KU LEUVEN

NUCLEAR AND RADIATION PHYSICS

Mass separation of ^{225}Ac from ^{227}Ac and from irradiated Th targets to support Targeted Alpha Therapy

Proposal MED024

CERN MEDICIS Collaboration Board IV

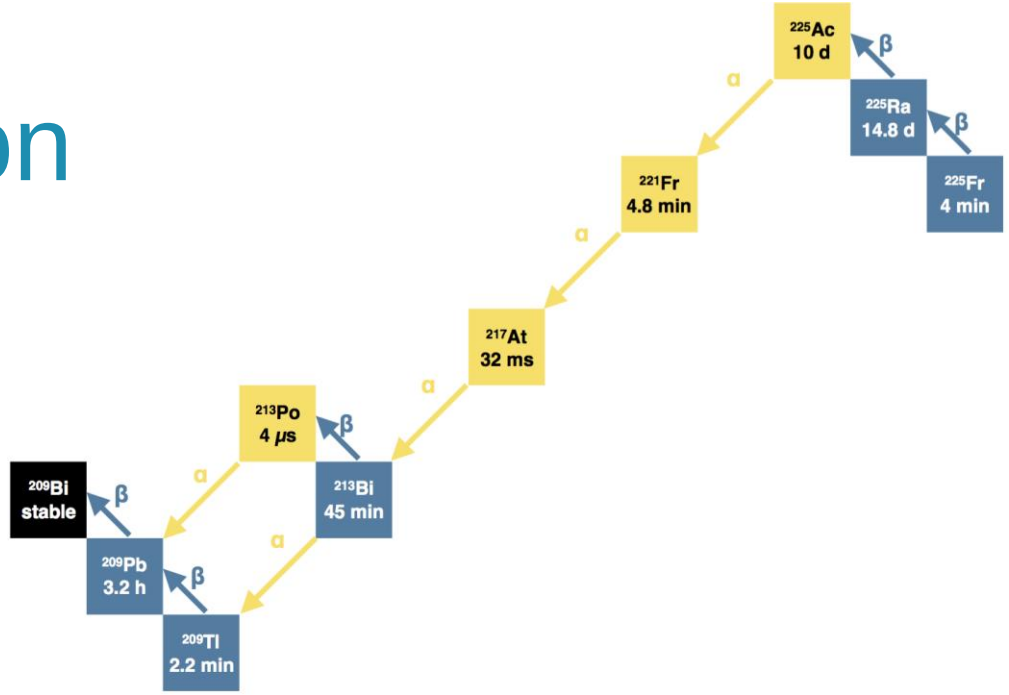
18 September 2019

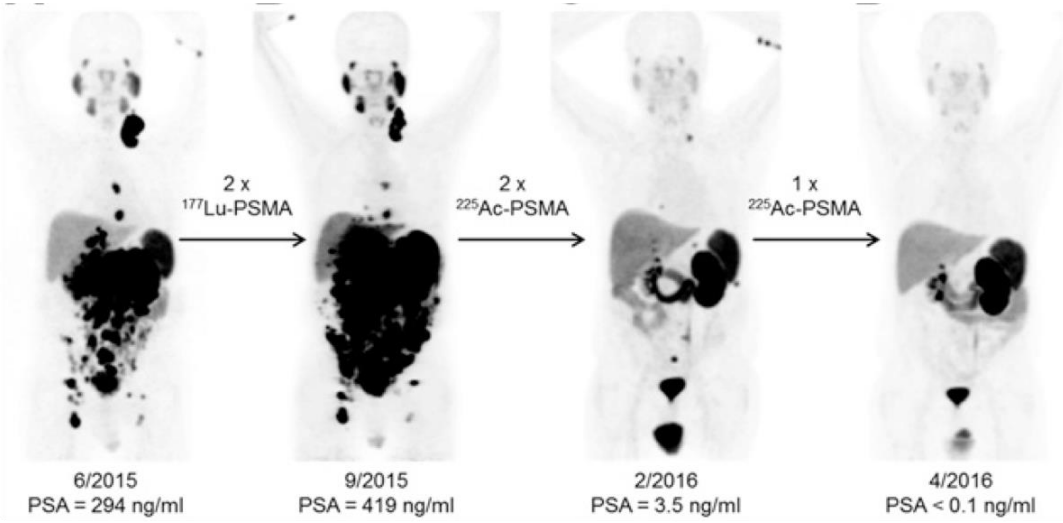
^{225}Ac for medical application

- Direct use as an α emitter
  - 4 α particles in close succession
  - $T_{1/2}$ ~ 10 days

- As a generator for ^{213}Bi
  - 100% α emission
  - $T_{1/2}$ ~ 45 min

- Can be combined with ^{68}Ga for theranostics applications





*C. Kratochwil et al, The Journal of Nuclear Medicine **57** (2016) 1941-1944*

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Sources of ^{225}Ac

Existing supply

- In the decay chain of ^{229}Th
- Extracted from ^{233}U bread during the XX^{th} century weapon research
- 3 main suppliers: ORNL, ITU, IPPE
- Global annual production of 63 GBq
- Supporting some clinical trials worldwide but insufficient for future use & not sustainable

