


APPENDIX

Appendix A

77-1316		Wavelength= 1.54060								C	
SiO2		2 θ	Int	h	k	l	2 θ	Int	h	k	l
Silicon Oxide		21.990	999*	1	0	1	60.330	22	3	1	1
		25.318	7	1	1	0	62.040	25	3	0	2
		28.451	83	1	1	1	65.113	19	3	1	2
Cristobalite, syn		31.453	103	1	0	2	65.652	13	2	0	4
Rad.: CuK α 1: 1.54060	Filter: d-sp: Calculated	36.109	121	2	0	0	66.843	11	2	2	3
Cut off: 17.7	Int.: Calculated	36.386	42	1	1	2	67.935	1	3	2	0
	I/Cor.: 4.91	38.448	1	2	0	1	68.639	18	2	1	4
Ref: Calculated from ICSD using POWD-12++, (1997)		40.548	1	2	1	0	69.456	9	3	2	1
Ref: Pluth, J.J., Smith, J.V., Faber, J., J. Appl. Phys., 57, 1045 (1985)		42.681	24	2	1	1	69.804	6	3	0	3
		43.161	2	1	0	3	70.500	15	1	0	5
		44.847	21	2	0	2	72.710	18	3	1	3
Sys.: Tetragonal	S.G.: P4 $_1$ 2 $_1$ 2 (92)	47.046	44	1	1	3	73.394	1	1	1	5
a: 4.9709(1)	b: c: 6.9278(2)	48.627	43	2	1	2	73.933	17	3	2	2
	A: C: 1.3937	51.991	4	2	2	0	76.610	1	4	0	0
α :	β :	γ :	Z: 4	mp:			52.816	7	0	0	4
Ref: Ibid.							53.767	1	2	2	1
							54.172	22	2	0	3
							56.196	4	1	0	4
Dx: 2.331	Dm: ICSD #: 047220	57.110	30	3	0	1	80.088	1	3	0	4
		57.498	12	2	1	3	80.861	2	4	1	1
		58.685	4	3	1	0	81.192	11	3	2	3
Peak height intensity. R-factor: 0.000. PSC: tP12. Mwt: 60.08. Volume[CD]: 171.18.		58.877	4	2	2	2	81.853	11	2	1	5
		59.448	1	1	1	4	82.211	4	3	3	0

2 θ	Int	h	k	l
82.376	3	4	0	2
82.870	6	3	1	4
83.638	3	3	3	1
85.145	1	4	1	2
86.455	1	1	0	6
87.901	4	3	3	2
89.210	15	4	2	1
89.210	15	1	1	6
89.482	10	4	0	3

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Appendix Figure A2 XRD reference data of silicon oxide in synthesis cristobalite form


08-0013		Wavelength= 1.5418									
κ -Al ₂ O ₃		2 θ	Int	h	k	l	2 θ	Int	h	k	l
Aluminum Oxide		14.449	20				57.687	20			
		16.233	20				60.077	40			
		19.596	20				61.579	10			
		28.332	10				62.547	40			
Rad.: CuK α λ : 1.5418 Filter: Ni Beta d-sp:		29.281	40				64.334	60			
Cut off: Int.: Estimation I/Cor.:		30.088	10				65.039	80			
Ref: Rooksby, H., X-Ray Identification and Crystal Structures of Clay, 264 (1951)		31.387	50				66.661	40			
		31.962	70				67.698	10Cb			
		32.929	80				70.301	20			
		34.911	100				72.289	20			
Sys.: S.G.:		36.680	80				73.132	20			
		36.993	20				73.863	20			
a:	b:	c:	A:	C:			75.163	20			
							40.073	30			
α :	β :	γ :	Z:	mp:			42.647	90			
Ref:							44.178	10			
							44.870	60			
							46.473	10			
Dx:	Dm:	SS/FOM: F =					47.503	40			
							48.664	50			
							49.974	10			
							50.898	20			
Synthetic form - produced at low temperature, said to be a mixture of "new" κ alumina and θ alumina.							52.499	10			
* Reflections corresponding to those of θ alumina.							53.796	10			
Deleted by JVS March 8, 1960. Mwt: 101.96.							56.263	50			



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Appendix Figure A3 XRD reference data of aluminum oxide in κ -Al₂O₃ form

83-2080		Wavelength= 1.54060								C	
Al ₂ O ₃		2 θ	Int	h	k	l	2 θ	Int	h	k	l
Aluminum Oxide		25.568	683	0	1	2	86.472	27	1	2	8
		35.140	999*	1	0	4	88.968	62	0	2	10
		37.763	460	1	1	0					
Corundum - synthetic		41.668	5	0	0	6					
Rad.: CuK α 1: 1.54060	Filter: d-sp: Calculated	43.339	961	1	1	3					
		46.161	14	2	0	2					
Cut off: 17.7	Int.: Calculated I/ cor.: 1.00	52.533	467	0	2	4					
Ref: Calculated from ICSD using POWD-12++, (1997)		57.482	906	1	1	6					
Ref: Finger, L.W., Hazen, R.M., Year Book Carnegie Inst. Washington, 76, 525 (1977)		59.717	23	2	1	1					
		61.106	33	1	2	2					
		61.286	83	0	1	8					
Sys.: Rhombohedral	S.G.: R $\bar{3}c$ (167)	66.493	343	2	1	4					
a: 4.7607(9)	b: c: 12.995(2) A: C: 2.7296	68.181	521	3	0	0					
α :	β : γ : Z: 6 mp:	70.391	11	1	2	5					
Ref: Ibid.		74.277	13	2	0	8					
		76.854	145	1	0	10					
		77.213	85	1	1	9					
		80.389	8	2	1	7					
		80.664	57	2	2	0					
Dx: 3.983	Dm: ICSD #: 200140	83.184	6	0	3	6					
		84.320	45	2	2	3					
Peak height intensity. R-factor: 0.030. PSC: hR10. Mwt: 101.96. Volume[CD]: 255.06.		85.102	3	1	3	1					
		86.313	33	3	1	2					

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Appendix Figure A4 XRD reference data of aluminum oxide in corundum form

82-0512		Wavelength= 1.54060								C	
SiO ₂		2 θ	Int	h	k	l	2 θ	Int	h	k	l
Silicon Oxide		21.762	999*	1	0	1	61.491	19	3	0	2
		25.184	5	1	1	0	64.547	29	2	0	4
		28.212	72	1	1	1	64.547	29	3	1	2
Cristobalite		30.962	87	1	0	2	66.039	12	2	2	3
Rad.: CuK α 1: 1.54060 Filter: d-sp: Calculated		35.914	159	1	1	2	67.511	21	2	1	4
		35.914	159	2	0	0	67.511	21	3	2	0
Cut off: 17.7 Int.: Calculated I/Cor.: 5.35		38.172	1	2	0	1	68.965	21	1	0	5
Ref: Calculated from ICSD using POWD-12++, (1997)		40.326	1	2	1	0	68.965	21	3	2	1
Ref: Lacks, D.J., Gordon, R.G., Phys. Rev. B: Condens. Matter, 48, 2889 (1993)		42.385	20	1	0	3	71.877	15	1	1	5
		42.385	20	2	1	1	71.877	15	3	1	3
		44.363	28	2	0	2	73.310	15	3	2	2
Sys.: Tetragonal S.G.: P4 ₁ 2 ₁ 2 (92)		46.269	40	1	1	3	76.118	8	2	2	4
a: 4.997 b: c: 7.07 A: C: 1.4148		48.133	43	2	1	2	76.118	8	4	0	0
α : β : γ : Z: 4 mp:		51.674	6	0	0	4	77.535	10	2	0	5
Ref: Ibid.		51.674	6	2	2	0	77.535	10	4	0	1
		53.400	23	2	0	3	78.927	12	3	0	4
		53.400	23	2	2	1	78.927	12	4	1	0
		55.068	4	1	0	4	80.281	24	2	1	5
Dx: 2.261 Dm: ICSD #: 074530		56.734	47	2	1	3	80.281	24	3	2	3
		56.734	47	3	0	1	81.670	11	3	1	4
		58.349	5	2	2	2	81.670	11	4	0	2
Peak height intensity. R-factor: 0.112. PSC: tP12. Mwt: 60.08. Volume[CD]: 176.54.		58.349	5	3	1	0	83.063	3	3	3	1
		59.934	18	3	1	1	84.429	2	1	0	6

2 θ	Int	h	k	l
84.429	2	4	1	2
87.120	15	1	1	6
87.120	15	3	3	2
88.526	12	4	0	3
88.526	12	4	2	1
89.869	3	3	2	4




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Appendix Figure A5 XRD reference data of silicon oxide in cristobalite form

79-1455		Wavelength= 1.54060								C		
Al4.59Si1.41O9.7		2 θ	Int	h	k	l	2 θ	Int	h	k	l	
Aluminum Silicon Oxide												
		16.435	590	1	1	0	53.590	34	2	3	1	
		23.111	1	0	2	0	53.851	71	3	2	1	
		23.536	22	2	0	0	54.056	111	4	2	0	
Mullite - synthetic												
		25.980	650	1	2	0	57.568	139	0	4	1	
		26.266	999*	2	1	0	58.362	53	4	0	1	
Rad.:	CuK α 1:	1.54060	Filter:	d-sp:	Calculated							
		30.984	183	0	0	1	58.969	13	1	4	1	
Cut off:	17.7	Int.:	Calculated	I/Icor.:	0.83							
Ref:	Calculated from ICSD using POWD-12+, (1997)											
Ref:	Ban, T., Okada, K., J. Am. Ceram. Soc., 75, 227 (1992)											
		37.000	133	1	3	0	60.878	190	4	3	0	
		37.556	12	3	1	0	61.469	5	1	5	0	
		39.008	8	0	2	1	62.613	3	5	1	0	
Sys.:	Orthorhombic	S.G.:	Pbam (55)	39.274	174	2	0	1	63.056	5	2	4
a:	7.5539(2)	b:	7.6909(2)	c:	2.88391(6)	A:	0.9822	C:	0.3750	40.864	555	1
										63.621	74	4
										64.580	165	0
										64.580	165	0
										65.466	34	2
										65.466	34	2
										66.434	55	5
										66.434	55	5
Ref:	Ibid.											
		47.235	10	0	4	0	67.145	10	1	1	2	
		48.145	62	4	0	0	69.566	15	3	4	1	
		48.838	8	1	4	0	69.566	15	0	2	2	
		49.008	5	1	3	1	69.743	39	4	4	0	
		49.453	87	3	1	1	69.743	39	2	0	2	
		50.783	14	3	3	0	69.880	19	4	3	1	
		53.430	61	2	4	0	70.431	103	1	5	1	
Dx:	3.158	Dm:	ICSD #: 066449									
Peak height intensity. R-factor: 0.011. PSC: oP15.70. Mwt: 318.64. Volume[CD]: 167.54.												

