ORNL NEUTRON CROSS SECTION MEASUREMENTS FOR NCSP

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Resonance Region Nuclear Data Work for NCSP

- Objective: Provide measured and evaluated resonance-region crosssection data to address the priority NCSP nuclear data needs
- Vision: Addresses multiple Nuclear
 Data 5- and 10-year goals and attributes identified in the NCSP Vision
- Final product: rigorous ENDF/B resonance evaluations produced from cross-section measurements and analyses
- Measurement work effort focused on cerium and vanadium—identified differential nuclear data needs by NCSP Nuclear Data Advisory Group (NDAG)

NCSP Five Year Plan

Nuclear Data										
Prior	ity Needs */ Additio	Thermal scattering (BeO, HF, D ₂ O, SiO ₂ , CH ₂ , C ₂ F ₄ , C ₅ O ₂ H ₈ , etc.), ²³⁹ Pu, Cr, ²³⁷ Np, Pb, ⁵⁵ Mn, Ti, ²⁴⁰ Pu / ²³³ U, Th, Be, ⁵¹ V, Zr, F, K, Ca, Mo, Na, La								
C	ompleted Evaluation	is (FY)	Minor A	ctinides (1	3), <mark>SiO₂ (1</mark>	2), ⁵⁵ Mn (1	2), 180,128,	^{183,184,186} W (1	4)	
	Materials	Pre FY2015	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	Post- FY2021
Measurements	Calcium (Ca)									
	Cerium (Ce)		and parts							
	Copper (Cu)									
	Iron (Fe)	DE CON	Will have							
	Lucite (C5O2H8)									
	Tantalum (Ta)			The second second	Electrone and					
	Strontium (Sr)									
	Tungsten (W)					2				
	Vanadium (V)									
	Zirconium (Zr)			Carlos Martin	Margare and		Inc. of the local division of			
	Polyethylene (CH ₂)	H ₂ O / CH ₂		2				-		
	Materials	Pre FY2015	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	Post- FY2021
	Calcium (Ca)									
	Cerium (Ce)									
	Cobalt (Co)									
	Copper (Cu)									
	Dysprosium (Dy)									
	Gadolinium (Gd)									
	Iron (Fe)									
S24	Lead (Pb)									
tion	Nickel (Ni)									
na	Oxygen (O)									
val	Rhodium (Rh)								0	
eE	Plutonium-239									
let	Tantalum (Ta)									
Comp	Strontium (Sr)								-	
	Tungsten (W)									
	Uranium-235									
	Uranium-238									
	Vanadium (V)				12/2/25	-				
	Zirconium (Zr)									
	Hydrofluoric Acid									
	Lucite (C5O2H8)	200								
	Polyethylene (CH ₂)									
		ORNL		RPI		LANL		LLNL/NCSU		
•	Requests for additiona	I IE measuren	nents: Ni, Mo	o, Cr (Fe-Cr al	loys), Mn in i	ntermediate	energy rang	e (VNIITF, NCE	RC).	
:	Request for measurem	ents and eval	uation of ang	ular distribu	tions at high	energy for Cu	le:			

*Note: work has been completed for some priority needs (e.g., ⁵⁵Mn, Ti, and Cr), and these isotopes/nuclides are maintained on the list for reference. Furthermore, the table represents the list of materials that can be addressed during the next five years under the current budget target. The additional priority needs will be addressed beyond the next five years.



Pulse Width: 1nsFrequency: 40 Hz - 800 HzAverage Current: 4.7 μ A - 75 μ ANeutron intensity: 1.6 10^{12} - 2.5 10^{13} n/s

GELINA



- Time-of-flight facility
- Pulsed white neutron source

 $(10 \text{ meV} < E_n < 20 \text{ MeV})$

- Multi-user facility with 10 flight paths (10 m - 400 m)
- The measurement stations have special equipment to perform:
 - Total cross section measurements
 - Partial cross section measurements



Capture Cross-Section Measurements at GELINA

Total energy detection

- C₆D₆ liquid scintillators
 - 125°
 - PHWT
 - WF from MC simulations
- Flux measurements (IC)
 - ¹⁰B(n,α)
 - ²³⁵U(n,f)

 $Y_{exp} = N\sigma_{\varphi} \frac{C_{w} - B_{w}}{C_{\omega} - B_{\omega}}$





Transmission Measurements at GELINA

Sample & Background Filters

Detector



Detector stations Moderated: L= 30 m,50 m,(100 m,200 m) Fast: L= 400 m



Low energy : ${}^{6}Li(n,t)\alpha$ Li-glass

High energy : H(n,n)H Plastic scintillator

$$T = \frac{C_{in}}{C_{out}} \cong e^{-n\sigma_{tot}}$$



Data Taking at GELINA

- Data are taken in list mode: TOF and pulse-height for detector(s) and flux monitor.
- Usually at least 2 experiments are performed for each isotope. Different sample thickness and black resonance filter add even more run time.



ORNL Measurement Activities for Cerium

- Measurements of Ce using natural (88.45% 140-Ce) metallic samples.
- The samples are in AI canning due to reactivity with air.
- Old experiments used CeO₂ samples.



- Transmission experiments with different sample thickness were performed using FP4 50 m station.
- Neutron capture using detector system at FP14, 60 m.
- Experiments performed with different background filter combinations.
- Resolving resonances above 200 keV.
- Transmission and capture experiments using enriched Ce142 oxide sample are planned.



