Intermediate- and Longer-term Nuclear Data Requirements for Medical Applications

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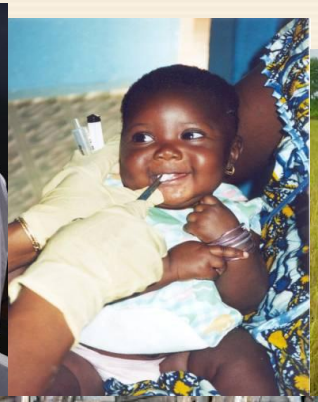
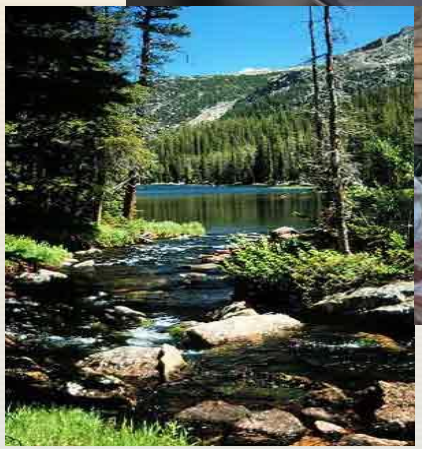
Nuclear Sciences and Applications: Serving Basic Human Needs



IAEA
International Atomic Energy Agency

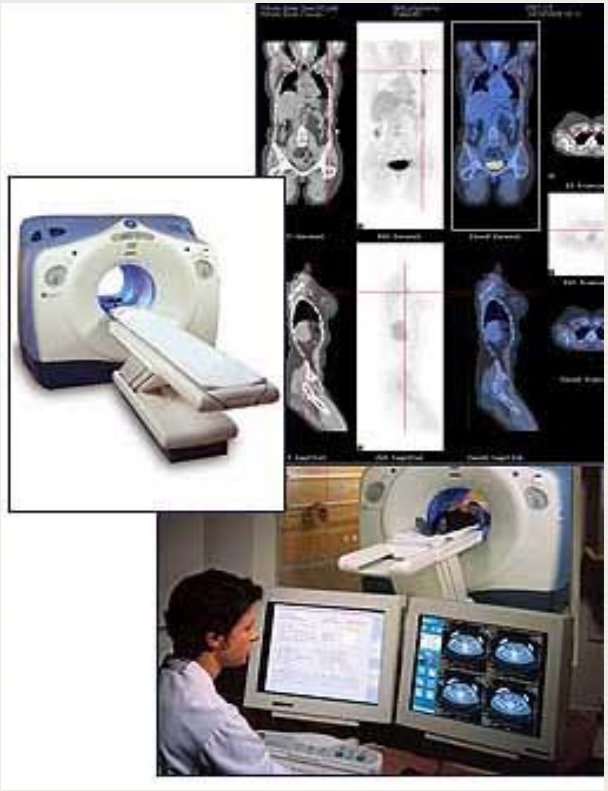
Atoms for Health: Disease Prevention and Control

- Nutrition
- Nuclear Medicine
- Radiobiology and Radiotherapy
- Dosimetry and Medical Physics
- Fighting Global Cancer

IAEA

Nuclear Medicine

- Nuclear imaging techniques enable accurate and detailed diagnoses
- Optimized treatment of illnesses such as cancer and cardio-vascular disease
- Objectives:
  - better integrate nuclear technology use and planning in disease treatment
  - improve human resource capacity (e.g., physicians, physicists, radiopharmacists)

