APPENDIX

Appendix A

Appendix A1 The reagents preparation for ascorbic acid method

a) Sulfuric acid solution, 5N: Prepared by diluting 70 ml of conc H_2SO_4 with deionized water to 500 ml.

b) Potassium antimonyl tartrate solution: Prepared by dissolving 1.3715g of K $(SbO)C_4H_4O_6.1/2H_2O$ and diluting to 500 ml with deionized water in volumetric flask. Stored in a glass-stoppered bottle.

c) Ammonium molybdate solution: Prepared by dissolving 20 g of $(NH_4)_6Mo_7O_{24}.4H_2O$ in 500 ml deionized water. Stored in a plastic bottle at 4°C.

d) Ascorbic acid solution, 0.1M: Prepared by dissolving 1.76 g of ascorbic acid in 100 ml deionized water. The solution was stable for about 1 week at 4°C.

e) Combined reagent: Mix all reagents above in the follow proportions for 100 ml of the combined reagent: 50 ml of 5N H_2SO_4, 5 ml of potassium antimonyl tartrate solution, 15 ml of ammonium molybdate solution, and 30 ml of ascorbic acid solution, with mixing after addition of each reagent.

All reagents must reach room temperature before being mixed and must be mixed in the given order. If turbidity forms in combined reagent, it was shaken and left to stand for a few minutes until the turbidity disappeared before proceeding. The combined reagent was stable for 4 hours.

Appendix B

Appendix Table B1 Data from experiment of uncalcined ball clay after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	pH	Ball clay weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g Ball clay	absorbance (average)
				Before adsorption	After adsorption	Amount adsorption		
5	20	5.64	1.0047	5.0106	4.3355	0.6751	13.4114	0.2764
	40	5.40	1.0054	5.0106	3.9707	1.0399	20.6439	0.2533
	60	5.47	1.0026	5.0106	3.7409	1.2697	25.2721	0.2388
	120	5.29	1.0012	5.0106	3.1885	1.8221	36.3215	0.2038
	180	5.29	1.0012	5.0106	3.1885	1.8221	34.0783	0.2103
	240	5.29	1.0066	5.0106	3.2919	1.7187	37.1039	0.2008
10	20	5.35	1.0026	10.0212	8.7019	1.3193	13.1295	0.2212
	40	5.28	1.0043	10.0212	8.2722	1.7490	17.3822	0.2103
	60	5.37	1.0034	10.0212	8.0267	1.9945	19.8339	0.2041
	120	5.21	1.0050	10.0212	7.1935	2.8277	28.0793	0.1830
	180	5.30	1.0026	10.0212	7.1935	2.8277	28.1426	0.1830
	240	5.30	1.0020	10.0212	6.7814	3.2398	32.2652	0.1726
20	20	5.14	1.0054	20.0424	18.4581	1.5843	7.8620	0.2342
	40	5.16	1.0033	20.0424	18.0635	1.9789	9.8391	0.2292
	60	5.19	1.0044	20.0424	16.7480	3.2944	16.3656	0.2126
	120	5.14	1.0042	20.0424	16.4060	3.6364	18.0696	0.2082
	180	5.17	1.0051	20.0424	15.2397	4.8027	23.8431	0.1934
	240	5.14	1.0052	20.0424	14.8889	5.1535	25.5835	0.1890
30	20	5.10	1.0030	30.0637	26.9296	3.1341	10.3938	0.3416
	40	5.09	1.0046	30.0637	26.4823	3.5814	11.8574	0.3359
	60	5.13	1.0071	30.0637	27.0436	3.0201	9.9744	0.3430
	120	5.07	1.0057	30.0637	25.6843	4.3794	14.4859	0.3258
	180	5.07	1.0058	30.0637	24.8950	5.1687	17.0939	0.3158
	240	5.05	1.0052	30.0637	24.8863	5.1774	17.1336	0.3157
blank	240	5.45	1.0026	0.0000	0.0282	-0.0282		0.0179

Appendix Table B2 Data from experiment of calcination ball clay at 750ºC after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	pH	Ball clay weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g Ball clay	absorbance (average)
				Before adsorption	After adsorption	Amount adsorption		
5	20	5.65	1.0039	5.0277	4.5234	0.5043	9.9908	0.2877
	40	5.47	1.0020	5.0277	4.4199	0.6078	12.0657	0.2811
	60	5.56	1.0034	5.0277	4.2164	0.8113	16.0815	0.2682
	120	5.59	1.0034	5.0277	3.9726	1.0551	20.9160	0.2528
	180	5.93	1.0022	5.0277	3.7324	1.2953	25.7060	0.2376
	240	5.72	1.0029	5.0277	3.4798	1.5479	30.6971	0.2216
10	20	5.55	1.0029	10.0554	9.1116	0.9438	9.3582	0.2313
	40	5.46	1.0021	10.0554	8.8661	1.1893	11.8020	0.2251
	60	5.44	1.0022	10.0554	8.3268	1.7286	17.1531	0.2114
	120	5.52	1.0036	10.0554	7.9979	2.0575	20.3860	0.2031
	180	5.70	1.0037	10.0554	7.8050	2.2504	22.2980	0.1982
	240	5.66	1.0018	10.0554	7.3095	2.7459	27.2602	0.1857
20	20	5.25	1.0039	20.1107	18.8810	1.2297	6.0908	0.2394
	40	5.29	1.0022	20.1107	18.5214	1.5893	7.8842	0.2349
	60	5.33	1.0040	20.1107	17.8111	2.2996	11.3930	0.2259
	120	5.44	1.0018	20.1107	16.7851	3.3256	16.5071	0.2129
	180	5.47	1.0028	20.1107	16.0309	4.0798	20.2326	0.2033
	240	5.54	1.0027	20.1107	15.3468	4.7639	23.6248	0.1947
30	20	5.17	1.0029	30.1662	28.5188	1.6474	5.4447	0.3616
	40	5.19	1.0021	30.1662	27.7997	2.3665	7.8277	0.3524
	60	5.29	1.0016	30.1662	26.7473	3.4189	11.3153	0.3391
	120	5.38	1.0027	30.1662	25.3004	4.8658	16.0863	0.3208
	180	5.40	1.0047	30.1662	24.5286	5.6376	18.6007	0.3110
	240	5.45	1.0015	30.1662	23.8271	6.3391	20.9818	0.3021
blank	240	5.91	1.0013	0.0000	0.0175	-0.0175		0.0111

Appendix Table B3 Data from experiment of uncalcined kaolin after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	pH	Kaolin weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g Kaolin	absorbance (average)
				Before adsorption	After adsorption	Amount adsorption		
5	20	5.85	1.0092	5.0106	4.5770	0.4336	8.5715	0.2916
	40	5.53	1.0048	5.0106	4.4157	0.5949	11.8154	0.2813
	60	5.43	1.0045	5.0106	4.5034	0.5072	10.0761	0.2869
	120	5.31	1.0039	5.0106	4.3385	0.6721	13.3583	0.2764
	180	5.66	1.0021	5.0106	4.2350	0.7756	15.4466	0.2699
	240	5.29	1.0057	5.0106	4.1543	0.8563	16.9917	0.2648
10	20	5.38	1.0048	10.0212	9.2135	0.8077	8.0218	0.2341
	40	5.23	1.0022	10.0212	9.0688	0.9524	9.4821	0.2304
	60	5.13	1.0044	10.0212	9.0688	0.9524	9.4595	0.2304
	120	5.12	1.0063	10.0212	8.9855	1.0357	10.2706	0.2283
	180	5.24	1.0032	10.0212	8.6084	1.4128	14.0533	0.2188
	240	5.12	1.0025	10.0212	8.6216	1.3996	13.9335	0.2191
20	20	4.95	1.0054	20.0424	18.9347	1.1077	5.4959	0.2402
	40	4.90	1.0058	20.0424	18.5313	1.5111	7.4953	0.2351
	60	4.96	1.0039	20.0424	19.0837	0.9587	4.7651	0.2421
	120	4.89	1.0045	20.0424	18.8470	1.1954	5.9376	0.2391
	180	4.91	1.0039	20.0424	17.9963	2.0461	10.1690	0.2283
	240	4.80	1.0065	20.0424	18.0402	2.0022	9.9255	0.2289
30	20	4.78	1.0067	30.0637	29.2214	0.8423	2.7863	0.3706
	40	4.76	1.0023	30.0637	28.5374	1.5263	5.0655	0.3619
	60	4.79	1.0050	30.0637	28.1866	1.8771	6.2112	0.3574
	120	4.75	1.0028	30.0637	27.7043	2.3594	7.8255	0.3513
	180	4.73	1.0027	30.0637	28.0288	2.0349	6.7502	0.3554
	240	4.64	1.0040	30.0637	27.8972	2.1665	7.1774	0.3538
blank	240	5.81	1.0034	0.0000	0.0253	-0.0253		0.0160

Appendix Table B4 Data from experiment of calcination kaolin at 750ºC after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	pH	Kaolin weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g Kaolin	absorbance (average)
				Before adsorption	After adsorption	Amount adsorption		
5	20	5.94	1.0052	5.0277	4.8312	0.1965	3.8874	0.3247
	40	5.85	1.0042	5.0277	4.7610	0.2667	5.2820	0.3202
	60	6.01	1.0057	5.0277	4.6874	0.3403	6.7316	0.3156
	120	5.87	1.0058	5.0277	4.5593	0.4684	9.2633	0.3074
	180	6.09	1.0025	5.0277	4.5120	0.5157	10.2318	0.3044
	240	5.98	1.0031	5.0277	4.3261	0.7016	13.9121	0.2927
10	20	5.73	1.0038	10.0554	9.4712	0.5842	5.7883	0.2474
	40	5.76	1.0018	10.0554	9.3133	0.7421	7.3667	0.2434
	60	5.84	1.0042	10.0554	9.3002	0.7552	7.4804	0.2431
	120	5.75	1.0018	10.0554	9.0152	1.0402	10.3264	0.2359
	180	5.91	1.0036	10.0554	8.8179	1.2375	12.2646	0.2309
	240	5.76	1.0069	10.0554	8.4846	1.5708	15.5145	0.2224
20	20	5.42	1.0065	20.1107	19.3677	0.7430	3.6697	0.2491
	40	5.49	1.0045	20.1107	19.2099	0.9008	4.4593	0.2471
	60	5.66	1.0028	20.1107	18.6661	1.4446	7.1627	0.2402
	120	5.49	1.0013	20.1107	18.1487	1.9620	9.7430	0.2337
	180	5.80	1.0054	20.1107	17.9909	2.1198	10.4850	0.2317
	240	5.59	1.0017	20.1107	17.5612	2.5495	12.6556	0.2262
30	20	5.31	1.0055	30.1662	28.7951	1.3711	4.5193	0.3686
	40	5.40	1.0045	30.1662	28.4969	1.6693	5.5088	0.3648
	60	5.49	1.0047	30.1662	27.8655	2.3007	7.5908	0.3568
	120	5.36	1.0045	30.1662	27.6725	2.4937	8.2290	0.3543
	180	5.53	1.0070	30.1662	27.4445	2.7217	8.9600	0.3514
	240	5.42	1.0038	30.1662	26.8657	3.3005	10.8996	0.3441
blank	240	6.26	1.0035	0.0000	0.2938	-0.2938		0.1861

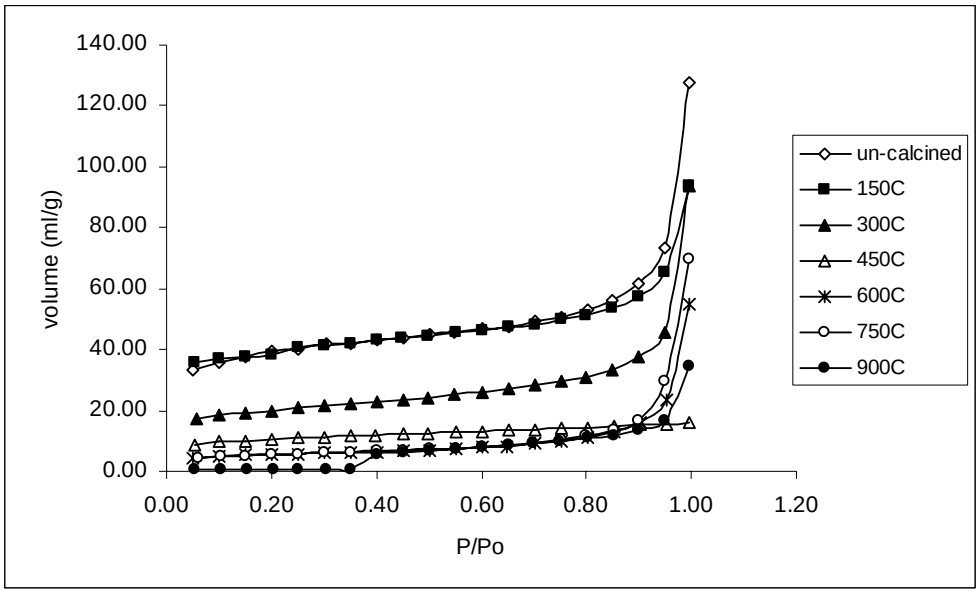
Appendix Table B5 Data from experiment of calcination perlite at 750ºC after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	Trial	pH	Perlite weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g perlite	absorbance (average)
					Before adsorption	After adsorption	Amount adsorption		
5	180	1	5.63	1.0380	5.0254	5.1283	-0.1029	-1.9726	0.3260
		2	5.64	1.0038	5.0254	5.1336	-0.1082	-2.1441	0.3263
		3	5.60	1.0445	5.0254	5.0915	-0.0661	-1.2587	0.3237
	240	1	6.27	1.0030	5.0254	5.0652	-0.0398	-0.7888	0.3220
		2	6.20	1.0261	5.0254	5.0704	-0.0450	-0.8731	0.3223
		3	6.23	1.0110	5.0254	5.0704	-0.0450	-0.8861	0.3223
30	180	1	5.78	1.0330	30.1525	31.4740	-1.3215	-4.2427	0.3990
		2	5.97	1.0391	30.1525	31.2109	-1.0584	-3.3781	0.3957
		3	5.59	1.0083	30.1525	31.3161	-1.1636	-3.8274	0.3970
	240	1	5.76	1.0145	30.1525	30.9741	-0.8216	-2.6860	0.3927
		2	5.75	1.0347	30.1525	31.3161	-1.1636	-3.7298	0.3970
		3	6.07	1.0077	30.1525	30.9215	-0.7690	-2.5309	0.3920
blank	240	1	6.28	1.0342	0.0000	0.0368	-0.0368		0.0233
		2	6.37	1.0068	0.0000	0.0053	-0.0053		0.0033
		3	6.37	1.0069	0.0000	0.0110	-0.0110		0.0070
		average				0.0177	-0.0177		0.0112

Appendix Table B6 Data from experiment of calcination diatomite at 750ºC after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	Trial	pH	Diatomite weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g diatomite	absorbance (average)
					Before adsorption	After adsorption	Amount adsorption		
5	180	1	5.84	1.0093	5.0254	4.5346	0.4908	9.6765	0.3017
		2	5.61	1.0143	5.0254	4.4294	0.5960	11.6933	0.2950
		3	5.72	1.0150	5.0254	4.6030	0.4224	8.2811	0.3060
	240	1	6.00	1.0132	5.0254	4.8503	0.1751	3.4389	0.3217
		2	5.90	1.0039	5.0254	4.6556	0.3698	7.3297	0.3093
		3	5.95	1.0040	5.0254	4.5977	0.4277	8.4761	0.3057
30	180	1	5.44	1.0008	30.1525	29.6333	0.5192	1.7207	0.3783
		2	5.20	1.0025	30.1525	28.7124	1.4401	4.7640	0.3667
		3	5.49	1.0008	30.1525	30.3173	-0.1648	-0.5461	0.3870
	240	1	5.70	1.0056	30.1525	28.5020	1.6505	5.4434	0.3640
		2	6.00	1.0056	30.1525	29.2912	0.8613	2.8404	0.3740
		3	5.96	1.0003	30.1525	29.5017	0.6508	2.1577	0.3767
blank	240	1	6.12	1.0022	0.0000	0.1715	-0.1715		0.1087
		2	5.93	1.0057	0.0000	0.2336	-0.2336		0.1480
		3	5.94	1.0187	0.0000	0.2768	-0.2768		0.1753
		average				0.2273	-0.2273		

Appendix C



Appendix Figure C1 Nitrogen adsorption isotherms of the natural zeolite calcination at various temperatures

Date: 02/06/2006

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

Sample ID	Natural Zeolite 25				
Description	TISTR				
Comments					
Sample Weight	0.2047 g				
Adsorbate	NITROGEN	Outgas Temp	300.0 °C	Operator	Rungrueng
Cross-Sec Area	16.2 Å²/molecule	Outgas Time	3.0 hrs	Analysis Time	931.7 min
NonIdeality	6.580E-05	P/Po Toler	0	End of Run	01/18/2006
Molecular Wt	28.0134 g/mol	Equil Time	3	File Name	AS010327.RAI
Station #	1	Bath Temp.	77.40		

