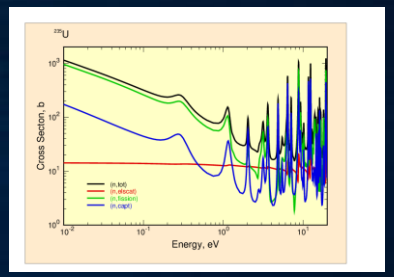
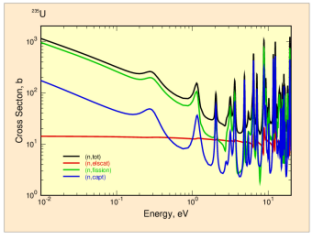


ICSBEP … more than just k_{eff}

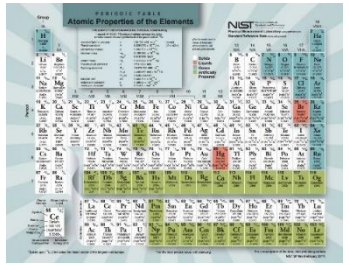
Dr. A. C. (Skip) Kahler
Kahler Nuclear Data Dervices, LLC

Presented at the
IAEA Consultant's Meeting on
International Radiation Characterization Benchmark Experiment
Project (IRCBEP)

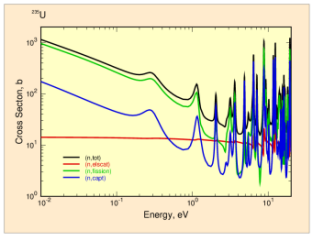
August 6 – 8, 2018
Vienna, Austria



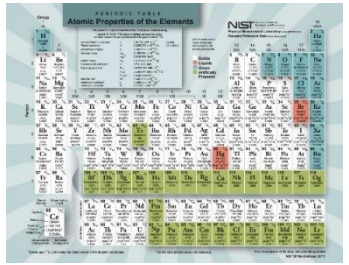
ICSBEP … a brief review



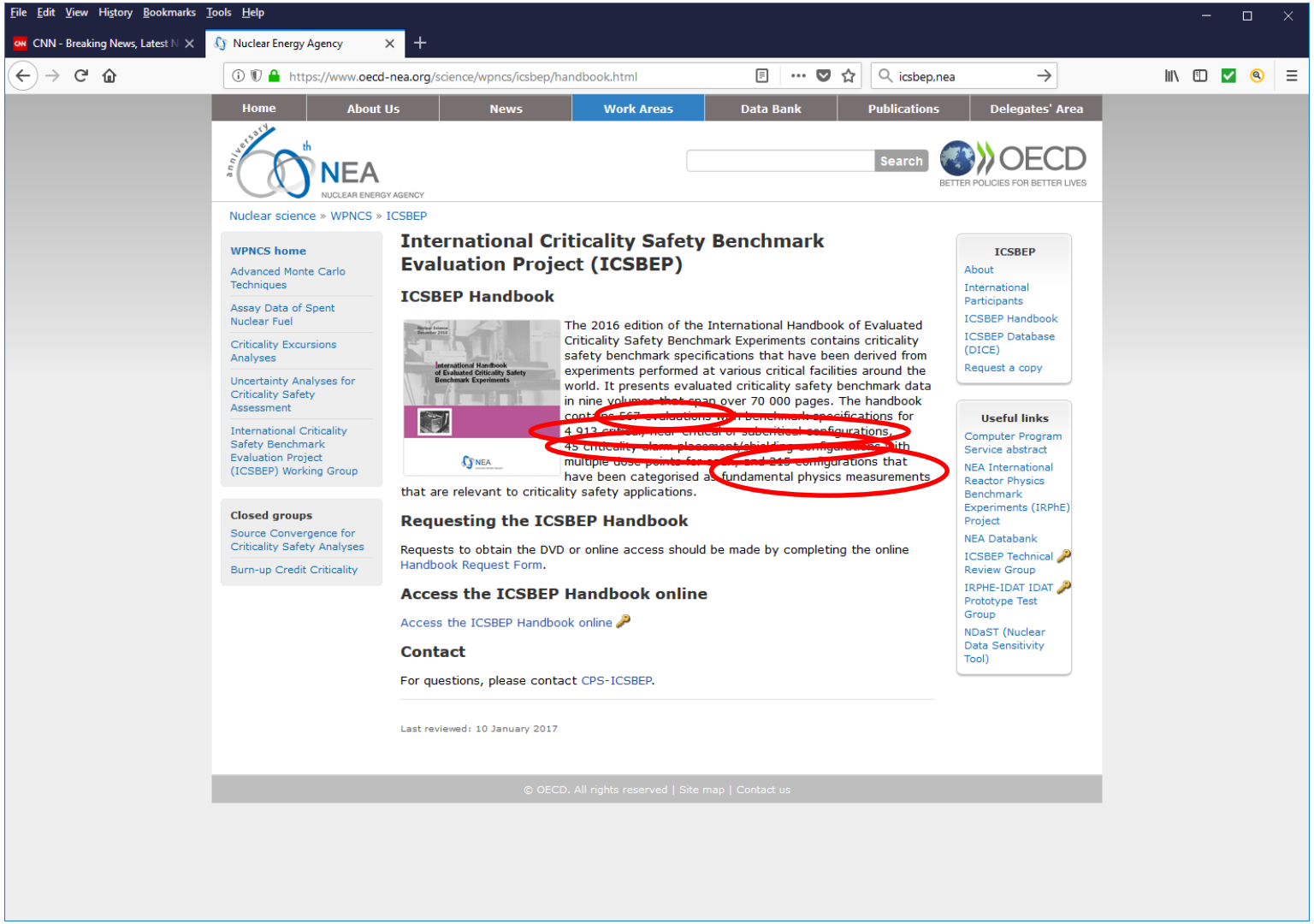
- ICSBEP = International Criticality Safety Benchmark Evaluation Project.
  - Evaluated benchmark experiment descriptions are distributed via DVD, or the web at https://www.oecd-nea.org/science/wpncs/icsbep/handbook.html.
- Started in 1992 by the US Department of Energy … CSBEP at that time.
- Expanded to include International partners in 1994; affiliated with the OECD/NEA in 1995.
- The original Handbook was published in hardcopy form … seven 3” 3-ring binders.