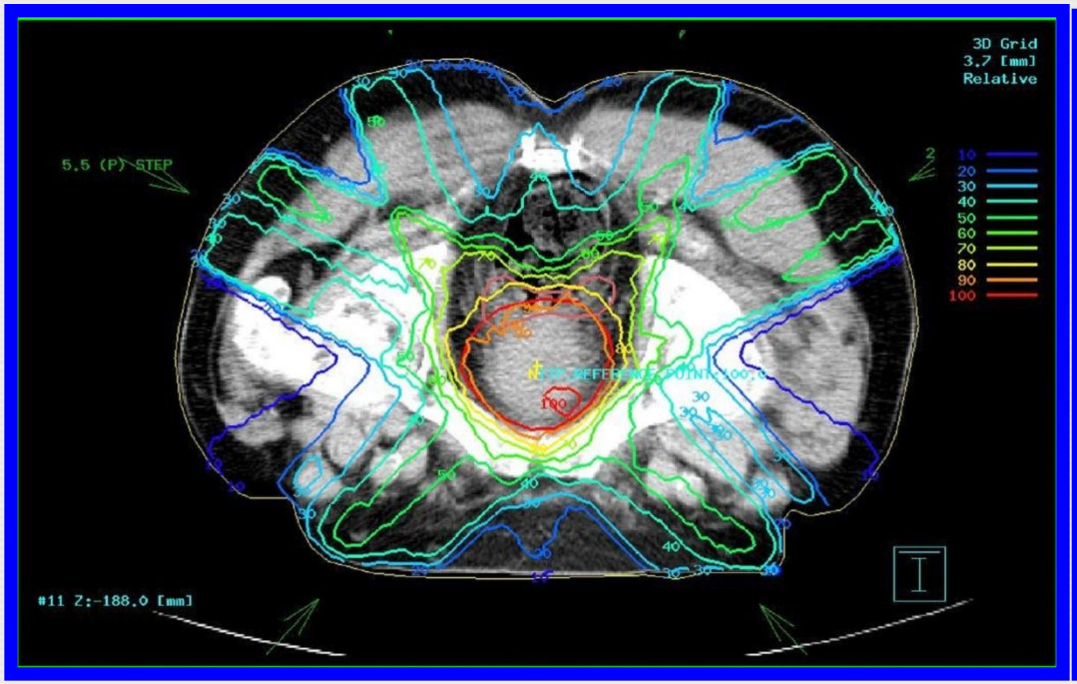


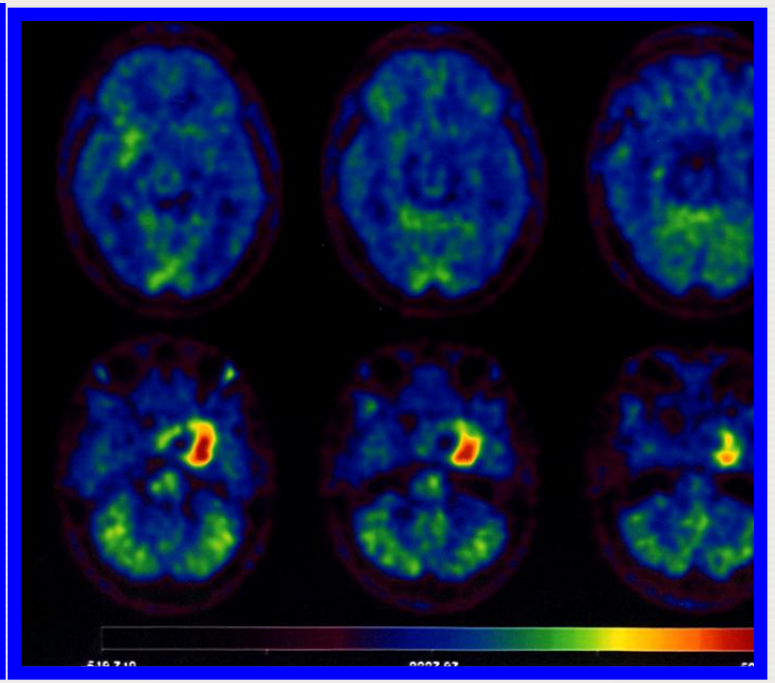
Combined PET-CT machine

IAEA

Nuclear Data for Medical Applications

Rationale: Cancer therapy & Diagnosis





Beneficiaries: MS medical physicists, radioisotope producers, scientists …

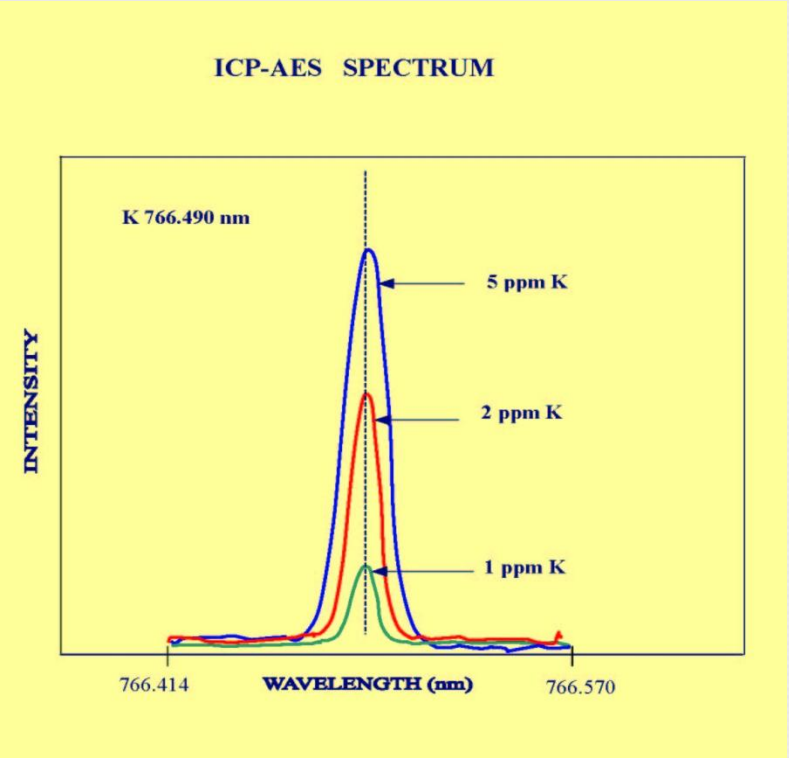
Objectives: Improve data for medical radioisotope production, and for patient dose delivery calculations in radiotherapy

IAEA

Implementation Mechanisms: Database Services

IAEA plays a key international role as a repository and provider of scientific data and knowledge

