



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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OFFICE OF
AIR AND RADIATION

Mr. Jose R. Franco, Manager
Carlsbad Field Office
U.S. Department of Energy
P.O. Box 3090
Carlsbad, New Mexico 88221-3090

Dear Mr. Franco:

The U.S. Environmental Protection Agency is continuing with its completeness review of the U.S. Department of Energy's (DOE) 2014 Compliance Recertification Application (CRA-2014) for the Waste Isolation Pilot Plant. This letter transmits the third set of Agency completeness comments and questions (see Enclosure). We request that DOE respond in a timely manner. If you have any questions concerning this request, please have your staff contact Kathleen Economy at (202) 343-9844 or economy.kathleen@epa.gov.

Sincerely,

Jonathan D. Edwards
Director
Radiation Protection Division

Enclosure: Third Set of CRA 2014 Completeness Questions

- cc: Electronic Distribution
- George Basabilvazo, DOE/CBFO
- Russ Patterson, DOE/CBFO
- Frank Marcinowski, DOE/HQ
- Doug Tonkay, DOE/HQ
- Alton Harris, DOE/HQ
- Ricardo Maestas, NMED
- Nick Stone, EPA Region 6
- EPA WIPP Team
- EPA WIPP Docket

UNIQUE #	DOE UFC	DATE REC'VD	ADDRESSEES
5486.00	1501351	JUN 12 2015	J. Franco See list on back

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D. Bryson ✓	B. Carlsen ✓	R. Salness ✓
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J.R. Stroble ✓	K. Urquidez ✓	
C. Gadbury ✓	R. Patterson ✓	

THIRD SET OF EPA COMPLETENESS COMMENTS FOR CRA 2014

3-C-1. Assumed Plutonium Oxidation State. The Pu oxidation state assumed for Performance Assessment (PA) is important because significantly higher brine solubilities are predicted for Pu(III) than for Pu(IV). In Appendix SOTERM Section 3.6.2, results from recent long-term experiments with aqueous Pu and iron are presented in which the predominant long term aqueous oxidation state was Pu(III). Other recent studies also have indicated that Pu(IV) is reduced to Pu(III) in the presence of reduced iron (Altmaier et al. 2009, Felmy et al. 2011, Felmy et al. 2012, Kirsch et al. 2011). Plymale et al. (2012) determined that Pu(IV) solids in contact with solutions containing chelating agents such as EDTA can undergo reductive dissolution to Pu(III) by either biotic or abiotic mechanisms. Appendix SOTERM states that “The predominance of Pu(III) at long times provides a strong data point on the reducing conditions that iron creates under WIPP-relevant conditions, but does not account for radiolytic impacts on Eh, and the effects of organic complexation which will stabilize Pu(IV) relative to Pu(III).” Assuming that radiolysis will affect the Pu oxidation state in WIPP repository brines conflicts with the peer-reviewed Chemical Conditions conceptual model assumption that radiolysis will not affect the oxidation-reduction conditions in the repository (SCA 2008). In addition, EDTA, which is present in the WIPP inventory, has been shown to cause reduction of Pu(IV) to Pu(III) rather than to stabilize Pu(IV) (e.g., Boukhalfa et al. 2007, Plymale et al. 2012).

Currently, Pu(III) is the assumed oxidation state for 50% of PA realizations and Pu(IV) is the assumed oxidation state for the other 50% of PA realizations. Because of recent data showing that Pu(IV) reduction to Pu(III) may be more likely than previously assumed, DOE must provide an assessment of all currently available data relevant to the assumed Pu oxidation state for PA. If the current Pu oxidation states assumption is inconsistent with the available data, DOE must provide an analysis that supports a higher proportion of Pu(III) in the PA realizations and include this higher proportion of Pu(III) in PA.

Altmaier, M., V. Neck, J. Lützenkirchen and T. Fanghänel. 2009. Solubility of plutonium in MgCl₂ and CaCl₂ solutions in contact with metallic iron. *Radiochimica Acta* 97:187-192.

