IAEA Activities Supporting Mo-99 Production without the use of HEU

Joanie Dix

$^{99}$Mo Topical Meeting

Washington, DC 24-27 June 2014
IAEA Priorities for $^{99}$Mo

**HEU Minimization**
Transition of $^{99}$Mo production away from the use of highly enriched uranium (HEU)

**Stability of Supply**
Diversification of supply and movement to full cost recovery to ensure the global demand is met
The IAEA can assist Member States in their $^{99}$Mo work through various types of activities. These include:

- Coordinated Research Projects
- Technical Cooperation Projects
- Regular program activities
  - Networks and coalitions
  - Participation in complimentary, international activities
  - Meetings
  - Missions
  - Publications
  - General Conference side-events
Conversion of Major $^{99}$Mo Producers to LEU

- Supported by US DOE-NNSA and the Government of Norway
- Series of working group meetings for key stakeholders to review progress, exchange information and explore opportunities for mutually beneficial collaboration
- Receiving updates on LEU high-density targets, and accompanying chemical processes
- Most recent meeting took place 27-28 January 2014
Small-scale, non-HEU $^{99}$Mo production

- Draft publication on Feasibility of Small-Scale $^{99}$Mo Production using LEU Fission or Neutron Activation Methods
  - In final review now; scheduled for publication in 2014
  - Incorporates the results of the Coordinated Research Project on small-scale production (2005-2011)
Small-scale, non-HEU $^{99}$Mo production

- Technical Cooperation Project started in 2013
- Aimed at assisting small-scale, national-level producers in setting up their production capability;
  - NOT aimed at creating commercial producers
- Will rely on LEU fission or n, gamma-based production
- Open to any IAEA Member States wishing to receive advice and assistance
- Production infrastructure fact-finding missions were completed to Mexico, Morocco, Peru, Poland, and Romania. Similar missions were conducted in Egypt (2010) and Malaysia (2011)
Small-scale, non-HEU $^{99}$Mo production

- **Expert Missions**
  - $^{99}$Mo production project progress review missions
  - Production infrastructure readiness missions
  - IAEA and project counterpart missions to $^{99}$Mo production facilities and laboratories

- **EURASIA Coalition work**
  - Reactors in Eastern Europe and former Soviet states cooperating to produce low specific activity $^{99}$Mo via neutron capture of $^{98}$Mo (launched in 2008)
• Intended to study technical and economic aspects of $^{99}$Mo waste streams in cooperation with the OECD-NEA
• Work on this study was halted due to the low response rate (<50%)
• Without this information, the study would not have the necessary data to contribute any meaningful analysis
Coordinated Research Project on Accelerator-based Alternatives to Non-HEU Production of $^{99}$Mo/$^{99m}$Tc
Participating Countries

- ARMENIA
- BRAZIL
- CANADA
- HUNGARY
- INDIA
- ITALY
- JAPAN
- KINGDOM OF SAUDI ARABIA
- POLAND
- SYRIA
- UNITED STATES
Alternative Routes to $^{99}\text{Mo/}^{99\text{mTc}}$ Production

- $^{100}\text{Mo}(p,pn)^{99}\text{Mo}$
- $^{100}\text{Mo}(\gamma,n)^{99}\text{Mo}$
- $^{98}\text{Mo}(n,\gamma)^{99}\text{Mo}$
- $^{100}\text{Mo}(n,2n)^{99}\text{Mo}$

$^{99}\text{Mo}$ (T$_{1/2} = 66$ h)

- $^{100}\text{Mo}(p,2n)^{99\text{mTc}}$
- $^{98}\text{Mo}(d,n)^{99\text{mTc}}$
- $^{98}\text{Mo}(p,\gamma)^{99\text{mTc}}$

$^{99\text{mTc}}$ (T$_{1/2} = 6$ h)
Cyclotron Production of $^{99m}$Tc

$^{100}$Mo(p,2n)$^{101}$Tc → $^{99m}$Tc
Cyclotron Production of $^{99m}$Tc

$^{100}$Mo(p,2n)$^{99m}$Tc

Irradiation → Target Processing → Radionuclide Separation
Main issues

- Target preparation (withstand heat generated by the beam)
- Radionuclidic separation Mo/$^{99m}$Tc: fast and high yield
- Recovery of the target: enriched and high cost
- Radionuclidic impurity: choose optimum beam energy, time of irradiation and decay time; select the target carefully!
- Delivery of $^{99m}$Tc
Radionuclidic Impurities

$^{100,9x}$Mo(p,2n)$^{9x}$Tc series

![Graph showing cross-section vs. incident proton energy for various isotopes of Tc](image-url)
## Radionuclidic Impurities

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<tr>
<th>Z</th>
<th>95Ru</th>
<th>96Ru</th>
<th>97Ru</th>
<th>98Ru</th>
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<td>1.643 H</td>
<td>2.83 D</td>
<td>1.87%</td>
<td>12.76%</td>
<td>12.60%</td>
<td>17.08%</td>
<td>31.55%</td>
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<td>42</td>
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<td>293 M</td>
<td>20.0 H</td>
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<td>4.21 E+6 Y</td>
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<td>15.46 S</td>
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<td>65.976 H</td>
<td>7.3 E+18 Y</td>
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<td>3.47 E+7 Y</td>
<td>100%</td>
<td>2.03 E+4 Y</td>
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Conclusions

Optimized Production Conditions

- Target enrichment: $\geq 99.05\%$
- Proton Energy Window: $15 > E_p > 20$ MeV
- Irradiation Time: $< 3$ hours
- Proton Current: $400\ \mu$A
- In-Target Yield: $\sim 6$ Ci
Points of Contact

• Nuclear Energy – Research Reactor Section
  J.Dix@iaea.org
  E.Bradley@iaea.org

• Nuclear Science & Applications – Radioisotope Products and Radiation Technology Section
  J.A.Osso-Junior@iaea.org
  M.Venkatesh@iaea.org