- ✓ Fission reactors
- ✓ Fusion
- ✓ **Medicine**
- ✓ Water resources
- ✓ Atmospheric and marine data



IAEA

High-precision Beta-intensity Measurements and Evaluations for Specific PET Radioisotopes

Consultants' Meeting, IAEA Headquarters, Vienna, Austria

3-5 September 2008, IAEA report INDC(NDS)-0535

Tadashi Nozaki	ex-RIKEN, Japan	
Syed Qaim	Forschungszentrum Jülich, Germany	[Chairman]
Deon Steyn	iThemba Laboratory, South Africa	
Stephen Waters	ex-Cyclotron Unit, Hammersmith Hospital, UK	
Roberto Capote:	IAEA Nuclear Data Section	[Scientific Secretary]
Alan Nichols	IAEA Nuclear Data Section	[Rapporteur]

High-precision Beta-intensity Measurements and Evaluations for Specific PET Radioisotopes

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Radionuclides – standard β^+ emitters	Requirements				
	$t_{1/2}$	P_{β^+}	P_X	P_γ	evaluate
^{11}C, ^{13}N, ^{15}O, ^{18}F	none – well-defined decay data				
$^{68}Ge/^{68}Ga$, $^{82}Sr/^{82}Rb$	none – well-defined ^{68}Ga and ^{82}Rb decay data				
Radionuclides – hadron therapy					
^{10}C, ^{14}O, ^{17}F, ^{18}Ne, ^{19}Ne	none – adequate decay data				

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3-5 September 2008, IAEA report INDC(NDS)-0535

Radionuclides – non-standard β^+ emitters	Requirements				
	$t_{1/2}$	P_{β^+}	P_X	P_γ	evaluate
^{57}Ni	√	√	√		√
^{66}Ga, ^{72}As, ^{73}Se, ^{86}Y, ^{94}Tc^{m}		√	√		√
^{75}Br, ^{77}Kr		√			(√)
^{64}Cu				√ 1345.8-keV γ	(√)
^{76}Br, ^{120}I					√
^{81}Rb, ^{82}Rb^{m}, ^{83}Sr	inaccurately defined decay data				√
^{22}Na, ^{30}P, ^{34}Cl^{m}, ^{38}K, ^{45}Ti, ^{48}V, ^{49}Cr, ^{51}Mn, ^{52}Mn, ^{52}Mn^{m}, ^{52}Fe, ^{55}Co, ^{61}Cu, ^{90}Nb, ^{110}In^{m}, ^{124}I, ^{152}Tb, ^{44}Ti/^{44}Sc, ^{62}Zn/^{62}Cu, ^{140}Nd/^{140}Pr	none – reasonably well-defined decay data				

1st Research Coordination Meeting, 3-7 December 2012

Improvements in Charged-particle Monitor Reactions and Nuclear Data for Medical Isotope Production

Consultants' Meeting, IAEA Headquarters, Vienna, Austria
21-24 June 2011, IAEA report INDC(NDS)-0591

Marie-Martine Bé	Laboratoire National Henri Becquerel, France
Guinyun Kim	Kyungpook National University, Republic of Korea
Yasuki Nagai	Osaka University, Japan
Meiring Nortier	Los Alamos National Laboratory, USA [Rapporteur]
Syed Qaim	Forschungszentrum Jülich, Germany [Chairman]
Ferenc Tarkányi	Hungarian Academy of Sciences, Hungary
Roberto Capote:	IAEA Nuclear Data Section [Scientific Secretary]

1st Research Coordination Meeting, 3-7 December 2012

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Consultants' Meeting, IAEA Headquarters, Vienna, Austria 21-24 June 2011, IAEA report INDC(NDS)-0591

Cross sections	Decay data	Additional comments
monitor reactions		
$^{27}Al(p,x)^{22,24}Na$	–	include isotope activity ratios up to beam energy of 800 MeV
$^{27}Al(d,x)^{22,24}Na$		include isotope activity ratios
$^{27}Al(^{3}He,x)^{22,24}Na$		higher energies up to 100 MeV
$^{27}Al(\alpha,x)^{22,24}Na$		
$^{nat}Ti(d,x)^{46}Sc$	–	high energy deuterons
$^{nat}Ni(d,x)^{56,58}Co$	–	
$^{nat}Cu(p,x)^{58}Co$	$^{62,63}Zn$	energies > 50 MeV
$^{nat}Cu(p,x)^{62,63,65}Zn$		inconsistencies – resolve with respect to isotope activity ratios; evaluate $^{62,63}Zn$ decay schemes
$^{nat}Cu(d,x)^{62,63,65}Zn$		
$^{nat}Mo(p,x)^{96g+m}Tc$	–	
–	^{61}Cu	evaluate ^{61}Cu decay scheme