Boukhalfa, H., G.A. Icopini, S.D. Reilly, and M.P. Neu. 2007. Plutonium (IV) reduction by the metal-reducing bacteria *Geobacter metallireducens* GS15 and *Shewanella oneidensis* MR1. *Applied and Environmental Microbiology* 73:5897-5903.

Felmy, A.R., D.A. Moore, K.M. Rosso, O. Qafoku, D. Rai, E.C. Buck and E. S. Ilton. 2011. Heterogeneous reduction of PuO₂ with Fe(II): importance of the Fe(III) reaction product. *Environmental Science and Technology* 45:3952-3958.

Felmy, A.R., D.A. Moore, C.I. Pearce, S.D. Conradson, O. Qafoku, E.C. Buck, K.M. Rosso and E.S. Ilton. 2012. Controls on soluble Pu concentrations in PuO₂/Magnetite Suspension. *Environmental Science and Technology* 46:11610-11617.

Kirsch, R., D. Fellhauer, M. Altmaier, V. Neck, A. Rossberg, T. Fanghänel, L. Charlet and A.C. Scheinost. 2011. Oxidation state and local structure of plutonium reacted with magnetite, mackinawite and chukanovite. *Environmental Science and Technology* 45:7267-7274.

Plymale A.E., V.L. Bailey, J.K. Fredrickson, S.M. Heald, E.C. Buck, L. Shi, Z. Wang, C.T. Resch, D.A. Moore and H. Bolton. 2012. Biotic and abiotic reduction and solubilization of Pu(IV)O₂•H₂O(am) as affected by anthraquinone-2,6-disulfonate (AQDS) and ethylenediaminetetracetate (EDTA). *Environmental Science and Technology* 46:2132-2140.

SCA (S. Cohen and Associates). 2008. Verification of the Waste Isolation Pilot Plant Chemistry Conceptual Models. Prepared for the U.S. Environmental Protection Agency Office of Radiation and Indoor Air, September 2008.

3-C-2. Boron Species in WIPP Brine. The Compliance Certification Application (CCA) and CRA-2004 refer to the presence of boric acid [B(OH)₃] in WIPP brine. However, the CRA-2009 (Appendix SOTERM, Table SOTERM-2) and CRA-2014 (Appendix SOTERM, Table SOTERM-4) indicate that “boron species will be present in brine as boric acid, hydroxyl polynuclear forms (B₃O₃(OH)₄⁻), and/or borate forms (e.g., B₄O₇²⁻).” Borkowski et al. (2010a) indicates that tetraborate is present in WIPP brine and Borkowski et al. (2010b) determined the stability complex and Pitzer coefficients for the neodymium(III)-tetraborate aqueous species. Lucchini (2013) refers to tetraborate in WIPP brines during comparisons of measured and modeled brine compositions. Consequently, there appears to have been an evolution in the assumed boron species in WIPP brines since the CCA. Because complexation by tetraborate has been identified as important for actinide(III) speciation in WIPP brines (Borkowski et al. 2010b), DOE must identify all expected chemical constituents that contain boron species in WIPP brines. The basis for that determination must be included.

Borkowski, M., J.-F. Lucchini, M.K. Richmann and D.T. Reed. 2010a. Actinide(III) Solubility in WIPP Brine: Data Summary and Recommendations. Los Alamos National Laboratory, LCO-ACP-08, Rev 0.

Borkowski, M., M. Richmann, D. Reed and Y. Xiong. 2010b. Complexation of Nd(III) with Tetraborate Ion and Its Effect on Actinide(III) Solubility in WIPP Brine. *Radiochimica Acta* 98:577-582.

Lucchini, J.-F. 2013. WIPP Actinide-Relevant Brine Chemistry. Los Alamos National Laboratory, LCO-ACP-15, Rev. 0.

