Design and Evaluation of an Energy-Efficient CO2 Capture System Utilizing Sodium Hydroxide for Ammonium Bicarbonate Fertilizer Synthesis

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Atmospheric carbon dioxide (CO2) concentrations are approximately 50% greater than levels in the pre-industrial era. Carbon dioxide is the most prominent greenhouse gas, and is driving global warming through the greenhouse effect. Rising temperatures have had drastic consequences all over the world. Existing carbon capture devices have faced many barriers of cost, scalability, and energy demand, limiting their role in meaningful climate mitigation. Here, I present a novel, low-energy carbon capture and utilization (CCU) system which integrates chemistry, physics, and engineering design to convert CO2 into ammonium bicarbonate (NH4HCO3), a valuable nitrogen fertilizer. This CCU system employs a rotating wheel structure, 3D printed from a low-cost plastic resistant to caustic materials such as NaOH or NH4OH, which maximizes air exposure and allows for optimal absorption of CO2, as well as facilitating 3 linked exothermic reactions: 1) CO2 capture via 5M NaOH, 2) conversion to sodium bicarbonate (NaHCO3), and 3) reaction with ammonium hydroxide (NH4OH) to produce NH4HCO3 and regenerate NaOH for maximum efficiency and cost-effectiveness. This cyclic process minimizes input and associated difficulties and costs, offering a scalable and economically feasible carbon capture process. Preliminary engineering analyses suggest these CCU units can operate at low cost, provide domestic fertilizer production, and generate revenue through fertilizer sales and carbon credits. By combining carbon capture with agricultural profitability, this work demonstrates an extremely beneficial approach that addresses the ever-growing problem of global warming while remaining economically viable.

Awards Won:

Aramco: Third Place Prize Environmental Engineering (ENEV)