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Adsorption of Cs^+ and Sr^{2+} on Diverse Zeolite Types

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Zeolites are widely recognized as highly effective adsorbents due to their distinctive porous structures and exceptional ion-exchange capabilities. Their ability to immobilize radionuclides, such as cesium (Cs^+) and strontium (Sr^{2+}), has attracted considerable attention within the field of nuclear waste disposal. This study examines the adsorption behavior of Cs^+ and Sr^{2+} on five distinct zeolites (4A, 13X, Y, mordenite, and SSZ-13), with each characterized by unique structural and chemical properties that govern interactions with these radionuclides.

Batch adsorption experiments were conducted over a 6-hour period under geochemically relevant conditions simulating both brackish-to-saline environments (high ionic strength) and fresh water environments (low ionic strength), with high and low initial ion concentrations of Cs^+ and Sr^{2+}. Following the reaction period, the solutions were analyzed to assess the adsorption efficiencies of each zeolite for Cs^+ and Sr^{2+}. For Cs^+, SSZ-13 exhibited the highest adsorption efficiency, followed by mordenite, while for Sr^{2+}, 4A showed the highest adsorption efficiency, with 13X ranking second. Additionally, batch experiments were conducted using the selected zeolites on mixed Cs^+–Sr^{2+} solutions. These experiments were performed under eight distinct conditions, combining different ionic strengths and ion concentration levels. In addition, a composite system comprising SSZ-13 and 4A was evaluated under the same conditions. After the experiments, the solutions were filtered and analyzed using ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry) and LC-ICP-TQ-MS (Liquid Chromatography–Inductively Coupled Plasma Triple Quadrupole Mass Spectrometry). The results demonstrate the relationship between various zeolite types and radionuclide immobilization, contributing to a more comprehensive geochemical understanding of ion exchange processes and the unique characteristics of these materials. Future work will include detailed mineralogical analyses of post-adsorption residues, as well as systematic desorption studies to assess the regeneration and long-term performance of these materials.