Experiment for Cerium 142 I

- Need isotopic enriched sample of 142-CeO₂ from ORNL isotopes. Material needed is about 30g.
- Too expensive for buying (22\$/mg). Lease from ORNL isotopes is an alternative.
- However the new DOE lease policy requires NO RAD ADDED, i.e. <0.6Bq/g.
- ORNL Isotopes procedure: For the activity check a baseline is established with 30mg of material before the experiments. After returning the sample 30mg from the sample are used to check for activation. The material (60mg) used need to be purchased, because of destructive measurements technique. The measurement is checking for α-,β- and γ- activity.
- If radiation is detected you need to buy the material.
- ORNL approach is testing and simulate the irradiation:



Experiment for Cerium 142 II

- SCALE calculation with neutron flux profile from GELINA at the 60m flight station.
 - SCALE calculates all interactions and reactions of the neutron with the sample. Output is the corresponding activity
 - Irradiation time 15 days for a typical experiment.





Experiments for Cerium 142 III

- ORIGEN calculation with neutron flux profile from GELINA at the 60m flight station.
 - ORIGEN calculates all possible reactions of the neutron with the sample and subsequent decay with time.
 - Irradiation time 15 days for a typical experiment.



National Laboratory

Experiments for Cerium 142 IV

- Purchased 60mgr from ORNL isotopes.
- Established baseline with 30mg before irradiation.
- Irradiation of 30mg at RPI at a 10m flight path with a flux 7E5 n/sec/cm² for about one hour.
- Similar total number of neutrons like for one experiment at GELINA.
- Shipped irradiated sample back for analysis.

R: Customer Name: Charge Number: Date Received:	Oak Ridge N Chemical adioactive Mater Hickman, E. C. 3687ANCH 3/1/2016 9:30:00	y ratory	Results of Analyses for: RMAL16110 Approved By 04/07/2016			
Lab Sample IE Anal) Customo lysis	er Sample ID Result	Date/Tir	ne Sampled Uncertainty	Filtered? Units	Matrix Procedure No.
RMAL16110-001		177590	3/1/2016	7:00:00	Unfiltered	
Sample is NO-RA Z-Beta = -5.482.	AD by SBMS protocol wi	th LD-Alpha = 2.5E-01 Bq/	mL, LD-Bet	a = 5.0E-01 Bq/mL, Z	Alpha = 0.4107,	
G-Alp/Bet	G-Alpha	2.7E-01	+/-	1.1E-01	Bq/mL	CSD-EPA-900.0
	G-Beta	1.1E-01	+/-	1.4E-01	Bq/mL	
G-Scan	K-40	3.2E+01	+/-	2.0E+01	Bq/g	CSD-EPA-901.1
RMAL16110-002		177590-R	3/1/2016	7:00:00	Unfiltered	
Sample is NO-RA Z-Beta = -2.268.	AD by SBMS protocol wi	th LD-Alpha = 2.5E-01 Bq/	nL, LD-Bet	a = 5.0E-01 Bq/mL, Z-	Alpha = -1.905,	
G-Alp/Bet	G-Alpha	1.6E-01	+/-	9.0E-02	Bq/mL	CSD-EPA-900.0
	G-Beta	3.2E-01	+/-	1.6E-01	Bq/mL	
G-Scan	K-40	2.4E+01	+/-	2.0E+01	Ba/a	CSD-EPA-901 1

End of data for Request Number : RMAL16110

No Rad added



Background Determination in Transmission using Black Resonance Filters



Counts / ns

Observations For Cerium

- ENDF/B-VII shows for the (n,γ) and (n,tot) data serious discrepancies compared to our data and literature.
- Resonances are misassigned or missing.
- Investigation indicate that after the reevaluation of WPEC SG23 (fission products) those wrongly assigned resonances made it into ENDF/B VII.1
- Sometimes a reevaluation without new data and consulting the literature does not seem to be a good idea.





ORNL Measurement Activities for Vanadium

- ⁵¹V 99.75% natural abundance. V is non reactive in air.
- Measurements using metallic samples of different thickness.
- Transmission experiments with different samples are performed using FP4, 50 m station.
- Neutron capture at FP14, 60 m.
- Experiments performed with different background filter combinations.
- Capture and transmission experiments performed in 2015/2016. Need to be finalize.



V (n, y) Raw Data for Thin Sample



(n,γ) of 0.35mm Vanadium sample



Transmission of 2mm Vanadium sample



Status of NCSP Experiments at EC-JRC Geel

	W	Cu	Ca	Се	V
Sample	metallic disks 182,183,184,186	metallic disks 63 and 65	metallic disks nat Ca	metallic disks Nat Ce, Ce-142	metallic disks
Experiments GELINA	60m, 30m (n,γ) transmission	60m (n,γ)	60m (n,γ) transmission	Nat Ce 60m (n,γ) Nat Ce transmission ¹⁴² Ce sample problems	60m (n,γ) transmission
Data Sorting	finished 60m + transmission	finished 60m	finished 60m transmission	finished for thin and thick sample	finished for thin and thick sample
Reduced to Cross section	X-section, transmission	X-section	X-section transmission 0.6, 1.0, 5 cm samples	2mm X-section 2mm transmission 10mm transmission	thin X-section 0.35 and 2mm transmission
Data Testing	Data ready for evaluation	Data ready for evaluation	Data ready for evaluation	In progress	In progress
Analysis and Evaluation	Finalized Submitted to NNDC	Finalized Submitted to NNDC	Finalizing Submitted to NNDC	Started	

People Involved in the Experiments

- Peter Schillebeeckx, EC-JRC Geel
- Carlos Paradela, EC-JRC Geel
- Stefan Kopecky, EC-JRC Geel
- Peter Siegler, EC-JRC Geel
- Ruud Wynats, EC-JRC Geel
- Clint Ausmus, ORNL

People Involved in the Evaluations

- Marco Pigni, ORNL
- Vlad Sobes, ORNL

