

LAMPIRAN I :

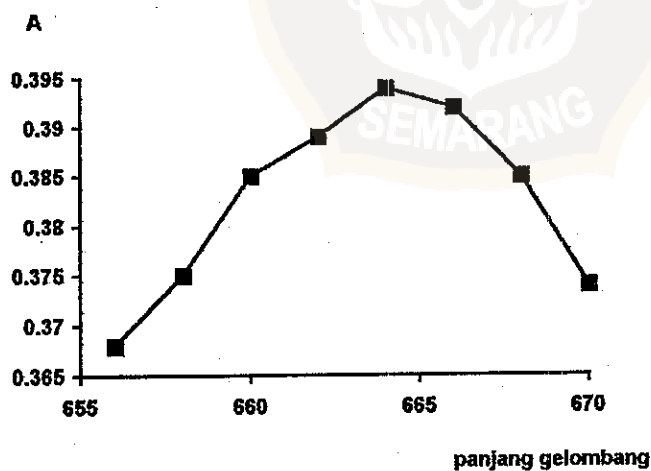
HASIL PERHITUNGAN DAN GRAFIK

I. Penentuan Luas Permukaan

1.1 Penentuan λ maks Metilen Biru Klorida

Tabel 1.1 Hasil Penentuan λ maks Metilen Biru Klorida

λ	A
656	0,368
658	0,375
660	0,385
662	0,389
664	0,394
666	0,392
668	0,385
670	0,374



Grafik 1.1 Panjang Gelombang Maksimum Metilen Biru Klorida

1. 2 Penentuan Kurva Kalibrasi Metilen Biru Klorida

Tabel 1.2 Hasil Penentuan Kurva Kalibrasi Metilen Biru Klorida

C (mg/l)	A
0,5	0,170
1	0,273
2	0,463
3	0,490
4	0,531
5	0,822
6	1,161
7	1,28

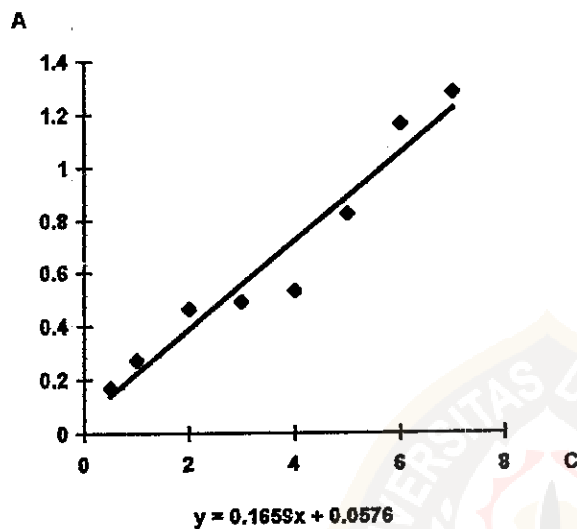
x	y	x.y	x ²
0,5	0,170	0,085	0,25
1	0,273	0,273	1
2	0,463	0,926	4
3	0,490	1,470	9
4	0,531	2,124	16
5	0,822	4,110	25
6	1,161	6,966	36
7	1,28	8,960	49
$\Sigma = 28,5$	$\Sigma = 5,19$	$\Sigma = 24,914$	$\Sigma = 140,25$

