 ICES-2017-116

CO_2 Capacity Sorbent Analysis Using Volumetric Measurement Approach

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In support of air revitalization system sorbent selection for future space missions, Ames Research Center (ARC) has performed CO_2 capacity tests on various solid sorbents to complement structural strength tests conducted at Marshall Space Flight Center (MSFC). The materials of interest are: Grace Davison Grade 544 13X, Honeywell UOP APG III, LiLSX VSA-10, BASF 13X, and Grace Davison Grade 522 5A. CO_2 capacity was for all sorbent materials using a Micromeritics ASAP 2020 Physisorption Volumetric Analysis machine to produce 0°C, 10°C, 25°C, 50°C, and 75°C isotherms. These data are to be used for modeling data and to provide a basis for continued sorbent research. The volumetric analysis method proved to be effective in generating consistent and repeatable data for the 13X sorbents, but the method needs to be refined to tailor to different sorbents.

Nomenclature

AES	=	Advanced Exploration Systems
ARC	=	Ames Research Center
ARREM	=	Atmosphere Revitalization Recovery and Environmental Monitoring
ASAP	=	Accelerated Surface Area and Porosimetry
CDRA	=	Carbon Dioxide Removal Assembly
CO_2	=	Carbon Dioxide
ISS	=	International Space Station
MSFC	=	Marshall Space Flight Center
TGA	=	Thermogravimetric Analysis

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I. Introduction

In support of the Atmosphere Revitalization Recovery and Environmental Monitoring (ARREM) project that was initiated under the Advanced Exploration Systems (AES) program and expanded into the scope of the International Space Station (ISS) program, NASA's ECLSS Systems Maturation Team was tasked to review alternative CO_2 removal technology systems to meet the requirements of human spaceflight beyond low earth orbit.[1-3] As a part of this effort, the team at Ames Research Center (ARC) has assisted the program lead at Marshall Space Flight Center (MSFC) in evaluating alternative sorbents for robustness. While the team at MSFC performed mechanical crush strength studies on various zeolite types such as 5A, LiLSX, and 13X, the team at ARC supported efforts to characterize the adsorption capacity of these materials for water and CO_2.[4] This paper will focus on CO_2 capacity studies performed on these various zeolite types:

1. Grace Davison Grade 544 13X (2 different lots)
2. BASF 13X
3. Grace Davison Grade 522 5A
4. Grace Davison Grade 514 4A
5. APG III
6. VSA-10 LiLSX

II. Experimental Method

Adsorption capacity isotherms were performed at Ames Research Center using a Micromeritics Accelerated Surface Area and Porosimetry (ASAP) 2020 instrument and accompanying software. The ASAP 2020 measures sorbent adsorptive capacity for any desired gas input and is capable of operation from cryogenic to >100°C temperature ranges, provided the use of an appropriate temperature controlled bath. The ASAP 2020 operates on a volumetric method, as opposed to a Thermogravimetric Analyzer, which operates on a gravimetric method. In order to achieve this, the machine operation is depicted in Figure 1. As a requirement, the analysis manifold volume must be known, and its temperature and pressure must be monitored precisely. The sample tube volume must also be known precisely, and must be defined for each new sample tube, sample, and temperature bath. The ASAP 2020 is capable of activating, or degassing, the sample; measuring the sample tube volume not occupied by the sample, also known as the free-space volume; and performing the isothermal capacity measurement of the desired gas on the sorbent at user-defined pressure values.

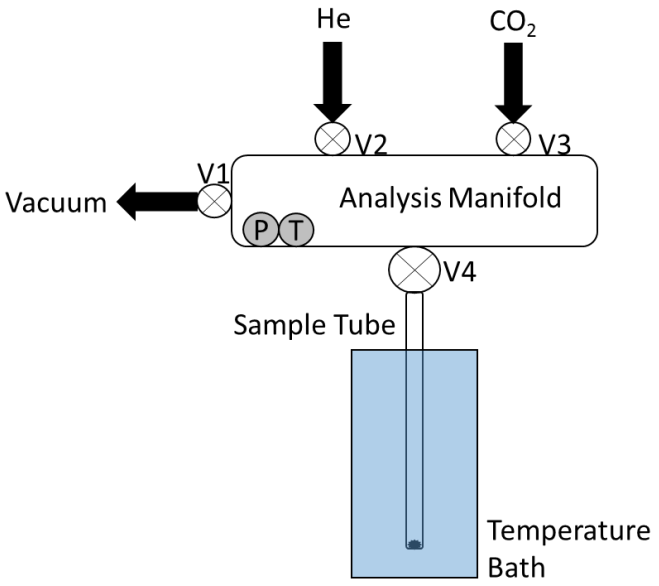


Figure 1: ASAP 2020 Analysis Manifold. Simplified depiction of the analysis manifold with pressure and temperature sensors; vacuum, Helium, and Carbon Dioxide ports; and sample tube with sample immersed in a temperature bath

A. Sample Degas/Activation

In order to begin an isotherm analysis, the sample must first be activated. The ASAP 2020 performs this function on designated "degas" ports by exposing the sample to vacuum (approximately 4 mTorr) and heating using heating mantles. For the materials explored at Ames, the material was warmed up at a ramp-rate of 3°C/min to 110°C and held for 3 hours at this intermediate temperature. Then the material was ramped at 5°C/min to 350°C and held at this final soak temperature for 6 hours.

B. Free-space Measurement

In order to find the volume of the sample tube not occupied by the sample, also known as the free-space volume, the ASAP 2020 first evacuates the analysis manifold and the sample tube containing the activated sample. Then the

sample tube valve (V4 in Figure 1) and the vacuum valve V1 are closed and the analysis manifold is injected with a known amount of helium via valve V2. After the gas has time to reach thermal and pressure equilibrium inside the analysis manifold, the sample tube valve is opened to allow helium to fill the sample tube. A pressure measurement once thermal equilibrium has been reached can then yield the free-space volume, V_s. Helium is used since it will not pre-load the sorbents studied in this effort and would only affect cryogenic adsorption analysis via helium entrapment. The analysis temperatures of this study were 0°C, 10°C, 25°C, 50°C, and 75°C. This procedure to find the free-space volume is performed automatically before every sample analysis by the ASAP 2020.

C. Adsorption Measurement

To begin measuring the amount of CO_2 on the selected sorbent, the analysis manifold and sample tube are once again evacuated. Once the user-defined vacuum pressure threshold has been reached, the sample valve V4 and the vacuum valve V1 are closed. CO_2 is injected into the analysis manifold and allowed to reach thermal equilibrium, at which point the quantity of CO_2, n_m, can be determined from the universal gas law,

$$n = \frac{PV}{RT} \tag{1}$$

where P is the manifold pressure, V is the known manifold volume, R is the universal gas constant, and T is the manifold temperature. The sample tube valve is then opened to expose the sample to the CO_2 in the analysis manifold. The sorbent will adsorb some of the CO_2, n_{ads}, and the pressure will be measured by the pressure transducer in the analysis manifold until equilibrium has been reached. At this equilibrium point, the pressure P_e is recorded. In order to calculate the quantity of CO_2 that has been adsorbed on the sample, n_{ads}, the quantity of CO_2 remaining in the sample tube-analysis manifold, n_e, is calculated using the free-space volume previously determined, and n_{ads} is calculated from:

$$n_{ads} = n_m - n_e \tag{2}$$

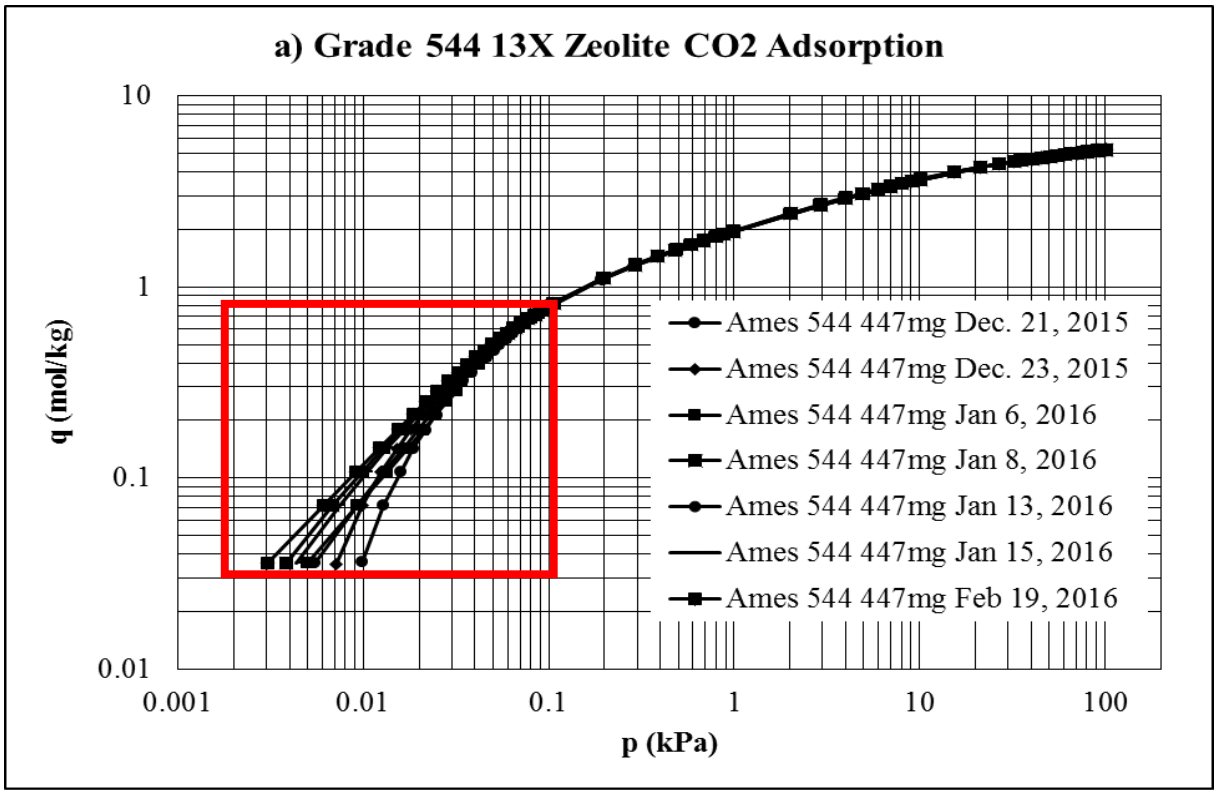
This process of isolating the sample tube, injecting a known quantity of CO_2 into the analysis manifold, exposing the sample, and measuring the equilibrium pressure is repeated until a full isotherm is developed over the desired pressure range.[5]

III. Results and Lessons Learned

D. Method Definition

Initially, many isotherms were conducted in order to familiarize with the ASAP 2020 and to begin to optimize the analysis method to use with the materials of interest previously stated. For these analyses, the Grace Davison Grade 544 13X (lot 1000216159) was used as the sample material and the analysis temperature was set at 25°C. At first, samples were activated on the ASAP's designated degas ports and transferred to the analysis port since this was the recommended procedure and so that one sample could be activated while another was analyzed. When these designated degas ports were used to activate the material, deviations in the low pressure region < 0.1 kPa were observed even when the same sample was analyzed repeatedly, see Figure 2a. It was hypothesized that the activation procedure may not be sufficient, so the soak times at 110°C and 350°C were varied, but still the analysis showed poor consistency in the low pressure range. This issue was fixed by performing the activation procedure on the analysis port of the ASAP 2020 in order to eliminate the chance of environmental preloading on the sample in the process of transferring the sample tube from the degas port to the analysis port. Once this fix was implemented, isotherms from the same sample and different samples from the same lot all exhibited equal performance, see Figure 2b. Performing the activation and analysis on the analysis port of the ASAP prevented a more rapid sample analysis turnover rate, but provided more consistent and reliable results.

