Sensitivity of selected benchmarks to Cr-53 and Cr-50 capture

Andrej Trkov, Oscar Cabellos and Roberto Capote

January 2018

Measurements of kinf are highly sensitive to the capture cross section. Despite the large corrections from calculations and the large associated uncertainties, they are nevertheless useful for data validation. The k_{inf} benchmarks show much larger discrepancies between evaluated data libraries. The largest discrepancies seem to arise with chromium and are similar in all libraries. The case with a stainless-steel reflector is most likely over-predicted for the same reason, due to the Cr data.

The HISS experiment (HEU-COMP-INTER-004) for ^{235}U and the KBR series of experiments (HEU-COMP-INTER-005) for the structural materials are listed below. The stainless-steel KBR-09(SS) benchmark and the chromium KBR-15(Cr) benchmarks contain relatively large amount of chromium in the measured sample, as shown in the Table below. However, the stainless-steel fuel can and tubing also contain chromium, which affects all benchmarks of the series. The differences in the calculated k_{eff} from the reference benchmark values are shown in Fig. 1.

Table: Composition in weight percent of the measured samples in different cases.

	KBR-07(Ni)	KBR-09(SS)	KBR-10(Mo)	KBR-15(Cr)	KBR-16(Zr)
Fe	-	69.8	-	.16	-
Ni	99.9	10.2	-	-	-
Mn	-	1.2	-	-	-
Mo	-	-	100.	-	-
Cr	-	17.6	-	99.23	-
Zr	-	-	-	-	99.95

The capture cross sections of ^{53}Cr differ strongly in different evaluated data libraries, as seen from Fig.2. The capture cross section in BROND-3.1 was renormalized to the preliminary measurements by Guber (as compiled in EXFOR from ND2013 publication) and are significantly higher compared to other libraries. The final published capture cross section data by Guber were lower, and were used in ENDF/B-VIII.0 evaluation. The cross sections for ^{50}Cr adopt the same resonance parameters, so there is no impact due to the substitution of ^{50}Cr data between different libraries. The capture cross sections of the Cr isotopes are shown on Fig.3. The evaluation of the resonance parameters of the minor Cr isotopes is difficult because the resonances of ^{50}Cr and ^{53}Cr near 5 keV overlap; one should also note the strong resonance of ^{52}Cr just below 2 keV.

It is interesting to note that substituting the BROND-3.1 data for ^{50,53}Cr into the e80b6 library greatly reduces the discrepancy between the calculated and the benchmark k_{inf} in the KBR benchmarks (the HISS benchmark contains no chromium). However, the real effect probably is driven both by Cr-50 and Cr-53 data as the new evaluation of Cr-53 data alone does not improve the benchmarks.

No.	ICSBEP label	Short name	Common name
1	HEU-COMP-INTER-004	hci004	HISS
2	HEU-COMP-INTER-005	hci005-007	KBR-07(Ni)
3	HEU-COMP-INTER-005	hci005-009	KBR-09(SS)
4	HEU-COMP-INTER-005	hci005-010	KBR-10(Mo)
5	HEU-COMP-INTER-005	hci005-015	KBR-15(Cr)
6	HEU-COMP-INTER-005	hci005-016	KBR-16(Zr)