$$a = \frac{N \sum x.y - \sum x. \sum y}{N \sum x^2 - (\sum x)^2}$$

$$a = \frac{8(24,914) - (28,5)(5,19)}{8(140,25) - (28,5)^2}$$

$$a = \frac{51,397}{309,75}$$

$$a = 0,166 \quad a \text{ Metilen Biru Klorida} = 0,166$$



Grafik 1.2 Kurva Kalibrasi Metilen Biru Klorida

1. 3 Penentuan Waktu Setimbang Metilen Biru Klorida

$$C_0 = 3 \text{ mg/L}$$

$$v = 25 \text{ mL}$$

$$m = 5 \text{ mg}$$

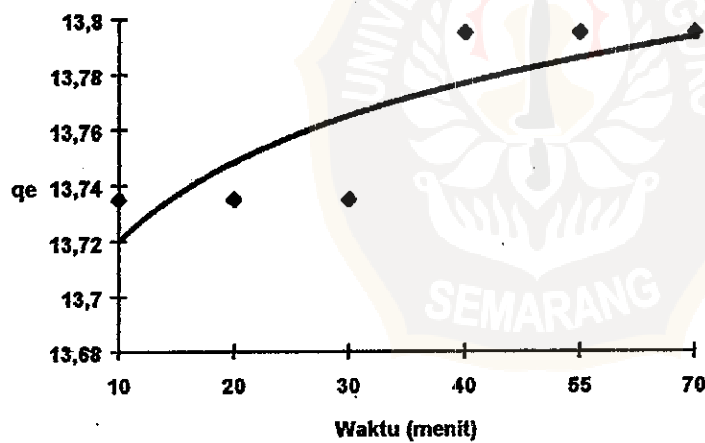
$$m/v = 0,005 \text{ g}/0,025 \text{ L} = 0,2 \text{ g/L}$$

a. MKRb

tabel 1. 3a. Hasil Penentuan t setimbang MBK untuk Karbon Aktif

MKRb

t (menit)	C_e (mg/L)	$C_o - C_e$ (mg/L)	q_e (mg/g)
10	0,253	2,747	13,735
20	0,253	2,747	13,735
30	0,253	2,747	13,735
40	0,241	2,759	13,795
55	0,241	2,759	13,795
70	0,241	2,759	13,759



Grafik 1. 3a. Waktu Setimbang MBK untuk Karbon Aktif MKRb

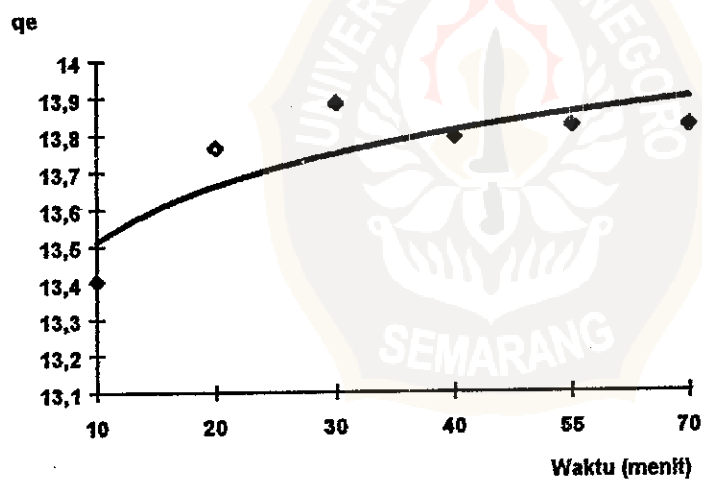
t setimbang MKRb = 40 menit

c. MRC

Tabel 1.3c. Hasil Penentuan t Setimbang MBK untuk Karbon Aktif

MRC

t (menit)	C_e (mg/L)	$C_0 - C_e$ (mg/L)	q_e (mg/g)
10	0,319	2,681	13,405
20	0,247	2,753	13,765
30	0,223	2,777	13,885
40	0,241	2,759	13,795
55	0,235	2,765	13,825
70	0,235	2,765	13,825



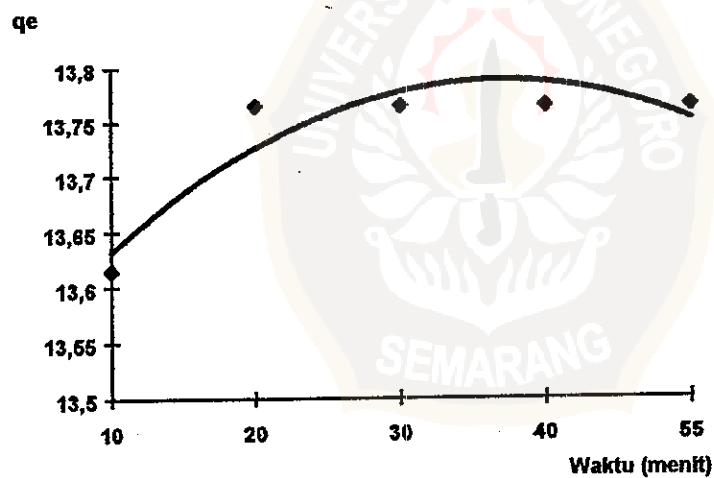
Grafik 1. 3c. Waktu Setimbang MBK untuk Karbon Aktif MRC

