] 2 blank lines

These line numbers may be used for reviewing. After reviewing, these line numbers should be deleted (Word: Layout tab, Line Numbers, None).

Title: font Size 12.0, Bold

↑

Top margin 30 mm

↓

Red letters are just comments!

Please delete all!!

]

**Adsorption of Europium(III) with Solvent Impregnated Kapok Fiber  
Containing 2-Ethylhexyl Phosphonic Acid Mono-2-Ethylhexyl Ester**

Author name: font Size 12.0

] 1 blank line

Natsuki HIGA1, Syouhei NISHIHAMA1,\*, Satoshi TSUKAHARA2,\*   
and Kazuharu YOSHIZUKA1

Address: font Size 10.5, Italic

*1Department of Chemical Engineering, The University of Kitakyushu, Hibikino 1-1, Kitakyushu 808-0135, Japan; 2Department of Chemistry, Graduate School of Science, Osaka University, 1-1, Machikaneyama, Toyonaka, Osaka 560-0043, Japan*

*\* Corresponding author(s): nishihama@kitakyu-u.ac.jp (S. Nishihama); sxt@chem.sci.osaka-u.ac.jp (S. Tsukahara)*

(Received December 25, 2015; Accepted February 1, 2016)

] 1 blank line

If there are multiple corresponding authors, please provide e-mail addresses and names of all authors. If there is only one corresponding author, please provide only the e-mail address.

Font size 9, Italic

Solvent impregnated kapok fiber is prepared, employing 2-ethylhexyl phosphonic acid mono-2-ethylhexy ester as an extractant, and adsorption property of Eu(III) is investigated. The kapok fiber possesses higher impregnation ability for the extractant than conventional solvent impregnated resins, such as crosslinked polystyrene and crosslinked polymethacrylic ester, and thus the solvent impregnated kapok fiber has higher adsorption ability for Eu(III). The adsorption of Eu(III) with solvent impregnated kapok fiber progresses with Langmuir adsorption mechanism and the high maximum adsorption amount of 0.685 mmol/g is obtained.

Abstract: font Size 10.5, 100-150 words

↑

Right Margin 25 mm

↓

↑

Left Margin 25 mm

↓

] 2 blank lines

]

**1. Introduction**

Solvent extraction has been widely used as processes for separation, purification, and recovery of rare metals, due to its simplicity of equipment and operation. The combination of solvent extraction with adsorption and/or ion exchange has been therefore investigated, for the second generation of the extraction system. There are two ways to bridge the gap between the adsorption and the solvent extraction; solvent impregnated resins (SIR) [1-3] and extractant-containing microcapsules [4,5]. The SIR has been therefore actively investigated by many researchers, and a critical review of the works was recently published [6].

The SIR however still has some points which should be improved, and one of the points is lower impregnation capacity of the extractant into polymer resin cause of lower adsorption capacity. Tanaka *et al.* revealed that kapok fiber, a commercial oil sorbent, possesses high impregnation amount of extractant, and solvent impregnated kapok fiber (SIF) was applied for the adsorption of base metals [7] and precious metals [8]. In a present work, 2-ethylhexyl phosphonic acid mono-2-ethylhexyl ester (PC-88A) impregnated kapok fiber is prepared by using two kinds of fibers, and the characteristics of the SIFs are investigated.

] 1 blank line

No space between sections!

**2. Experimental**

**2.1 Reagents**

PC-88A was supplied by Daihachi Chemical Industry Co., kapok fibers (KT-65 and M-4050) were supplied by Kakui Co., and polymer resins (HP20 and HP2MG) were supplied by Nippon Rensui Co. The compositions of KT-65 and M-4050 are shown in Table 1. HP20 is styrene/divinylbenzene copolymer resin and HP2MG is methacrylic ester copolymer resin. Eu(NO3)3•6H2O was supplied by Aldrich and all other reagents were supplied by Wako Pure Chemical Industries, as analytical-grade reagents.

↑

Bottom margin 36 mm

↓

**2.2 Preparation of SIF and SIR**

No space between sections!