2 θ	Int	h	k	l
70.841	40	1	2	2
70.974	60	2	1	2
71.500	27	5	1	1
71.866	16	3	5	0
72.572	9	5	3	0
73.875	12	0	6	0
74.184	105	2	5	1
74.585	42	2	2	2
75.101	107	5	2	1
75.101	107	1	6	0
75.446	33	6	0	0
76.630	17	6	1	0
76.827	32	1	3	2
77.173	9	3	1	2
78.256	16	4	4	1
78.782	4	2	6	0
80.152	6	6	2	0
80.474	25	4	5	0
80.474	25	2	3	2
80.687	17	3	2	2
80.978	23	5	3	1
82.239	1	0	6	1
83.440	1	1	6	1
83.765	4	6	0	1
83.765	4	0	4	2
84.463	10	4	0	2
84.983	1	1	4	2
85.616	4	4	1	2
85.944	6	6	3	0
86.474	4	3	3	2
87.028	10	2	6	1
88.375	6	6	2	1
88.564	18	2	4	2
88.683	14	4	5	1
89.070	35	4	2	2
89.070	35	5	4	1

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Appendix Figure A6 XRD reference data of aluminum silicon oxide in mullite form


74-2369		Wavelength= 1.54060			C	
Na ₂ WO ₄		2 θ	Int	h	k	l
Sodium Tungsten Oxide		16.806 855		1	1	1
		27.612 999*		2	2	0
		32.499 937		3	1	1
		33.988 5		2	2	2
Rad.: CuK α 1; 1.54060 Filter:		39.447 19	d-sp: Calculated	4	0	0
		43.155 143		3	3	1
Cut off: 17.7 Int.: Calculated		48.828 341	l/oor.: 9.10	4	2	2
Ref: Calculated from ICSD using POWD-12++, (1997)		52.004 251		5	1	1
Ref: Sadikov, G.G., Shishakov, N.A., Izv. Akad. Nauk SSSR, Ser		57.015 249		4	4	0
Khim., 1965, 1277 (1965)		59.886 113		5	3	1
		64.499 123		6	2	0
Sys.: Cubic		67.181 76	S.G.: Fd3m (227)	5	3	3
		71.540 6		4	4	4
a: 9.13	b:	74.101 52	A:	5	5	1
c:	A:	78.302 121	C:	6	4	2
α :	β :	80.791 117	Z: 8	7	3	1
γ :	Z: 8	84.902 25	mp:	8	0	0
Ref: Ibid.		87.355 11		7	3	3
Dx: 5.129	Dm:		ICSD #: 028474			
Peak height Intensity. R-factor: 0.050. PSC: cF56. Mwt: 293.83. Volume[CD]: 761.05.						

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Appendix Figure A7 XRD reference data of Na₂WO₄

73-1826					Wavelength= 1.54060					C
Mn ₂ O ₃	2 θ	Int	h	k	l	2 θ	Int	h	k	l
Manganese Oxide	16.289	1	1	1	1	42.896	7	2	0	4
	18.819	11	0	0	2	42.896	7	4	2	0
	18.819	11	0	2	0	44.023	1	1	4	2
	21.087	1	0	2	1	44.023	1	4	2	1
	21.087	1	2	1	0	45.120	91	3	2	3
Rad.: CuK α 1: 1.54060 Filter:						45.120	91	3	3	2
						47.244	12	2	4	2
Cut off: 17.7 Int.: Calculated						47.244	12	4	2	2
I/ICor.: 5.07						48.300	2	3	0	4
Ref: Calculated from ICSD using POWD-12++, (1997)						48.300	2	4	3	0
Ref: Norrestam, R., Acta Chem. Scand., 21, 2871 (1967)						49.309	106	3	4	1
						49.309	106	4	3	1
Sys.: Orthorhombic	S.G.: Pbca (61)					50.332	1	3	3	3
a: 9.4118(8) b: 9.4177(7) c: 9.4233(7) A: 0.9994 C: 1.0006						50.332	1	5	1	1
α :	β :	γ :	Z: 16	mp:		52.282	1	3	4	2
Ref. Ibrid.						52.282	1	4	3	2
						53.227	21	1	5	2
						53.227	21	5	2	1
						55.123	293	4	0	4
Dx: 5.022 Dm:	ICSD #: 024342					55.123	293	4	4	0
						56.068	2	4	1	4
						56.068	2	4	4	1
Peak height intensity. R-factor: 0.030. C.D. Cell: a=9.418,						56.971	16	3	4	3
b=9.423, c=9.412, a/b=0.9994, c/b=0.9988, S.G.=Pbca(61).						56.971	16	4	3	3
PSC: oP80. Mwt: 157.87. Volume[CD]: 835.26.										


2 θ	Int	h	k	l	2 θ	Int	h	k	l
57.871	1	1	5	3	80.178	9	7	3	2
57.871	1	5	3	1	81.801	12	0	8	0
58.781	4	0	6	0	81.801	12	8	0	0
58.781	4	6	0	0	82.513	1	0	8	1
59.672	1	0	6	1	82.513	1	8	1	0
59.672	1	6	1	0	83.228	16	1	1	8
60.557	28	1	6	1	83.228	16	8	1	1
60.557	28	6	1	1	84.832	10	2	8	0
62.299	9	0	6	2	84.832	10	8	2	0
62.299	9	6	2	0	85.609	1	4	7	2
63.169	2	2	6	1	85.609	1	8	2	1
63.169	2	6	1	2	86.382	14	5	6	3
64.047	54	4	5	1	86.382	14	6	5	3
64.047	54	5	4	1	87.901	5	2	8	2
64.889	1	3	5	3	87.901	5	8	2	2
64.889	1	5	3	3	88.659	1	0	8	3
65.683	132	2	2	6	88.659	1	8	3	0
65.683	132	6	2	2	89.427	9	1	8	3
66.545	1	4	2	5	89.427	9	8	3	1
66.545	1	4	5	2					
67.423	35	6	1	3					
67.423	35	6	3	1					
69.039	28	4	4	4					
69.852	1	2	6	3					
69.852	1	6	3	2					
70.678	6	4	5	3					
70.678	6	5	4	3					
71.435	1	1	1	7					
71.435	1	5	1	5					
71.530	1	5	5	1					
71.530	1	7	1	1					
72.269	10	4	0	6					
72.269	10	6	4	0					
73.136	1	2	7	0					
73.136	1	7	0	2					
73.894	17	2	7	1					
73.894	17	7	1	2					
75.493	8	4	6	2					
75.493	8	6	2	4					
76.281	1	5	4	4					
76.281	1	7	2	2					
77.830	1	3	5	5					
77.830	1	5	5	3					
79.443	1	6	4	3					
79.443	1	6	5	0					
80.178	9	5	1	6					

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Appendix Figure A8 XRD reference data of Mn₂O₃

72-0478		Wavelength= 1.54060								C	
MnWO ₄		2 θ	Int	h	k	l	2 θ	Int	h	k	l
Manganese Tungsten Oxide		15.397	159	0	1	0	51.000	12	0	3	1
		18.381	614	1	0	0	51.246	201	1	3	0
		23.590	556	0	1	1	51.773	31	1	2	2
		24.064	396	1	1	0	52.169	143	2	0	2
		29.837	999*	1	1	1	52.364	93	1	2	2
		30.302	944	1	1	1	52.501	152	2	2	1
		31.080	231	0	2	0	53.086	160	2	2	1
		35.973	373	0	0	2	53.339	123	2	0	2
		35.973	373	0	2	1	54.526	31	1	3	1
		36.349	86	1	2	0	54.729	25	2	1	2
		37.258	164	2	0	0	54.811	24	1	3	1
		39.340	11	0	1	2	55.862	9	2	1	2
		40.330	133	1	0	2	57.262	18	3	0	0
		40.534	38	2	1	0	57.655	37	0	1	3
		40.534	38	1	2	1	59.674	14	3	1	0
		40.912	173	1	2	1	60.654	125	1	3	3
		41.044	109	1	0	2	61.452	92	1	1	3
		43.411	50	1	2	2	61.776	44	2	3	0
		44.084	59	1	1	2	61.981	66	2	2	2
		44.241	78	2	1	1	62.398	98	3	1	1
		44.905	82	2	1	1	63.030	57	2	2	2
		47.390	30	0	3	0	63.183	121	3	1	1
		48.261	140	0	2	2	63.938	81	1	3	2
		49.280	131	2	2	0	64.456	100	1	3	2
Rad.: CuK α 1 λ : 1.54060	Filter:	d-sp: Calculated									
Cut off: 17.7	Int.: Calculated	I/Cor.: 5.07									
Ref: Calculated from ICSD using POWD-12++, (1997)											
Ref: Weitzel, H., Z. Kristallogr., Kristallgeom., Kristallphys., Kristallchem., 144, 238 (1976)											
Sys.: Monoclinic	S.G.: P2/c (13)										
a: 4.8238(7)	b: 5.7504(1)	c: 4.9901(8)	A: 0.8389	C: 0.8678							
α :	β : 91.180(1)	γ :	Z: 2	mp:							
Ref: Ibid.											
Dx: 7.266	Dm:	ICSD #: 015850									
Peak height intensity. R-factor: 0.038. C.D. Cell: a=4.990, b=5.750, c=4.824, β =91.18, a/b=0.8678, c/b=0.8389, S.G.=P2/a(13). PSC: mP12. Mwt: 302.79. Volume[CD]: 138.39.											