- Virtually all evaluated experiments are identified using a XXX-YYY-ZZZ-###.# nomenclature.
  - XXX defines the fuel … HEU, IEU, LEU, Pu, MIX (Pu-U), 233U, SPEC … one volume per fuel system.
    - HEU is ≥ 60% ^{235}U; LEU is ≤ 10% ^{235}U; rest is INTERmediate.
  - YYY is fuel form …
    - MET=metal; COMP=compound (e.g., UO_2); SOL=solution; MISC if a mixture of forms.
  - ZZZ is a average spectrum energy indicator …
    - FAST is 50% or more greater than 100 keV, THERM is 50% or more less than 0.625 eV; rest in INTERmediate; MIXED is no category is greater than 50%.
- The Handbook is updated ~annually.

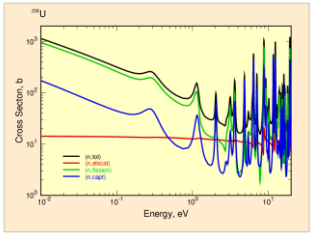


ICSBEP … a brief review

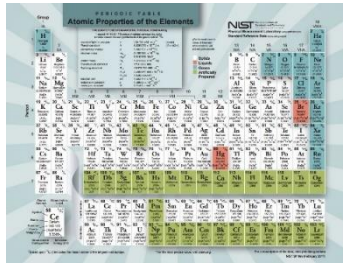


- ICSBEP = International Criticality Safety Benchmark Evaluation Project.
  - Web site at https://www.oecd-nea.org/science/wpncs/icsbep/handbook.html.
- Some Handbook statistics …
- Now nine volumes
  - Criticality alarm/Shielding (beginning in 2004).
  - Fundamental Physics (beginning in 2006).