t setimbang MRC = 55 menit

d. MKRg

Tabel 1.3d. Hasil Penentuan t Setimbang MBK untuk Karbon Aktif MKRg

t (menit)	Ce (mg/L)	Co - Ce (mg/L)	qe (mg/g)
10	0,277	2,723	13,615
20	0,247	2,753	13,765
30	0,247	2,753	13,765
40	0,259	2,741	13,705
55	0,247	2,753	13,765
70	0,259	2,741	13,705



Grafik 1. 3d. Waktu Setimbang MBK untuk Karbooon Aktif MKRg

t setimbang MKRg = 20 menit

1. 4 Penentuan Luas Permukaan

$$v = 50 \text{ mL}$$

$$m = 5 \text{ mg}$$

$$m/v = 0,005 \text{ g} / 0,050 \text{ L} = 0,1 \text{ g/L}$$

a. MKRb

Tabel 1.4a. Hasil Penentuan X_m untuk Karbon Aktif MKRb

Ao	Co (mg/L)	Ae	Ce (mg/L)	Co - Ce (mg/L)	qe (mg/g)
0,616	3,711	0,292	1,759	1,952	19,52
0,755	4,548	0,412	2,482	2,066	20,66
1,026	6,181	0,648	3,904	2,277	22,77
1,227	7,392	0,641	3,861	3,531	35,31
1,367	8,235	0,711	4,283	3,952	39,52
1,390	8,373	0,396	2,386	5,987	59,87
1,549	9,331	0,605	3,645	5,686	56,86

$$X_m = 59,87 \text{ mg/g}$$

$$N_a = 6,022 \cdot 10^{23} \text{ /gmol}$$

$$a = 197 \cdot 10^{-20} \text{ m}^2 \text{ /molekul}$$

$$M = 320,5 \text{ g/mol}$$

$$S = \frac{X_m \cdot N_a \cdot a}{M}$$

$$S = \frac{59,87 \cdot 10^{-3} \times 6,022 \cdot 10^{23} \times 197 \cdot 10^{-20}}{320,5}$$

$$S = 221,609 \text{ m}^2 \text{ /g}$$

Luas permukaan MKRb = 221,609 m²/g

b. INDb

Tabel 1.4b. Hasil Penentuan X_m untuk Karbon Aktif INDb

A _o	C _o (mg/L)	A _e	C _e (mg/L)	C _o - C _e (mg/L)	q _e (mg/g)
0,616	3,711	0,060	0,361	3,350	33,50
0,755	4,548	0,127	0,765	3,783	37,83
0,922	5,554	0,060	0,361	5,193	51,93
1,087	6,548	0,081	0,488	6,060	60,60
1,142	6,880	0,099	0,596	6,284	62,84
1,155	6,958	0,216	1,301	5,657	56,57

X_m = 62,84 mg/g

$$S = \frac{X_m \cdot N_a \cdot a}{M}$$

$$S = \frac{62,84 \cdot 10^{-3} \times 6,022 \cdot 10^{23} \times 197 \cdot 10^{-20}}{320,5}$$

S = 232,603 m²/g

Luas permukaan INDb = 232,603 m²/g



c. MRC

tabel 1.4c. Hasil Penentuan X_m untuk Karbon Aktif MRC

A_o	C_o (mg/L)	A_e	C_e (mg/L)	$C_o - C_e$ (mg/L)	q_e (mg/g)
0,616	3,711	0,152	0,916	2,795	27,95
0,755	4,548	0,252	1,518	3,030	30,30
0,922	5,554	0,391	2,355	3,199	31,99
1,020	6,145	0,356	2,145	4,000	40,00
1,087	6,548	0,235	1,524	5,024	50,24
1,142	6,880	0,557	3,355	3,525	35,25