3-C-3. Adequacy of EQ3/6 Database. The actinide solubility and aqueous speciation data in the EQ3/6 database DATA0.FM1 was last updated using data available in 2002 (Giambalvo 2003, Nowak 2005). Since 2002, relevant data have been developed in investigations carried out by WIPP investigators and by outside researchers. The absence of an update to the EQ3/6 database despite more than a decade of potentially relevant new data leads to the following observations:

- In CRA-2014 Appendix SOTERM Sections 3.3 and 3.7, DOE reviewed the chemistry of thorium and americium, respectively, including data that has become available since the last EQ3/6 database update. However, these data (such as Neck et al. 2002, Neck et al. 2003, Altmaier et al. 2004, Altmaier et al. 2005, Altmaier et al. 2006, Borkowski et al. 2012, Neck et al. 2009) were not used to revise the EQ3/6 database.
- Xiong (2011) experimentally determined the solubilities of natural and synthetic hydromagnesite samples and calculated a different solubility for synthetic hydromagnesite than the solubility in the EQ3/6 database. An assessment was not provided in the CRA of the possible effects of this different solubility on CO₂ fugacities, calculated pH values and actinide solubilities in WIPP repository brines.
- Borkowski et al. (2010) determined the stability constant for the neodymium-tetraborate aqueous species and also calculated Pitzer ion-interaction parameters. These data were not incorporated into the EQ3/6 database, even though WIPP brines contain borate, boric acid or hydroxyl polynuclear species and complexation of the +III actinides by tetraborate could increase solubilities modeled for PA.
- Thakur et al. (2014) determined a β^0_{101} for AmEDTA⁻ (20.55) that differs from the value in DATA0.FM1 (18.97). Because AmEDTA⁻ is the predominant Am(III) aqueous species in WIPP brines, the β^0_{101} for AmEDTA⁻ could significantly affect aqueous Am speciation and solubilities, but the revised value was not included in the EQ3/6 database.

DOE maintained at the time of the CRA-2009 PABC that the effects of not updating the EQ3/6 database with new data available at that time were conservative, because higher actinide solubilities would be predicted using the unrevised database. However, the cumulative effects of the new data that are now available may be non-conservative and must be quantitatively evaluated. DOE must: 1) carry out and document a thorough review of all available +III and +IV actinide aqueous speciation and solubility data and hydromagnesite solubility data; 2) use the results of this review to defensibly update the EQ3/6 database; and 3) use this revised database to recalculate the actinide solubilities and associated uncertainty distributions for PA. DOE must provide the documentation of these components as part of the CRA.

Altmaier, M., V. Neck and T. Fanghänel. 2004. Solubility and colloid formation of Th(IV) in concentrated NaCl and MgCl₂ solution. *Radiochimica Acta* 92:537-543.

Altmaier, M., V. Neck, M.A. Denecke, R. Yin and T. Fanghänel. 2006. Solubility of ThO₂•xH₂O(am) and the formation of ternary Th(IV) hydroxide-complexes in NaHCO₃-Na₂CO₃ solutions containing 0-4 M NaCl. *Radiochimica Acta* 94:495-500.

Altmaier, M., V. Neck, R. Müller and T. Fanghänel. 2005. Solubility of ThO₂•xH₂O(am) in carbonate solution and the formation of ternary Th(IV) hydroxide-carbonate complexes. *Radiochimica Acta* 93:83-92.

Borkowski, M., M. Richmann, D.T. Reed and Y. Xiong. 2010. Complexation of Nd(III) with tetraborate ion and its effect on actinide(III) solubility in WIPP brine. *Radiochimica Acta* 98:577-582.

Borkowski, M., M. Richmann and J.F. Lucchini. 2012. Solubility of An(IV) in WIPP brine: thorium analog studies in WIPP simulated brine. Los Alamos National Laboratory LCO-ACP-17.