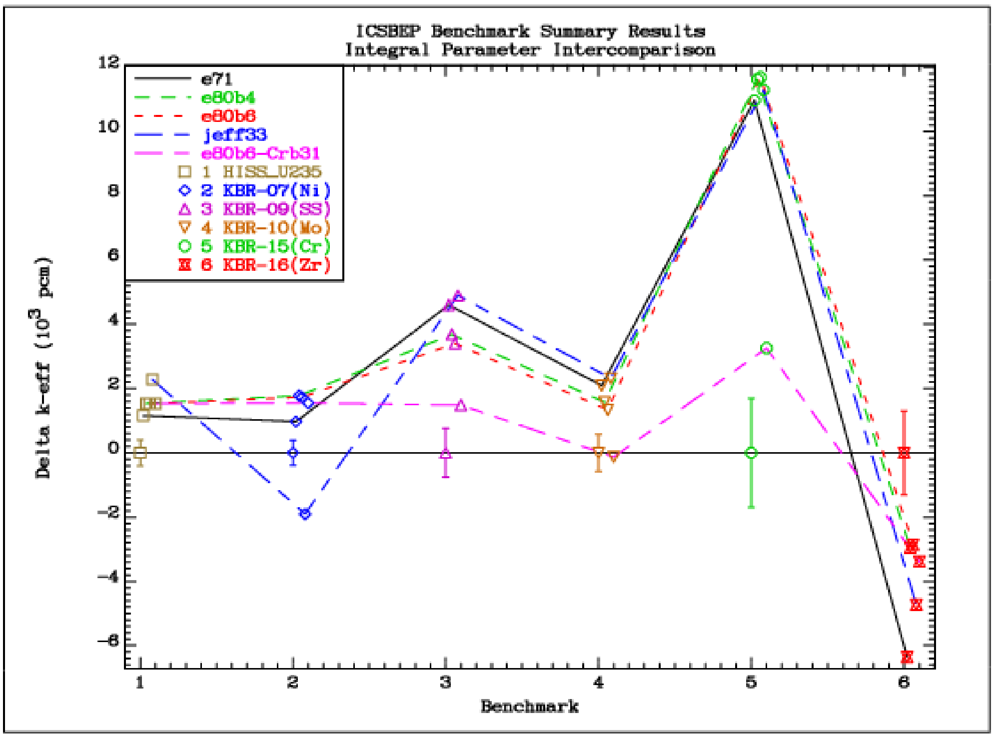

Figure 1: Comparison of the differences between the calculated k_{inf} values and the reference benchmark values for the HISS and KBR benchmarks. e80b6 results correspond to the ENDF/B-VIII.beta5 library. e80b6-Crb31 results correspond to the Brond-3.1 Cr evaluation with all other elements taken from the ENDF/B-VIII.beta5 library. A large impact of Cr data on these benchmarks is evident.

