The Case For and Against a Gadolinium Bias in SCALE: Opening Arguments

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Outline

• HST-014 and HST-016
  – Brief description and ICSBEP sample results
  – SCALE 6.1 validation report, including S/U analysis
  – SCALE 6.2.2 validation report

• MST-007 & HTC Phase 2 results

• Where are we and where are we going?
HST-014 and HST-016

- HST-014 through HST-019 are experiments from IPPE (Russia)
- Uranyl nitrate of varying uranium concentration
- Three cases for each uranium concentration with no Gd, some Gd, and more Gd dissolved in solution
- ICSBEP sample results show discrepancy between calculated and expected values (C/E ratio) increasing with Gd concentration
- Models were built in SCALE 6 and added to VALID in July, 2009
- HST-016-003 identified as outlier in Sedat’s paper on CE KENO validation in 2010
Sample results from ICSBEP Handbook
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SCALE 6.1 Validation Report

- Strong bias as a function of Gd concentration identified in SCALE 6.1 validation report (Marshall and Rearden)
- No other cases in VALID at the time contained soluble Gd
- Is it the code, the data, or the experiments?
- Calculated $k_{\text{eff}}$ sensitivities indicated an ~16% error in $^{157}\text{Gd}$ capture cross section to explain discrepancy
  - Estimated uncertainty is ~3% or less in SCALE 6.1 covariance library for energy range of $^{157}\text{Gd}$ sensitivity
SCALE 6.1 HST Results (Fig. 4 from ORNL/TM-2011/450)
Integral (n,γ) sensitivity is -0.156 for HST-016-003, and uncertainty is less than 5% over energy range where all sensitivity resides.

A 2% change in cross section is therefore 
\[ -0.156 \times 0.02 = 0.0031 \Delta k. \]

C/E however is 1.02428

Is cross section off by almost 8 sigma?
Adding SCALE 6.2.2 validation results

• ENDF/B-VII.1 & VII.0 nearly identical despite new \textsuperscript{157}Gd evaluation

• Can this many different codes and cross section sets show the same bad behavior?

• What about other experiments?
MST-007 and HTC Phase 2

• MIX-SOL-THERM-007 has soluble gadolinium over a wider concentration range than HST-014 and HST-016
  – Possible that a Pu evaluation error could impact results

• HTC Phase 2 has several experiments with soluble gadolinium
  – Lattices instead of solutions
  – Proprietary experiments not in the ICSBEP Handbook
    • Available to US nationals under an NDA from ORNL for some purposes
  – Not in VALID, but reviewed internally during development NUREG/CR-7109
All results now

- SCALE 6.2.2 with CE KENO and ENDF/B-VII.1
- Uncertainties in Gd concentration also shown
- No clear bias in MST-007 results
- Maybe a slight negative bias in HTC results?
Where are we now?

• Two related experiment series indicate a large bias in $^{157}\text{Gd}$ capture cross section
  – S/U analysis indicates that $^{157}\text{Gd}$ is an unlikely source of the bias

• Two other experiment series do not support existence of large positive bias

• Data adjustment analyses (e.g., TSURFER) consistently reject HST-014 and HST-016 as experiments with inconsistent results

• Data community has had discussions about what to do with these experiments
Where are we going?

• ORNL would like to perform additional validation for soluble Gd systems
  – More systems are available on the ICSBEP Handbook
  – DICE says 172 cases have soluble gadolinium, of which 13 are in VALID
  – Adding more just takes time, money, and people

• Can comparison of results from modern codes & cross sections be used to demonstrate that the experiment evaluation is the problem?
  – Current effort at IRSN
That’s it – any questions?