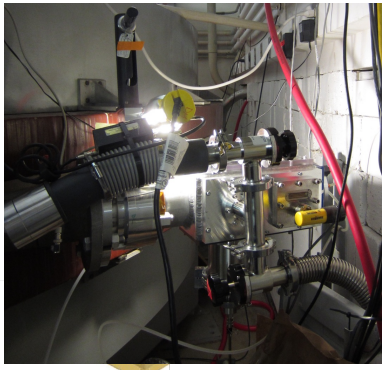
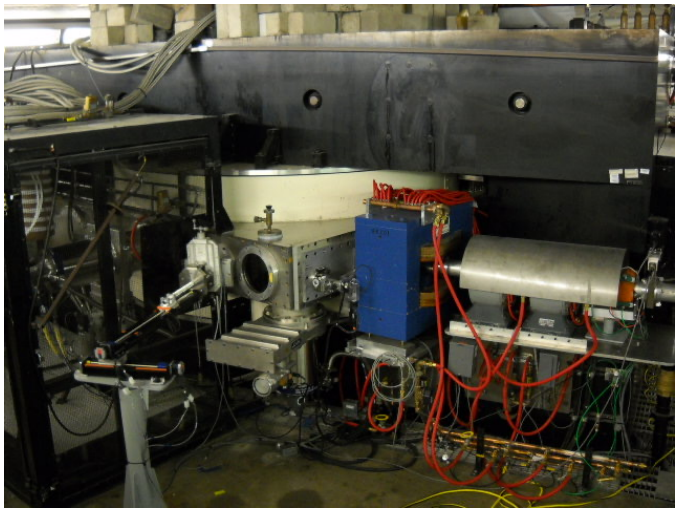
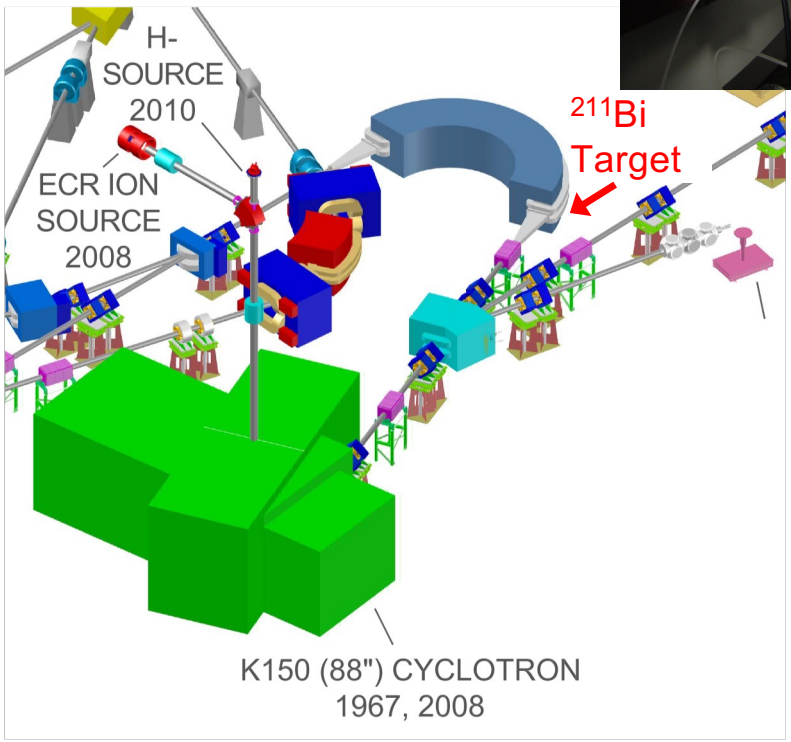
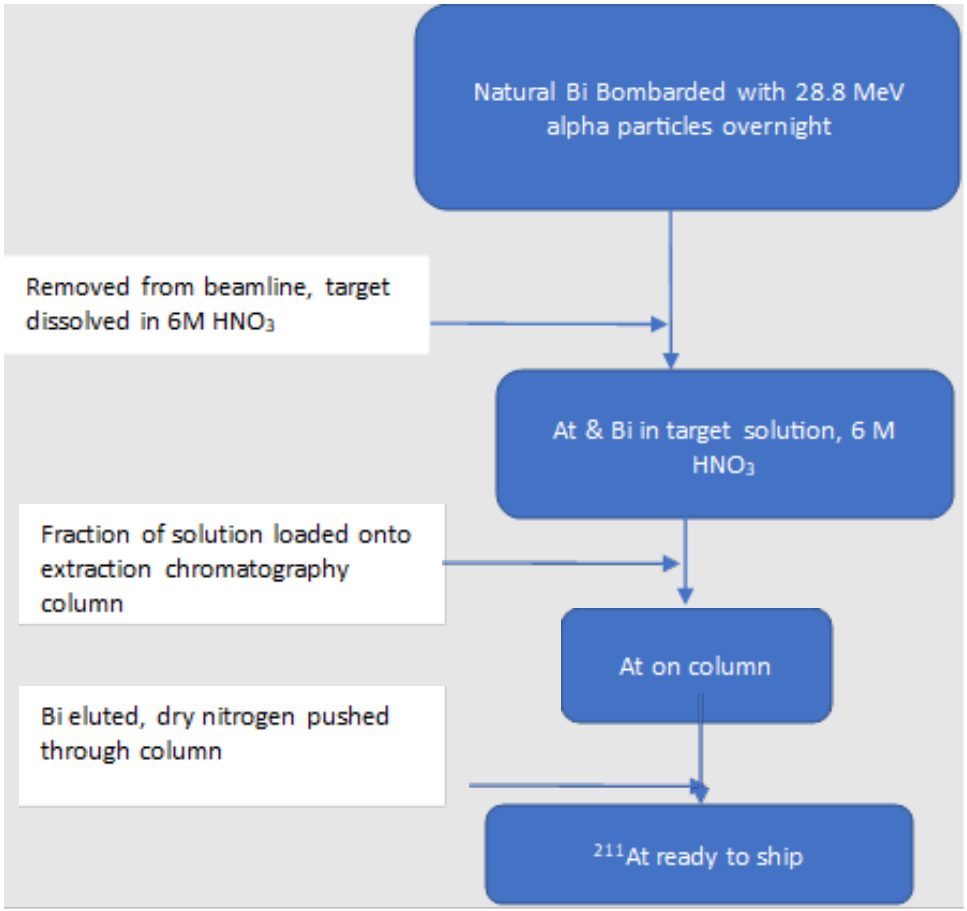
Texas A&M - K150 Cyclotron

- $^{209}Bi + \alpha \rightarrow {}^{211}At + 2n$
- Energy: 28.8 MeV
- +1 charge state

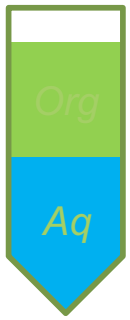







Natural Bi Bombarded with 28.8 MeV alpha particles overnight
Removed from beamline, target dissolved in 6M HNO_3
At & Bi in target solution, 6 M HNO_3
Fraction of solution loaded onto extraction chromatography column
At on column
Bi eluted, dry nitrogen pushed through column
^{211}At ready to ship