2 θ	Int	h	k	l	2 θ	Int	h	k	l
64.701	102	0	2	3	87.748	47	2	4	2
66.593	15	3	2	0	88.025	29	1	2	4
67.516	18	1	2	3	88.690	2	2	4	2
67.784	88	0	4	1	89.036	26	2	0	4
67.991	46	1	4	0	89.146	32	3	3	2
68.270	17	1	2	3	89.473	25	4	0	2
68.760	9	3	0	2	89.649	11	1	5	1
69.166	28	3	2	1	89.968	22	4	2	1
69.934	28	3	2	1					
69.934	28	2	1	3					
70.251	25	3	0	2					
70.785	29	1	4	1					
71.031	35	3	1	2					
71.031	35	1	4	1					
71.413	20	2	1	3					
72.422	11	3	1	2					
73.122	21	2	3	2					
74.093	18	2	3	2					
75.647	2	0	3	3					
76.281	26	0	0	4					
76.382	23	2	2	3					
76.382	23	0	4	2					
77.420	48	3	2	2					
77.420	48	3	3	0					
77.815	17	2	2	3					
78.289	5	1	3	3					
78.389	6	0	1	4					
78.794	13	3	2	2					
78.794	13	1	0	4					
79.001	14	1	3	3					
79.418	35	4	0	0					
79.742	66	2	4	1					
79.742	66	1	0	4					
80.214	45	2	4	1					
80.887	6	1	1	4					
81.503	3	4	1	0					
81.829	9	1	1	4					
83.788	16	4	1	1					
84.100	11	0	5	0					
84.601	44	3	1	3					
84.601	44	0	2	4					
86.701	33	3	1	3					
87.033	40	1	5	0					
87.033	40	1	2	4					
87.173	27	2	0	4					
87.748	47	3	3	2					


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Appendix Figure A9 XRD reference data of MnWO₄

80-0132		Wavelength= 1.54060										C
Mn(WO ₄)		2 θ	Int	h	k	l	2 θ	Int	h	k	l	
Manganese Tungsten Oxide		15.370	194	0	1	0	52.130	144	2	0	2	
		18.357	643	1	0	0	52.286	107	1	2	2	
		23.561	545	0	1	1	52.432	158	2	2	1	
		24.028	455	1	1	0	52.997	173	2	2	1	
Rad.: CuK α 1: 1.54060 Filter: d-sp: Calculated		29.807	999*	1	1	1	53.259	122	2	0	2	
Cut off: 17.7 Int.: Calculated I/Cor.: 4.88		30.256	949	1	1	1	54.438	19	1	3	1	
Ref: Calculated from ICSD using POWD-12++, (1997)		31.025	204	0	2	0	54.683	27	2	1	2	
Ref: Macavei, J., Schulz, H., Z. Kristallogr., 207, 193 (1993)		35.969	484	0	0	2	54.683	27	1	3	1	
		35.969	484	0	2	1	55.776	11	2	1	2	
		36.288	72	1	2	0	57.181	16	3	0	0	
Sys.: Monoclinic S.G.: P2/c (13)		37.208	167	2	0	0	57.601	33	0	1	3	
a: 4.83(1) b: 5.7603(9) c: 4.994(1) A: 0.8385 C: 0.8670		39.301	14	0	1	2	59.587	17	3	1	0	
α : β : 91.140(2) γ : Z: 2 mp:		40.304	129	1	0	2	60.607	121	1	1	3	
Ref: Ibid.		40.844	189	1	2	1	60.810	86	0	3	2	
		40.993	115	1	0	2	61.376	87	1	1	3	
		43.377	55	1	1	2	61.669	46	2	3	0	
		44.026	69	1	1	2	61.913	50	2	2	2	
		44.193	73	2	1	1	62.322	93	3	1	1	
		44.833	77	2	1	1	62.926	50	2	2	2	
Dx: 7.239 Dm: ICSD #: 067906		47.304	32	0	3	0	63.080	114	3	1	1	
		48.200	126	0	2	2	63.850	83	1	3	2	
		49.203	118	2	2	0	64.348	103	1	3	2	
Peak height intensity. R-factor: 0.000. C.D. Cell: a=4.994, b=5.760, c=4.830, β =91.14, α /b=0.8670, c/b=0.8385, S.G.=P2/a(13). PSC: mP12. Mwt: 302.79. Volume[CD]: 138.92.		51.154	209	1	3	0	64.477	67	2	3	1	
		51.716	24	1	2	2	64.626	100	0	2	3	


2 θ	Int	h	k	l	2 θ	Int	h	k	l
64.626	100	0	4	0	87.903	25	1	2	4
66.489	12	3	2	0	88.512	2	2	4	2
67.449	21	1	2	3	88.971	35	2	0	4
67.657	90	0	4	1	88.971	35	3	3	2
67.860	46	1	4	0	89.368	18	4	0	2
68.176	18	1	2	3	89.465	16	1	5	1
68.694	9	3	0	2	89.690	17	1	5	1
69.071	30	3	2	1	89.832	21	4	2	1
69.879	23	2	1	3					
70.133	27	3	0	2					
70.657	27	1	4	1					
70.895	44	3	1	2					
70.895	44	1	4	1					
71.306	18	2	1	3					
72.298	12	3	1	2					
73.023	20	2	3	2					
73.960	18	2	3	2					
75.540	1	0	3	3					
76.210	26	0	0	4					
76.210	26	0	4	2					
76.307	24	2	2	3					
77.285	50	3	2	2					
77.285	50	3	3	0					
77.689	18	2	2	3					
78.189	3	1	3	3					
78.311	6	0	1	4					
78.652	7	3	2	2					
78.737	7	1	0	4					
78.876	9	1	3	3					
79.025	7	1	4	2					
79.294	34	4	0	0					
79.601	56	2	4	1					
79.601	56	1	0	4					
80.057	42	2	4	1					
80.819	7	1	1	4					
81.373	3	4	1	0					
81.727	9	1	1	4					
83.671	14	4	1	1					
83.923	11	0	5	0					
84.523	45	3	1	3					
84.523	45	4	1	1					
86.549	31	3	1	3					
86.848	36	1	5	0					
87.107	31	2	0	4					
87.625	43	2	4	2					
87.625	43	3	3	2					


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Appendix Figure A10 XRD reference data of Mn(WO₄)

76-0935					Wavelength= 1.54060					C
SiO2	2 θ	Int	h	k	l	2 θ	Int	h	k	l
Silicon Oxide	21.943	999*	1	0	1	60.220	23	3	1	1
	25.278	7	1	1	0	61.911	25	3	0	2
	28.396	85	1	1	1	64.978	20	3	1	2
Cristobalite low temperature form - from Ellora Caves, Indi-	31.366	103	1	0	2	65.454	13	2	0	4
Rad.: CuK α 1 λ : 1.54060 Filter: d-sp: Calculated	36.051	126	2	0	0	66.679	12	2	2	3
	36.295	43	1	1	2	67.814	1	3	2	0
Cut off: 17.7 Int.: Calculated I/lor.: 5.01	38.378	1	2	0	1	68.436	20	2	1	4
Ref: Calculated from ICSD using POWD-12++, (1997)	40.481	1	2	1	0	69.326	9	3	2	1
Ref: Peacor, D.R., Z. Kristallogr., Kristallgeom.,	42.604	26	2	1	1	69.634	6	3	0	3
Kristallphys., Kristallchem., 138, 274 (1973)	43.028	2	1	0	3	70.248	16	1	0	5
	44.747	20	2	0	2	72.534	19	3	1	3
Sys.: Tetragonal S.G.: P4 $_1$ 2 $_1$ 2 (92)	46.910	45	1	1	3	73.138	1	1	1	5
a: 4.9787 b: c: 6.9502 A: C: 1.3960	48.520	46	2	1	2	73.779	19	3	2	2
α : β : γ : Z: 4 mp:	51.903	4	2	2	0	76.468	1	4	0	0
Ref: Ibid.	52.633	7	0	0	4	77.061	6	2	2	4
	53.671	1	2	2	1	77.912	9	4	0	1
	54.028	22	2	0	3	78.795	1	2	0	5
	56.010	4	1	0	4	79.274	12	4	1	0
Dx: 2.317 Dm: ICSD #: 034927	57.006	32	3	0	1	79.861	1	3	0	4
	57.349	12	2	1	3	80.704	3	4	1	1
	58.585	4	3	1	0	80.995	12	3	2	3
Peak height intensity. R-factor: 0.037. PSC: tP12. Mwt:	58.753	5	2	2	2	81.579	12	2	1	5
60.08. Volume[CD]: 172.28.	59.258	1	1	1	4	82.055	3	3	3	0

2 θ	Int	h	k	l
82.200	3	4	0	2
82.636	7	3	1	4
83.474	4	3	3	1
84.960	2	4	1	2
86.118	1	1	0	6
87.710	4	3	3	2
88.864	14	1	1	6
88.974	10	4	2	1
89.262	8	4	0	3
89.839	1	2	2	5

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Appendix Figure A12 XRD reference data of silicon oxide in cristobalite form


03-0227		Wavelength= 1.7902			
SiO2	2 θ	Int	h	k	l
Silicon Oxide	24.029	100	2	2	0
	25.346	80	0	0	4
	27.176	80	1	4	1
Tridymite, (heated)	31.974	20	0	0	5
Rad.: CoKa λ : 1.7902 Filter: Fe2O3 d-sp: 143.2	35.203	40	2	2	4
Cut off: Int.: Estimation I/cor.:	42.494	60	4	0	0
Ref: Clark, C., J. Am. Ceram. Soc., 29, 25 (1946)	44.380	10	1	7	0
	46.018	20	0	4	6
	51.242	10	4	4	2
	52.327	10	2	7	3
	54.048	10	4	0	5
Sys.: Orthorhombic S.G.:	57.196	10	2	1	8
a: 9.88 b: 17.1 c: 16.3 A: 0.5778 C: 0.9532	61.139	10	1	8	5
α :	64.389	10	0	8	6
β :	67.554	10	1	10	3
γ :	69.016	10	2	4	9
Z: 64 mp:	71.611	10	6	4	1
Ref: Wyckoff, The Structure of Crystals, 1st Ed.	72.155	10	6	1	4
	80.175	10	6	4	5
Dx: 2.319 Dm: 2.260 SS/FOM: F ₂₂ = 1(0.042, 829)	81.591	10	7	3	0
ω : 1.478 η ω β : 1.479 ϵ γ : 1.481 Sign:+ 2V:	84.599	10	7	1	4
Ref: Ibid.	87.875	10	3	11	5

Color: Colorless
 Heated 3 hours to 1400 C, held at 1400 C for 5 hours. Low form. Low tridymite occurs in many polytypic forms, the patterns of which are characterized by the same strong reflections and different weak ones. C.D. Cell: a=16.300, b=17.100, c=9.880, a/b=0.9532, c/b=0.5778, S.G.=. Delete: Berry parcel of March 25, 1962, for Set 14. Mwt: 60.08. Volume[CD]: 2753.85.