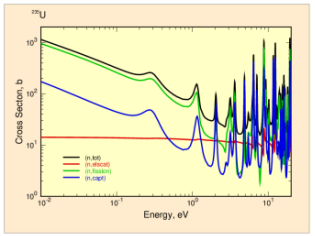
ICSBEP … a brief review



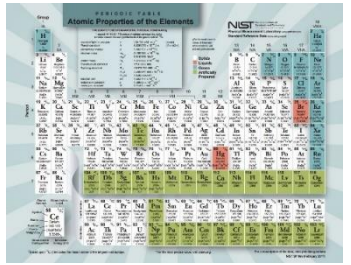
- Nine volumes, 70,000+ pages … how can you find what you want?

- (1) The old fashioned way … if you're in this meeting I'm not the first person to call you a "nerd" … and nerds love to read … so settle into comfortable chair and eNJOY yourself …

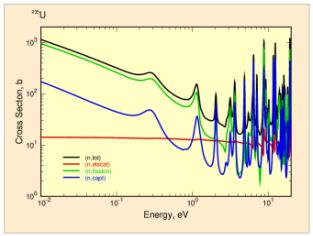
- (2) Our friends at the OECD NEA Data Bank have developed a ICSBEP database search tool … DICE.
  - DICE = Database of International Criticality Experiments



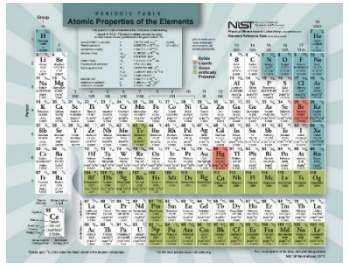
DICE …



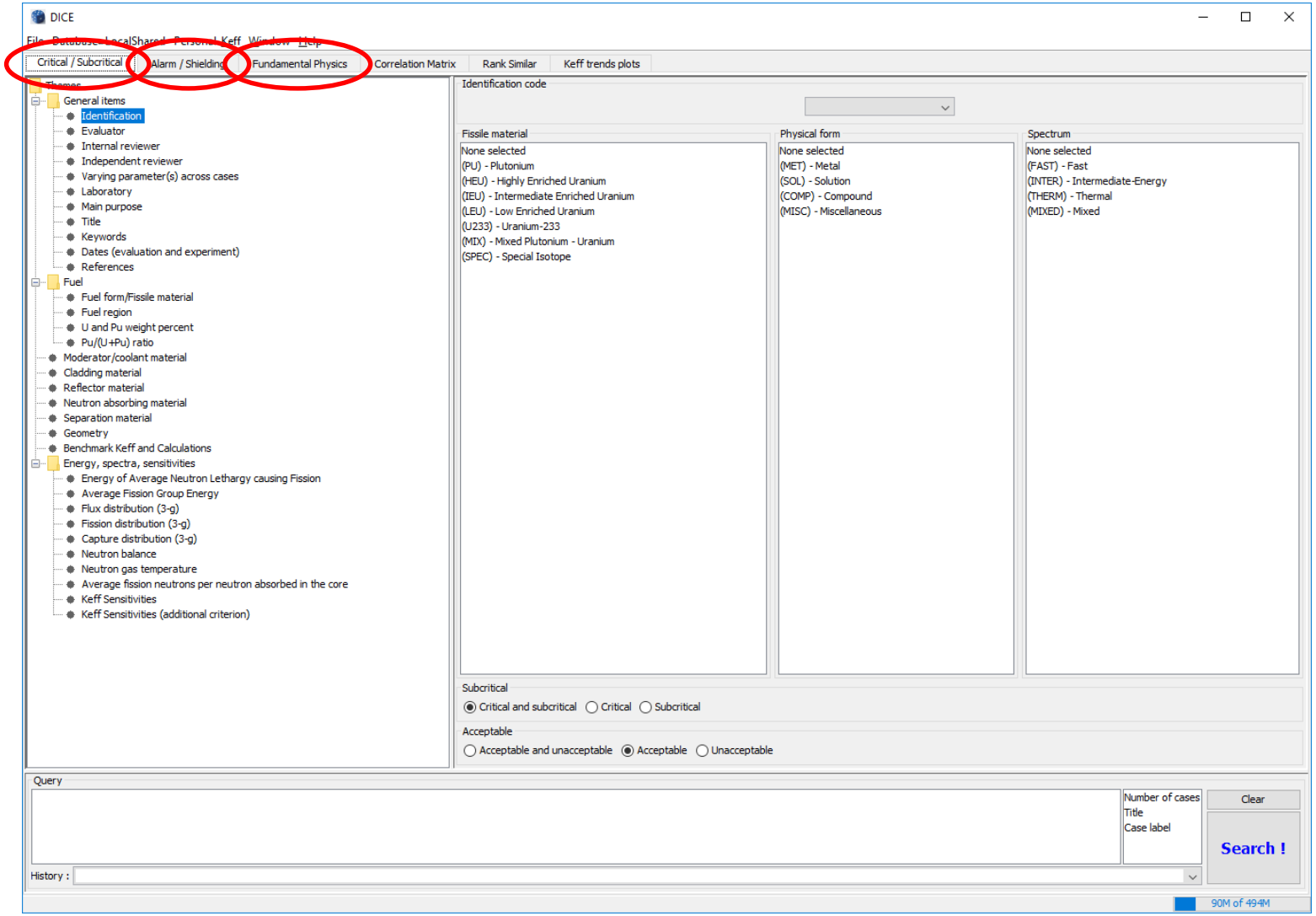
- DICE is packaged with the ICSBEP DVD, or …
- DICE is available online at https://www.oecd-nea.org/science/wpncs/icsbep/dice.html.