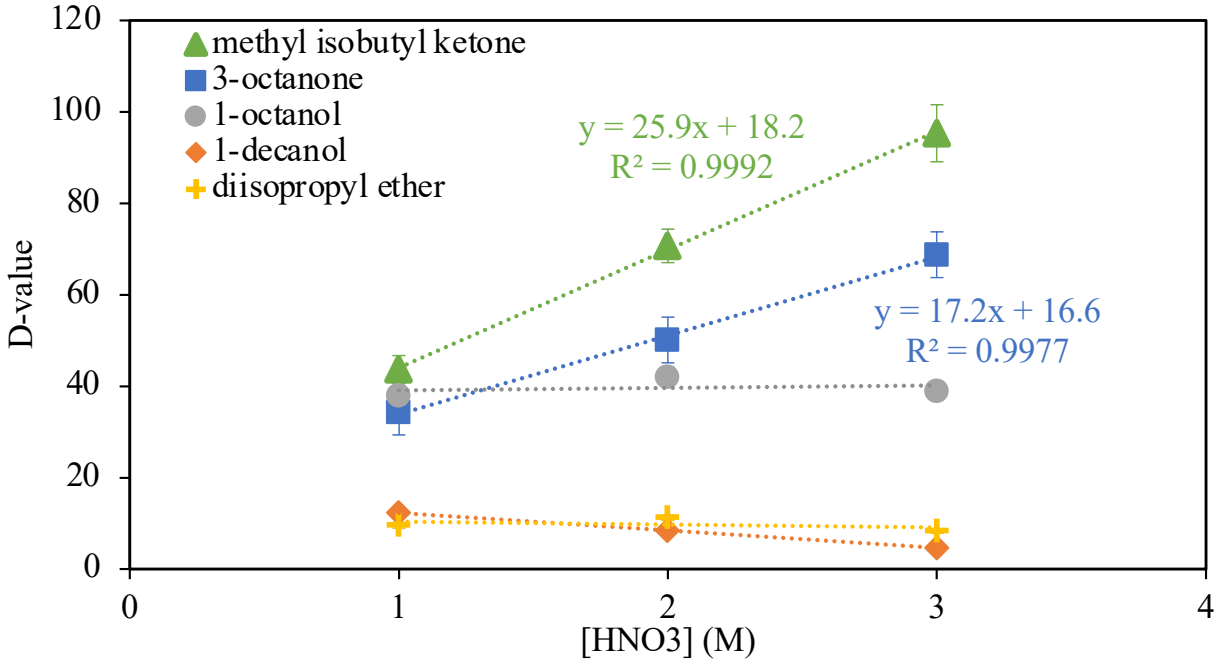
At-211 Separations



$D = C_{org}/C_{aq}$

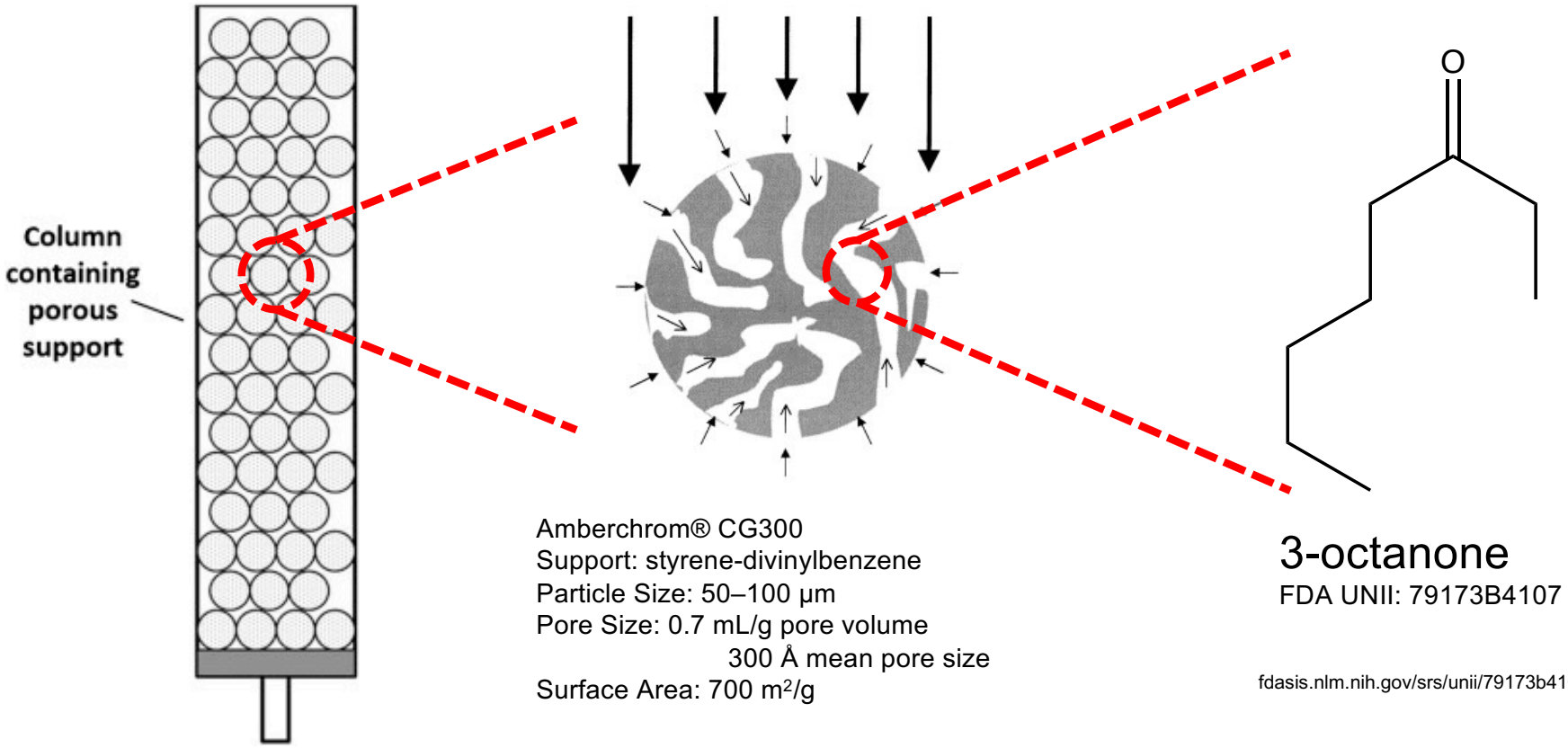
Bi D ≤ 0.1

Solvent	Dielectric Constant
methyl isobutyl ketone	13.11
3-octanone	10.5
1-octanol	10.3
1-decanol	7.93
Diisopropyl ether	3.81



Burns et al, *Chemical Communications, 2020*

Extraction Chromatography



Amberchrom® CG300
Support: styrene-divinylbenzene
Particle Size: 50–100 µm
Pore Size: 0.7 mL/g pore volume
300 Å mean pore size
Surface Area: 700 m^2/g