Throughout this phase of repeatedly running the same two samples, it was found that the ASAP 2020 will occasionally suffer from leaky seals or dusting contamination, so efforts were taken to purge the analysis manifold between analyzing the different sorbent sets.



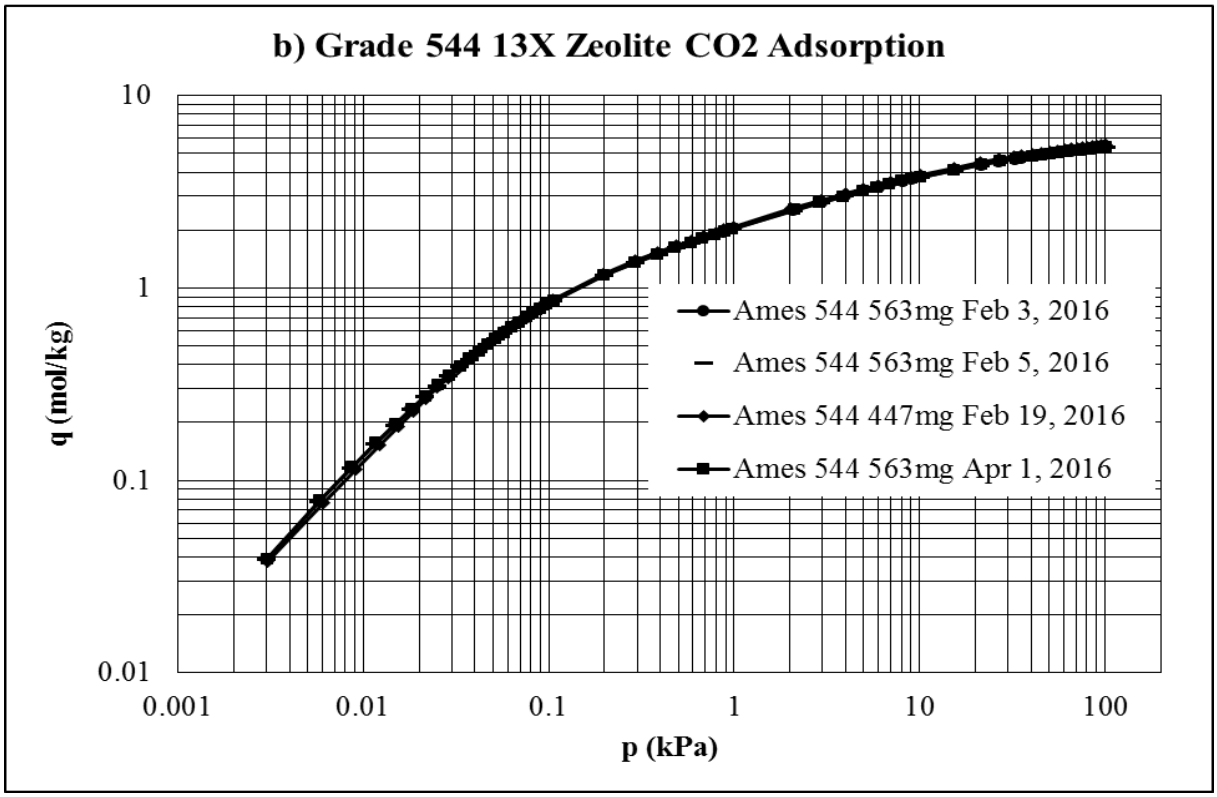


Figure 2. Plot a) shows a single sample through multiple CO_2 analysis runs. In the low pressure region < 0.1 kPa, the data deviates and is inconsistent. Plot b) shows that this issue was resolved by performing the activation procedure directly on the analysis port, removing the need to transfer the sample from degas to analysis port. The analysis temperature for both plots was 25°C

The analysis properties and parameters were varied during this phase of testing in order to find a suitable analysis method. Among the properties changed were altering the analysis pressure table and the low pressure dosing method. The analysis pressure table defines the target pressures at which the instrument will record adsorption data. The ASAP 2020 allows the user to define a pressure table based on absolute pressures or pressures relative to saturation pressure. The default pressure table for micropore zeolite analysis was found to be generally well suited for the desired isotherm range, so the only alterations made were to redefine a saturation pressure and remove some of the high-range pressure targets in order to speed up analysis time. The saturation pressure was set to 760 torr and the pressure table used for the subsequent analyses is shown in Table 1. For low pressure adsorption analysis, the ASAP 2020 has a built in Low Pressure Incremental Dose Method which focuses on adsorption below the lowest pressure target set by the analysis pressure table. The Low Pressure Incremental Dose Method allows the machine to dose the sample with user-defined quantities of analysis gas and measures the equilibrium pressure, allowing for better visualization of the Henry's Law region of the isotherm. From the preliminary tests, it was found that a 0.8 cc/g low pressure dose amount was effective in terms of balancing time and sufficient Henry's Law visualization.

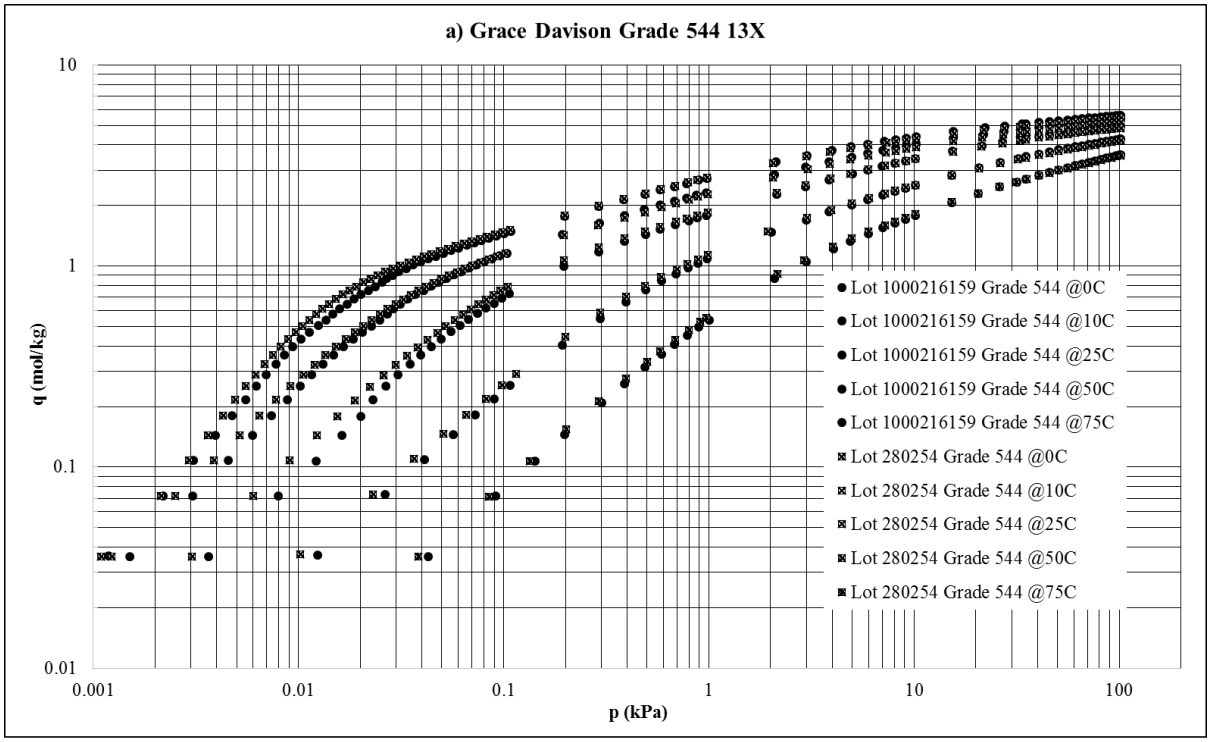
Table 1

P/P0	Add point every	P (Torr)	Add point every	P0 (Torr)
0.001		0.76		760
0.01	0.001	7.6	0.76	
0.1	0.01	76	7.6	
0.95	0.05	722	38	
0.998		758.48		

Table 1. Analysis pressure table for zeolite CO_2 isotherms. The second and fourth columns define the pressure increments at which the machine will take measurements between the set pressures in the first and third columns.

E. Isotherm Analysis

Analysis on the varying lots of 13X sorbent (Grace Davison Grade 544 lots 1000216159 and 280254, and BASF lot F300005063) show mostly consistent behavior (Figure 3a/b). Slight overall variances between lots and measurement instances has been documented previously,[6] and should not be cause for concern in terms of modeling, however the variations observed between the Grace Davison lots 1000216159 and 280254 are only limited to the low pressure region < 0.1 kPa. The datasets were repeated twice in succession for statistical confidence, but still seemed to show the differences visible in the plot. It was hypothesized that these differences and sensitivity in this pressure region could have been due to an older seal fritz used to cap the sample tubes, but further investigation would be necessary to fully characterize this issue. At the time, it was determined that these data would be sufficient to provide modeling basis. Comparison between the Grace Davison and BASF 13X materials showed that they are very comparable to each other in terms of isotherm shape and CO_2 capacity. All 13X materials involved in this study showed reasonable adherence to Henry's Law, exhibiting a linear relationship between adsorption quantity and pressure at the low pressure ends of the isotherms.



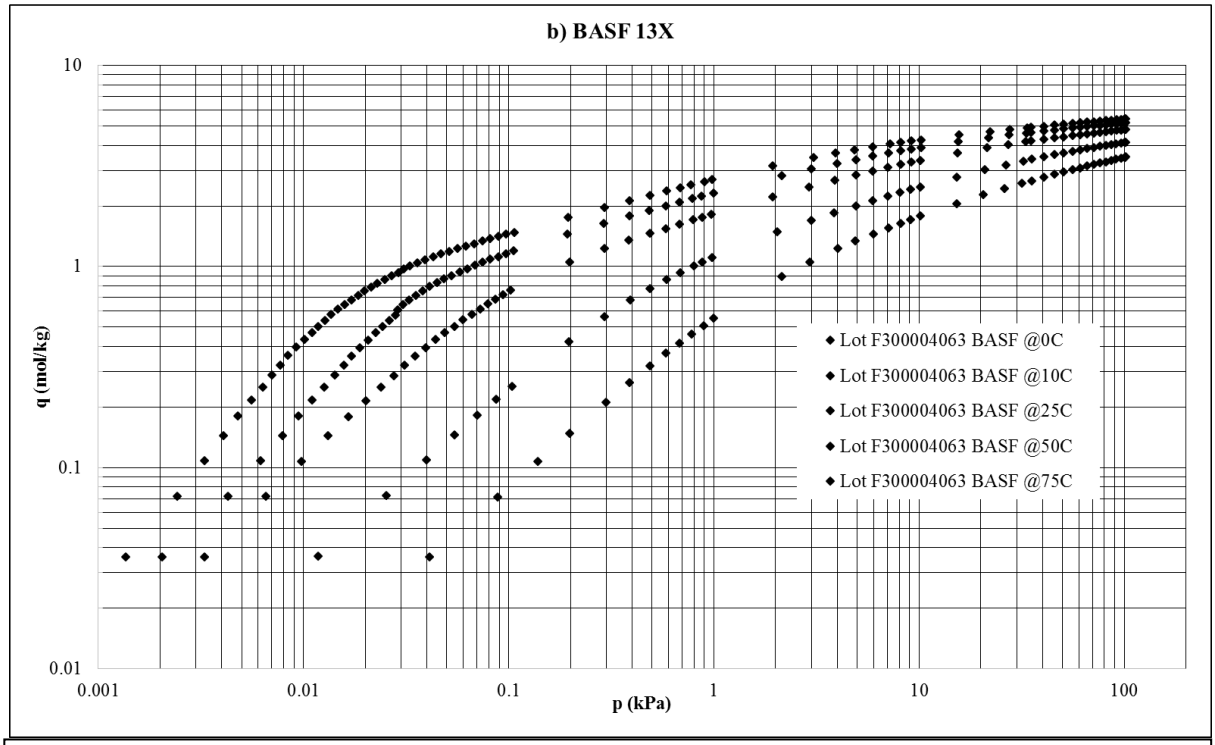


Figure 3. Plot a) shows a comparison between two different Grace Davison Grade 544 13X lots. There are slight variations in the lower pressure regions. The BASF isotherm data is shown in Plot b), and seems to show an imperfection in the 10°C plot near the 0.03 kPa reading.