Giambalvo, E.R. 2003. Release of FMT Database FMT_021120.CHEMDAT. Memorandum to L.H. Brush, March 10, 2003, ERMS 526372.

Neck, V., M. Altmaier, R. Müller, A. Bauer, T. Fanghänel and J.I. Kim. 2003. Solubility of crystalline thorium dioxide. *Radiochimica Acta* 91:253-262.

Neck, V., M. Altmaier, T. Rabung, J. Lützenkirchen and T. Fanghänel. 2009. Thermodynamics of trivalent actinides and neodymium in NaCl, MgCl₂, and CaCl₂ solutions: solubility, hydrolysis, and ternary Ca-M(III)-OH complexes. *Pure and Applied Chemistry* 81:1555-1568.

Neck, V., R. Müller, M. Bouby, M. Altmaier, J. Rothe, M.A. Denecke, and J.I. Kim. 2002. Solubility of Amorphous Th(IV) Hydroxide-Application of LIBD to Determine the Solubility Product and EXAFS for Aqueous Speciation. *Radiochimica Acta* 90:485-494.

Nowak, E.J. 2005. Recommended Change in the FMT Thermodynamic Data Base. Memorandum to L.H. Brush, April 1, Sandia National Laboratories, Carlsbad, New Mexico, ERMS 539227.

Thakur, P., Y. Xiong, M. Borkowski and G.R. Choppin. 2014. Improved thermodynamic model for interaction of EDTA with trivalent actinides and lanthanide to ionic strength of 6.60 m. *Geochimica et Cosmochimica Acta* 133:299-312.

Xiong, Y. 2011. Experimental determination of solubility constant of hydromagnesite (5424) in NaCl solutions up to 4.4 m at room temperature. *Chemical Geology* 284:262-269.

3-C-4. Exclusion of Experimental Data with Borate from Am(III) Solubility Uncertainty Analysis. Brush and Domski (2013) used their Criterion G-9 to select data for the actinide solubility uncertainty analysis; Criterion G-9 specifies that experimental solubility data should be excluded if the solutions contained dissolved elements or species for which μ^0/RT ¹ data or Pitzer parameters were not included in the EQ3/6 database (DATA0.FM1). The application of this criterion was reasonable when the experiments included species that are not present in the WIPP repository, for example, when it was used to exclude the Th(IV) experimental data of Colás et al. (2011) because of gluconate in the experimental solutions. However, Brush and Domski (2013)

¹ The μ^0/RT value is used in the FMT database, but log K is used in the EQ3/6 database, so Criterion G-9 should cite the log K value

used the presence of borate in GWB and ERDA-6 to exclude solubility data that were obtained in mildly basic WIPP brines. The undeclared assumption for this exclusion would be an admission that the current Am(III) model is inadequate for predicting solubilities in WIPP brines at anticipated repository p_H values. A revised uncertainty analysis for Am(III) must be performed by DOE after the following items have been completed: 1) The Am(III)-tetraborate stability constant and Pitzer parameter data have been incorporated and other appropriate updates have been made to the EQ3/6 database (which satisfy Comments 3-C-3 and 3-C-4) and, 2) Solubility data obtained in mildly basic WIPP brines, such as the Khalili et al. (1994) solubility results have been included in the database.

Brush L.H., and P.S. Domski. 2013. Uncertainty analysis of actinide solubilities for the WIPP CRA-2014 PA, Rev. 1. Supersedes ERMS 559278.

Colás, E., M. Grivé, I. Roho and L. Duro. 2011. Solubility of ThO₂•xH₂O(am) in the presence of gluconate. *Radiochimica Acta* 99:269-273.

Khalili, F.I., V. Symeopoulos, J.-F. Chen and G.R. Choppin. 1994. Solubility of Nd in brine. *Radiochimica Acta* 66/67:51-55.