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
Appendix Figure A13 XRD reference data of silicon oxide in tridymite form

32-1187		Wavelength= 1.5418				
Na ₂ W ₂ O ₇		2 θ	Int	h	k	l
Sodium Tungsten Oxide		10.432	45			
		11.644	20			
		15.656	85			
		18.368	80			
		20.416	70			
Rad.: CuK α λ : 1.5418 Filter: Ni Beta d-sp:		21.463	60			
Cut off: Int.: I/cor.:		23.101	100			
Ref: Drobasheva, T. et al., Russ. J. Inorg. Chem. (Engl. Transl.), 20, 1714 (1975)		25.084	80			
		27.103	45			
		28.059	90			
		28.610	80			
Sys.:		29.086	60			
S.G.:		32.199	40			
a:	b:	c:	A:	C:		
α :	β :	γ :	Z:	mp:		
Ref:		41.618	20			
		45.343	30			
		47.085	30			
		54.628	30			
Dx:						
Dm:						
SS/FOM: F =						
Mwt: 525.68.						

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Appendix Figure A14 XRD reference data of Na₂W₂O₇

21-0547		Wavelength= 2.2909				
Mn		2 θ	Int	h	k	l
Manganese		33.026	100	1	1	1
		42.933	10	2	1	0
		47.502	20	2	1	1
		55.210	60	2	2	0
Rad.: CrK α λ : 2.2909 Filter: d-sp:		65.583	5	3	1	1
Cut off: Int.: Estimation I/cor.:		69.012	50	2	2	2
Ref: Lux, Ignatowicz, Chem. Ber., 101, 2995 (1968)		72.593	5	3	2	0
		75.499	10	3	2	1
		84.968	5	4	1	0
		90.708	20	3	3	1
		97.034	10	4	2	1
Sys.: Cubic		100.209	10	3	3	2
S.G.: P		106.347	20	4	2	2
a: 7.00	b:	c:	A:	C:		
α :	β :	γ :	Z: [28]	mp:		
Ref: Ibid.						
Dx: 7.447		Dm:	SS/FOM: F ₁₃ = 5;(0.132, 20)			
CAS #: 7439-96-5. PSC: cP28. Mwt: 54.94. Volume[CD]: 343.00.						

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Appendix Figure A15 XRD reference data of Mn

Appendix B

Date: 05/25/2006

Quantachrome Corporation
Quantachrome Autosorb Automated Gas Sorption System Report
Autosorb for Windows® Version 1.19 Page 20 of 25

Sample ID	SilicaPoder				
Description	TISTR				
Comments					
Sample Weight	0.0856 g	Outgas Temp	300.0 °C	Operator	Rungrueng
Adsorbate	NITROGEN	Outgas Time	3.0 hrs	Analysis Time	81.3 min
Cross-Sec Area	16.2 Å ² /molecule	P/Po Toler	0	End of Run	05/22/2006
NonIdeality	6.580E-05	Equil Time	3	File Name	AS010464.R
Molecular Wt	28.0134 g/mol	Bath Temp.	77.40		
Station #	1				

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

Multipoint BET.....	2.228E+02	m ² /g
Single Point BET.....	2.153E+02	m ² /g
Langmuir Surface Area.....	3.540E+02	m ² /g
t-Method External Surface Area.....	2.228E+02	m ² /g
t-Method Micro Pore Surface Area.....	0.000E+00	m ² /g
DR Method Micro Pore Area.....	2.899E+02	m ² /g

PORE VOLUME DATA

t-Method Micro Pore Volume.....	0.000E+00	cc/g
DR Method Micro Pore Volume.....	1.030E-01	cc/g
HK Method Cumulative Pore Volume.....	8.916E-02	cc/g
SF Method Cumulative Pore Volume.....	9.140E-02	cc/g

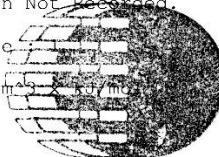
PORE SIZE DATA

DR Method Micro Pore Width	1.075E+02	Å
DA Method Pore Diameter (Mode).....	1.800E+01	Å
HK Method Pore Width (Mode).....	1.838E+01	Å
SF Method Pore Diameter (Mode).....	3.506E+01	Å

DATA REDUCTION PARAMETERS

Thermal Transpiration : ON
Effective Molecule Diameter (D) 3.5400 Å
Effective Cell Stem Inner Diameter (d) 4.0000 mm
Last Po Acquired 787.59 mm Hg
Additional Initialization Information Not Recorded.

BJH/DH Moving Average Size
Interaction Constant (K) 2.9600 nm³ Å²/m²



TISTR

Appendix Figure B1 BET analysis of SiO₂ powder purified from rice husk ash

Date: 05/25/2006

Quantachrome Corporation
Quantachrome Autosorb Automated Gas Sorption System Report Page 17 of 25
Autosorb for Windows® Version 1.19

Sample ID	RHA treat HCl 1M 500C				
Description	TISTR				
Comments					
Sample Weight	0.1435 g				
Adsorbate	NITROGEN	Outgas Temp	300.0 °C	Operator	Rungrueng
Cross-Sec Area	16.2 Å ² /molecule	Outgas Time	3.0 hrs	Analysis Time	75.4 min
NonIdeality	6.580E-05	P/Po Toler	0	End of Run	05/18/2006
Molecular Wt	28.0134 g/mol	Equil Time	3	File Name	AS010461.R
Station #	1	Bath Temp.	77.40		

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

Multipoint BET.....	1.248E+02	m ² /g
Single Point BET.....	1.208E+02	m ² /g
Langmuir Surface Area.....	1.989E+02	m ² /g
t-Method External Surface Area.....	1.248E+02	m ² /g
t-Method Micro Pore Surface Area.....	0.000E+00	m ² /g
DR Method Micro Pore Area.....	1.584E+02	m ² /g

PORE VOLUME DATA

t-Method Micro Pore Volume.....	0.000E+00	cc/g
DR Method Micro Pore Volume.....	5.630E-02	cc/g
HK Method Cumulative Pore Volume.....	4.860E-02	cc/g
SF Method Cumulative Pore Volume.....	4.986E-02	cc/g

PORE SIZE DATA

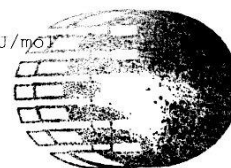
DR Method Micro Pore Width	1.067E+02	Å
DA Method Pore Diameter (Mode).....	1.840E+01	Å
HK Method Pore Width (Mode).....	1.398E+01	Å
SF Method Pore Diameter (Mode).....	2.621E+01	Å

DATA REDUCTION PARAMETERS

Thermal Transpiration : ON
Effective Molecule Diameter (D) 3.5400 Å
Effective Cell Stem Inner Diameter (d) 4.0000 mm
Last Po Acquired 788.70 mm Hg
Additional Initialization Information Not Recorded.

BJH/DH Moving Average Size : 1

Interaction Constant (K) 2.9600 nm³ x kJ/mol



TISTR

Appendix Figure B2 BET analysis of RHA_1_500 support



ASAP 2020 V1.04 H

Unit 1

Serial #: 189

Page 32

Sample: RHA1M-900C
 Operator: brs
 Submitter:
 File: C:\2020\DATA\A-PINS~1\000-334.SMP

Started: 2/23/2006 12:30:02PM	Analysis Adsorptive: N2
Completed: 2/24/2006 2:08:26AM	Analysis Bath Temp.: -195.834 °C
Report Time: 3/7/2006 2:59:39PM	Thermal Correction: No
Sample Mass: 0.1528 g	Smoothed Pressures: No
Warm Free Space: 28.4480 cm ³ Measured	Cold Free Space: 89.3228 cm ³
Equilibration Interval: 30 s	Low Pressure Dose: 0.100 cm ³ /g STP
Automatic Degas: Yes	

Comments: t2+f=35.4625g, t2+f+s=35.6162g, degas=35.6155g,run=35.6153g

Notes:

Summary Report

Surface Area

Single point surface area at P/Po = 0.200159886: 4.1534 m²/g

BET Surface Area: 5.1937 m²/g

Langmuir Surface Area: 3.5867 m²/g

t-Plot External Surface Area: 8.0232 m²/g

BJH Adsorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 1.8465 m²/g

BJH Desorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 4.8839 m²/g

Pore Volume

t-Plot micropore volume: -0.001656 cm³/g

BJH Adsorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.010235 cm³/g

BJH Desorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.014634 cm³/g

Pore Size

BJH Adsorption average pore width (4V/A): 221.715 Å

BJH Desorption average pore width (4V/A): 119.857 Å

Horvath-Kawazoe

Maximum pore volume at P/Po = 0.000000000: 0.000000 cm³/g

Median pore width: 0.0000 Å

Appendix Figure B3 BET analysis of RHA_1_900 support

Date: 05/25/2006

Quantachrome Corporation
Quantachrome Autosorb Automated Gas Sorption System Report
Autosorb for Windows® Version 1.19 Page 23 of 25