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

Multipoint BET	1.262E+02	m²/g
Single Point BET	1.262E+02	m²/g
BJH Method Cumulative Adsorption Surface Area	7.366E+01	m²/g
BJH Method Cumulative Desorption Surface Area	3.693E+01	m²/g
DH Method Cumulative Adsorption Surface Area	7.705E+01	m²/g
DH Method Cumulative Desorption Surface Area	3.905E+01	m²/g
DR Method Micro Pore Area	1.818E+02	m²/g

PORE VOLUME DATA

Total Pore Volume for pores with Diameter less than 3868.3 Å at P/Po = 0.99503	1.975E-01	cc/g
BJH Method Cumulative Adsorption Pore Volume	1.664E-01	cc/g
BJH Method Cumulative Desorption Pore Volume	1.367E-01	cc/g
BJH Interpolated Cumulative Adsorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	1.664E-01	cc/g
BJH Interpolated Cumulative Desorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	1.367E-01	cc/g
DH Method Cumulative Adsorption Pore Volume	1.628E-01	cc/g
DH Method Cumulative Desorption Pore Volume	1.338E-01	cc/g
DR Method Micro Pore Volume	6.460E-02	cc/g
HK Method Cumulative Pore Volume	5.822E-02	cc/g
SF Method Cumulative Pore Volume	5.917E-02	cc/g

PORE SIZE DATA

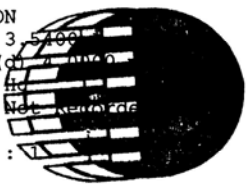
Average Pore Diameter	6.259E+01	Å
BJH Method Adsorption Pore Diameter (Mode)	1.940E+01	Å
BJH Method Desorption Pore Diameter (Mode)	3.816E+01	Å
DH Method Adsorption Pore Diameter (Mode)	1.940E+01	Å
DH Method Desorption Pore Diameter (Mode)	3.816E+01	Å
DR Method Micro Pore Width	8.112E+01	Å
DA Method Pore Diameter (Mode)	1.740E+01	Å
HK Method Pore Width (Mode)	1.492E+01	Å
SF Method Pore Diameter (Mode)	2.805E+01	Å

DATA REDUCTION PARAMETERS

Thermal Transpiration : ON
Effective Molecule Diameter (D) 3.5400
Effective Cell Stem Inner Diameter (d)
Last Po Acquired 788.55 mm Hg
Additional Initialization Information

BJH/DH Moving Average Size :

Interaction Constant (K) 2.9600 nm^3 x kJ/mol



TISTR

Appendix Figure C2 BET analysis of non calcination mordenite

Date: 06/16/2006

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

Sample ID	Mrdenite 150				
Description	TISTR				
Comments					
Sample Weight	0.0997 g				
Adsorbate	NITROGEN	Outgas Temp	300.0 °C	Operator	Rungrueng
Cross-Sec Area	16.2 Å²/molecule	Outgas Time	3.0 hrs	Analysis Time	434.1 min
NonIdeality	6.580E-05	P/Po Toler	0	End of Run	05/31/2006 18
Molecular Wt	28.0134 g/mol	Equil Time	3	File Name	AS010467.RAW
Station #	1	Bath Temp.	77.40		

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

Multipoint BET	1.248E+02	m²/g
Single Point BET	1.262E+02	m²/g
BJH Method Cumulative Adsorption Surface Area	4.669E+01	m²/g
BJH Method Cumulative Desorption Surface Area	2.905E+01	m²/g
DH Method Cumulative Adsorption Surface Area	4.868E+01	m²/g
DH Method Cumulative Desorption Surface Area	2.970E+01	m²/g
DR Method Micro Pore Area	1.767E+02	m²/g

PORE VOLUME DATA

Total Pore Volume for pores with Diameter less than 3634.9 Å at P/Po = 0.99470	1.450E-01	cc/g
BJH Method Cumulative Adsorption Pore Volume	1.034E-01	cc/g
BJH Method Cumulative Desorption Pore Volume	8.732E-02	cc/g
BJH Interpolated Cumulative Adsorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	1.034E-01	cc/g
BJH Interpolated Cumulative Desorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	8.732E-02	cc/g
DH Method Cumulative Adsorption Pore Volume	1.013E-01	cc/g
DH Method Cumulative Desorption Pore Volume	8.530E-02	cc/g
DR Method Micro Pore Volume	6.279E-02	cc/g
HK Method Cumulative Pore Volume	5.840E-02	cc/g
SF Method Cumulative Pore Volume	5.846E-02	cc/g

PORE SIZE DATA

Average Pore Diameter	4.648E+01	Å
BJH Method Adsorption Pore Diameter (Mode)	2.190E+01	Å
BJH Method Desorption Pore Diameter (Mode)	3.815E+01	Å
DH Method Adsorption Pore Diameter (Mode)	2.190E+01	Å
DH Method Desorption Pore Diameter (Mode)	3.815E+01	Å
DR Method Micro Pore Width	6.280E+01	Å
DA Method Pore Diameter (Mode)	1.460E+01	Å
HK Method Pore Width (Mode)	1.462E+01	Å
SF Method Pore Diameter (Mode)	2.750E+01	Å

DATA REDUCTION PARAMETERS

Thermal Transpiration : ON
Effective Molecule Diameter (D) 3.5400 Å
Effective Cell Stem Inner Diameter (d) 4.0800 mm
Last Po Acquired 798.09 mm Hg
Additional Initialization Information Not Recorded

BJH/DH Moving Average Size : 1

Interaction Constant (K) 2.9600 nm^3 x kJ/mol

Appendix Figure C3 BET analysis of calcination mordenite at 150ºC

Date: 06/16/2006

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

Sample ID	Mrdenite 300				
Description	TISTR				
Comments					
Sample Weight	0.0863 g				
Adsorbate	NITROGEN	Outgas Temp	300.0 °C	Operator	Rungrueng
Cross-Sec Area	16.2 Å²/molecule	Outgas Time	3.0 hrs	Analysis Time	387.1 min
NonIdeality	6.580E-05	P/Po Toler	0	End of Run	06/01/2006 17
Molecular Wt	28.0134 g/mol	Equil Time	3	File Name	AS010468.RAW
Station #	1	Bath Temp.	77.40		

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

Multipoint BET	6.497E+01	m²/g
Single Point BET	6.509E+01	m²/g
BJH Method Cumulative Adsorption Surface Area	4.028E+01	m²/g
BJH Method Cumulative Desorption Surface Area	5.406E+01	m²/g
DH Method Cumulative Adsorption Surface Area	4.168E+01	m²/g
DH Method Cumulative Desorption Surface Area	5.463E+01	m²/g
DR Method Micro Pore Area	9.303E+01	m²/g

PORE VOLUME DATA

Total Pore Volume for pores with Diameter less than 4924.4 Å at P/Po = 0.99610	1.447E-01	cc/g
BJH Method Cumulative Adsorption Pore Volume	1.299E-01	cc/g
BJH Method Cumulative Desorption Pore Volume	1.200E-01	cc/g
BJH Interpolated Cumulative Adsorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	1.299E-01	cc/g
BJH Interpolated Cumulative Desorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	1.200E-01	cc/g
DH Method Cumulative Adsorption Pore Volume	1.265E-01	cc/g
DH Method Cumulative Desorption Pore Volume	1.171E-01	cc/g
DR Method Micro Pore Volume	3.306E-02	cc/g
HK Method Cumulative Pore Volume	2.974E-02	cc/g
SF Method Cumulative Pore Volume	3.009E-02	cc/g

PORE SIZE DATA

Average Pore Diameter	[illegible]	Å
BJH Method Adsorption Pore Diameter (Mode)	[illegible]	Å
BJH Method Desorption Pore Diameter (Mode)	[illegible]	Å
DH Method Adsorption Pore Diameter (Mode)	[illegible]	Å
DH Method Desorption Pore Diameter (Mode)	[illegible]	Å
DR Method Micro Pore Width	[illegible]	Å
DA Method Pore Diameter (Mode)	1.740E+01	Å
HK Method Pore Width (Mode)	[illegible]	Å
SF Method Pore Diameter (Mode)	2.796E+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 792.47 mm Hg
Additional Initialization Information Not Recorded.

BJH/DH Moving Average Size : 1

Interaction Constant (K) 2.9600 nm^3 x kJ/mol

Appendix Figure C4 BET analysis of calcination mordenite at 300ºC

Date: 02/24/2006

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

Sample ID	Mordenite450C				
Description	TISTR				
Comments					
Sample Weight	0.3131 g				
Adsorbate	NITROGEN	Outgas Temp	300.0 °C	Operator	Rungrueng
Cross-Sec Area	16.2 Å²/molecule	Outgas Time	3.0 hrs	Analysis Time	309.4 min
NonIdeality	6.580E-05	P/Po Toler	0	End of Run	02/20/2006 20
Molecular Wt	28.0134 g/mol	Equil Time	3	File Name	AS010439.RAW
Station #	1	Bath Temp.	77.40		

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

Multipoint BET	3.458E+01	m²/g
Single Point BET	3.454E+01	m²/g
BJH Method Cumulative Adsorption Surface Area	2.342E+01	m²/g
BJH Method Cumulative Desorption Surface Area	1.327E+01	m²/g
DH Method Cumulative Adsorption Surface Area	2.458E+01	m²/g
DH Method Cumulative Desorption Surface Area	1.397E+01	m²/g
DR Method Micro Pore Area	5.017E+01	m²/g

PORE VOLUME DATA

Total Pore Volume for pores with Diameter less than 4925.7 Å at P/Po = 0.99610	2.475E-02	cc/g
BJH Method Cumulative Adsorption Pore Volume	1.747E-02	cc/g
BJH Method Cumulative Desorption Pore Volume	1.052E-02	cc/g
BJH Interpolated Cumulative Adsorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	1.747E-02	cc/g
BJH Interpolated Cumulative Desorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	1.052E-02	cc/g
DH Method Cumulative Adsorption Pore Volume	1.743E-02	cc/g
DH Method Cumulative Desorption Pore Volume	1.049E-02	cc/g
DR Method Micro Pore Volume	1.783E-02	cc/g
HK Method Cumulative Pore Volume	1.578E-02	cc/g
SF Method Cumulative Pore Volume	1.598E-02	cc/g

PORE SIZE DATA

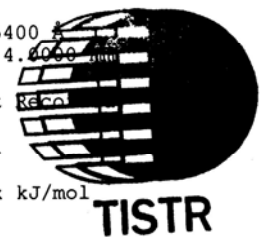
Average Pore Diameter	2.862E+01	Å
BJH Method Adsorption Pore Diameter (Mode)	1.437E+01	Å
BJH Method Desorption Pore Diameter (Mode)	1.409E+01	Å
DH Method Adsorption Pore Diameter (Mode)	1.437E+01	Å
DH Method Desorption Pore Diameter (Mode)	1.409E+01	Å
DR Method Micro Pore Width	8.863E+01	Å
DA Method Pore Diameter (Mode)	1.740E+01	Å
HK Method Pore Width (Mode)	1.448E+01	Å
SF Method Pore Diameter (Mode)	2.713E+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 515.50 mm Hg
Additional Initialization Information Not Reco

BJH/DH Moving Average Size : 1

Interaction Constant (K) 2.9600 nm^3 x kJ/mol



Appendix Figure C5 BET analysis of calcination mordenite at 450ºC

Date: 05/25/2006

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

Sample ID	Mordenite 600C				
Description	TISTR				
Comments					
Sample Weight	0.0672 g				
Adsorbate	NITROGEN	Outgas Temp	300.0 °C	Operator	Rungrueng
Cross-Sec Area	16.2 Å²/molecule	Outgas Time	3.0 hrs	Analysis Time	308.2 min
NonIdeality	6.580E-05	P/Po Toler	0	End of Run	05/23/2006
Molecular Wt	28.0134 g/mol	Equil Time	3	File Name	AS010460.R
Station #	1	Bath Temp.	77.40		

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

Multipoint BET	1.779E+01	m²/g
Single Point BET	1.777E+01	m²/g
BJH Method Cumulative Adsorption Surface Area	1.613E+01	m²/g
BJH Method Cumulative Desorption Surface Area	3.081E+01	m²/g
DH Method Cumulative Adsorption Surface Area	1.677E+01	m²/g
DH Method Cumulative Desorption Surface Area	3.116E+01	m²/g
DR Method Micro Pore Area	2.562E+01	m²/g

PORE VOLUME DATA

Total Pore Volume for pores with Diameter less than 3495.4 Å at P/Po = 0.99449	8.692E-02	cc/g
BJH Method Cumulative Adsorption Pore Volume	8.610E-02	cc/g
BJH Method Cumulative Desorption Pore Volume	8.763E-02	cc/g
BJH Interpolated Cumulative Adsorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	8.610E-02	cc/g
BJH Interpolated Cumulative Desorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	8.763E-02	cc/g
DH Method Cumulative Adsorption Pore Volume	8.394E-02	cc/g
DH Method Cumulative Desorption Pore Volume	8.550E-02	cc/g
DR Method Micro Pore Volume	9.103E-03	cc/g
HK Method Cumulative Pore Volume	8.122E-03	cc/g
SF Method Cumulative Pore Volume	8.227E-03	cc/g

PORE SIZE DATA

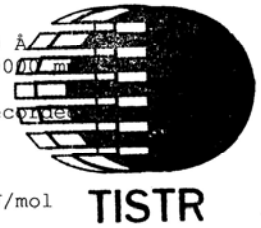
Average Pore Diameter	1.955E+02	Å
BJH Method Adsorption Pore Diameter (Mode)	4.908E+01	Å
BJH Method Desorption Pore Diameter (Mode)	3.814E+01	Å
DH Method Adsorption Pore Diameter (Mode)	4.908E+01	Å
DH Method Desorption Pore Diameter (Mode)	3.814E+01	Å
DR Method Micro Pore Width	8.490E+01	Å
DA Method Pore Diameter (Mode)	1.740E+01	Å
HK Method Pore Width (Mode)	1.473E+01	Å
SF Method Pore Diameter (Mode)	2.768E+01	Å

DATA REDUCTION PARAMETERS

Thermal Transpiration : ON
Effective Molecule Diameter (D) 3.5400 Å
Effective Cell Stem Inner Diameter (d) 4.0000 m
Last Po Acquired 788.08 mm Hg
Additional Initialization Information Not Recorded

BJH/DH Moving Average Size : 1

Interaction Constant (K) 2.9600 nm^3 x kJ/mol



Appendix Figure C6 BET analysis of calcination mordenite at 600ºC

Date: 02/24/2006

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

Sample ID	Mordenite750C				
Description	TISTR				
Comments					
Sample Weight	0.2296 g				
Adsorbate	NITROGEN	Outgas Temp	300.0 °C	Operator	Rungrueng
Cross-Sec Area	16.2 Å²/molecule	Outgas Time	3.0 hrs	Analysis Time	682.3 min
NonIdeality	6.580E-05	P/Po Toler	0	End of Run	02/16/2006 22
Molecular Wt	28.0134 g/mol	Equil Time	3	File Name	AS010438.RAW
Station #	1	Bath Temp.	77.40		

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

Multipoint BET	1.825E+01	m²/g
Single Point BET	1.816E+01	m²/g
BJH Method Cumulative Adsorption Surface Area	1.440E+01	m²/g
BJH Method Cumulative Desorption Surface Area	2.662E+01	m²/g
DH Method Cumulative Adsorption Surface Area	1.461E+01	m²/g
DH Method Cumulative Desorption Surface Area	2.715E+01	m²/g
DR Method Micro Pore Area	2.588E+01	m²/g

PORE VOLUME DATA

Total Pore Volume for pores with Diameter less than 3264.0 Å at P/Po = 0.99410	1.075E-01	cc/g
BJH Method Cumulative Adsorption Pore Volume	1.050E-01	cc/g
BJH Method Cumulative Desorption Pore Volume	1.089E-01	cc/g
BJH Interpolated Cumulative Adsorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	1.050E-01	cc/g
BJH Interpolated Cumulative Desorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	1.089E-01	cc/g
DH Method Cumulative Adsorption Pore Volume	1.020E-01	cc/g
DH Method Cumulative Desorption Pore Volume	1.062E-01	cc/g
DR Method Micro Pore Volume	9.196E-03	cc/g
HK Method Cumulative Pore Volume	8.016E-03	cc/g
SF Method Cumulative Pore Volume	8.139E-03	cc/g

PORE SIZE DATA

Average Pore Diameter	2.357E+02	Å
BJH Method Adsorption Pore Diameter (Mode)	1.434E+01	Å
BJH Method Desorption Pore Diameter (Mode)	3.822E+01	Å
DH Method Adsorption Pore Diameter (Mode)	1.434E+01	Å
DH Method Desorption Pore Diameter (Mode)	3.822E+01	Å
DR Method Micro Pore Width	9.250E+01	Å
DA Method Pore Diameter (Mode)	1.740E+01	Å
HK Method Pore Width (Mode)	1.473E+01	Å
SF Method Pore Diameter (Mode)	2.768E+01	Å

