ALES –

AKTINIDI-LANTANIDI EROTUS- JA SEPAROINTIMATERIAALIT

ACTINIDE AND LANTHANIDE SEPARATION METHODS

KYT 2022

Otto-Matti Hiltunen and Risto Koivula

BACKGROUND

Brief introduction of ALES

- Advanced nuclear fuel cycles
- Nuclear waste management solutions
- Spent fuel reprocessing and nuclide separation
- Continuum for KYT 2018 project: adjustable separation materials

BACKGROUND

Brief introduction of ALES

•Group separation of actinides and lanthanides from acidic media

•Synthesis of selective composite/hybrid ion exchange materials

RATIONALE

- Nuclear waste disposal

  •The separation and transmutation of the long life radionuclides in the nuclear waste (concept of partitioning and transmutation, P&T)

  •The advanced separation techniques enable the best disposal and storage option for different elements

  •P&T is part of the research for the development of new generation nuclear power technology.

RATIONALE

- Nuclear waste disposal

  •Separation of side actinides, such as Np, Am, Cm from nuclear waste

  •Enhanced utilization of the energy in the used fuel

  •Decrease in the storage time and radiotoxicity of the entire waste fraction

AIMS AND OBJECTIVES

- Development of novel hybrid materials

  - Solid phase extractant (SPE) materials
  - Inorganic, metal oxide support and chelating organic ligands

    similar to e.g. Purex-process
  - Ion exchangers
    - Porous tunnel- or layered structure of metal oxide, ZrO_2
  - Functional organic groups provide adjustability for Ac/Ln selectivity

- High Ac/Ln group separation

RESULTS

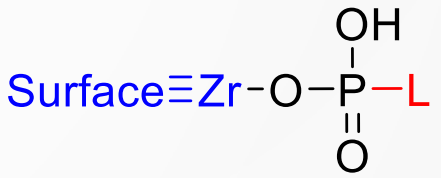
- A range of succesfully synthetized and characterized hybrid sorbent materials

  •Synthesis and introduction of multiple organophosphorous ligands to the zirconia support

  •Phosphorous provides suitable linkages between organic and inorganic moieties and endures required harsh conditions

  •Free OH^- groups functionalization spots on the zirconia surface

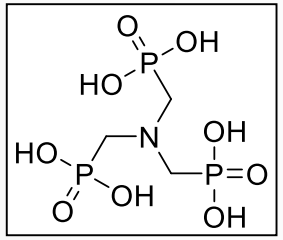
  •Ligand composition varied and tested in order to afford desired group selectivity for the material



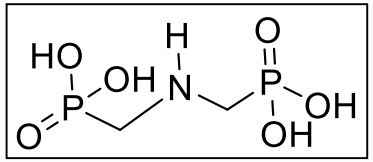
sininen = epäorgaaninen osa
punainen = orgaaninen osa