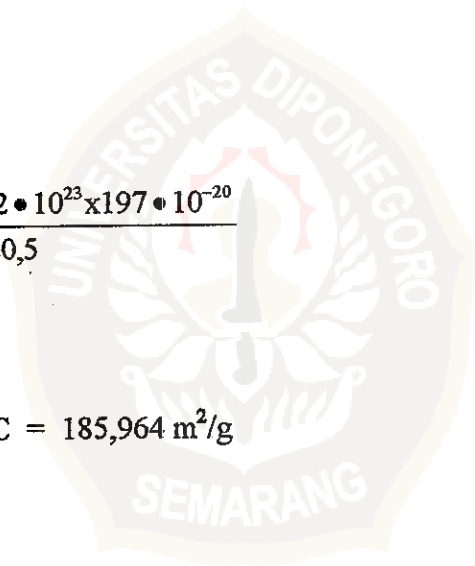
$$X_m = 50,24 \text{ mg/g}$$

$$S = \frac{X_m \cdot N_a \cdot a}{M}$$

$$S = \frac{50,24 \cdot 10^{-3} \times 6,022 \cdot 10^{23} \times 197 \cdot 10^{-20}}{320,5}$$

$$S = 185,964 \text{ m}^2/\text{g}$$

$$\text{Luas permukaan MRC} = 185,964 \text{ m}^2/\text{g}$$



d. MKRg

Tabel 1. 4d. Hasil Penentuan X_m untuk Karbon Aktif MKRg

A_o	C_o (mg/L)	A_e	C_e (mg/L)	$C_o - C_e$ (mg/L)	q_e (mg/g)
0,616	3,711	3,323	1,946	1,765	17,65
0,755	4,548	0,380	2,289	2,259	22,59
1,026	6,181	0,461	2,777	3,404	34,04
1,227	7,392	0,635	3,825	3,567	35,67
1,367	8,235	0,707	4,259	3,976	39,76
1,390	8,373	0,830	5,000	3,373	33,73

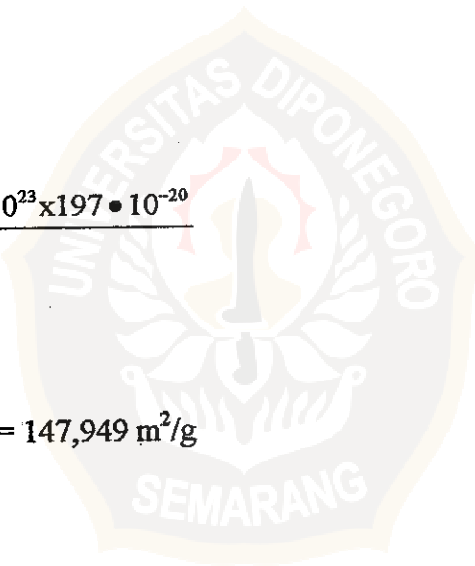
$$X_m = 39,76 \text{ mg/g}$$

$$S = \frac{X_m \cdot N_a \cdot a}{M}$$

$$S = \frac{39,97 \cdot 10^{-3} \times 6,022 \cdot 10^{23} \times 197 \cdot 10^{-20}}{320,5}$$

$$S = 147,949 \text{ m}^2/\text{g}$$

$$\text{Luas permukaan MKRg} = 147,949 \text{ m}^2/\text{g}$$



II. Adsorpsi

2. 1 Penentuan Kurva Kalibrasi

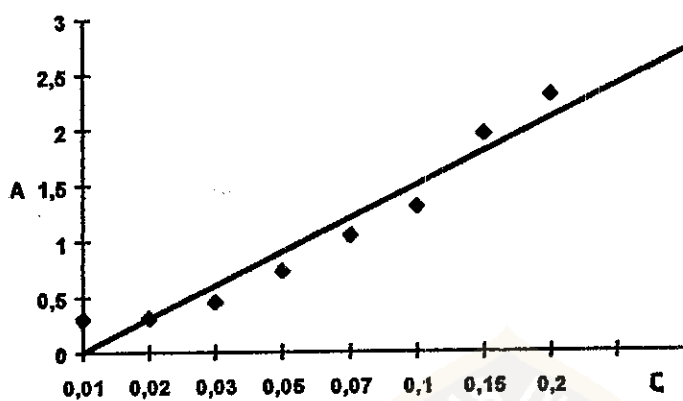
Tabel 2. 1 Hasil Penentuan Kurva Kalibrasi o-Kresol