DATA REDUCTION PARAMETERS

Thermal Transpiration : ON
Effective Molecule Diameter (D) 3.54[illegible]
Effective Cell Stem Inner Diameter (d) [illegible]
Last Po Acquired 792.18 mm Hg
Additional Initialization Information None

BJH/DH Moving Average Size : 1

Interaction Constant (K) 2.9600 nm^3 x kJ/mol

Appendix Figure C7 BET analysis of calcination mordenite at 750ºC

Date: 06/16/2006

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

Sample ID	Mrdenite 900				
Description	TISTR				
Comments					
Sample Weight	0.1037 g				
Adsorbate	NITROGEN	Outgas Temp	300.0 °C	Operator	Rungrueng
Cross-Sec Area	16.2 Å²/molecule	Outgas Time	3.0 hrs	Analysis Time	296.2 min
NonIdeality	6.580E-05	P/Po Toler	0	End of Run	06/07/2006 19
Molecular Wt	28.0134 g/mol	Equil Time	3	File Name	AS010469.RAW
Station #	1	Bath Temp.	77.40		

AREA-VOLUME-PORE SIZE SUMMARY

SURFACE AREA DATA

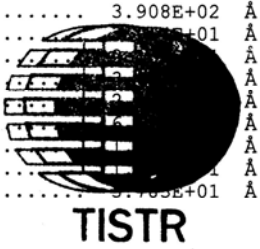
Multipoint BET	2.661E+00	m²/g
Single Point BET	2.678E+00	m²/g
BJH Method Cumulative Adsorption Surface Area	3.266E+01	m²/g
BJH Method Cumulative Desorption Surface Area	4.306E+01	m²/g
DH Method Cumulative Adsorption Surface Area	3.361E+01	m²/g
DH Method Cumulative Desorption Surface Area	5.536E+01	m²/g
DR Method Micro Pore Area	3.970E+00	m²/g

PORE VOLUME DATA

Total Pore Volume for pores with Diameter less than 408.1 Å at P/Po = 0.95055	2.599E-02	cc/g
BJH Method Cumulative Adsorption Pore Volume	6.663E-02	cc/g
BJH Method Cumulative Desorption Pore Volume	7.027E-02	cc/g
BJH Interpolated Cumulative Adsorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	6.663E-02	cc/g
BJH Interpolated Cumulative Desorption Pore Volume for pores in the range of 5000.0 to 0.0 Å Diameter	7.027E-02	cc/g
DH Method Cumulative Adsorption Pore Volume	6.522E-02	cc/g
DH Method Cumulative Desorption Pore Volume	7.533E-02	cc/g
DR Method Micro Pore Volume	1.411E-03	cc/g
HK Method Cumulative Pore Volume	1.326E-03	cc/g
SF Method Cumulative Pore Volume	1.346E-03	cc/g

PORE SIZE DATA

Average Pore Diameter	3.908E+02	Å
BJH Method Adsorption Pore Diameter (Mode)	[illegible]	Å
BJH Method Desorption Pore Diameter (Mode)	[illegible]	Å
DH Method Adsorption Pore Diameter (Mode)	[illegible]	Å
DH Method Desorption Pore Diameter (Mode)	[illegible]	Å
DR Method Micro Pore Width	[illegible]	Å
DA Method Pore Diameter (Mode)	[illegible]	Å
HK Method Pore Width (Mode)	[illegible]	Å
SF Method Pore Diameter (Mode)	[illegible]	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 791.10 mm Hg
Additional Initialization Information Not Recorded.

BJH/DH Moving Average Size : 1

Interaction Constant (K) 2.9600 nm^3 x kJ/mol

Appendix Figure C8 BET analysis of calcination mordenite at 900ºC

Appendix D

SEMQuant results. Listed at 11:03:01 PM on 28/2/06
Operator: Chaweewan
Client: none
Job: Job 2006_1
Spectrum label: 25 C ADSORB

System resolution = 76 eV

Quantitative method: ZAF (3 iterations).
Analysed elements combined with: O (Valency: -2)
Method : Stoichiometry Normalised results.
Nos. of ions calculation based on 32 anions per formula.

3 peaks possibly omitted: -0.02, 0.24, 8.02 keV

Standards :

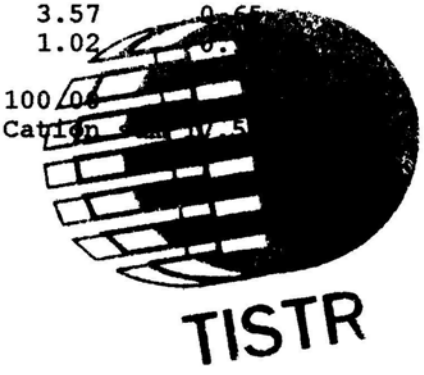
Na K	NaCl 8/27/02
Mg K	mgo sem 3/13/98
Al K	Al 5/22/02
Si K	sic_c 3/19/98
K K	KBr 5/22/02
Ca K	CaSiO 8/27/02
Fe K	Fe 8/27/02

Elmt	Spect. Type	Element %	Atomic %		Compound %	Nos. of ions
Na K	ED	1.05	0.94	Na2O	1.42	0.47
Mg K	ED	0.30	0.26	MgO	0.50	0.13
Al K	ED	5.77	4.38	Al2O3	10.91	2.17
Si K	ED	37.94	27.67	SiO2	81.15	13.72
K K	ED	1.19	0.62	K2O	1.43	0.31
Ca K	ED	2.55	1.30	CaO	3.57	0.65
Fe K	ED	0.79	0.29	FeO	1.02	0.[illegible]
O		50.41	64.54			
Total		100.00	100.00		100.06	
					Cation [illegible]	

* = <2 Sigma

Fit Indices

Na K	25.4
Mg K	2.4
Al K	0.8
Si K	2.6
K K	0.1
Ca K	0.1
Fe K	0.3
O Ka	0.0



Appendix Figure D1 Chemical composition analysis of non calcinations mordenite

SEMQuant results. Listed at 15:23:29 PM on 19/5/06
Operator: Chaweewan
Client: none
Job: Job 2006_1
Spectrum label: 1500 C

System resolution = 77 eV

Quantitative method: ZAF (3 iterations).
Analysed elements combined with: O (Valency: -2)
Method : Stoichiometry Normalised results.
Nos. of ions calculation based on 32 anions per formula.

3 peaks possibly omitted: -0.02, 0.24, 8.04 keV

Standards :

Na K	NaCl 8/27/02
Mg K	mgo sem 3/13/98
Al K	Al 5/22/02
Si K	sic_c 3/19/98
K K	KBr 5/22/02
Ca K	CaSiO 8/27/02
Ti K	Ti 5/22/02
Fe K	Fe 8/27/02

Elmt	Spect. Type	Element %	Atomic %		Compound %	Nos. of ions
Na K	ED	0.90	0.81	Na2O	1.21	0.40
Mg K	ED	0.50	0.42	MgO	0.83	0.21
Al K	ED	6.36	4.88	Al2O3	12.02	2.43
Si K	ED	36.26	26.69	SiO2	77.57	13.31
K K	ED	1.81	0.95	K2O	2.17	0.48
Ca K	ED	2.60	1.34	CaO	3.64	0.67
Ti K	ED	0.24	0.10	TiO2	0.39	0.05
Fe K	ED	1.68	0.62	FeO	2.16	0.31
O		49.66	64.18			32.00
Total		100.00	100.00		100.00	
					Cation sum	17.86

* = <2 Sigma

Fit Indices

Na K	14.8
Mg K	1.6
Al K	0.8
Si K	0.4
K K	0.2
Ca K	0.2
Ti K	0.5
Fe K	0.4
O Ka	0.0

TISTR

Appendix Figure D2 Chemical composition analysis of mordenite calcined at 150ºC

SEMQuant results. Listed at 15:22:30 PM on 19/5/06
Operator: Chaweewan
Client: none
Job: Job 2006_1
Spectrum label: 3000 C

System resolution = 77 eV

Quantitative method: ZAF (3 iterations).
Analysed elements combined with: O (Valency: -2)
Method : Stoichiometry Normalised results.
Nos. of ions calculation based on 32 anions per formula.

4 peaks possibly omitted: -0.02, 0.24, 8.02, 8.62 keV

Standards :

Na K	NaCl 8/27/02
Mg K	mgo sem 3/13/98
Al K	Al 5/22/02
Si K	sic_c 3/19/98
K K	KBr 5/22/02
Ca K	CaSiO 8/27/02
Ti K	Ti 5/22/02
Fe K	Fe 8/27/02

Elmt	Spect. Type	Element %	Atomic %		Compound %	Nos. of ions
Na K	ED	0.81	0.72	Na2O	1.09	0.36
Mg K	ED	0.40	0.34	MgO	0.66	0.17
Al K	ED	5.97	4.55	Al2O3	11.27	2.26
Si K	ED	37.23	27.30	SiO2	79.64	13.56
K K	ED	1.49	0.78	K2O	1.79	0.39
Ca K	ED	2.46	1.27	CaO	3.45	0.63
Ti K	ED	0.13	0.06	TiO2	0.22	0.03
Fe K	ED	1.46	0.54	FeO	1.88	0.27
O		50.06	64.44			32.00
Total		100.00	100.00		100.00	
					Cation sum	17.66

* = <2 Sigma

Fit Indices

Na K	24.8
Mg K	2.9
Al K	1.0
Si K	0.6
K K	0.2
Ca K	0.2
Ti K	0.4
Fe K	0.6
O Ka	0.0

TISTR

Appendix Figure D3 Chemical composition analysis of mordenite calcined at 300ºC

SEMQuant results. Listed at 11:22:18 PM on 28/2/06
Operator: Chaweewan
Client: none
Job: Job 2006_1
Spectrum label: 450 C ADSORB

System resolution = 77 eV

Quantitative method: ZAF (3 iterations).
Analysed elements combined with: O (Valency: -2)
Method : Stoichiometry Normalised results.
Nos. of ions calculation based on 32 anions per formula.

4 peaks possibly omitted: -0.02, 0.24, 4.54, 8.08 keV

Standards :

Na K	NaCl 8/27/02
Mg K	mgo sem 3/13/98
Al K	Al 5/22/02
Si K	sic_c 3/19/98
K K	KBr 5/22/02
Ca K	CaSiO 8/27/02
Fe K	Fe 8/27/02

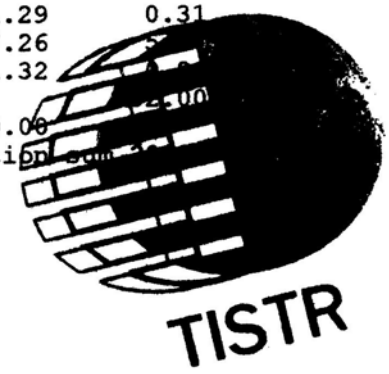
Elmt	Spect. Type	Element %	Atomic %		Compound %	Nos. of ions
Na K	ED	0.65	0.63	Na2O	0.88	0.33
Mg K	ED	0.55	0.50	MgO	0.91	0.26
Al K	ED	4.78	3.90	Al2O3	9.03	2.03
Si K	ED	27.72	21.73	SiO2	59.31	11.30
K K	ED	1.07	0.60	K2O	1.29	0.31
Ca K	ED	19.48	10.70	CaO	27.26	[illegible]
Fe K	ED	1.03	0.40	FeO	1.32	[illegible]
O		44.71	61.53			
Total		100.00	100.00		100.00	

Cation [illegible]

* = <2 Sigma

Fit Indices

Na K	14.8
Mg K	1.0
Al K	1.4
Si K	2.7
K K	0.2
Ca K	0.9
Fe K	0.4
O Ka	0.0



Appendix Figure D4 Chemical composition analysis of mordenite calcined at 450ºC

SEMQuant results. Listed at 15:27:47 PM on 19/5/06
Operator: Chaweewan
Client: none
Job: Job 2006_1
Spectrum label: 6000 C

System resolution = 77 eV

Quantitative method: ZAF (3 iterations).
Analysed elements combined with: O (Valency: -2)
Method : Stoichiometry Normalised results.
Nos. of ions calculation based on 32 anions per formula.

2 peaks possibly omitted: -0.02, 0.24 keV

Standards :

Na K	NaCl 8/27/02
Mg K	mgo sem 3/13/98
Al K	Al 5/22/02
Si K	sic_c 3/19/98
K K	KBr 5/22/02
Ca K	CaSiO 8/27/02
Ti K	Ti 5/22/02
Fe K	Fe 8/27/02

Elmt	Spect. Type	Element %	Atomic %		Compound %	Nos. of ions
Na K	ED	0.98	0.88	Na2O	1.32	0.44
Mg K	ED	0.46	0.39	MgO	0.76	0.19
Al K	ED	6.19	4.73	Al2O3	11.69	2.35
Si K	ED	36.70	26.94	SiO2	78.52	13.42
K K	ED	1.59	0.84	K2O	1.92	0.42
Ca K	ED	2.68	1.38	CaO	3.75	0.69
Ti K	ED	0.19	0.08	TiO2	0.32	0.04
Fe K	ED	1.34	0.49	FeO	1.72	0.25
O		49.87	64.27			32.00
Total		100.00	100.00		100.00	
					Cation sum	17.79

* = <2 Sigma

Fit Indices

Na K	24.3
Mg K	1.8
Al K	0.8
Si K	2.5
K K	0.1
Ca K	0.1
Ti K	0.1
Fe K	0.2
O Ka	0.0

TISTR

Appendix Figure D5 Chemical composition analysis of mordenite calcined at 600ºC

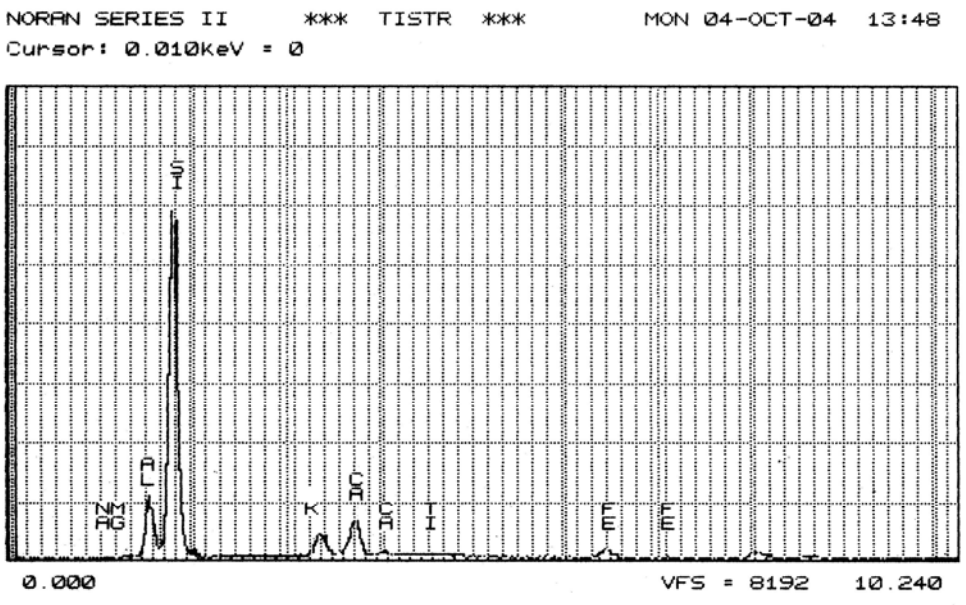
```
*X 'SQ
SQ -3B/80

SQ: SETUP DEFINITIONS

SQ: QUANTIFY

CLINOPTILOLITE P3 4/10/47
Standardless Analysis
  25.0 kV   40.0 Degrees

Refit _MNK' _MNK"
Refit _TIK' _TIK" _MNK
Chi-sqd = 1.98

Element        Rel. K-ratio          Net Counts
  Na-K    0.00737 +/- 0.00218       270 +/-    80
  Mg-K    0.00734 +/- 0.00253       528 +/-   182
  Al-K    0.12283 +/- 0.00407     10996 +/-   364
  Si-K    0.63923 +/- 0.00487     68322 +/-   521
  K -K    0.06088 +/- 0.00225      5643 +/-   209
  Ca-K    0.10522 +/- 0.00329      8472 +/-   265
  Ti-K    0.00456 +/- 0.00104       325 +/-    74
  Mn-K    0.00000 +/- 0.00000         0 +/-     0
  Fe-K    0.05257 +/- 0.00351      2622 +/-   175

PRZ Correction 25.00 kV  40.00 deg
No.of Iterations = 18

Element  K-ratio     Z      A      F      Atom%    Wt%     Formula  Compound%
  Na-K    0.002   1.040  3.198  0.995    0.75    0.83      Na2O      1.11
  Mg-K    0.002   1.021  2.206  0.991    0.48    0.55      MgO       0.92
  Al-K    0.042   1.058  1.665  0.987    5.61    7.23      Al2O3    13.66
  Si-K    0.211   1.033  1.540  0.999   24.97   33.46      SiO2     71.59
  K -K    0.021   1.097  1.185  0.992    1.42    2.66      K 2O      3.20
  Ca-K    0.036   1.075  1.143  0.998    2.29    4.37      CaO       6.12
  Ti-K    0.002   1.181  1.085  0.997    0.09    0.20      TiO2      0.33
  Mn-K    0.000   1.212  1.023  1.000    0.00    0.00      MnO       0.00
  Fe-K    0.018   1.193  1.012  1.000    0.81    2.15      Fe2O3     3.07
  O -K    0.109   0.947  4.693  1.000   63.59   48.55 S    ---       ---
                                        Total= 100.00%    Total=  100.00%
```