Results: Phosphonic acid ligands for grafting ZrO_2

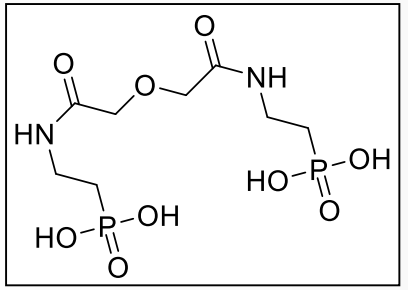
Nitrilotrismethyl-



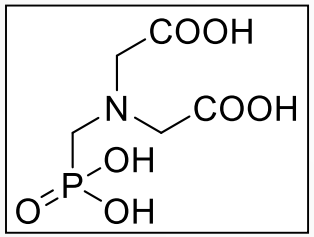
Iminodimethyl-



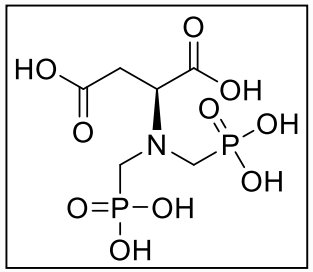
Diglycolamide-



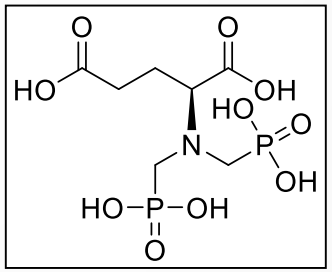
Iminodiacetic acid-



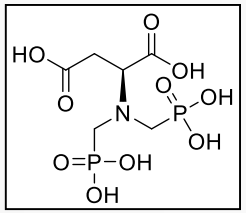
Aspartic acid-

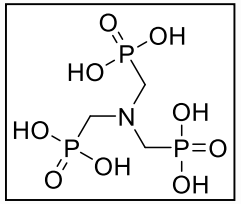


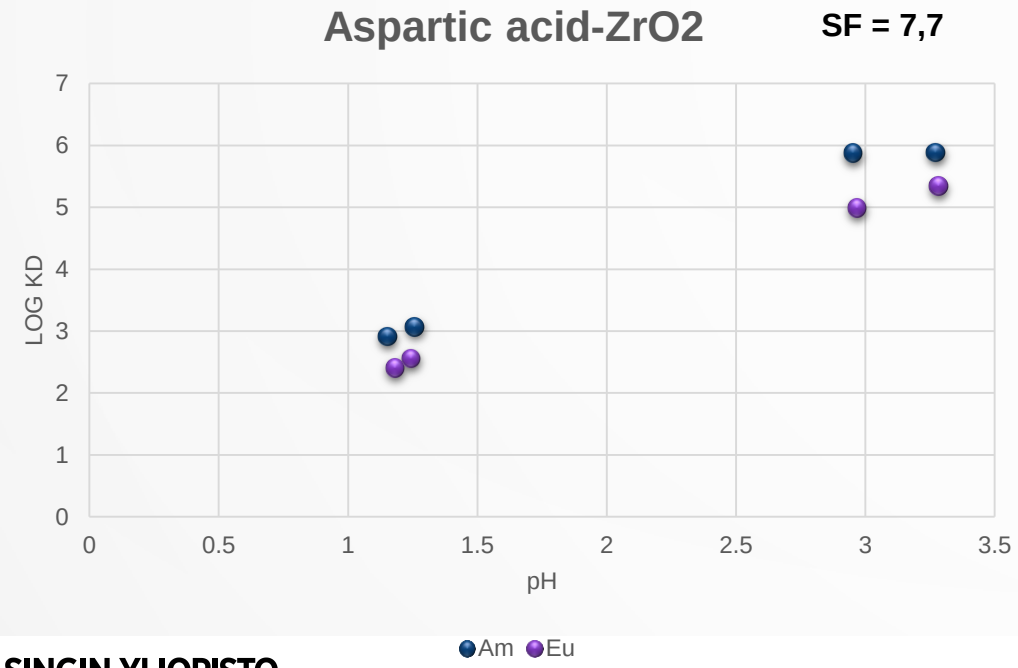
Glutamic acid-

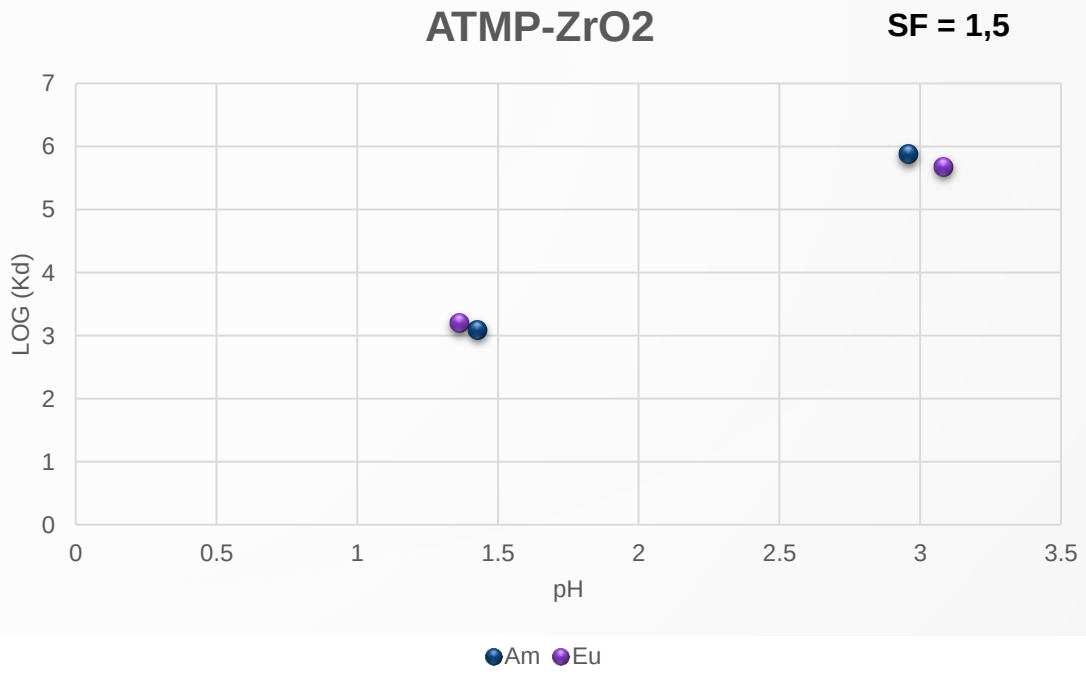


Results: Selected examples – batch experiments



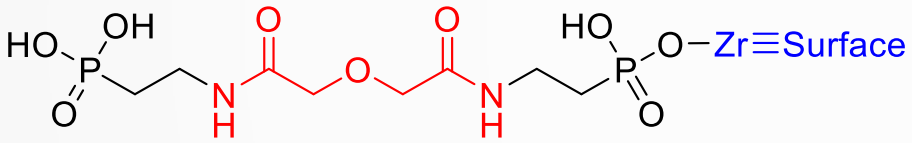


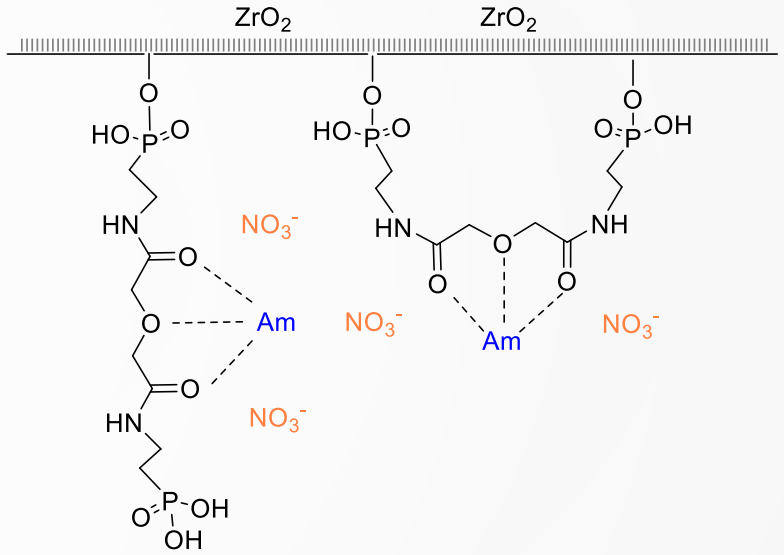




Results: Diglycol amide (DGA)-functionalized zirconia

