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Possibility of Production of Molybdenum-99 Using Neutron Activation at the WWR-SM Research Reactor with LEU Fuel

U. S. Salikhbaev, S. Khujaev, S. A. Baytelesov, F. R. Kungurov, A. Boltabaev
Institute of Nuclear Physics AS RUz
Ulugbek, 100214, Tashkent – Uzbekistan

ABSTRACT

The yield of ^{99}Mo from the ^{98}Mo(n,c)^{99}Mo reaction significantly depends of the energy spectrum of the neutron flux. It is well known that the cross-section for this reaction is about 130 mb, whereas the resonance integral of the reaction is ~690 mb. The aim of this work was to investigate the conditions that let to increase ^{99}Mo yield from the targets with natural and enriched isotope composition under irradiation by resonance neutrons at the WWR-SM research reactor.

The calculations of integrated cross-sections of all Mo isotopes in the region of the ^{98}Mo resonances showed that screening in the target with natural isotope composition by other isotopes is relatively small. So the ^{98}Mo in the natural mixture can be activated by resonance neutrons approximately in the same manner as pure ^{98}Mo.

Experimental measurements of the 98Mo(n,c) effective cross-section using the MoO3 sample with natural and enriched composition in the reactor channels with the beryllium moderator with the thickness of 20 up to 90 mm showed that the effective cross-sections in these channels reach the value of 700 mb. The contribution of the epithermal neutrons into the 98Mo activity was 60% for the enriched targets and 70% for natural molybdenum, respectively. At that channel it is possible to produce 99Mo with specific activity up to 4.5-5.0 Cu/g with enriched samples on the base of reactors with neutron flux of ($1.0 \cdot 10^{14}$ n/(cm2 s)). Such 99Mo specific activity is enough not only to realize extraction technologies production of 99mTc, but to manufacture sorption generators of 99mTc without wastes.

The effective cross section of radiation capture σ^* reaction depends essentially on the contribution of the resonant component of the neutron spectrum. It is known that in the neutron energy range 0-1 keV, the dependence of its cross section has six resonance regions. Conducted calculation of the absorption of neutrons by individual isotopes of molybdenum content in the mixture with C i (Table 1) showed that if in the thermal region (0-1 keV), most of the neutrons

with energy En is absorbed by the competing reactions on the isotopes ^{95}Mo and ^{97}Mo, in of resonances (Δi) contribution of the absorption is small enough. That is, in this energy spectrum of neutrons specific activity ^{99}Mo depends mainly on the concentration of molybdenum-98 in the starting target.

Table 1.

Absorption of neutrons by the isotopes of molybdenum in the resonance regions Δi.

E_n, эВ	$\int_{E_{i1}}^{E_{i2}} C_i \cdot \sigma(E)dE$ molybdenum isotopes in regions Δ_i						
	^{98}Mo	^{92}Mo	^{94}Mo	^{95}Mo	^{96}Mo	^{97}Mo	^{100}Mo
0-1	$2{,}4\cdot10^{-3}$	$9{,}5\cdot10^{-5}$	$6\cdot10^{-5}$	0,285	$4{,}2\cdot10^{-3}$	0,045	$4{,}7\cdot10^{-3}$
10-14	3,652	$5{,}2\cdot10^{-4}$	$2{,}3\cdot10^{-3}$	0,312	0,018	0,012	$3{,}4\cdot10^{-3}$
399-403	6,832	$0{,}8\cdot10^{-3}$	$6{,}4\cdot10^{-5}$	0,08	$3{,}1\cdot10^{-3}$	2,88	0,04
425-435	96,98	$8{,}8\cdot10^{-5}$	$1{,}6\cdot10^{-4}$	0,95	0,028	0,16	0,03
460-480	136,27	$9{,}8\cdot10^{-4}$	$1{,}7\cdot10^{-4}$	3,4	$3{,}9\cdot10^{-3}$	0,36	0,02
610-615	60,0	$1{,}4\cdot10^{-4}$	$9{,}3\cdot10^{-5}$	0,83	$4{,}2\cdot10^{-4}$	0,05	$6{,}4\cdot10^{-4}$
814-821	94,1	$1{,}7\cdot10^{-4}$	$1{,}7\cdot10^{-4}$	0,01	$4{,}5\cdot10^{-4}$	0,16	$8{,}3\cdot10^{-4}$

To slow the fast neutrons of fission spectrum up to energies of the resonant level at the reactor WWR-SM it was used beryllium assembly with a layer thickness of the moderator from 35 to 70 mm, mounted around the vertical channel. When irradiated in the channel a series of samples of natural oxide MoO^3 the average value ofσ*was obtained for the reaction ^{98}Mo (n,γ) ^{99}Mo, equal to 650±30 mb. Estimated contribution to the resonance integral of the magnitude of activation ^{98}Mo here is about 70%.

More correct estimation of the contribution of the resonant component, carried out using the cadmium difference in samples of natural composition and MoO^3 enriched in ^{98}Mo to 98.6% showed that the natural oxide value of the contribution reaches 70%, and for the enriched one - 60%. This provides the possibility of up to 8 Ci/g of ^{99}Mo for 180 hours of the device, even when using a target of natural composition.