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Separation of ^{213}Bi via an inverse $^{225}\text{Ac}/^{213}\text{Bi}$ radionuclide generator based on sulfonated carbon materials

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Bismuth-213 (^{213}Bi) is an alpha-emitting radioisotope with large potential in nuclear medicine for cancer treatment. Several clinical trials of ^{213}Bi -based radiopharmaceuticals have provided evidence for its therapeutic efficacy. ^{213}Bi is produced from the relatively long-lived parent nuclide actinium-225 (^{225}Ac) and then separated in a radionuclide generator. The patient dose of ^{213}Bi is estimated to be 1 mCi/kg body mass, and the optimal $^{225}\text{Ac}/^{213}\text{Bi}$ radionuclide generator should separate ^{213}Bi from 100-150 mCi ^{225}Ac . However, previously used sorbent materials (e.g. Dowex 50W-X8, AG MP-50, Actinide Resin, UTEVA Resin, and Termoxid-39) have limitations, including poor radiolytic, chemical and physical stabilities. Therefore, developing alternative materials to overcome those shortcomings is a priority.

This study evaluated sulfonated carbon materials for use in inverse $^{225}\text{Ac}/^{213}\text{Bi}$ radionuclide generators. The synthesis protocol was optimized with regard to the pyrolysis temperature and sulfonation conditions. The materials were characterized with regard to the pore size distribution, the nature of the functional groups and the zeta potential. The separation of Bi^{3+} , La^{3+} (as surrogate for ^{225}Ac) and Ac^{3+} using the sulfonated carbon materials were examined by batch experiments, as a function of different parameters (e.g. pH, salt concentration, solid-to-liquid ratio, and contact time). The sulfonated carbon materials exhibited a high selective uptake of Bi^{3+} in the presence of high salt concentrations at low pH. Inversely, the sorption capacity for La^{3+} and Ac^{3+} onto the sulfonated carbon materials decreased with increasing salt concentrations and decreasing pH. Batch desorption results showed that a high percentage of Bi^{3+} can be eluted from sulfonated carbon materials by HCl, NaI, or NaCl solutions. More importantly, the sulfonated carbon materials showed high levels of resistance against radiolysis, fast sorption kinetics, good durability, and recyclability. The evaluation of the different materials enabled a better understanding of the sorption mechanisms of Bi^{3+} and Ac^{3+} onto these sulfonated carbon materials.

Based on the separation performance, the most suitable sorbent was examined using column chromatography. The ^{213}Bi yield from the inverse generator reached 94% in 1 mL of 1 M HCl with an ^{225}Ac impurity of less than 0.04% of the eluted ^{213}Bi activity. Experiments also revealed that a guard column with AG MP-50 reduced the impurity of ^{225}Ac without affecting the ^{213}Bi yield. These findings indicate that the sulfonated carbon materials are promising adsorbents in inverse $^{225}\text{Ac}/^{213}\text{Bi}$ radionuclide generators for the production of high-purity ^{213}Bi for medical applications.

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