Introduction: Carbonaceous chondrite meteorites preserve materials from the early Solar System. These materials are useful for the experimental modeling of nebula processes, including gas/grain adsorption, and catalysis on solid surfaces and in solution. [1,2]

Experimental Methods: The studies used powdered samples of the Allende CV3 and Murchison CM2 meteorites. Adsorption isotherms for \( \text{N}_2 \) were constructed by equilibrium pressure determination, and for \( \text{H}_2\text{O} \) by gravimetric analysis of adsorption. Catalysis was studied by gas flow over heated meteorite powders and mass spectrometric monitoring. Catalysis in solution was studied by processing of solutions at 0 - 100 \( ^\circ \text{C} \) with and without powdered meteorite catalysts, followed by GCMS product analysis.

Gas/Grain Adsorption: In the nebula, adsorption on dust grain surfaces can control the partial pressures of gases. In this respect, isotherms were constructed for the adsorption of water vapor and \( \text{N}_2 \) on Murchison CM2 and Allende CV3 materials. The isotherms yielded heats of adsorption of 56.5±2.5 kJ/mol for \( \text{H}_2\text{O} \) on Murchison. [1] Temperature programmed desorption of CO yielded a binding energy of 13.5±3.0 kJ/mol to Murchison-based nanoparticles, vs. 9.8±0.2 kJ mol\(^{-1}\) for binding to ice. [2] These data are used to construct adsorption isotherms for diverse and extreme nebula pressures and temperatures.

Surface Catalysis: The oxidation of CO to \( \text{CO}_2 \) can occur in the Solar Nebula by O atoms produced by CO photodissociation on carbonaceous chondrite surfaces. Experimentally, the Murchison materials that contain clay-like constituents, catalysed CO/\( \text{CO}_2 \) conversion with a lower onset temperature than Allende materials. We also observed that acetaldehyde (CH\(_3\)CHO) is oxidised to form acetic acid (CH\(_3\)COOH) on Allende meteorite surfaces. [3] Similarly, surface-catalyzed oxidation of C\(_2\)H\(_2\) and H\(_2\)CO on carbonaceous chondrite surfaces may convert them into other known astrochemical molecules such as HC-CHO or H\(_2\)C=C=O, H\(_2\)C=CHOH respectively.

Catalysis in Solution: Catalyzed reactions in solution can occur in carbonaceous asteroids during aqueous alteration, or in meteorite pores on aqueous planets. For model reactions, we processed solutions of astrochemical molecules including NH\(_3\), HCN, CH\(_3\)OH, H\(_2\)CO, CH\(_3\)CHO and CH\(_3\)CN in the presence of Allende and Murchison catalysts, and found complex organic products. These products suggest that solutions in carbonaceous chondrite pores could form complex prebiotic organics.

Future Work: Materials from the early Solar System, delivered by meteorites, can be used to model the astro-physical chemistry of Solar Nebula processes. Such modeling was demonstrated by adsorption isotherms, gas/solid binding energies, and catalysis on particle surfaces and in solution. Similar studies can be extended to a wide range of chemical components and processes involving solids in interstellar clouds and in solar nebulae, and extrapolated to the wide range of conditions that prevail in these environments.


Figure 1. Adsorption isotherms of water on the Murchison meteorite at 278, 293, and 311 K. Inset shows low pressure points at higher resolution.