

# ADSORPTION OF CO<sub>2</sub> ON MOLECULAR SIEVES AND ACTIVATED CARBON

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## INTRODUCTION

Fossil fuels supply more than 98% of the world's energy needs. However, the combustion of fossil fuels is one of the major sources of the green house gas CO<sub>2</sub>. It is necessary to develop technologies that will allow us to utilize the fossil fuels while reducing the emissions of green house gases. Commercial CO<sub>2</sub> capture technology that exists today is very expensive and energy intensive. Improved technologies for CO<sub>2</sub> capture are necessary to achieve low energy penalties. Pressure swing adsorption (PSA) is one of the potential techniques that could be applicable for removal of CO<sub>2</sub> from high pressure gas streams such as those encountered in Integrated Gasification Combined Cycle (IGCC) systems.

PSA processes are based on preferential adsorption of the desired gas ( eg. CO<sub>2</sub>) on porous materials at a high pressure. When the pressure is decreased, the gas is desorbed from the porous sorbent and the sorbent can be reused for subsequent adsorption. PSA technology has gained interest due to low energy requirements and low capital investment costs. Development of regenerable sorbents that have high selectivity for CO<sub>2</sub> and high adsorption capacity for CO<sub>2</sub> is critical for the success of the PSA process.

In this work three sorbents from United Catalyst, namely, molecular sieve 13X, molecular sieve 4A, and activated carbon were utilized to study the adsorption of CO<sub>2</sub>. Volumetric adsorption studies of CO<sub>2</sub>, N<sub>2</sub>, or H<sub>2</sub> with the three sorbents were conducted at 25 °C up to a pressure of 300 psi (~2x 10<sup>6</sup> Pa).

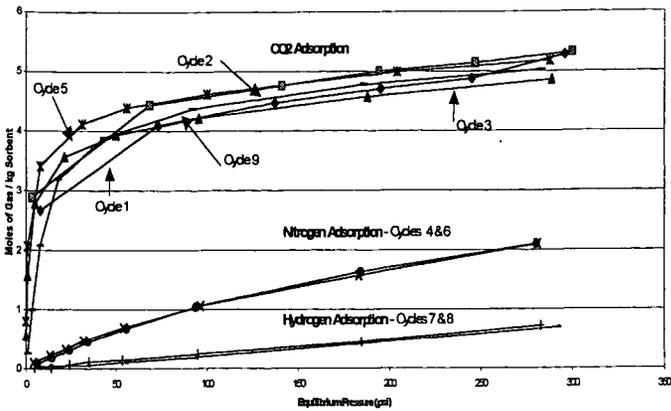
## EXPERIMENTAL

The sorbents Zeochem-Z10-02/13X molecular sieve, Z4-01/4A molecular sieve and activated carbon were obtained from United Catalysts, Inc. Adsorption isotherms at 25 °C of pure CO<sub>2</sub>, N<sub>2</sub>, or H<sub>2</sub> on molecular sieve 13X, molecular sieve 4A, and activated carbon were measured up to an equilibrium pressure of about 300 psi (~2x 10<sup>6</sup> Pa) utilizing volumetric adsorption apparatus. Approximately 10 ml of the sorbent materials were placed in the sample chamber, which was evacuated to ~ 5x10<sup>-5</sup> Torr. The amount of CO<sub>2</sub> adsorbed was calculated utilizing the pressure measurements before and after the exposure of the sample chamber to CO<sub>2</sub>. Base line data with CO<sub>2</sub> were obtained utilizing 10 ml of glass beads. A total of 9-10 adsorption cycles were performed with each sorbent. After each cycle the sorbent was evacuated overnight. After two cycles, each, were performed with hydrogen and nitrogen, a final cycle was performed with CO<sub>2</sub> to evaluate whether the adsorption was affected by the adsorption of the other gases.