Sample ID	RHA treat HCl 3M 900C				
Description	TISTR				
Comments					
Sample Weight	0.0915 g				
Adsorbate	NITROGEN	Outgas Temp	300.0 °C	Operator	Rungrueng
Cross-Sec Area	16.2 Å ² /molecule	Outgas Time	3.0 hrs	Analysis Time	59.3 min
NonIdeality	6.580E-05	P/Po Toler	0	End of Run	05/22/2006
Molecular Wt	28.0134 g/mol	Equil Time	3	File Name	AS010465.R
Station #	1	Bath Temp.	77.40		

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

Multipoint BET.....	1.098E+01	m ² /g
Single Point BET.....	1.080E+01	m ² /g
Langmuir Surface Area.....	1.694E+01	m ² /g
t-Method External Surface Area.....	8.498E+00	m ² /g
t-Method Micro Pore Surface Area.....	2.478E+00	m ² /g
DR Method Micro Pore Area.....	1.523E+01	m ² /g

PORE VOLUME DATA

t-Method Micro Pore Volume.....	1.306E-03	cc/g
DR Method Micro Pore Volume.....	5.414E-03	cc/g
HK Method Cumulative Pore Volume.....	4.809E-03	cc/g
SF Method Cumulative Pore Volume.....	4.896E-03	cc/g

PORE SIZE DATA

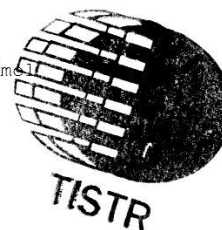
DR Method Micro Pore Width	9.462E+01	Å
DA Method Pore Diameter (Mode).....	1.760E+01	Å
HK Method Pore Width (Mode).....	1.402E+01	Å
SF Method Pore Diameter (Mode).....	2.630E+01	Å

DATA REDUCTION PARAMETERS

Thermal Transpiration : ON
Effective Molecule Diameter (D) 3.5400 Å
Effective Cell Stem Inner Diameter (d) 4.0000 mm
Last Po Acquired 786.87 mm Hg
Additional Initialization Information Not Recorded.

BJH/DH Moving Average Size : 1

Interaction Constant (K) 2.9600 nm³ x kJ/m³



Appendix Figure B4 BET analysis of RHA_3_900 support

Date: 11/22/2006

Quantachrome Corporation
Quantachrome Autosorb Automated Gas Sorption System Report
Autosorb for Windows® Version 1.19

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Sample ID	Aluminosilicate 1200C				
Description	TISTR				
Comments					
Sample Weight	0.1788 g				
Adsorbate	NITROGEN	Outgas Temp	300.0 °C	Operator	Rungrueng
Cross-Sec Area	16.2 Å ² /molecule	Outgas Time	3.0 hrs	Analysis Time	61.2 min
NonIdeality	6.580E-05	P/Po Toler	0	End of Run	01/03/1980 12
Molecular Wt	28.0134 g/mol	Equil Time	3	File Name	AS6B0837.RAW
Station #	1	Bath Temp.	77.40		

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

Multipoint BET.....	1.160E+01	m ² /g
Single Point BET.....	1.140E+01	m ² /g
Langmuir Surface Area.....	1.813E+01	m ² /g
t-Method External Surface Area.....	1.028E+01	m ² /g
t-Method Micro Pore Surface Area.....	1.320E+00	m ² /g
DR Method Micro Pore Area.....	1.499E+01	m ² /g

PORE VOLUME DATA

t-Method Micro Pore Volume.....	6.266E-04	cc/g
DR Method Micro Pore Volume.....	5.326E-03	cc/g
HK Method Cumulative Pore Volume.....	4.781E-03	cc/g
SF Method Cumulative Pore Volume.....	4.884E-03	cc/g

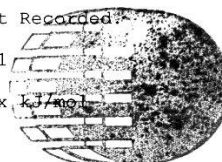
PORE SIZE DATA

DR Method Micro Pore Width	9.190E+01	Å
DA Method Pore Diameter (Mode).....	1.780E+01	Å
HK Method Pore Width (Mode).....	1.417E+01	Å
SF Method Pore Diameter (Mode).....	2.657E+01	Å

DATA REDUCTION PARAMETERS

Thermal Transpiration : ON
Effective Molecule Diameter (D) 3.5400 Å
Effective Cell Stem Inner Diameter (d) 4.0000 mm
Last Po Acquired 805.36 mm Hg
Additional Initialization Information Not Recorded

BJH/DH Moving Average Size : 1

Interaction Constant (K) 2.9600 nm³ x

TISTR

Appendix Figure B5 BET analysis of mullite sintered at 1200°C



ASAP 2020 V1.04 H

Unit 1

Serial #: 189

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Sample: Aluminosilicate

Operator: brs

Submitter:

File: C:\2020\DATA\A-PINS~1\1000-298.SMP

Started: 1/6/2006 1:50:54PM	Analysis Adsorptive: N2
Completed: 1/7/2006 1:52:09AM	Analysis Bath Temp.: -195.792 °C
Report Time: 2/9/2006 12:33:45PM	Thermal Correction: No
Sample Mass: 0.4222 g	Smoothed Pressures: No
Warm Free Space: 28.1049 cm ³ Measured	Cold Free Space: 87.9150 cm ³
Equilibration Interval: 30 s	Low Pressure Dose: 0.010 cm ³ /g STP
Automatic Degas: Yes	

Comments: t1+f=35.8257g t1+f+s (pre-degas)=36.2492g, run=36.2479g

Summary Report

Surface Area

Single point surface area at P/Po = 0.100183276: 3.0618 m²/gBET Surface Area: 3.2040 m²/gLangmuir Surface Area: 3.6419 m²/gt-Plot External Surface Area: 3.6149 m²/gBJH Adsorption cumulative surface area of pores
between 17.000 Å and 3000.000 Å width: 1.7404 m²/gBJH Desorption cumulative surface area of pores
between 17.000 Å and 3000.000 Å width: 2.5056 m²/g

Pore Volume

t-Plot micropore volume: -0.000122 cm³/gBJH Adsorption cumulative volume of pores
between 17.000 Å and 3000.000 Å width: 0.017357 cm³/gBJH Desorption cumulative volume of pores
between 17.000 Å and 3000.000 Å width: 0.024475 cm³/g

Pore Size

BJH Adsorption average pore width (4V/A): 398.919 Å

BJH Desorption average pore width (4V/A): 390.711 Å

Horvath-Kawazoe

Maximum pore volume at P/Po = 0.000000000: 0.000000 cm³/g

Median pore width: 0.0000 Å

Appendix Figure B6 BET analysis of mullite 1300°C

Date: 11/22/2006

Quantachrome Corporation
 Quantachrome Autosorb Automated Gas Sorption System Report
 Autosorb for Windows® Version 1.19

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Sample ID	Aluminosilicate 1400C				
Description	TISTR				
Comments					
Sample Weight	0.4004 g	Outgas Temp	300.0 °C	Operator	Rungrueng
Adsorbate	NITROGEN	Outgas Time	3.0 hrs	Analysis Time	60.2 min
Cross-Sec Area	16.2 Å ² /molecule	P/Po Toler	0	End of Run	11/20/2006 14
NonIdeality	6.580E-05	Equil Time	3	File Name	AS6B0836.RAW
Molecular Wt	28.0134 g/mol	Bath Temp.	77.40		
Station #	1				

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

Multipoint BET.....	1.525E+00	m ² /g
Single Point BET.....	1.478E+00	m ² /g
Langmuir Surface Area.....	2.421E+00	m ² /g
t-Method External Surface Area.....	1.502E+00	m ² /g
t-Method Micro Pore Surface Area.....	2.272E-02	m ² /g
DR Method Micro Pore Area.....	1.958E+00	m ² /g

PORE VOLUME DATA

t-Method Micro Pore Volume.....	2.251E-06	cc/g
DR Method Micro Pore Volume.....	6.960E-04	cc/g
HK Method Cumulative Pore Volume.....	6.132E-04	cc/g
SF Method Cumulative Pore Volume.....	6.302E-04	cc/g

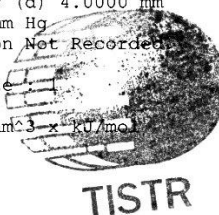
PORE SIZE DATA

DR Method Micro Pore Width	1.012E+02	Å
DA Method Pore Diameter (Mode).....	1.800E+01	Å
HK Method Pore Width (Mode).....	1.858E+01	Å
SF Method Pore Diameter (Mode).....	3.534E+01	Å

DATA REDUCTION PARAMETERS

Thermal Transpiration : ON
 Effective Molecule Diameter (D) 3.5400 Å
 Effective Cell Stem Inner Diameter (d) 4.0000 mm
 Last Po Acquired 797.00 mm Hg
 Additional Initialization Information Not Recorded

BJH/DH Moving Average Size

Interaction Constant (K) 2.9600 nm³ x KJ/mol

Appendix Figure B7 BET analysis of mullite sintered at 1400°C

Date: 11/22/2006

Quantachrome Corporation
Quantachrome Autosorb Automated Gas Sorption System Report
Autosorb for Windows® Version 1.19

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Sample ID	Aluminosilicate 1500C				
Description	TISTR				
Comments					
Sample Weight	0.4553 g	Outgas Temp	300.0 °C	Operator	Rungrueng
Adsorbate	NITROGEN	Outgas Time	3.0 hrs	Analysis Time	60.7 min
Cross-Sec Area	16.2 Å ² /molecule	P/Po Toler	0	End of Run	01/03/1980 06
NonIdeality	6.580E-05	Equil Time	3	File Name	AS6B0835.RAW
Molecular Wt	28.0134 g/mol	Bath Temp.	77.40		
Station #	1				

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

Multipoint BET.....	5.634E-01	m ² /g
Single Point BET.....	5.690E-01	m ² /g
Langmuir Surface Area.....	8.373E-01	m ² /g
t-Method External Surface Area.....	1.714E-01	m ² /g
t-Method Micro Pore Surface Area.....	3.920E-01	m ² /g
DR Method Micro Pore Area.....	8.427E-01	m ² /g