3-octanone
FDA UNII: 79173B4107

fdasis.nlm.nih.gov/srs/unii/79173b4107

Cartridge Column Loading

3-octanone impregnated on Amberchrom® CG300

ID = 7 mm

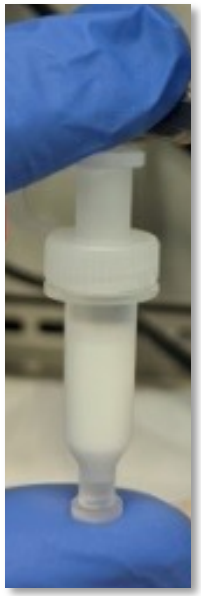
Bed Volume = 0.5 mL

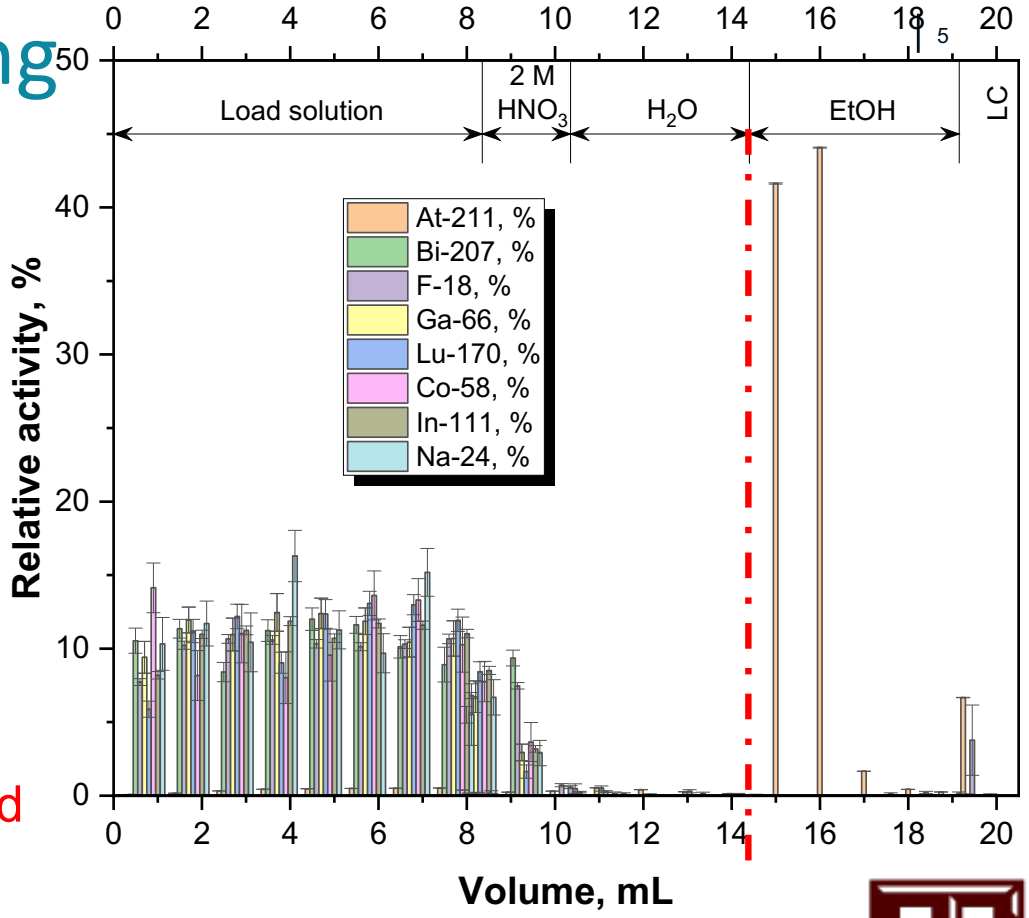
Bed Height = 12.99 mm

~60 mCi ^{211}At

~0.5 M Bi^{3+}

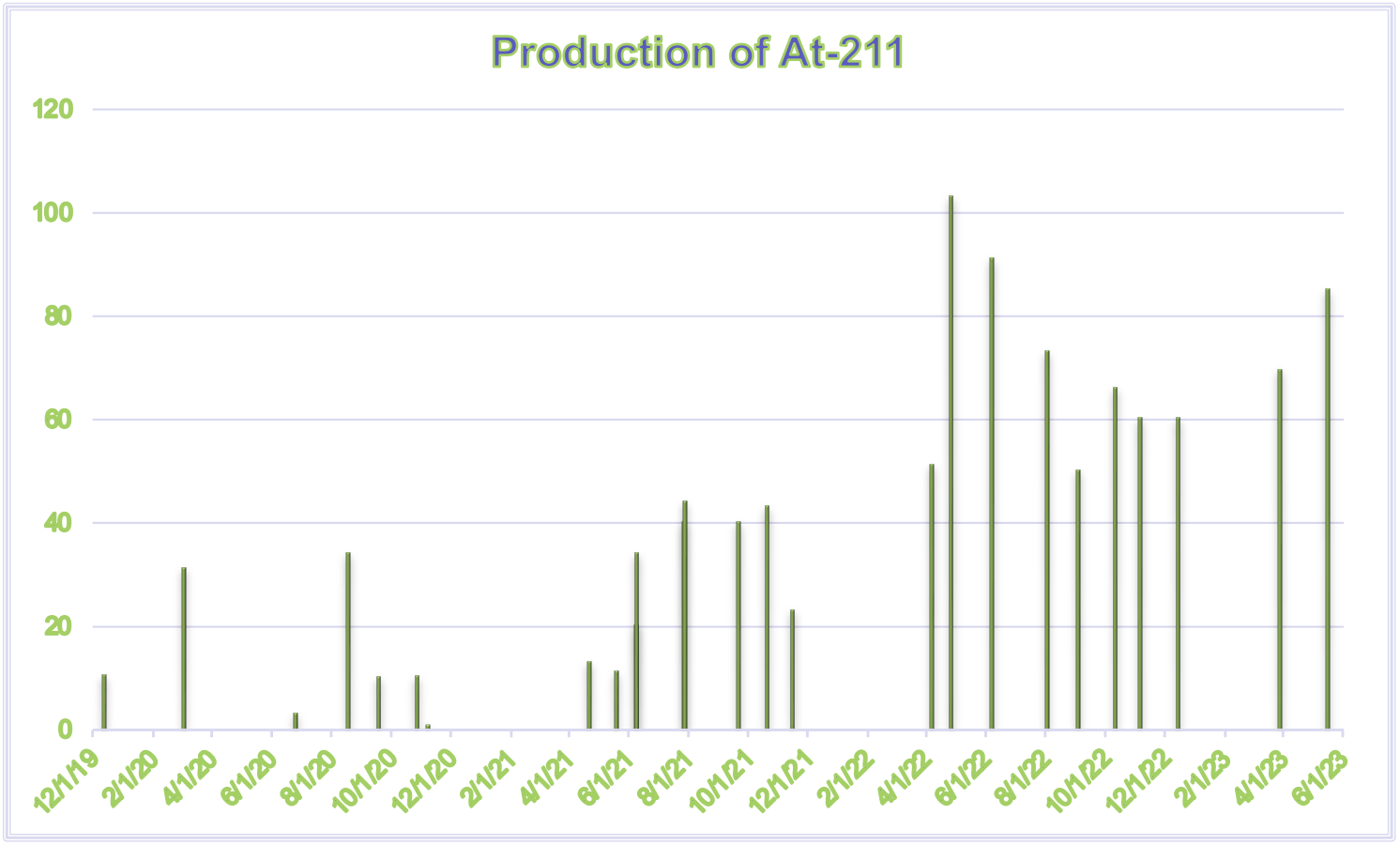
<20 min to recover ^{211}At





Free liquid removed from cartridge and held for 3.5 & 34 h between Wash and Strip

Tereshatov, E. E.; et al. *Chem. Eng. J.* **2022**, *442*, 136176.