The Honeywell UOP APG III material exhibited slightly different shaped isotherms compared to the 13X (Figure 4), and for the 0°C, 10°C, and 25°C instances show more pronounced bend in the curve in the low pressure

region. The APG III material shows higher capacity for CO_2 than the 13X materials. At 0.3 kPa $ppCO_2$, the APG III shows approximately a 25% capacity improvement over the 13X. Like the 13X, the APG III material showed reasonable adherence to Henry's Law at low pressures.

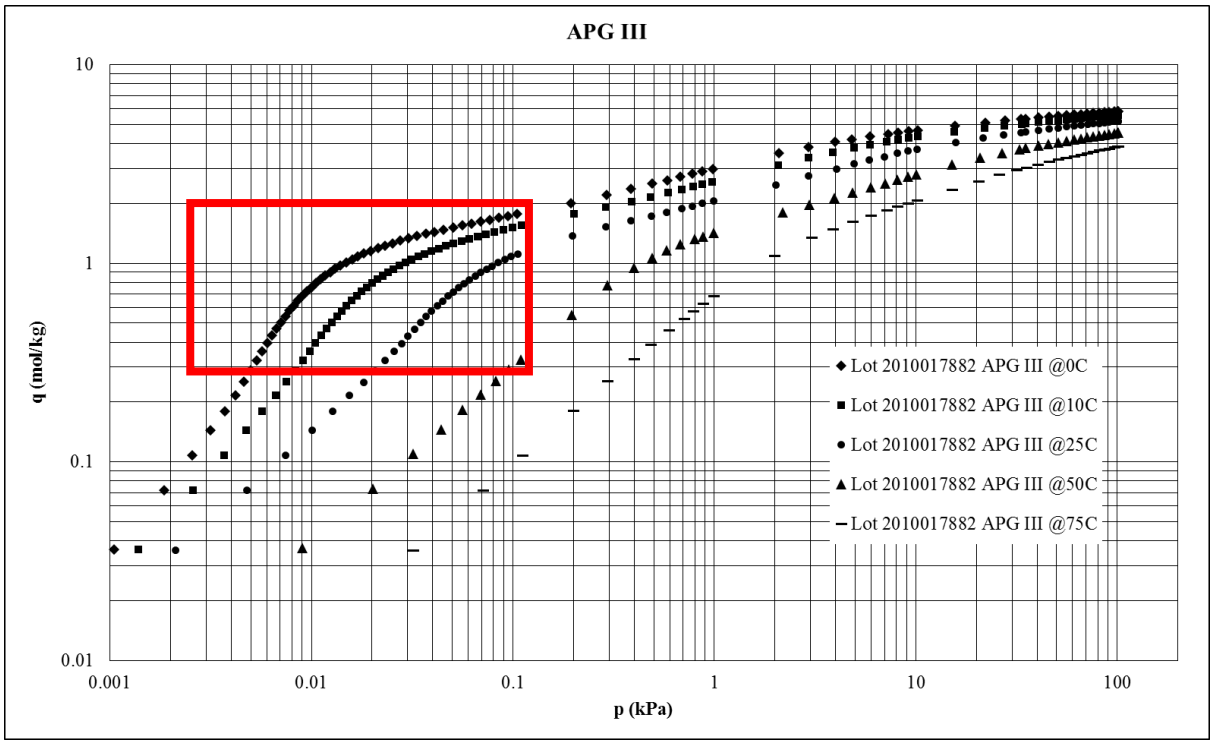


Figure 4. The Honeywell UOP APG III zeolite CO_2 isotherms at 0°C, 10°C, 25°C, 50°C, and 75°C. This material exhibits a more pronounced bend in the low pressure region for the 0°C, 10°C, and 25°C isotherms.

The Grade 522 5A zeolite (Figure 5) also shows a different isotherm curvature. Notably, the bend in the low pressure region is not present. Rather, the isotherms show a very linear progression on the log-log scale. Even though this linear trend is visible, it is unclear whether or not the Henry's Law region for this material was observed fully at all temperatures, specifically the 0°C isotherm. The first three points of this curve seem to converge closer to the 10°C dataset. In comparison with the 13X, the Grade 522 5A material shows approximately 45% less capacity at 0.3 kPa $ppCO_2$.

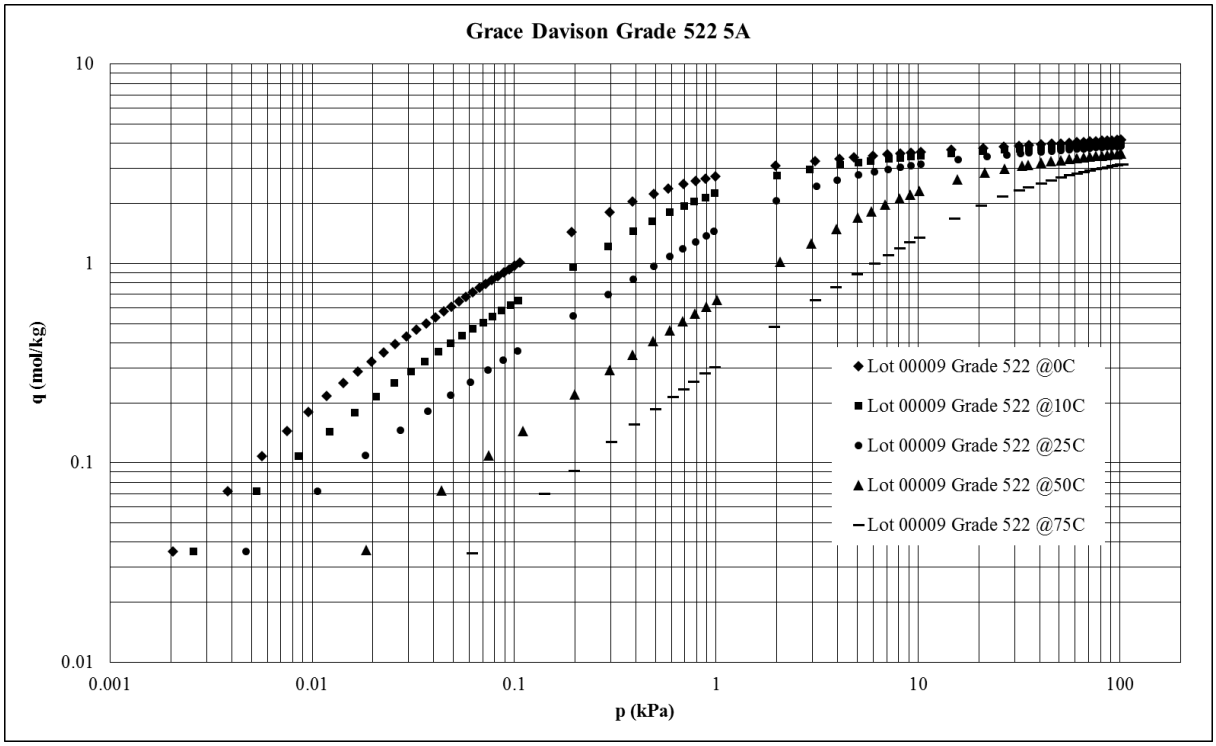


Figure 5. The Grace Davison Grade 522 5A zeolite CO_2 isotherms at 0°C, 10°C, 25°C, 50°C, and 75°C.

The LiLSX VSA-10 material (Figure 6) exhibits the highest capacity for CO_2, consistent with previous findings[4]. At 0.3 kPa ppCO_2, the VSA-10 shows approximately a 75% increased performance in terms of CO_2 capacity

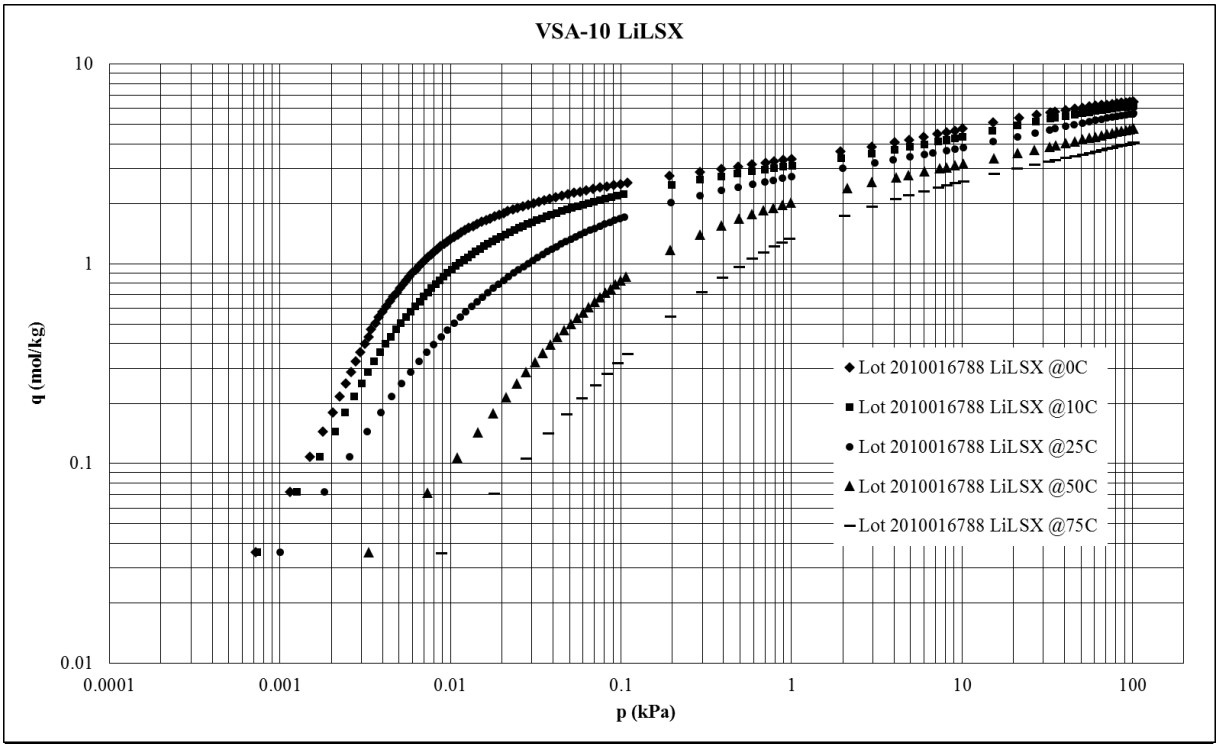


Figure 6. The LiLSX VSA-10 zeolite CO_2 isotherms at 0°C, 10°C, 25°C, 50°C, and 75°C.

compared to the 13X. In this data series, the 0°C curve converges with the 10°C curve at the lowest pressure readings. It is thought that the analysis parameters and the machine limits may be causing this trend, since the lowest pressure achievable by the machine is approximately 0.0005 kPa, and the lowest recorded adsorption point was measured at 0.0007 kPa. Once again, the data proved to be sufficient in terms of modeling, but with a more tailored analysis, better data at for the lower temperature isotherms may yield better Henry's Law agreement.

