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Adsorption of gaseous CO_2 on anhydrous cation-exchanged montmorillonite

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Negative Emission Technologies (NETs) are key in climate change mitigation. Given the large scale at which CO_2 needs to be sequestered (GTs/year), adsorbents need to be cheap and widely available. Smectites, natural layered aluminosilicates, possess a negative charge compensated by cations present in the interlayer space. Smectites can (co)adsorb solvents, in particular water but also CO_2 and/or organic compounds, in their interlayer space under specific conditions, thereby greatly increasing their sorption capacity. This interlayer spacing is set by the size of the interlayer cations. The interaction between CO_2 and these smectites as a function of their interlayer cation was studied before numerically and experimentally in particular for supercritical CO_2 ($scCO_2$) in the context of cap-rock integrity in the injection of $scCO_2$ into geological formations.

This work presents adsorption measurements (gravimetrical, manometrical and volumetrical) of gaseous CO_2 on various cation-exchanged forms of anhydrous smectite (Wyoming montmorillonite (MMT)). Using seven alkali- and alkaline earth metal cations and three quaternary ammonium cations, a wide range of ionic radii was used in the CO2 adsorption measurements. The CO_2 exposure pressure was varied from 0.1 bar to 10 bar at temperatures ranging from -20°C up to 300°C and the resulting CO2 capacity is determined.

We find that interlayer adsorption of CO_2 (1) requires the interlayer cations to be larger than a certain critical radius and (2) increases with decreasing temperature for cations beyond this critical radius (Figure 1a). Noteworthy is that the critical radius itself decreases with increasing pressure and/or decreasing temperature. For interlayer cations beyond this critical radius, the interlayer physisorption of CO_2 and kinetics of desorption at room temperature were confirmed via infrared spectroscopy (Figure 1c-d). At 1 bar of CO_2, a maximum adsorption capacity of 1.4 mmol/g MMT is found for Cs-exchanged MMT in the range of temperatures studied.

These results provide valuable insights into the applicability of widely available natural adsorbent clays for carbon capture and/or sequestration for the mitigation of climate change.

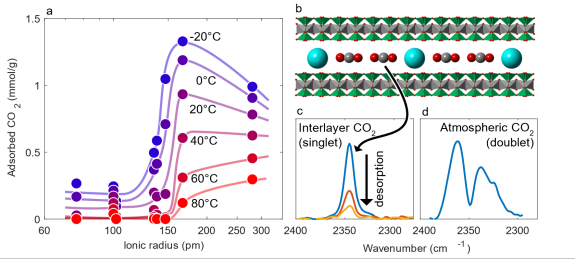

Figure 1: (a) CO_2 adsorption capacity on MMT as a function of cationic radius at various temperatures and 1 bar of CO_2, (b) schematic of CO_2 adsorbed in the interlayer of MMT, (c,d) infrared spectra of interlayer CO_2 and atmospheric CO_2.