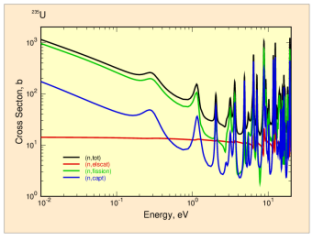


DICE …

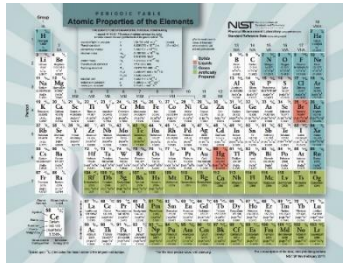


- What you see when DICE starts up …
- Search categories include …
  - Critical/Subcritical (shown here)
  - Alarm/Shielding
  - Fundamental Physics
- Lots of subcategories …





DICE … reaction rate ratio measurements



- Fundamental Physics …
- Reaction rate ratio …

DICE

File Database=LocalShared Personal-Keff Window Help

Critical / Subcritical | Alarm / Shielding | Fundamental Physics | Correlation Matrix | Rank Similar | Keff trends plots

Themes
- General items
  - Identification
  - Evaluator
  - Internal reviewer
  - Independent reviewer
  - Main purpose
  - Title
  - Keywords
  - Dates (evaluation and experiment)
  - References
- Target
  - Target
- Source
  - Particle & strength
  - Time dependency
  - Geometry
- Detector
  - Type
  - Efficiency

Identification code

Facility	Source type	Target material	Experiment type
None selected	None selected	None selected	None selected
(NIST) - National Institute of Standar	(1/E) - Slowing Down	(U235) - Uranium-235	(FISS) - Fission
(LLNL) - Lawrence Livermore National	(DT) - Fusion	(U238) - Uranium-238	(CAPT) - Capture
(OU) - Osaka University (Oktavian)	(ALPHAN) - Alpha-n	(NP237) - Neptunium-237	(NTOF) - Neutron Time of Flight
(VNIITF) - Russian Federal Nuclear Ce	(CF) - Californium Fission	(PU239) - Plutonium-239	(TRANS) - Transmission
(IPPE) - Institute of Physics and Powe	(AM) - Americium Fission	(BE) - Beryllium	(RRR) - Reaction Rate Ratios
(JINR) - Joint Institute for Nuclear Re	(VDG) - Van de Graaf Accelerator	(PB) - Lead	(MULT) - Neutron Multiplication
(NCERC) - National Criticality Experim	(FR) - Fast Reactor	(MG) - Magnesium	
	(PU) - Plutonium Fission	(MGO) - Magnesium Oxyde	
		(MULT) - Multiple	
		(HE3) - Helium-3	

Query

Number of cases
Title
Case label

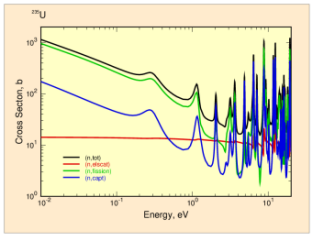
Clear

Search !