The Grade 514 4A material (Figure 7) isotherms exhibit an odd shape, since the 50°C and 75°C isotherms seem to show the opposite curvature in the low pressure region compared to the 0°C, 10°C, and 25°C isotherms. In terms of performance at 0.3 kPa $ppCO_2$, the Grade 514 4A exhibited approximately 13% less capacity compared to the 13X materials. This material showed poor adherence to Henry's Law since the low pressure range slopes are all different between the five isotherms. We think that by revising and tailoring the 0°C and 10°C analysis methods, we

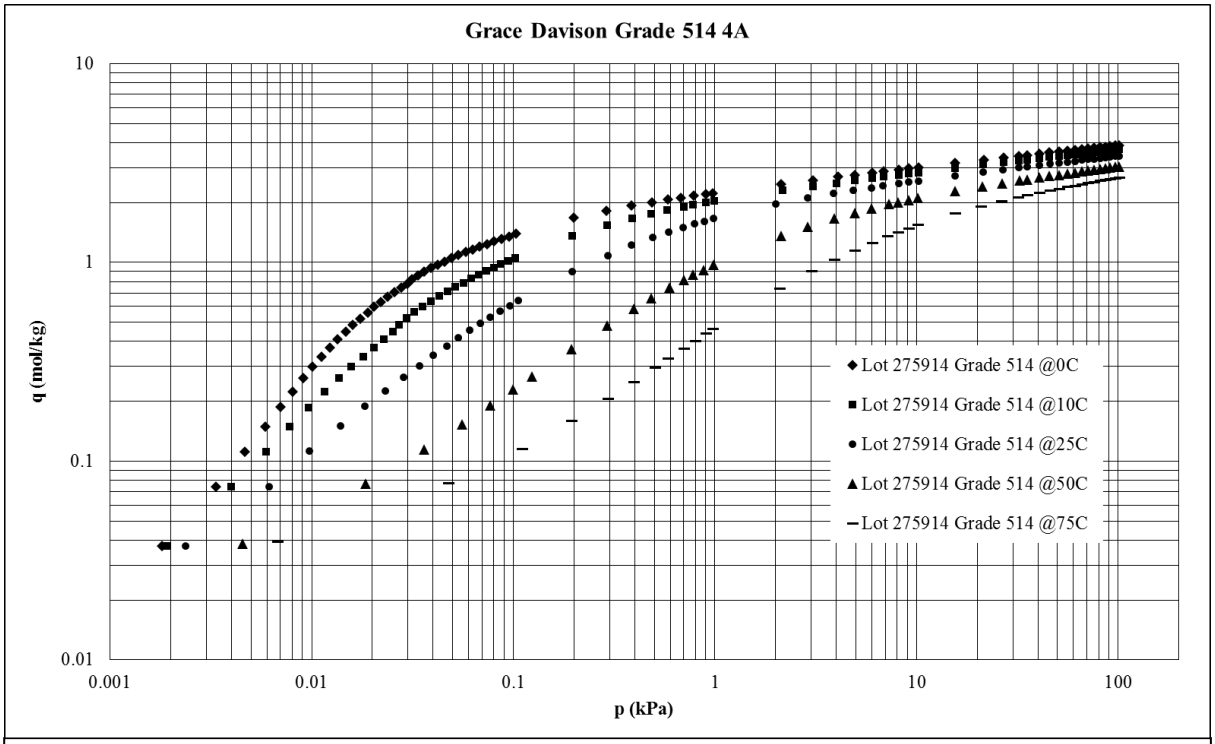


Figure 6. The LiLSX VSA-10 zeolite CO_2 isotherms at 0°C, 10°C, 25°C, 50°C, and 75°C.

can produce better Henry's Law agreement for those isotherms, but for 50°C and 75°C the temperature seems to have a profound effect on the isotherm shape because the curvature appears to inflect the opposite direction from the lower temperature isotherms.

IV. Summary

Overall, with the prescribed analysis properties (pressure table, Low Pressure Dosing Method options), the 13X materials showed the best adherence to Henry's Law linearity at low pressures. We think that similar quality curves can be achieved with the other materials with slight changes to the analysis properties to tailor to each specific material, but for the purposes of modeling, it was determined that the current dataset provided was sufficient. Even though the data was very repeatable with the same sample, variations in the 13X isotherms were observed between different Grace Davison lots, suggesting that perhaps there were confounding variables not addressed through repeated runs of the same sample, such as poorly sealing or degrading o-rings in the sample tube seal fritz or dusting contamination in the analysis manifold. The dataset used to generate the above plots is included in the appendix.

Appendix

13X	Grace Davison Grade 544								
Lot	1000216159								
0C		10C		25C		50C		75C	
P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)
0.00119	0.03606	0.00150	0.03603	0.00365	0.03591	0.01243	0.03647	0.04281	0.03592
0.00220	0.07212	0.00306	0.07205	0.00798	0.07175	0.02649	0.07287	0.09144	0.07157
0.00309	0.10818	0.00454	0.10805	0.01220	0.10758	0.04123	0.10924	0.14238	0.10704
0.00394	0.14423	0.00597	0.14405	0.01629	0.14340	0.05675	0.14558	0.19852	0.14487
0.00475	0.18028	0.00738	0.18006	0.02018	0.17923	0.07301	0.18189	0.29944	0.20809
0.00554	0.21633	0.00881	0.21607	0.02311	0.21582	0.09003	0.21816	0.38957	0.26024
0.00625	0.25240	0.01019	0.25207	0.02669	0.25239	0.10796	0.25440	0.48852	0.31364
0.00699	0.28845	0.01164	0.28805	0.03061	0.28894	0.19266	0.40396	0.58658	0.36317
0.00776	0.32449	0.01320	0.32402	0.03491	0.32548	0.29447	0.54853	0.68185	0.40755
0.00856	0.36052	0.01484	0.35996	0.03947	0.36202	0.39390	0.66512	0.78567	0.45250
0.00941	0.39653	0.01658	0.39591	0.04435	0.39855	0.49145	0.75981	0.89119	0.49640
0.01031	0.43255	0.01851	0.43183	0.04963	0.43507	0.59011	0.84310	1.00291	0.53998
0.01135	0.46854	0.02054	0.46775	0.05529	0.47160	0.69357	0.91638	2.09591	0.86557
0.01247	0.50452	0.02269	0.50366	0.06122	0.50811	0.79206	0.98230	2.99360	1.04914
0.01362	0.54052	0.02486	0.53949	0.06762	0.54463	0.88448	1.03560	4.03912	1.21357
0.01473	0.57650	0.02717	0.57524	0.07438	0.58113	0.97771	1.08668	4.89089	1.32474
0.01594	0.61248	0.02906	0.61180	0.08175	0.61763	2.02571	1.47335	5.97723	1.44497
0.01724	0.64845	0.03148	0.64833	0.08957	0.65412	2.98843	1.69855	7.07000	1.54839
0.01864	0.68439	0.03423	0.68485	0.09797	0.69060	3.86209	1.85707	8.08808	1.63452
0.02015	0.72028	0.03727	0.72136	0.10692	0.72707	4.96130	2.01886	9.10580	1.71142
0.02189	0.75611	0.04063	0.75787	0.19597	0.99804	5.96181	2.14227	10.12502	1.78101
0.02373	0.79191	0.04431	0.79437	0.29065	1.17957	7.02383	2.25633	15.19417	2.06326
0.02557	0.82765	0.04830	0.83087	0.38705	1.32369	8.08972	2.35726	20.60846	2.28684
0.02689	0.86421	0.05258	0.86737	0.49266	1.44146	9.10223	2.44249	26.12928	2.46927
0.02877	0.90074	0.05726	0.90385	0.58040	1.52472	10.11738	2.52047	31.56486	2.61923
0.03093	0.93726	0.06242	0.94033	0.68507	1.60817	15.22673	2.83366	35.24249	2.70817
0.03345	0.97377	0.06797	0.97680	0.79818	1.68227	20.76840	3.07830	40.56895	2.82281
0.03629	1.01027	0.07405	1.01327	0.87851	1.72987	26.39291	3.26896	45.64199	2.92085
0.03946	1.04677	0.08058	1.04972	0.97489	1.78566	32.16282	3.42578	50.79078	3.00840
0.04297	1.08325	0.08772	1.08616	2.14343	2.26678	35.11511	3.49472	55.77480	3.08483
0.04680	1.11973	0.09546	1.12258	2.95298	2.48213	40.57710	3.60692	60.83867	3.15764
0.05100	1.15621	0.10380	1.15899	3.86279	2.67427	45.65091	3.69919	66.02907	3.22495
0.05561	1.19268	0.19338	1.43609	4.99942	2.86680	50.77222	3.78110	70.99330	3.28436
0.06057	1.22914	0.29195	1.63723	5.92889	2.99521	55.78896	3.85148	76.08351	3.34220
0.06599	1.26560	0.38706	1.78599	6.98876	3.12150	60.90821	3.91670	81.24442	3.39799
0.07185	1.30204	0.48302	1.90613	8.09125	3.23617	65.96174	3.97539	86.29636	3.44673
0.07817	1.33848	0.58039	2.01048	9.11695	3.32968	71.02204	4.02964	91.26000	3.49264
0.08495	1.37490	0.68061	2.10167	10.15177	3.41308	76.10969	4.08002	96.42079	3.53685
0.09231	1.41131	0.78120	2.18650	15.37981	3.73165	81.22746	4.12577	100.38057	3.56958
0.10019	1.44771	0.86783	2.25243	21.43148	3.97728	86.22708	4.16743	100.80021	3.57636
0.10858	1.48410	0.96902	2.32008	27.03403	4.14223	91.31940	4.20775	101.18533	3.58428
0.19839	1.77462	2.08621	2.84319	33.09271	4.28021	96.40992	4.24546		
0.29018	1.97638	2.96730	3.10330	35.16380	4.32086	100.41725	4.27358		
0.38582	2.14176	3.85483	3.30168	40.56332	4.41407	100.80680	4.27816		
0.48856	2.28297	4.95987	3.49234	45.77694	4.49104	101.18085	4.28401		
0.57775	2.38736	5.91729	3.62538	50.79617	4.55598				
0.67793	2.48580	7.06069	3.75758	55.81691	4.61380				
0.77593	2.57584	8.12357	3.86053	60.97353	4.66702				
0.89542	2.67212	9.16113	3.94723	65.97595	4.71352				
0.97739	2.73094	10.20061	4.02356	71.08974	4.75729				
2.12855	3.29350	15.47829	4.30630	76.15322	4.79704				
3.00505	3.55211	21.82740	4.52355	81.20340	4.83373				
3.99439	3.76237	27.44719	4.66114	86.28301	4.86816				
4.90704	3.91192	33.49737	4.77618	91.37722	4.90045				
5.94290	4.04678	35.06792	4.80258	96.46331	4.93032				
7.17966	4.17646	40.61862	4.88395	100.45317	4.95301				
8.13706	4.25993	45.66394	4.94758	100.81231	4.95827				
9.17810	4.33881	50.71279	5.00379	101.21795	4.96272				
10.23226	4.40826	55.78921	5.05432						
15.56903	4.66259	60.86507	5.09972						
22.09623	4.86017	65.97284	5.14122						
27.63257	4.98051	71.04028	5.17902						
33.60688	5.08258	76.07492	5.21373						
35.11771	5.10574	81.14709	5.24624						
40.65602	5.17974	86.24956	5.27681						
45.67178	5.23788	91.30083	5.30501						
50.73505	5.28967	96.36812	5.33182						
55.81420	5.33627	100.40475	5.35220						
60.95845	5.37870	100.81458	5.35735						
65.95281	5.41641	101.23247	5.36115						
71.11888	5.45222								
76.12058	5.48448								
81.18566	5.51457								
86.26642	5.54275								
91.34389	5.56950								
96.40750	5.59462								
100.44123	5.61354								
100.81144	5.61757								
101.21492	5.62130								