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Cross sections	Decay data	Additional comments
diagnostic γ emitters		
$^{90}Zr(n,p)^{90g+m}Y$	–	consider new measurements for data validation and production
$^{100}Mo(n,2n)^{99}Mo$	–	consider new measurements for data validation and production
$^{100}Mo(p,2n)^{99g+m}Tc$		evaluate
$^{100}Mo(p,pn)^{99}Mo$		evaluate
$^{100}Mo(d,3n)^{99g+m}Tc$		evaluate
$^{100}Mo(d,p2n)^{99}Mo$		evaluate
$^{112}Cd(p,2n)^{111}In$	–	new measurements and evaluation
$^{124}Xe(p,2n)^{123}Cs$	–	^{123}I production - re-evaluate
$^{124}Xe(p,pn)^{123}Xe$		^{123}I production - re-evaluate
$^{124}Xe(p,x)^{121}I$		^{123}I production – evaluate side reaction (impurity)

Improvements in Charged-particle Monitor Reactions and Nuclear Data for Medical Isotope Production

Consultants' Meeting, IAEA Headquarters, Vienna, Austria

21-24 June 2011, IAEA report INDC(NDS)-0591

Cross sections	Decay data	Additional comments
β^+ emitters $^{55}Mn(p,4n)^{52}Fe$ $^{nat}Ni(p,x)^{52}Fe$ $^{52}Cr(^3He,3n)^{52}Fe$	^{52}Fe?	no evaluation of decay scheme?
$^{58}Ni(p,\alpha)^{55}Co$ $^{54}Fe(d,n)^{55}Co$ $^{56}Fe(p,2n)^{55}Co$	–	
$^{61}Ni(p,n)^{61}Cu$ $^{64}Zn(p,\alpha)^{61}Cu$	–	
–	^{64}Cu	discrepancy in the intensity of weak gamma line
$^{66}Zn(p,n)^{66}Ga$ $^{63}Cu(\alpha,n)^{66}Ga$	^{66}Ga	measure positron intensities, and evaluate
$^{68}Zn(p,n)^{68}Ga$ $^{65}Cu(\alpha,n)^{68}Ga$	–	
$^{nat}Ge(p,xn)^{72}As$	^{72}As	measure positron intensities, and evaluate

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Cross sections	Decay data	Additional comments
β^+ emitters (cont.)		
$^{75}As(p,3n)^{73}Se$ $^{72}Ge(\alpha,3n)^{73}Se$	^{73}Se	measure positron intensity, and evaluate
$^{76}Se(p,n)^{76}Br$ $^{77}Se(p,2n)^{76}Br$ $^{75}As(\alpha,3n)^{76}Br$	^{76}Br	measure positron intensities, and evaluate
$^{86}Sr(p,n)^{86}Y$ $^{88}Sr(p,3n)^{86}Y$ $^{85}Rb(\alpha,3n)^{86}Y$	^{86}Y	measure positron intensities, and evaluate
$^{89}Y(p,n)^{89}Zr$ $^{89}Y(d,2n)^{89}Zr$	^{89}Zr	evaluate ^{89}Zr decay scheme
$^{94}Mo(p,n)^{94}Tc^m$ $^{92}Mo(\alpha,x)^{94}Tc^m$	$^{94}Tc^m$	evaluate $^{94}Tc^m$ decay scheme
$^{111}Cd(p,2n)^{110}In^m$	–	
$^{120}Te(p,n)^{120}I$ $^{122}Te(p,3n)^{120}I$	^{120}I	evaluate ^{120}I decay scheme

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Cross sections	Decay data	Additional comments
generators		
$^{62}Zn/^{62}Cu$ generator:	–	
$^{63}Cu(p,2n)^{62}Zn$		
$^{68}Ge/^{68}Ga$ generator:	–	
$^{nat}Ga(p,xn)^{68}Ge$		new measurements, and evaluate
$^{69}Ga(p,2n)^{68}Ge$		new measurements, and evaluate
$^{71}Ga(p,4n)^{68}Ge$		new measurements, and evaluate
$^{72}Se/^{72}As$ generator:	–	
$^{75}As(p,4n)^{72}Se$		
$^{nat}Br(p,x)^{72}Se$		
$^{82}Sr/^{82}Rb$ generator:	–	
$^{nat}Rb(p,xn)^{82}Sr$		

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21-24 June 2011, IAEA report INDC(NDS)-0591

Cross sections	Decay data	Additional comments
α emitters		
$^{229}Th(\alpha)^{225}Ra(\alpha)^{225}Ac(\alpha)$ decay chain to ^{213}Bi:	–	
$^{232}Th(p,x)^{225}Ra$		new measurements up to 200 MeV, and evaluate
$^{232}Th(p,x)^{225}Ac$		new measurements up to 200 MeV, and evaluate
$^{226}Ra(p,2n)^{225}Ac$		additional measurements, and evaluate
$^{232}Th(p,x)^{227}Ac$		long-lived ^{227}Ac impurity (21.8 y), and contaminant of ^{225}Ac
$^{230}U(\alpha)^{226}Th(\alpha)$ decay chain:	^{230}U decay chain	
$^{231}Pa(d,3n)^{230}U$		new measurements, and evaluate; evaluate all decay schemes in decay chain
$^{231}Pa(p,2n)^{230}U$		new measurements, and evaluate
$^{232}Th(p,3n)^{230}Pa(\beta^-)^{230}U$		^{230}Pa β^- branch of only 7.8% – new measurements, and evaluate
$^{227}Th(\alpha)^{223}Ra(\alpha)$ decay chain:	–	
$^{232}Th(p,x)^{227}Th$		new measurements, and evaluate

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21-24 June 2011, IAEA report INDC(NDS)-0591

Cross sections	Decay data	Additional comments
electron and X-ray emitters $^{130}Ba(n,\gamma)^{131}Ba(EC)^{131}Cs$ $^{131}Xe(p,n)^{131}Cs$ $^{133}Cs(p,3n)^{131}Ba(EC)^{131}Cs$	–	
–	^{103}Pd	evaluate ^{103}Pd decay scheme

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Summary

Excitation functions: numerous – too many?

