355. Study Level Recovery Processes of Thorium and Several Rare Earth Elements from Monazite Ore

Makayla Hyde and Jaclyn Choate

Chemical and Biomolecular Engineering Department, The University of Tennessee – Knoxville

Introduction

Monazite ore is composed of several minerals including several rare earth elements (REEs) and thorium phosphates. The thorium content of monazite varies up to 20% with North American monazite ores containing about 5% thorium.

Monazite Ore on displace at Smithsonian National Museum of Natural History https://www.minerals.net/mineral/monazite.aspx

Compound	Mass %
La_2O_3	16.64%
Ce_2O_3	33.52%
ThO_2	5.40%
P_2O_5	29.00%
Nd_2O_3	13.75%
SiO_2	1.55%
U_3O_8	0.15%
Total	**100%**

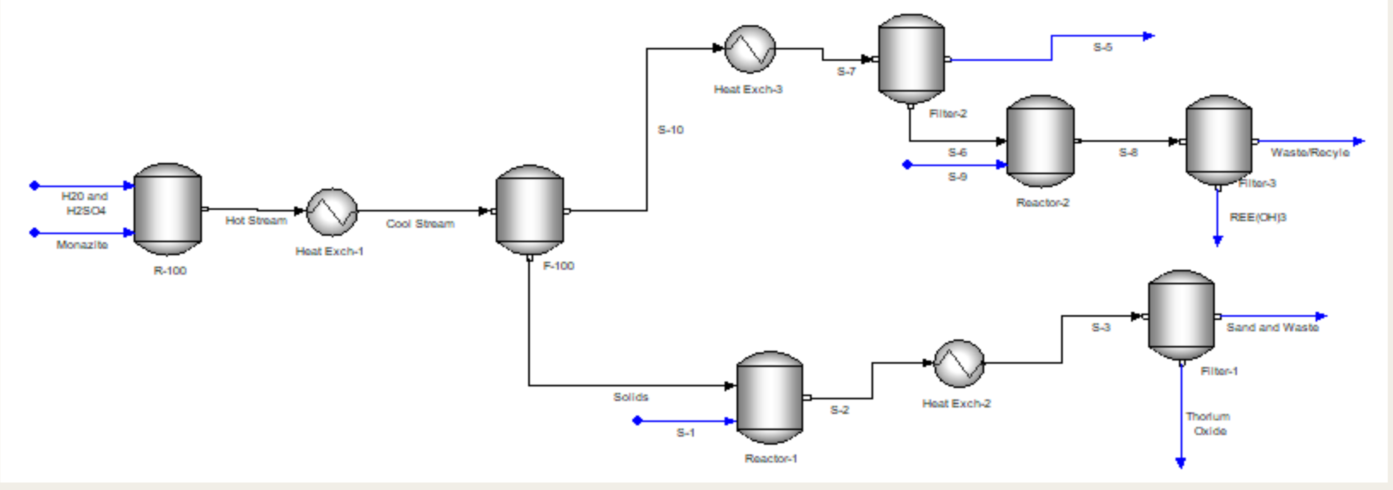
Typical Composition of Monazite Ore

Past research has looked at the extraction of REE from monazite ore but discarded the thorium phosphate compound as waste. Since thorium could be a possible fuel for state-of-the-art future nuclear reactors, this research focuses on a way to recover thorium from the monazite ore.