Appendix Figure D6 Chemical composition analysis of mordenite calcined at 750ºC

```
SQ: QUANTIFY

CLINOPTILOLITE P1 4/10/47
Standardless Analysis
  25.0 kV   40.0 Degrees

Refit _MNK' _MNK"
Refit _NAK" _TIK" _MNK
Chi-sqd = 2.08

Element        Rel. K-ratio          Net Counts
  Na-K    0.00443 +/- 0.00114      174 +/-    45
  Mg-K    0.00680 +/- 0.00231      526 +/-   179
  Al-K    0.12289 +/- 0.00379    11817 +/-   364
  Si-K    0.63337 +/- 0.00474    72718 +/-   544
  K -K    0.05748 +/- 0.00219     5724 +/-   218
  Ca-K    0.12003 +/- 0.00326    10381 +/-   282
  Ti-K    0.00516 +/- 0.00100      396 +/-    77
  Mn-K    0.00000 +/- 0.00000        0 +/-     0
  Fe-K    0.04984 +/- 0.00332     2670 +/-   178

PRZ Correction 25.00 kV  40.00 deg
No.of Iterations = 2

Element  K-ratio     Z      A      F      Atom%    Wt%      Formula  Compound%
  Na-K    0.001    1.042  3.176  0.995    0.44     0.49      Na2O      0.66
  Mg-K    0.002    1.023  2.172  0.991    0.43     0.50      MgO       0.83
  Al-K    0.041    1.059  1.647  0.986    5.49     7.07      Al2O3    13.35
  Si-K    0.213    1.034  1.531  0.999   25.13    33.67      SiO2     72.02
  K -K    0.019    1.099  1.188  0.992    1.34     2.49      K 2O      3.00
  Ca-K    0.040    1.077  1.141  0.999    2.58     4.92      CaO       6.89
  Ti-K    0.002    1.184  1.084  0.997    0.10     0.22      TiO2      0.37
  Mn-K    0.000    1.215  1.021  1.000    0.00     0.00      MnO       0.00
  Fe-K    0.017    1.195  1.011  1.000    0.76     2.01      Fe2O3     2.88
  O -K    0.113    0.949  4.533  1.000   63.73    48.63 S    ---        ---
                                         Total= 100.00%     Total=  100.00%
```

Appendix Figure D7 Chemical composition analysis of mordenite calcined at 750ºC (cont'd)

```
SQ: QUANTIFY

CLINOPTILOLITE P2 4/10/47
Standardless Analysis
  25.0 kV   40.0 Degrees

Refit _MNK' _MNK"
Refit _TIK" _MNK  _FEK"
Chi-sqd = 1.88

Element        Rel. K-ratio          Net Counts
  Na-K     0.00886 +/- 0.00209      335 +/-    79
  Mg-K     0.00876 +/- 0.00249      652 +/-   185
  Al-K     0.13012 +/- 0.00403    12087 +/-   373
  Si-K     0.63486 +/- 0.00483    70121 +/-   534
  K -K     0.05629 +/- 0.00218     5392 +/-   209
  Ca-K     0.11341 +/- 0.00327     9486 +/-   272
  Ti-K     0.00417 +/- 0.00103      308 +/-    76
  Mn-K     0.00000 +/- 0.00000        0 +/-     0
  Fe-K     0.04352 +/- 0.00188     2243 +/-    97

PRZ Correction 25.00 kV  40.00 deg
No.of Iterations = 1

Element  K-ratio     Z      A      F      Atom%    Wt%      Formula  Compound%
  Na-K    0.003   1.043  3.138  0.995     0.87     0.96      Na2O      1.29
  Mg-K    0.003   1.023  2.172  0.991     0.55     0.64      MgO       1.06
  Al-K    0.043   1.060  1.652  0.986     5.78     7.46      Al2O3    14.10
  Si-K    0.209   1.034  1.543  0.999    24.83    33.35      SiO2     71.35
  K -K    0.019   1.100  1.189  0.993     1.30     2.43      K 2O      2.92
  Ca-K    0.038   1.077  1.141  0.999     2.41     4.63      CaO       6.48
  Ti-K    0.001   1.184  1.082  0.998     0.08     0.18      TiO2      0.30
  Mn-K    0.000   1.216  1.020  1.000     0.00     0.00      MnO       0.00
  Fe-K    0.014   1.196  1.010  1.000     0.65     1.75      Fe2O3     2.50
  O -K    0.115   0.949  4.471  1.000    63.52    48.60 S    ---       ---
                                        Total=  100.00%    Total=   100.00%
```



Appendix Figure D8 Chemical composition analysis of mordenite calcined at 750ºC (cont'd)

SEMQuant results. Listed at 15:32:40 PM on 19/5/06
Operator: Chaweewan
Client: none
Job: Job 2006_1
Spectrum label: 9000 C

System resolution = 77 eV

Quantitative method: ZAF (3 iterations).
Analysed elements combined with: O (Valency: -2)
Method : Stoichiometry Normalised results.
Nos. of ions calculation based on 32 anions per formula.

4 peaks possibly omitted: -0.02, 0.24, 2.26, 8.02 keV

Standards :

Na K	NaCl 8/27/02
Mg K	mgo sem 3/13/98
Al K	Al 5/22/02
Si K	sic_c 3/19/98
K K	KBr 5/22/02
Ca K	CaSiO 8/27/02
Ti K	Ti 5/22/02
Fe K	Fe 8/27/02

Elmt	Spect. Type	Element %	Atomic %		Compound %	Nos. of ions
Na K	ED	1.09	0.98	Na2O	1.48	0.49
Mg K	ED	0.51	0.43	MgO	0.84	0.21
Al K	ED	5.97	4.57	Al2O3	11.29	2.28
Si K	ED	36.55	26.85	SiO2	78.19	13.38
K K	ED	1.31	0.69	K2O	1.58	0.35
Ca K	ED	3.60	1.86	CaO	5.04	0.92
Ti K	ED	0.16	0.07	TiO2	0.27	0.03
Fe K	ED	1.02	0.38	FeO	1.31	0.19
O		49.78	64.18			32.00
Total		100.00	100.00		100.00	
					Cation sum	17.86