3-C-5. Am(III) Solubility Uncertainty Distribution. Brush and Domski (2013) used 172 solubility measurements to determine the Am(III) solubility uncertainty distribution:

- 109 values from Borkowski et al. (2009)
- 56 values from Neck et al. (2009)
- 6 values from Runde and Kim (1995)
- 1 value from Rao et al. (1999)

Consequently, the majority of the solubility measurements used to calculate the Am(III) solubility uncertainty distribution were from Borkowski et al. (2009). Brush and Domski (2013) established Criterion G7 for the selection of data for actinide solubility uncertainty analysis; Criterion G7 states that experimental results should be included only if the solubility-controlling solid phase was characterized. As previously noted during review of the PABC-2009 (EPA 2010), inclusion of the Nd(III) solubility data from Borkowski et al. (2009) in the uncertainty analysis is inconsistent with Criterion G7 because only indirect means were used to characterize the solid phases. In fact, modeling calculations carried out during the PABC-2009 review predicted different solid phases than those indirectly determined under some conditions (EPA 2010). As previously observed in the Technical Support Document for the CRA-2009 PABC (EPA 2010), including the Borkowski et al. (2009) data in the uncertainty evaluation significantly decreased the mean concentration of the +III actinides used in PA and will lead to non-conservative predicted +III actinide concentrations. DOE must exclude the Borkowski et al. (2009) data when the Am(III) uncertainty distribution is recalculated after completion of the EQ3/6 database update (see Comment 3-C-3, above).

Borkowski, M., J.-F. Lucchini, M.K. Richmann and D.T. Reed. 2009. Actinide (III) Solubility in WIPP Brine, Data Summary and Recommendations. Los Alamos National Laboratory, LCO-ACP-08, LA-14360.

Brush L.H., and P.S. Domski. 2013. Uncertainty analysis of actinide solubilities for the WIPP CRA-2014 PA, Rev. 1. Supersedes ERMS 559278.

EPA (U.S. Environmental Protection Agency). 2010. Technical Support Document for Section 194.24, Evaluation of the Compliance Recertification Actinide Source Term, Backfill Efficacy and Culebra Dolomite Distribution Coefficient Values (Revision1), Docket A-98-49, Item II-B1-25, November 2010.

Neck, V., M. Altmaier, T. Rabung, J. Lützenkirchen and T. Fanhänel. Thermodynamics of trivalent actinides and neodymium in NaCl, MgCl₂, and CaCl₂ solutions: Solubility, hydrolysis, and ternary Ca-M(III)-OH complexes. *Pure and Applied Chemistry* 81:1555-1568.

Rao, L., D. Rai, A.R. Felmy and C.F. Novak. 1999. Solubility of NaNd(CO₃)₃•6H₂O(c) in mixed electrolyte (Na-Cl-CO₃-HCO₃) and synthetic brine solutions. In *Actinide Speciation in High Ionic Strength Media: Experimental and Modeling Approaches to Predicting Actinide Speciation and Migration in the Subsurface*. Proceedings of an American Chemical Society Symposium on Experimental and Modeling Studies of Actinide Speciation in Non-Ideal Systems. Held August 26-28, 1996 in Orlando, Florida. Eds. D.T. Reed, S.B. Clark and L. Rao. Kluwer Academic/Plenum Publishers, pp. 153-169.

Runde, W., and J.I. Kim. 1995. Untersuchungen der Übertragbarkeit von Labordaten Natürliche Verhältnisse: Chemisches Verhalten von Drei- und Fünfwertigem Americium in Salinen NaCl-Lösungen (Study of the Extrapolability of Laboratory Data to Natural Conditions: Chemical Behavior of Trivalent and Pentavalent Americium in Saline NaCl Solutions). RCM-01094, Institute for Radiochemistry, Technical University of Munich, Munich, Federal Republic of Germany, ERMS 241862.

