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

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^{99}Mo Topical Meeting

Washington, DC 24-27 June 2014

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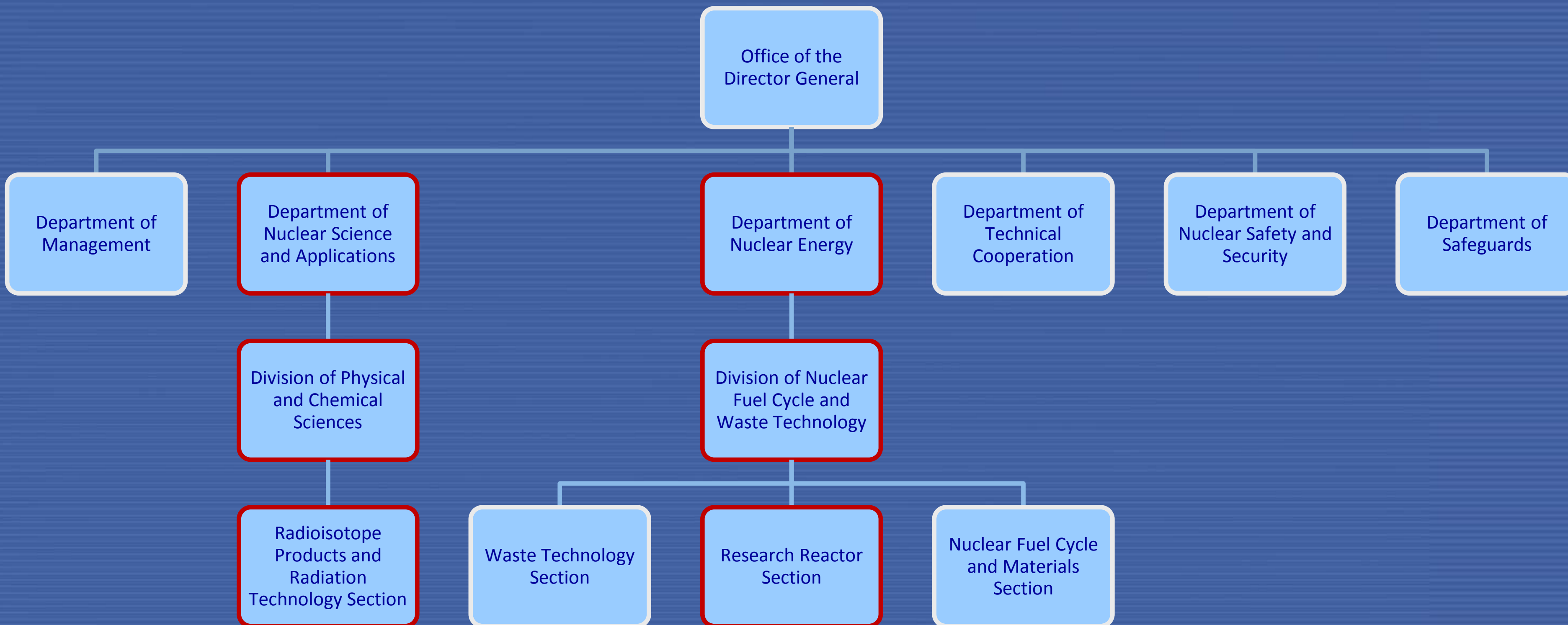
International Atomic Energy Agency

IAEA Organization for ^{99}Mo Work



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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

^{99}Mo IAEA Projects

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

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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)

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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)

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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)

Full Cost Recovery & Managing ^{99}Mo Waste Streams

- 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 $^{99}Mo/^{99m}Tc$

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Participating Countries

- ARMENIA
- BRAZIL
- CANADA
- HUNGARY
- INDIA
- ITALY
- JAPAN
- KINGDOM OF SAUDI ARABIA
- POLAND
- SYRIA
- UNITED STATES

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Alternative Routes to $^{99}Mo/^{99m}Tc$ Production

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

→ ^{99}Mo ($T_{1/2}$ = 66 h)

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

→ ^{99m}Tc ($T_{1/2}$ = 6 h)