PORE VOLUME DATA

t-Method Micro Pore Volume.....	2.068E-04	cc/g
DR Method Micro Pore Volume.....	2.995E-04	cc/g
HK Method Cumulative Pore Volume.....	2.813E-04	cc/g
SF Method Cumulative Pore Volume.....	2.821E-04	cc/g

PORE SIZE DATA

DR Method Micro Pore Width	6.739E+01	Å
DA Method Pore Diameter (Mode).....	1.520E+01	Å
HK Method Pore Width (Mode).....	1.373E+01	Å
SF Method Pore Diameter (Mode).....	2.574E+01	Å

DATA REDUCTION PARAMETERS

Thermal Transpiration : ON
Effective Molecule Diameter (D) 3.5400 Å
Effective Cell Stem Inner Diameter (d) 4.0000 mm
Last Po Acquired 795.67 mm Hg
Additional Initialization Information Not Recorded

BJH/DH Moving Average Size : 1

Interaction Constant (K) 2.9600 nm³ x 10¹¹ mol⁻¹

Appendix Figure B8 BET analysis of mullite sintered at 1500°C



ASAP 2020 V1.04 H

Unit 1

Serial #: 189

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Sample: Na₂WO₄-Mn-SiO₂
 Operator: brs
 Submitter:
 File: C:\2020\DATA\A-PINS-1\000-335.SMP

Started: 2/26/2006 4:45:37PM	Analysis Adsorptive: N ₂
Completed: 2/27/2006 3:59:21AM	Analysis Bath Temp.: -195.834 °C
Report Time: 3/7/2006 2:55:06PM	Thermal Correction: No
Sample Mass: 0.2720 g	Smoothed Pressures: No
Warm Free Space: 28.1210 cm ³ Measured	Cold Free Space: 88.4039 cm ³
Equilibration Interval: 30 s	Low Pressure Dose: 0.100 cm ³ /g STP
Automatic Degas: Yes	

Comments: t3+f=35.5944g,t3+f+s=35.8675g,degas=35.8663g, run=35.8664g

Summary Report

Surface Area

Single point surface area at P/P₀ = 0.180265712: 2.3711 m²/g

BET Surface Area: 3.0182 m²/g

Langmuir Surface Area: 2.1069 m²/g

t-Plot External Surface Area: 4.7599 m²/g

BJH Adsorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 1.0979 m²/g

BJH Desorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 2.0842 m²/g

Pore Volume

t-Plot micropore volume: -0.000988 cm³/g

BJH Adsorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.002389 cm³/g

BJH Desorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.003426 cm³/g

Pore Size

BJH Adsorption average pore width (4V/A): 87.034 Å

BJH Desorption average pore width (4V/A): 65.752 Å

Horvath-Kawazoe

Maximum pore volume at P/P₀ = 0.000000000: 0.000000 cm³/g

Median pore width: 0.0000 Å

Appendix Figure B9 BET analysis of Na₂WO₄-Mn/SiO₂ powder



ASAP 2020 V1.04 H

Unit 1

Serial #: 189

Page 30

Sample: Na₂WO₄-Mn-RHA-500C
 Operator: brs
 Submitter:
 File: C:\2020\DATA\A-PINS~1\000-301.SMP

Started: 1/11/2006 4:27:27PM	Analysis Adsorptive: N ₂
Completed: 1/12/2006 1:14:01AM	Analysis Bath Temp.: -195.808 °C
Report Time: 2/9/2006 12:19:08PM	Thermal Correction: No
Sample Mass: 0.3835 g	Smoothed Pressures: No
Warm Free Space: 27.8909 cm ³ Measured	Cold Free Space: 87.9873 cm ³
Equilibration Interval: 25 s	Low Pressure Dose: 0.100 cm ³ /g STP
Automatic Degas: Yes	

Comments: t3+f=35.6033g, t3+f+s=35.9875, degas=35.9864g, run=35.9868g

Summary Report

Surface Area

Single point surface area at P/P₀ = 0.300136194: 1.1247 m²/g

BET Surface Area: 1.2438 m²/g

Langmuir Surface Area: 1.2888 m²/g

t-Plot External Surface Area: 2.0737 m²/g

BJH Adsorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 0.4169 m²/g

BJH Desorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 1.3720 m²/g

Pore Volume

t-Plot micropore volume: -0.000417 cm³/g

BJH Adsorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.001401 cm³/g

BJH Desorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.001910 cm³/g

Pore Size

BJH Adsorption average pore width (4V/A): 134.448 Å

BJH Desorption average pore width (4V/A): 55.686 Å

Horvath-Kawazoe

Maximum pore volume at P/P₀ = 0.000000000: 0.000000 cm³/g

Median pore width: 0.0000 Å

Appendix Figure B10 BET analysis of Na₂WO₄-Mn/RHA_1_500



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Unit 1

Serial #: 189

Page 30

Sample: Na₂WO₄-Mn-RHA-900C
 Operator: brs
 Submitter:
 File: C:\2020\DATA\A-PINS~1\000-305.SMP

Started: 1/12/2006 6:36:25PM	Analysis Adsorptive: N ₂
Completed: 1/13/2006 5:53:52AM	Analysis Bath Temp.: -195.808 °C
Report Time: 2/9/2006 12:40:14PM	Thermal Correction: No
Sample Mass: 0.2722 g	Smoothed Pressures: No
Warm Free Space: 28.0000 cm ³ Measured	Cold Free Space: 87.8025 cm ³
Equilibration Interval: 30 s	Low Pressure Dose: 0.100 cm ³ /g STP
Automatic Degas: No	

Comments: t1+f=35.8269g, t3+f+s=36.1020g, degas=36.1010g, run=36.0991

Summary Report

Surface Area

Single point surface area at P/Po = 0.200495925: 1.4652 m²/g

BET Surface Area: 1.9401 m²/g

Langmuir Surface Area: 3.2910 m²/g

t-Plot External Surface Area: 3.1350 m²/g

BJH Adsorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 0.0737 m²/g

BJH Desorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 0.8171 m²/g

Pore Volume

t-Plot micropore volume: -0.000718 cm³/g

BJH Adsorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.000554 cm³/g

BJH Desorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.001066 cm³/g

Pore Size

BJH Adsorption average pore width (4V/A): 300.813 Å

BJH Desorption average pore width (4V/A): 52.172 Å

Horvath-Kawazoe

Maximum pore volume at P/Po = 0.000000000: 0.000000 cm³/g

Median pore width: 0.0000 Å

Appendix Figure B11 BET analysis of Na₂WO₄-Mn/RHA_1_900



ASAP 2020 V1.04 H

Unit 1

Serial #: 189

Page 31

Sample: Na₂WO₄-Mn-RH4
 Operator: brs
 Submitter:
 File: C:\2020\DATA\A-PINS~1\000-339.SMP

Started: 3/3/2006 3:53:57PM	Analysis Adsorptive: N ₂
Completed: 3/4/2006 3:13:40AM	Analysis Bath Temp.: -195.821 °C
Report Time: 3/7/2006 2:36:14PM	Thermal Correction: No
Sample Mass: 0.2259 g	Smoothed Pressures: No
Warm Free Space: 28.2138 cm ³ Measured	Cold Free Space: 87.8226 cm ³
Equilibration Interval: 30 s	Low Pressure Dose: 0.100 cm ³ /g STP
Automatic Degas: Yes	

Comments: t1+f=35.8264g,t1+f+s=36.0534g,degas=36.0515g,run=36.0523g

Summary Report

Surface Area

Single point surface area at P/P₀ = 0.200312536: 1.3203 m²/g
 BET Surface Area: 1.8249 m²/g
 Langmuir Surface Area: 1.1501 m²/g
 t-Plot External Surface Area: 2.4338 m²/g
 BJH Adsorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 0.0934 m²/g
 BJH Desorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 0.9305 m²/g

Pore Volume

t-Plot micropore volume: -0.000456 cm³/g
 BJH Adsorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.000626 cm³/g
 BJH Desorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.001111 cm³/g

Pore Size

BJH Adsorption average pore width (4V/A): 268.298 Å
 BJH Desorption average pore width (4V/A): 47.766 Å

Horvath-Kawazoe

Maximum pore volume at P/P₀ = 0.000000000: 0.000000 cm³/g
 Median pore width: 0.0000 Å

Appendix Figure B12 BET analysis of Na₂WO₄-Mn/RHA_3_900



ASAP 2020 V1.04 H

Unit 1

Serial #: 189

Page 31

Sample: Na₂WO₄-Mn-mullite-1200C
 Operator: brs
 Submitter:
 File: C:\2020\DATA\A-PINS~1\000-338.SMP

Started: 3/2/2006 6:43:42PM	Analysis Adsorptive: N ₂
Completed: 3/3/2006 10:01:00AM	Analysis Bath Temp.: -195.817 °C
Report Time: 3/7/2006 2:34:24PM	Thermal Correction: No
Sample Mass: 0.2671 g	Smoothed Pressures: No
Warm Free Space: 28.1413 cm ³ Measured	Cold Free Space: 87.9636 cm ³
Equilibration Interval: 30 s	Low Pressure Dose: 0.100 cm ³ /g STP
Automatic Degas: Yes	

Comments: t3+f=35.5953g,t3+f+s=35.8649g,degas=35.8634g,run=35.8624g

Summary Report

Surface Area

Single point surface area at P/P₀ = 0.200194717: 8.7118 m²/g

BET Surface Area: 9.3508 m²/g

Langmuir Surface Area: 8.6202 m²/g

t-Plot External Surface Area: 10.6133 m²/g

BJH Adsorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 6.6968 m²/g

BJH Desorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 9.4439 m²/g

Pore Volume

t-Plot micropore volume: -0.000770 cm³/g

BJH Adsorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.050785 cm³/g

BJH Desorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.088743 cm³/g

Pore Size

BJH Adsorption average pore width (4V/A): 303.341 Å

BJH Desorption average pore width (4V/A): 375.876 Å

Horvath-Kawazoe

Maximum pore volume at P/P₀ = 0.000000000: 0.000000 cm³/g

Median pore width: 0.0000 Å

Appendix Figure B13 BET analysis of Na₂WO₄-Mn/mullite_1200



ASAP 2020 V1.04 H

Unit 1

Serial #: 189

Page 30

Sample: Na₂WO₄-Mn-RHA-1300C
 Operator: brs
 Submitter:
 File: C:\2020\DATA\A-PINS~1\000-303.SMP