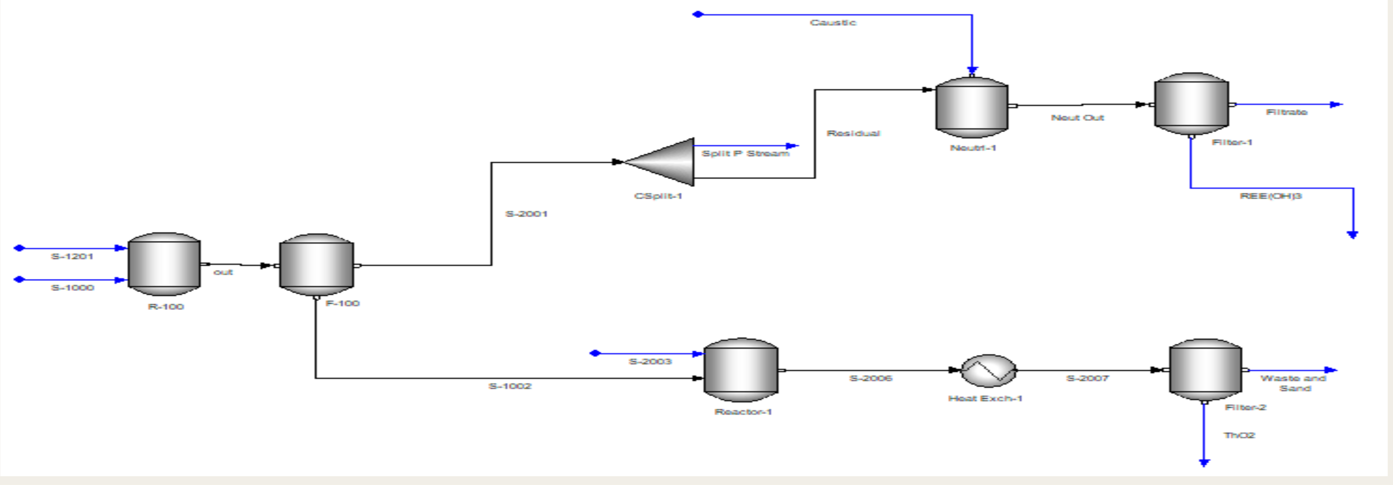
Conceptual Processes

Both processes are scaled for a 1000 kg/hr flow of North American monazite ore. The process will start by acid leaching the ore with sulfuric acid. The products of this step will be dissolved in water and filtered so that thorium will be separated. After this filtration, the process is divided into upper and lower processes containing rare earth elements or thorium, respectively. Products and byproducts will be neutralized with ammonium or sodium hydroxide. Separate product streams of rare earth oxides and thorium oxide will be achieved as byproducts and products, respectively.

