

COMPETITIVE ADSORPTION OF CO₂, H₂O VAPOR, N₂ AND SO₂ ON ACTIVATED CARBON FOR CO₂ CAPTURE FROM FLUE GASES

^{a,b} J. G. Bell
^c M. G. Roper
^c M. J. Benham
^a K. M. Thomas

^a School of Engineering,
Newcastle University
Newcastle upon Tyne NE1 7RU,
United Kingdom

^b ZHAW School of Engineering
8400 Winterthur, Switzerland

^c Hiden Isochema Ltd.
422 Europa Boulevard,
Warrington WA5 7TS,
United Kingdom

INTRODUCTION

Combustion of fossil fuels for power generation has a major environmental impact through emissions of CO₂, SO_x, NO_x, and other trace species. Post-combustion capture of CO₂ from flue gases at source has the potential to mitigate anthropogenic climate change, but existing CO₂ capture technology is not currently considered economically viable.^[1] Use of porous materials for carbon capture and storage (CCS) from flue gases is therefore being considered as a low-energy economic method. Cyclic CO₂ separation processes proposed include pressure swing adsorption/vacuum swing adsorption (PSA/VSA) and temperature swing adsorption (TSA).

Adsorption of flue gas on porous materials is a complex process due to competitive adsorption of the constituent species, including CO₂, H₂O vapor, N₂, O₂ and SO₂, with different mechanisms and potential reactions of species in the pores. Consequently, a thorough understanding of the adsorption processes and selectivity is critical for the design of potential sorbents for CCS applications. In this poster, we present single component and multicomponent adsorption data for the main flue gas constituents, using a well characterized activated carbon, Filtrasorb F400, as a model sorbent.^[2]

VAPOR ADSORPTION

Water sorption isotherms (Figure 1) show Type V behavior and hence imply initial adsorption on surface functional groups, followed by cluster formation and subsequent merging of adsorbed water clusters. The isosteric enthalpy of adsorption determined from the isotherms was relatively constant at 43.4 +/- 1.5 kJ mol⁻¹ for surface excess values above 0.4 mmol g⁻¹.

Sorption kinetics are slow (Figure 1 inset) and follow the single exponential (linear driving force) model. The relatively large enthalpy of adsorption and slow adsorption kinetics indicate that the presence of water vapor may have an impact on CO₂ adsorption.

