Evaluation of Ionic Liquid-Based Plug Flow Microextraction Behavior of Europium(III)

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Separation and detection of Eu ion (Eu(III)) were performed in a plug flow microfluidic device coupled to a thermal lens spectrometry (TLS) system. Using this system, both ionic liquid (IL) and dodecane phases containing 0.1 M TODGA could extract efficiently Eu(III) in less than 15 seconds with the TLS, achieving sub micromolar Eu(III) detection limits.

Keywords: Microextraction, Europium(III), Ionic Liquid, Thermal Lens Spectroscopy, TODGA

For decommissioning the Fukushima Daiichi nuclear power station, efficient waste management requires analysis streamlining. Since ^{154}Eu is one of the 30 direct detection nuclides for waste management streamlining, this research aim to separate and detect Eu(III) as a model ion in a plug flow microfluidic device coupled to a thermal lens spectrometry (TLS) detection system[1]. Microfluidic devices have added advantages over batch scale extraction methods, in particular, very small amount of reagent (nano-microliter), large surface-to-volume ratios, short diffusion distance, and high mass transfer properties[2].

1-butyl-3-methylimidazolium bis[(trifluoromethyl)sulfonyl]imide ($[C_4min][NTf_2]$) as ionic liquid (IL) phase and dodecane as organic phase were used, and N,N,N',N′-tetraoctyl diglycolamide (TODGA) was adopted as an extractant. By using syringe pump, both aqueous phase containing Eu(III) and IL phase containing 0.1 M TODGA were introduced into a 500 μm capillary, and aqueous phase plugs, Fig.1 b), were formed at the T-junction part. Eu(III) in aqueous plugs was extracted into the IL phase along the channel, and mutual Aq./IL phase separation was done using a diaphragm phase separator. The depleted aqueous phase was mixed with Arsenazo III colorimetric dye solution and introduced into a microfluidic chip equipped with TLS fiber. The TLS system (ex. 658 nm) enabled to determine the concentrations of Eu(III) in the depleted aqueous phase with the addition of Arsenazo III. TLS measurements were compared with UV-vis measurements. The residence time, velocity and nitric acid concentrations were tested to determine the effect on the IL and dodecane extraction systems.

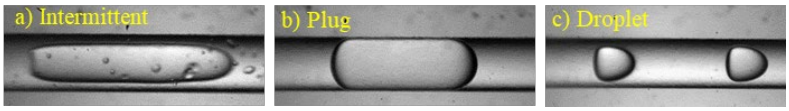

Fig. 1: IL/Aq. microchannel flow patterns

Both batch experiments and microfluidic extraction experiments were performed for extraction comparisons. After 1 hour batch extraction, the dodecane and IL systems showed opposite distribution and extraction trends. As the HNO_3 increased, the dodecane system increased the distribution ratios (D) and extractabilities (E%); D = 96 and E% = 99 % at 3 M HNO_3, while the IL system increased extraction at lower HNO_3 concentrations with maximum extraction being at 0.001 M HNO_3, D = 72 and E% = 98.6 %. The microfluidic extraction with the dodecane system achieved E% = 98 % in 3 M HNO_3 within 5 s, where the IL system achieved E% = 96 % in 0.001 M HNO_3 in 15 s. The TLS system was able to detect Eu(III) ions at sub micromolar levels. As a result, the micro plug flow could reduce the extraction time needed by 240-720 times, additionally, utilization of IL allows for the expansion of detectable pH range waste samples. This developed microsystem provides an alternative method for analytical in-field screening.

References

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