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How can we achieve a sustainable nuclear fuel cycle?

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Abstract

Dealing with spent nuclear fuel is key if nuclear fission is to be used more widely going forward. Nuclear power is close to carbon neutral, but spent nuclear fuel has a storage lifetime of ~300,000 years. Reprocessing spent nuclear fuel is carried out on large scale using the PUREX "Plutonium Uranium Reduction and Extraction" process. The spent nuclear fuel is reduced to 15% of its original weight and the separated uranium and plutonium reused as "Mixed Oxide Fuel". In the civil sector, this was carried out by the UK at Sellafield (now curtailed) and continues in France at La Hague. A plant in Rokashamura in Japan has been mothballed after the Fukushima accident. The residual waste must be stored for ~9,000 years with most of the remaining radiotoxicity due to traces of the minor actinides, neptunium, americium and curium, constituting just 0.1% of the original spent fuel. Separation of these minor actinides from the chemically very similar lanthanides (rare earths) in the last 15% of waste remaining after PUREX is the key step for future reprocessing. If separated, the minor actinides can be used as fuel in the next generation of nuclear reactors and converted into benign products, but lanthanides will cause the fission process to shut down if introduced into the reactor pile as they absorb neutrons efficiently. Removing the minor actinides from post PUREX waste will mean that the final residue need only be stored for 300 years. The highly challenging separation of the chemically very similar minor actinides from the lanthanides has been achieved using nitrogen-bearing organic ligands developed at Reading University. This can lead to significantly improved handling of spent nuclear fuels and means that waste nuclear fuel need not be a long-term storage liability but a source of yet more clean power.

Keywords: nuclear waste; actinides; lanthanides; partitioning

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