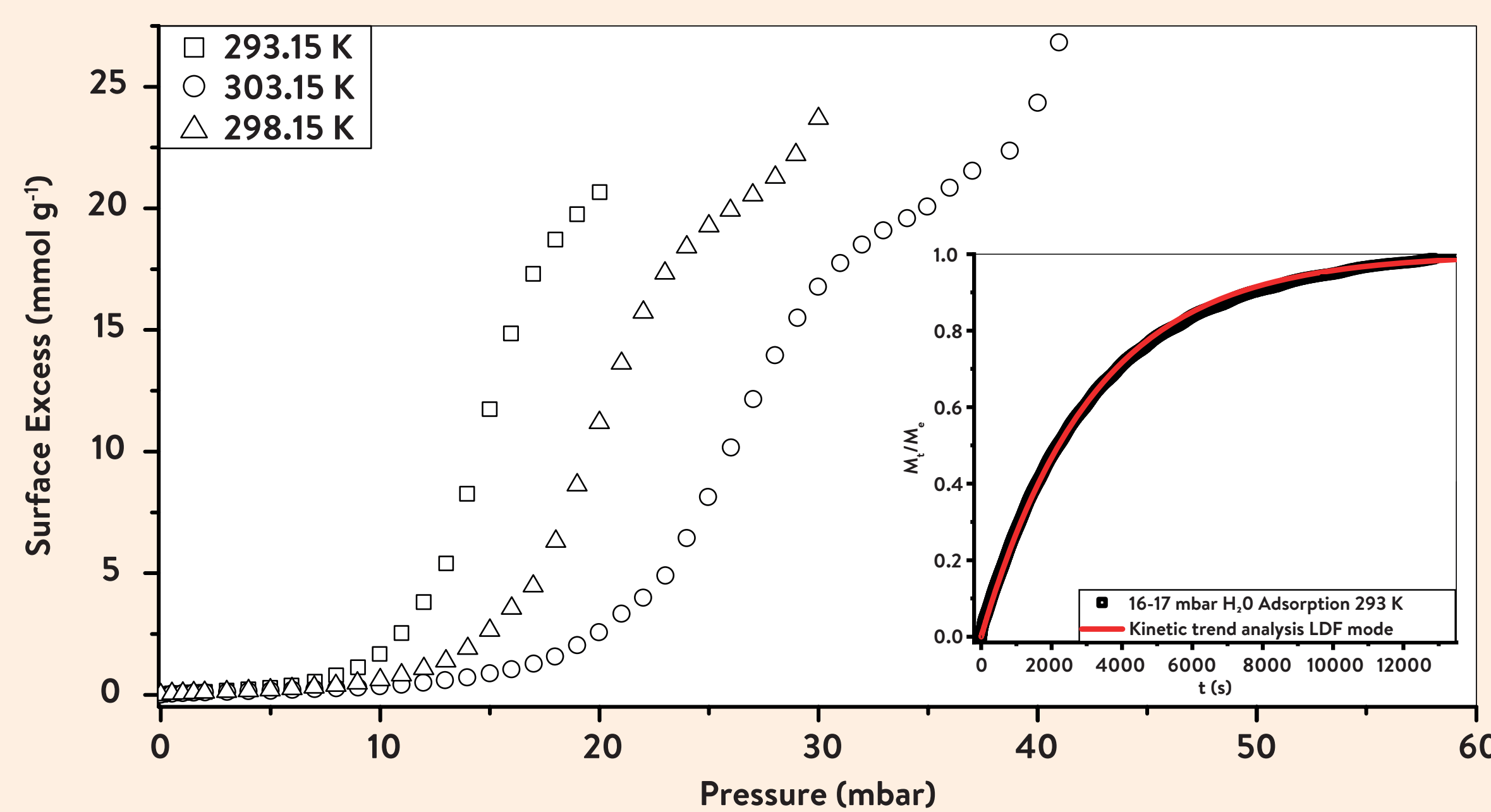


Figure 1: H₂O vapor adsorption isotherms at three temperatures. **Inset:** example sorption kinetics for 16-17 mbar point from 293 K isotherm.



GAS ADSORPTION

Single component adsorption isotherms for all four components studied (Figure 2) show varying uptake amounts and pressure ranges for the individual species. CO₂ and N₂ adsorption exhibit Type I behavior, while a Type I/II isotherm is evident for SO₂ adsorption. H₂O (see Vapor Adsorption above) is included for completeness.

Isosteric enthalpies of adsorption derived from the isotherms are in the order H₂O > SO₂ > CO₂ > N₂ for surface excess values > 1 mmol g⁻¹. CO₂ and N₂ adsorption kinetics are rapid, whereas SO₂ adsorption kinetics are somewhat slower, yet still faster than the kinetics for H₂O vapor adsorption.