The SIF containing PC-88A was prepared by the following method. The kapok fibers were firstly cut into ca. 0.5 × 0.5 cm pieces, and then were washed with methanol. After drying, the cut fibers were contacted with ethanol solution of PC-88A (0.3 mol/L - 1.0 mol/L as monomeric species) at a ratio of 50 mL/g for more than 12 h at 298 K. Ethanol was then removed by evaporation, and the fiber was washed with excess amount of D.I. water and dried for overnight at 353 K. The SIR was also prepared by the same manner as the SIF. The impregnated amount of PC-88A in the SIF or SIR was determined by the difference of weight of fiber or resin before and after impregnation.

No space between sections!

**2.3 Adsorption of Eu(III)**

The aqueous solutions were prepared by dissolving Eu(NO3)3·6H2O in D.I. water. The concentration of Eu(III), in the case for time course variation and pH dependency, was set to ca. 1.0 mmol/L, while the concentration was varied from 1.0 × 10–6 mol/L to 22 mmol/L for the adsorption isotherm experiments. The pH value was adjusted by adding appropriate concentrations of HNO3 or NaOH solution. A 0.02 g of SIF or a 0.03 g of SIR was added to 10 mL of Eu(III) aqueous solution to be shaken at 298 K (25 °C) for more than 4 h in the case of SIF and for more than 12 h in the case of SIR, which are enough to be reached to equilibrium from preliminary experiments. After filtration, the equilibrium pH was measured by a pH meter (Horiba F-23). The concentrations of Eu were determined by an inductively coupled plasma atomic emission spectrophotometer (ICP-AES; Shimadzu ICPS-7000). The amount of Eu(III) adsorbed, *q*, is defined by eq. (1).

Use eq. and eqs. to express equation(s).

 (1)  
where [Eu]0 and [Eu]e are initial and equilibrium concentrations of Eu(III) in the aqueous phase, *L* is volume of aqueous solution, and *w* is weight of adsorbent including PC-88A and support. The leakage of PC-88A during adsorption was also determined by measuring phosphorus concentration in the aqueous phase after adsorption.

] 1 blank line

No space between sections!

Always full spelling!

**3. Results and Discussion**

**3.1 Preparation of SIF**

Impregnation abilities of PC-88A into kapok fibers and conventional resins are investigated by changing concentrations of PC-88A at the impregnation procedure. Table 1 shows the impregnation amount of PC-88A in each support. In all support systems, impregnation amount is almost saturated with 0.3 mol/L of PC-88A, and the impregnation amount is hardly changed by increasing in PC-88A concentration. Impregnation is therefore conducted with 0.3 mol/L of PC-88A hereafter. Kapok fibers have much higher impregnation abilities than both of conventional resins. Among two kapok fibers, M-4050 possesses slightly higher impregnation ability than KT-65. This may be due to the content of kapok, as shown in Table 1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Table 1. Impregnation amount of PC-88A on polymer resins. | | | | |
| [PC-88A]  (mol/L) | Impregnation amount (mmol/support-g) | | | |
| Sample A | Sample B | Sample C | Sample D |
| 0.1 | 2.00 | 2.10 | 1.90 | 1.80 |
| 0.2  Always full spelling! | 2.00 | 2.10 | 1.90 | 1.80 |

**3.2 Adsorption behavior of Eu(III)**

Figure 1 shows time course variations of adsorption of Eu(III) with SIFs. The adsorption reaches equilibrium within 3 h in both systems. Figure 2 shows the effect of pH on adsorption amount of Eu(III), together with leakage of PC-88A. In all systems, the adsorption increases with increase in pH, as same as in the solvent extraction system. Comparing the adsorption behavior with SIF and SIR, much higher adsorption amount is obviously obtained in SIF systems. Comparing the support fiber of SIF, KT-65 and M-4050, the adsorption amount of Eu(III) with SIF prepared by M-4050 is lower than that by KT-65 at higher pH region, in spite of higher impregnation amount of PC-88A by M-4050. The leakage of PC-88A from SIF by M-4050 is much higher than that from SIF by KT-65 as well as the conventional SIRs. The smaller adsorption ability of SIF by M-4050 is caused by the leakage of PC-88A from SIF. The KT-65 is therefore concluded to be suitable support for PC-88A than M-4050 and also conventional polymer resins. The maximum adsorption amount with SIF is 3.6 times higher than the conventional SIR. The kapok fiber is therefore expected as a new support for impregnating the extractant.

