ISTC PROJECT 2578
Comments from E. Gonzalez (CIEMAT)

Transmutation of radioactive nuclear waste – present status and requirement for the problem-oriented nuclear data base. Approach to scheduling the experiments (reactor, target, blanket).

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- Introduction
- Analysis of projects performed or proposed
- Assessment of the present-day demand for nuclear data on transmutation nuclear waste
- Recommendations

Projects related to neutron microscopic data :

- Nuclear data measurements,
- Nuclear data evaluations

Projects with status 8 or 6:

183.1, 183.2, 304, 471, 540, 554, 609, 731, 1309, 1828, 1971, 2213, 2253, B-003, B-404, 964, 2524

Projects with status 3:

217, 969, 1049, 1069, 1191, 1227, 1749, 2199, B-379

No data available

Absent deliverables

	Measurements, energy region			Deliverables	
Nuclide	Thermal	Intermediate	Fast + above 20 MeV	EXFOR	Evaluated files
^{232}Th		σ_f, σ_c – 471	σ_f – 540, 609 TNY, DNY – 2253	471, 540	B-404, 964 (20-200 MeV)
^{231}Pa					B-404
^{233}Pa			DNY – 471		B-404
^{232}U					
^{233}U		DNY – 471, γ - 471	σ_f – 540, 609, TNY, DNY - 2253	540	B-404, 964 (20-200 MeV)
^{234}U		σ_f – 471 σ_c–471	TNY, DNY - 2253	471,	B-404, 964 (20-200 MeV)
^{235}U	ν - 554		σ_f – 609	554	964 (20-200 MeV)
^{236}U			σ_f – 471 ν - 471	471,	964 (20-200 MeV)
^{238}U			σ_f – 540, 609, DNY - 2253	540	B-404, 964 (20-200 MeV)
^{237}Np	DNY - 2253	σ_f – 471 σ_c–471 DNY – 471 γ - 471	σ_f – 304, 540, 609 DNS - 2253	471, 540	304, 964 (20-200 MeV)
^{238}Np					B-003
^{239}Np			DNY – 471		
^{238}Pu					B-003
^{239}Pu	ν - 554	DNY – 471, γ - 471 ν - 554	σ_f – 540, 609	540, 554	964 (20-200 MeV)
^{240}Pu			SFNS – 183 σ_f – 1971	183	
^{241}Pu					
^{242}Pu			SFNS – 183 σ_f – 471, ν - 471	183 471	B-003
^{241}Am			σ_f – 304, 471 ν - 471 PNS - 1828	471	304, B-003
^{242}Am					B-003
^{242m}Am	NS - 183		σ_f – 304,	183,	304, B-003
^{243}Am			σ_f – 304, 471, 540, 1971 ν - 471 PNS – 1828, TNY, DNY - 2253	471	304, B-003
^{243}Cm	PNS - 1828		σ_f – 304,		304, B-003
^{244}Cm			SFNS – 183, ν - 554	183, 554	
^{245}Cm	NS – 183, DNY - 2253		σ_f – 471 ν - 471	183, 471	B-003
^{246}Cm			SFNS – 183	183,	B-003
^{248}Cm			ν - 554	554	
^{252}Cf	PNS - 1828		ν - 554, PNS - 1828	554	

Notes:

Information available only to some ISTC members or not fully available (at least for the report) for:

471: EXFOR – data are partially available but no Final report
540: EXFOR – data are partially available but no Final report
554: EXFOR – data are partially available but no Final report or publications available
609: No outcome available
1309: EXFOR – data are partially available but no Final report
1828: No EXFOR or Final Report only 1 publication
1971: No outcome available
2213: No outcome available (project is underway)
2253: No outcome available (project is underway)

It would be good to identify actions and schedules to improve the present status

Projects related to interaction of charged particles with materials

	Projects, parameters to measure
Thin targets (measurement and evaluation of cross-sections)	187 – p: tot,el,inel,(d^2/dEdΩ, p,xn) etc.; 839 – (p,x); 839.2 – (p,x); 1145 – (d^2/dEdΩ, p,xn); 1309 – (p,f); 1314 – (p,f); 1405 – (p,f) 2002 – (p,x) in Pb, Bi; 2213 – (p,f) in W 3266 – (p,x) Fe,
Complex experiments (reaction rates, integral and spectral parameters)	157 – energy release, reaction rates in W target; 477 – energy release, reaction rates in PbCl target; 2405 – reaction rates in Pb target.
Development of pilot installation	2267 – (p,x) in target and structural materials in their comparison with results of the Projects No. 839, 2002 and 3266.