* = <2 Sigma

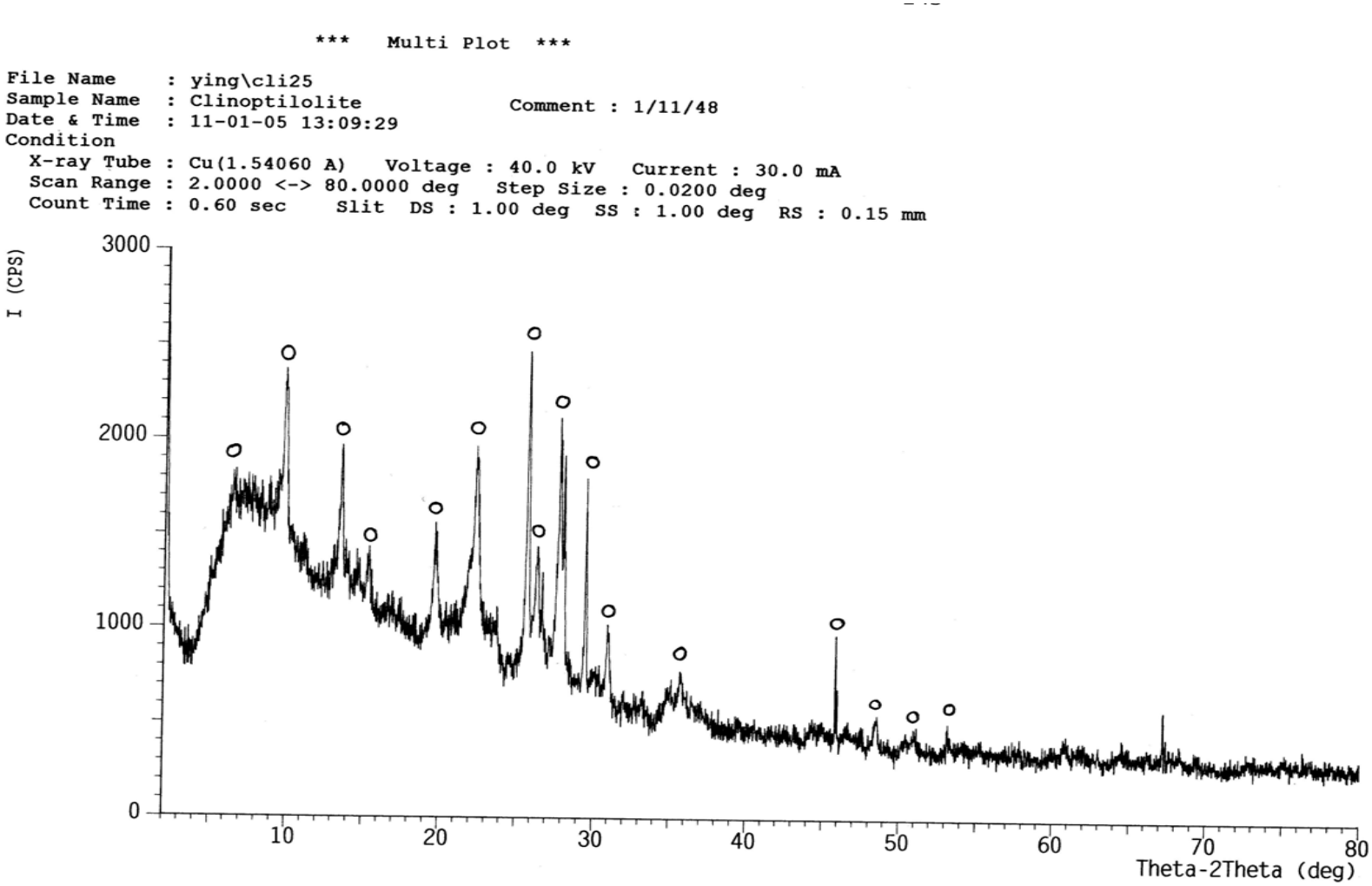
Fit Indices

Na K	34.5
Mg K	3.3
Al K	0.8
Si K	1.6
K K	0.1
Ca K	0.1
Ti K	0.4
Fe K	0.6
O Ka	0.0

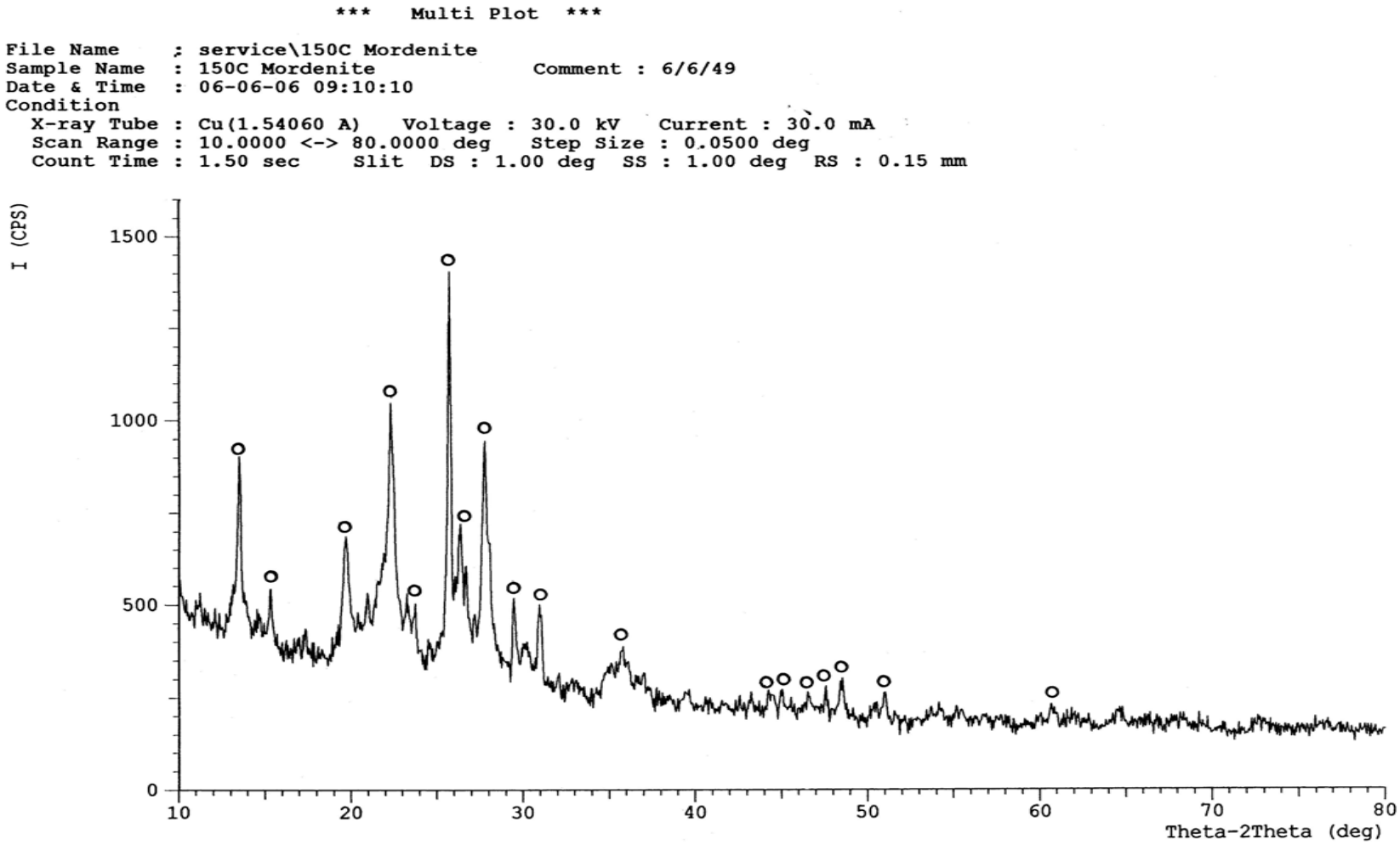
TISTR

Appendix Figure D9 Chemical composition analysis of mordenite calcined at 900ºC

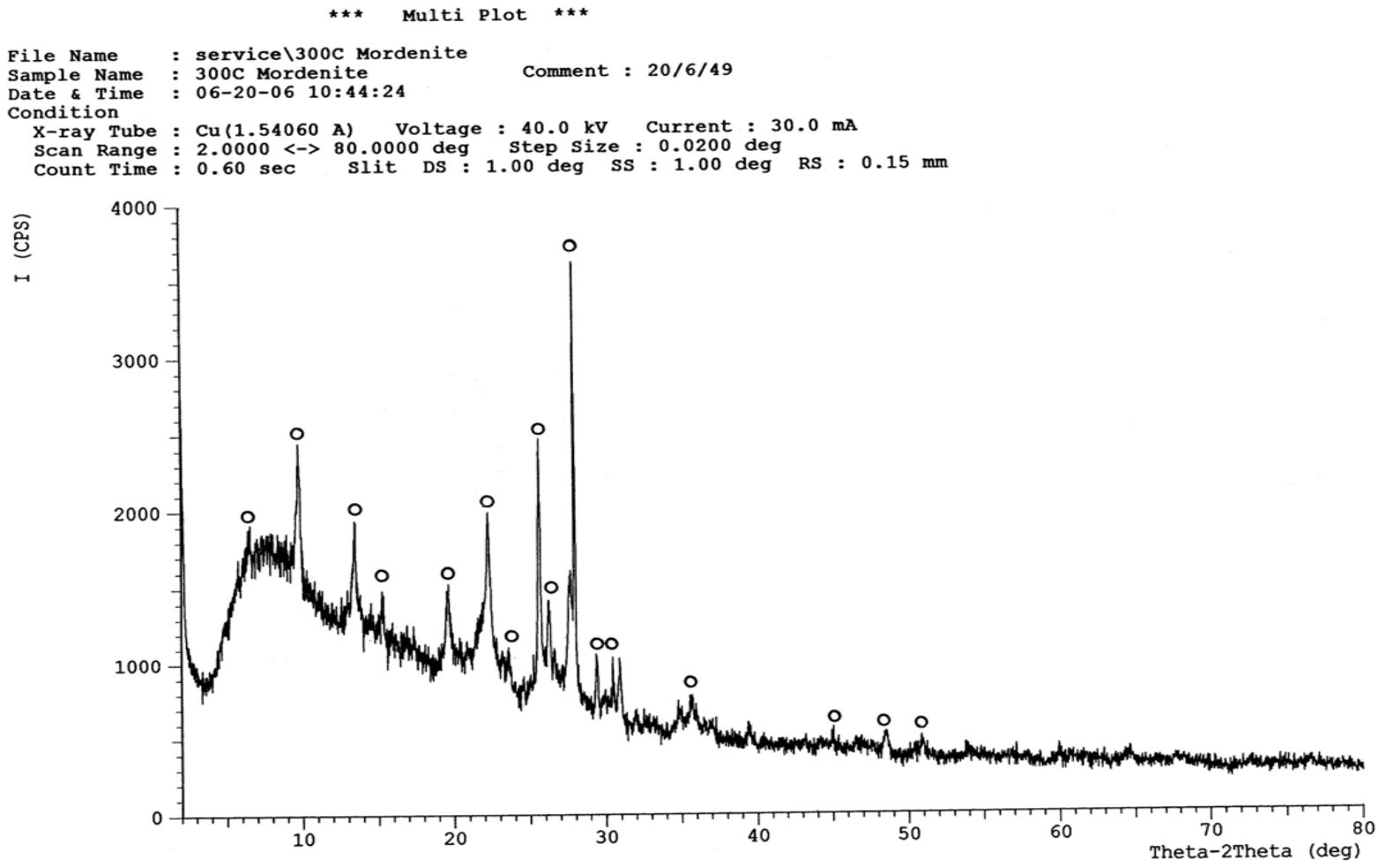
Appendix E



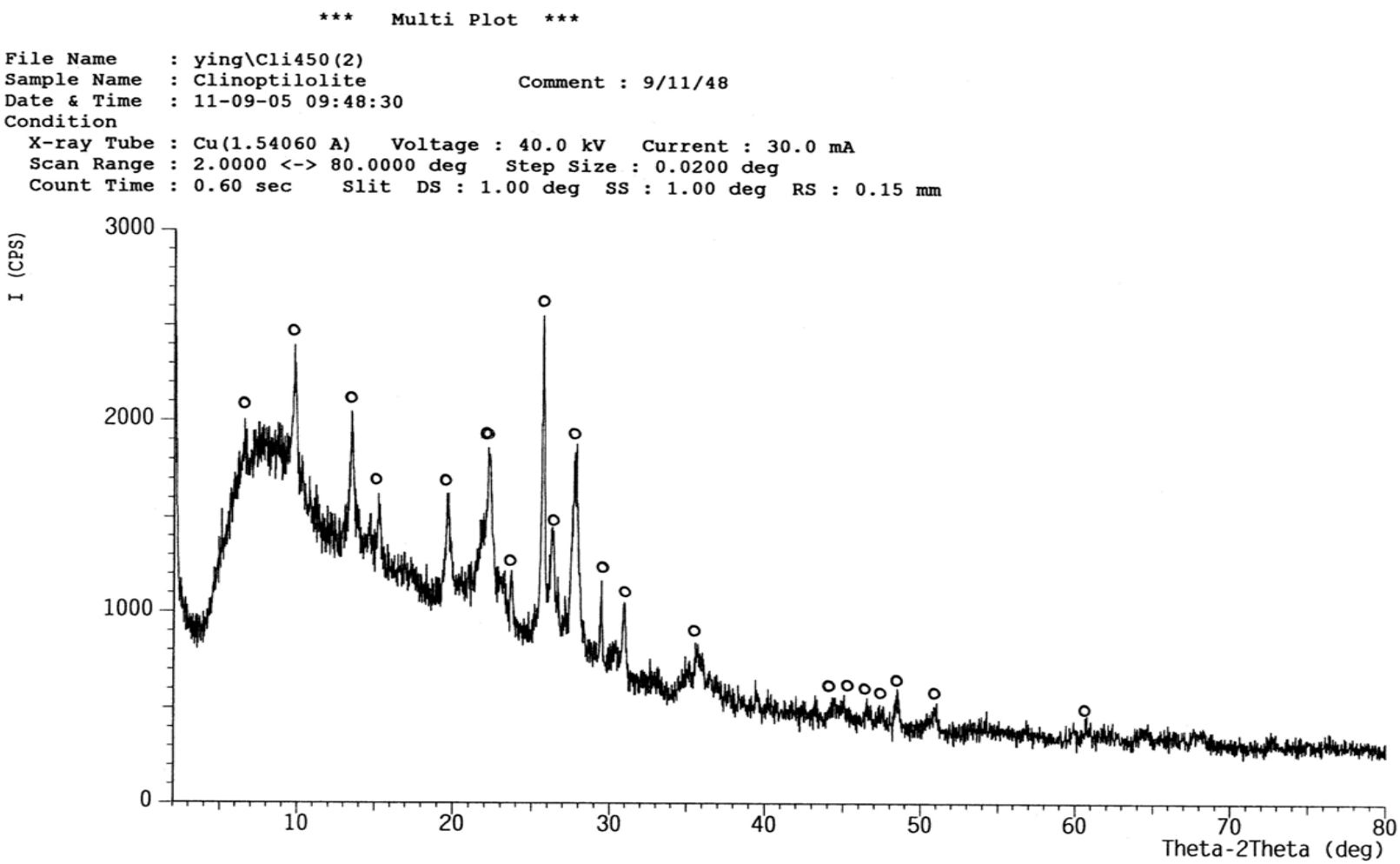
Appendix Figure E1 XRD pattern of mordenite un- calcined



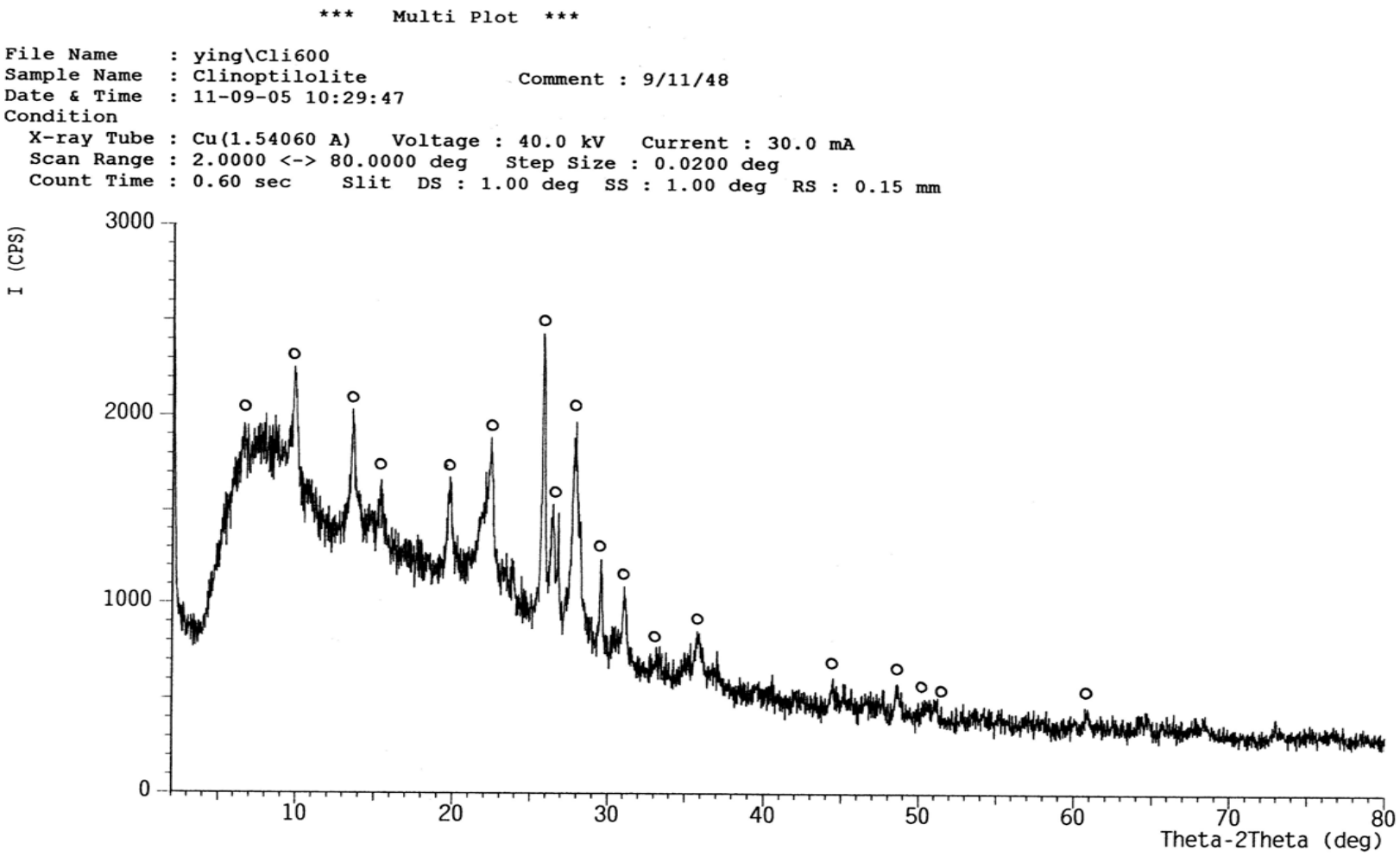
Appendix Figure E2 XRD pattern of mordenite calcined at 150ºC



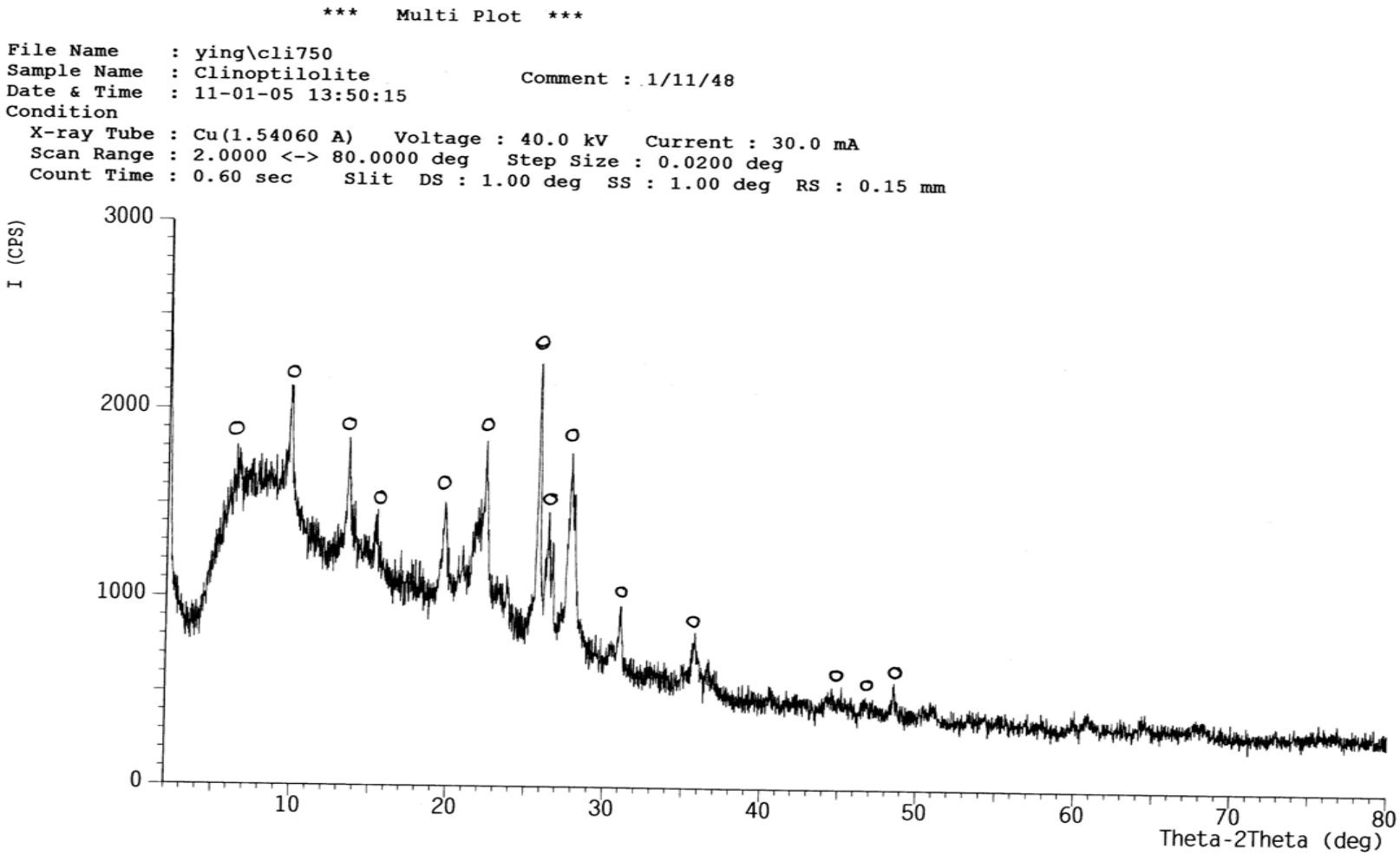
Appendix Figure E3 XRD pattern of mordenite calcined at 300ºC



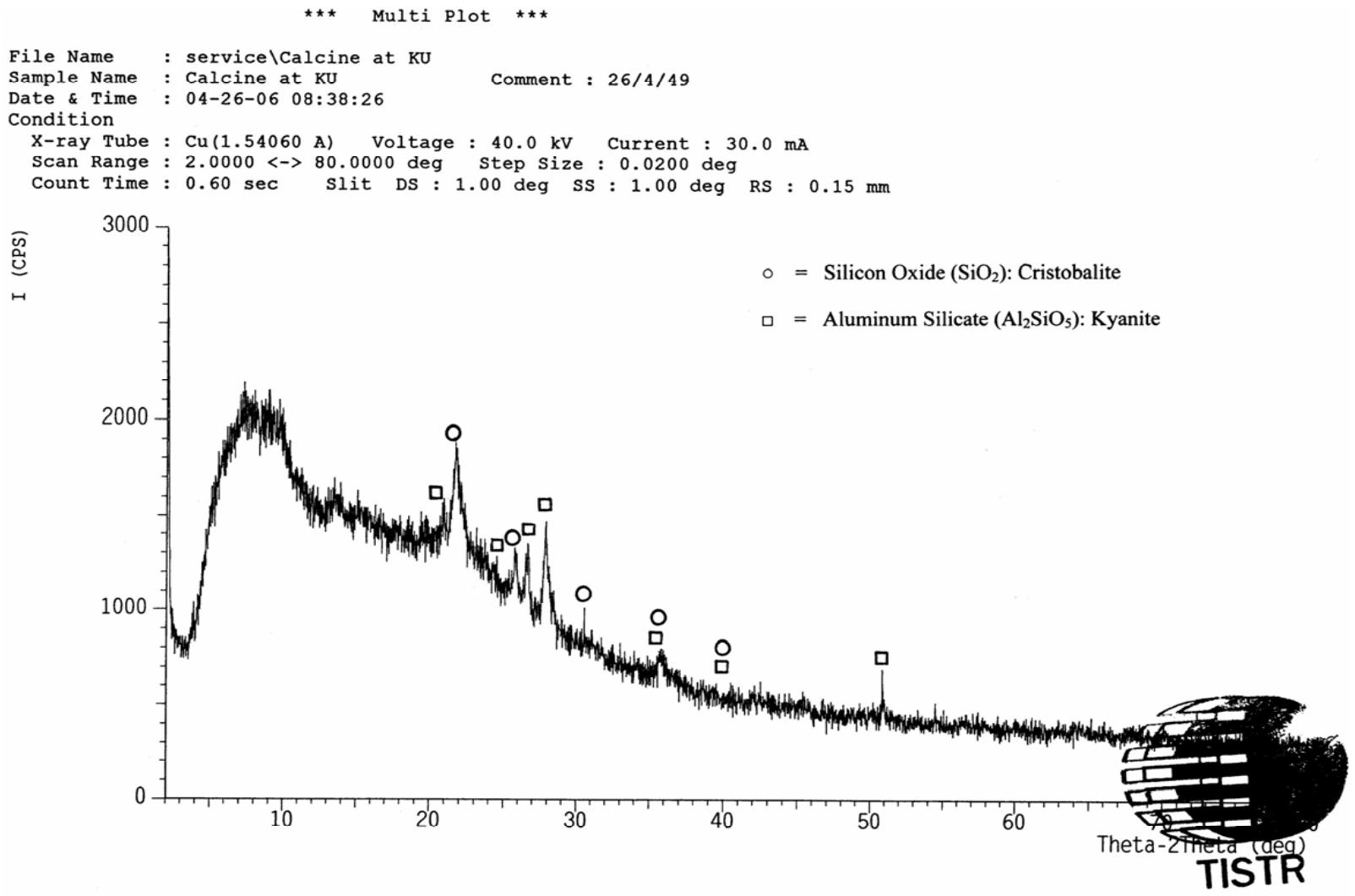
Appendix Figure E4 XRD pattern of mordenite calcined at 450ºC



