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Surface cation migration in silicate glasses: XPS insights into processes relevant to CO_2 mineralisation

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Effective mitigation of CO_2 in air and water demands scalable and long lasting carbon capture strategies. Basalt and basaltic glass, common alkaline rocks, weather naturally in the presence of CO_2 and water, forming stable carbonate phases through divalent cation mediated mineralisation. Alkaline silicate materials, including industrial wastes such as stone wool insulation from building demolition, share compositional similarities with basalt, especially in the availability of divalent cations, thus offering a promising pathway for permanent CO_2 storage. At the same time, their reuse provides an end-of-life solution for construction waste, diverting potentially valuable materials from landfill. Because mineralisation reactions initiate at the solid-air and solid-liquid interface, understanding surface evolution in amorphous silicate materials under ambient conditions is key to clarify the mechanisms governing cation release and early stage carbonate formation. In this study, we examined the surfaces of soda-lime-silica glass, synthetic calcium–aluminium–silicate (CAS) glass, which serves as a model for the anorthite component of basalt, and natural obsidian. There is clear evidence of surface composition change following fracture and during exposure to controlled humidity.

X-ray photoelectron spectroscopy (XPS), a surface sensitive technique that probes the outermost ~10 nm, provides quantitative information about element composition and the local chemical environment. XPS measurements indicate that exposure to air at ambient temperature and humidity over hours to weeks drives cation redistribution. For example, sodium rich obsidian exhibits surface sodium enrichment, while calcium rich CAS glass shows increased surface calcium after one week in air. These results suggest that, even under ambient conditions, amorphous silicate glasses undergo measurable surface rearrangement and cation migration, processes that influence reactivity and carbonate formation potential, findings that are key to developing CO_2 mineralisation technologies.