Investigating the Production, Separation, and Chemistry of ^{211}At

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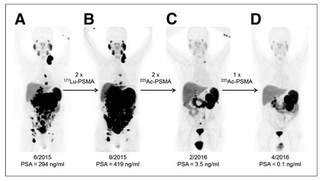
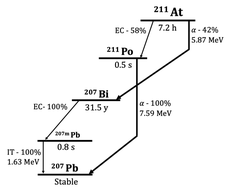
Why ^{211}At?

- The successful clinical trial performance of alpha emitters, such as ^{225}Ac-PSMA, has increased interest in targeted alpha therapy (TAT).[1]
- One promising isotope for use in TAT is ^{211}At with a moderately short half-life and simple, 100% alpha-emitting decay scheme (1 alpha/decay) making it well suited for use in a clinical setting.



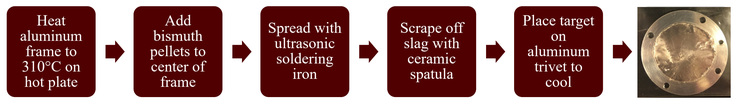
PET/CT scans of a patient receiving doses of ^{225}Ac-PMSA-617, a PSMA-based alpha therapy.[1]



Decay scheme of ^{211}At.

- With little known about the fundamental chemistry of astatine, a better understanding is necessary for progress in TAT and superheavy element chemistry (as astatine is a homologue of the recently discovered element 117, tennessine).[3]
- There are very few facilities with the capability of producing ^{211}At which, alongside the small quantity produced during each irradiation and short half life ($t_{1/2}$ = 7.2 h), make the recovery of ^{211}At important.

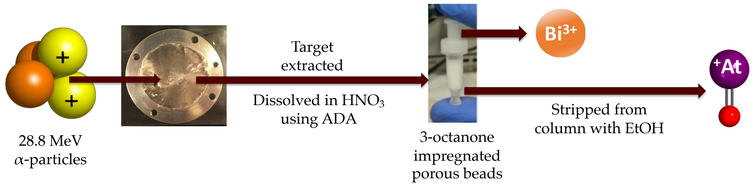
Production and Isolation of ^{211}At



Target preparation procedure for metallic bismuth targets.

Standard production pathway for ^{211}At via ^{209}Bi(α,2n)^{211}At.

Automatic Dissolution Apparatus (ADA).[3]



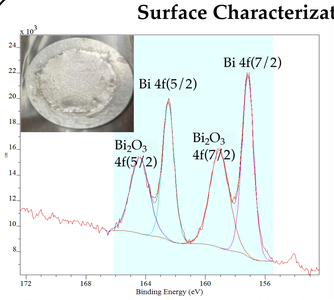
Procedure for target dissolution and astatine recovery after irradiation overnight.

Motivations

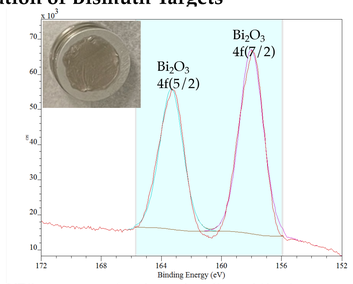
- In the past, target dissolution has been inconsistent with some targets not fully dissolving in the expected time. This leads to loss of ^{211}At which, due to the already small quantity produced, is a pressing issue.
- Our procedure for ^{211}At recovery involves stripping ^{211}At from 3-octanone impregnated porous beads using ethanol. This process also strips the ketone, failing to result in free At. Using a different stripping agent, one that doesn't strip the ketone, would result in free At.
- With little known about the fundamental chemistry of astatine, studies on its affinity for various species and oxidation state are important to get a better picture.

Results & Conclusions

Surface Characterization of Bismuth Targets



XPS spectrum of regularly prepared target.

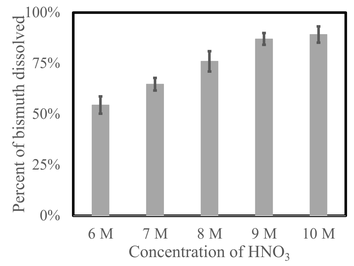


XPS spectrum of an intentionally-oxidized target.

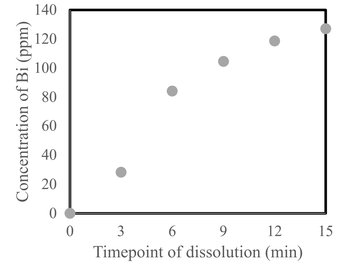
Conclusions

- When testing different nitric acid concentrations to dissolve cold bismuth targets, it was found that 9 M and 10 M had no significant difference in percent dissolution.
- Analyzing the dissolution solution at different time points shows that there is a diminishing return as time progresses. This is also evidence of an inefficient dissolution method.
- Time, and in turn oxidation, negatively affect the dissolution of targets.
- Agitation of solution allows for a consistent, fast dissolution compared to still solution. This is also true for older, oxidized targets.