3-C-6. Magnesite Formation from MgO Carbonation. Clayton (2013, Section 2.7) states that “In the event that CO₂ generation is occurring, but brucite is not available in BRAGFLO simulations, MgO will be converted directly to magnesite.” EPA has reviewed the potential for magnesite formation in the WIPP repository directly from MgO and has repeatedly determined that hydromagnesite should be assumed to form instead of magnesite (EPA 1998, SCA 2008, EPA 2010). Correctly including the formation of hydromagnesite instead of magnesite will decrease the amount of water in the water balance calculations, which could significantly impact the amount of water in the repository. DOE must assess the effects on the water balance of incorrectly assuming magnesite formation instead of hydromagnesite in PA simulations when brucite was not available. DOE must also provide an assessment of the effects of this assumption when combined with the other assumptions summarized in Completeness Comment 2-C-3 (Edwards 2015) that also increase the amount of brine calculated for the water balance.

Clayton, D.J. 2013. Justification of Chemistry Parameters for Use in BRAGFLO for AP-164, Rev. 1. Sandia National Laboratories, ERMS 599466.

Edwards, J.D. 2015. Second Set of CRA 2014 Completeness Questions, U.S. Environmental Protection Agency Radiation Protection Division, Letter to J.R. Franco, U.S. Department of Energy Carlsbad Field Office, February 27, 2015.

EPA (U.S. Environmental Protection Agency). 2010. Technical Support Document for Section 194.24, Evaluation of the Compliance Recertification Actinide Source Term, Backfill Efficacy and Culebra Dolomite Distribution Coefficient Values (Revision1), Docket A-98-49, Item II-B1-25, November 2010.

3-C-7. Lead Inventory, Gas Generation and Water Balance. In past WIPP performance assessments, lead corrosion has been assumed to have insignificant effects on gas generation because of the relatively small amount of lead in the packaging and waste inventory (EPA 2010). However, use of shielded containers to emplace some RH waste may significantly increase the amount of lead in the repository. Van Soest (2012) provided only the RH packaging material lead inventory and this value has decreased since PAIR-2008. Please provide an estimate of the total lead that will be in the WIPP repository (waste lead plus packaging material) and the basis for that estimate, taking into account the expected increased lead from shielded containers. Based on this total lead inventory, DOE must assess whether lead corrosion may significantly affect gas generation and repository water balance.

Van Soest, G.D. 2012. Performance Assessment Inventory Report -2012. INV-PA-12, Revision 0, LA-UR-12-26643.

3-C-8. Incorrect Reference to Felmy et al. (1996) and Clark and Tait (1996). Appendix SOTERM, Section 3.6.1.1 states that “Clark and Tait (Clark and Tait 1996) and Felmy et al. (Felmy et al. 1996) have experimentally observed the reduction of Pu(VI) carbonates by either Fe^0 or Fe^{2+} to Pu(IV). However, the Felmy et al. citation refers to a study of thorium(IV) hydrous oxide solubility and Clark and Tait (1996) indicate that plutonium(VI) chloride complexes were reduced to plutonium(V) by Fe^0 or Fe^{2+} . Please provide the correct references.

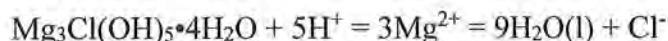
Clark, D.L., and C.D. Tait. 1996. Memorandum to Sandia WIPP Records Center (Subject:SWCF-A: 1.1.10.1.1: NQ: Actinide Source Term: LANL Monthly Reports). Sandia National Laboratories, WIPP Central File A: WBS 1.1.10.1.1. WPO 31106.

Felmy, A.R., D. Rai, S.M. Sterner, M.J. Mason and N.J. Hess. 1996. Thermodynamic models for highly charged aqueous species: solubility of Th(IV) hydrous oxide in concentrated NaHCl_3 and Na_2CO_3 solutions. Sandia National Laboratories, ERMS 240226.

