

Study on the sorption and desorption behavior of La³⁺ and Bi³⁺ by bis(2-ethylhexyl)phosphate modified activated carbon

**Hongshan Zhu^{a,b,c}, Stephan Heinitz^a, Koen Binnemans^b, Steven Mullens^c, Thomas
Cardinaels^{a,b,*}**

^a Belgian Nuclear Research Centre (SCK CEN), Institute for Nuclear Materials Science, Boeretang
200, B-2400 Mol, Belgium

^b KU Leuven, Department of Chemistry, Celestijnenlaan 200F, P.O. 2404, B-3001 Leuven, Belgium

^c Flemish Institute for Technological Research (VITO NV), Sustainable Materials Management,
Boeretang 200, 2400 Mol, Belgium

E-mail of corresponding author: thomas.cardinaels@sckcen.be

Supporting Information (SI)

Preliminary column test

Columns with 1-mL empty cartridges (AC-100-R01) were obtained from TrisKem International, and the columns were filled with 0.5 g HDEHP/AC. The initial solution used 3 mL for the column with 300 ± 30 kBq of ^{225}Ac at $\text{pH } 5 \pm 1$. The prepared HDEHP/AC column was rinsed with water before 3 mL of ^{225}Ac solution was loaded onto the column at a flow rate of 0.5 ± 0.03 mL min^{-1} . Subsequently, another HDEHP/AC column was connected to the first column as the guard column during the eluting process. Finally, 5 mL of 1 mol L^{-1} NaI/ 0.01 mol L^{-1} HNO_3 solution was used for eluting ^{213}Bi at a flow rate of 0.6 ± 0.2 mL min^{-1} . The schematic separation process is shown in Fig. 11a.

Effect of solid-to-liquid ratio

The solid-to-liquid ratio was an important factor in choosing an appropriate sorbent mass for the generator column, especially when the density of extractant that immobilized onto materials was low. The results show that the K_d values and sorption percentages for Bi^{3+} onto HDEHP/AC were more than 10^5 mL g^{-1} and 99.7%, respectively, as calculated by the detection limit threshold. This demonstrates that the HDEHP/AC had a strong affinity for Bi^{3+} even at much lower solid-to-liquid ratios (e.g., 1 g L^{-1}). Fig. S1 shows that the sorption percentages and K_d values of HDEHP/AC for La^{3+} increased rapidly as the solid-to-liquid ratio increased from 0 to 4 g L^{-1} . This

was because the high sorbent dose generally offered sufficient active sites for La^{3+} , resulting in a lower equilibrium concentration of La^{3+} in the solution. The sorption percentages then stabilized because of nearly all of La^{3+} adsorbed onto the HDEHP/AC.

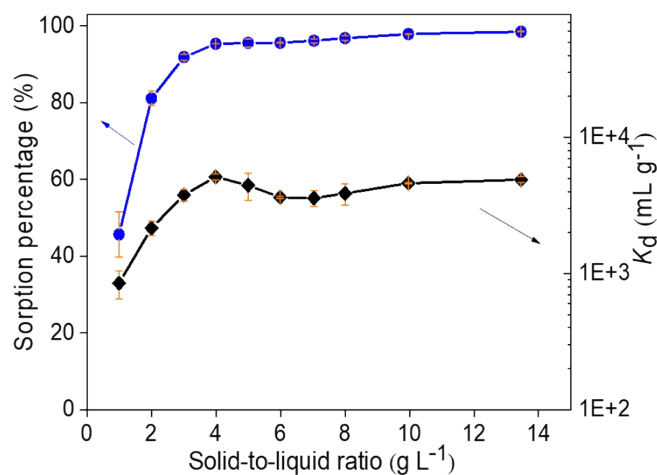


Fig. S1. The effect of solid-to-liquid ratio on the sorption performance of HDEHP/AC for La^{3+} and Bi^{3+} in the binary system. ($C_0(\text{La}^{3+}) = 10 \mu\text{mol L}^{-1}$ and $C_0(\text{Bi}^{3+}) = 10 \mu\text{mol L}^{-1}$, $\text{pH} = 2$, $t = 24 \text{ h}$).

Table S1. Elemental composition and specific surface area of HDEHP/AC

Elemental composition					N ₂ adsorption
C (wt%)	H (wt%)	N (wt%)	O (wt%)	P (wt%)	BET area (m ² g ⁻¹)
82.8 ± 0.2	3.14 ± 0.01	0.19 ± 0.01	7 ± 1	2.42 ± 0.08	528

Table S2. Kinetic parameters of La³⁺/Bi³⁺ sorption onto HDEHP/AC

Model	Parameters	La ³⁺ (Single)	Bi ³⁺ (Single)	La ³⁺ (Binary)	Bi ³⁺ (Binary)
Pseudo-first-order	k_1 (min ⁻¹)	0.103	0.308	0.045	0.268
	q_e (μmol g ⁻¹)	5.175	10.583	3.682	10.313
	R^2	0.857	0.951	0.943	0.978
Pseudo-second-order	k_2 (g μmol ⁻¹ min ⁻¹)	0.028	0.038	0.015	0.029
	q_e (μmol g ⁻¹)	5.590	11.319	4.069	11.228
	R^2	0.957	0.997	0.977	0.995
Intraparticle diffusion model	K_{IPD} (μmol g ⁻¹ min ^{-1/2})	0.245	0.797		
	C (μmol g ⁻¹)	2.692	5.301		
	R^2	0.860	0.797		
Elovich model	α (μmol g ⁻¹ min ⁻¹)	5.535	24.354		
	β (g μmol ⁻¹)	1.244	0.600		
	R^2	0.970	0.946		

Table S3. Langmuir and Freundlich isotherm parameters for La³⁺ sorption onto

HDEHP/AC.

q_{\max} (μmol g ⁻¹)	Langmuir		Freundlich		
	K_L (L μmol ⁻¹)	R^2	K_F (μmol ¹⁻ⁿ ·L ⁿ g ⁻¹)	1/n	R^2
15.226	0.242	0.984	3.545	0.469	0.970