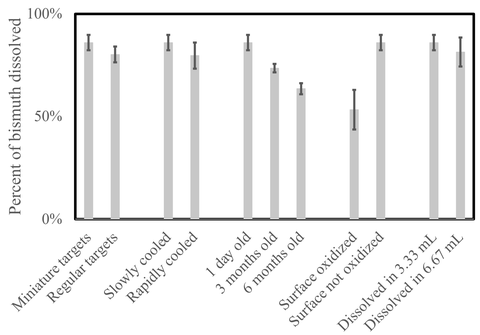
Target Preparation/Dissolution



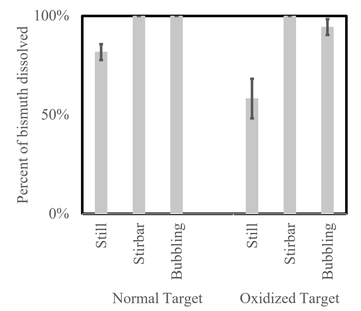
Percent of bismuth dissolved from targets in various concentrations of nitric acid.



Concentration of bismuth in solution (analyzed by ICP-OES) at various timepoints in the dissolution.

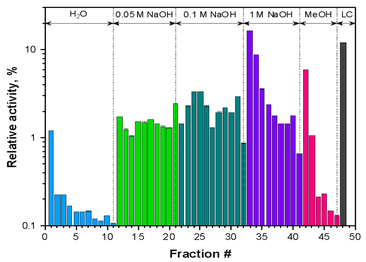


Percent of bismuth dissolved from targets by various target preparation parameters and dissolution techniques.

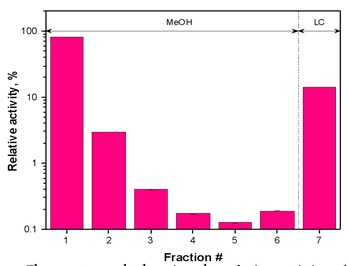


Percent of bismuth dissolved from targets prepared normally and purposefully oxidized using different methods of dissolution.

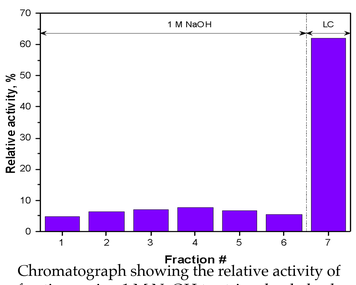
Extraction Chromatography



Chromatograph showing the elution of ^{211}At from the 3-octanone impregnated column using various solvents.



Chromatograph showing the relative activity of fractions using MeOH to strip a loaded column.

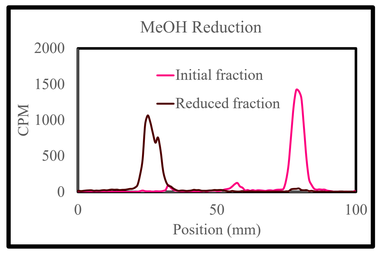


Chromatograph showing the relative activity of fractions using 1 M NaOH to strip a loaded column.

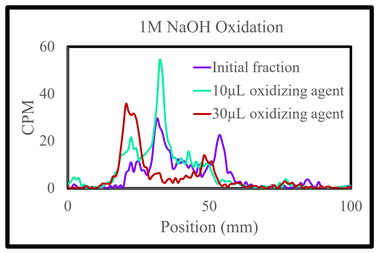
Conclusions

- Water was unable to strip a significant quantity of ^{211}At.
- Methanol yielded the same results as ethanol has shown in previous separations.
- Three concentrations (0.005, 0.1, and 1 M) of NaOH were tested sequentially on a single column. This resulted in significant activity stripped with the 1 M NaOH but did not yield the same results when repeated on a separate column.

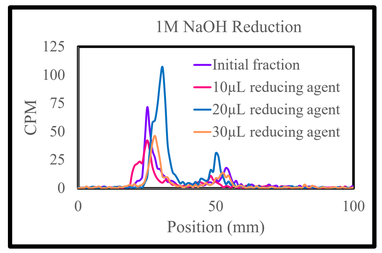
RadioTLC



RadioTLC of the first eluted methanol fraction before and after adding 10 μL of reducing agent.



RadioTLC of the fourth eluted 1 M NaOH fraction initially and after adding 10 and 30 μL of oxidizing agent.



RadioTLC of the first eluted 1 M NaOH fraction initially and after adding 10, 20, and 30 μL of reducing agent.

Reducing agent: hydrazine hydrate ($NH_2NH_2 \cdot H_2O$)

Oxidizing agent: potassium dichromate ($K_2Cr_2O_5$)

Conclusions

- The first eluted 1 M NaOH fraction has the expected (based on previous experiments) peaks. The fourth eluted fraction has interesting peaks, possibly caused by the lack of 3-octanone to stabilize it.
- The MeOH fraction was able to be reduced and shows similar behavior to EtOH reductions.

Further Work

- Implementing solution agitation into ADA.
- Testing saline, dichloromethane, and chloroform as stripping agents.
- Attempting to change oxidation state of astatine before loading onto the column.

References

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Acknowledgements

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