13X	Grace Davison Grade 544								
Lot	280254								
0C		10C		25C		50C		75C	
P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)
0.00123	0.03602	0.00109	0.03602	0.00302	0.03588	0.01021	0.03688	0.03854	0.03587
0.00214	0.07204	0.00252	0.07202	0.00605	0.07174	0.02303	0.07328	0.08492	0.07144
0.00292	0.10808	0.00386	0.10802	0.00909	0.10759	0.03659	0.10966	0.13362	0.10695
0.00362	0.14411	0.00516	0.14401	0.01226	0.14342	0.05086	0.14603	0.20189	0.15449
0.00428	0.18016	0.00645	0.17999	0.01552	0.17922	0.06581	0.18240	0.29088	0.21249
0.00491	0.21619	0.00777	0.21596	0.01889	0.21501	0.08157	0.21876	0.39393	0.27506
0.00554	0.25223	0.00912	0.25191	0.02238	0.25078	0.09799	0.25513	0.50115	0.33499
0.00617	0.28825	0.01053	0.28785	0.02605	0.28654	0.11537	0.29147	0.57782	0.37586
0.00683	0.32428	0.01199	0.32378	0.02988	0.32229	0.19948	0.44532	0.68825	0.42983
0.00750	0.36029	0.01355	0.35969	0.03391	0.35802	0.29468	0.58515	0.79616	0.47912
0.00820	0.39629	0.01520	0.39560	0.03815	0.39375	0.39362	0.70365	0.90757	0.52698
0.00892	0.43229	0.01694	0.43151	0.04267	0.42945	0.48684	0.79738	0.97295	0.55369
0.00967	0.46828	0.01877	0.46741	0.04744	0.46513	0.58583	0.88301	2.15774	0.91359
0.01045	0.50427	0.02069	0.50330	0.05242	0.50082	0.69875	0.96616	2.90688	1.06753
0.01127	0.54026	0.02271	0.53918	0.05771	0.53647	0.78456	1.02061	4.02728	1.24769
0.01216	0.57624	0.02488	0.57504	0.06331	0.57209	0.88522	1.07866	4.98304	1.37091
0.01311	0.61220	0.02720	0.61090	0.06922	0.60768	0.99212	1.13754	6.01536	1.48229
0.01411	0.64815	0.02968	0.64673	0.07552	0.64326	1.93323	1.48325	7.21015	1.59200
0.01521	0.68410	0.03233	0.68256	0.08210	0.67882	3.00976	1.73373	8.09469	1.66481
0.01642	0.72003	0.03522	0.71839	0.08899	0.71539	3.94925	1.89840	9.10319	1.73999
0.01772	0.75596	0.03836	0.75418	0.09660	0.75194	4.95106	2.04203	10.12353	1.80871
0.01916	0.79187	0.04179	0.78997	0.10480	0.78849	6.03664	2.17169	15.23367	2.08352
0.02072	0.82780	0.04556	0.82572	0.19735	1.06958	7.19176	2.29059	20.50726	2.29624
0.02246	0.86370	0.04969	0.86145	0.29091	1.24321	8.09622	2.37289	25.95585	2.46975
0.02437	0.89958	0.05423	0.89714	0.38792	1.37604	9.11081	2.45576	31.45871	2.61558
0.02650	0.93544	0.05923	0.93282	0.48669	1.48241	10.11625	2.53108	35.40951	2.70765
0.02884	0.97128	0.06442	0.96948	0.58078	1.56838	15.24717	2.83174	40.65531	2.81525
0.03143	1.00710	0.07036	1.00611	0.69323	1.65734	20.76742	3.06288	45.57497	2.90408
0.03429	1.04293	0.07707	1.04273	0.78067	1.71714	26.36607	3.24261	50.72159	2.98964
0.03743	1.07873	0.08455	1.07933	0.87890	1.77970	31.95135	3.38667	55.84711	3.06606
0.04088	1.11450	0.09281	1.11591	0.98907	1.84503	35.20196	3.45908	60.87622	3.13456
0.04460	1.15024	0.10190	1.15248	2.13313	2.31410	40.62932	3.56420	66.00572	3.19751
0.04880	1.18598	0.19667	1.41679	2.95210	2.53117	45.66194	3.64846	71.04206	3.25551
0.05340	1.22167	0.28882	1.58968	3.92068	2.72721	50.70820	3.72408	76.13700	3.30924
0.05841	1.25732	0.38804	1.73469	4.88931	2.88323	55.83514	3.79242	81.14530	3.36106
0.06387	1.29294	0.48728	1.85398	6.00335	3.03149	60.88657	3.85312	86.30547	3.40953
0.06980	1.32854	0.58986	1.96083	7.19798	3.16340	65.97136	3.90883	91.32875	3.45282
0.07622	1.36411	0.69137	2.05335	8.10703	3.25021	71.02978	3.96023	96.34671	3.49554
0.08288	1.40067	0.79832	2.14199	9.14604	3.33791	76.12986	4.00748	101.25454	3.53883
0.09037	1.43720	0.88556	2.20596	10.15786	3.41386	81.20343	4.05051		
0.09848	1.47371	0.98462	2.27216	15.45604	3.71255	86.24894	4.09103		
0.10736	1.51021	2.05702	2.76367	21.30343	3.93144	91.33157	4.12837		
0.19891	1.78982	3.02858	3.03638	26.87491	4.08346	96.38138	4.16432		
0.29126	1.98803	3.88632	3.21643	32.65281	4.20714	101.22690	4.19938		
0.38523	2.14946	4.86879	3.37879	35.16769	4.25375				
0.49091	2.29767	6.01136	3.53014	40.61684	4.34137				
0.58231	2.40660	7.27269	3.66511	45.67948	4.41153				
0.68595	2.51080	8.12316	3.74205	50.78921	4.47361				
0.79255	2.60568	9.16069	3.82459	55.81433	4.52802				
0.87795	2.67365	10.19274	3.89673	60.91035	4.57802				
0.97943	2.74611	15.57089	4.17097	66.00020	4.62313				
2.04660	3.25243	21.52287	4.36699	71.05946	4.66438				
2.98752	3.51887	27.13357	4.50132	76.15886	4.70283				
3.86757	3.69699	32.89906	4.60869	81.22894	4.73814				
4.89639	3.85562	35.26853	4.64748	86.32889	4.77079				
5.99086	3.98816	40.61202	4.72342	91.39839	4.80145				
7.37553	4.12026	45.66470	4.78565	96.47647	4.82997				
8.13102	4.18070	50.72886	4.84082	101.29002	4.85807				
9.18139	4.25425	55.79701	4.89012						
10.22173	4.31838	60.88773	4.93471						
15.65760	4.56003	65.93623	4.97514						
21.75992	4.73524	71.04080	5.01268						
27.34100	4.85222	76.11562	5.04716						
32.81111	4.94309	81.16085	5.07927						
35.22781	4.97848	86.32418	5.10961						
40.65916	5.04790	91.31761	5.13749						
45.66407	5.10353	96.41607	5.16412						
50.76803	5.15384	101.21542	5.19143						
55.80278	5.19829								
60.89826	5.23903								
65.95470	5.27620								
71.04684	5.31053								
76.15140	5.34229								
81.18466	5.37147								
86.26398	5.39917								
91.33523	5.42525								
96.41661	5.44970								
101.23280	5.47492								

13X	BASF								
Lot	F300004063								
0C		10C		25C		50C		75C	
P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)
0.00137	0.03605	0.00205	0.03600	0.00331	0.03594	0.01176	0.03641	0.04113	0.03592
0.00242	0.07211	0.00429	0.07199	0.00657	0.07187	0.02540	0.07275	0.08876	0.07154
0.00330	0.10817	0.00621	0.10798	0.00981	0.10778	0.03968	0.10907	0.13841	0.10702
0.00408	0.14422	0.00790	0.14397	0.01316	0.14365	0.05467	0.14536	0.19782	0.14771
0.00481	0.18027	0.00944	0.17996	0.01664	0.17950	0.07031	0.18163	0.29849	0.21162
0.00557	0.21631	0.01106	0.21592	0.02022	0.21535	0.08675	0.21787	0.38701	0.26444
0.00633	0.25237	0.01267	0.25188	0.02384	0.25117	0.10392	0.25407	0.48673	0.31986
0.00700	0.28842	0.01428	0.28785	0.02762	0.28686	0.19677	0.42274	0.58297	0.37027
0.00770	0.32446	0.01571	0.32383	0.03105	0.32333	0.29412	0.56410	0.67900	0.41662
0.00843	0.36051	0.01721	0.35980	0.03500	0.35978	0.39297	0.68152	0.77997	0.46296
0.00919	0.39654	0.01878	0.39575	0.03932	0.39622	0.48875	0.77664	0.89150	0.50945
0.01009	0.43256	0.02064	0.43168	0.04398	0.43264	0.58808	0.86138	0.99824	0.55187
0.01099	0.46855	0.02253	0.46761	0.04895	0.46907	0.68728	0.93535	2.13397	0.89029
0.01181	0.50457	0.02429	0.50349	0.05431	0.50548	0.80017	1.00653	2.93026	1.05390
0.01271	0.54057	0.02615	0.53930	0.06000	0.54190	0.88049	1.05244	4.02864	1.22712
0.01367	0.57657	0.02812	0.57505	0.06601	0.57831	0.98021	1.10542	4.88009	1.33766
0.01469	0.61255	0.02890	0.61163	0.07243	0.61472	2.04011	1.48529	5.98602	1.45667
0.01590	0.64852	0.03055	0.64816	0.07920	0.65113	2.97144	1.69902	7.07764	1.55821
0.01718	0.68451	0.03278	0.68467	0.08647	0.68752	3.86575	1.85599	8.10111	1.64159
0.01844	0.72048	0.03531	0.72117	0.09422	0.72391	4.94751	2.00909	9.10827	1.71565
0.01980	0.75645	0.03812	0.75767	0.10251	0.76030	5.95931	2.13083	10.12290	1.78336
0.02131	0.79241	0.04125	0.79416	0.19867	1.05271	7.04189	2.24187	15.22148	2.05642
0.02298	0.82832	0.04471	0.83065	0.29302	1.22661	8.08377	2.33652	20.56143	2.27010
0.02493	0.86417	0.04857	0.86714	0.38634	1.35409	9.10817	2.41889	26.04000	2.44277
0.02691	0.89995	0.05284	0.90362	0.48695	1.46223	10.11530	2.49326	31.75965	2.59359
0.02910	0.93565	0.05761	0.94011	0.58151	1.54809	15.29217	2.79312	35.35158	2.67484
0.03076	0.97218	0.06274	0.97658	0.68136	1.62814	20.83828	3.02287	40.55168	2.77979
0.03303	1.00868	0.06849	1.01306	0.79357	1.70697	26.45870	3.20129	45.66196	2.87185
0.03581	1.04515	0.07469	1.04952	0.87762	1.75941	32.21783	3.34728	50.75555	2.95440
0.03907	1.08162	0.08145	1.08597	0.97420	1.81589	35.25279	3.41380	55.85692	3.02847
0.04276	1.11808	0.08894	1.12242	1.93535	2.22530	40.55232	3.51622	60.84076	3.09603
0.04681	1.15453	0.09714	1.15885	2.90109	2.48828	45.67486	3.60161	65.98556	3.15911
0.05132	1.19097	0.10595	1.19526	3.87415	2.68688	50.68998	3.67599	70.96397	3.21755
0.05636	1.22740	0.19259	1.44871	4.93478	2.85703	55.80839	3.74408	76.16119	3.27308
0.06185	1.26383	0.29064	1.64088	5.91932	2.98690	60.88290	3.80424	81.16189	3.32296
0.06780	1.30026	0.38644	1.78545	7.02410	3.11015	65.97163	3.85924	86.25503	3.37042
0.07436	1.33666	0.48434	1.90400	8.12091	3.21529	71.02232	3.90938	91.30976	3.41569
0.08139	1.37307	0.58284	2.00783	9.13093	3.30003	76.11117	3.95597	96.45431	3.45591
0.08909	1.40945	0.68204	2.09716	10.16513	3.37697	81.20096	3.99953	100.34460	3.48666
0.09735	1.44583	0.78807	2.17975	15.37640	3.66932	86.27290	4.03959	100.81209	3.49510
0.10623	1.48219	0.87279	2.23686	21.42666	3.89384	91.29973	4.07667	101.23813	3.50314
0.19487	1.75448	0.99453	2.31646	27.10147	4.04670	96.40228	4.11228		
0.29407	1.96780	2.14659	2.82665	33.08808	4.17192	100.43337	4.13863		
0.38683	2.12512	2.97783	3.05545	35.09036	4.20830	100.80758	4.14323		
0.48829	2.26471	3.99016	3.26084	40.63841	4.29656	101.18999	4.14887		
0.59090	2.38442	4.91046	3.41071	45.68235	4.36576				
0.68604	2.47298	5.93003	3.54482	50.75350	4.42677				
0.77383	2.55228	7.11730	3.67012	55.83649	4.48088				
0.89956	2.64987	8.11687	3.76003	60.90166	4.52973				
0.97865	2.70446	9.15190	3.84111	66.03742	4.57460				
1.93176	3.16994	10.19935	3.91302	71.06648	4.61473				
3.05256	3.48747	15.53496	4.18013	76.15026	4.65217				
3.91239	3.65853	21.81251	4.38210	81.21217	4.68682				
4.85533	3.80371	27.50091	4.51339	86.30948	4.71915				
5.95809	3.93772	33.37263	4.61901	91.37049	4.74943				
7.24598	4.06216	35.18473	4.64792	96.47336	4.77787				
8.13681	4.13401	40.52646	4.72237	100.46168	4.79933				
9.18497	4.20756	45.68482	4.78450	100.82806	4.80472				
10.23616	4.27196	50.72954	4.83795	101.22327	4.80895				
15.58951	4.50967	55.83457	4.88620						
22.08867	4.69440	60.88473	4.92937						
27.70353	4.80939	65.96806	4.96904						
33.58578	4.90448	71.03381	5.00528						
35.14527	4.92715	76.10914	5.03879						
40.65352	4.99694	81.18584	5.07012						
45.67541	5.05213	86.28934	5.09940						
50.73492	5.10152	91.31340	5.12645						
55.81473	5.14599	96.40452	5.15236						
60.91066	5.18623	100.43714	5.17210						
65.99347	5.22286	100.82306	5.17772						
71.04311	5.25648	101.23953	5.18167						
76.10479	5.28764								
81.17853	5.31663								
86.24351	5.34388								
91.32435	5.36944								
96.41653	5.39382								
100.44735	5.41203								
100.80325	5.41545								
101.19540	5.41967								