Production of At-211
120
100
80
60
40
20
0
12/1/19
2/1/20
4/1/20
6/1/20
8/1/20
10/1/20
12/1/20
2/1/21
4/1/21
6/1/21
8/1/21
10/1/21
12/1/21
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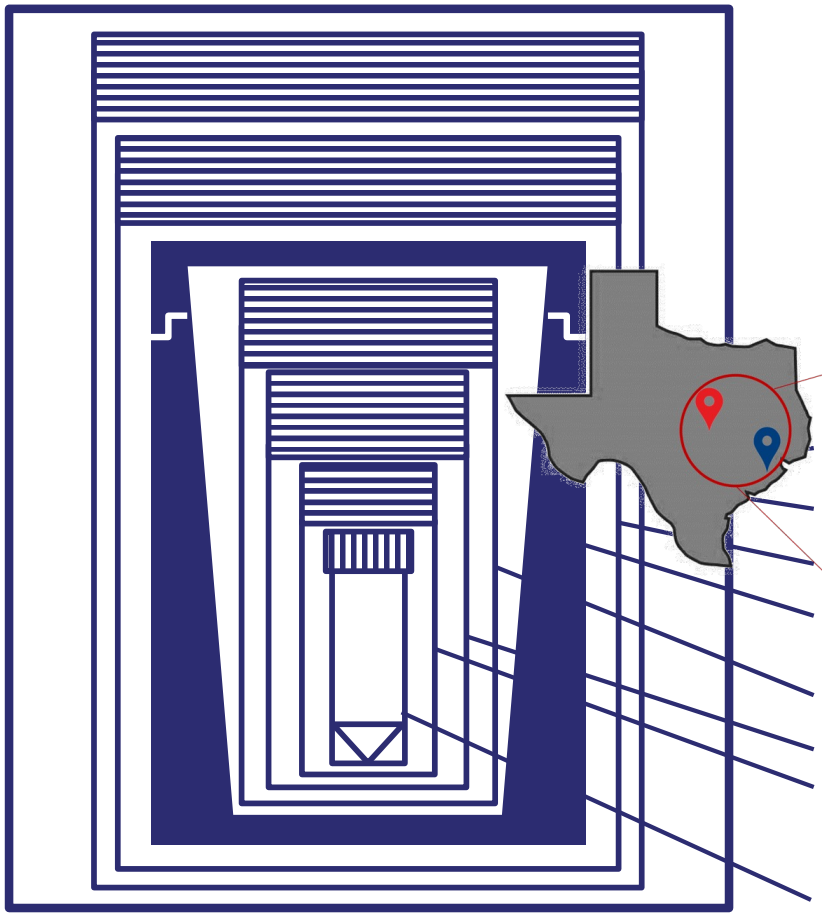
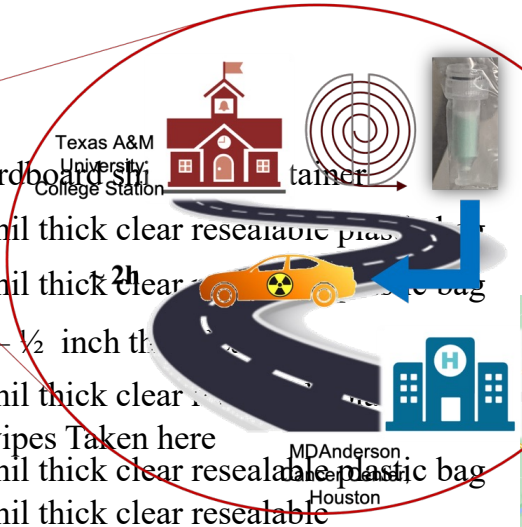
6/1/23





Cardboard Shi tainer

4 mil thick clear resealable pla

4 mil thick clear

¼ – ½ inch th

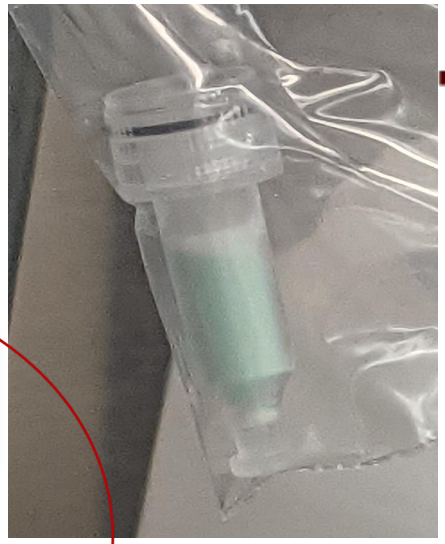
2 mil thick clear

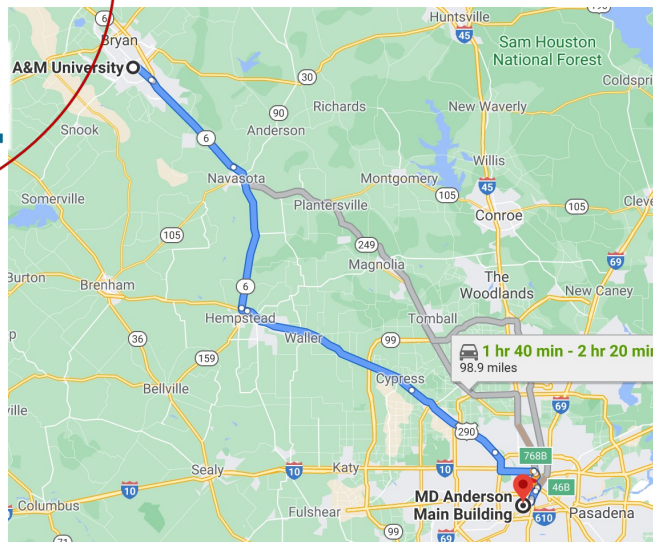
Swipes Taken here

2 mil thick clear resealable plastic bag

2 mil thick clear resealable plastic bag

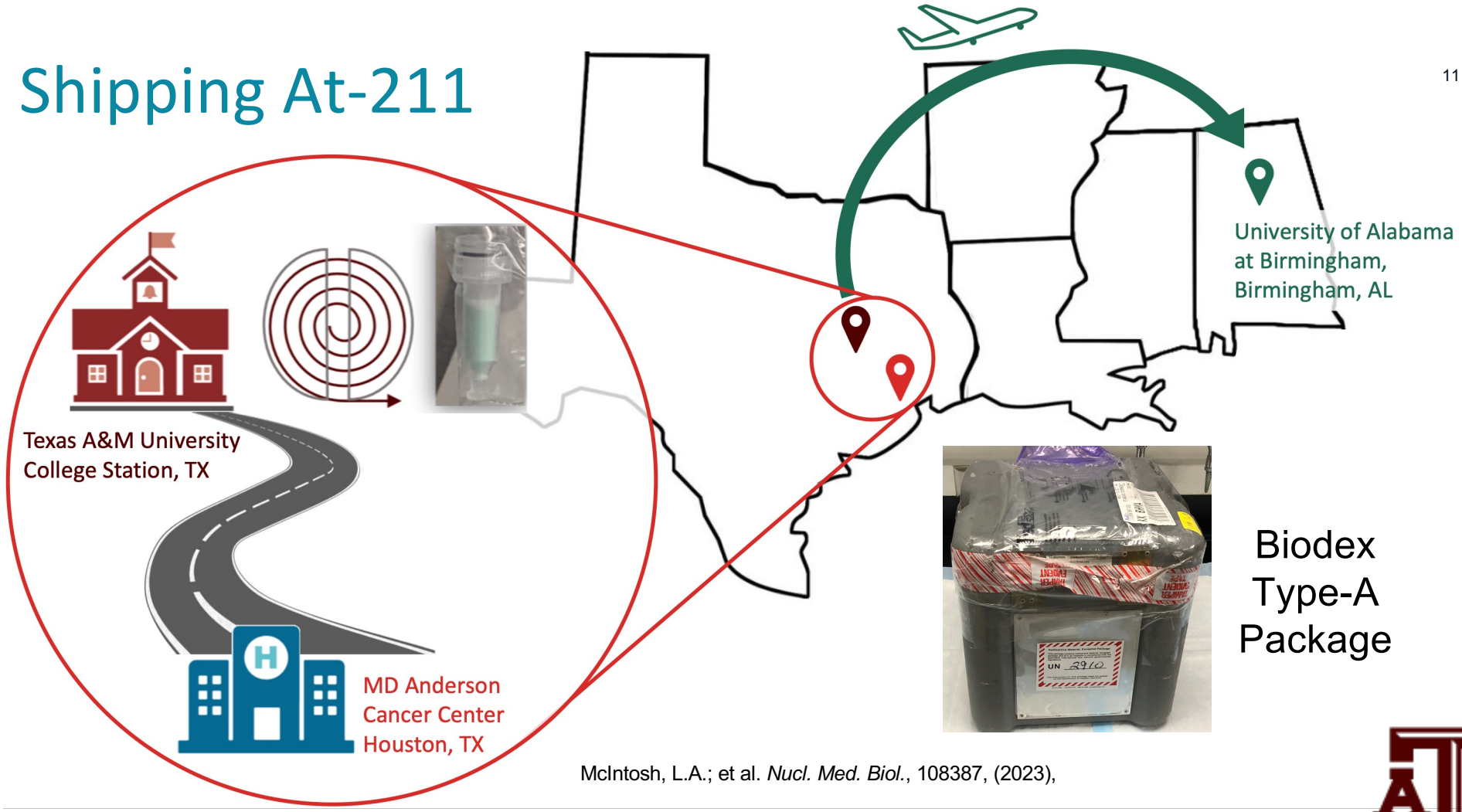
2 mL poly screw-cap cartridge containing 9.8 mCi of $^{211}AtO_xNO_3$





