METHODS of RADIONUCLIDE PRODUCTION for MEDICAL ISOTOPE USABILITY

<< MEETING THE DEMAND >>

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PHYS 575 - Radiation and Detectors
Introduction
Existing Infrastructure


Other Production Methods

- Heterogeneous reactors
- **Accelerators**
- Sub-critical assemblies
- Neutron capture
- Spallation

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https://en.wikipedia.org/wiki/Enriched_uranium
Introduction
The Nuclear Medicine Market


Technetium-99m
Brain, Thyroid, Parathyroid, Heart, Lungs, Liver, Kidney, Spleen, or Bone Marrow
Cross Sectional Energies
Molybdenum-100 / Molybdenum-99 Conversions

• Neutrons
• Protons
• Deuterons

• Electrons
• Photoneutrons and Photoprotons
Medical Radioisotopes
Technetium-99m from Molybdenum-99

https://en.wikipedia.org/wiki/Technetium-99m_generator

<table>
<thead>
<tr>
<th>nuclide symbol</th>
<th>Z(p)</th>
<th>N(n)</th>
<th>isotopic mass (u)</th>
<th>excitation energy</th>
<th>half-life[^1]</th>
<th>decay mode(s)[^2][^3]</th>
<th>daughter isotope(s)[^3]</th>
<th>nuclear spin</th>
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<tbody>
<tr>
<td>99mMo[6][8]</td>
<td>42</td>
<td>57</td>
<td>98.9077119(21)</td>
<td>2.7489(6) d</td>
<td>β^-</td>
<td>99mTc</td>
<td>1/2+</td>
<td></td>
</tr>
</tbody>
</table>

99m Tc $\gamma$ 141 keV 6 h $\rightarrow$ 99m Tc $eta^-$ 249 keV 211 000 y $\rightarrow$ 99 Ru

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Fission Reactors
Molybdenum Processing

https://en.wikipedia.org/wiki/Hot_cell

Fission Reactors

Technetium Processing

Specific Activity

\[ A = \phi \cdot n \cdot \sigma \cdot (1 - e^{-\lambda t}) \]

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Accelerator Reactors
Technetium-99m Separation

- Thermal Chromatographic Separation via vapor pressure.
- Organic Solvent Extraction (MEK Process) via aqueous solution.
- Chromatographic Column (ABEC) via immiscible liquids.
- Nuclear kinetic recoil via photonuclear reactions.

https://en.wikipedia.org/wiki/Technetium-99m
Accelerator Reactors
Technetium-99m Separation - Commercialization

http://www.northstarnm.com/radiogenix-technology
Fission Reactors

General Overview – Typical Construction

High flux reactors (TRIGA)
energies $> 1.10^{14}$ neutrons/cm$^2$/s

- Research
- Operational purposes
- Radioisotope production

http://www.rcp.ijs.si/ric/description-a.html
Fission Reactors

General Overview – Fuel Rods

- Fuel Rods
- Top-end fixture (stainless steel)
- Triangular spacer
- Upper graphite insert
- Central zirconium rod
- Uranium-zirconium hydride fuel
- Molybdenum disc
- Lower graphite insert
- Stainless steel cladding
- Bottom-end fixture (stainless steel)
Fission Reactors
Radioisotope Production


Medium flux reactors
energies between $1.10^{12}$ and $1.10^{14}$ neutrons/cm$^2$/s
Accelerator Reactors
Cyclotron Production – Compact Designs

Lorentz Force
\[ F = q[E + (v \times B)] \]
Accelerator Reactors
Linear Particle Accelerator Production
Comparison
Fission vs. LINAC Produced Isotopes

Comparison shows nearly identical diagnostic images.
Meeting Global Demand
New Models for Technetium Supply

http://www.northstarnm.com/streamlined-distribution
Molybdenum

The Answer to the Ultimate Question of Life, the Universe, and Everything...?

**Citations**