APG III	UOP Honeywell								
Lot	2010017882								
0C		10C		25C		50C		75C	
P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)
0.00105	0.03604	0.00139	0.03605	0.00211	0.03598	0.00898	0.03678	0.03197	0.03600
0.00185	0.07209	0.00259	0.07208	0.00480	0.07193	0.02022	0.07315	0.07107	0.07174
0.00256	0.10816	0.00370	0.10811	0.00743	0.10784	0.03189	0.10948	0.11169	0.10744
0.00315	0.14423	0.00475	0.14413	0.01008	0.14375	0.04389	0.14581	0.19952	0.18052
0.00371	0.18029	0.00570	0.18016	0.01277	0.17965	0.05626	0.18214	0.29445	0.25483
0.00420	0.21636	0.00665	0.21619	0.01546	0.21552	0.06898	0.21846	0.39769	0.33046
0.00463	0.25244	0.00754	0.25221	0.01813	0.25140	0.08202	0.25478	0.48391	0.38991
0.00501	0.28851	0.00834	0.28823	0.02074	0.28726	0.09549	0.29109	0.59242	0.46070
0.00537	0.32457	0.00910	0.32426	0.02324	0.32317	0.10940	0.32738	0.70430	0.52769
0.00571	0.36064	0.00982	0.36028	0.02564	0.35907	0.19621	0.54891	0.78259	0.57320
0.00604	0.39672	0.01046	0.39628	0.02798	0.39496	0.29465	0.77337	0.87854	0.62827
0.00638	0.43279	0.01117	0.43230	0.03019	0.43087	0.39803	0.94931	0.98775	0.68566
0.00671	0.46885	0.01188	0.46830	0.03248	0.46677	0.49091	1.06756	1.99151	1.09459
0.00706	0.50491	0.01263	0.50432	0.03479	0.50269	0.58021	1.15788	3.04145	1.34916
0.00742	0.54097	0.01338	0.54032	0.03713	0.53859	0.68011	1.24119	3.86476	1.48980
0.00778	0.57703	0.01417	0.57630	0.03950	0.57449	0.79924	1.31981	4.83577	1.61946
0.00817	0.61307	0.01492	0.61230	0.04204	0.61037	0.87850	1.36693	5.97208	1.74609
0.00858	0.64912	0.01581	0.64827	0.04472	0.64626	0.99075	1.42296	7.13832	1.85347
0.00901	0.68515	0.01676	0.68426	0.04755	0.68214	2.18840	1.80965	8.08716	1.93125
0.00947	0.72120	0.01775	0.72024	0.05049	0.71799	2.95186	1.96912	9.10294	2.00611
0.00996	0.75724	0.01880	0.75622	0.05374	0.75382	3.92812	2.13348	10.09998	2.07484
0.01049	0.79327	0.01997	0.79218	0.05721	0.78965	4.85504	2.26679	15.08049	2.35915
0.01105	0.82928	0.02119	0.82813	0.06098	0.82546	5.97213	2.40508	20.46678	2.59980
0.01167	0.86528	0.02254	0.86410	0.06505	0.86126	7.06349	2.52498	25.88474	2.79636
0.01237	0.90128	0.02400	0.90007	0.06947	0.89703	8.07800	2.62493	31.66143	2.96033
0.01313	0.93728	0.02561	0.93600	0.07428	0.93278	9.10107	2.71774	35.25721	3.04440
0.01396	0.97328	0.02737	0.97193	0.07914	0.96938	10.09085	2.80011	40.44496	3.15343
0.01489	1.00926	0.02932	1.00784	0.08479	1.00596	15.11744	3.14320	45.71372	3.24979
0.01590	1.04523	0.03148	1.04377	0.09109	1.04252	20.88811	3.41416	50.74438	3.33095
0.01696	1.08121	0.03388	1.07967	0.09826	1.07905	26.71571	3.59998	55.75273	3.40587
0.01826	1.11716	0.03654	1.11554	0.10618	1.11555	32.57873	3.74666	60.94021	3.47477
0.01972	1.15310	0.03943	1.15140	0.19792	1.37605	35.05608	3.80146	65.90627	3.53711
0.02136	1.18904	0.04279	1.18724	0.29047	1.52842	40.63302	3.90848	71.04131	3.59711
0.02321	1.22495	0.04656	1.22307	0.38516	1.63803	45.65476	3.99230	76.13530	3.65083
0.02531	1.26086	0.05079	1.25884	0.48773	1.73326	50.71962	4.06687	81.14480	3.69963
0.02771	1.29677	0.05554	1.29458	0.57962	1.80600	55.87983	4.13458	86.23089	3.74721
0.03041	1.33264	0.06090	1.33030	0.68915	1.88381	60.86600	4.19376	91.31732	3.79326
0.03350	1.36848	0.06659	1.36685	0.77634	1.93912	65.98271	4.24936	96.44180	3.83507
0.03689	1.40431	0.07327	1.40337	0.87279	1.99749	71.06149	4.29908	100.39251	3.86597
0.04089	1.44010	0.08091	1.43987	0.98948	2.05856	76.08911	4.34525	100.80842	3.87103
0.04539	1.47586	0.08951	1.47634	2.02442	2.48132	81.22560	4.38850	101.22565	3.87547
0.05044	1.51159	0.09927	1.51278	2.93461	2.74537	86.23769	4.42896		
0.05610	1.54726	0.11010	1.54917	4.02660	2.99031	91.34905	4.46671		
0.06208	1.58378	0.20099	1.76518	4.95705	3.15913	96.39408	4.50096		
0.06889	1.62026	0.28996	1.91340	5.88644	3.30331	100.39325	4.52856		
0.07663	1.65672	0.38851	2.04581	6.96825	3.44495	100.84385	4.53392		
0.08516	1.69316	0.48153	2.15173	8.09782	3.57232	101.20858	4.53816		
0.09451	1.72957	0.59003	2.26122	9.12655	3.67323				
0.10467	1.76595	0.68919	2.34787	10.18404	3.76117				
0.19436	2.00995	0.78775	2.42982	15.74750	4.07127				
0.29151	2.20590	0.87391	2.49564	21.66041	4.28545				
0.38569	2.36201	0.97189	2.56422	27.37639	4.43693				
0.49160	2.51009	2.06653	3.11703	33.23652	4.55810				
0.58193	2.62010	2.94131	3.40199	35.09759	4.59190				
0.67932	2.72234	3.88575	3.62834	40.62503	4.68047				
0.77643	2.81967	4.92349	3.81915	45.71210	4.75055				
0.87096	2.89827	5.92169	3.96299	50.75813	4.81150				
0.98164	2.99029	7.14205	4.09940	55.85734	4.86641				
2.08729	3.57967	8.16493	4.18951	60.91464	4.91585				
2.93664	3.84908	9.20055	4.26770	66.01686	4.96107				
3.96262	4.07668	10.24536	4.33690	71.10742	5.00232				
4.81843	4.21547	15.51091	4.59326	76.15041	5.04017				
5.94685	4.35335	21.97872	4.79623	81.26038	5.07573				
7.32408	4.48264	27.49077	4.92096	86.28615	5.10821				
8.14159	4.54655	33.49434	5.02784	91.37387	5.13904				
9.19445	4.61886	35.12351	5.05376	96.46593	5.16831				
10.24877	4.68207	40.64149	5.13033	100.47479	5.19034				
15.60015	4.91618	45.69871	5.19119	100.81391	5.19538				
22.15489	5.10117	50.73866	5.24491	101.21892	5.19945				
27.66043	5.21407	55.84242	5.29357						
33.29113	5.30631	60.90697	5.33730						
35.19851	5.33409	66.00844	5.37757						
40.61574	5.40382	71.03151	5.41384						
45.68448	5.46057	76.12812	5.44799						
50.74445	5.51086	81.17651	5.47963						
55.88934	5.55660	86.27658	5.50928						
60.88993	5.59706	91.32815	5.53704						
65.97579	5.63461	96.41028	5.56327						
71.04757	5.66930	100.43834	5.58322						
76.12976	5.70114	100.81384	5.58862						
81.17032	5.73064	101.21991	5.59275						
86.25933	5.75880								
91.36917	5.78536								
96.41658	5.80976								
100.44436	5.82859								
100.82100	5.83382								
101.23453	5.83776								

