ENVIRONMENTAL IMPORTANCE OF THE $^{107}\text{Ag}(n,\gamma)^{108}\text{Ag}_m$ REACTION IN NUCLEAR POWER REACTORS, AND NEW $\sigma_7^i$ AND $I_s$ MEASUREMENTS

M. GAVRILAS,* V. P. GUINN

Department of Chemistry, University of California, Irvine, California 92717 (USA)

(Received December 12, 1986)

$^{108}\text{Ag}_m$ is an $(n,\gamma)$ activation product of $^{107}\text{Ag}$ and is produced in nuclear power reactors. Due to the wide range of reported values for the $\sigma_7^i$ cross section of the $^{107}\text{Ag}(n,\gamma)^{108}\text{Ag}_m$ reaction new measurements were made — resulting in a $\sigma_7^i$ value of $0.477 \pm 0.033$ barn, and an $I_s$ value of $0.80 \pm 0.15$ barn. The environmental importance of the $^{110}\text{Ag}_m$ and $^{108}\text{Ag}_m$ radionuclides is discussed.

Introduction

In nuclear power reactors, various radionuclides are produced that can appear in the reactor primary coolant water. Some are produced by neutron activation (mostly $(n,\gamma)$), some by fission of $^{235}\text{U}$, some by both processes. Although extensive purification of the reactor coolant water is employed, small fractions of some of these radionuclides appear in the effluent to the environment. Whereas the shorter-lived species are of little environmental importance, due to their rapid decay, the longer-lived ones are of potential environmental concern — especially those that are heavily concentrated by various aquatic biological species.

Two of these long-lived species, 127-year $^{108}\text{Ag}_m$ and 249.76-day $^{110}\text{Ag}_m$, were studied in this investigation. Both are produced by $(n,\gamma)$ activation of silver, and as very low-yield fission products. Silver is present in many power reactors, for example, in Ag-In-Cd alloy control rods, in Pb-Sn-Ag alloy flux/temperature monitors, and in Ag-plated Ni-Cr-Fe alloy O-rings. The first two of these sources of Ag are sealed (e.g., in Inconel and quartz, respectively), but the Ag in the O-rings is directly exposed to the reactor coolant water. Corrosion of

*Permanent address: Environmental Programs, Baltimore Gas and Electric Company, Charles Center, P.O.Box 1475, Baltimore, Maryland 21203, USA.
M. GAVRILAS, V. P. GUINN: ENVIRONMENTAL IMPORTANCE

the Inconel cladding of the control rods and/or cracking of the quartz cladding of the flux/temperature monitor alloy pieces, however, can also release Ag to the coolant water. All three of these Ag-containing materials are exposed to high neutron fluxes in power reactors. Corrosion of the fuel cladding metal, and leakage through cladding pin holes or cracks, can also release fission-product radio-silver to the coolant water.

Using the currently accepted available activation cross sections, it is readily apparent that the formation of both $^{108}\text{Ag}^m$ and $^{110}\text{Ag}^m$ by the $^{108}\text{Cd}(n,p)\; ^{108}\text{Ag}^m$, $^{109}\text{Ag}(n,2n)\; ^{108}\text{Ag}^m$, $^{110}\text{Cd}(n,p)\; ^{110}\text{Ag}^m$, and $^{113}\text{In}(n,a)\; ^{110}\text{Ag}^m$ fast-neutron reactions is very small, compared with their thermal-neutron $(n,\gamma)$ reaction formation from Ag - even for a fission-spectrum neutron flux ($\phi_{\text{F.S.}}$) equal to the thermal-neutron flux ($\phi_{\text{th}}$).

In order to calculate the expected $^{108}\text{Ag}^m$ and $^{110}\text{Ag}^m$ activity levels resulting from $(n,\gamma)$ activation of Ag with thermal and epithermal neutrons, for different fluxes ($\phi_{\text{th}}$ and $\phi_{\text{epi}}$), various irradiation times ($t_i$), and various decay times ($t_d$), one needs good values for the cross sections for the formation of each by thermal neutrons ($\sigma_0^0$) and by epithermal neutrons ($I_\gamma$). For the $^{109}\text{Ag}(n,\gamma)\; ^{110}\text{Ag}^m$ reaction, consistent values have been reported for $\sigma_0^0$, and fairly consistent values for $I_\gamma$; the currently accepted values /1/ being, respectively, 4.7±0.2 barns and 72.3±4.0 barns. Whereas this same reference /1/ gives $\sigma_0^0$ and $I_\gamma$ values of, respectively, 0.33±0.09 barn and 1.2±0.2 barns for the $^{107}\text{Ag}(n,\gamma)\; ^{108}\text{Ag}^m$ reaction. The agreement amongst the various reported $\sigma_0^0$ values is very poor - variously reported as 3.0±1.5 b/2/, 10b/3/, -4b/4/, 1.5b/5/, 0.4b/6/, -0.3b/7/, and 0.33±0.08b/8/. It was thus deemed worthwhile to reinvestigate the cross sections for the $^{107}\text{Ag}(n,\gamma)\; ^{108}\text{Ag}^m$ reaction. The experiments conducted, and the results obtained, are described below.

Experimental

Metallic silver powder enriched in $^{107}\text{Ag}$ (98.22 atom %, containing 1.78 atom % $^{109}\text{Ag}$), obtained from the Stable Isotopes Division of the Oak Ridge National Laboratory, was