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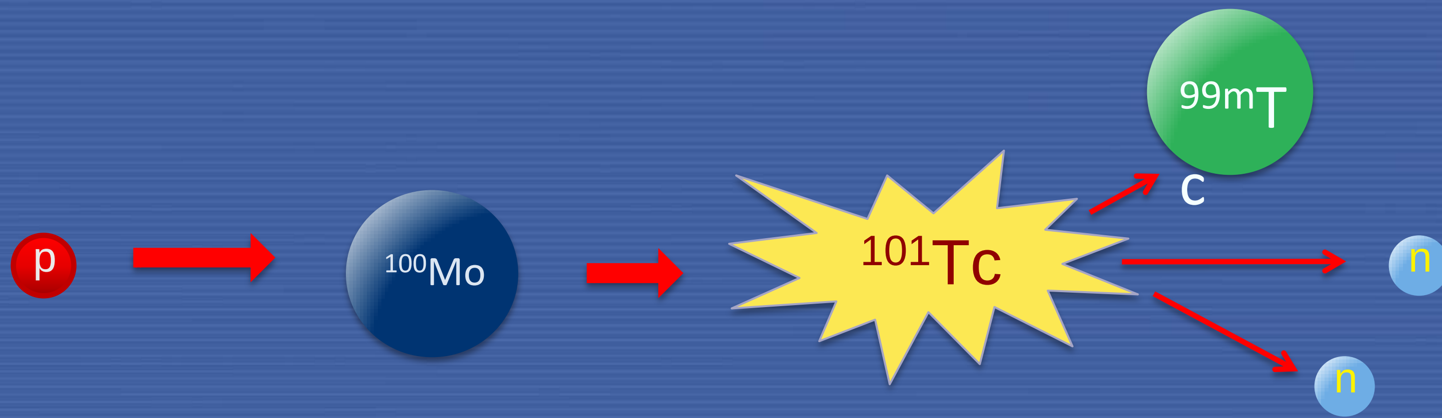
Cyclotron Production of ^{99m}Tc