5A	Grace Davison Grade 522								
Lot	00009								
0C		10C		25C		50C		75C	
P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)
0.00205	0.03599	0.00257	0.03595	0.00469	0.03581	0.01852	0.03645	0.06204	0.03527
0.00382	0.07199	0.00533	0.07186	0.01066	0.07242	0.04387	0.07265	0.14091	0.06991
0.00563	0.10797	0.00853	0.10773	0.01834	0.10896	0.07480	0.10869	0.19775	0.09185
0.00754	0.14393	0.01223	0.14354	0.02734	0.14547	0.11022	0.14462	0.30207	0.12742
0.00959	0.17987	0.01628	0.17933	0.03746	0.18196	0.19902	0.22124	0.39298	0.15584
0.01179	0.21579	0.02074	0.21507	0.04866	0.21844	0.29694	0.29250	0.50019	0.18680
0.01422	0.25168	0.02558	0.25079	0.06091	0.25491	0.38556	0.34994	0.60785	0.21551
0.01684	0.28755	0.03090	0.28648	0.07416	0.29136	0.48827	0.41008	0.68920	0.23543
0.01963	0.32340	0.03612	0.32308	0.08845	0.32779	0.58878	0.46418	0.77413	0.25599
0.02264	0.35923	0.04205	0.35966	0.10376	0.36422	0.68477	0.51166	0.88190	0.28119
0.02584	0.39506	0.04842	0.39623	0.19564	0.54656	0.78721	0.56000	0.98528	0.30361
0.02924	0.43087	0.05528	0.43279	0.29097	0.70004	0.89583	0.60892	1.92673	0.48188
0.03283	0.46666	0.06257	0.46934	0.38745	0.83597	1.01015	0.65591	3.10352	0.65872
0.03673	0.50244	0.07030	0.50590	0.49099	0.96734	2.07112	1.02047	3.91088	0.76341
0.04066	0.53821	0.07842	0.54245	0.58862	1.08101	2.97063	1.26553	4.98375	0.88802
0.04478	0.57399	0.08693	0.57900	0.68070	1.18060	3.95702	1.49015	6.06137	1.00194
0.04909	0.60975	0.09578	0.61556	0.78854	1.28415	5.03840	1.69562	7.12487	1.10497
0.05356	0.64549	0.10496	0.65212	0.89009	1.37573	5.89671	1.83316	8.08638	1.19293
0.05773	0.68214	0.19528	0.95806	0.97330	1.44590	6.87766	1.96995	9.08998	1.27806
0.06236	0.71878	0.29143	1.22135	1.98887	2.06166	8.10731	2.11488	10.12228	1.35868
0.06718	0.75541	0.38815	1.44628	3.15321	2.44320	9.15434	2.21990	15.14992	1.69087
0.07225	0.79203	0.48267	1.63063	3.95807	2.61184	10.17927	2.30965	20.50586	1.95795
0.07754	0.82865	0.58783	1.80397	5.08789	2.77860	15.65234	2.64313	26.04225	2.16807
0.08301	0.86527	0.69280	1.94508	6.09144	2.88704	21.38357	2.85143	31.57337	2.33300
0.08865	0.90189	0.78009	2.04392	7.11823	2.97399	26.90525	2.98742	35.12646	2.42308
0.09447	0.93851	0.88373	2.14663	8.18616	3.04628	32.71241	3.09183	40.61054	2.53828
0.10044	0.97514	0.98588	2.24523	9.20688	3.10320	35.04174	3.12749	45.59621	2.62665
0.10659	1.01178	1.99688	2.75028	10.29090	3.15490	40.60765	3.19814	50.69302	2.70537
0.19295	1.44210	2.91449	2.96358	15.84864	3.33027	45.66871	3.25170	55.82596	2.77318
0.29693	1.80976	4.10975	3.12589	21.96940	3.44554	50.71739	3.29749	60.82516	2.83270
0.38596	2.04292	5.07981	3.21373	27.39683	3.51683	55.81460	3.33707	65.98874	2.88592
0.48999	2.24255	5.80773	3.26580	32.27576	3.56748	60.86695	3.37242	71.01260	2.93207
0.58115	2.37707	7.17376	3.34158	35.34571	3.59496	65.96224	3.40386	76.06338	2.97596
0.68951	2.50189	8.18229	3.38666	40.67390	3.63583	71.02455	3.43298	81.21756	3.01511
0.78962	2.59063	9.24987	3.42671	45.69935	3.66918	76.14095	3.45926	86.25487	3.05290
0.88528	2.66927	10.34507	3.46182	50.77944	3.69874	81.22042	3.48287	91.38595	3.08612
0.98928	2.73695	14.57645	3.56258	55.86840	3.72535	86.26209	3.50460	96.34427	3.11729
1.96308	3.09243	21.09612	3.66341	60.94901	3.74913	91.30793	3.52465	100.48869	3.13962
3.08077	3.26970	26.69746	3.72451	65.99288	3.77084	96.38001	3.54395	102.63230	3.15444
4.07343	3.36507	31.99025	3.77044	71.09085	3.79096	100.44570	3.55876		
4.81778	3.41821	35.46205	3.79651	76.15506	3.80947	100.80622	3.56165		
5.99488	3.48337	40.58318	3.83005	81.25325	3.82689	101.16141	3.56684		
7.02832	3.52872	45.68244	3.85919	86.31745	3.84330				
8.18782	3.57054	50.76085	3.88515	91.36752	3.85865				
9.21758	3.60266	55.86945	3.90861	96.47395	3.87326				
10.29002	3.63144	60.90354	3.92982	100.48902	3.88445				
14.59797	3.71919	66.01133	3.94946	100.83743	3.88900				
20.93409	3.80573	71.04164	3.96760	101.23791	3.89273				
26.46329	3.86074	76.14844	3.98488						
31.70707	3.90281	81.20087	4.00092						
35.36238	3.92829	86.26140	4.01596						
40.61098	3.96024	91.31988	4.03034						
45.68385	3.98741	96.40348	4.04356						
50.77503	4.01190	100.42180	4.05324						
55.87158	4.03414	100.84254	4.05585						
60.91258	4.05423	101.18300	4.05794						
66.00614	4.07299								
71.05960	4.09028								
76.12257	4.10656								
81.20740	4.12205								
86.25287	4.13658								
91.32550	4.15048								
96.42702	4.16381								
100.42707	4.17421								
100.81032	4.17799								
101.20776	4.18159								

VSA-10	LiLSX								
Lot	2010016788								
0C		10C		25C		50C		75C	
P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)
0.00072	0.03609	0.00102	0.03605	0.00101	0.03607	0.00330	0.03592	0.00881	0.03560
0.00115	0.07218	0.00212	0.07208	0.00182	0.07214	0.00734	0.07178	0.01800	0.07114
0.00149	0.10826	0.00298	0.10815	0.00256	0.10820	0.01091	0.10764	0.02756	0.10663
0.00178	0.14436	0.00363	0.14420	0.00325	0.14427	0.01443	0.14350	0.03752	0.14211
0.00203	0.18045	0.00415	0.18025	0.00390	0.18032	0.01778	0.17934	0.04805	0.17753
0.00224	0.21655	0.00459	0.21633	0.00450	0.21638	0.02108	0.21519	0.05897	0.21294
0.00244	0.25264	0.00497	0.25240	0.00516	0.25244	0.02438	0.25103	0.07057	0.24833
0.00262	0.28873	0.00532	0.28847	0.00583	0.28848	0.02777	0.28688	0.08273	0.28368
0.00279	0.32482	0.00562	0.32455	0.00652	0.32452	0.03125	0.32272	0.09549	0.31985
0.00296	0.36090	0.00591	0.36062	0.00724	0.36055	0.03485	0.35855	0.10910	0.35597
0.00313	0.39700	0.00621	0.39667	0.00799	0.39659	0.03835	0.39438	0.19483	0.54793
0.00330	0.43309	0.00651	0.43275	0.00878	0.43261	0.04231	0.43021	0.29673	0.72572
0.00343	0.46918	0.00682	0.46881	0.00960	0.46861	0.04642	0.46601	0.38991	0.85429
0.00361	0.50528	0.00712	0.50486	0.01046	0.50463	0.05075	0.50178	0.49200	0.97195
0.00380	0.54136	0.00743	0.54092	0.01136	0.54063	0.05525	0.53757	0.58413	1.06353
0.00400	0.57744	0.00777	0.57699	0.01232	0.57662	0.05973	0.57335	0.68509	1.14862
0.00420	0.61354	0.00812	0.61303	0.01333	0.61261	0.06477	0.60911	0.79183	1.22688
0.00440	0.64961	0.00849	0.64909	0.01439	0.64857	0.06980	0.64486	0.87678	1.28177
0.00461	0.68570	0.00888	0.68514	0.01543	0.68455	0.07538	0.68058	0.97577	1.34023
0.00482	0.72177	0.00915	0.72118	0.01662	0.72052	0.08122	0.71629	2.04366	1.74746
0.00504	0.75784	0.00960	0.75723	0.01786	0.75649	0.08731	0.75197	2.94902	1.94590
0.00527	0.79392	0.01006	0.79326	0.01909	0.79245	0.09281	0.78844	4.06262	2.11671
0.00550	0.82999	0.01041	0.82929	0.02048	0.82842	0.09922	0.82485	4.84963	2.21064
0.00574	0.86607	0.01093	0.86533	0.02192	0.86437	0.10635	0.86123	5.97831	2.32182
0.00599	0.90212	0.01146	0.90136	0.02338	0.90032	0.19380	1.17817	7.25282	2.42333
0.00625	0.93820	0.01188	0.93738	0.02500	0.93628	0.29188	1.40446	8.10424	2.48273
0.00652	0.97426	0.01250	0.97341	0.02671	0.97223	0.38734	1.56520	9.12901	2.54558
0.00680	1.01032	0.01313	1.00942	0.02851	1.00815	0.48930	1.68700	10.15026	2.60295
0.00709	1.04638	0.01365	1.04543	0.03042	1.04408	0.58318	1.77967	15.41413	2.83076
0.00740	1.08244	0.01435	1.08142	0.03244	1.08000	0.68728	1.86252	20.99114	3.00543
0.00771	1.11848	0.01510	1.11742	0.03458	1.11590	0.77929	1.91623	26.59876	3.14198
0.00805	1.15454	0.01574	1.15343	0.03686	1.15181	0.88321	1.97084	32.26329	3.25792
0.00840	1.19059	0.01658	1.18940	0.03920	1.18770	0.98706	2.02266	35.24007	3.31253
0.00877	1.22661	0.01746	1.22539	0.04180	1.22359	2.13035	2.40600	40.59603	3.40140
0.00916	1.26265	0.01825	1.26138	0.04458	1.25947	2.96725	2.56581	45.68656	3.47805
0.00958	1.29868	0.01925	1.29734	0.04754	1.29534	4.11857	2.72208	50.78921	3.54833
0.01003	1.33471	0.02031	1.33332	0.05070	1.33120	4.84892	2.80075	55.87428	3.61255
0.01051	1.37075	0.02130	1.36930	0.05399	1.36704	5.99313	2.90454	60.84558	3.67298
0.01102	1.40677	0.02251	1.40525	0.05762	1.40286	7.36371	3.00746	66.03635	3.73078
0.01157	1.44278	0.02380	1.44121	0.06153	1.43868	8.11554	3.05663	71.00054	3.78320
0.01218	1.47879	0.02503	1.47717	0.06575	1.47446	9.13838	3.11720	76.09907	3.83569
0.01283	1.51480	0.02653	1.51313	0.07027	1.51024	10.15779	3.17329	81.22218	3.88381
0.01356	1.55078	0.02813	1.54908	0.07504	1.54600	15.31418	3.39789	86.20305	3.92997
0.01438	1.58677	0.02969	1.58502	0.08027	1.58173	21.14884	3.58986	91.35865	3.97436
0.01522	1.62276	0.03156	1.62096	0.08592	1.61745	26.68460	3.73821	96.37494	4.01556
0.01612	1.65873	0.03356	1.65688	0.09197	1.65303	32.57339	3.87284	100.41726	4.04833
0.01708	1.69471	0.03572	1.69278	0.09825	1.68937	35.30368	3.92990	100.79120	4.05480
0.01813	1.73068	0.03805	1.72868	0.10524	1.72569	40.64372	4.03210	101.20484	4.06337
0.01925	1.76664	0.04042	1.76458	0.19632	2.02732	45.74537	4.12086		
0.02049	1.80261	0.04319	1.80047	0.28937	2.20661	50.71189	4.20149		
0.02172	1.83857	0.04617	1.83634	0.38783	2.33505	55.85862	4.27749		
0.02320	1.87454	0.04942	1.87217	0.48482	2.43031	60.84799	4.34707		
0.02480	1.91048	0.05295	1.90800	0.58985	2.51282	66.00688	4.41360		
0.02656	1.94641	0.05666	1.94381	0.69500	2.58151	71.01248	4.47430		
0.02848	1.98234	0.06089	1.97958	0.78126	2.63005	76.09860	4.53352		
0.03059	2.01824	0.06551	2.01535	0.88816	2.68155	81.19218	4.58878		
0.03291	2.05414	0.07054	2.05108	0.99754	2.72932	86.24214	4.64048		
0.03547	2.09003	0.07607	2.08680	1.99531	3.01911	91.32869	4.69010		
0.03820	2.12589	0.08197	2.12249	3.06552	3.20842	96.43916	4.73718		
0.04132	2.16175	0.08864	2.15815	3.94166	3.32490	100.41669	4.77225		
0.04479	2.19758	0.09549	2.19451	4.93009	3.43375	100.80442	4.78011		
0.04862	2.23337	0.10340	2.23082	6.03731	3.53752	101.27545	4.78582		
0.05287	2.26916	0.19736	2.49553	6.75902	3.59813				
0.05750	2.30492	0.28985	2.64693	8.09964	3.69925				
0.06277	2.34065	0.38900	2.75624	9.11988	3.76900				
0.06854	2.37634	0.48467	2.83755	10.14588	3.83348				
0.07507	2.41197	0.58598	2.90818	15.22271	4.10140				
0.08233	2.44756	0.70226	2.97550	21.10687	4.34384				
0.09042	2.48306	0.78871	3.01884	26.88054	4.53781				
0.09926	2.51933	0.89463	3.06580	32.65747	4.70105				
0.10933	2.55554	1.01182	3.11074	35.18967	4.76547				
0.19299	2.75555	1.93732	3.38161	40.64405	4.89008				
0.29115	2.89974	3.08843	3.60180	45.60335	4.99062				
0.38659	2.99934	3.94781	3.72901	50.77128	5.08425				
0.48570	3.08146	4.93082	3.85436	55.82600	5.16693				
0.58832	3.15219	6.06128	3.97875	60.91479	5.24252				
0.70227	3.21952	7.31558	4.10045	66.02291	5.31142				
0.78697	3.26469	8.09722	4.16957	71.05961	5.37396				
0.89475	3.31507	9.09900	4.25265	76.14627	5.43209				
1.00348	3.36177	10.12039	4.33154	81.24970	5.48619				
1.93571	3.65472	15.07791	4.64857	86.29912	5.53576				
2.97027	3.87938	21.19802	4.94087	91.35146	5.58221				
4.03677	4.06267	26.96905	5.15146	96.44039	5.62616				
4.88992	4.18943	33.05897	5.32721	100.45718	5.65890				
5.97348	4.33139	35.00479	5.37694	100.81112	5.66384				
7.15700	4.46905	40.63618	5.50221	101.20383	5.66922				
8.09658	4.56708	45.69990	5.59890						
9.10833	4.66361	50.72418	5.68283						
10.13480	4.75363	55.82442	5.75795						
15.19775	5.10500	60.87656	5.82466						
21.54902	5.40663	66.00828	5.88581						
27.41125	5.60609	71.02076	5.93995						
33.07758	5.75506	76.10247	5.99025						
35.03331	5.79967	81.19506	6.03656						
40.49761	5.90857	86.24868	6.07886						
45.70157	5.99617	91.33481	6.11865						
50.69867	6.06909	96.38420	6.15530						
55.79347	6.13461	100.43333	6.18336						
60.88466	6.19290	100.81177	6.18862						
66.03381	6.24577	101.20860	6.19364						
71.03427	6.29247								
76.09015	6.33548								
81.25341	6.37574								
86.24465	6.41181								
91.32679	6.44624								
96.40945	6.47810								
100.43801	6.50201								
100.81428	6.50654								
101.21881	6.51077								