Considered alternative routes

- $^{226}Ra(\gamma,n)^{225}Ra \rightarrow {}^{225}Ac$
- $^{226}Ra(p,2n)^{225}Ac$ @ 16.8 MeV
  - Best on paper
  - Difficulties associated with ^{226}Ra
- $^{232}Th(p,x)^{225}Ac$ @ >70 MeV
  - Co-production of ^{227}Ac
- ISOL
  - TRIUMF ISAC
  - CERN ISOLDE / MEDICIS

*A.K.H. Robertson, C.F. Ramogida, P. Schaffer, V. Radchenko, Current Radiopharmaceuticals **11** (2018) 156-172*

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Sources of ^{225}Ac

	Production Method	Facility	Capabilities	Monthly ^{225}Ac Production [GBq (Ci)]
Current Sources	^{229}Th generator	ORNL ITU IPPE	0.704 g (150 mCi) of ^{229}Th 0.215 g (46 mCi) of ^{229}Th 0.704 g (150 mCi) of ^{229}Th	2.2 (0.06) 1.1 (0.03) 2.2 (0.06)
Potential	$^{232}Th(p, x)^{225}Ac$	TRIUMF	500 MeV, 120 µA	11266.5 (304.05)
		BNL	200 MeV, 173 µA	2675.84 (72.32)
		INR Arronax	160 MeV, 120 µA 70 MeV, 2×375 µA	1002.0 (27.08) 462.1 (12.49)
		LANL	100 MeV, 250 µA	444.0 (12.00)
		iThemba LABS	66 MeV, 250 µA	127.7 (3.45)
Future	$^{226}Ra(p, 2n)^{225}Ac$	20 MeV, 500 µA cyclotron 15 MeV, 500 µA cyclotron		3983.1 (107.65) 1157.4 (31.28)
Sources	ISOL	TRIUMF (existing) TRIUMF (potential upgrades)		0.37 (0.01) 190.6 (5.15)
	$^{226}Ra(\gamma, n)^{225}Ra$	medical linac ALTO	18 MeV, 26 µA 50 MeV, 10 µA	48.1 (1.3) 55.5 (1.5)
	$^{226}Ra(n, 2n)^{225}Ra$	fast breeder reactor		~37 (1)

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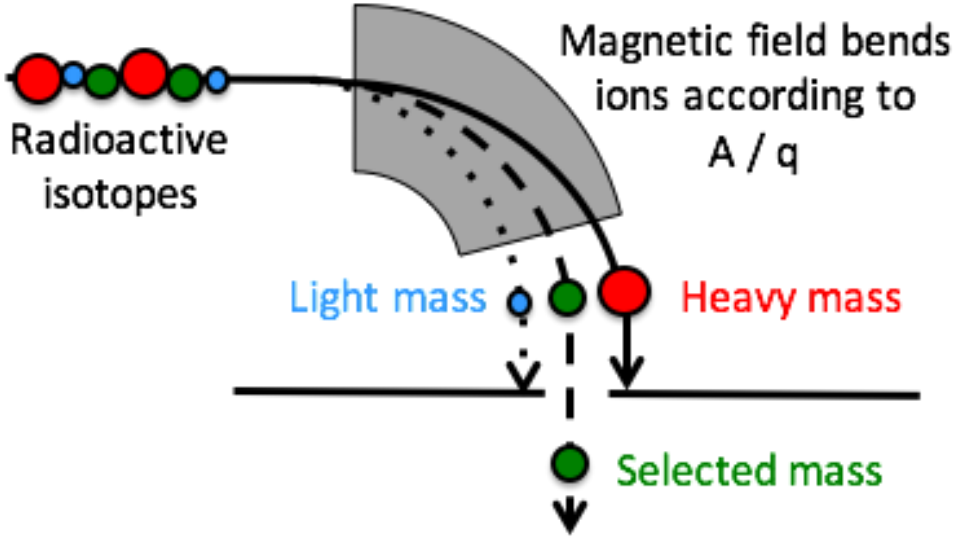
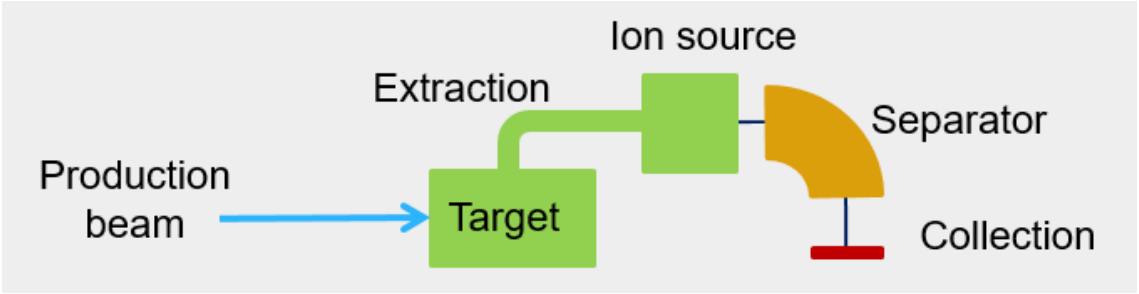
Handling Ac with the ISOL method

- High-energy spallation of ^{232}Th or ^{238}U yields to the co-production of Ra / Ac with A=220-230
- Radiochemistry yields a mix ^{225}Ac / ^{227}Ac (2%), deteriorating in time
  - Waste management problem
- Mass separation yields a mix ^{225}Ac / ^{225}Ra
  - Acceptable as a co-generator
  - Efficiency?