3-C-9. Intrinsic Colloid Parameter Values. The concentration (CONCINT) used for intrinsic plutonium colloids in either the Pu(III) or Pu(IV) oxidation state in the actinide source term

model was 1×10^{-9} M in the CCA PAVT, the CRA-2004 PABC and the CRA-2009 PABC. This intrinsic plutonium colloid concentration was an upper limiting value based on the detection limit in experiments conducted for the CCA (CCA Appendix SOTERM). The revised intrinsic colloid enhancement parameters used in the CRA-2014 PA do not appear to be bounding values. For example, the revised value of CONCINT for thorium(IV) is based on a single experimental data point (pH 9.1) selected from a group of experiments because this particular experiment had the lowest concentration and was deemed closest to long-term equilibrium (Reed et al. 2013). In addition, the revised americium(III) CONCINT value is 4×10^{-9} M based on the average concentration in ERDA-6 experiments, even though higher concentrations were observed in GWB experiments. DOE must demonstrate that all of the CONCINT parameters used in PA represent upper bounding values based on the available experimental data.

3-C-10. Phase 5 Solubility in DATA0.FM1. EQ3/6 database version DATA0.FMT.R1 was reviewed and accepted during the EQ3/6 code evaluation (SCA 2011, Appendix A). The database used for the WIPP CRA-2014 EQ3/6 actinide solubility calculations was DATA0.FM1 (DATA0.FMT.R2). Xiong (2011) documented that the only difference between DATA0.FMT.R1 and DATA0.FM1 is the addition of data for magnesium chloride hydroxide hydrate [$\text{Mg}_3\text{Cl}(\text{OH})_5 \cdot 4\text{H}_2\text{O}$, Phase 5], citing Xiong et al. (2010) as the data source. Both Xiong et al. (2009) and Xiong et al. (2010) report a log K of 43.21 ± 0.33 at 25°C for the reaction:



However, the data for this solid in DATA0.FM1 includes a log K at 25°C of 42.96. DOE must explain this small difference between the log K values in the documentation and the database.

SCA. (S. Cohen and Associates). 2011. EQ3/6 Computer Code Evaluation. Prepared for U.S. Environmental Protection Agency Office of Radiation and Indoor Air. Draft March 2011.

Xiong, Y.-L. 2011. Release of EQ3/6 Database DATA0.FM1. Email to J.J. Long, March 9, 2011. ERMS 555152.

Xiong, Y.-L., H.-R. Deng, M. Nemer and S. Johnsen. 2009. Thermodynamic Data for Phase 5 ($\text{Mg}_3\text{Cl}(\text{OH})_5 \cdot 4\text{H}_2\text{O}$) Determined from Solubility Experiments. Memorandum to L. Brush, Sandia National Laboratories, May 18, 2009. ERMS 551294.

Xiong, Y.-L., H.-R. Deng, M. Nemer and S. Johnsen. 2010. Experimental determination of the solubility of magnesium chloride hydroxide hydrate ($\text{Mg}_3\text{Cl}(\text{OH})_5 \cdot 4\text{H}_2\text{O}$, phase 5) at room temperature, and its importance to nuclear waste isolation in geological repositories in salt formations. *Geochimica et Cosmochimica Acta* 74:4605-4611.

3-C-11. Appendix SOTERM Typographical Errors/Errata. Section SOTERM-3.6.1.3, Page SOTERM-67, line 3; Section SOTERM-3.5.1.1 and Section SOTERM-3.5.1.2 should be Section SOTERM-3.6.1.1 and Section SOTERM-3.6.1.2

Appendix SOTERM, Section SOTERM-6.0 References: The correct date for the following reference is 2010: Reed, D.T., J.-F. Lucchini, M. Borkowski, and M.K. Richmann. ~~2009~~2010. Reduction of Higher Valent Plutonium by Iron under Waste Isolation Pilot Plant (WIPP)-Relevant Conditions: Data Summary and Recommendations. LCO-ACP-09, LANL\ACRSP Report. Los Alamos, NM: Los Alamos National Laboratory.

