

NE585 – Nuclear fuel cycle analysis
Project 3 – Front end of the nuclear fuel cycle

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Preface

Refer to these references to start for aqueous reprocessing –

- (1) [Countercurrent equilibrium extraction](#)
- (2) [Nuclear fuel reprocessing](#)
- (3) [Principles of stagewise separation process calculations](#)
- (4) [Liquid-liquid extraction example problem I](#)
- (5) [Liquid-liquid extraction example problem II](#)

Use standard assumptions –

- Constant distribution coefficient
- Complete mixing
- Fresh solvent

Required for full credit – In problems 3 – 8, please address how the solution will affect the engineering design of a commercial scale PUREX facility.

1 Volume flow

(10)

Derive an expression for $\frac{F}{P}$ and $\frac{W}{P}$ explicitly in terms of x_F , x_P , x_W .

2 SWU

(10)

Plot $\frac{SWU}{P}$ and $\frac{SWU}{F}$ as a function of x_P . There is an interesting implication(s) of this curve, which we talked about, in terms of the JPCOA. What is it? Note that medical isotopes require $x_P = 0.20$.

3 Extract concentration

(20)

Prove that the extract concentration (y_N) can be expressed as -

$$y_N = \frac{\beta^N - 1}{\beta - 1}(Dx_1 - y_0) + y_0.$$

4 Material balance

(20)

Now eliminate x_1 by applying an ‘overall material balance’ to the above expression; i.e., a material balance on stage 1 and stage N.

5 Extraction factor

(20)

Finally, using the definition of fractional recovery of the extractable component (ρ) and extraction factor (β), into the result from (4) above, and eliminate y_N .

6 Decontamination factor

(20)

Derive the contamination factor (f_{AB}) based on the result in (5) for both $y_0 = 0$ and $y_0 \neq 0$. What does the decontamination factor actually mean? How does the efficiency compare if $y_0 = 0$ or $y_0 \neq 0$?

7 Maximum decontamination factor

(25)

- (a) Consider a multistage extraction system with two extractable components. What is the theoretical maximum for the decontamination factor?
- (b) If the extraction factor for U is 5 and for Tc is 0.01. What is the decontamination factor? What does it physically mean?

8 Extraction limit

(25)

Show *with math* that for an extraction factor less than unity, complete extraction is impossible, even if an infinite number of stages is available. When (or would) there be a case where the extraction factor would be less than unity?

9 Uranium tails

(50)

How are uranium tails managed? Critically discuss this issue.

10 BONUS – Enrichment

(50)

What would be the speed and radius of a gas centrifuge that would make it equivalent to gas diffusion?
What are the dimensions of the gas centrifuge? Which is better?

11 BONUS – Cost analysis

(50)

Taking the cost equation, what is the driver or limited factor for cost? What needs to happen for a plant to be profitable? What challenges are there? Feel free to make graph(s).

$$c_P = [V_P - V_F - (x_P - x_F) \frac{V_F - V_W}{x_f - x_w}] c_S + (\frac{x_P - x_W}{x_F - x_w}) c_F$$

c_P = enriched U price

c_S = SWU price

c_F = natural uranium price

$V_i = V(x_i)$; i.e., value function

Tables

Figures