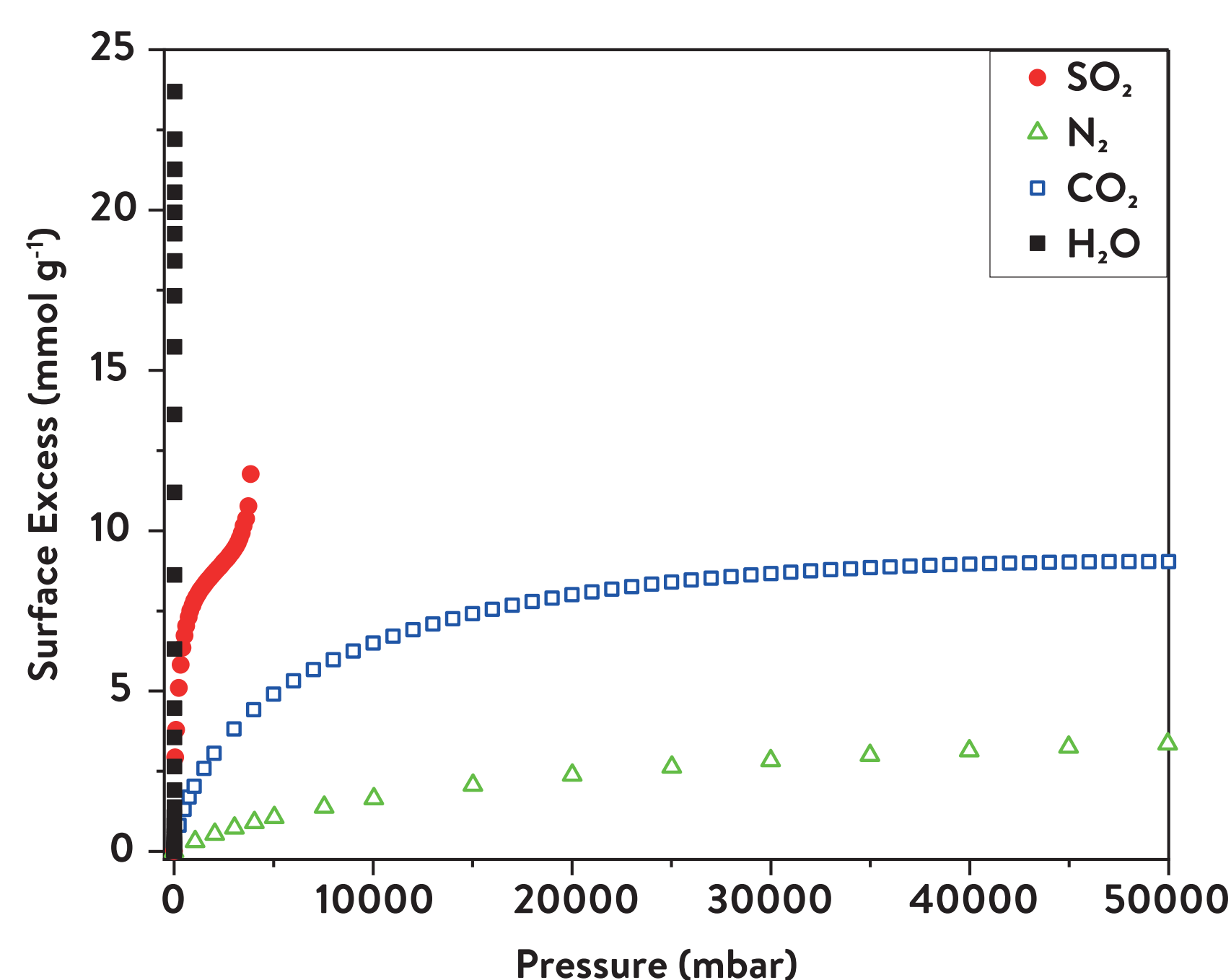


Figure 2: N₂, CO₂, SO₂ and H₂O adsorption isotherms on activated carbon F400 at 298 K.