History :

8 Evaluations, 137 Cases

48M of 494M



DICE … reaction rate ratio measurements

- Fundamental Physics …
- Reaction rate ratio …
- Seems like only one experiment …
- But additional data are available when searching beyond the official ICSBEP database …

DICE

File Database=LocalShared Personal-Keff Window Help

Critical / Subcritical | Alarm / Shielding | Fundamental Physics | Correlation Matrix | Rank Similar | Keff trends plots

Select columns | Refine search | New search | Horiz. | Vert. | Flat | Plots | ParPlots | PDF | HTML

Columns
- General items
  - Identification
  - Evaluator
  - Internal reviewer
  - Independent reviewer
  - Main purpose
  - **Title**
  - Keyword
  - Year approved
  - Year revised
  - Years experiment performed
  - Revision
  - References
  - **Number of cases**
  - **Case label**
- Target
  - Material
- Source
  - Particle
  - Time dependency
  - Frequency (Hz)
  - Strength
  - Geometry
- Detector
  - Type
  - Size
  - Efficiency

Uncheck all

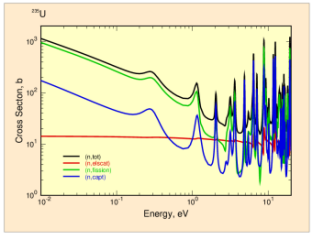
Apply

Evaluation identification	Number of cases	Title
FUND-IPPE-FR-MULT-RRR-001	45	CROSS SECTION RATIOS FOR MANY NUCLIDES MEASURED IN T