## RESULTS AND DISCUSSION

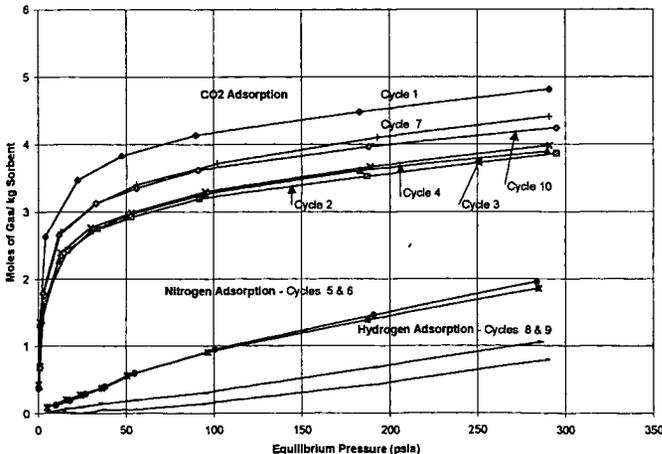
Volumetric adsorption isotherms of CO<sub>2</sub>, N<sub>2</sub> and H<sub>2</sub> on molecular sieve 13X at 25 °C are shown in Figure 1. Up to 50 psi the CO<sub>2</sub> adsorption increased rapidly when the pressure was increased. The increase in CO<sub>2</sub> adsorption after 50 psi appeared to be gradual. The adsorption isotherms for repeated cycles were very similar. This indicated that the adsorption is fully reversible and complete regeneration can be obtained by evacuation of the material after adsorption. At all pressures, adsorption isotherms of nitrogen were lower than those of the CO<sub>2</sub>, and adsorption isotherms of hydrogen were significantly lower than those of CO<sub>2</sub>. Both nitrogen and hydrogen isotherms were completely reversible. Preferential adsorption of CO<sub>2</sub> indicates that this material can be used for separation of CO<sub>2</sub> from some gas mixtures. The final adsorption isotherm (cycle 9-which was obtained after the adsorption experiments with nitrogen and hydrogen) was conducted with CO<sub>2</sub> and it is very similar to the previous adsorption isotherms with CO<sub>2</sub>. This indicates that the sorbent was not affected by the adsorption of nitrogen and hydrogen.

Figure 1 - Adsorption Isotherms on ZEOCHEM-Z1042P3



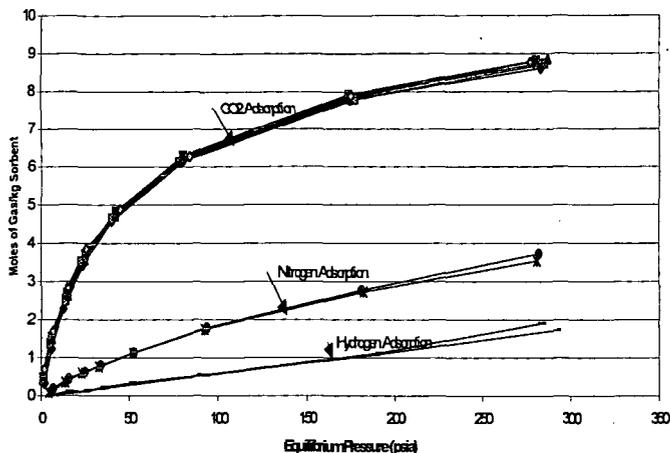
The volumetric adsorption isotherms for molecular sieve 4A(Zeochem Z4-01-4A) are shown in Figure 2. The adsorption isotherms indicate that the uptake of CO<sub>2</sub> is higher than the uptakes of the other two gases, nitrogen and hydrogen. This preferential uptake of CO<sub>2</sub> makes this sorbent suitable for the separation of CO<sub>2</sub> from gaseous mixtures. The adsorption isotherms of CO<sub>2</sub> for molecular sieve 4A are not highly reproducible, indicating that the adsorption is not completely reversible. The adsorption at the first cycle was the highest. The uptake of CO<sub>2</sub> for molecular sieve 4A was lower than that of molecular sieve 13X at all equilibrium pressures up to 250 psia. However, both nitrogen and hydrogen adsorption isotherms of molecular sieve 4A appear to be similar to those of molecular sieve 13X. The adsorptions of nitrogen and hydrogen did not affect the final adsorption isotherm of CO<sub>2</sub>.

Figure2 - Adsorption Isotherms of ZEOCHEM Z4-01-4A/4x8



The adsorption isotherms for activated carbon are shown in Figure 3. It is interesting to note that all the isotherms are extremely reproducible, which indicates the excellent reversibility of adsorption. The CO<sub>2</sub> uptake for activated carbon was lower than that of the two molecular sieves at lower pressures (< 50 psi), but at higher pressures the CO<sub>2</sub> uptake for activated carbon was higher than that of the molecular sieves. Nitrogen and hydrogen adsorption isotherms appear to be very reproducible. The final CO<sub>2</sub> adsorption cycle (cycle 10) was very similar to the first cycle, which indicated that the sorbent was not affected by the adsorption of other gases.

Figure 3- Adsorption Isotherms of Activated Carbon



### CONCLUSIONS

All three sorbents, molecular sieves 13X and 4A, and activated carbon, showed preferential adsorption of CO<sub>2</sub> over nitrogen or hydrogen at all pressures up to 250 psia. The molecular sieve 13X showed better CO<sub>2</sub> uptake than molecular sieve 4A. At lower pressures activated carbon had a lower CO<sub>2</sub> uptake than the uptakes of the molecular sieves, but at higher pressures the adsorption was higher for activated carbon than for the molecular sieves.