Started: 1/13/2006 2:12:39PM	Analysis Adsorptive: N ₂
Completed: 1/14/2006 12:50:38AM	Analysis Bath Temp.: -195.811 °C
Report Time: 2/9/2006 12:27:09PM	Thermal Correction: No
Sample Mass: 0.3895 g	Smoothed Pressures: No
Warm Free Space: 28.4550 cm ³ Measured	Cold Free Space: 88.8082 cm ³
Equilibration Interval: 25 s	Low Pressure Dose: 0.100 cm ³ /g STP
Automatic Degas: Yes	

Comments: t₂+f=34.8892g,t₂+f+s=35.2794g,degas=35.2802g,run=35.2787g

Summary Report

Surface Area

Single point surface area at P/P₀ = 0.100201963: 2.4172 m²/g

BET Surface Area: 2.3975 m²/g

Langmuir Surface Area: 2.6452 m²/g

t-Plot External Surface Area: 3.7311 m²/g

BJH Adsorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 1.3520 m²/g

BJH Desorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 2.7222 m²/g

Pore Volume

t-Plot micropore volume: -0.000416 cm³/g

BJH Adsorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.006313 cm³/g

BJH Desorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.020859 cm³/g

Pore Size

BJH Adsorption average pore width (4V/A): 186.774 Å

BJH Desorption average pore width (4V/A): 306.508 Å

Horvath-Kawazoe

Maximum pore volume at P/P₀ = 0.000000000: 0.000000 cm³/g

Median pore width: 0.0000 Å

Appendix Figure B14 BET analysis of Na₂WO₄-Mn/mullite_1300



ASAP 2020 V1.04 H

Unit 1

Serial #: 189

Page 30

Sample: Na₂WO₄-Mn-mullite-1400C
 Operator: brs
 Submitter:
 File: C:\2020\DATA\A-PINS~1\000-337.SMP

Started: 2/28/2006 10:48:09AM	Analysis Adsorptive: N ₂
Completed: 2/28/2006 9:43:21PM	Analysis Bath Temp.: -195.845 °C
Report Time: 3/7/2006 2:44:42PM	Thermal Correction: No
Sample Mass: 0.3173 g	Smoothed Pressures: No
Warm Free Space: 28.3974 cm ³ Measured	Cold Free Space: 88.9227 cm ³
Equilibration Interval: 30 s	Low Pressure Dose: 0.100 cm ³ /g STP
Automatic Degas: Yes	

Comments: t2+f=35.4772g,t2+f+s=35.7952g,degas=35.7960g,run=35.7945g

Summary Report

Surface Area

Single point surface area at P/P₀ = 0.140158274: 2.2095 m²/g

BET Surface Area: 2.9484 m²/g

Langmuir Surface Area: 2.1235 m²/g

t-Plot External Surface Area: 5.0889 m²/g

BJH Adsorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 1.2355 m²/g

BJH Desorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 2.3548 m²/g

Pore Volume

t-Plot micropore volume: -0.001099 cm³/g

BJH Adsorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.003344 cm³/g

BJH Desorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.005108 cm³/g

Pore Size

BJH Adsorption average pore width (4V/A): 108.279 Å

BJH Desorption average pore width (4V/A): 86.770 Å

Horvath-Kawazoe

Maximum pore volume at P/P₀ = 0.000000000: 0.000000 cm³/g

Median pore width: 0.0000 Å

Appendix Figure B15 BET analysis of Na₂WO₄-Mn/mullite_1400



ASAP 2020 V1.04 H

Unit 1

Serial #: 189

Page 30

Sample: Na₂WO₄-Mn-Mullite1500C
 Operator: brs
 Submitter:
 File: C:\2020\DATA\A-PINS-1\000-333.SMP

Started: 2/21/2006 3:02:42PM	Analysis Adsorptive: N ₂
Completed: 2/22/2006 12:17:44AM	Analysis Bath Temp.: -195.834 °C
Report Time: 3/7/2006 3:03:58PM	Thermal Correction: No
Sample Mass: 0.5470 g	Smoothed Pressures: No
Warm Free Space: 28.0365 cm ³ Measured	Cold Free Space: 87.2964 cm ³
Equilibration Interval: 30 s	Low Pressure Dose: 0.100 cm ³ /g STP
Automatic Degas: Yes	

Comments: t1+f=35.8419g, t3+f+s=36.3916g,degas=36.3890g, run=36.3889g

Summary Report

Surface Area

Single point surface area at P/Po = 0.199959029: 1.2001 m²/g

BET Surface Area: 1.3822 m²/g

Langmuir Surface Area: 0.5335 m²/g

t-Plot External Surface Area: 2.0515 m²/g

BJH Adsorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 0.4859 m²/g

BJH Desorption cumulative surface area of pores
 between 17.000 Å and 3000.000 Å width: 1.1418 m²/g

Pore Volume

t-Plot micropore volume: -0.000358 cm³/g

BJH Adsorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.001626 cm³/g

BJH Desorption cumulative volume of pores
 between 17.000 Å and 3000.000 Å width: 0.002978 cm³/g

Pore Size

BJH Adsorption average pore width (4V/A): 133.816 Å

BJH Desorption average pore width (4V/A): 104.328 Å

Horvath-Kawazoe

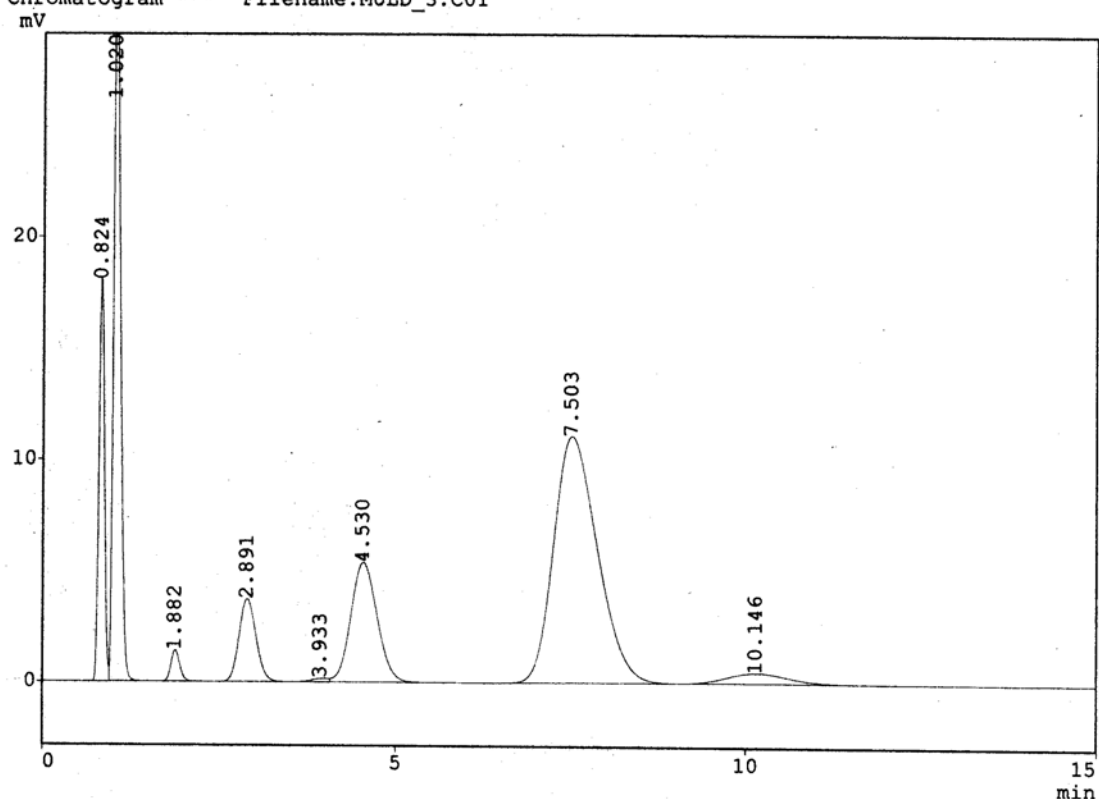
Maximum pore volume at P/Po = 0.000000000: 0.000000 cm³/g

Median pore width: 0.0000 Å

Appendix Figure B16 BET analysis of Na₂WO₄-Mn/mullite_1500

Appendix C

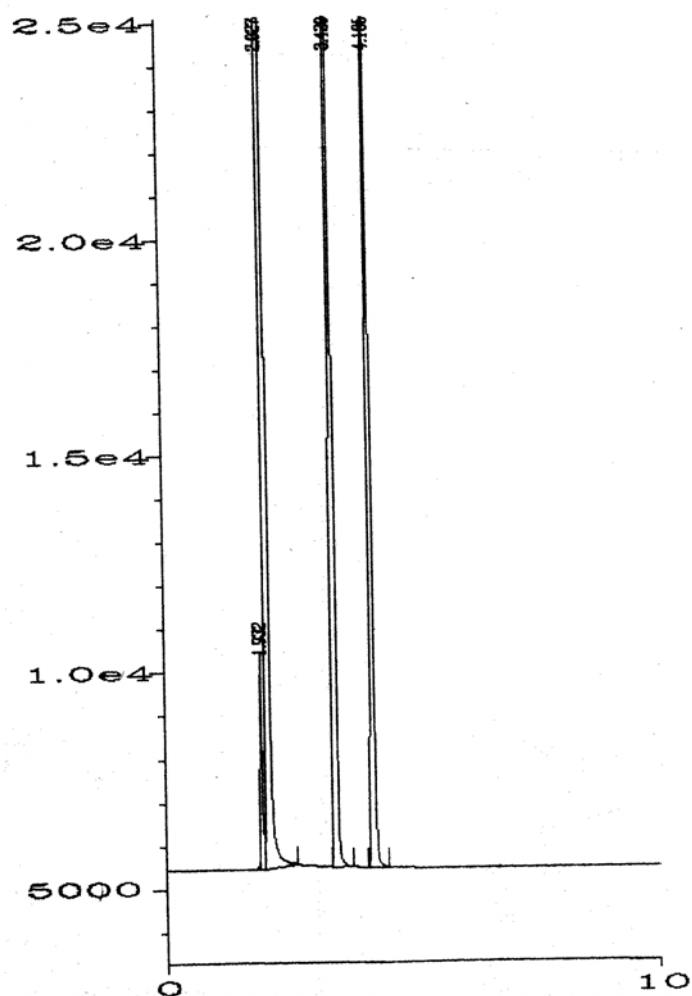
Chromatogram *** Filename: MULD_3.C01



Peaks report

Peak No.	Time	Area	Concentration (vol.%)	Name
1	0.824	98771	-	
2	1.020	214751	-	
3	1.882	11898	1.5707	CO ₂
4	2.891	61021	3.3382	O ₂
5	3.933	2380	-	
6	4.530	138935	-	N ₂
7	7.503	480810	-	CH ₄
8	10.146	28022	0.7506	CO