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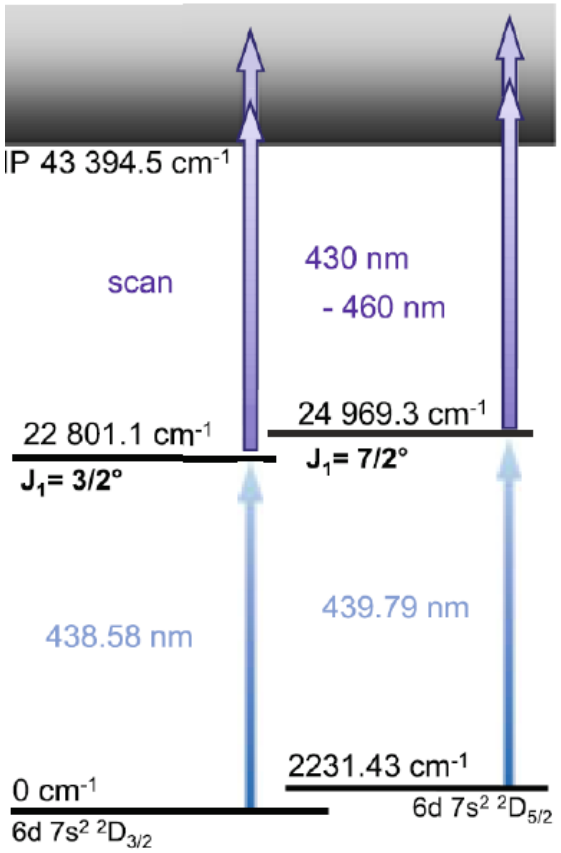
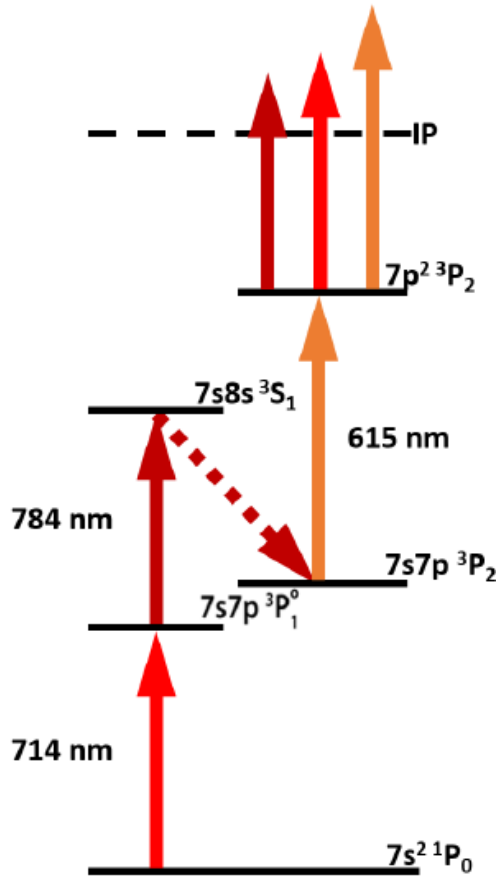
Handling Ac with the ISOL method

- Surface ionization of Ra has a long history at ISOLDE & laser ionization is now available as well
- Laser ionization of Ac has been demonstrated at Mainz / TRIUMF / LISOL / ISOLDE
- Release of Fr/Ra/Ac from UC_x has been studied at ISOLDE under IS637 yielding ~ few % efficiency





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MED024: ^{225}Ac at MEDICIS

- Production route 1: mass separation of chemically-separated actinium, namely ^{225}Ac / ^{227}Ac (2%). This sample may be engineered from separate supplies of either isotope as well to reproduce the conditions.
- Production route 2: direct extraction and separation of ^{225}Ac from an irradiated ^{232}Th sample (metallic foil, ThO_x, ThC_x?). Considering irradiation at TRIUMF while CERN undergoes LS2.
- Characterization
  - Pre-separation & post-separation (full post-analysis of the sample at SCK•CEN)
  - Total activity and specific activities of ^{225}Ac & ^{227}Ac
  - Determining the process efficiency and enrichment factor

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MED024: aims & request

- Characterize the separation of ^{225}Ac / ^{227}Ac in a quantitative way
- Start from chemically-separated Ac, as well as from various forms of irradiated Th
- Provide ^{225}Ac for the future operation of MEDICIS and offer a long-term solution for the purification of ^{225}Ac.

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Irradiation at TRIUMF

- Irradiations planned at Beam Line 1A
- Radiochemistry to be performed on site prior to shipping