Appendix Figure E5 XRD pattern of mordenite calcined at 600ºC

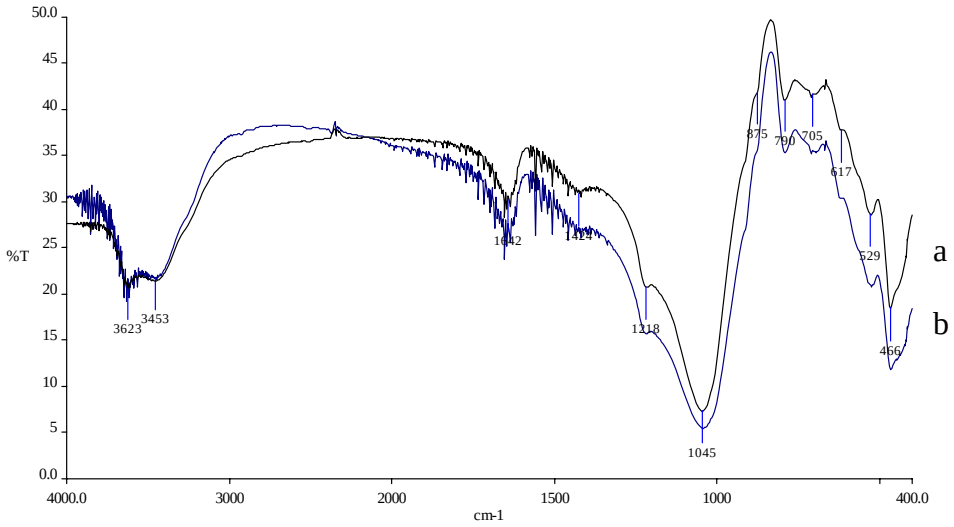


Appendix Figure E6 XRD pattern of mordenite calcined at 750ºC

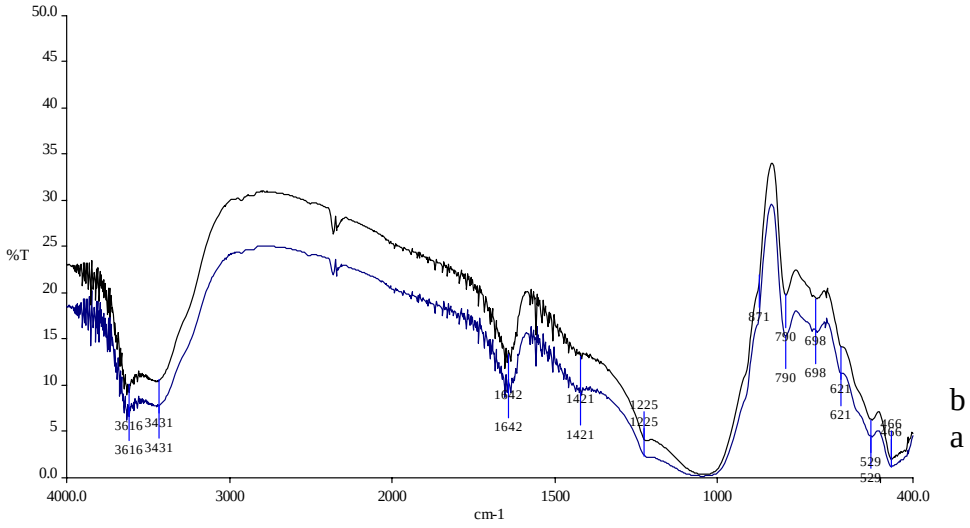


Appendix Figure E7 XRD pattern of mordenite calcined at 900ºC

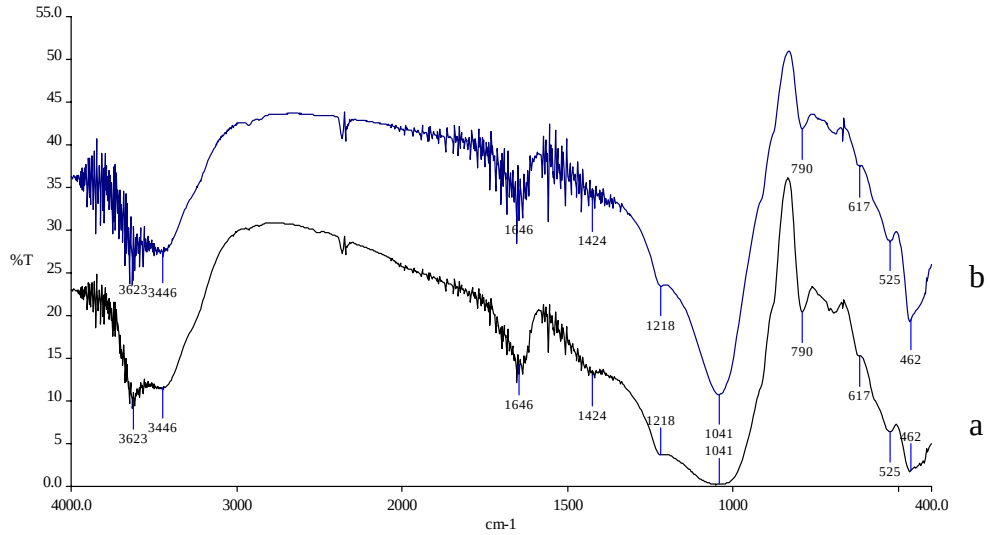
Appendix F



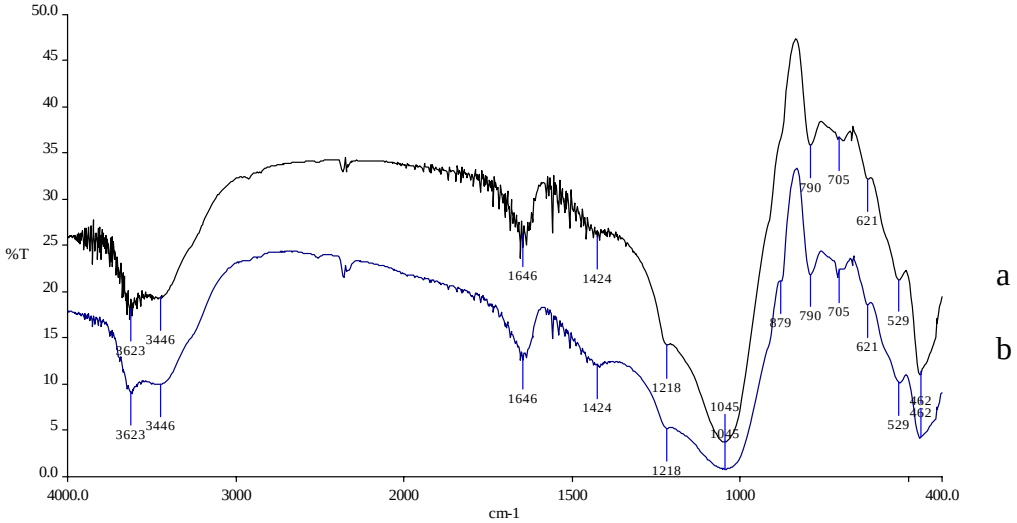
Appendix Figure F1 FTIR spectra of uncalcined mordenite: (a) before adsorbed, (b) after adsorbed orthophosphate 30 mg-P/L



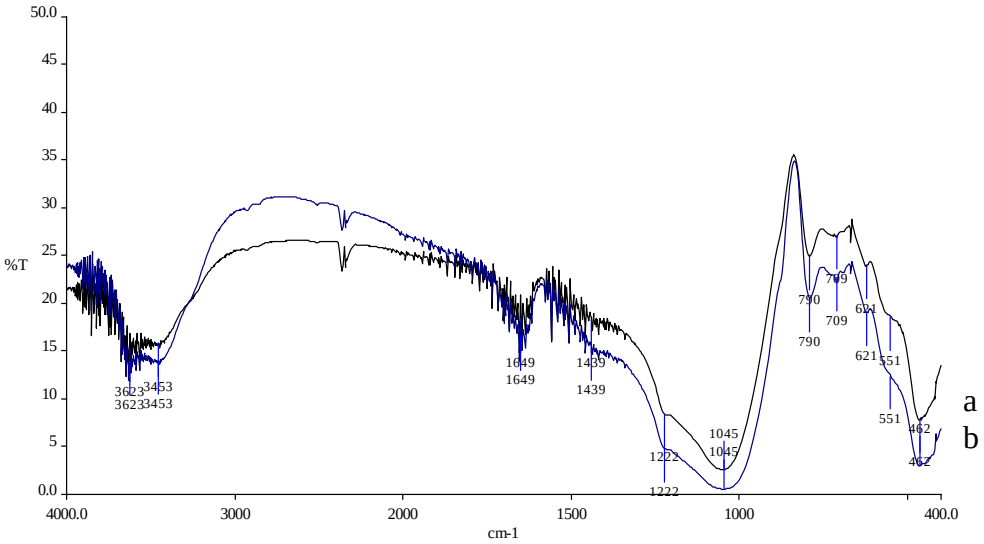
Appendix Figure F2 FTIR spectra of mordenite calcination at 150ºC: (a)before adsorbed, (b) after adsorbed orthophosphate 30 mg-P/L



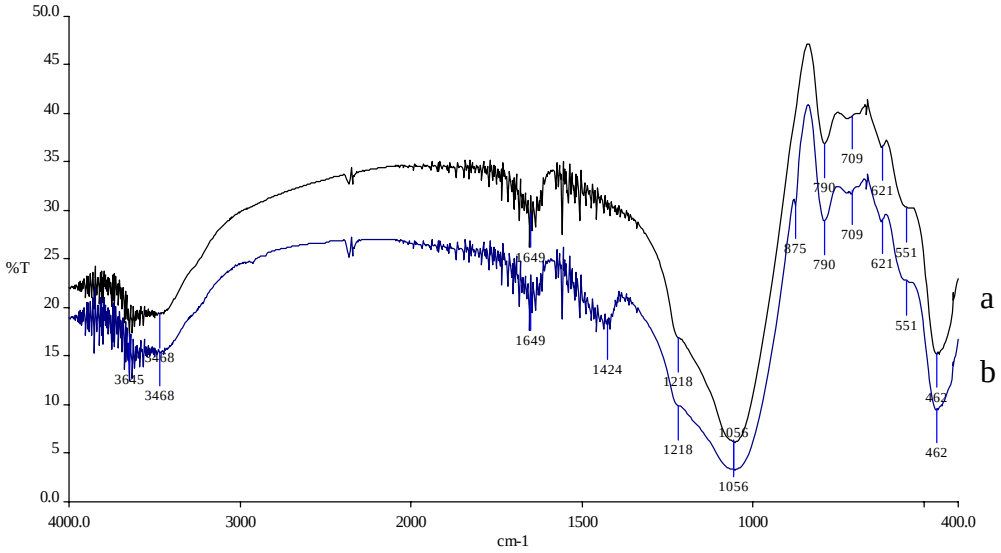
Appendix Figure F3 FTIR spectra of mordenite calcination at 300ºC: (a)before adsorbed, (b) after adsorbed orthophosphate 30 mg-P/L



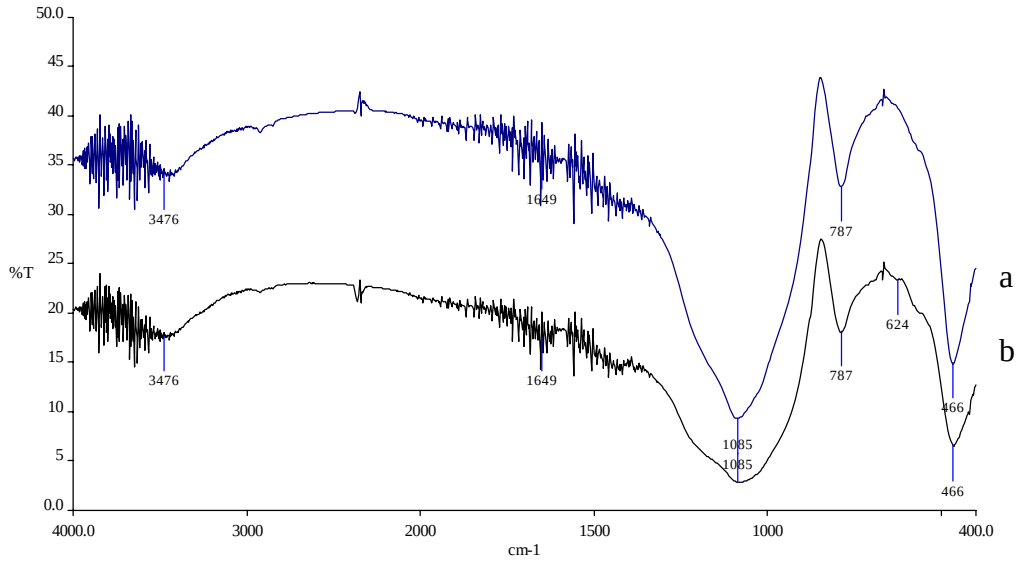
Appendix Figure F4 FTIR spectra of mordenite calcination at 450ºC: (a)before adsorbed, (b) after adsorbed orthophosphate 30 mg-P/L



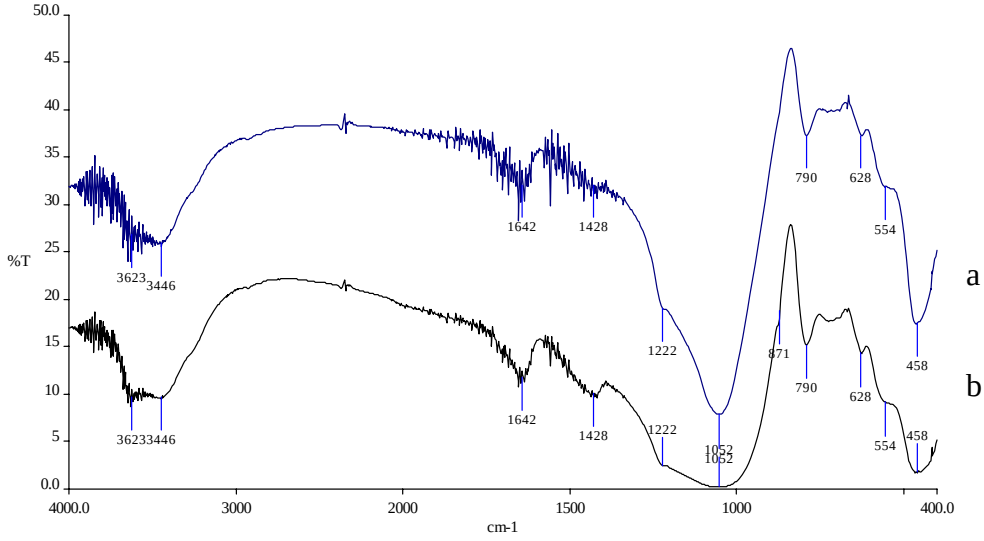
Appendix Figure F5 FTIR spectra of mordenite calcination at 600ºC:
(a)before adsorbed, (b) after adsorbed orthophosphate
30 mg-P/L



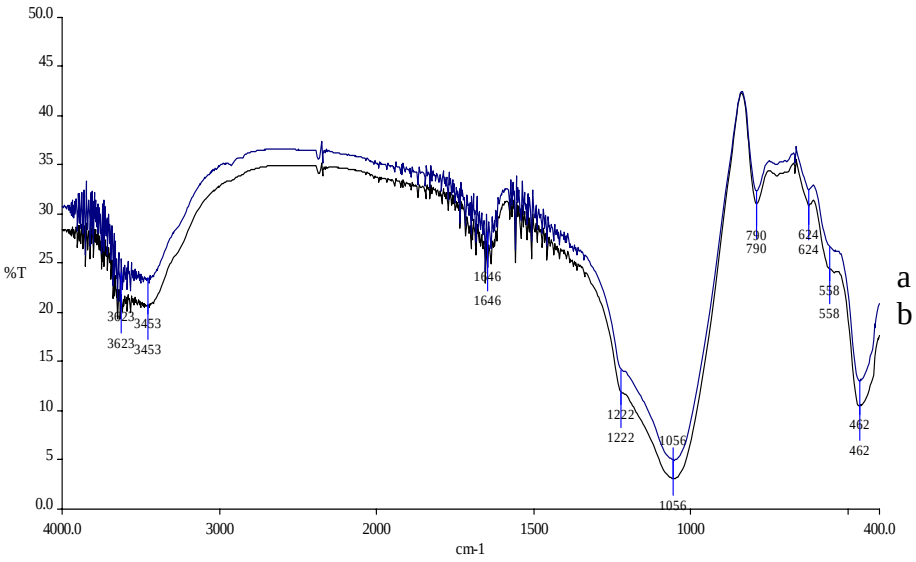
Appendix Figure F6 FTIR spectra of mordenite calcination at 750ºC:
(a)before adsorbed, (b) after adsorbed orthophosphate
30 mg-P/L



Appendix Figure F7 FTIR spectra of mordenite calcination at 900ºC: (a)before adsorbed, (b) after adsorbed orthophosphate 30 mg-P/L



Appendix Figure F8 FTIR spectra of mordenite calcination at 750ºC and treated with EDTA 0.05M: (a) before adsorbed, (b) after adsorbed orthophosphate 30 ppm