McIntosh, L.A.; et al. *Nucl. Med. Biol.*, 108387, (2023),

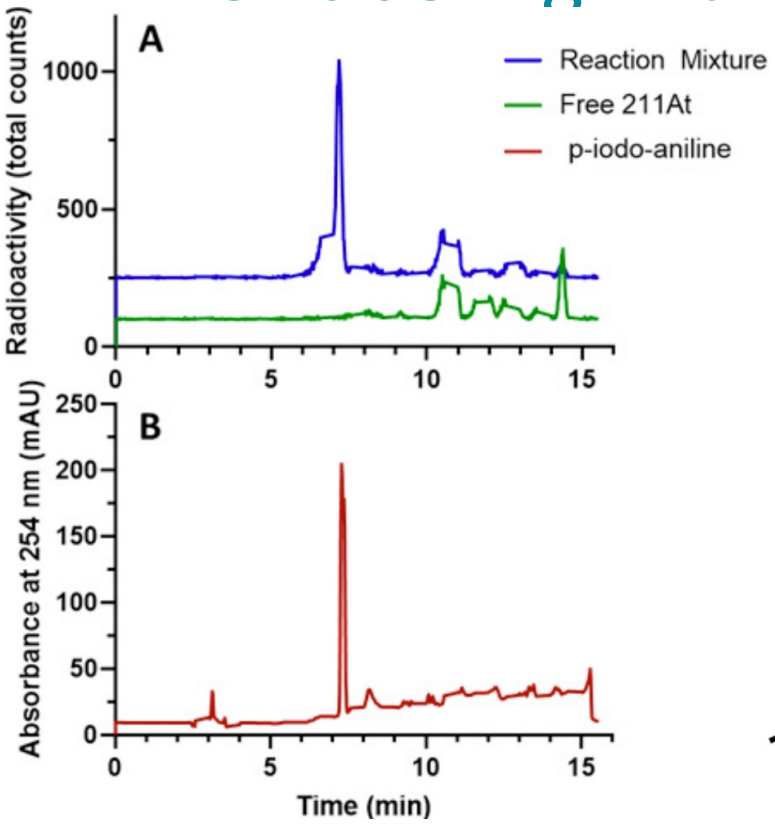
Shipping At-211

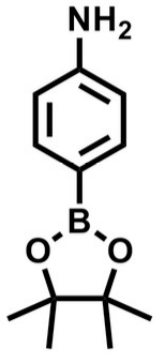


Biodex
Type-A
Package

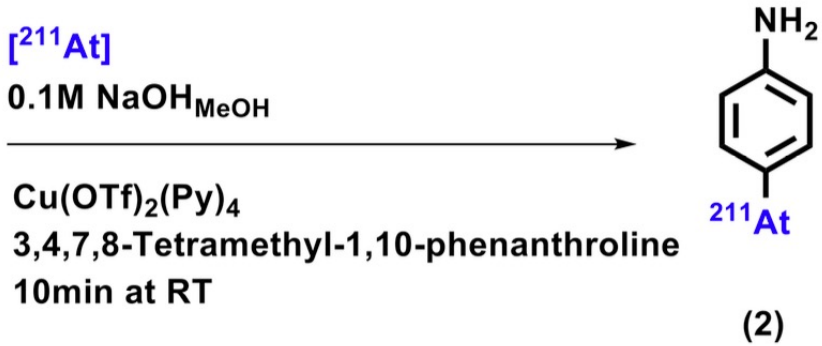
McIntosh, L.A.; et al. *Nucl. Med. Biol.*, 108387, (2023),

Aniline Labeling with ^{211}At





(1)



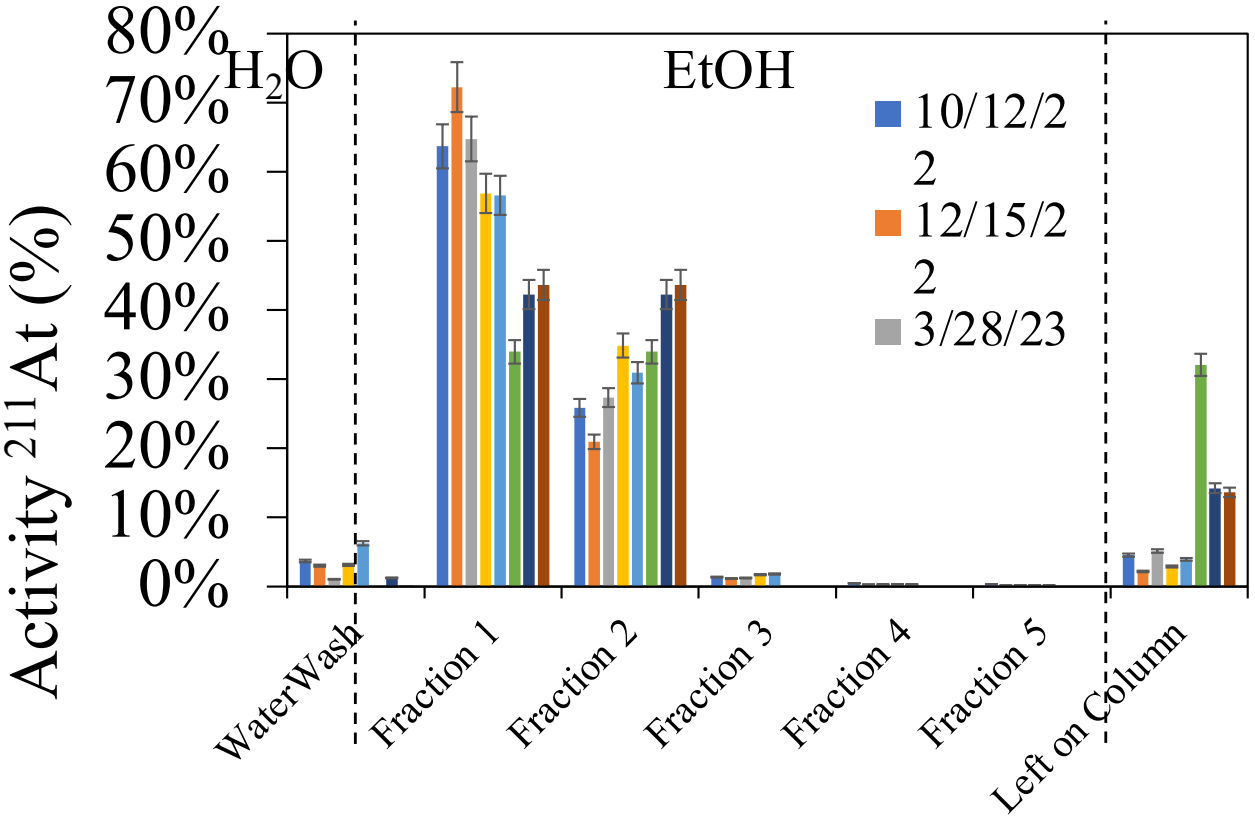
(2)

Labeling Yield
(non-decay corrected)
36 ± 22% (n = 4)