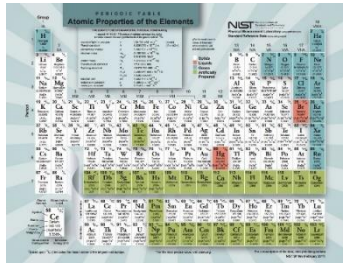
Case identification	Case label
FUND-IPPE-FR-MULT-RRR-001-001	Th-232(n,f)
FUND-IPPE-FR-MULT-RRR-001-002	U-233(n,f)
FUND-IPPE-FR-MULT-RRR-001-003	U-234(n,f)
FUND-IPPE-FR-MULT-RRR-001-004	U-236(n,f)
FUND-IPPE-FR-MULT-RRR-001-005	U-238(n,f)
FUND-IPPE-FR-MULT-RRR-001-006	Np-237(n,f)
FUND-IPPE-FR-MULT-RRR-001-007	Pu-239(n,f)
FUND-IPPE-FR-MULT-RRR-001-008	Pu-240(n,f)
FUND-IPPE-FR-MULT-RRR-001-009	Pu-241(n,f)
FUND-IPPE-FR-MULT-RRR-001-010	Pu-242(n,f)
FUND-IPPE-FR-MULT-RRR-001-011	Am-241(n,f)
FUND-IPPE-FR-MULT-RRR-001-012	Th-232(n,γ)
FUND-IPPE-FR-MULT-RRR-001-013	U-236(n,γ)
FUND-IPPE-FR-MULT-RRR-001-014	U-238(n,γ)
FUND-IPPE-FR-MULT-RRR-001-015	Np-237(n,γ)
FUND-IPPE-FR-MULT-RRR-001-016	Th-232(n,2n)
FUND-IPPE-FR-MULT-RRR-001-017	U-238(n,2n)
FUND-IPPE-FR-MULT-RRR-001-018	Nb-93(n,2n)Nb-92-M
FUND-IPPE-FR-MULT-RRR-001-019	Al-27(n,α)Cr-51
FUND-IPPE-FR-MULT-RRR-001-020	Fe-54(n,α)Cr-51
FUND-IPPE-FR-MULT-RRR-001-021	Co-59(n,α)Mn-56
FUND-IPPE-FR-MULT-RRR-001-022	Mo-92(n,α)Zr-89
FUND-IPPE-FR-MULT-RRR-001-023	Nb-93(n,α)Y-90-M
FUND-IPPE-FR-MULT-RRR-001-024	Mg-24(n,p)Na-24
FUND-IPPE-FR-MULT-RRR-001-025	Al-27(n,p)Mg-27
FUND-IPPE-FR-MULT-RRR-001-026	Ti-46(n,p)Sc-46
FUND-IPPE-FR-MULT-RRR-001-027	Ti-47(n,p)Sc-47
FUND-IPPE-FR-MULT-RRR-001-028	Ti-48(n,p)Sc-48
FUND-IPPE-FR-MULT-RRR-001-029	Fe-54(n,p)Mn-54
FUND-IPPE-FR-MULT-RRR-001-030	Fe-56(n,p)Mn-56
FUND-IPPE-FR-MULT-RRR-001-031	Ni-58(n,p)Co-58
FUND-IPPE-FR-MULT-RRR-001-032	Co-59(n,p)Fe-59
FUND-IPPE-FR-MULT-RRR-001-033	Mo-92(n,p)Nb-92-M
FUND-IPPE-FR-MULT-RRR-001-034	Cr-50(n,γ)Cr-51
FUND-IPPE-FR-MULT-RRR-001-035	Mn-55(n,γ)Mn-56
FUND-IPPE-FR-MULT-RRR-001-036	Fe-58(n,γ)Fe-59
FUND-IPPE-FR-MULT-RRR-001-037	Co-59(n,γ)Co-60
FUND-IPPE-FR-MULT-RRR-001-038	Ni-64(n,γ)Ni-65
FUND-IPPE-FR-MULT-RRR-001-039	Cu-63(n,γ)Cu-64
FUND-IPPE-FR-MULT-RRR-001-040	Cu-65(n,γ)Cu-66
FUND-IPPE-FR-MULT-RRR-001-041	Mo-98(n,γ)Mo-99
FUND-IPPE-FR-MULT-RRR-001-042	Zr-94(n,γ)Zr-95
FUND-IPPE-FR-MULT-RRR-001-043	Zr-96(n,γ)Zr-97
FUND-IPPE-FR-MULT-RRR-001-044	In-115(n,n')In-115-M
FUND-IPPE-FR-MULT-RRR-001-045	Au-197(n,γ)Au-198

1 Evaluation, 45 Cases

42M of 494M



Reaction Rate Ratio Measurements



- But additional data are available when searching beyond the official ICSBEP database …
- From the ND2013 Conference …
- All measured data were recently re-analyzed/updated to modern nuclear data
  - Godiva (central region)
  - Jezebel (central region)
  - Flattop-25 (central and radial)
  - Flattop-Pu (central and radial)

ELSEVIER

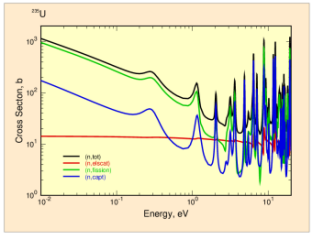
Available online at www.sciencedirect.com
ScienceDirect
Nuclear Data Sheets 118 (2014) 1–25

Nuclear Data Sheets
www.elsevier.com/locate/nds

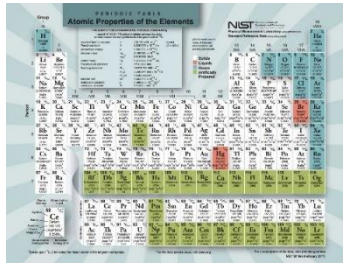
The CIELO Collaboration: Neutron Reactions on ^{1}H, ^{16}O, ^{56}Fe, $^{235,238}U$, and ^{239}Pu