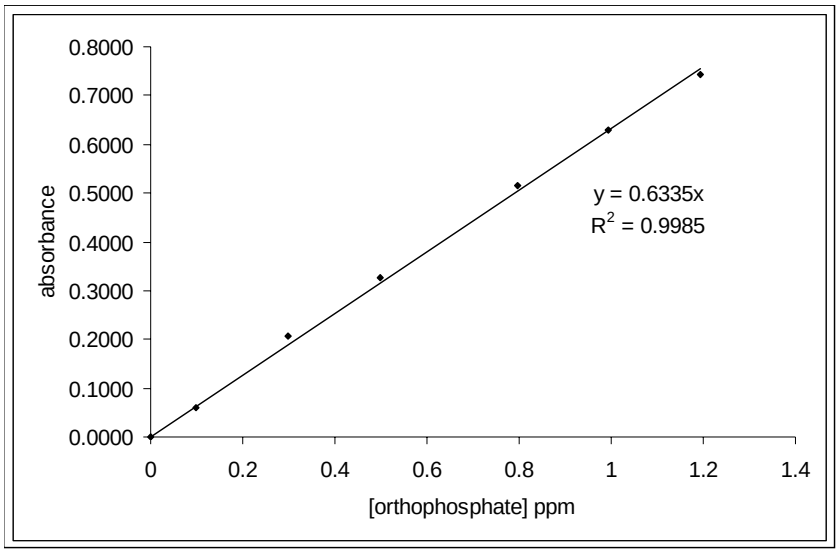


Appendix Figure F9 FTIR spectra of mordenite calcination at 750ºC and treated with HCl 0.5M: (a) before adsorbed, (b) after adsorbed orthophosphate 30 ppm

Appendix G

Appendix Table G1 The calibration curve data of orthophosphate

Phosphorus concentration (mg-P/L)	Absorbance			
	trial 1	trial 2	trial 3	Average
0.0995	0.060	0.061	0.061	0.0607
0.2985	0.206	0.205	0.206	0.2057
0.4975	0.326	0.326	0.326	0.3260
0.7960	0.514	0.514	0.514	0.5140
0.9951	0.629	0.630	0.631	0.6300
1.1941	0.741	0.741	0.743	0.7417



Appendix Figure G1 Orthophosphate calibration curve

Appendix Table G2 Data from experiment of uncalcined mordenite after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	pH	Mordenite weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g MOR	absorbance (average)
				Before adsorption	After adsorption	Amount adsorption		
5	20	7.49	1.0142	5.0322	4.7272	0.3051	5.9807	0.3009
	40	7.70	1.0149	5.0322	4.8254	0.2068	4.0496	0.3071
	60	7.76	1.0125	5.0322	4.7991	0.2331	4.5779	0.3054
	120	7.75	1.0047	5.0322	4.6009	0.4313	8.5310	0.2929
	180	8.08	1.0077	5.0322	4.6518	0.3805	7.5035	0.2961
	240	8.00	1.0143	5.0322	4.6062	0.4261	8.3467	0.2932
10	20	7.24	1.0087	10.0645	9.6987	0.3658	3.6034	0.2463
	40	7.52	1.0204	10.0645	9.4444	0.6201	6.0392	0.2399
	60	7.60	1.0070	10.0645	9.4882	0.5763	5.6891	0.2410
	120	7.62	1.0147	10.0645	9.2076	0.8569	8.3939	0.2339
	180	7.82	1.0042	10.0645	9.2427	0.8218	8.1319	0.2348
	240	7.96	1.0068	10.0645	9.1857	0.8788	8.6722	0.2333
20	20	6.96	1.0074	20.1289	19.3146	0.8144	4.0143	0.2450
	40	7.21	1.0101	20.1289	19.6390	0.4899	2.4105	0.2491
	60	7.27	1.0095	20.1289	19.0690	1.0599	5.2163	0.2419
	120	7.36	1.0138	20.1289	19.1304	0.9985	4.8946	0.2427
	180	7.49	1.0123	20.1289	19.2795	0.8495	4.1688	0.2446
	240	7.56	1.0079	20.1289	19.4110	0.7179	3.5385	0.2462
30	20	6.92	1.0086	30.1934	29.2944	0.8990	2.9520	0.3714
	40	7.14	1.0082	30.1934	29.5750	0.6184	2.0312	0.3750
	60	7.17	1.0097	30.1934	29.4873	0.7061	2.3173	0.3739
	120	7.23	1.0054	30.1934	28.8998	1.2937	4.2607	0.3664
	180	7.23	1.0054	30.1934	28.8998	1.2937	4.2607	0.3664
	240	7.49	1.0152	30.1934	29.6890	0.5044	1.6486	0.3764
blank	240	8.62	1.0067	0.0000	0.0225	-0.0225		0.0142

Appendix Table G3 Data from experiment of calcination mordenite at 150ºC after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	pH	Mordenite weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g MOR	absorbance (average)
				Before adsorption	After adsorption	Amount adsorption		
5	20	8.03	1.0049	5.0163	4.5521	0.4642	9.2084	0.2891
	40	7.94	1.0135	5.0163	4.7363	0.2800	5.5088	0.3008
	60	8.03	1.0049	5.0163	4.4960	0.5203	10.3214	0.2856
	120	8.15	1.0059	5.0163	4.4188	0.5975	11.8384	0.2807
	180	8.35	1.0044	5.0163	4.3259	0.6904	13.7031	0.2748
	240	8.29	1.0059	5.0163	4.2592	0.7571	15.0008	0.2706
10	20	7.65	1.0140	10.0326	9.2535	0.7791	7.6586	0.2348
	40	7.80	1.0093	10.0326	9.2535	0.7791	7.6991	0.2348
	60	7.75	1.0061	10.0326	8.9027	1.1299	11.1933	0.2259
	120	7.87	1.0099	10.0326	8.7537	1.2789	12.6234	0.2221
	180	8.09	1.0093	10.0326	8.4818	1.5508	15.3133	0.2152
	240	8.06	1.0116	10.0326	8.5651	1.4675	14.4597	0.2173
20	20	7.29	1.0123	20.0652	19.6236	0.4416	2.1742	0.2488
	40	7.48	1.0053	20.0652	19.5535	0.5117	2.5365	0.2479
	60	7.28	1.0175	20.0652	18.8870	1.1782	5.7691	0.2394
	120	7.47	1.0055	20.0652	18.6502	1.4150	7.0115	0.2364
	180	7.56	1.0108	20.0652	18.0012	2.0640	10.1796	0.2282
	240	7.76	1.0103	20.0652	18.0100	2.0552	10.1379	0.2283
30	20	7.19	1.0066	30.0978	29.0597	1.0381	3.4299	0.3683
	40	7.40	1.0147	30.0978	28.9720	1.1258	3.6852	0.3672
	60	7.16	1.0147	30.0978	28.0424	2.0554	6.7296	0.3554
	120	7.26	1.0120	30.0978	27.8671	2.2307	7.3207	0.3532
	180	7.48	1.0119	30.0978	27.7004	2.3974	7.8714	0.3511
	240	7.52	1.0153	30.0978	27.0866	3.0112	9.8526	0.3433
blank	240	9.10	1.0134	0.0000	0.0116	-0.0116		0.0073

Appendix Table G4 Data from experiment of calcination mordenite at 300ºC after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	pH	Mordenite weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g MOR	absorbance (average)
				Before adsorption	After adsorption	Amount adsorption		
5	20	7.87	1.0049	5.0254	4.6775	0.3479	6.8882	0.2972
	40	8.30	1.0054	5.0254	4.4706	0.5548	10.9819	0.2841
	60	8.17	1.0063	5.0254	4.2934	0.7320	14.4768	0.2729
	120	8.26	1.0016	5.0254	4.1479	0.8775	17.4342	0.2637
	180	8.27	1.0055	5.0254	4.0321	0.9933	19.6566	0.2563
	240	8.31	1.0061	5.0254	3.9654	1.0600	20.9624	0.2521
10	20	7.73	1.0071	10.0508	9.0843	0.9665	9.5483	0.2306
	40	8.01	1.0059	10.0508	8.9659	1.0849	10.7315	0.2276
	60	7.91	1.0063	10.0508	8.6765	1.3743	13.5885	0.2202
	120	8.02	1.0090	10.0508	8.4441	1.6067	15.8425	0.2143
	180	7.62	1.0014	20.1016	17.4987	2.6029	12.9301	0.2219
	240	8.22	1.0096	10.0508	8.2336	1.8172	17.9097	0.2090
20	20	7.66	1.0093	20.1016	18.6475	1.4541	7.1682	0.2364
	40	7.66	1.0100	20.1016	18.6563	1.4453	7.1178	0.2366
	60	7.51	1.0141	20.1016	18.7002	1.4014	6.8736	0.2371
	120	7.57	1.0039	20.1016	17.7092	2.3924	11.8574	0.2246
	180	7.62	1.0014	20.1016	17.4987	2.6029	12.9301	0.2219
	240	7.81	1.0026	20.1016	17.5075	2.5941	12.8697	0.2220
30	20	7.41	1.0077	30.1525	28.2064	1.9461	6.4045	0.3576
	40	7.47	1.0060	30.1525	28.0223	2.1302	7.0231	0.3552
	60	7.40	1.0071	30.1525	27.5136	2.6389	8.6875	0.3488
	120	7.41	1.0041	30.1525	28.1450	2.0075	6.6299	0.3568
	180	7.47	1.0054	30.1525	27.5312	2.6213	8.6442	0.3490
	240	7.48	1.0115	30.1525	27.4522	2.7003	8.8529	0.3480
blank	240	8.68	1.0066	0.0000	0.0142	-0.0142		0.0090

Appendix Table G5 Data from experiment of calcination mordenite at 450ºC after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	pH	Mordenite weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g MOR	absorbance (average)
				Before adsorption	After adsorption	Amount adsorption		
5	20	7.52	1.0237	4.9947	5.0546	-0.0599	-1.1699	0.3214
	40	7.58	1.0493	4.9947	5.0178	-0.0231	-0.4461	0.3191
	60	7.77	1.0791	4.9947	4.6986	0.2961	5.5094	0.2989
	120	7.61	1.0967	4.9947	4.6635	0.3312	6.0552	0.2967
	180	7.81	3.0528	12.5547	5.6676	5.4259	13.1950	0.2795
	240	7.89	1.0998	4.9947	4.5057	0.4890	8.9079	0.2867
10	20	7.30	1.0671	9.9894	10.0621	-0.0727	-0.7025	0.6387
	40	7.48	1.0811	9.9894	9.9428	0.0466	0.4316	0.6311
	60	7.63	1.0532	9.9894	9.6131	0.3763	3.5694	0.6102
	120	7.52	1.0449	9.9894	9.6026	0.3868	3.6919	0.6096
	180	7.55	1.0995	9.9894	9.4798	0.5096	4.5593	0.6018
	240	7.68	1.0729	9.9894	9.1746	0.8148	7.6030	0.5824
20	20	7.12	1.0210	19.9787	22.0011	-2.0224	-9.9203	0.5580
	40	7.33	1.0495	19.9787	21.9528	-1.9741	-9.4140	0.5568
	60	7.28	1.0405	19.9787	19.6946	0.2841	1.3389	0.2498
	120	7.40	1.0730	19.9787	20.3699	-0.3912	-1.8183	0.2583
	180	7.41	1.0656	19.9787	19.3175	0.6612	3.0709	0.2450
	240	7.43	1.0558	19.9787	19.2299	0.7488	3.5020	0.2439
30	20	7.01	1.0555	29.9681	28.8629	1.1052	3.5258	0.7312
	40	7.14	1.0713	29.9681	31.1297	-1.1616	-3.6102	0.7883
	60	7.10	1.0246	29.9681	29.4728	0.4953	1.6192	0.3737
	120	7.16	1.0278	29.9681	29.0694	0.8987	2.9136	0.3686
	180	7.29	1.0402	29.9681	28.7274	1.2407	3.9822	0.3642
	240	7.36	1.0526	29.9681	28.4116	1.5565	4.9563	0.3602
blank	240	8.43	1.0489	0.0000	0.0195	-0.0195		0.0123

Appendix Table G6 Data from experiment of calcination mordenite at 600ºC after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	pH	Mordenite weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g MOR	absorbance (average)
				Before adsorption	After adsorption	Amount adsorption		
5	20	7.09	1.0329	5.0447	4.9869	0.0578	1.1179	0.3178
	40	7.26	1.0038	5.0447	5.0132	0.0315	0.6203	0.3194
	60	7.51	1.0175	5.0447	4.8238	0.2209	4.2921	0.3074
	120	7.51	1.0175	5.0447	4.8238	0.2209	4.2921	0.3074
	180	7.74	1.0125	5.0447	5.0887	-0.0440	-0.8628	0.3242
	240	7.86	1.0317	5.0447	5.2044	-0.1597	-3.0698	0.3316
10	20	6.91	1.0438	10.0895	10.1873	-0.0978	-0.9259	0.2589
	40	7.12	1.0046	10.0895	10.0689	0.0206	0.2021	0.2559
	60	7.24	1.0056	10.0895	9.9242	0.1653	1.6349	0.2522
	120	7.44	1.0048	10.0895	9.6787	0.4108	4.0532	0.2460
	180	7.54	1.0114	10.0895	9.6743	0.4152	4.0686	0.2459
	240	7.63	1.0027	10.0895	9.8672	0.2223	2.1976	0.2508
20	20	6.75	1.0458	20.1790	19.9304	0.2486	1.2049	0.2529
	40	6.88	1.0025	20.1790	19.6234	0.5556	2.7453	0.2490
	60	7.01	1.0074	20.1790	20.1321	0.0469	0.2285	0.2554
	120	7.12	1.0081	20.1790	19.8953	0.2837	1.3962	0.2524
	180	7.31	1.0269	20.1790	20.0268	0.1522	0.7357	0.2541
	240	7.32	1.0162	23.1790	28.4030	0.6544	3.2251	5.5038
30	20	6.56	1.0183	30.2685	28.7965	1.4720	4.7790	0.3652
	40	6.74	1.0040	30.2685	29.3753	0.8932	2.9364	0.3726
	60	6.91	1.0238	30.2685	29.5331	0.7354	2.3733	0.3746
	120	7.03	1.0131	30.2685	31.1029	-0.8344	-2.7200	0.3944
	180	7.15	1.0176	30.2685	29.2700	0.9985	3.2466	0.3712
	240	7.16	1.0268	30.2685	30.1645	0.1040	0.3291	0.3826
blank	240	8.39	1.0209	0.0000	0.0293	-0.0293		0.0186

Appendix Table G7 Data from experiment of calcination mordenite at 750ºC after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	pH	Mordenite weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g MOR	absorbance (average)
				Before adsorption	After adsorption	Amount adsorption		
5	20	10.70	1.0426	4.9753	0.7447	4.2306	81.6365	0.0476
	40	11.01	1.0536	4.9753	0.4027	4.5726	87.2858	0.0259
	60	11.25	1.0270	4.9753	0.3045	4.6708	91.4108	0.0197
	120	11.58	1.0199	4.9753	0.5798	4.3955	86.5929	0.0371
	180	11.68	1.0143	4.9753	0.6360	4.3393	85.9825	0.0407
	240	11.69	1.0536	4.9753	0.5974	4.3779	83.5395	0.0382
10	20	10.06	1.0481	9.9506	3.9334	6.0172	57.6150	0.2496
	40	10.62	1.0570	9.9506	1.5463	8.4043	79.9157	0.0983
	60	11.28	1.0453	9.9506	0.4413	9.5093	91.4216	0.0283
	120	10.96	1.0135	9.9506	0.5588	9.3918	93.1219	0.0358
	180	11.72	1.0351	9.9506	0.4237	9.5269	92.5843	0.0272
	240	11.46	1.0556	9.9506	0.6640	9.2866	88.5303	0.0424
20	20	8.80	1.0090	19.9013	13.0871	6.8142	33.9255	0.8294
	40	10.15	1.0216	19.9013	8.7444	11.1569	54.8579	0.5543
	60	10.19	1.0498	19.9013	1.7409	18.1604	86.9140	0.1107
	120	10.40	1.0229	19.9013	1.4779	18.4234	90.5514	0.0940
	180	10.98	1.0280	19.9013	1.3621	18.5392	90.6330	0.0867
	240	11.22	1.0201	19.9013	1.2393	18.6620	91.9391	0.0789
30	20	7.80	1.0560	29.9681	27.0308	2.9373	9.3701	0.6851
	40	8.72	1.0702	29.9681	23.1415	6.8266	21.3252	0.5866
	60	10.20	1.0246	29.8520	11.8137	18.0383	58.9839	0.7488
	120	10.75	1.0278	29.8520	9.2320	20.6200	67.1904	0.5852
	180	11.11	1.0402	29.8520	6.5432	23.3088	74.8841	0.4149
	240	11.29	1.0526	29.8520	2.6863	27.1657	86.4578	0.1706
blank	240	11.73	1.0358	0.0000	0.0060	-0.0060		0.0038

Appendix Table G8 Data from experiment of calcination mordenite at 900ºC after orthophosphate adsorption