C (g/l)	A
0,01	0,300
0,02	0,308
0,03	0,454
0,05	0,733
0,07	1,052
0,10	1,308
0,15	1,964
0,20	2,312

x	y	x.y	x ²
0,01	0,300	0,003	0,0001
0,02	0,308	0,006	0,0004
0,03	0,454	0,014	0,0009
0,05	0,733	0,037	0,0025
0,07	1,052	0,074	0,0049
0,10	1,308	0,131	0,0100
0,15	1,964	0,295	0,0225
0,2	2,312	0,462	0,0400
$\Sigma = 0,63$	$\Sigma = 8,431$	$\Sigma = 1,022$	$\Sigma = 0,0813$

$$a = \frac{N \sum x.y - \sum x. \sum y}{N \sum x^2 - (\sum x)^2}$$

$$a = \frac{8(1,022) - (0,63)(8,431)}{8(0,0813) - (0,63)^2} \quad a = \frac{2,86447}{0,2535} \quad a = 11,3$$



Grafik 2. 2 kurva Kalibrasi o-Kresol

2. 2 Penentuan Waktu Setimbang

a. MKRb

$$C_0 = 0,2 \text{ g/L}$$

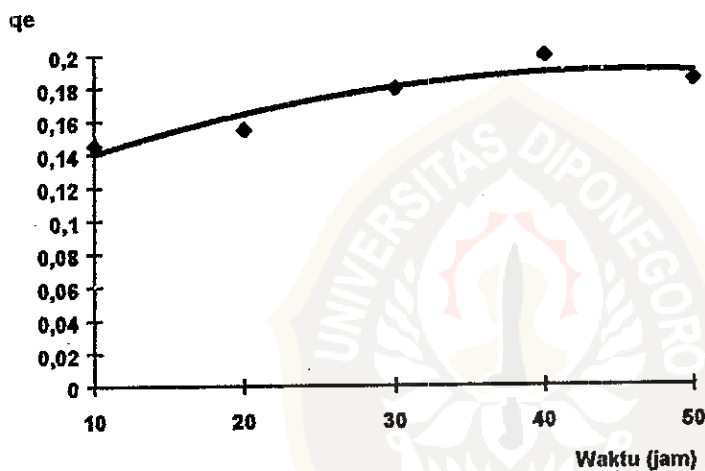
$$v = 25 \text{ mL}$$

$$m = 0,005 \text{ g}$$

$$m/v = 0,2 \text{ g/mL}$$

Tabel 2. 2a. Hasil Penentuan t Setimbang o-Kresol untuk Karbon Aktif MKRb

t (jam)	C_e (g/L)	$C_o - C_e$ (g/L)	q_e (g/g)
10	0,171	0,029	0,145
20	0,169	0,031	0,155
30	0,164	0,036	0,180
40	0,160	0,040	0,200
50	0,163	0,037	0,185