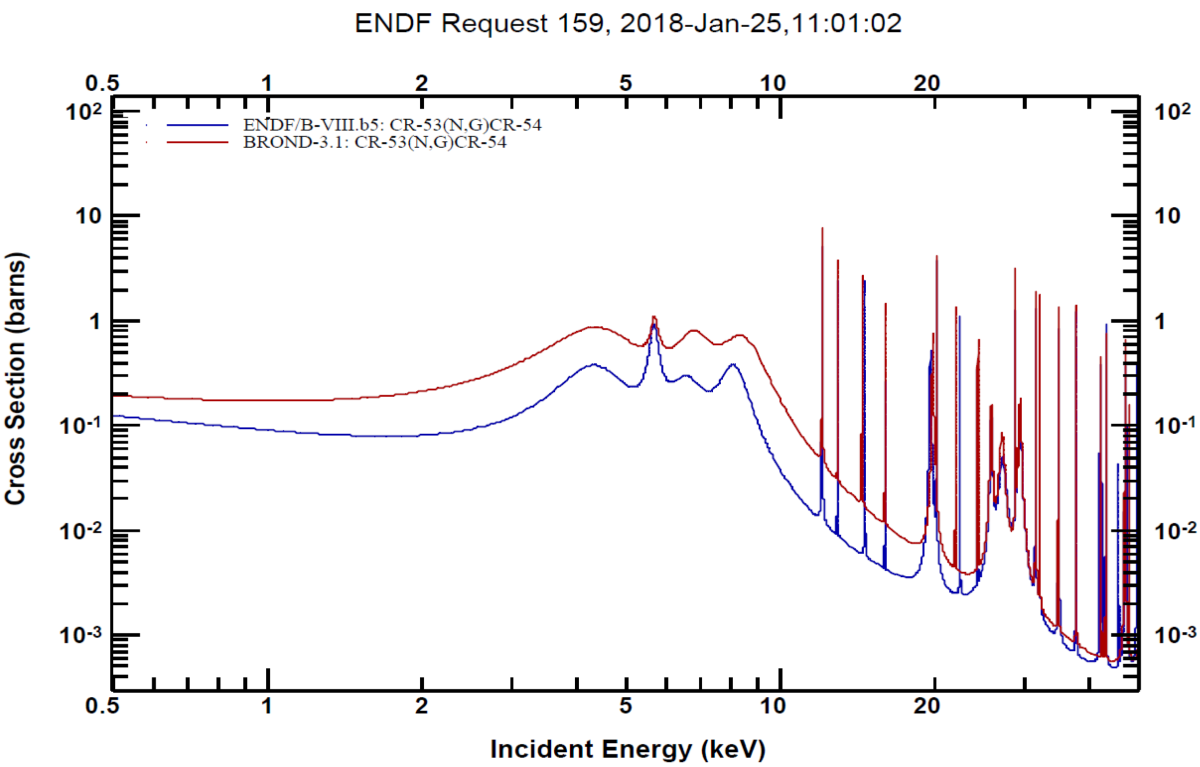

Figure 2: Comparison of the ^{53}Cr(n,g) cross sections from the ENDF/B-VIII.b5 and BROND-3.1 libraries. The Cross sections in ENDF/B-VII.1 are identical to ENDF/B-VIII.b5.

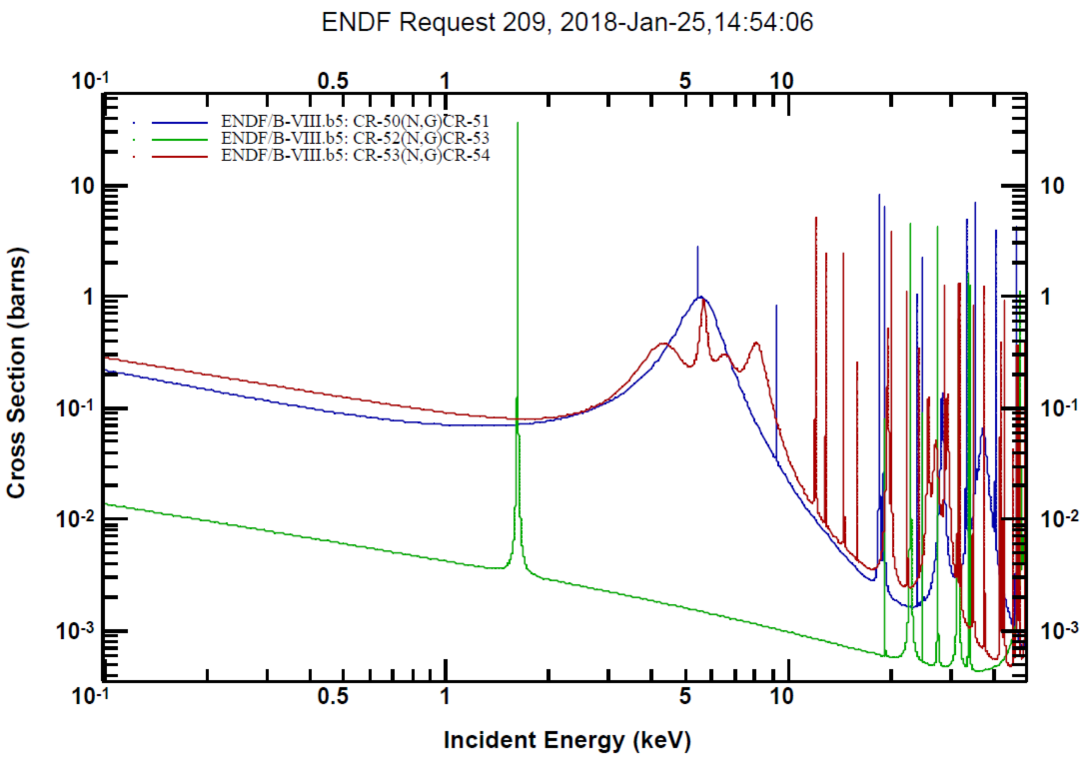

Figure 3: Comparison of the capture cross sections of ^{50,52,53}Cr isotopes from the ENDF/B-VIII.b5 library. Capture in ^{nat}Cr is dominated by capture on Cr-50 and especially Cr-53 isotope. The the sensitivity

Additionally, it should be mentioned that the sensitivity of the PMI002 benchmark to Cr-53 capture is very high (see the figure below), resulting in almost a 1% decrease in K-eff if Cr-53 evaluation is changed from B/VII.1 to BROND-3.1. A similar sensitivity to the Cr-50 capture ross section is expected, unfortunately new data and new evaluations seem needed.