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Theoretical consideration of the specific activity of Tc-99m produced by the Mo-100(p,2n)Tc-99m reaction at cyclotrons

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Even today the generator-produced radionuclide ^{99m}Tc is used for the vast majority of nuclear medical diagnoses. The parent radionuclide ⁹⁹Mo is generally produced via fission of highly-enriched ²³⁵U, however, at a few nuclear reactor sites in the world only. Due to ageing reactors the world supply of fission-produced ⁹⁹Mo has become somewhat insecure over the last few years. Alternative methods of direct production of ^{99m}Tc using accelerators are therefore presently attracting great attention. The (p,2n) reaction on highly enriched ¹⁰⁰Mo appears to be the most promising one. Over the years several cross section measurements thereof have been reported.

However, a critical analysis of the data and the influence of co-produced long-lived Tc-isotopes on the specific activity of ^{99m}Tc need to be critically considerated. From ¹⁰⁰Mo the two long-lived radioisotopes ^{99g}Tc and ⁹⁸Tcare co-produced. ^{99g}Tc is formed directly by the ¹⁰⁰Mo(p,2n)^{99g}Tc reaction and indirectly via the decay of ⁹⁹Mo and ^{99m}Tc during irradiation and after EOB. ⁹⁸Tc is generated by the ¹⁰⁰Mo(p,3n) reaction directly.

We calculated excitation functions for the formation of ⁹⁹Mo and ^{99m}Tc as well as for the long-lived technetium isotopes ^{99g}Tc and ⁹⁸Tc by the code TALYS for the proton-induced reactions on ¹⁰⁰Mo. For the first two nuclides calculations were also performed using the code STAPRE. The direct and indirect production of ^{99m}Tc was critically analysed. The integral yields of ⁹⁹Mo, ^{99m}Tc, ^{99g}Tc and ⁹⁸Tc were calculated for four chosen irradiation times as a function of proton energy. Therefore the activities of ⁹⁹Mo and ^{99m}Tc as well as the number of atoms of ^{99m}Tc, ^{99g}Tc and ⁹⁸Tc were deduced for six realistic proton energy ranges.

The dependence of the specific activity of ^{99m}Tc was calculated in relation to energy range, irradiation and cooling time. The specific activity of ^{99m}Tc produced directly at a cyclotron was critically compared with that obtained from a fission ⁹⁹Mo loaded generator. The long-lived isotopes ^{99g}Tc and ⁹⁸Tc cause no significant radiation and mass dose to the patient but have a strong influence on the specific activity of the cyclotron produced ^{99m}Tc depending on the production conditions. At a suggested 22 MeV incident proton energy, for example, the ratio of long-lived Tc nuclei to ^{99m}Tc nuclei may far exceed 5.0, thereby possibly affecting the kit formulation of radiopharmaceuticals and also exceeding the limits set by radiopharmaceutical regulations, e.g. in Italy. Thus, detailed experimental and theoretical investigations related to the effect of a decreasing specific activity of ^{99m}Tc on the preparation of radiopharmaceuticals appear absolutely necessary.

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