Tc-99 transmutation as the new source of stable ruthenium

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The world production of Tc-99 in power reactors is 7.5 t/year but its requirements in world market are below a few hundreds g/year. Many nuclear countries plan to isolate Tc-99 from radioactive wastes for long-term controlled storage or liquidation. Tc-99 transmutation to short-lived and stable nuclides is the only radical method of this long-lived radionuclide liquidation. High Tc-99 capture cross sections with thermal and intermediate neutrons are a base of this strategy.

In this work we develop our early publication [1] about production of stable and applicable ruthenium by Tc-99 transmutation in reactors with thermal neutrons. Natural Ru is noble metal, its price is about 10 $/g, its world stocks are about 3100 t and its world requirements are 7.4 t/year, that could be satisfied completely by Tc-99 transmutation. Stable isotopes Ru-100, Ru-101, Ru-102 are the main products of Tc-99 transmutation with thermal and intermediate neutrons:

$$\text{Tc-99} \rightarrow \text{Tc-100} \rightarrow \text{Ru-100} \rightarrow \text{Ru-101} \rightarrow \text{Ru-102} \rightarrow \text{Ru-103}$$
$$\rightarrow \text{short-lived and stable isotopes of Rh and Pd.}$$

Transmutation Ru could be applicable in non-nuclear industry if it will contain the quantity of radioactive nuclides which is lower than permissible level.

We have calculated Tc-99 transmutation and Ru production dynamics during Tc-99 point-target irradiation by thermal neutrons with spectrum hardness of γ=0.3 (fig.1,2). Stable ruthenium yield achieves maximum with thermal neutron fluence of about $5*10^{22}$ cm^{-2} (γ=0.3) and equals about 99% of all nuclei, 0.1 - 0.2% are nonburnt Tc-99 and after 1 year of target keeping the rest are stable isotopes of Rh and Pd. The analysis of all possible reactions of Tc-99 with thermal neutrons shows that there are no long-lived radioactive isotopes among transmutation products.

Ru activity after irradiation will be result of a presence of nonburnt Tc-99 and fission products produced from actinides impurities in Tc-99 target. About 99-99.5% of nonburnt Tc-99 must be separated from transmutation products to achieve the concentration of less than 10^{-5} g of Tc-99/g of Ru which is lower than the permissible level for a surface and an equipment in nuclear industry. Probably it will require full dissolution of targets because of production of Ru-Tc solid solutions under irradiation (for example, in the case of completely metalic Tc targets). In the opposite case Tc-99 before irradiation must contain less than $5*(10^{-11} - 10^{-10})$ g of actinides/g of Tc-99 in order to produced fission products activity will be less than 10^2 Bq/g for use of Ru in industry (latter value in brackets relates to target keeping during 10 years after irradiation). But if Tc-99 rest separation from Ru after 1 year keeping will lead to extraction of about 90% of all fission products activity except Ru-106, then Tc-99 target must contain less than $2*10^{-10}$ g of actinides/g of Tc-99 before irradiation for immediate use of Ru.