Taggant for Nuclear Material in the Enrichment Process

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4 May 2012

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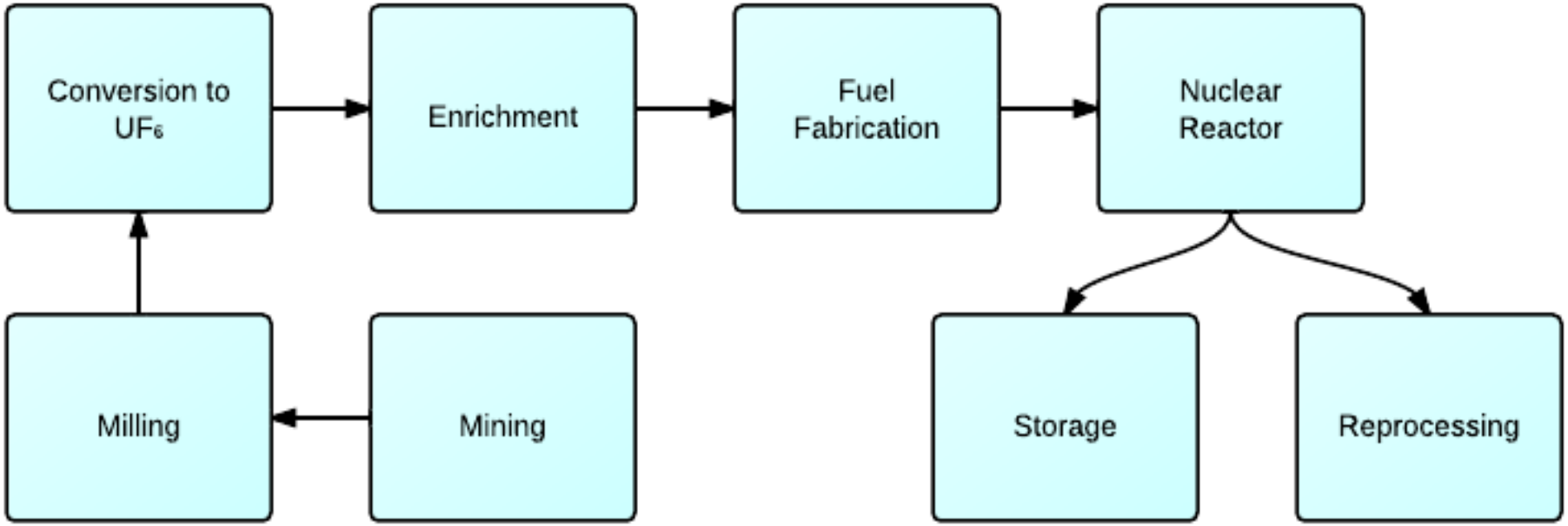
Background

Nuclear Forensics

- Supports efforts to reduce nuclear terrorism & maintain control of nuclear resources
- Purpose: determine the origin & route of transit of radioactive materials used in illegal activities
- Reduces illicit trafficking of nuclear materials

Background

Nuclear Fuel Cycle



Background

Taggants

- Taggant: A material bearing a unique signature used for the identification of an object or other material
- Current Uses
  - Electronics
  - Radiofrequency identifiers
  - Explosives

Background

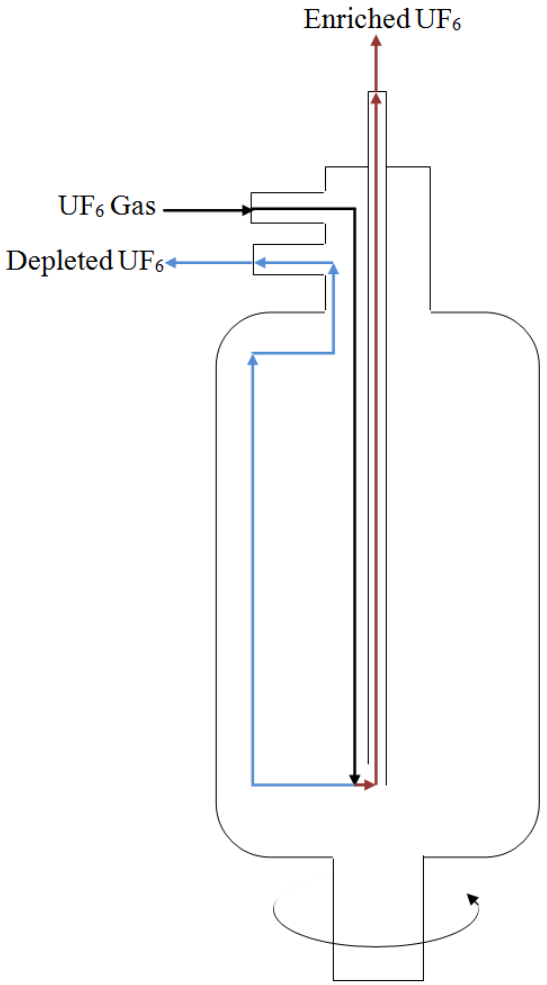
Previously Proposed Taggants

- Isotopes of uranium
  - ^{233}U – Storage sites
  - ^{236}U – Conversion facilities
- Rare earth element mixtures – Mines & fuel fabrication plants
  - Varied combinations of lanthanoids
- Chemical tracers – Conversion facilities
  - Porphyrins
  - Phtalocyanines
  - Aromatic amines
  - Calixerenes

