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Illuminating the mineralogy and geochemistry of mineral processing byproducts with coupled synchrotron XRD and XANES

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Increasing global demand for mineral and energy resources, coupled with declining ore grades, are creating growing global stockpiles of by-products including waste rock (~ 56 GT/yr) and tailings (~7 GT/yr). These are unusual geological materials, at extremes of pH and salinity, typically exhibiting elevated concentrations of elements and minerals present at otherwise low concentrations throughout Earth's crust, bearing process-derived minerals that are unstable under Earth surface temperatures and pressures, and in the case of tailings, with very fine particle sizes. Understanding and predicting the weathering behaviour of these materials, and opportunities for reprocessing or reuse, hinges on accurate mineralogical identification and quantification, which can be challenging in such complex, multi-phase mixtures often bearing novel minerals. Using synchrotron XRD and XANES, our work with bauxite residue (alumina refining tailings) has solved structures for novel process minerals in the sodalite and cancrinite groups, and identified mineralogical hosts and speciation of trace elements including As, Cr, and V. Incorporation of anions into sodalites increases unit cell size in the order carbonate<chloride<sulfate<aluminate, with unit cells ranging from 8.89 to 9.02 Å. Chloride-, sulfate-, and aluminate-type sodalites tend to lie in space group P43n, whereas space group P23 more accurately describes carbonate-type sodalite. Iron oxides have been identified as major hosts for Cr and V, incorporated through isomorphous substitution; whereas As appears to be present mostly as surface sorbed arsenate. Hosts and speciation did not change during pH neutralisation, indicating that potential release during weathering is minimal. Ongoing thermodynamic and physical analysis of these materials, coupled with the mineralogical data above, will be used to improve the accuracy of existing geochemical models for predicting weathering behaviour, and can be used as a pre-screening tool to identify suitable reuse pathways for tailings.

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