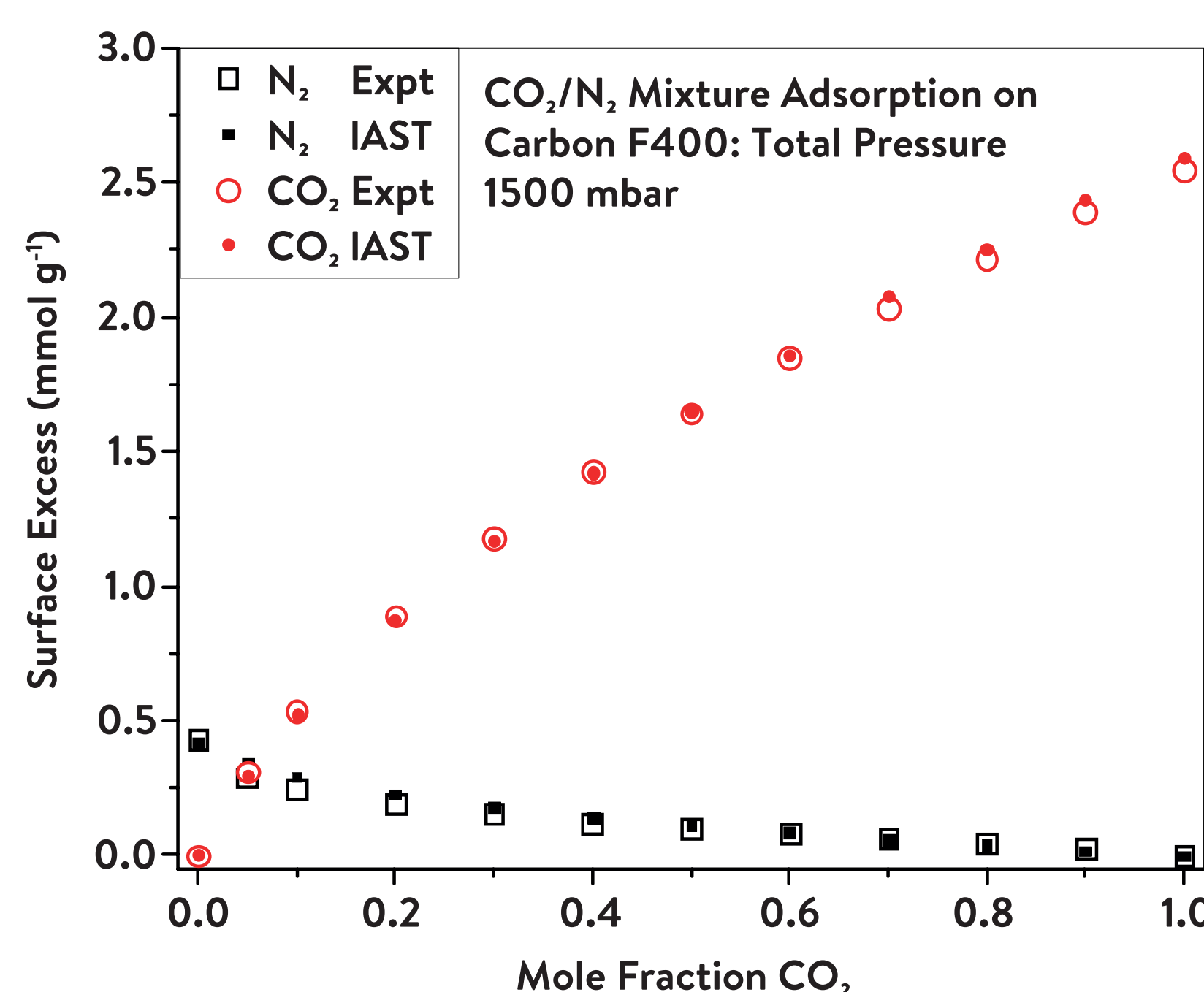


Figure 3: Experimental (IMB method) and calculated (IAST) binary CO₂/N₂ adsorption isotherms at 1500 mbar and 298 K.