Grafik 2. 2a. Waktu Setimbang o-Kresol untuk Karbon Aktif MKRb

t setimbang MKRb = 30 jam

b. INDb

$$C_o = 0,200 \text{ g/L}$$

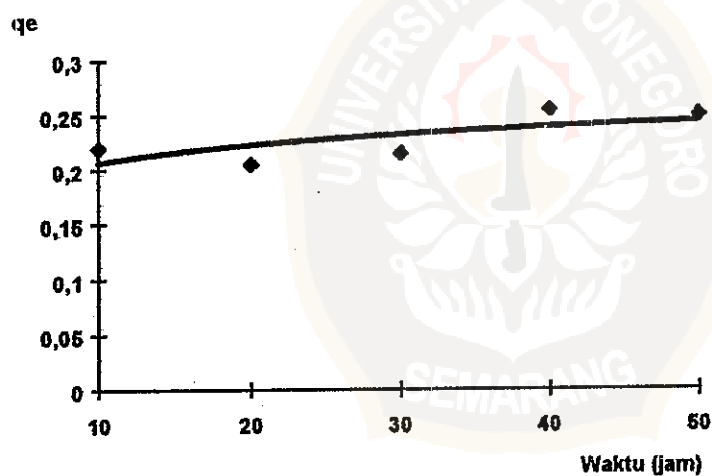
$$v = 25 \text{ mL}$$

$$m = 0,005 \text{ g}$$

$$m/v = 0,2 \text{ g/mL}$$

Tabel 2. 2b. Hasil Penentuan t Setimbang o-Kresol untuk Karbon Aktif INDb

t(jam)	C_e (g/L)	$C_o - C_e$ (g/L)	q_e (g/g)
10	0,156	0,044	0,220
20	0,159	0,041	0,205
30	0,157	0,043	0,215
40	0,149	0,051	0,255
50	0,150	0,050	0,250



Grafik 2. 2b. Waktu Setimbang o-Kresol untuk Karbon Aktif INDb

t setimbang INDb = 30 jam

c. MRC

$$C_o = 0,2 \text{ g/L}$$

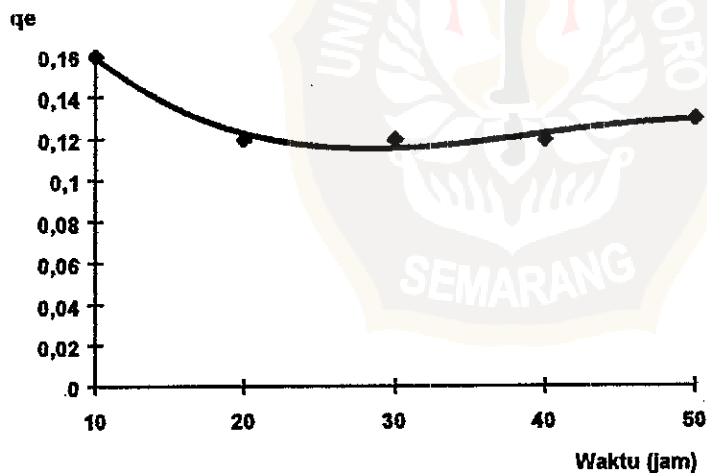
$$v = 50 \text{ mL}$$

$$m = 0,005 \text{ g}$$

$$m/v = 0,1 \text{ g/mL}$$

Tabel 2. 2c. Hasil Penentuan t Setimbang o-Kresol untuk Karbon Aktif MRC

t (jam)	C_e (g/L)	$C_o - C_e$ (g/L)	q_e (g/g)
10	0,184	0,016	0,16
20	0,188	0,012	0,12
30	0,188	0,012	0,12
40	0,188	0,012	0,12
50	0,188	0,012	0,12



Grafik 2. 2c. Waktu Setimbang o-Kresol untuk Karbon Aktif MRC

t setimbang MRC = 20 jam

d. MKRg

$$C_o = 0,2 \text{ g/L}$$

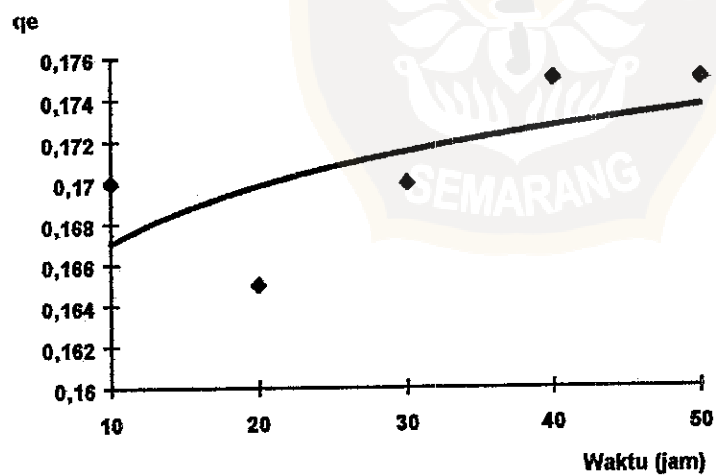
$$v = 25 \text{ mL}$$

$$m = 0,005 \text{ g}$$

$$m/v = 0,2 \text{ g/mL}$$

Tabel 2. 2d. Hasil Penentuan t Setimbang o-Kresol untuk Karbon Aktif MKRg

t (jam)	C_e (g/L)	$C_o - C_e$ (g/L)	q_e (g/g)
10	0,166	0,034	0,170
20	0,167	0,033	0,165
30	0,166	0,034	0,170
40	0,165	0,035	0,175
50	0,165	0,035	0,175