Phosphate concentration (mg-P/L)	Shaking time (minute)	pH	Mordenite weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g MOR	absorbance (average)
				Before adsorption	After adsorption	Amount adsorption		
5	20	11.12	1.0070	4.9981	0.8768	4.1213	81.8888	0.0568
	40	10.98	1.0015	4.9981	0.7365	4.2616	85.1380	0.0479
	60	11.24	1.0046	4.9981	0.4401	4.5580	90.7764	0.0291
	120	11.40	1.0049	4.9981	0.6698	4.3283	86.1870	0.0437
	180	11.72	1.0096	4.9981	0.2331	4.7650	94.4239	0.0160
	240	11.59	1.0343	4.9981	0.5137	4.4844	86.7743	0.0338
10	20	10.62	1.0096	9.9962	4.7302	5.2660	52.1865	0.3009
	40	10.92	1.0062	9.9962	1.5713	8.4249	83.7653	0.1008
	60	11.15	1.0044	9.9962	1.5784	8.4178	83.8417	0.1012
	120	11.24	1.0077	9.9962	1.2960	8.7002	86.3721	0.0833
	180	11.70	1.0246	9.9962	0.2822	9.7140	94.8414	0.0191
	240	11.53	1.0089	9.9962	1.2855	8.7107	86.3676	0.0827
20	20	8.62	1.0099	19.9924	16.6691	3.3233	16.4483	0.2114
	40	9.45	1.0078	19.9924	11.0215	8.9709	44.5300	0.1399
	60	10.12	1.0044	19.9924	9.0308	10.9616	54.5893	0.1147
	120	10.72	1.0046	19.9924	3.7427	16.2497	80.9048	0.0477
	180	11.05	1.0088	19.9924	2.3834	17.6090	87.3140	0.0304
	240	11.36	1.0098	19.9924	1.4801	18.5123	91.6914	0.0190
30	20	7.58	1.0064	29.9886	28.2012	1.7874	5.9269	0.3576
	40	7.98	1.0065	29.9886	26.2017	3.7869	12.5338	0.3322
	60	8.87	1.0043	29.9886	22.5535	7.4351	24.6912	0.2860
	120	10.40	1.0016	29.9886	13.8102	16.1784	53.8637	0.1752
	180	10.58	1.0253	29.9886	11.4512	18.5374	60.2547	0.1453
	240	11.01	1.0395	29.9886	8.1100	21.8786	70.2121	0.1030
blank	240	11.69	1.0303	0.0000	0.0195	-0.0195		0.0123

Appendix H

Appendix Table H1 The data from thermal treatment at 750ºC

Phosphate concentration (mg-P/L)	Time(m)	Ce*	Ce/(X/M)*	X/M*	logCe*	log(X/M)*
5	20	0.7447	0.0062	121.8498	-0.1280	2.0858
10		3.9334	0.0233	171.9911	0.5948	2.2355
20		13.0871	0.0649	202.5484	1.1168	2.3065
30		27.0308	0.3370	84.2408	1.4319	1.9255
5	40	0.4027	0.0031	130.2819	-0.3950	2.1149
10		1.5463	0.0065	238.5628	0.1893	2.3776
20		8.7444	0.0271	327.5230	0.9417	2.5152
30		23.1415	0.1216	191.7229	1.3644	2.2827
5	60	0.3045	0.0022	136.4388	-0.5164	2.1349
10		0.4413	0.0016	272.9100	-0.3553	2.4360
20		1.7409	0.0034	518.9106	0.2408	2.7151
30		11.8137	0.0223	531.6357	1.0724	2.7256
5	120	0.5798	0.0045	129.2477	-0.2367	2.1114
10		0.5588	0.0020	277.9857	-0.2527	2.4440
20		1.4779	0.0027	540.6269	0.1696	2.7329
30		9.2320	0.0153	605.1196	0.9653	2.7818
5	180	0.6360	0.0050	128.3366	-0.1966	2.1084
10		0.4237	0.0015	276.3809	-0.3729	2.4415
20		1.3621	0.0025	541.1143	0.1342	2.7333
30		6.5432	0.0105	673.9819	0.8158	2.8286
5	240	0.5974	0.0048	124.6902	-0.2237	2.0958
10		0.6640	0.0025	264.2789	-0.1778	2.4221
20		1.2393	0.0023	548.9123	0.0932	2.7395
30		2.6863	0.0035	777.5918	0.4292	2.8908

***** average 3 trials from experiment

Appendix I

Appendix Table I1 The orthophosphate desorption from mordenite at temperature of calcination 750ºC

Phosphate concentration (mg-P/L)	Shaking time (minute)	pH	Mordenite weight (g)	Phosphate concentration (mg-P/L)			%desorbed per 1g MOR	absorbance (average)
				Before adsorption	Amount adsorption	Amount desorption		
5	60	10.15	1.0083	5.0254	4.7385	0.0735	1.4497	0.0503
	120	10.55	1.0051	5.0254	4.7578	0.0640	1.2666	0.0443
	180	10.67	1.0052	5.0254	4.8065	0.0233	0.4608	0.0186
	240	10.64	1.0007	5.0254	4.8703	0.0640	1.2722	0.0443
	300	10.90	1.0045	5.0254	4.8065	0.0247	0.4892	0.0194
	360	10.89	1.0049	5.0254	4.8703	0.0150	0.2980	0.0133
10	60	10.08	1.0074	10.0508	9.0118	0.1328	1.3113	0.0617
	120	9.88	1.0043	10.0508	8.7193	0.1151	1.1403	0.0819
	180	9.94	1.0047	10.0508	8.0123	0.1159	1.1471	0.1268
	240	9.94	1.0044	10.0508	8.7891	0.0726	0.7194	0.0776
	300	10.00	1.0046	10.0508	8.5793	0.1145	1.1341	0.0908
20	60	9.73	1.0040	20.1016	18.1359	0.3096	1.5335	0.1993
	120	9.69	1.0077	20.1016	17.2789	0.1331	0.6571	0.0876
	180	9.91	1.0037	20.1016	17.0348	0.0987	0.4894	0.0658
30	60	10.35	1.0041	30.1525	27.2715	0.1192	0.3938	0.0793
	120	10.44	1.0059	30.1525	27.2926	0.0882	0.2908	0.0597
blank	360	11.73	1.0358	0.0000	0.0060	-0.0060		0.0038

Appendix J

Appendix Table J1 The amount of Fe^{2+} were extracted from calcination mordenite at 750º extraction with 0.05M EDTA

sample	Trial	$[Fe^{2+}]$ (mg/L)	
		/1g MOR	Average
750C	1	2.0759	2.0956 ± 0.1294
	2	2.0374	
	3	1.9554	
	4	2.1195	
	5	2.1591	
	6	2.2688	
	7	2.2433	
	8	2.1291	
	9	1.9082	
	10	2.0480	
	11	1.9196	
	12	2.2824	

Appendix Table J2 The amount of Fe^{2+} were extracted from calcination mordenite at 750º extraction with 0.5M HCl

Sample	Trial	$[Fe^{2+}]$ (mg/L)	
		/1g MOR	Average
750C	1	1.4149	2.2170 ± 0.3807
	2	1.4735	
	3	1.6437	
	4	1.8652	
	5	1.6767	
	6	1.8396	
	7	1.9390	
	8	2.2313	
	9	2.3794	
	10	2.3768	
	11	2.5177	
	12	2.4873	
	13	2.7427	
	14	2.6045	
	15	2.6339	
	16	2.6347	
	17	2.4281	
	18	2.3341	
	19	2.4893	
	20	2.3059	
	21	2.3881	
	22	2.3036	
	23	2.2004	
	24	2.2965	

Appendix Table J3 Orthophosphate adsorption of mordenite after metal oxide extraction with 0.05M EDTA

Phosphate concentration (mg-P/L)	Shaking time (minute)	Trial	pH	Mordenite weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g MOR	absorbance (average)
					Before adsorption	After adsorption	Amount adsorption		
5	60	1	7.08	1.0036	5.0254	5.2772	-0.2518	-4.9926	0.3343
		2	6.96	1.0068	5.0254	5.2404	-0.2150	-4.2487	0.3320
		3	7.01	1.0053	5.0254	5.2772	-0.2518	-4.9841	0.3343
blank	60	1	7.69	1.0031	0.0000	0.0000	0.0000		0.0000
		2	8.45	1.0045	0.0000	0.0000	0.0000		0.0000
		3	8.04	1.0030	0.0000	0.0011	-0.0011		0.0007
		average				0.0004	-0.0004		
30	300	1	6.90	1.0049	30.1525	30.5655	-0.4130	-1.3629	0.3873
		2	6.87	1.0086	30.1525	30.4602	-0.3077	-1.0119	0.3860
		3	6.88	1.0078	30.1525	30.1445	0.0080	0.0262	0.3820
blank	300	1	8.87	8.8700	1.0016	0.0000	0.0058		0.0037
		2	9.27	9.2700	1.0074	0.0000	0.0026		0.0017
		3	9.22	9.2200	1.0064	0.0000	0.0079		0.0050
		average					0.0054		

Appendix Table J4 Orthophosphate adsorption of mordenite after metal oxide extraction with 0.5M HCl

Phosphate concentration (mg-P/L)	Shaking time (minute)	Trial	pH	Mordenite weight (g)	Phosphate concentration (mg-P/L)			%adsorbed per 1g MOR	absorbance (average)
					Before adsorption	After adsorption	Amount adsorption		
5	60	1	5.21	1.0043	5.0254	5.8537	-0.8283	-16.4120	0.3710
		2	5.38	1.0006	5.0254	5.8853	-0.8599	-17.1005	0.3730
		3	4.76	1.001	5.0254	5.7169	-0.6915	-13.7465	0.3623
blank	60	1	4.79	1.0024	0.0000	0.0042	-0.0042		0.0027
		2	5.69	1.0004	0.0000	0.0021	-0.0021		0.0013
		3	5.48	1.0047	0.0000	0.0016	-0.0016		0.0010
		average				0.0026	-0.0026		
10	120	1	4.38	1.0028	10.0508	9.5729	0.4779	4.7414	0.2427
		2	4.35	1.0007	10.0508	9.4808	0.5700	5.6668	0.2403
		3	4.24	1.0013	10.0508	9.2835	0.7673	7.6241	0.2353
blank	120	1	4.84	1.0024	0.0000	0.0037	-0.0037		0.0023
		2	4.95	1.0057	0.0000	0.0032	-0.0032		0.0020
		3	4.93	1.0094	0.0000	0.0037	-0.0037		0.0023
		average				0.0035	-0.0035		
20	240	1	4.08	1.0050	20.1016	17.9372	2.1644	10.7137	0.2273
		2	4.11	1.0050	20.1016	18.1214	1.9802	9.8021	0.2297
		3	4.10	1.0019	20.1016	17.8057	2.2959	11.4000	0.2257
blank	240	1	4.78	1.0016	0.0000	0.0047	-0.0047		0.0030
		2	4.78	1.0076	0.0000	0.0016	-0.0016		0.0010
		3	4.73	1.0024	0.0000	0.0100	-0.0100		0.0063
		average				0.0054	-0.0054		
30	300	1	4.00	1.0043	30.1525	31.8567	-1.7042	-5.6278	0.4037
		2	4.02	1.0054	30.1525	32.4618	-2.3093	-7.6176	0.4113
		3	4.00	1.0021	30.1525	32.4618	-2.3093	-7.6427	0.4113
blank	300	1	4.78	1.0064	0.0000	0.0074	-0.0074		0.0047
		2	4.70	1.0002	0.0000	0.0011	-0.0011		0.0007
		3	4.78	1.0002	0.0000	0.0016	-0.0016		0.0010
		average				0.0033	-0.0033		

Appendix K

Appendix Table K1 The zeta potential of mordenite which varies pH

samples	Zeta potential (mV)										
	pH 12	pH11	pH 10	pH 9	pH 8	pH 7	pH 6	pH 5	pH 4	pH 3	pH 2
room temperature	-29.10	-31.00	-33.70	-33.50	-32.60	-31.40	-19.80	-15.50	-15.60	-8.70	-7.90
room temperature adsorbed	-36.50	-34.00	-38.60	-37.90	-38.00	-39.90	-33.10	-27.60	-25.00	-21.50	-12.90
calcined at 150ºC	-35.40	-35.30	-35.60	-35.80	-34.20	-36.80	-35.40	-33.60	-28.70	-22.90	-16.80
calcined at 150ºC adsorbed	-36.40	-37.00	-36.30	-34.40	-37.10	-34.80	-36.40	-34.80	-29.90	-22.20	-18.10
calcined at 300ºC	-35.40	-34.90	-33.70	-38.40	-36.90	-36.00	-31.80	-27.00	-22.50	20.60	-12.30
calcined at 300ºC adsorbed	-33.80	-32.20	-32.30	-34.30	-36.10	-36.10	-30.30	-25.30	-21.70	-20.10	-9.60
calcined at 450ºC	-32.20	-34.60	-37.10	-38.40	-37.40	-37.40	-29.40	-26.20	-23.50	-20.10	-16.30
calcined at 450ºC adsorbed	-35.70	-35.70	-37.70	-38.40	-39.60	-36.50	-28.10	-24.40	-23.00	-17.70	-12.60
calcined at 600ºC	-29.50	-30.10	-24.40	-19.90	-25.50	-23.20	-4.60	-1.50	0.20	1.00	-2.20
calcined at 600ºC adsorbed	-26.70	-27.90	-25.00	-21.00	-24.00	-26.00	-0.70	2.00	2.30	2.60	2.90
calcined at 750ºC	0.00	-24.70	-22.20	-6.70	-7.50	-0.50	-5.20	-1.00	-2.80	0.20	-0.90
calcined at 750ºC adsorbed	-25.90	-26.30	-26.30	-26.10	-29.10	-24.30	-9.80	-6.10	-6.50	13.70	4.80
calcined at 900ºC	-28.90	-26.10	-29.90	-27.00	-28.90	-24.00	-13.50	-6.90	-10.40	-4.10	5.00
calcined at 900ºC adsorbed	-23.80	-19.90	-26.20	-20.40	-15.60	-14.10	-6.60	-14.70	-8.40	-2.00	2.70

Appendix Table K2 The zeta potential of mordenite at pH of adsorption

conditions		pH	zeta potential (mV)
uncalcined	before	6.87	-15.14
	after	5.49	-13.5
150ºC	before	6.86	-14.8
	after	6.31	-15.4
300ºC	before	6.38	-15.3
	after	5.82	-15.4
450ºC	before	5.67	-15.8
	after	6.13	-13.6
600ºC	before	5.97	-15.1
	after	6.10	-16.2
750ºC	before	6.17	-12.8
	after	6.07	-14.7
900ºC	before	6.02	-17.8
	after	6.34	-14.7

Appendix L

Appendix Table L1 Equilibrium reactions of element at 25ºC

Reaction No.	Equilibrium reaction	log K^0
1	$Al(OH)_3$ (amorp) + $3H^+ \rightleftharpoons Al^{3+} + 3H_2O$	9.66
2	$Al^{3+} + H_2O \rightleftharpoons AlOH^{2+} + H^+$	-5.02
3	SiO_2 (amorp) + $3H_2O \rightleftharpoons H_4SiO_4^0$	-2.74
4	SiO_2 (soil) + $2H_2O \rightleftharpoons H_4SiO_4^0$	-3.10
5	$Ca^{2+} + H_2PO_4^- \rightleftharpoons CaH_2PO_4^+$	1.40
6	$Ca^{2+} + H_2PO_4^- \rightleftharpoons CaHPO_4^0 + H^+$	-4.46
7	$Ca^{2+} + H_2PO_4^- \rightleftharpoons CaPO_4^- + 2H^+$	-13.09
8	$H_2PO_4^- \rightleftharpoons HPO_4^{2-} + H^+$	-7.20
9	$HPO_4^{2-} \rightleftharpoons PO_4^{3-} + 2H^+$	-12.35
10	$H_2PO_4^- \rightleftharpoons PO_4^{3-} + 2H^+$	-19.55
11	$H_3PO_4^0 \rightleftharpoons H_2PO_4^- + H^+$	-2.15
12	$Fe^{2+} + H_2PO_4^- \rightleftharpoons FeH_2PO_4^+$	2.70
13	$Fe^{2+} + H_2PO_4^- \rightleftharpoons FeHPO_4^0 + H^+$	-3.60
14	$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	13.04
15	$AlPO_4.\ 2H_2O$ (variscite) + $2H^+ \rightleftharpoons Al^{3+} + H_2PO_4^- + 2H_2O$	-2.50
16	$FePO_4.\ 2H_2O$ (strengite) + $2H^+ \rightleftharpoons Fe^{3+} + H_2PO_4^- + 2H_2O$	-6.85
17	$CaHPO_4.\ 2H_2O$ (brushite) + $H^+ \rightleftharpoons Ca^{2+} + H_2PO_4^- + 2H_2O$	0.63

CURRICULUM VITEA

NAME : Miss Noppakao Ex-un

BIRTH DATE : November 7, 1979

BIRTH PLACE : Sakon Nakhon, Thailand

EDUCATION :

YEAR	INSTITUTION	DEGREE/DIPLOMA
2002	Khon Kaen Univ.	B.Sc. (Chemistry)
2006	Kasetsart Univ.	M.S. (Chemistry)

WORK PLACE : Faculty of Science, Kasetsart University

SCHOLARSHIP/AWARDS : Teaching Assistant of Laboratory in General Chemistry