Riccardo Muzzioli
UTMDACC

McIntosh, L.A.; et al. *Nucl. Med. Biol.*, 108387, (2023),

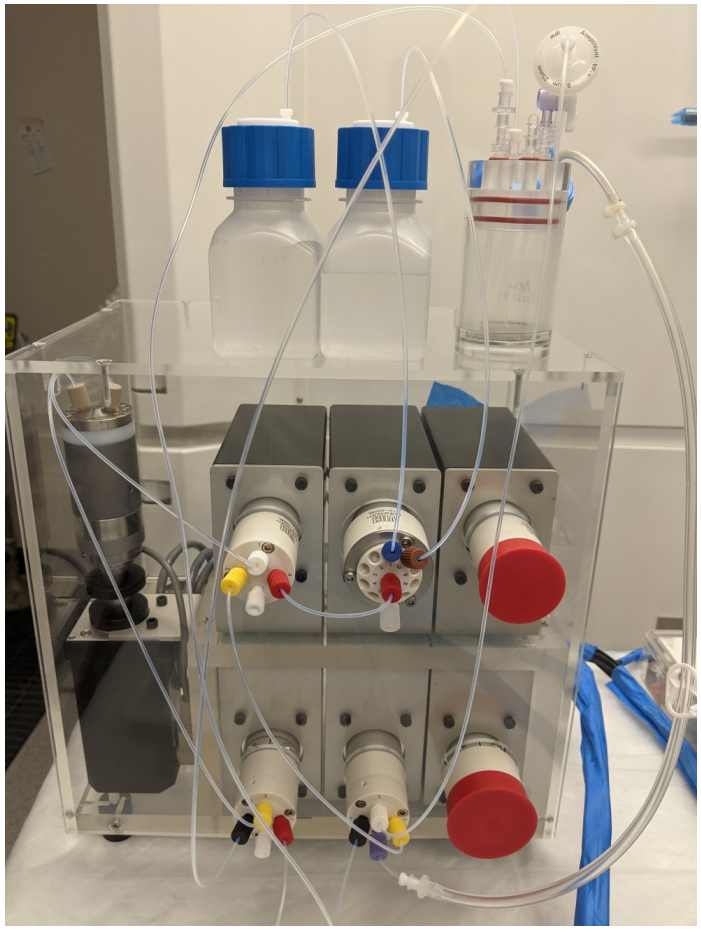
^{211}At Shipments from TAMU to UAB

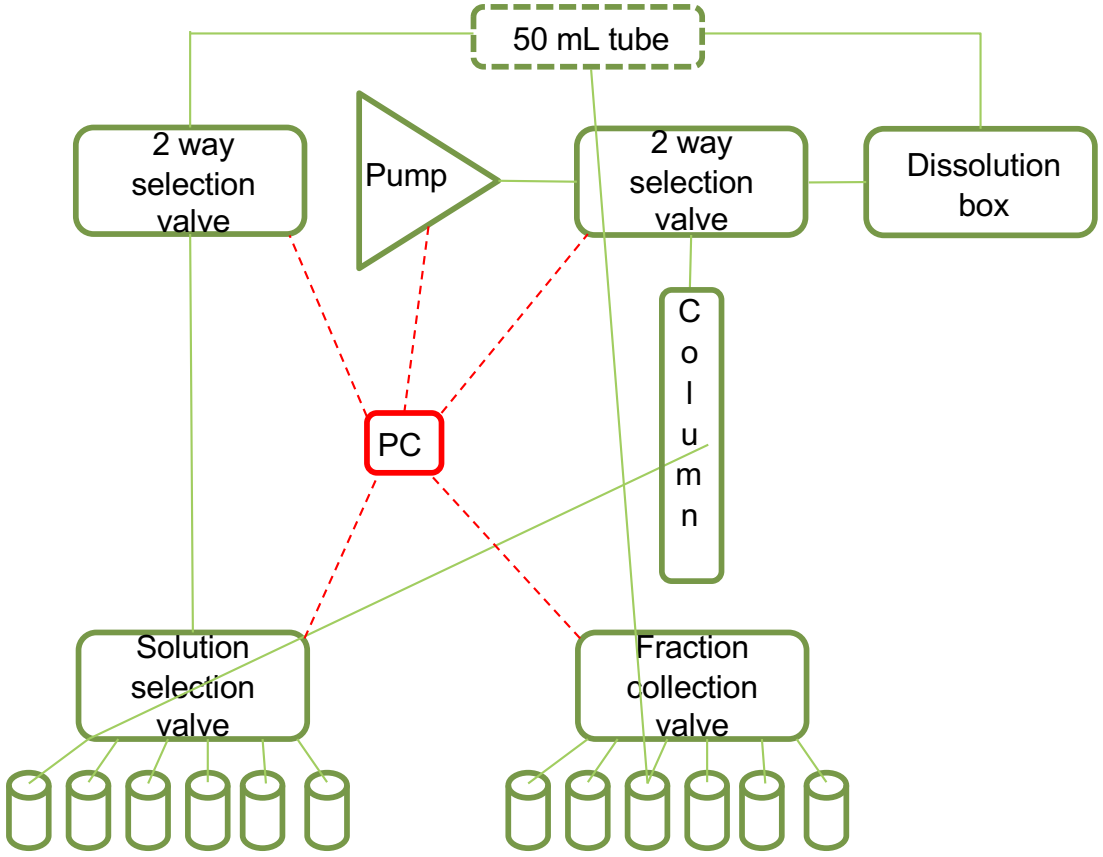


Shipment Date	Received Activity (mCi)
10/11/22	0.66 ± 0.07
12/14/22	1.67 ± 0.17
3/28/23	1.77 ± 0.18
5/19/23*	0.016 ± 0.002
6/14/23	1.07 ± 0.11
8/3/23*†	0.138 ± 0.014
8/22/23†	1.44 ± 0.14
9/7/23†	1.42 ± 0.14

McIntosh, L.A.; et al. *Nucl. Med. Biol.*, 108387, (2023),

Automated Dissolution Apparatus





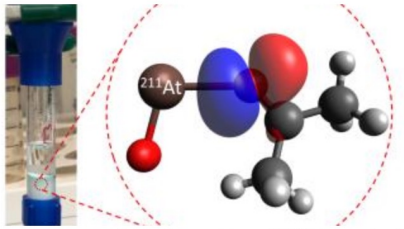
E. E. Tereshatov, et al, Chemical Engineering Journal, **442**, 136176 (2022)

NIDC | NATIONAL ISOTOPE DEVELOPMENT CENTER
MANAGED BY THE U.S. DEPARTMENT OF ENERGY ISOTOPE PROGRAM

New Elegant Method for Rapid Recovery of Anti-Cancer Agent At-211

April 30, 2021

Astatine is an extremely rare element. It occurs naturally only due to the radioactive decay of other elements in the earth's crust. There are no known stable isotopes of astatine, and none of its isotopes has a half-life greater than 8 hours. This means half of the nuclei in a sample of astatine will decay every eight hours. One isotope of the element,



nage courtesy of Jon Burns, Texas A&M University At-11 – ketone interaction within the chromatography olumn.

Cancer Countermeasures on a Column

April 5, 2022

The Science

Researchers supported by the DOE Isotope Program are studying the isotope astatine-211 (At-211) for a new cancer treatment called targeted alpha therapy. This type of treatment may do more damage to cancer cells and cause less harm to the rest of the body than current cancer therapies because it emits alpha particles. Alpha particles deposit a large amount of energy in a small volume of tissue. Researchers have now developed a novel method of separating and shipping At-211. The method separates radioactive At-211 from nonradioactive bismuth, where At-211 is present at the level of 1 in 35,000,000 atoms. The At-211 is then loaded into a column made of resin for delivery to a cancer center.

