DOE IP Virtual Seminar Series

Cerium-134

Ce-134 AGENDA
OCTOBER 16, 2023, 1 PM EDT

1:00 – 1:15 PM  Veronika Mocko, PhD | Los Alamos National Laboratory
1:15 – 1:30 PM  Robert Flavell, MD, PhD | University of California San Francisco
1:30 – 1:45 PM  Timothy Haystead, PhD | Duke University Center
1:45 – 2:00 PM  James Kelly, PhD | Weill Cornell Medicine
2:00 – 2:30 PM  Moderated Q&A Segment

Veronika Mocko, October 16th 2023

LA-UR-23-31751
Motivation: $^{134}\text{Ce} / ^{134}\text{La}$ as imaging companion for $\alpha$-radiotherapy

- Increased application of targeted alpha therapy $^{225}\text{Ac}$ ($T_{1/2}$ 9.9d), $^{227}\text{Th}$ ($T_{1/2}$ 18.7d)
- PET radiometals: $^{68}\text{Ga}$ ($T_{1/2}$ 67.7min), $^{64}\text{Cu}$ ($T_{1/2}$ 12.7h), $^{132}\text{La}$ ($T_{1/2}$ 4.8h), $^{133}\text{La}$ ($T_{1/2}$ 3.9h)
  - $^{68}\text{Ga}$, $^{64}\text{Cu}$ – different chemistry and coordination
  - All too short lived to track biological fate over several days

In vivo generator

$^{134}$Ce production

- \( ^{\text{nat}}\text{La} (p, 6n)^{134}\text{Ce} \)
- Energy range for production optimized

Optimum $^{134}$Ce production energy range range: 77.9 – 67.8 MeV
$^{134}$Ce production

- $^{\text{nat}}$La ($p$, $6n$)$^{134}$Ce
- 32 g of La metal (45.7 x 3 mm)
- Incident energy 77.9 MeV, Exit energy 67.8 MeV H$^+$
- Beam current 100 $\mu$A, Cumulative charge ~3000 $\mu$A.h
$^{134}\text{Ce}$ Isolation

Target opening

La dissolution

8M HNO$_3$

$^{134}\text{Ce(NO}_3\text{)}_6^{2-}$

La-Ce separation

6M HNO$_3$ + 0.3M NaBrO$_3$

$^{134}\text{Ce}$ elutes with 50 mM HNO$_3$

One column rapid separation with high yield > 80%

$^{134}\text{Ce}$ radiochemical purity

$^{139}\text{La} (p,6n)^{134}\text{Ce} \ (T_{1/2} \ 3.16 \ d)$
$^{139}\text{La} (p,5n)^{135}\text{Ce} \ (T_{1/2} \ 0.74 \ d)$
$^{139}\text{La} (p,3n)^{137m}\text{Ce} \ (T_{1/2} \ 1.43 \ d)$
$^{139}\text{La} (p,n)^{139}\text{Ce} \ (T_{1/2} \ 137.64 \ d)$
Product characterization: gamma spectroscopy & ICP-OES

- Radionuclidic purity >99.8% (excluding $^{135}\text{Ce}$, $^{137}\text{mCe}$, $^{139}\text{Ce}$ and daughters)
- $^{135}\text{Ce} < 1\%$, $^{137}\text{mCe} < 5\%$, $^{139}\text{Ce} < 3\%$
- Specific activity >4,000 Ci/g, typical 8,000-12,000 Ci/g on ship date
- Form: Ce(III) in 0.1 M HCl
- Concentration > 5 mCi/mL, typical 10-20 mCi/mL
- Total Ce 42-101 µg, total Ce concentration 1.4-10.4 µg/mL
- Total La 50-169 µg, total La concentration 1.7-17.4 µg/mL

Product Information

Specifications

- **Radioisotope**: Ce-134
- **Half-Life/Decay**: 3.18 days to lanthanum-134
- **Chemical Form**: Ce(III) in 0.5M HCl
- **Available Specific Activity**: > 4000 Ci/g
- **Activity Concentration**: > 5 mCi/mL
- **Radionuclidic Purity**: > 99.8% (excluding Ce-135, Ce-137m, Ce-139 and La daughters, Ce-135 < 1%, Ce-137m < 5%, Ce-139 < 3%)
- **Production Route**: Proton-irradiation of La target
- **Processing**: Dissolution and ion exchange
- **Primary Container**: Glass crimp-top vial
- **Availability**: Monthly
- **Unit of Sale**: Millions

Energy (keV)
**134Ce application in vivo**

Developing the 134Ce and 134La pair as companion positron emission tomography diagnostic isotopes for 225Ac and 227Th radiotherapeutics

- First application of 134Ce in vivo
- 134Ce(III) DTPA mimics 225Ac
- 134Ce(IV) HOPO mimics 227Th

- 134Ce allows for long-term tumor targeting with DOTA-based antibody drug conjugates
- 134Ce better match for 225Ac/227Th due to longer half life than 132La(T1/2 4.8h), 133La(T1/2 3.9h)

Collaborator: Rebecca Abergel
**139Ce**

- New product available through NIDC
- $T_{1/2} = 137.641\text{ d}$
- Production from La, $^{\text{nat}}\text{La} (p,n)^{139}\text{Ce}$
- Radionuclidic purity >99.9%
- Specific activity >25 Ci/g, when produced 600 Ci/g
- Form: Ce(III) in 0.5 M HCl
- Concentration > 1 mCi/mL

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Announcing domestic supply chain of Cerium-139

November 4, 2022

The U.S. Department of Energy Isotope Program is pleased to announce cerium-139 (Ce-139) has been added to our catalog and is available for purchase.

Ce-139 is used in mixed calibration sources and to determine attenuation maps for SPECT medical diagnostic tomography. It also can be used as a tracer instead of short lived Ce-134. Historically, Russia has been the world’s primary producer of this isotope. Ce-139 is being produced in the Isotope Production Facility at Los Alamos National Laboratory.

For further inquiries about Ce-139 please contact the NIDC at contact@isotopes.gov or click the link below to request a quote.

[Request a quote](https://example.com/request-quote)
Summary and outlook

• In 2021&2022 LANL produces 2 evaluation batches
• Production and processing procedures for $^{134}$Ce transferred to BNL
• Both LANL and BNL demonstrated production of Ci-level $^{134}$Ce to provide year-round steady supply
• High specific activity and radioisotope purity $^{134}$Ce product
• Collaborators demonstrated that $^{134}$Ce allows for long-term tumor targeting
• In case of growing demand, La encapsulation in welded target shells can provide larger batches of $^{134}$Ce and likely also improved $^{134}$Ce/$^{139}$Ce ratio
• $^{139}$Ce can be potentially used as longer-lived $^{134}$Ce surrogate
The team

Program manager: Kirk Rector
Team lead: Carl Iverson


LANL colleagues: Cooley Jason

University of Wisconsin: Engle Jonathan, LBNL/Univ. of California: Abergel Rebecca