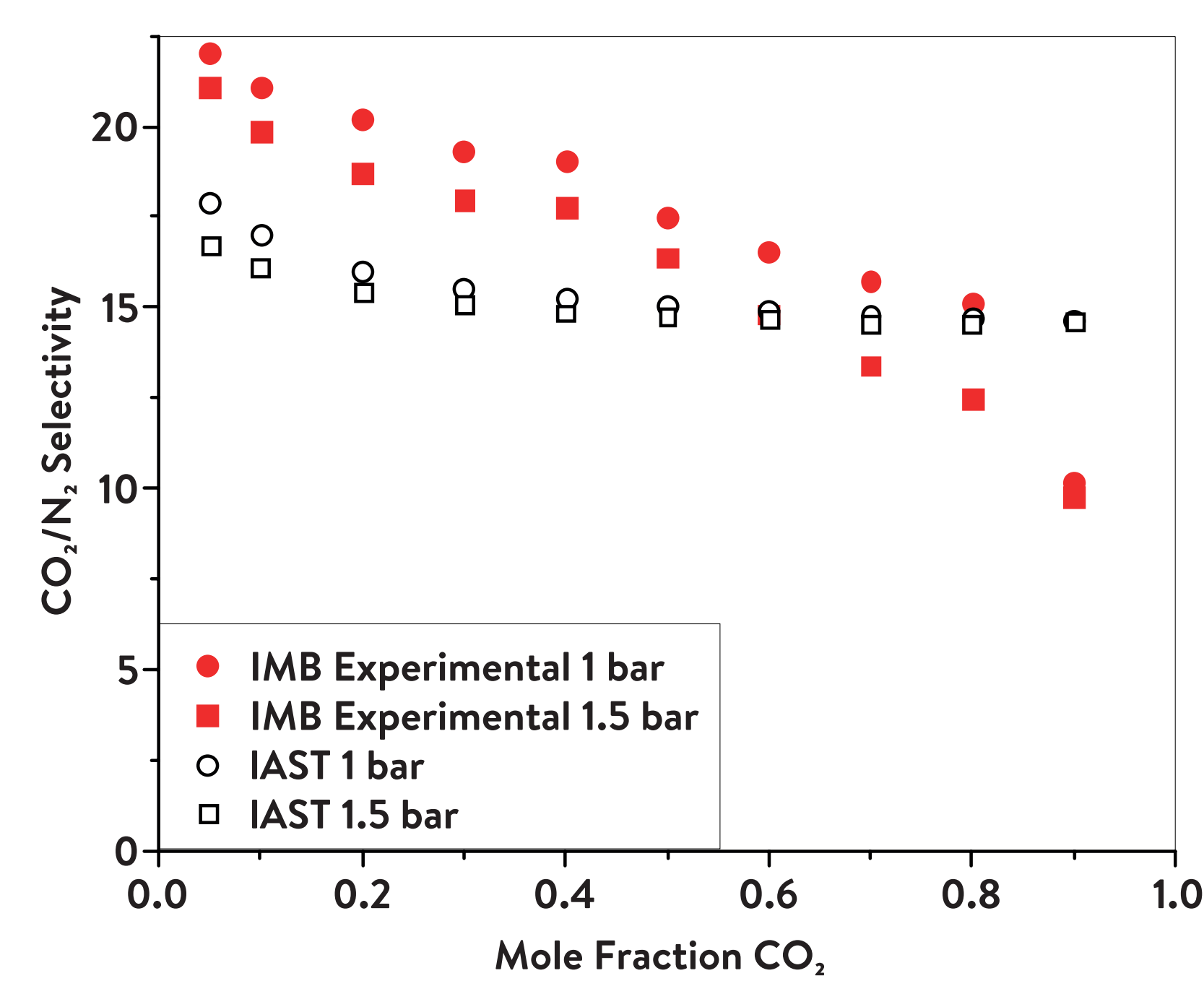


Figure 4: CO₂/N₂ selectivity values at 1000 and 1500 mbar determined from experimental and IAST binary adsorption isotherms.

Binary adsorption for CO₂/N₂ mixtures were measured at 1000 and 1500 mbar, at 298 K. Figure 3 shows experimental data at 1500 mbar compared with results from Ideal Adsorbed Solution Theory (IAST) using the single component data. The agreement is visually good, but selectivity values (Figure 4) calculated from the binary adsorption data highlight differences. As selectivity is a critical parameter for separation processes, the potential propagation of errors and hence the need for high accuracy isotherms is demonstrated.

Figures 1 – 4 adapted with permission from reference 2. Copyright 2021 American Chemical Society.

SUMMARY

- ▶ High quality single component adsorption data are required for thermodynamic and kinetic analyses
- ▶ IAST can be used to predict multicomponent sorption equilibria from single component isotherms
- ▶ The IGA-003-MC allows direct, rapid determination of multicomponent sorption equilibria using the IMB method
- ▶ Selectivities are determined from IAST and IMB method analyses and are sensitive to equilibrium sorption values
- ▶ Techniques suitable for study of competitive adsorption under DAC conditions are currently under evaluation^[4]

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