- measurements
- evaluations

Decay data

- measurements
- evaluations – comprehensive decay schemes?

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Improvements in Charged-particle Monitor Reactions and Nuclear Data for Medical Isotope Production

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21-24 June 2011, IAEA report INDC(NDS)-0591

Summary

Decay-data evaluations – ALN

^{52}Fe (?), ^{61}Cu, ^{64}Cu (?), ^{62}Zn, ^{63}Zn, ^{66}Ga, ^{72}As, ^{73}Se, ^{76}Br, ^{86}Y, ^{89}Zr, ^{94}Tc^{m}, ^{103}Pd (+Auger), ^{120}I, and ^{230}U decay chain
(^{230}U(α)^{226}Th(α)^{222}Ra(α)^{218}Rn(α)^{214}Po(α)^{210}Pb(β^-)^{210}Bi(β^-)^{210}Po(α)^{206}Pb(stable))

already available on DDEP Web page: ^{64}Cu, ^{66}Ga, ^{218}Rn, ^{214}Po, ^{210}Pb, ^{210}Bi, ^{210}Po – re-evaluate all of them?

Intermediate-term Nuclear Data Needs for Medical Applications: Cross Sections and Decay Data

Technical Meeting
IAEA Headquarters, Vienna, Austria
22-26 August 2011, IAEA report INDC(NDS)-0596

Marie-Martine Bé	Laboratoire National Henri Becquerel, France
Brett Carlson	Instituto Tecnológico de Aeronáutica (ITA), Brazil
Filip Kondev	Argonne National Laboratory, USA
Ondrej Lebeda	Czech Academy of Sciences, Czech Republic
Alan Nichols	University of Surrey, UK [Rapporteur]
Syed Qaim	Forschungszentrum Jülich, Germany [Chairman]
Deon Steyn	iThemba Laboratory, South Africa
Sandor Takács	Hungarian Academy of Sciences, Hungary

Roberto Capote: IAEA Nuclear Data Section [Scientific Secretary]

Intermediate-term Nuclear Data Needs for Medical Applications:
Cross Sections and Decay Data

Technical Meeting
IAEA Headquarters, Vienna, Austria
22-26 August 2011

Nuclear Medicine: Nuclear Data Considerations

Future applications in nuclear medicine?

- diagnostic
  new developments over next 15 years?
- therapeutic
  new developments over next 15 years?

If we answer the above question for nuclear medicine, we define our needs for nuclear data measurements and evaluations over both the intermediate- and longer-term timescales

Intermediate-term Nuclear Data Needs for Medical Applications: Cross Sections and Decay Data

Technical Meeting
IAEA Headquarters, Vienna, Austria
22-26 August 2011

Radionuclides:

Diagnostic γ-ray emitters

β^+ emitters

Therapeutic β^-, X-ray and γ-ray emitters

Therapeutic Auger-electron emitters

Therapeutic α emitters

Proton and heavy-ion beam therapy

Intermediate-term Nuclear Data Needs for Medical Applications: Cross Sections and Decay Data

Technical Meeting
IAEA Headquarters, Vienna, Austria
22-26 August 2011

Nuclear Data:

Cross-section production data

Decay data

Modelling?

Intermediate Term:

5 to 15 years → up to 2025

Intermediate-term Nuclear Data Needs for Medical Applications: Cross Sections and Decay Data

Relevant recent past:

1. Cross sections – IAEA-NDS CRP 1995-2000: **Charged Particle Cross-Section Database for Medical Radioisotope Production: Diagnostic Radioisotopes and Monitor Reactions**, IAEA-TECDOC-1211, May 2001
2. Cross sections – IAEA-NDS CRP 2003-2010: **Nuclear Data for the Production of Therapeutic Radionuclides**, IAEA Technical Reports Series No. 473, IAEA, Vienna, Austria, December 2011
3. Decay data – IAEA-NDS CRP 1998-2005: **Update of X Ray and Gamma Ray Decay Data Standards for Detector Calibration and Other Applications**, IAEA-STI/PUB/1287, published as 2 volumes, May 2007
4. Decay data – IAEA-NDS CRP 2005-2010: **Updated Decay Data Library for Actinides**, prepared in draft, IAEA, Vienna, Austria, to be published

Immediate past and future:

Cross sections and decay data – <u>one</u> further IAEA-NDS CRP proposed already based on:

- **High-Precision Beta-Intensity Measurements and Evaluations for Specific PET Radioisotopes** (see IAEA report INDC(NDS)-0535, 2008)
- **Improvements in Charged-Particle Monitor Reactions and Nuclear Data for Medical Isotope Production** (see IAEA report INDC(NDS)-0591, 2011)

Intermediate-term Nuclear Data Needs for Medical Applications: Cross Sections and Decay Data

Immediate past and future:

22-26 August 2011, IAEA Headquarters, Vienna, Austria

Intermediate-term Nuclear Data Needs for Medical Applications: Cross Sections and Decay Data

A.L. Nichols, S.M. Qaim and R. Capote Noy

IAEA report INDC(NDS)-0596, September 2011

Intermediate-term Nuclear Data Needs for Medical Applications: Cross Sections and Decay Data

Technical Meeting
IAEA Headquarters, Vienna, Austria
22-26 August 2011

Diagnostic γ-ray emitters

Radionuclide	Requirements	Comments
$^{99}Tc^{m}$	^{100}Mo(p,xn), (p,α), (d,xn); (γ,n), (γ,f); decay-data evaluated in previous CRP (IAEA-STI/PUB/1287); Auger electrons	Accelerator production; highly-enriched ^{100}Mo (> 99%) should be investigated
^{97}Ru	^{3}He and ^{4}He on Mo	Limited application
^{123}I	See IAEA-TECDOC-1211 and IAEA-STI/PUB/1287; Auger electrons	Several production reactions and discrepancies to be studied in planned CRP
^{147}Gd	^{4}He on Sm; proton on Eu	Special application in MRI + SPECT
^{203}Pb		Special application in tracer studies

β^+ emitters

Radionuclide	Requirements	Comments
^{11}C, ^{13}N, $^{14,15}O$, ^{30}P, ^{38}K	Activation cross sections for proton-induced reactions with energies up to 250 MeV	Cross sections well defined for $E_p < 20$ MeV → **higher energies of interest up to 250 MeV for proton therapy**
$^{34}Cl^m$	Cross-section measurements and evaluations	Low priority
^{43}Sc	**Cross-section measurements and evaluations**	Good positron-decay characteristics, but difficult to produce
^{45}Ti, ^{48}V, ^{49}Cr, ^{90}Nb	**Cross-section measurements and evaluations**	Potentially important for radioimmunotherapy
$^{51,52}Mn$	**Cross-section measurements evaluations**	Special application in MRI + PET
^{52}Fe, ^{55}Co, ^{61}Cu, $^{110}In^m$	**Cross-section evaluations**	Several novel applications
^{57}Ni, ^{72}As, ^{73}Se, $^{94}Tc^m$	**Cross-section measurements and evaluations; β^+ and X-ray emission probabilities**	Decay-data evaluation in planned CRP

β^+ emitters (continued)

Radionuclide	Requirements	Comments
^{64}Cu	Cross sections –see previous CRP (IAEA Technical Reports Series No. 473)	Important β^+ emitter, especially for radioimmunotherapy
^{66}Ga	**Cross-section measurements and evaluations; β^+ and X-ray emission probabilities**	Decay-data evaluation in planned CRP
^{68}Ga	**Cross-section measurements and evaluations**	Direct production, as well as ^{68}Ge/^{68}Ga generator route
^{75}Br, ^{77}Kr	Cross-section measurements and evaluations; β^+ and X-ray emission probabilities	Limited application
^{76}Br, ^{89}Zr	**Cross-section measurements and evaluations; β^+ and X-ray emission probabilities**	Decay-data evaluation in planned CRP
^{81}Rb, ^{82}Rb^m, ^{83}Sr,	Cross-section measurements and evaluations; β^+ and X-ray emission probabilities	Limited application
^{86}Y	**Cross-section evaluations; β^+ and X-ray emission probabilities**	**Important positron emitter for quantification of dosimetry calculations**; decay-data evaluation in planned CRP

β^+ emitters (continued)

Radionuclide	Requirements	Comments
^{95}Ru	^{3}He and ^{4}He beam cross-section measurements and evaluations	Limited application; many gamma rays, together with ~14% β^+ emission
^{120}I^{g}	**Cross-section evaluations; β^+ and X-ray emission probabilities**	Decay-data evaluation in planned CRP
^{121}I	Cross-section measurements and evaluations	Borderline – longer-term consideration (easier to produce than ^{120}I); many gamma rays, together with ~11% β^+ emission
^{124}I	Cross sections – see previous CRP (IAEA Technical Reports Series No. 473)	Important positron emitter for quantification of dosimetry calculations
^{152}Tb	**Cross-section measurements and evaluations**	Potentially useful as lanthanide-based positron emitter