Always full spelling!

Always full spelling!

Figure 1. Effect of pH on the distribution ratio of Eu(III) and leakage of PC-88A.



] 1 blank line

**4. Conclusion**

The abbreviation of Solvent Extraction Research and Development, Japan (SERDJ) is Solvent Extr. Res. Dev., Jpn. The solvent impregnated kapok fiber is prepared, using PC-88A as an extractant, and the adsorption property of Eu(III) with the SIF is investigated. KT-65 possesses higher adsorption ability for Eu(III) than M-4050 due to less leakage of the extractant from SIF during the adsorption. The KT-65 has also ca. 35 % higher impregnation ability of PC-88A than conventional polymer resins, HP20 and HP2MG, and the amximum adsorption amount of 0.685 mmol/g of Eu(III), which is 3.6 times higher than HP20, is obtained.

] 1 blank line

**Acknowledgement**

This study was supported by a Grant-in-Aid for Scientific Research (No. xxxx) of the Ministry of Education, Science, Sports and Culture of Japan.

] 1 blank line

**References**

1. J. Shibata, S. Matsumoto, H. Yamamoto, *Solvent Extr. Res. Dev., Jpn.*, **7**, 167-175 (2000).
2. T. Nakamura, T. Ikawa, S. Nishihama, K. Yoshizuka, *Ion Exch. Lett.*, **2**, 22-26 (2009).
3. K. Onishi, T. Nakamura, S. Nishihama, K. Yoshizuka, *Ind. Eng. Chem. Res.*, **49**, 6554-6558 (2010).
4. S. Nishihama, N. Sakaguchi, T. Hirai, I. Komasawa, *Hydrometallurgy*, **64**, 35-42 (2002).
5. S. Nishihama, G. Nishimura, T. Hirai, I. Komasawa, *Ind. Eng. Chem. Res.*, **43**, 751-757 (2004).
6. N. Kabay, J.L. Cortina, A. Trochimczuk, M. Streat, *Reac. Func. Polym.*, **70**, 484-496 (2010).
7. H. T. Huynh, M. Tanaka, *Ind. Eng. Chem. Res.*, **42**, 4050-4054 (2003).
8. D. Sakamoto, H. Narita, M. Tanaka, K. Morisaku, *Solvent. Extr. Res. Dev., Jpn.*, **14**, 79-85 (2007).
9. G. D. Wignall, in “*Encyclopedia of Polymer Science and Engineering*”, 2nd ed., ed. by H. F. Mark, N. M. Bikales, Wiley-Interscience, New York, Vol. 10, Chap. 6, pp. 112-150 (1999).

Author(s) of this section

Title of this section

1. “*Endofullerenes*”, ed. by T. Akasaka, S. Nagase, Kluwer Academic, Dordrecht (2002).
2. R. I. Edward, W. A. M. te Riele, ‘*Commercial processes for precious metals*’ in “*Handbook of Solvent Extraction*”, ed. by T. C. Lo, M. H. I. Baird, C. Hanson, John Wiley and Sons, New York, pp. 725-732 (1983).

Author(s) of this book

Title of this book

1. A. E. Martell, R. M. Smith, “*Critical Stability Constants*”, Plenum Press, New York and London, pp. 1-10 (1974).
2. A. N. Baumann, ‘*Separation of dissolved substances from wet process phosphoric acid*’, US Patent 4,640,828 (1987).
3. H. Tsutsui, Ph.D. thesis, The University of Tokyo, Japan (1987).
4. S. Tsukahara, Master thesis, Tohoku University, Japan (1988).
5. K. Katayama, S. Tsukahara, *Proceedings of 33rd International Conference on Solution Chemistry*, 1GO04, p. 97, Kyoto, Kyoto, Japan (2013).
6. N. Sahiner, *Water, Air, Soil Pollut.*, **225**, 1982 (8 pages) (2014).

Add ‘Proceedings of’ to the conference name (do not abbreviate). Also, add the presentation number (if any), page number, city, prefecture (if any), country (year). The city, preference, country, and year are related to the conference.

If the reference has an article number, please write it as this example. In this example, 1982 is the article number.