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Ionic Geochemistry: Enhanced Soil Analysis for Mineral Exploration via High-Efficiency Ligand-Based Mobile Ion Extraction with Simultaneous Detection of 57 Elements in a Single Extraction

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Ligand-based extraction of mobile ions is a precise and efficient technique for uncovering and tracing buried mineralization sources by extracting mobile ions physiosorbed onto soil particles. This study focuses on developing a streamlined method that employs strong ligands—EDTA, citric acid, potassium cyanide, and ammonium chloride—in a single digestion process. ICP-MS was chosen as the analytical method to achieve low detection limits while enhancing the efficiency of exploration in terms of cost and time. 200 samples were collected from a semi-arid region in Eastern-Anti-Atlas, Morocco, prepared by sieving to a particle size of 180 µm without prior crushing or grinding. Ligand quantities and the extraction pH were optimized using a Box-Behnken experimental design, with the pH set to 8.5. The resulting leachate was analyzed for 57 elements using ICP-MS. This method successfully detected elevated concentrations of gold and its pathfinder elements in mineralized zones, revealing anomalies that were not identifiable using conventional techniques. It provided superior geochemical contrast with reduced background noise. Principal Component Analysis (PCA) validated the sampling reliability, with a significant KMO coefficient of 0.74 and strong correlations between gold and its pathfinders. Additionally, the mild digestion process was benchmarked against more aggressive methods, such as aqua regia and four-acid digestion, confirming its efficacy. This innovative method will enhance mineral exploration strategies by improving geochemical resolution while reducing costs and time required for drilling target identification.