Neutral complex extractant, selective DGA ligand



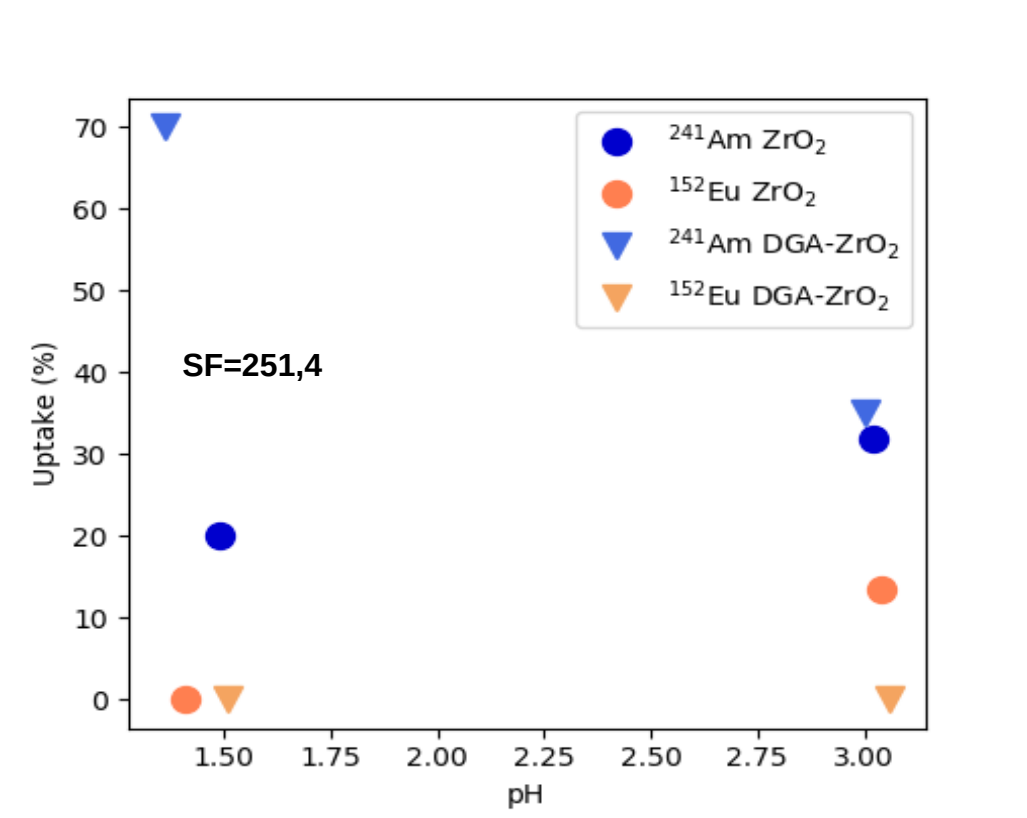


$$M^{3+}(aq.) + 3NO_3^-(aq.) + mL\,(org) \rightarrow M(NO_3)_3 \bullet mL\,(org)$$

Batch conditions:

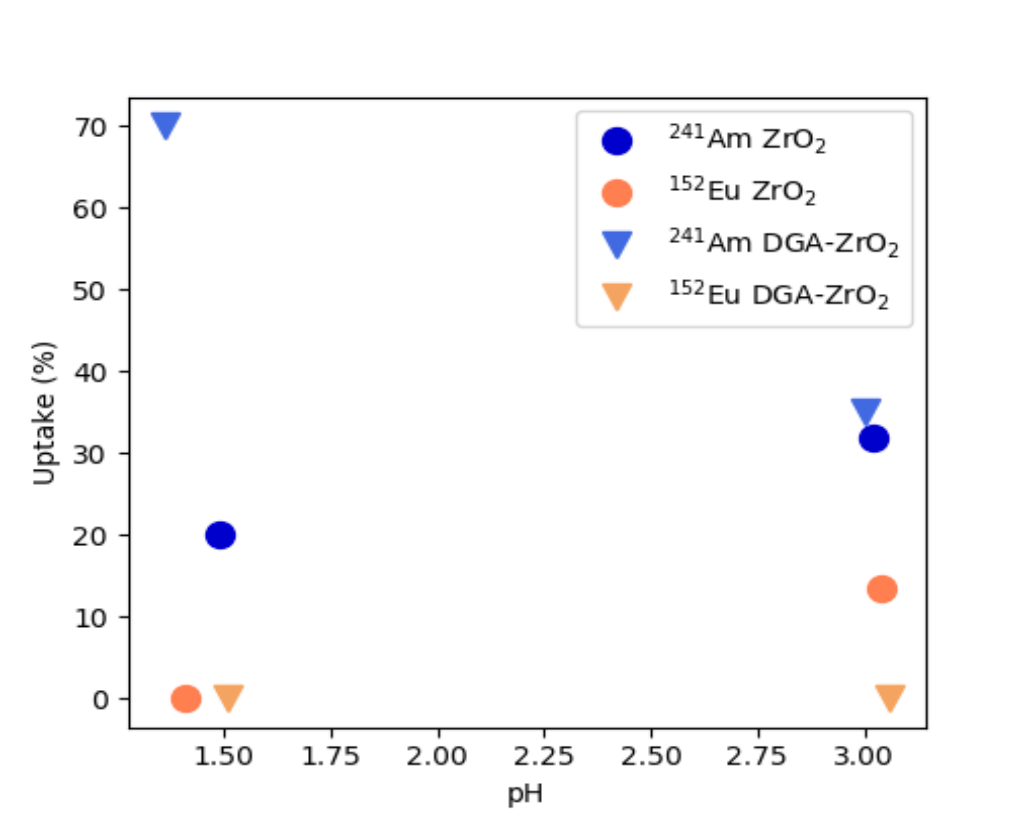
- High acid concenration (NO_3^-), low pH
- ^{241}Am and ^{152}Eu tracers used

Results: DGA-functionalized zirconia– batch experiments



- The most promising results obtained with DGA-functionalized ZrO_2 hybrid
- The results illustrate that in low pH the group selectivity properties of the material are relatively high – high separation factor
- The sorbent material clearly favours ^{241}Am over ^{152}Eu

Results: DGA-functionalized zirconia– batch experiments



- Bare ZrO_2 used as a reference material – not comparable separation values
- Sorption mechanism indicates that neutral complexation mechanism may be dominant
- The total sorption has not yet reached the desired level (> 99%)
- Effect of NO_3^- concentration and ligand loading

CONCLUSIONS

- Development of novel functionalized zirconia separation material
- The selectivity of DGA-ZrO_2 material is promising for sequestration of ^{241}Am and ^{152}Eu from dissolved used nuclear fuel or legacy waste.
- The stability of the hybrid material in the presence of acid indicates that it could be used as a solid-phase extractant without substancial degradation, and ideally reused