β^+ emitters (continued): generators

Radionuclide	Requirements	Comments
$^{44}Ti/^{44}Sc$	Cross-section measurements and evaluations; evaluation of parent $T_{1/2}$	Long-lived parent ($T_{1/2}$ of 60 y); difficult to produce
$^{52}Fe/^{52}Mn^{m}$	Cross-section and decay-data measurements and evaluations	Special application in MRI + PET
$^{62}Zn/^{62}Cu$	Cross-section measurements and evaluations; β^+ and X-ray emission probabilities	Decay-data evaluation in planned CRP
$^{68}Ge/^{68}Ga$, $^{82}Sr/^{82}Rb$	Cross-section measurements and evaluations	Well-established systems, but databases inadequate
$^{72}Se/^{72}As$	Cross-section measurements and evaluations; β^+ and X-ray emission probabilities	Decay-data evaluation in planned CRP
$^{140}Nd/^{140}Pr$	Cross-section measurements and evaluations; Auger-electron and other low-energy electron data for ^{140}Nd microdosimetry	Radiotherapy + PET; parent ^{140}Nd(EC) to operate as therapeutic radionuclide, while ^{140}Pr is positron emitter (*in-vivo* generator)

Therapeutic β^-, X-ray and γ-ray emitters

Radionuclide	Requirements	Comments
^{47}Sc	**Cross-section measurements and evaluations**	Low-energy β^- emitter
^{67}Cu	Cross sections – see previous CRP (IAEA Technical Reports Series No. 473); **decay-data measurements and evaluation, particularly g.s. to g.s. transition**	**Important radionuclide** – emission of low-energy β^- particles, and preparation of organometallic complexes
^{103}Pd	Cross sections – see previous CRP (IAEA Technical Reports Series No. 473); **decay-data discrepancies – measurements and evaluation**; Auger electrons	Decay-data evaluation in planned CRP
^{131}Cs	**Cross-section measurements and evaluations**	X-ray emitter
^{131}Ba	**Cross-section measurements and evaluations; decay-data evaluation**	X-ray emitter
^{161}Tb	**^{160}Gd(n,γ)^{161}Gd(β^-)^{161}Tb: decay-data measurements and evaluation**	Low-energy β^- emitter

Therapeutic β^-, X-ray and γ-ray emitters (continued)

Radionuclide	Requirements	Comments
^{166}Ho	Cross sections and decay data – see previous CRP (IAEA Technical Reports Series No. 473 and IAEA-STI/PUB/1287); **require cross-section measurements and evaluation for ^{164}Dy(2n,γ)^{166}Dy(β^-)^{166}Ho**	High-flux reactor required for double-neutron capture
^{169}Er	**Cross-section measurements and evaluations, including spallation beam cross sections; decay-data measurements and evaluation**	Low-energy β^- emitter
^{175}Yb	**Cross-section measurements and evaluations for charged-particle reactions; decay-data measurements and evaluation**	Low-energy β^- emitter
^{191}Os /^{191}Ir^m	**Cross-section measurements and evaluations**	Low-energy β^- emitter for radiotherapy + SPECT; potential *in-vivo* generator
^{191}Pt /^{191}Ir^m	**Cross-section and decay-data measurements and evaluations**	X-ray emitter; potential *in-vivo* generator

Therapeutic Auger-electron emitters

Radionuclide	Requirements	Comments
^{67}Ga, ^{111}In	Cross sections evaluated in two previous CRPs ((IAEA-TECDOC-1211 (^{67}Ga and ^{111}In), and IAEA Technical Reports Series No. 473 (^{67}Ga)); Auger electrons may become an issue	Both ^{67}Ga and ^{111}In finding increased application in internal radiotherapy
^{71}Ge	**Cross-section measurements and evaluations**; Auger electrons may become an issue	Half-life is rather long at 11.4 d
^{77}Br	**Cross-section evaluations**; Auger electrons may become an issue	
^{99}Tc^{m}	**Auger-electron (E_e < 25 keV) and other low-energy electron (E_e < 1 keV) data for microdosimetry**; decay-data evaluated in previous CRP (IAEA-STI/PUB/1287); **further needs for cross-section data will arise if produced by charged-particle reactions**	Regularly used for diagnosis, but also increased application in therapeutics
^{103}Pd	Cross sections evaluated in previous CRP (IAEA-TECDOC-1211); **decay-data measurements and evaluation**	Decay-data evaluation in planned CRP

Therapeutic Auger-electron emitters (continued)

Radionuclide	Requirements	Comments
^{123}I	See IAEA-TECDOC-1211 and IAEA-STI/PUB/1287; Auger electrons	Regularly used for diagnosis, but also increased application in therapeutics; several production reactions and discrepancies to be studied in planned CRP
^{140}Nd	**Cross-section evaluations of several reactions**; Auger electrons may become an issue	Auger and EC decay; *in-vivo* generator (^{140}Pr) – see previous table (β^+ emitters: generators)
^{178}Ta	^{176}Hf(α,2n)^{178}W(EC)^{178}Ta; Auger electrons may become an issue	Auger and EC decay; *in-vivo* generator (^{178}W)
^{193}Pt ^{m}, ^{195}Pt ^{m}	**Cross-section measurements and evaluations**; Auger electrons may become an issue	Large number of Auger electrons emitted
^{197}Hg	**Cross-section and decay-data measurements and evaluations**; Auger electrons may become an issue	

