$
水銀柱ミリメートル	mmHg	1mmHg=133.322Pa
オングストローム	Å	$1\ Å=0.1nm=100pm=10^{-10}m$
海里	M	1 M=1852m
バーン	b	$1\ b=100fm^2=(10^{-12}cm)2=10^{-28}m^2$
ノット	kn	1 kn=(1852/3600)m/s
ネーパ	Np	SI単位との数値的な関係は、対数量の定義に依存。
ベル	B	
デジベル	dB	

表９．固有の名称をもつCGS組立単位

名称	記号	SI 単位で表される数値
エルグ	erg	$1\ erg=10^{-7}\ J$
ダイン	dyn	$1\ dyn=10^{-5}N$
ポアズ	P	$1\ P=1\ dyn\ s\ cm^{-2}=0.1Pa\ s$
ストークス	St	$1\ St=1cm^2\ s^{-1}=10^{-4}m^2\ s^{-1}$
スチルブ	sb	$1\ sb=1cd\ cm^{-2}=10^4cd\ m^{-2}$
フォト	ph	$1\ ph=1cd\ sr\ cm^{-2}\ 10^4lx$
ガル	Gal	$1\ Gal=1cm\ s^{-2}=10^{-2}ms^{-2}$
マクスウェル	Mx	$1\ Mx=1G\ cm^2=10^{-8}Wb$
ガウス	G	$1\ G=1Mx\ cm^{-2}=10^{-4}T$
エルステッド(c)	Oe	$1\ Oe \triangleq (10^3/4\pi)A\ m^{-1}$

（c）３元系のCGS単位系とSIでは直接比較できないため、等号「 ≙ 」は対応関係を示すものである。

表10．SIに属さないその他の単位の例

名称	記号	SI 単位で表される数値
キュリー	Ci	$1\ Ci=3.7\times10^{10}Bq$
レントゲン	R	$1\ R=2.58\times10^{-4}C/kg$
ラド	rad	$1\ rad=1cGy=10^{-2}Gy$
レム	rem	$1\ rem=1\ cSv=10^{-2}Sv$
ガンマ	γ	1γ=1 nT=10-9T
フェルミ		1フェルミ=1 fm=10-15m
メートル系カラット		1メートル系カラット = 200 mg = 2×10-4kg
トル	Torr	1 Torr = (101 325/760) Pa
標準大気圧	atm	1 atm = 101 325 Pa
カロリー	cal	1cal=4.1858J（「15℃」カロリー），4.1868J（「IT」カロリー）4.184J（「熱化学」カロリー）
ミクロン	µ	$1\ \mu=1\mu m=10^{-6}m$

（第8版，2006年改訂）