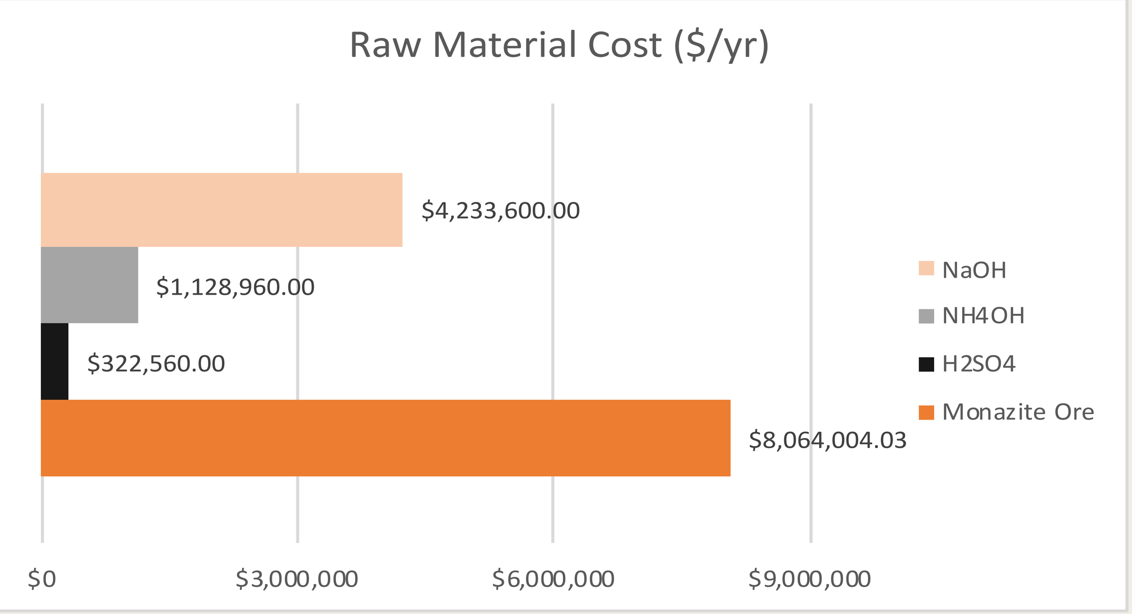
Process A

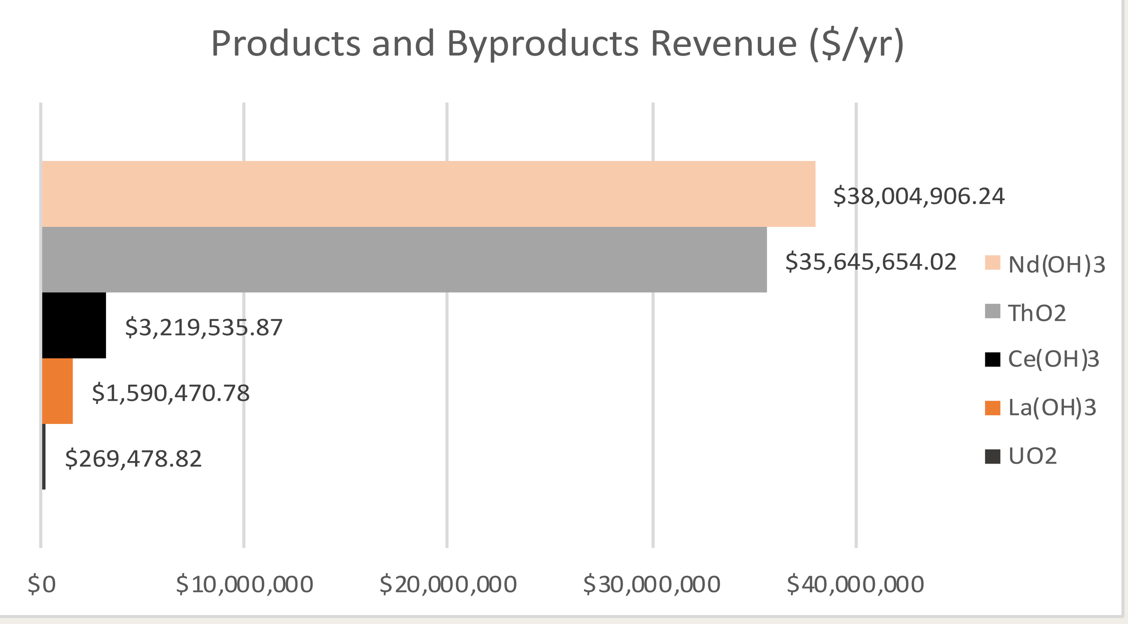


Process B



Results of Overall Recovery

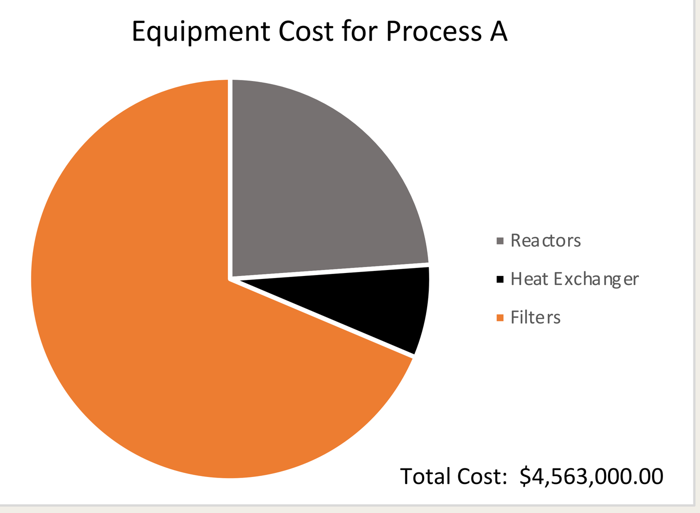


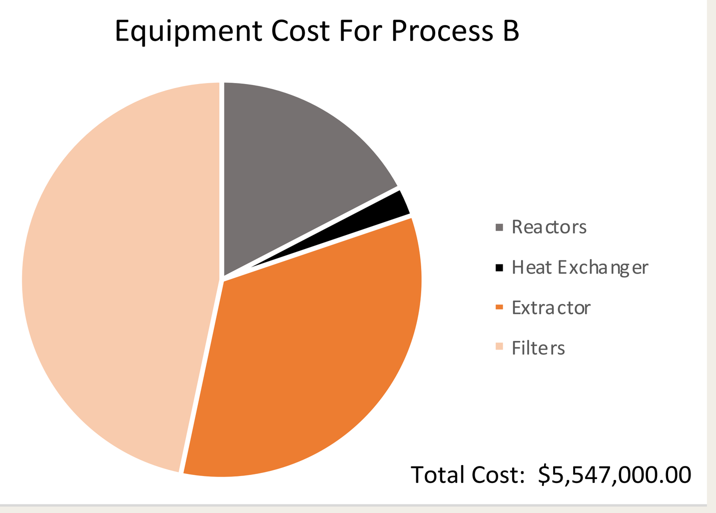


*Excludes Equipment and Operating Cost

Equipment Cost for Process A & Process B

Both processes achieve the same level of recovery of thorium and rare earth elements.



