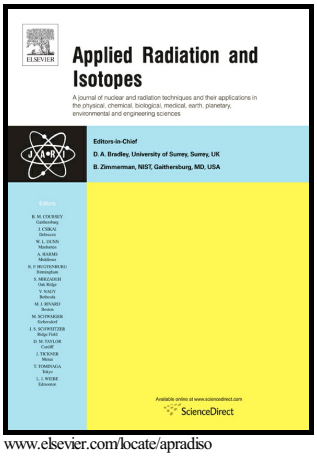

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Reference Materials for Neptunium Determination

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Introduction

Neptunium is a transuranic element of particular interest to the nuclear forensics, safeguards, and non-proliferation communities. The existence of large stocks of concentrated neptunium and that ^{237}Np is a fissile material (Sanchez, *et al*, 2003 and 2008) make analysis of the element important for nuclear forensics and non-proliferation. Potentially diagnostic information can be obtained from neptunium analyses, it is imperative that the analytical community is capable of making accurate and defensible neptunium measurements.

Neptunium-237 is the longest lived isotope of neptunium with a half-life of $2.144(7)\times10^{6}$ years (Chechev and Kuzmenko, 2010), and is the parent nuclide of the '*4n+1*' decay series, shown in figure 1. It may be noted that the half-life of ^{237}Np is derived from a single measurement (Lowles, *et al*, 1992) and is in need of additional measurement. It does not occur in nature, except in extremely small quantities; any neptunium present at the formation of the solar system has long since decayed away. The primary route of production is from irradiation of nuclear fuel:

$$^{235}\mathrm{U} \xrightarrow{n,\gamma} {}^{236}\mathrm{U} \xrightarrow{n,\gamma} {}^{237}\mathrm{U} \xrightarrow{\beta} \mathbf{^{237}Np} \xrightarrow{\alpha} \&c$$

$$^{238}\mathrm{U} \xrightarrow{n,2n} {}^{237}\mathrm{U} \xrightarrow{\beta} \mathbf{^{237}Np} \xrightarrow{\alpha} \&c$$

$$^{238}\mathrm{U} \xrightarrow{n,\gamma} {}^{239}\mathrm{U} \xrightarrow{\beta} {}^{239}\mathrm{Np} \xrightarrow{\beta} {}^{239}\mathrm{Pu} \xrightarrow{n,\gamma} {}^{240}\mathrm{Pu} \xrightarrow{n,\gamma} {}^{241}\mathrm{Pu} \xrightarrow{\beta} {}^{241}\mathrm{Am} \xrightarrow{\alpha} \mathbf{^{237}Np} \xrightarrow{\alpha} \&c$$

Also, ^{241}Pu and ^{241}Am may be activated

$$^{241}\mathrm{Pu} \xrightarrow{n,\gamma} {}^{242}\mathrm{Pu} \xrightarrow{n,\gamma} {}^{243}\mathrm{Pu} \xrightarrow{\beta} {}^{243}\mathrm{Am} \xrightarrow{n,\gamma} {}^{244}\mathrm{Am} \xrightarrow{\beta} {}^{244}\mathrm{Cm} \xrightarrow{n,\gamma} {}^{245}\mathrm{Cm} \xrightarrow{\alpha} {}^{241}\mathrm{Pu} \xrightarrow{\beta} {}^{241}\mathrm{Am} \xrightarrow{\alpha} \mathbf{^{237}Np} \xrightarrow{\alpha} \&c$$

$$^{241}\mathrm{Am} \xrightarrow{n,\gamma} {}^{242}\mathrm{Am} \xrightarrow{n,\gamma} {}^{243}\mathrm{Am} \xrightarrow{n,\gamma} {}^{244}\mathrm{Am} \xrightarrow{\beta} {}^{244}\mathrm{Cm} \xrightarrow{n,\gamma} {}^{245}\mathrm{Cm} \xrightarrow{\alpha} {}^{241}\mathrm{Pu} \xrightarrow{\beta} {}^{241}\mathrm{Am} \xrightarrow{\alpha} \mathbf{^{237}Np} \xrightarrow{\alpha} \&c$$

Neptunium-237 itself may also be activated to form ^{236}Np and ^{238}Np, the quantities depending on the neutron spectrum during irradiation. Neptunium-237 has been produced in tonne quantities through various nuclear power programmes and has entered the environment from weapons test fall out and effluent from nuclear fuel reprocessing. Measurement of ^{241}Am:^{237}Np and ^{237}Np:^{233}U atom ratios can be used for age dating nuclear materials, and knowledge of the ^{236m}Np:^{237}Np atom ratio may be used as one of the parameters contributing to the spatial attribution of nuclear material. Despite the rate of production since 1945, ^{237}Np remains one of the least studied of the actinides between thorium and curium, with the possible exception of protactinium. However, the chemistry of neptunium is well