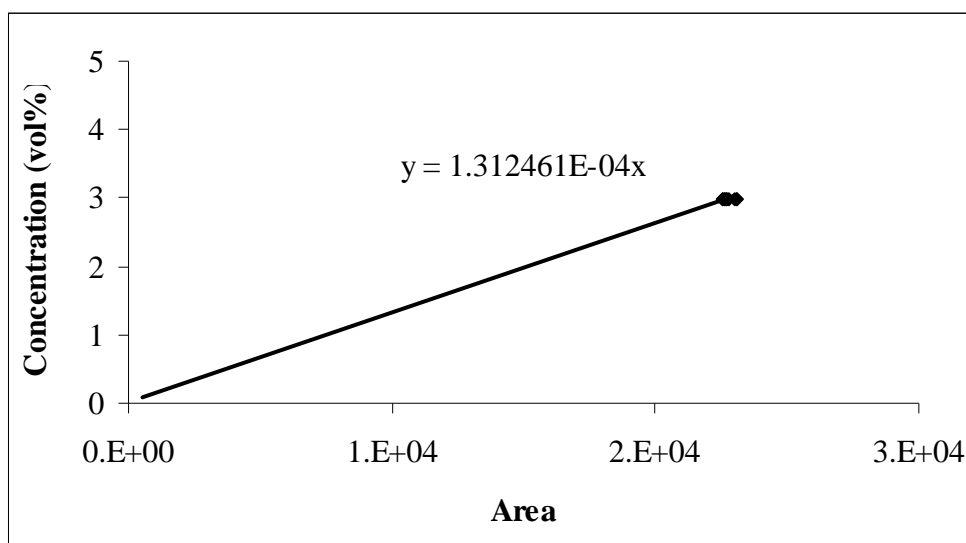
Appendix Figure C1 An example of GC chromatogram for the catalytic activity test of Na₂WO₄-Mn/mullite_1300 from WG-100 column (TCD detector).



Peaks report

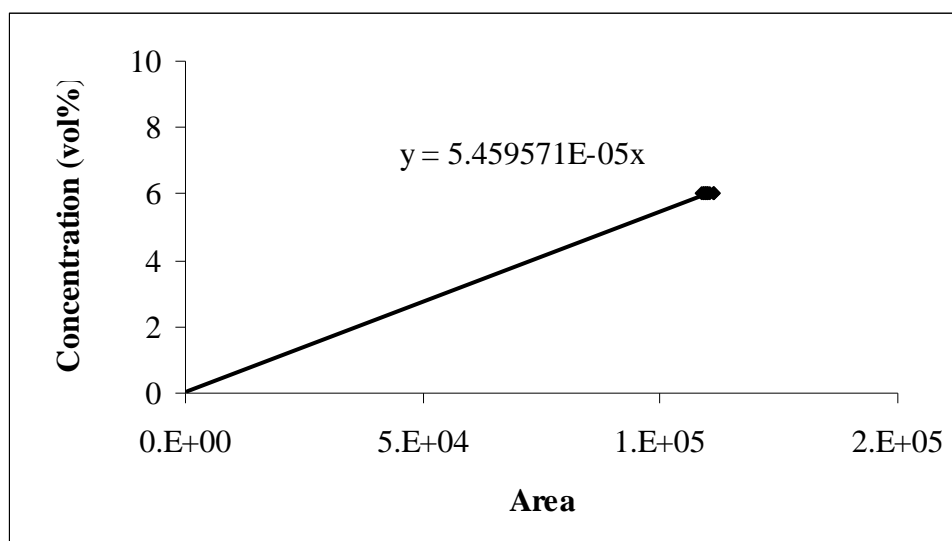
Peak No.	Time	Area	Concentration (vol.%)	Name
1	1.932	14622		
2	2.027	4948215		CH ₄
3	3.420	75041	0.1202	C ₂ H ₄
4	4.185	95898	0.1594	C ₂ H ₆

Appendix Figure C2 An example of GC chromatogram for the catalytic activity test of Na₂WO₄-Mn/mullite_1300 from DVB-plot capillary column (FID detector).



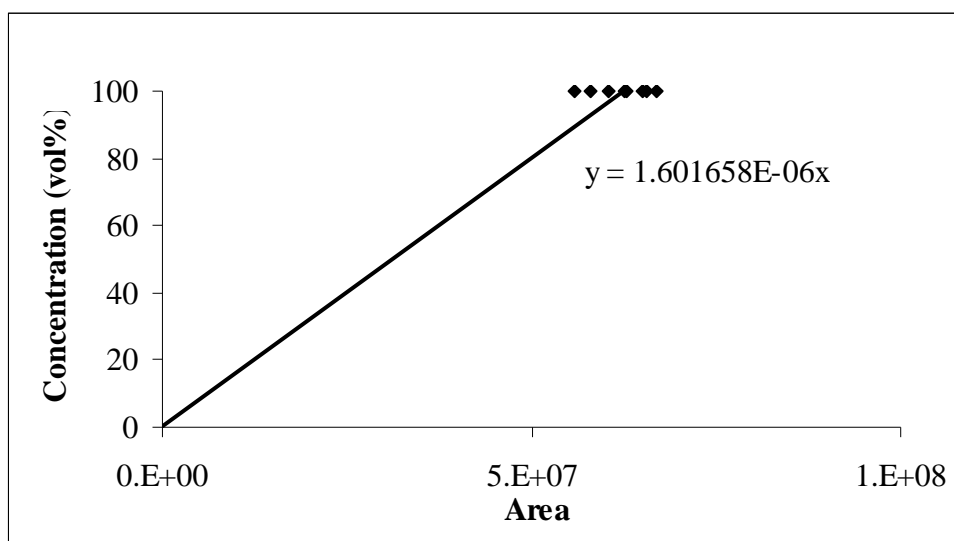
Area	Concentration (vol.)
23045	2.99
23057	2.99
22767	2.99
22716	2.99
23103	2.99
22567	2.99
22720	2.99
22595	2.99
22580	2.99
22649	2.99

Appendix Figure C3 Calibration curve of CO₂ gas from WG-100 column (TCD detector).



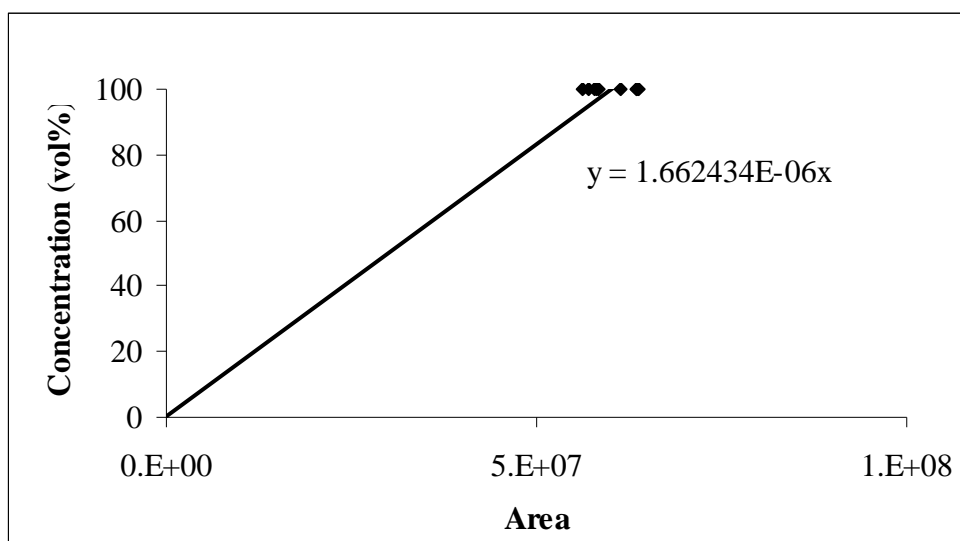
Area	Concentration (vol.%)
109193	6
109483	6
108583	6
109862	6
109310	6
110267	6
111210	6
111261	6
110054	6
109705	6

Appendix Figure C4 Calibration curve of CO gas from WG-100 column (TCD detector).



Area	Concentration (vol.%)
5.06E+07	99.9
4.97E+07	99.9
5.57E+07	99.9
6.57E+07	99.9
6.26E+07	99.9
6.28E+07	99.9
6.52E+07	99.9
6.70E+07	99.9
6.04E+07	99.9
5.79E+07	99.9

Appendix Figure C5 Calibration curve of C₂H₄ gas from DVB-plot capillary column (FID detector).



Area	Concentration (vol.%)
5.70E+07	99.9
6.38E+07	99.9
6.15E+07	99.9
6.34E+07	99.9
6.35E+07	99.9
5.84E+07	99.9
5.63E+07	99.9
5.77E+07	99.9
5.80E+07	99.9
5.34E+07	99.9

Appendix Figure C6 Calibration curve of C₂H₆ gas from DVB-plot capillary column (FID detector).