POSSIBILITIES OF PRODUCTION OF TECHNETIUM SHORT-LIVED RADIOACTIVE ISOTOPES

O.D. Maslov, **S.N. Dmitriev, A.V. Sabelnikov**

Joint Institute for Nuclear Research, Flerov Laboratory of Nuclear Reactions,

Dubna, Moscow reg. 141980 Russia

There are twenty two isotopes of technetium with masses ranging from 90 to 111. All the isotopes of technetium are radioactive. It is one of two elements with Z < 83 that have no stable isotopes; the other element is promethium (Z = 61). Technetium has three long-lived radioactive isotopes: ^{97}Tc ($T_{1/2}=2.6\cdot10^6$ years), ^{98}Tc ($T_{1/2}=4.2\cdot10^6$ years) and ^{99}Tc ($T_{1/2}=2.1\cdot10^5$ years). ^{95m}Tc ($T_{1/2}$=60 days), ^{97m}Tc ($T_{1/2}$=91 days), ^{96}Tc ($T_{1/2}$=4.3 days) are used as tracers for environmental research. At present the isotope ^{94m}Tc ($T_{1/2}$= 52 min) is studied as positron emitter or for nuclear medicine. However, the most useful isotope of technetium is ^{99m}Tc ($T_{1/2}$=6.01 hours), that is used in many medical radioactive isotope tests due to its short half-life, the energy of the gamma rays it emits, and the ability of technetium to be chemically bound to many biologically active molecules. In the Table are presented the conditions for production of the technetium short-lived isotopes.

Table

Isotope	$T_{1/2}$	Reaction	Conditions	Ref.
^{93m}Tc	43.5 min	$^{94}Mo(p, 2n)\ ^{93m}Tc$	^{94}Mo (93.9%), E_p=5-20 MeV, σ=90 mb (E_p=19 MeV)	1
^{93}Tc	2.7 h	$^{94}Mo(p, 2n)\ ^{93}Tc$	^{94}Mo (93.9%), E_p=5-20 MeV, σ=500 mb (E_p=19 MeV)	1
^{94m}Tc	53 min	$^{94}Mo(p, n)\ ^{94m}Tc$ $^{92}Mo(\alpha$, ðn) ^{94m}Tc $^{92}Mo(\alpha, 2n)\ ^{94}Ru\rightarrow{}^{94m}Tc$	^{94}Mo (93.9%), E_p=5-20 MeV, σ_{max}=480 mb (E_p=12 MeV), $Yield_{calc}$=2 GBq/μA·h; $^{93m,\ 93}Tc$ does not exist under given energy of protons. σ_{max}=311 mb (Å =25,9 Ì ýÂ) Yield=2.65 mCi/μA·h σ_{max}=788 mb (Å =26.2 Ì ýÂ) Yield=0.9 mCi/μA·h	1 2 2
^{94}Tc	4.9 h	$^{94}Mo(p, n)\ ^{94}Tc$	^{94}Mo (93.9%), E_p=5-20 MeV, σ=120 mb (E_p=12 MeV)	1
^{95m}Tc	60 d	$^{96}Mo(p, 2n)\ ^{95m}Tc$ $^{95}Mo(p, n)\ ^{95m}Tc$	Theoretical yeild ~ 22.4 Ci/g < ^{95}Tc	3 4
^{96}Tc	4.3 d	$^{197}Au(^{14}N, xpn)^{96}Tc$	^{14}N, E_N=35 MeV/nuclon	5

^{96}Tc	4.3 d	^{97}Mo(p, 2n) ^{96}Tc	E_p=90 MeV	
^{99m}Tc	6 h	^{235}U(n, f)^{99}Mo → ^{99m}Tc	Neutron beam=10^{14} n/sm^2·s, Yield (99Mo)= 10-30 kCi/g (^{nat}Mo), technological cycle	6, 7
^{99m}Tc ^{99m}Tc ^{99m}Tc	6 h 6 h 6 h	^{98}Mo(n, γ)^{99}Mo → ^{99m}Tc ^{100}Mo(n, 2n)^{99}Mo → ^{99m}Tc ^{nat}Mo(n, γ)^{99}Mo → ^{99m}Tc	Neutron beam=10^{14} n/sm^2·s, Yield (^{99}Mo)=4-10 Ci/g·144h Fast neutrons, σ=1400 mb Neutron beam=10^{14} n/sm^2·s, Yield (^{99}Mo) ≈ 1 Ci /g·144h	6, 7 6, 8 6, 7
^{99m}Tc	6 h	^{100}Mo(p, np)^{99}Mo → ^{99m}Tc ^{100}Mo(p, 2p)^{99}Nb → ^{99}Mo → ^{99m}Tc	5g ^{100}Mo (97%), E_p=70 MeV, I=400 μA, Yield (^{99}Mo)=48 Ci /g·100h	6, 7
^{99m}Tc	6 h	^{100}Mo(p, 2n)^{99m}Tc	5g ^{100}Mo (97%), E_p=70 MeV, I=400 μA, Yield=40 Ci /g·100h	6, 7
^{99m}Tc	6 h	^{nat}Mo(γ, n)^{99}Mo → ^{99m}Tc	Thick target, E_e=up to 30 MeV, I=500 μA, Yield (^{99}Mo)=370 kBq/μA·h·g	9
^{99m}Tc	6 h	^{100}Mo(γ, n)^{99}Mo → ^{99m}Tc	Microtron, Thick target, Yield (^{99}Mo)=90 kBq/μA·h·g	6, 7, 10
^{99m}Tc	6 h	^{100}Ru (γ, p) ^{99m}Tc		11
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^{99m}Tc	6 h	^{nat}Mo(γ, n)^{99}Mo → ^{99m}Tc	Microtron, 10g ^{nat}Mo, Yield (^{99}Mo)=50 kBq/μA·h·g	12
^{99m}Tc	6 h	^{100}Mo(γ, n)^{99}Mo → ^{99m}Tc	Microtron, σ=390 mb, Yield (^{99}Mo)=2.2 kBq/μA·h·mg	12
^{95m}Tc ^{95}Tc	60 d 20 ÷	^{nat}Ru (γ, n) ^{95}Ru($T_{1/2}$= 1.65 h, Y=7.2 kBq) → $^{95m, 95}$Tc	0.23 Bq/μA·h·mg ^{nat}Ru 4 Bq/μA·h·mg ^{96}Ru (100%) 0.7 Bq/μA·h·mg ^{nat}Ru 12 Bq/μA·h·mg ^{96}Ru (100%)	
^{97m}Tc	91 d	^{nat}Ru (γ, n) ^{97}Ru($T_{1/2}$= 2.9 d, Y=50 Bq) →$^{97m, 97}$Tc	$1.6·10^{-3}$ Bq/μA·h·mg ^{nat}Ru $8.5·10^{-2}$ Bq/μA·h·mg ^{98}Ru (100%)	

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