Thermochemistry of fuel, fission products and corrosion products in Molten Salt Reactors

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One of the major challenges of the 21st century is the management of a rising World population and energy needs, while reducing carbon dioxide emissions to mitigate the impact on climate change. Fossil fuels comprising coal, oil, and natural gas currently provide about 80% of the World energy supply, but are non-renewable, and therefore do not provide a viable solution for future generations. In light of these challenges, nuclear energy can play a key role in the energy mix . However, major concerns exist with respect to the long term sustainability of the nuclear fuel cycle, management of radioactive waste, and the need for increased safety margins.

In this context, the Molten Salt Reactor (MSR) was selected by the Generation IV International Forum (GIF), as one of the six designs for the future generation of nuclear fission technologies. This concept, based on a liquid fuel as opposed to the solid $(U_{1-x}Pu_x)O_2$ fuel of current Light Water Reactors, is highly innovative and provides an inherently safer design that remains subcritical in an accidental event or temperature increase. Furthermore, it can be coupled to a thorium fuel cycle for a sustainable energy production (thorium resources on Earth being three times larger than uranium).

A fundamental understanding of the physico-chemical properties of the liquid fuel are key for the reactor operation and its safety analysis. In Europe, the reference fuel proposed is a molten fluoride salt with UF_4, ThF_4 and PuF_3 dissolved in ^7LiF solvent. During irradiation, fission products such as Cs, I, Mo are moreover generated, which make the chemistry of the fuel particularly complex. The fate of these elements and their influence on the fuel properties strongly depend on their chemical state, which in turn depends on the reactor parameters such as temperature and redox potential. Finally, the suitability of this fuel salt with respect to its corrosion properties for the structural materials must also be taken into account. Nickel-based alloys have been found to withstand rather well the harsh operational conditions (high temperatures, contact with corrosive salts and high radiation dose) found in this type of reactor. But the phase equilibria of the fuel salt with potential corrosion products must also be assessed as a function of temperature, composition and redox potential of the salt.

In this presentation, an overview of the comprehensive thermodynamic database, based on the quasi-chemical model and quadruplet approximation, of the Molten Salt Reactor fuel salt, fission products and corrosion products being developed in collaboration between the Delft University of Technology and the Joint Research Centre-Karlsruhe will be presented.