Projects related to integral experiments

Project number	Title	Status	Dates From / To
017	Feasibility study of technologies for accelerator based conversion of military plutonium and long-lived radioactive waste	**8**	1994 / 1996
304	Measurements and Analysis of Basic Nuclear Data for Minor Actinides	**8**	1995 / 1997
559	Pilot Flow Lead-bismuth Target of MW Power for Accelerator-Driven Systems	**8**	1996 / 1998
910	Execution of the Complex of Benchmark Experiments for Testing the Nuclear Data of Vanadium - Main Component of Low-Activation Structural Materials for Perspective Nuclear Energetics	**8**	1997 / 2000
910 (2)	Execution of the Complex of Benchmark Experiments for Testing the Nuclear Data of Vanadium - Main Component of Low-Activation Structural Materials for Perspective Nuclear Energetics	**8**	2001 / 2002
1145	Nuclear-Physics Investigations Aimed at the Solution of Weapon Plutonium Conversion and Long-Lived Radioactive Wastes Transmutation Problems	**8**	1999 / 2002
1372	Analysis of Long-Lived Nuclear Waste Transmutation in Fast Reactors and High Energy Accelerators	**7**	2002 / 2005
1486	Experimental and Theoretical Justification of the Cascade Scheme of the Subcritical Molten-Salt Reactor for Transmutation of Long-Lived Radioactive Wastes of the Nuclear Fuel Cycle	**8**	2001 / 2003
2267	Construction of the Subcritical Assembly with Combined Neutron Spectra Driven by Proton Accelerator at Proton's Energy 660 MeV for Experiments on Long Lived Fission Products and Minor Actinides transmutation" (Phase I: Design, Design Documentation and Safety Substantiation)	**6**	2005 /
2582	Experimental Study of Minor Actinides Transmutation Problem at BFS-73-1 Fast Critical Assembly	**6**	2005 /
2680	MATINE - Study of Minor Actinide Transmutation in Nitrides: Modelling and Measurements of Out-of-pile Properties	**6**	2005 /

Projects related to integral experiments (proposed)

735	Transmutation of Radioactive and Transuranium Isotopes by High-Energy Neutrons of the Thermonuclear Reactor	I.Kuzmitsky	VNIIEF / SKB
1755	Experimental Study of Fast and Fast-Thermal Accelerator Driven Systems on the Basis of BFS-1 – Microtron Complex	B.Kochurov	ITEP
2661	Analytical and Experimental Substantiation of Neutron-Physical Characteristics of Fast Reactors with Lead Coolant	I.Matveenko	IPPE
2884	Integral Experiments at BFS Critical Facilities for Justification of Minor Actinides Transmutation and Their Analysis	Yu.Khomiakov	IPPE
2925	Measurement of Transmutation Properties of Minor Actinides Irradiated in Intermediate Reactor Neutron Spectrum	M.Melnik	RIAR

Other recent proposals

 # 3176 *Measurement and evaluation of cross sections for minor actinides in low energy region* Oleg E. Kolyaskin, RRC Kurchatov Institute.

 # 2952 *Measurement of energy dependence fission cross sections for minor actinides in high neutron energy range,* Igor A. Ivanin, RFNC-VNIIEF.

 # 1749 + # 2925 + # 2884 *formed a joint coordinated program linked to NUDATRA*

Recently 3176+2952+1749+2925? are being reformulated as a single project

ASSESSMENT OF THE PRESENT-DAY DEMAND FOR NUCLEAR DATA ON ACTINIDE AND FP TRANSMUTATION

Data requirement for code development (design of experimental and pilot facilities)

- Required nuclear data accuracy
- Current status and perspectives of nuclear data evaluation and development of nuclear models for heavy nuclei
- Effect of nuclear data uncertainties on radiation damage of structural materials

Analysis of transmutation facility parameter sensitivity to various nuclear data

- Density variation effect on effective neutron multiplication factor in the blanket
- Scoping analysis of the integral parameters sensitivity to nuclear data

ASSESSMENT OF THE PRESENT-DAY DEMAND FOR NUCLEAR DATA ON ACTINIDE AND FP TRANSMUTATION

Table 3.1. Existing and required (in brackets) uncertainties of actinide cross-sections.

Nuclide	Capture cross-section, %	Fission cross-section, %	Inelastic scattering cross-section, %
Np-237	15 (5)	7 (3)	30 (10)
Pu-238	25 (10)	10 (5)	40 (30)
Pu-239	6 (4)	3 (5)	20 (15)
Pu-240	10 (5)	5 (5)	20 (15)
Pu-241	15 (5)	5 (3)	20 (20)
Am-241	10 (5)	10 (5)	30 (10)
Am-242m	30 (10)	15 (5)	40 (30)
Am-243	30 (10)	10 (5)	30 (30)
Cm-242	50 (10)	15 (5)	30 (30)
Cm-243	50 (10)	15 (5)	30 (30)
Cm-244	30 (20)	10 (5)	30 (30)

Table 3.4. Cross-Sections Uncertainties for Selected Cross-Sections: Original Uncertainty and Required Uncertainty to Meet Integral Parameter Target Accuracy