Project Objective

Determine a material that will withstand centrifugal processes to behave as a taggant for $^{235}UF_6$

- Subject to specific requirements



Possible Applications

- Nuclear forensics
  - Provides a way to track nuclear materials from a specified enrichment plant type
- Safeguards
  - Provides a means of determining the levels of enrichment present within a cascade hall
  - Creates a deterrent against the removal of nuclear material from a centrifugal environment

Requirements

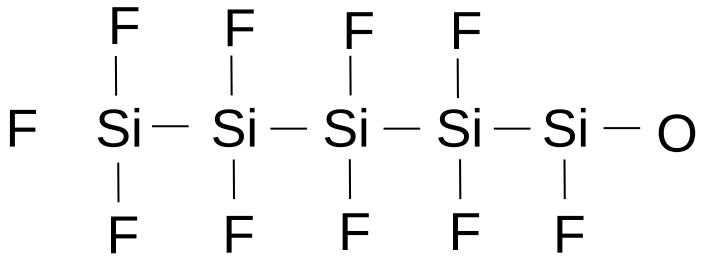
- Same mass as $^{235}UF_6$ mass (349.03 g/mol)
- Withstand expected conditions subjected to it in a centrifugal environment
- Remain volatile in expected temperatures and pressures subjected to it in a centrifugal environment
  - Centrifuges operate at a minimum vapor pressure of 666.6 Pa at 310 K and within a temperature range of 273-570 K
  - Sublimation point of $^{235}UF_6$ is 56.5°C
- Not alter enrichment process
- Not negatively impact any of the subsequent fuel cycle processes
- Have a unique signature
- Hard to replicate

Materials Considered

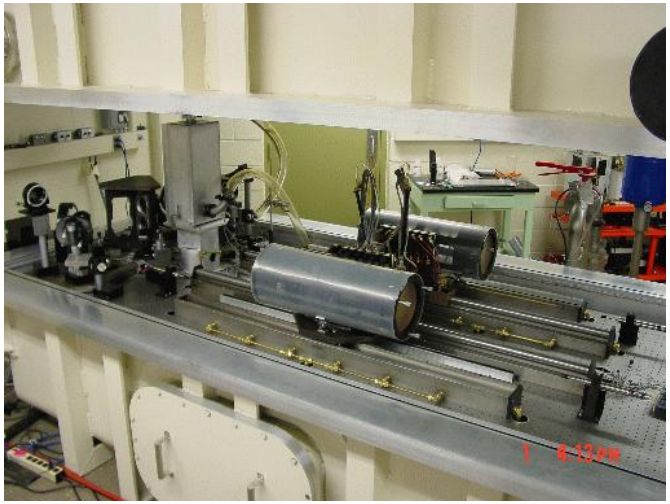
- Dimers
- Molecules
  - $C_{14}H_{15}O_2F_7$
  - $C_8H_5F_{13}$
  - $C_6F_{13}NO$
- Molecules lacking carbon
  - Si_5OF_{10}

Taggant of Interest

- Mass: 347.87 g/mol
  - Requires ^{18}O
  - Approximate using ^{234}U with a mass of 348.03 g/mol
- Hyperfluorinated
- Likely volatile within region of interest
  - Si_4F_{10} has a boiling point of 85.1°C
- Acceptable elemental concentrations for reactor if added at ppm or ppb level



Detection Methods



- Suggested methods:
  - IR spectroscopy
    - Measures compounds
  - XRF spectroscopy
    - Measures elements
- Possible alternative methods:
  - Mass spectrometry
  - Microanalysis
  - Laser-induced breakdown spectroscopy
  - Inductively-coupled plasma spectoscopy

Conclusion

- Si_5OF_{10} is a theoretically feasible taggant for the centrifugal enrichment process
  - Similarity in mass: Yes
  - Withstand expected conditions: Maybe
  - Remain volatile: Maybe
  - Not alter enrichment process: Maybe
  - No impact on subsequent processes: Yes
  - Unique signature: Yes
  - Hard to replicate: No
- The compound requires laboratory tests to establish its feasibility as a taggant experimentally

Acknowledgements

- Thank you to Brian Woods & Richard Metcalf for their guidance and support throughout the duration of this project.
- I'd like to thank Idaho National Laboratory for hosting me this summer.
- This research was performed under the Nuclear Forensics Undergraduate Scholarship Program, which is sponsored by the U.S. Department of Homeland Security Domestic Nuclear Detection Office.
- This research was also performed under the Science Undergraduate Laboratory Internship program, which is sponsored by the U.S. Department of Energy.

Homeland Security

U.S. DEPARTMENT OF ENERGY

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