Neutronic Chain Reactions in Bismuth Salts

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The production of the industrially significant radionuclide polonium-210 from the neutron irradiation of bismuth metal and the subsequent beta decay of bismuth-210 is highly inefficient due to the small neutron capture cross section of bismuth-209. In this paper, we report a previously undescribed self-sustaining nuclear chain reaction involving self-propagating neutron multiplication in bismuth salts that allow for rapid and cost-effective production of polonium-210. The reaction proceeds in a cycle of three alternating elementary steps – the capture of neutrons by bismuth-209 and the subsequent formation of polonium-210, the emission of high-energy alpha particles by polonium-210, and the production of more neutrons from (α,n) and (n,2n) reactions on light element and bismuth-209 nuclei respectively. Furthermore, the high hydrogen density of the compound also confers it intrinsic neutron moderation properties, increasing the neutron capture cross section of bismuth-209 at thermal neutron energies. The chain reaction was proven to have successfully occurred by irradiating a sample of the bismuth salt with a 80 μCi neutron source and monitoring the activity levels of the reaction. It was found that the activity of the reaction increased exponentially after an initial stable period following a derived formula for polonium production trends for the reaction, thus validating the occurrence of the reaction. Furthermore, alpha spectroscopy confirmed that polonium-210 had been produced by characterising the 5.41 MeV alpha emission peak of the reaction, further proving that the reaction was successful. Hence, this paper reports the successful initiation and characterisation of a novel nuclear chain reaction, and its potential applications offered by a method of rapidly producing large quantities of polonium-210.