**Appendix A**

Calculation detail on equilibrium constant of Ni2+ and [Au(CN)2]- ions extractant with three extractant systems can be expressed as:

 (A1)

 (A2)

 (A3)

where HR is D2EHPA, *x* and *y* are the stoichiometric coefficients associated with the D2EHPA and TBP extractants, respectively.

Based on the above complexation reaction, the equilibrium constant (*K*ex) of Ni2+ ions in the aqueous feed solutions can be written as:

 (A4)

 (A5)

 (A6)

Eqs. (A4) to (A6) can be written in terms of the distribution coefficient of the Ni2+ ions in the organic phase as:

 (A7)

 (A8)

 (A9)

Rearranging Eqs. (A7) to (A9) and taking the natural logarithm on both sides:

 (A10)

 (A11)

 (A12)

**Appendix B**

Detail calculation base on mass balance for separation of Ni2+ ions via HFSLM (Sharma et al., 2016).

 (B1)

where  is the bulk concentration of the Ni2+ ions in the feed-side (lumen-side) fluid at location “*z*” of the lumen (kmol/m3),  is the bulk concentration of the Ni2+ ions in the strip-side (shell-side) fluid at location “*z*” of the shell (kmol/m3),  is the feed-side film mass transfer coefficient (m/s),  is the strip-side film mass transfer coefficient (m/s),  is the hollow fiber thickness (m),  is the molecular diffusion coefficient of the metal-carrier complex in the HFSLM (m2/s),  is the feed-side distribution coefficient of Ni2+ ions and  is the strip-side distribution coefficient of Ni2+ ions.

 (B2)

Here,  is defined as the overall mass transfer coefficient of the transport process, m/s.

From the equilibrium constant () from Eqs. (A1) to (A3), the feed-membrane interface and the strip-membrane interface can be modified:

 (B3)

 (B4)

 (B5)

 (B6)

 (B7)

 (B8)

where,  and  are the organic-metal complex concentration at the feed-membrane interface and the strip-membrane interface respectively, kmol/m3.  and  are the concentrations of the H+ ions at the feed-membrane interface and the strip-membrane interface respectively, kmol/m3.

From the above-mentioned equations:

 (B9)

 (B10)

 (B11)

 (B12)

 (B13)

 (B14)

where  and  are the distribution coefficients on the feed and strip sides of the membrane, respectively, and  and  are the concentration of the metal ions in the feed phase at the feed-membrane interface and the concentration of metal ions in the strip phase at the strip-membrane interface, respectively, kmol/m3.

The ratio of  and  can be written as:

 (B15)

 (B16)

 (B17)

The high value of strip acidity or buffered feed phase or the high D2EHPA and TBP concentration results in low values of “*m*”. This implies that the strip-side equilibrium reaction is instantaneous and hence strip-side film resistance may be neglected (Ansari et al., 2009).

For the calculation of m, the organic extractant balance can be expressed as:

 (B18)

 (B19)

Here,  and  are the stoichiometric coefficients associated with the organic-metal complex,  is the sum of all the metal ions complexes with the organic extractant.

Similarly, as per the complexation reaction (Eqs. (A1) and (A3)), the H+ balance is as follows:

 (B20)

 (B21)

where  is the bulk concentration of the H+ ions in the feed reservoir or the bulk inlet concentration of the H+ ions in the feed-side fluid at the lumen inlet (kmol/m3) at respective time (t = 0 and t = t) and  is the bulk concentration of the H+ ions in the strip reservoir or the bulk inlet concentration of the H+ ions in the strip-side fluid at the shell inlet at respective time (t = 0 and t = t) (kmol/m3). For the present study, the feed was buffered as the pH was maintained constant at 8.6±0.05. Hence  was kept constant.

The mass balance across the feed/strip reservoirs is given as:

 (B22)

 (B23)

Here, *V* is the volume of feed and strip reservoir (m3), and t is the time (s).

The module exit concentrations for both feed phase and strip phase are calculated accordingly:

 (B24)

 (B25)

where  is the bulk outlet concentration of the Ni2+ ions in the feed-side fluid at the lumen exit (kmol/m3),  is the bulk concentration of the Ni2+ ions in the feed reservoir or the bulk inlet concentration of the Ni2+ ions in the feed-side fluid at the lumen inlet (kmol/m3),  is the volumetric flow of the feed phase through the lumen of the module (m3/s),  is the volumetric flow of the strip phase through the shell of the module (m3/s),  is the porosity of the membrane, *L* is the length of the module (m),  is the fiber inner radius (m),  is the fiber velocity (m/s),  is the bulk concentration of the Ni2+ ions in the strip reservoir or the bulk inlet concentration of the Ni2+ ions in the strip-side fluid at the shell inlet (kmol/m3) and  is the bulk outlet concentration of the Ni2+ ions in the strip-side fluid at the shell exit (kmol/m3).

Ni2+ and [Au(CN2)]- ions transport from the feed to the organic membrane phase is given by

 (B26)

 (B27)

The flux through the supported liquid membrane can be described by:

 (B28)

Where  is diffusional flux per unit area, moles/(s∙cm2); is amount, moles; *t* = time, sec; *D* = diffusion coefficient in the region, cm2/s; *A* = area available for diffusion, cm2. The driving force is the spatial gradient in concentration or, more properly, in activity.

The mass transfer coefficient for Ni2+ and [Au(CN)2]- ions extraction via HFSLM can be calculated from Eqs. (B29) and (B30), respectively (Wannachod et al., 2015):

 (B29)  (B30)

Ansari, S.A., Mohapatra, P.K., Manchanda, V.K., 2009. Recovery of Actinides and Lanthanides from High-Level Waste Using Hollow-Fiber Supported Liquid Membrane with TODGA as the Carrier. Industrial & Engineering Chemistry Research 48, 8605-8612.

Sharma, A., Patil, N., Patwardhan, A., Moorthy, R., Ghosh, P., 2016. Synergistic interplay between D2EHPA and TBP towards the extraction of lithium using hollow fiber supported liquid membrane. Separation Science and Technology 51.

Wannachod, T., Leepipatpiboon, N., Pancharoen, U., Phatanasri, S., 2015. Mass transfer and selective separation of neodymium ions via a hollow fiber supported liquid membrane using PC88A as extractant. Journal of Industrial and Engineering Chemistry 21, 535-541.