M.B. Chadwick,[1,*] E. Dupont,[2] E. Bauge,[3] A. Blokhin,[4] O. Bouland,[5] D.A. Brown,[6] R. Capote,[7] A. Carlson,[8] Y. Danon,[9] C. De Saint Jean,[5] M. Dunn,[10] U. Fischer,[11] R.A. Forrest,[7] S.C. Frankle,[1] T. Fukahori,[12] Z. Ge,[13] S.M. Grimes,[14] G.M. Hale,[1] M. Herman,[6] A. Ignatyuk,[4] M. Ishikawa,[12] N. Iwamoto,[12] O. Iwamoto,[12] M. Jandel,[1] R. Jacqmin,[1] T. Kawano,[1] S. Kunieda,[12] A. Kahler,[1] B. Kiedrowski,[1] I. Kodeli,[15] A.J. Koning,[16] L. Leal,[10] Y.O. Lee,[17] J.P. Lestone,[1] C. Lubitz,[18] M. MacInnes,[1] D. McNabb,[19] R. McKnight,[20] M. Moxon,[21] S. Mughabghab,[6] G. Noguere,[5] G. Palmiotti,[22] A. Plompen,[23] B. Pritychenko,[6] V. Pronyaev,[4] D. Rochman,[16] P. Romain,[3] D. Roubtsov,[24] P. Schillebeeckx,[23] M. Salvatores,[5] S. Simakov,[7] E.Sh. Soukhovitskii,[25] J.C. Sublet,[26] P. Talou,[1] I. Thompson,[19] A. Trkov,[15] R. Vogt,[19] and S. van der Marck[16]

CONTENTS



Supplemental Experimental Measurements



- Additional data may also be found that are not categorized in DICE …
  - Back to Option (1) on how to search 9 volumes and 70,000+ pages …
- From Section 1.4 (Supplemental Experimental Measurements) in LEU-COMP-THERM-008 …
- … and Appendix B …

1.4 Supplemental Experimental Measurements

In addition to determination of the critical soluble boron concentration, several other

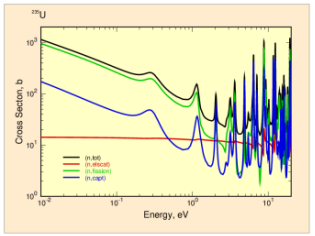
NEA/NSC/DOC(95)03/IV
Volume IV

LEU-COMP-THERM-008

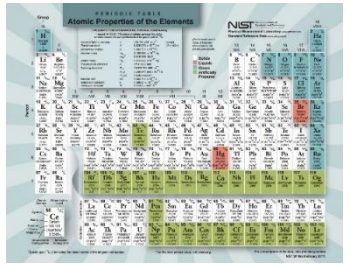
APPENDIX B: MEASUREMENTS OF ROD-BY-ROD POWER DENSITIES

In addition to measurements of the critical boron concentrations, measurements of the fission rates were made in some fuel rods in some of the experiments. In particular, "[t]he midplane relative power density over one-eighth of the central element was obtained for selected loadings. . . by using a sodium iodide (thallium activated) scintillation counter to count collimated fission product gammas from activated fuel rods" (Reference 1, p. 5). Such measurements were made for loadings 2 through 9, loading 11, and loadings 16 and 17 of Core XI. The results for a symmetric octant of the central assembly for loadings 2 through 9 are shown in Figures B.1 through B.8, and the results for loading 11 are shown in Figure B.9. The upper number in each location is the power density for that rod relative to the average for all the rods in the central assembly, and the numbers in parentheses are ". . . standard deviations obtained from two or more measurements" (Reference 1, p. 5).

Reference 1 also reports relative power density measurements for selected locations in loadings 16 and 17. Those results are shown in Tables B.1 and B.2, which are taken directly from Tables 13 and 14, respectively, in Reference 1.



IRPhEP … an under-utilized resource



- IRPhEP = International Reactor Physics Experiment Evaluation Project.
  - Web site at https://www.oecd-nea.org/science/wprs/irphe/.
- … corresponding database search tool is “IDAT”.
- Nothing else to add at this time … I’m as guilty as others in not taking advantage of this work, ☹.