4A	Grace Davison Grade 514								
Lot	275914								
0C		10C		25C		50C		75C	
P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)	P (kPa)	q (mol/kg)
0.00182	0.03733	0.00192	0.03732	0.00237	0.03731	0.00453	0.03849	0.00677	0.03934
0.00335	0.07467	0.00400	0.07463	0.00613	0.07451	0.01852	0.07678	0.04780	0.07777
0.00468	0.11202	0.00592	0.11195	0.00971	0.11254	0.03623	0.11491	0.11011	0.11516
0.00588	0.14937	0.00780	0.14925	0.01386	0.15054	0.05572	0.15298	0.19400	0.16015
0.00699	0.18673	0.00969	0.18655	0.01839	0.18853	0.07686	0.19100	0.29335	0.20660
0.00805	0.22407	0.01160	0.22382	0.02325	0.22653	0.09935	0.22896	0.39540	0.25140
0.00909	0.26141	0.01364	0.26109	0.02851	0.26455	0.12343	0.26684	0.50433	0.29734
0.01013	0.29875	0.01575	0.29832	0.03417	0.30257	0.19422	0.36635	0.58566	0.32921
0.01117	0.33605	0.01796	0.33555	0.04018	0.34060	0.29155	0.48213	0.69834	0.36841
0.01228	0.37337	0.02028	0.37278	0.04665	0.37863	0.39464	0.58429	0.80118	0.40405
0.01343	0.41067	0.02278	0.41000	0.05349	0.41667	0.48434	0.66188	0.90351	0.43954
0.01477	0.44795	0.02539	0.44721	0.06081	0.45471	0.59557	0.74755	0.97640	0.46237
0.01601	0.48524	0.02714	0.48526	0.06859	0.49275	0.69896	0.81644	2.08469	0.73745
0.01735	0.52254	0.02950	0.52328	0.07691	0.53079	0.77970	0.86448	3.01230	0.90484
0.01892	0.55981	0.03235	0.56128	0.08599	0.56883	0.87673	0.91834	3.89165	1.03214
0.02042	0.59708	0.03553	0.59928	0.09579	0.60685	0.98509	0.97396	4.94007	1.15491
0.02205	0.63435	0.03911	0.63729	0.10621	0.64487	2.12034	1.35497	6.02288	1.26035
0.02379	0.67160	0.04293	0.67530	0.19658	0.90166	2.89197	1.51293	7.16138	1.35509
0.02568	0.70885	0.04717	0.71332	0.29338	1.08608	3.91593	1.66423	8.11221	1.42353
0.02774	0.74608	0.05163	0.75134	0.38577	1.22087	4.93177	1.77719	9.12526	1.48852
0.02993	0.78333	0.05654	0.78938	0.49242	1.33879	5.98368	1.86881	10.14699	1.54669
0.03152	0.82135	0.06179	0.82742	0.58731	1.42375	7.30495	1.96117	15.47957	1.77056
0.03354	0.85935	0.06747	0.86547	0.69324	1.49810	8.11280	2.00949	20.83007	1.92341
0.03600	0.89733	0.07352	0.90353	0.78934	1.56000	9.14581	2.06268	26.26860	2.03982
0.03888	0.93531	0.07994	0.94158	0.88941	1.61384	10.18373	2.10941	31.82388	2.13362
0.04206	0.97330	0.08688	0.97965	0.98696	1.66293	15.56426	2.28661	35.32544	2.18457
0.04552	1.01128	0.09446	1.01770	2.00351	1.96362	21.15393	2.41172	40.60013	2.25154
0.04938	1.04927	0.10250	1.05576	2.89100	2.10776	26.57313	2.50316	45.68850	2.30709
0.05354	1.08727	0.19610	1.35920	3.87839	2.21742	32.32748	2.58128	50.72993	2.35669
0.05805	1.12528	0.29234	1.54241	4.86439	2.30114	35.23577	2.61655	55.82837	2.40148
0.06294	1.16329	0.38872	1.67004	5.99773	2.37785	40.64195	2.67303	60.90063	2.44152
0.06828	1.20130	0.48276	1.75941	6.79700	2.42375	45.64417	2.71932	65.94675	2.47790
0.07417	1.23932	0.58048	1.83340	8.13960	2.48867	50.77881	2.76159	71.01816	2.51339
0.08048	1.27735	0.69949	1.90352	9.17766	2.53233	55.80154	2.79938	76.16371	2.54635
0.08741	1.31537	0.78045	1.94605	10.18648	2.57015	60.91638	2.83416	81.18725	2.57572
0.09503	1.35339	0.89985	1.99631	15.54267	2.72213	66.00832	2.86630	86.27248	2.60305
0.10328	1.39141	0.99458	2.03372	21.37048	2.83826	71.05398	2.89556	91.30462	2.62894
0.19944	1.67559	2.16819	2.29761	26.80286	2.92246	76.11113	2.92333	96.44525	2.65287
0.29063	1.82472	3.06376	2.41380	32.14401	2.99060	81.20597	2.94937	101.18518	2.67884
0.38620	1.92837	4.02603	2.50530	35.31188	3.02667	86.28130	2.97359		
0.48521	2.00690	4.94921	2.57575	40.55710	3.07900	91.35630	2.99664		
0.58642	2.06999	6.02365	2.64485	45.68665	3.12444	96.42271	3.01842		
0.67659	2.11666	6.85271	2.69025	50.79996	3.16497	101.20055	3.04055		
0.78589	2.16487	8.13803	2.75031	55.85004	3.20127				
0.90517	2.20955	9.15537	2.79217	60.94017	3.23469				
0.97113	2.23265	10.20598	2.83183	66.00724	3.26547				
2.12695	2.47560	15.48774	2.98046	71.06131	3.29382				
3.07221	2.59560	21.39898	3.09899	76.16206	3.32072				
4.08720	2.69111	26.99994	3.18540	81.26742	3.34570				
4.95781	2.75730	32.18540	3.25154	86.31150	3.36909				
6.04229	2.82530	35.39726	3.28839	91.41856	3.39121				
6.85728	2.86974	40.62332	3.34088	96.45086	3.41206				
8.13881	2.93009	45.65595	3.38585	101.29431	3.43423				
9.15985	2.97265	50.74401	3.42677						
10.20117	3.01130	55.82430	3.46371						
15.48972	3.16085	60.89204	3.49783						
21.51423	3.28065	65.98834	3.52931						
27.00949	3.36524	71.03770	3.55838						
32.21227	3.43161	76.11400	3.58577						
35.31163	3.46711	81.16810	3.61123						
40.61963	3.52033	86.25271	3.63555						
45.66539	3.56538	91.32639	3.65855						
50.76856	3.60668	96.41133	3.68049						
55.82868	3.64378	101.21850	3.70387						
60.93853	3.67814								
65.99032	3.70957								
71.06662	3.73916								
76.12670	3.76651								
81.17645	3.79250								
86.27521	3.81702								
91.32789	3.84010								
96.39551	3.86234								
101.23429	3.88579								

Acknowledgements

The primary author would like to thank Dr. Armin Ebner and Dr. Jim Ritter from the Department of Chemical Engineering at the University of South Carolina for their expertise in adsorption isotherm analysis and support in operational aspects of the ASAP 2020. We would also like to thank Dr. Jim Knox and Gregory Cmarik for their continued support for the organization of technical interchange meetings and guidance.

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