.Isotope	Cross-section	Bound. (a)	Accuracy achieved (%)	Accuracy required (%)	Isotope	Cross-section	Bound. (a)	Accuracy achieved (%)	Accuracy required (%)
Pu239	σ_{fiss}	4	6.5	3.4	Cm241	σ_{fiss}	2	40	10.0
		5	4	3.1			3	40	8.5
Pu241	σ_{fiss}	6	10	5.6			4	40	5.0
Np237	σ_{fiss}	3	25	8.0	Cm245	σ_{fiss}	5	30	9.7
		4	25	5.1			6	30	9.6
	ν	4	5	4.1	Fe56	σ_{inel}	4	20	4.9
Am241	σ_{cap}	4	40	7.5	N15	σ_{el}	4	5	3.9
		5	40	5.5	Pb	σ_{inel}	1	40	20.4
		6	40	5.1			2	40	9.8
		7	20	5.9			3	40	10.6
		8	20	6.3			4	40	10.1
		9	20	6.9		$\sigma_{(n,2n)}$	1	100	21.5
	σ_{fiss}	2	20	5.6	Bi	σ_{inel}	1	40	18.8
		3	20	4.6			2	40	8.1
		4	20	3.9			3	40	9.3
	ν	3	5	3.8			4	40	14.0
		4	5	3.3		$\sigma_{(n,2n)}$	1	100	17.5
Am243	σ_{cap}	4	40	10.4	σ_{dpa}		1	20	20.0
		5	40	5.5			2	20	12.0
		6	40	5.1			3	20	12.1
		7	20	5.9			4	20	8.8
		8	20	6.3			5	20	20.0
	σ_{fiss}	2	20	7.6			6	20	20.0
		3	20	6.2			7	20	10.9
		4	20	5.4	$\sigma_{(n,\alpha)}$		1	20	10.8
	σ_{inel}	3	50	12.6			2	20	20.0
		4	50	7.6	$\sigma_{(n,p)}$		1	20	15.1
		5	50	12.0			2	20	12.4
		6	50	12.2			3	20	20.0

Identified needs of nuclear data:

1) Uncertainties and covariances – still very scarce on data libraries and badly needed for reliable assessment of uncertainties
2) Data on microscopic MA (+coolant and structural materials) cross-sections (σ_f, σ_c, $\sigma_{in,}$ $\sigma_{n,xn}$) affecting to the basic neutronic parameters: mainly energies < 10 MeV (particularly fast energies).
3) Data and models in the energy range above 20 MeV which have a significant influence on certain reactor design or performance like shielding, radiation damage evaluation (incl. gas production) or power vs beam intensity. Data for model validation.
4) Data on waste, decay heat and other aspects affecting the fuel cycle and the facilities activation. Notably the spallation fragments production.
5) Data defining or related to equilibrium fuels for scenarios with continuous recycling of actinides (particularly Pu238).
6) Integral experiments for final validation

Recommendations

The chapter needs some improvements: better outline to identify the rationale from the previous chapters, more clear summary on different needs, available infrastructures and experience on efficiency of different project types rather than prioritizing the future experiments.

Recommendations for differential experiments

List...

Recommendations for integral experiments

Neutronic parameters
Target irradiation
Low power demonstration facilities

Recommendations on the evaluated data preparation

Cross section files: to 150-200 MeV, with full covariance matrixes,using models to complete missing experimental information
Fission products yields for all actinides (Th to Cm) up to 150 MeV
Completing and correcting nuclear data decay libraries

Recommendations for differential experiments

1) Measurement of the total neutron yield, total neutron spectra and fission neutron spectra for isotopes of Th, Pa, U, Np, Pu, Am, as well as for spallation target materials Ta, W, Pb, Bi, irradiated by neutrons and protons of energies from 20 MeV up to 1 GeV.
2) Measurement of the total gamma yield and emission spectra for isotopes of Th, Pa, U, Np, Pu, Am in the energy region 20 MeV – 1 GeV.
3) Measurement of fission product yields for transuranics at the energies 20 - 200 MeV.
4) Obtaining the excitation functions for reactions (n,xn), (n,pxn), (n,2pxn) etc for isotopes of Th, Pa, U, Np, Pu, Am at the primary neutron energies 20 – 200 МэВ as well as for analogous reactions initiated by protons.
5) Measurements of the resistivity damage rates necessary for evaluation of damage energy cross-sections for iron, chromium, nickel and other components of steels at the energies 20 MeV – 1 GeV.
6) Measurements and analysis of the total yields, time and energy dependencies of characteristics of delayed neutrons from fission of Np-237, Am-241, Am-242m by fast neutrons.
7) Carrying out the sensitive measurements of neutron capture and fission cross-sections for minor actinides at resonance and fast neutron energies to define the accuracy of nuclear data.
8) Measurements of excitation functions to obtain secondary reaction alpha- and beta-active product yields from spallation target unit structural materials irradiated by protons and neutrons with energies up to ~ 1 GeV.