Medically relevant cross-section measurements for proton induced reactions on enriched molybdenum

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1. Introduction

1.1. History of Technetium

Small section on the discovery and the nuclear properties. Decay scheme, lifetime, etc. (Should I discuss the meaning of a metastable state?)

1.2. Role of ^{99m}Tc in medicine

1.2.1. Basics of Imaging Technique

Description of SPECT scanner relative to MRI/CT. Introduction to patient radiation, tie into "best" properties for isotope. Tie into chemical properties.

1.2.2. Chemical Properties

Describe labellings in context of ^{99m}Tc comparative ease.

1.2.3. The Uses of ^{99m}Tc in SPECT Scans

Discussion of the type of studies performed (with maybe a tie in to specific organ radiation sensitivities?)

1.3. Production of ^{99m}Tc

1.3.1. Reactor-based Production

Discuss reaction, method of separation, supply chain(?).

Current Supply Issues. Discuss limited number aging of reactor, HEU issues with AIP act, low competition in market.

1.3.2. Alternative Production Methods

- LEU vs/ HEU
- Other neutron methods
- Gamma-ray method
- Other charge-particle methods (ending with proton-irrad)

1.3.3. Cyclotron-Production of ^{99m}Tc

Discuss general method and connect with PET isotopes. Pro/Con list

1.4. Overview of Current Literature (where we are now)

- Large discrepancies in ^{100}Mo (p,2n) ^{99m}Tc XS.
- The role of contaminants
- Relying on calculations and limited measurements

1.5. Summary of Thesis Goals?

2. Materials and Methods

2.1. Target Composition and Thickness

Summary paragraph about foils. Purchased from, general size range, importance of composition/thickness.

2.1.1. Foil Composition

- ICP-MS background
- Molybdenum dissolution/chemistry
- Table of results
- Uncertainty discussion (measurement drift concerns)

2.1.2. Foil Thickness

- Measurement parameters of alpha-spec
- Traditional method of analysis, Bland et. al. function
- Alternative fitting method description
- Proof of concept test/results (REU student?)
- Results + comparison with by weight method
- Effect on energy
- Uncertainty discussion

2.2. Irradiation Parameters

Brief description of NSL/FN. Individual foil irradiations. Pick parameters to maximize isotopes of interest. Parameter range from 8min to 48 hours. Beam current delivered $\sim$ 400 - 900 nA. Spot size $\sim$ 2mm. Include a description of the beamline 9since before AM)?

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2.2.1. Energy Resolution

- Description of test around magnet
- Absolute energy + FWHM of energy
- Non-linearity in energy loss not important

2.3. Neutron Shielding

Discuss the need for reduction, how much is produced, how it is monitored, shielding calculations and measurements of its reduction.

2.4. Detector Settings

Brief description of 110% detector/castle setup. Describe sample geometry. Thickness of shielding. Background rates.

2.4.1. Description of how a HPGe works?

2.4.2. True Coincidence Summing

Need to discuss this before efficiency measurements because they will be corrected. Lots of math here... Maybe GEANT4 simulation?

2.4.3. Calibration

- Energy Calibration
  - Sources used, fit equation, graph?
  - Uncertainty in fitting?
- Efficiency Calibration
  - Sources used, fit equation, graph
  - Self-adsorption effects
  - Uncertainty in fitting(correlated errors).

2.4.4. High-rate Gamma-ray measurements

- Basic: deadtime correction
- Cause of pile-up in detector
- Impact as a potential source of error in activity
- PUR circuit discussion (mechanism)
- Methods of dealing with it (that I didn't use)?
- Measurement of pile-up effects (see Gilmore for details.)

3. Data Analysis

3.1. Activity Calculation

Description of tracking in time, not sum over period of time

3.1.1. Corrections for interfering processes

- Separation of species decaying into the same daughter nucleus using lifetime
- Separation of reactions on contaminants (why we use enriched samples) using recursive fit

4. Results

Emphasis the importance of even weakly produced Tc species (specific activity). Discuss decay to Mo-species and effect on target recycling.

4.1. Lifetime Measurements

Check that this is correct. Other effects that could cause this. I remember something in literature about others seeing this (for ^{96m}Tc).

4.1.1. Impact of Cross-section values

Lifetime inaccuracies have large impact of separation of meta/ground states.

4.1.2. Extraction of Lifetimes

Discuss how set-up was not meant for lifetime measurements, but can provide some information. Fitting in parallel with all runs and all gamma-ray lines reduces the possible systematic effects (branching ratio/gamma intensity issues).

4.2. Tc-Produced XS Results

4.3. Nb-Produced XS Results

4.4. Other XS Results

5. Discussion

5.1. TALYS Comparison

5.1.1. HF-Calculation Background?

Discuss optimal TALYS parameters given our results (if we are consistent).

5.2. Effect on Specific Activity for Accelerator Produced Isotopes

6. Conclusion

Discuss impact on medical isotope production. Suggest extension into ability to determine optimal irradiation procedures for individual target compositions (during the recycling process, composition will change). Maximize number of cycles and minimize patient radiation.

Acknowledgments

References