Lithium Handling and Chemical Compatibility for Tritium Breeding in Nuclear Technology

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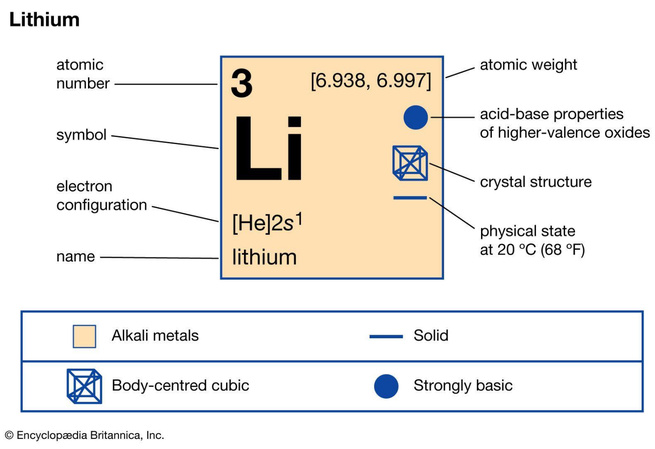
Introduction

Collisions between tritium and deuterium result in fusion energy that can be used within the space exploration industry. While deuterium is relatively abundant on Earth, tritium is much rarer to find and decays faster. Instead, tritium is created via neutron bombardment within the nuclear reactor. Most materials used in the past for tritium breeding are solid lithium-containing compounds. However, it may be possible to most efficiently breed tritium by using pure liquid lithium as a plasma-facing blanket. Through a literature review, the properties of lithium as a liquid are explored, as well as any safety concerns involving working with the element, and possible methods of procurement.



Research Questions

- How does lithium's behavior change as a liquid versus a solid?
- How will the laboratory procure pure lithium?
- How will the laboratory contain lithium before, during, and after experimentation?
- What are the radioactive properties of the element?
- What materials are compatible/incompatible with the element?
- What safety concerns must be considered when working with lithium?

Methods of Research

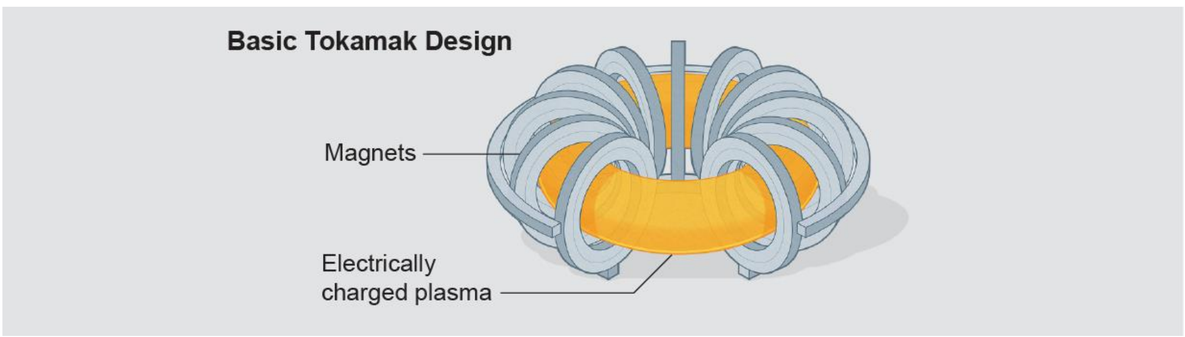
- Academic Databases
  - Google Scholar
  - Web of Science
  - EBSCO
  - ProQuest
- Citation Managers
  - RefWorks
  - Microsoft Excel
- Literature Review Formatting Resources
  - Johns Hopkins University (includes material on source vetting)
  - Purdue OWL

Procedure

1. Conduct background research (nuclear technology applications in the space exploration industry, current research into tritium breeding, knowledge about lithium in both solid and liquid forms).
2. Analyze sources for credibility (TRAPP method).
3. Organize relevant information for review and corroboration.
4. Write a literary review on the information found.
5. Research ways to procure lithium for research (vendors, contact information, safety concerns)

Key Findings

- Chemical properties of lithium
  - Melting point: 180.45 °C
  - Boiling point: 1344.1 °C
  - Density: .534 g/cm^3
  - Does not occur freely on Earth, only in compounds
- Tritium-forming chemical equations
  - $n + {}^6Li \rightarrow T + {}^4He + 4.78$ MeV
  - $n + {}^7Li \rightarrow T + {}^4He + n - 2.47$ MeV
- Radioactivity
  - Unstable isotopes
    - Lithium-8 $\quad {}^8Li \rightarrow 2\ {}^4He + e^-$
      - » Half-life of approximately .839s
    - Lithium-9 $\quad {}^9Li \rightarrow 2\ {}^4He + {}^1n + e^-$
      - » Half-life of approximately .174s
  - Radiation concerns are alpha- and beta-particle decay
- Safety concerns
  - Reacts violently with water and with air[1]
    - Contact with water causes reaction to form flammable hydrogen gas
  - Ignition releases lithium oxide (caustic) gas; inhalation will cause coughing and choking[1]
  - ***CANNOT*** use regular fire extinguishers for lithium fires.
    - Will react with substances in normal extinguishers (water, CO_2, CCl_4, $NaCO_3$, etc.)
    - Must use a dry powder extinguisher
  - Corrosive; contact with skin will cause damage
- Storage and Procurement
  - Must be blanketed with inert gas (argon, helium) or dry air
    - Nitrogen is NOT inert to lithium ($6\ Li + N_2 \rightarrow 2\ Li_3N + 164.56$ kJ/mol)
  - Pure iron is proven resistant to molten lithium at temperatures around 800°C
  - Carbon and stainless steel is proven resistant to molten lithium at temperatures around 300°C
  - Sample vendors: ThermoFisher, American Elements
  - Fire extinguisher vendors: Grainger, Safety Emporium



Bibliography

[1] Rumble, J. R. (Ed.). *CRC Handbook of Chemistry and Physics*. CRC Press/Taylor & Francis.

[2] Martí, J., Mazzanti, F., Astrakharchik, G. E., Batet, L., Portos-Amill, L., & Pedreño, B. (2022). *Nucleation of Helium in Liquid Lithium at 843 K and High Pressures*. *Materials (1996-1944)*, *15*(8), N.PAG. https://doi.org/10.3390/ma15082866

[3] Pisarev, A. A., Vertkov, A. V., Zharkov, M. Y., Mazul, I. V., Piskarev, P. Y., & Tarasyuk, G. M. (2024). *Flowing Liquid Lithium as a Plasma Facing Material*. *Physics of Atomic Nuclei*, *87*(1), S26–S36. https://doi.org/10.1134/S1063778824130052

[4] Jeppson, D. W., Ballif, J. L., Yuan, W. W., & Chou, B. E. (1978). *Lithium Literature Review: Lithium's Properties and Interactions*. Dept. of Energy. https://www.osti.gov/servlets/purl/6885395/.pdf

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