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

Cyclotron Production of ^{99m}Tc

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

Irradiation

Target Processing

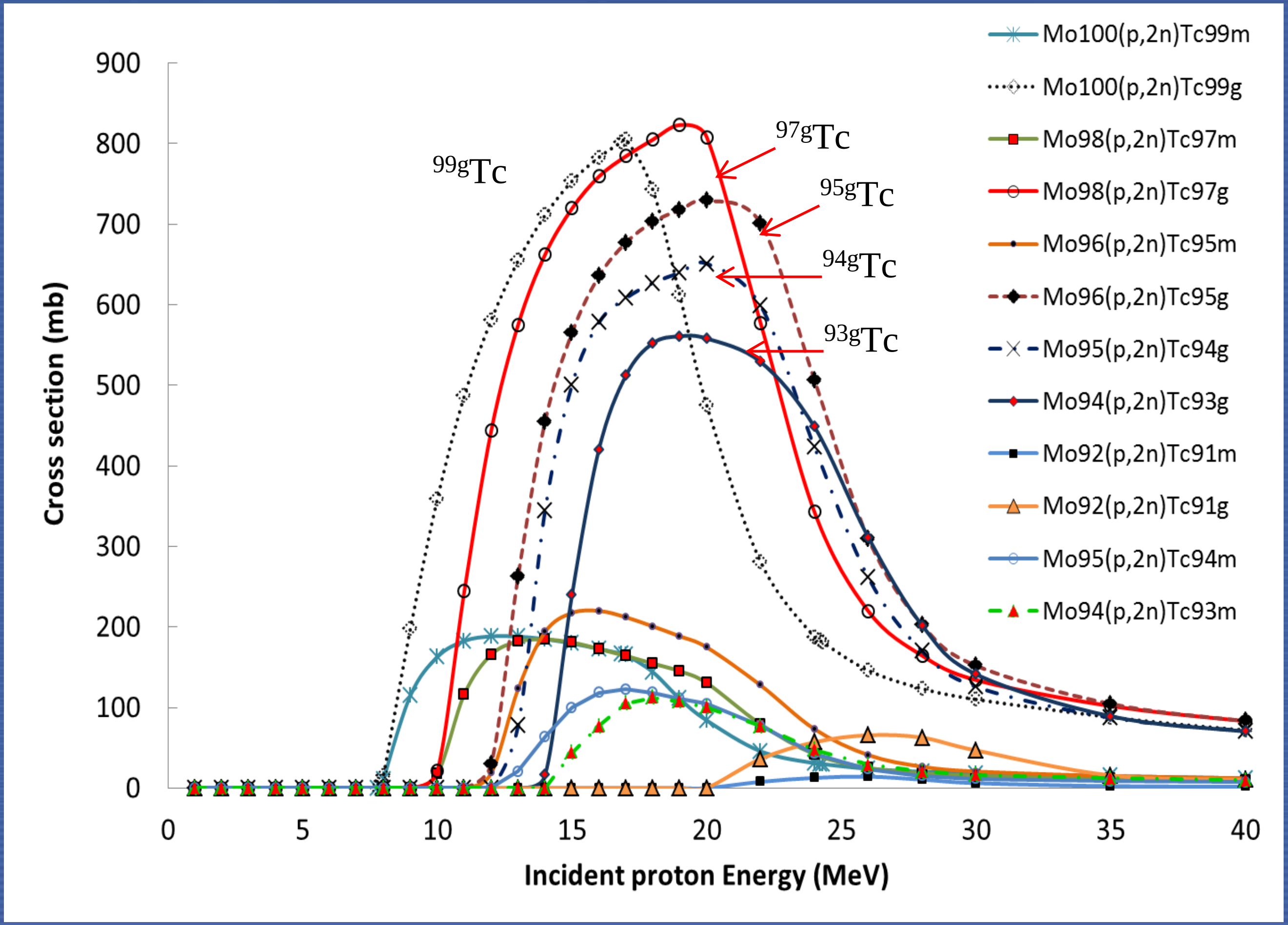
Radionuclide Separation

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



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Radionuclidic Impurities

Z	95Ru 1.643 H ε: 100.00%	96Ru STABLE 5.54%	97Ru 2.83 D ε: 100.00%	98Ru STABLE 1.87%	99Ru STABLE 12.76%	100Ru STABLE 12.60%	101Ru STABLE 17.06%	102Ru STABLE 31.55%	103Ru 39.247 D β-: 100.00%
43	94Tc 293 M ε: 100.00%	95Tc 20.0 H ε: 100.00%	96Tc 4.28 D ε: 100.00%	97Tc 4.21E+6 Y ε: 100.00%	98Tc 4.2E+6 Y β-: 100.00%	99Tc 2.111E+5 Y β-: 100.00%	100Tc 15.46 S β-: 100.00% ε: 2.6E-3%	101Tc 14.02 M β-: 100.00%	102Tc 5.28 S β-: 100.00%
42	93Mo 4.0E+3 Y ε: 100.00%	94Mo STABLE 9.15%	95Mo STABLE 15.84%	96Mo STABLE 16.67%	97Mo STABLE 9.60%	98Mo STABLE 24.39%	99Mo 65.976 H β-: 100.00%	100Mo 7.3E+18 Y 9.82% 2β-: 100.00%	101Mo 14.61 M β-: 100.00%
41	92Nb 3.47E+7 Y ε: 100.00% β- < 0.05%	93Nb STABLE 100%	94Nb 2.03E+4 Y β-: 100.00%	95Nb 34.991 D β-: 100.00%	96Nb 23.35 H β-: 100.00%	97Nb 72.1 M β-: 100.00%	98Nb 2.86 S β-: 100.00%	99Nb 15.0 S β-: 100.00%	100Nb 1.5 S β-: 100.00%
40	91Zr STABLE 11.22%	92Zr STABLE 17.15%	93Zr 1.61E+6 Y β-: 100.00%	94Zr STABLE 17.38%	95Zr 64.032 D β-: 100.00%	96Zr 2.35E+19 Y 2.80% 2β-	97Zr 16.749 H β-: 100.00%	98Zr 30.7 S β-: 100.00%	99Zr 2.1 S β-: 100.00%
	51	52	53	54	55	56	57	58	N

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Conclusions

Optimized Production Conditions

- Target enrichment: $\geq$ 99.05 %
- Proton Energy Window: 15 > Ep > 20 MeV
- Irradiation Time: < 3 hours
- Proton Current: 400 μA
- In-Target Yield: $\sim$ 6 Ci

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Points of Contact

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