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Selective separation of neutron poisons from spent nuclear fuel using a carboxyl-functionalized ionic liquid

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Reprocessing of spent nuclear fuel became the key issues for the environmentally friendly and sustainable development of nuclear energy. For the future development of nuclear energy requirements, the concept of an accelerator-driven advanced nuclear energy system (ADANES) has been proposed in China. ADANES consists of a burner system and a fuel recycle system. The waste transmutation, breeding, and power production are implemented in the burner driven by the neutron source outside the accelerator. It is not necessary to carry out the fine partitioning for minor actinides due to the higher-power neutron source. Hence, in this fuel reprocessing, only part of the fission products containing neutron poisons from spent nuclear fuels will be separated and disposed. The rest spent nuclear fuel, uranium dioxide along with transuraniums including Pu, Np and Am will be regenerated as new nuclear fuels and burned subsequently.
Neutron poison is a substance with a large neutron absorption cross-section in nuclear reactors, such as xenon-135 (σ = 2,000,000 b (barns) and samarium-149 (σ = 74,500 b). Actually, some lanthanides or rare earth elements, which accounts or about 1/3 of the fission products, have large neutron absorption cross sections and are neutron poisons. So these lanthanides should be separated from spent nuclear fuel before the next transmutation step.
In this work, water-saturated [Hbet][Tf₂N] was used to selectively dissolve rare earth oxides from the simulated spent nuclear fuel, leaving most of the valuable uranium oxides as solid in fuel matrix. The selective dissolution of rare earth elements is driven by the reactivity of the carboxylic acid group located on the cation of the ionic liquid under the appropriate experimental conditions. The lanthanide oxides dissolves easily at 40 ℃ with complete dissolution in a short time while UO₂ have very low solubility at this temperature with negligible amounts being dissolved. The dissolved rare earth metals by [Hbet][Tf₂N] will be in solution phase and the rest undissolved solid particles are uranium dioxides. After centrifugal separation, the valuable and reused uranium oxides or most spent nuclear fuel will be obtained. Rare earth metals dissolved in [Hbet][Tf₂N] can be stripped with an acidic solution. Such a selective dissolution system that automatically separates the rare earth metals including some other fission products is innovative and applicable to spent nuclear fuel reprocessing.

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