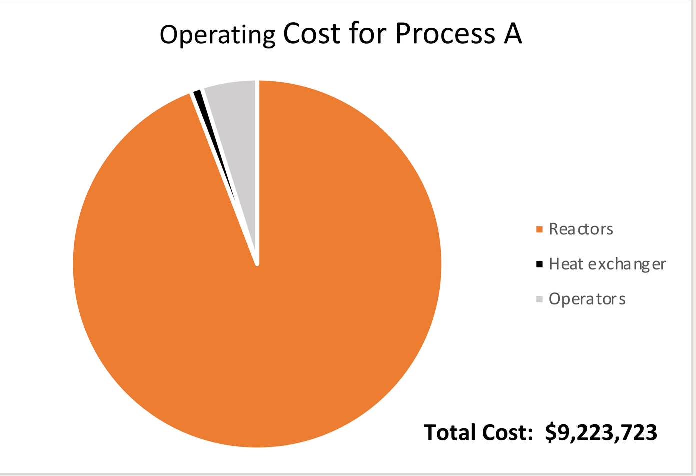


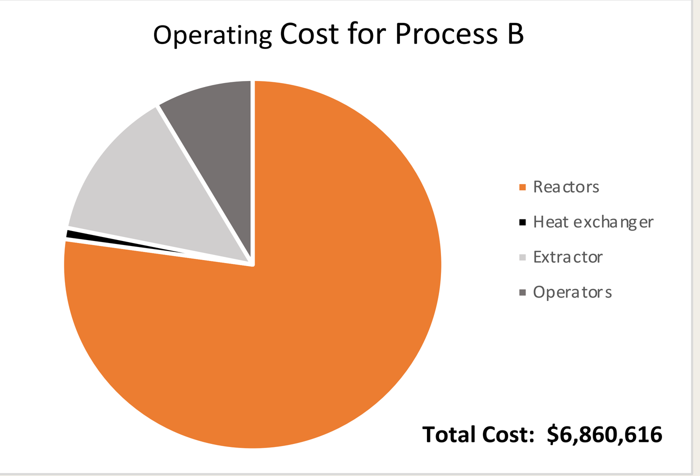
Major Differences:

Process A involves two more heat exchangers to heat and cool the entire process several times and one more filter to separate the rare earths from phosphorus. The biggest restriction is that it requires R-100 to run at 280℃ and 30 atm but the plus side is that the equipment cost is cheaper.

Process B involves only one heat exchanger to supercool the silicon sand and one less filter to achieve the same products. The biggest restriction is that it requires an extraction system that needs to remove 90% of phosphorus but the benefit is that phosphorus removed can be sold as a byproduct.

Operating Cost for Process A & Process B





Major Differences:

Process A costs three million more a year to operate. Operating cost include steam and ammonia to heat/cool the reactors, electricity to run the agitators, power to run the heat exchanger and yearly cost of operators for equipment.

Process B is significantly cheaper on a yearly basis.

Safety

Considering that we are extracting radioactive materials from this system, we must consider the protection of the workers and surrounding community from these dangerous materials. Our main concern lies with the thorium and uranium compounds. For both compounds, proper shielding must be present to limit exposure to any workers. Adequate protection will likely include protective walls, specialized clothing and masks, and ventilation-controlled work areas. Additional protection from thorium dust will include air filters and proper ventilation of the storage locations. This aims to reduce the hazardous exposure to the workers and the surrounding community and environment. Since thorium constantly undergoes alpha decay into appreciably more harmful elements, radon, an off-gas system will be needed for the whole process. This system will operate under partial vacuum and will cause the daughter products of thorium to be trapped onto carbon beds until radon is decayed. The whole process including the monazite storage area will need this off-gas system in order to be under the OSHA requirements for maximum expose to radon gas.

Conclusion

Total profit was calculated by taking revenue from products and byproducts and subtracting raw material costs, equipment costs and operating costs.

$$P_{Total} = P_{Products} - C_{Raw\ Material} - C_{Equipment} - C_{Operating}$$

$$P_{Total,Process\ A} = \$58{,}573{,}177.14 \quad vs \quad P_{Total,Process\ B} = \$63{,}557{,}734.27$$

Even though Process A had a lower equipment cost, the operating cost was significantly higher than Process B. The cost to heat and cool the process several times due to temperature extremes causes large operating costs. Since Process B had a cheaper operating cost and had profit from phosphorus being sold as a product, it was the more economically feasible option.

THE UNIVERSITY OF TENNESSEE KNOXVILLE

Department: Chemical and Biomolecular Engineering (CBE)

Faculty Advisor: Dr. Robert Counce

Email: mhyde6@vols.utk.edu