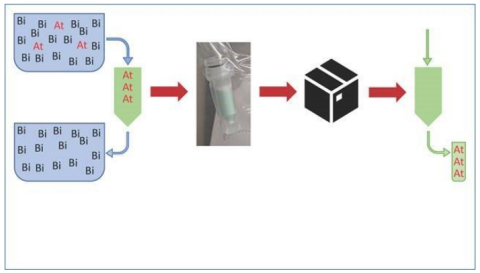


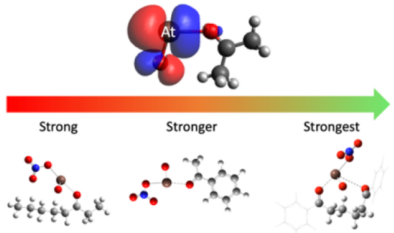
Image courtesy of Texas A&M University The medical radioisotope astatine is separated from bismuth then loaded into a resin column. Once dry, the column is ent for use

Tunable Bonds: A Step Towards Targeted At-211 Cancer Therapy

June 12, 2023

Astatine is the least abundant element on Earth, and all of its known isotopes have a half-life of less than 8 hours. One astatine isotope, astatine-211 (At-211), emits alpha particles and shows promise as a cancer therapy. However, very little is known about astatine's chemical interactions.

Researchers at Texas A&M University and the University of Alabama at Birmingham discovered a new, tunable chemical interaction of At-211 with a class of chemicals known as ketones. The interaction means scientists can tune the bond strength between ketones and At-211 by adjusting the type of ketone used. This allows scientists to control for how tightly the At-211 is held to the ketone. This discovery opens the door for developing cancer therapy drugs by linking At-211 to cancer targeting molecules.



The binding of At-211 with mono- and diketones with different bond strengths. Image courtesy of Jon Burns, University of Alabama at Birmingham

Recent Publications:

Compact automated apparatus for rapid astatine recovery from nitric acid media: Design, application, and impurity characterization, E.E. Tereshatov, J.D. Burns, S.J. Schultz, L.A. McCann, L.A. McIntosh, G.C. Tabacaru, M. Berko, E. Engelthaler, A. Hannaman, B. Harvey, K. Lofton, A. Tabacaru, Z. Tobin, S.J. Yennello, Chem. Eng. J. 442 (2022) 136176. https://doi.org/10.1016/j.cej.2022.136176.

Complexation of Astatine(III) with Ketones: Roles of NO_3^- Counterion and Exploration of Possible Binding Modes, J.D. Burns, E.E. Tereshatov, B. Zhang, G.C. Tabacaru, L.A. McIntosh, S.J. Schultz, L.A. McCann, B.M. Harvey, A. Hannaman, K.N. Lofton, M.Q. Sorensen, A.L. Vonder Haar, M.B. Hall, S.J. Yennello,, Inorg. Chem. 61(31) (2022) 12087-12096. https://doi.org/10.1021/acs.inorgchem.2c00085.

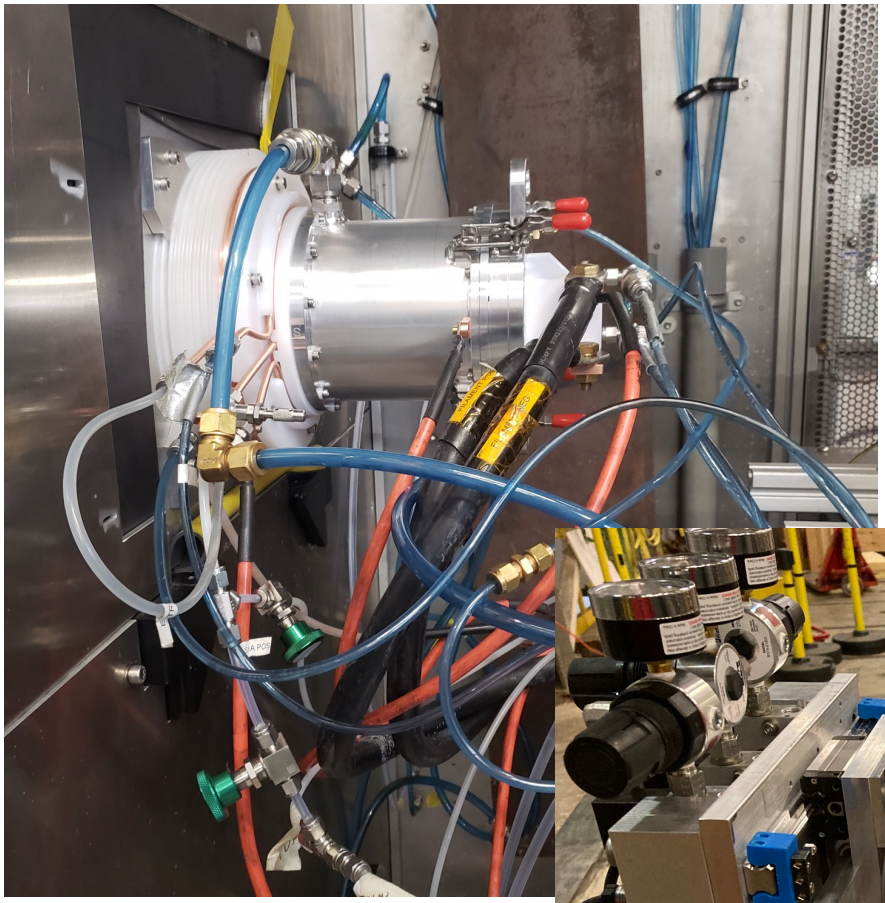
Mechanism of Astatine and Bismuth Sorption on Extraction Chromatography Resins from Nitric Acid Media, E. Tereshatov, J.D. Burns, S.J. Schultz, B.D. Green, G.A. Picayo, L.A. McCann, L.A. McIntosh, G.C. Tabacaru, A. Abbott, M. Berko, E. Engelthaler, K. Hagel, T. Hankins, B. Harvey, L. Hoekstra, K. Lofton, S. Regener, R. Rider, M. Sorensen, A. Tabacaru, D. Thomas, J. Tobar, Z. Tobin, S.J. Yennello, Chem. Eng. J. 464, 142742 (2023), https://doi.org/10.1016/j.cej.2023.142742.

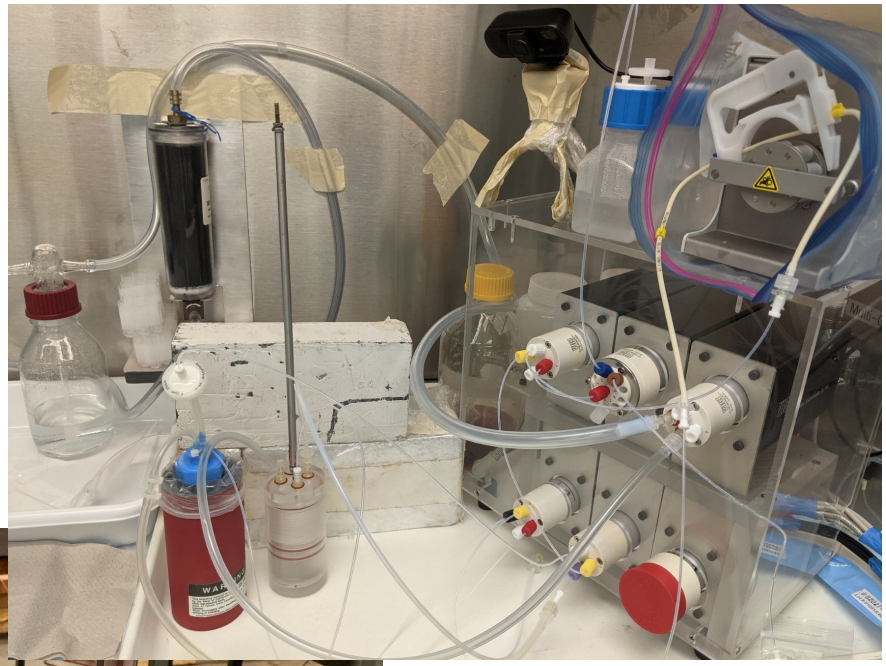
Behavior of astatine and bismuth in non-conventional solvents: Extraction into imidazolium-based ionic liquid and methyl anthranilate with active pharmaceuticals binary mixtures from nitric acid media, Evgeny E. Tereshatov, Jonathan D. Burns, Amy L. Vonder Haar, Steven J. Schultz, Lauren A. McIntosh, Gabriel C. Tabacaru, Laura A. McCann, Geoffrey Avila, Andrew Hannaman, Ashley Hood, Kylie N. Lofton, Mallory A. McCarthy, Maxwell Sorensen, Sherry J. Yennello, Separation and Purification Tech., 326, 124715 (2023), https://doi.org/10.1016/j.seppur.2023.124715.