Therapeutic α emitters

Radionuclide	Requirements	Comments
^{149}Tb	Cross-section measurements and evaluations of spallation and heavy-ion beam reactions	Emission of low-energy alpha particles (< 4 MeV) – potentially useful for special applications
^{211}At/^{211}Po	Cross sections and decay data evaluated in previous CRPs (IAEA Technical Reports Series No. 473, and "Updated Actinide Decay Data Library (to be published))	Well-established therapeutic radionuclide
^{225}Ac/^{213}Bi	Lack of cross-section data at higher energies for spallation reaction on ^{232}Th; decay chain evaluated in previous CRP ("Updated Actinide Decay Data Library" (to be published))	Potentially important therapeutic radionuclide
^{227}Ac/^{223}Ra	Inadequate cross-section data for ^{232}Th(p,x) production of ^{227}Ac – measurements and evaluation; ^{223}Ra decay data evaluated in previous CRP ("Updated Actinide Decay Data Library" (to be published))	Impurity in ^{225}Ac production
^{230}U/^{226}Th	Cross-section studies within planned CRP; decay-data evaluations of α-decay chain	Papers containing new decay-data measurements presented at ICRM2011 conference

Intermediate-term Nuclear Data Needs for Medical Applications:
Cross Sections and Decay Data

Technical Meeting
IAEA Headquarters, Vienna, Austria
22-26 August 2011

Proton beam therapy:

- non-elastic cross sections of C, N and O at E_p up to 250 MeV;
- activation cross sections of residual nuclei (^{11}C, ^{13}N, ^{15}O, ^{30}P and ^{38}K positron emitters)

Carbon beam therapy – complex fragmentation reactions → difficult to prepare data sets

Fragmentation and production of light particles and residues → require more precise models and validated parameter sets
Proton beam therapy → require more precise Monte-Carlo transport calculations for dose deposition of variations in morphology or in structure arising from bone or implants

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Longer term:

Increased dynamic and quantitative positron tomography (PET) coupled with X-ray tomography (CT) and magnetic resonance imaging (MRI) for organ imaging

Assessment of improved internal radiotherapy:

- PET and therapy involving radioimmuno reactions
- Auger-electron and α-particle therapy at the cellular level

Positron emitters and therapeutic radionuclides – long-term possibilities:

- metallic-based positron emitters (e.g., Ti, Ga, Cu radionuclides) → developments in organometallic-complex chemistry
- improved microdosimetry → requirement to better characterise suitable low-energy Auger-electron emitters

Nuclear Data Needs

Immediate future:

Planned IAEA-NDS CRP dedicated to cross sections and decay data for medical applications is based on:

High-Precision Beta-Intensity Measurements and Evaluations for Specific PET Radioisotopes (see IAEA report INDC(NDS)-0535, 2008)

Improvements in Charged-Particle Monitor Reactions and Nuclear Data for Medical Isotope Production (see IAEA report INDC(NDS)-0591, 2011)

Monitor reactions: ^{22,24}Na, ^{46}Sc, ^{56,58}Co, ^{62,63,65}Zn, ^{96}Tc^{m+g}

Reactions for diagnostic γ emitters: ^{99}Tc^{m}, ^{111}In, ^{123}I (^{123}Cs, ^{123}Xe, ^{121}I production)

Reactions for novel β^{+} emitters: ^{52}Fe, ^{55}Co, ^{61}Cu, ^{66,68}Ga, ^{72}As, ^{73}Se, ^{76}Br, ^{86}Y, ^{89}Zr, ^{94}Tc^{m}, ^{110}In^{m}, ^{120}I

Reactions for generators: ^{62}Zn/^{62}Cu, ^{68}Ge/^{68}Ga, ^{72}Se/^{72}As, ^{82}Sr/^{82}Rb

Reactions for therapeutic isotopes:

- α emitters – ^{225}Ra and ^{225}Ac production (→ ^{213}Bi); ^{227}Ac impurity
- electron and X-ray emitters – ^{131}Cs (also ^{131}Ba production)

Decay data evaluations: ^{52}Fe(?), ^{61}Cu, ^{64}Cu(?), ^{62,63}Zn, ^{66}Ga, ^{72}As, ^{73}Se, ^{76}Br, ^{86}Y, ^{89}Zr, ^{94}Tc^{m}, ^{103}Pd, ^{120}I, and ^{230}U decay chain

Nuclear Data Needs

Intermediate- and longer-term considerations

Further need for future IAEA-NDS CRP(s) dedicated to cross sections and decay data for medical applications based on recommendations:

Intermediate-term Nuclear Data Needs for Medical Applications: Cross Sections and Decay Data

A.L. Nichols, S.M. Qaim and R. Capote Noy

22-26 August 2011, IAEA Headquarters, Vienna, Austria

IAEA report INDC(NDS)-0596, September 2011

Previous tables refer

Nuclear Data Needs

Intermediate- and longer-term considerations

Previous assessments and recommendations of INDC(NDS)-0596 have also been presented at an IAEA Technical Meeting, as described in NDS policy document:

Long-term Needs for Nuclear Data Development

A. Plompen

2-4 November 2011, IAEA Headquarters, Vienna, Austria

IAEA report INDC(NDS)-0601, January 2012

Important Policy Document for IAEA Nuclear Data Section over next 5 to 15 years, up to 2025 (approximately 70%-80% of future programme beyond next 5 years)