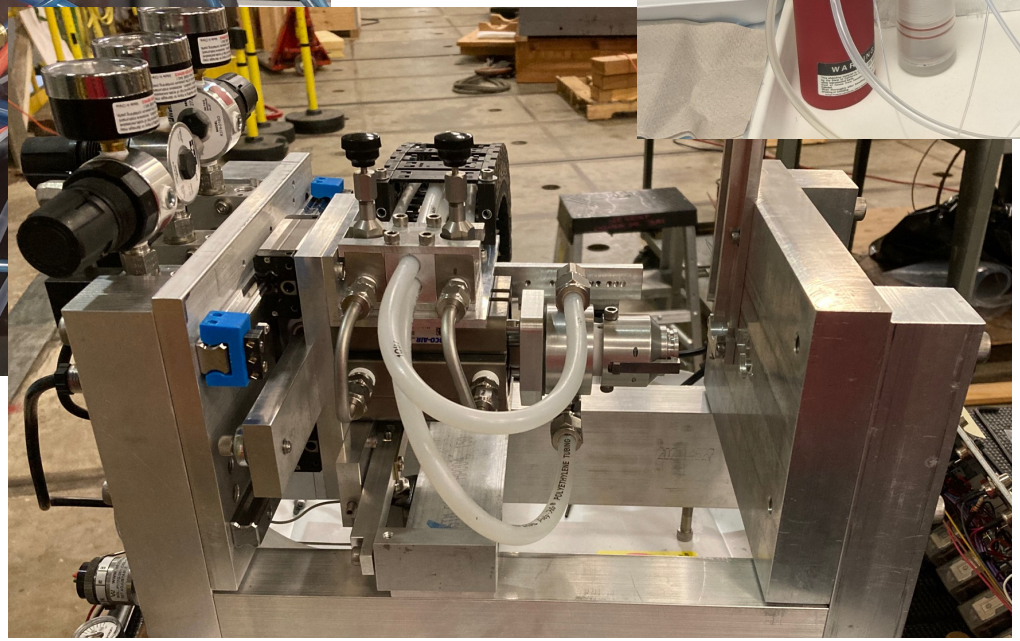
Production, isolation, and shipment of clinically relevant quantities of astatine-211: A simple and efficient approach to increasing supply, Lauren A. McIntosh, Jonathan D. Burns, Evgeny E. Tereshatov, Riccardo Muzzioli, Kris Hagel, Noimat A. Jinadu, Laura A. McCann, Gabriela A. Picayo, Federica Pisaneschi, David Piwnica-Worms, Steven J. Schultz, Gabriel C. Tabacaru, Austin Abbott, Brooklyn Green, Travis Hankins, Andrew Hannaman, Bryan Harvey, Kylie Lofton, Robert Rider, Maxwell Sorensen, Alexandra Tabacaru, Zachary Tobin, Sherry J. Yennello, Nuclear Medicine and Biology, 108387, (2023), https://doi.org/10.1016/j.nucmedbio.2023.108387.

Separation, speciation, and mechanism of astatine and bismuth extraction from nitric acid into 1-octanol and methyl anthranilate, Evgeny E. Tereshatov, Jonathan D. Burns, Amy L. Vonder Haar, Steven J. Schultz, Lauren A. McIntosh, Gabriel C. Tabacaru, Laura A. McCann, Geoffrey Avila, Andrew Hannaman, Kylie N. Lofton, Mallory A. McCarthy, Bowen Zhang, Michael B. Hall, Sherry J. Yennello, Separation and Purification Tech.,383, 120088 (2022),https://doi.org/10.1016/j.seppur.2021.120088.

Ion exchange behavior of astatine and bismuth, E. E. Tereshatov, J. D. Burns, S. J. Schultz, B. D. Green, G. A. Picayo, L. A. McCann, L.A. McIntosh, G.C. Tabacaru, A. Abbott, M. Berko, E. Engelthaler, K. Hagel, T. Hankins, B. Harvey, L. Hoekstra, K. Lofton, S. Regener, R. Rider, M. Sorensen, A. Tabacaru, D. Thomas, J. Tobar, Z. Tobin, S.J. Yennello, *New J. Chem.*, (2023),47, 12037-12047, https://doi.org/10.1039/D3NJ01316B

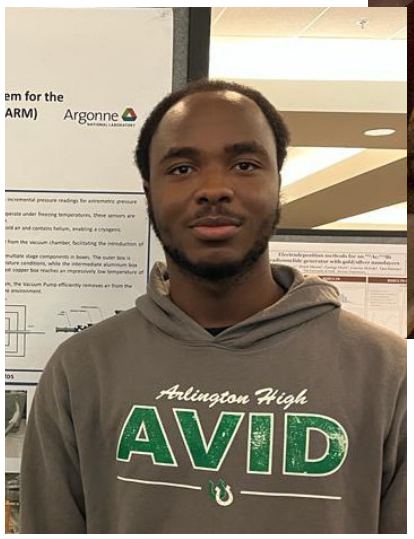


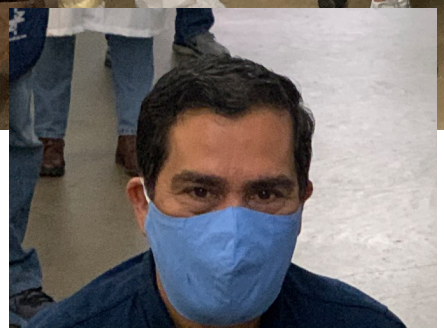





got beam?
ASK ME ABOUT MY
HIPPO
CAMPUS


ASK ME ABOUT MY
HIPPO
CAMPUS


Argonne
Arlington High
AVID



Acknowledgments

J. Burns, E. Tereshatov, G. Tabacaru, A. Tabacaru, L. McIntosh, L. McCann, S. Schultz, G. Picayo, L. Hoekstra, B. Greene, K. Lofton, A. VonderHaar, D. Thomas, A. Abbott, G. Avila, M. Berko, E. Engelthaler, K. Hagel, T. Hankins, A. Hannaman, B. Harvey, A. Hood, M. McCarthy, A.B. McIntosh, R. Rider, M. Sorensen and Z Tobin

R. Muzzioli, F. Pisaneschi, D. Piwnica-Worms – MD Anderson

Cyclotron Operations & Rad Safety Staff (B. Roeder & D. Menchaca)

Isotope Program: DE-SC0020958

Texas A&M University System National Laboratories Office

Los Alamos National Laboratory

DOE: DE-FG02-93ER40773

NNSA Grant: NA-DE0003841

Bright Chair at TAMU

T3 Grant from TAMU

TAMU Nuclear Solutions Institute

NSF GRFP (L. McCann)

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DE-SC0022550

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