Grafik 2. 2d. Waktu Setimbang o-Kresol untuk Karbon Aktif MKRg

t setimbang MKRg = 30 jam

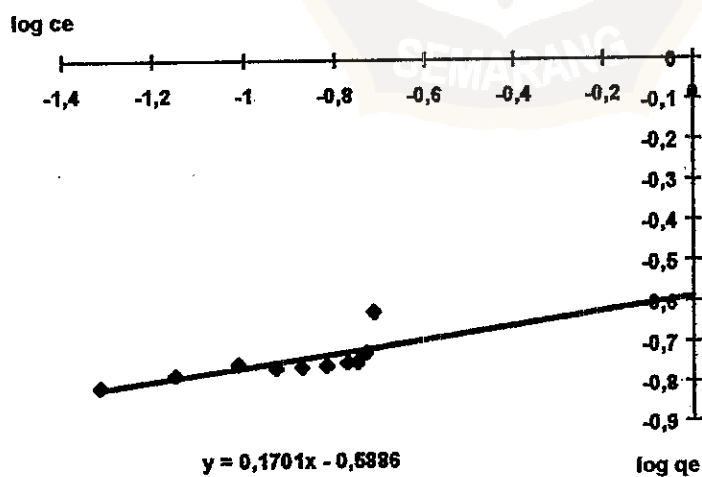
2.3 Adsorpsi

a. MKRb

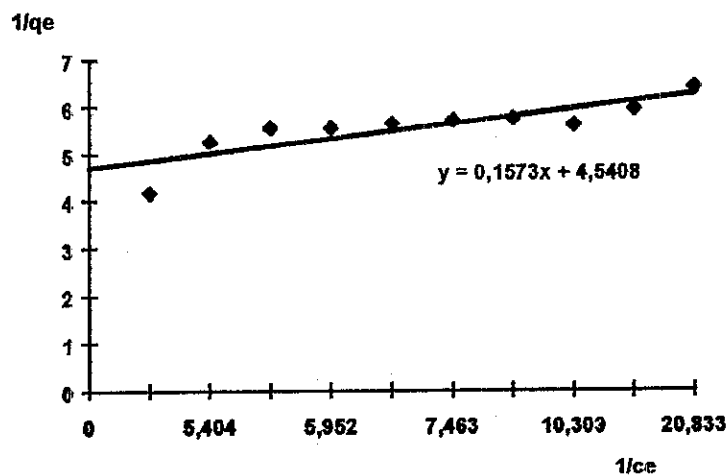
$$C_o = 0,204 \text{ g/L}$$

Tabel 2. 3a. Hasil Proses Adsorpsi o-Kresol untuk Karbon Aktif MKRb

Berat KA(g)	C_e (g/L)	$C_o - C_e$ (g/L)	m/v (g/L)	Q_e (g/g)	$1/C_e$ (L/g)	$1/q_e$ (g/g)	Log C_e	Log q_e
0,005	0,129	0,012	0,05	0,24	5,208	4,167	-0,716	-0,620
0,01	0,185	0,019	0,1	0,19	5,405	5,263	-0,733	-0,721
0,015	0,177	0,027	0,15	0,18	5,650	5,556	-0,753	-0,745
0,02	0,168	0,036	0,2	0,18	5,952	5,556	-0,774	-0,745
0,03	0,151	0,093	0,3	0,177	6,623	5,650	-0,820	-0,753
0,04	0,134	0,07	0,4	0,175	7,463	5,714	-0,874	-0,757
0,05	0,117	0,087	0,5	0,174	8,547	5,747	-0,932	-0,759
0,06	0,197	0,107	0,6	0,178	10,309	5,618	-1,015	-0,749
0,08	0,070	0,134	0,8	0,168	14,286	5,952	-1,152	-0,776
0,1	0,048	0,156	1,0	0,156	20,833	6,410	-1,317	-0,807



Grafik 2. 3 a₁. Isoterm Freundlich untuk Karbon Aktif MKRb



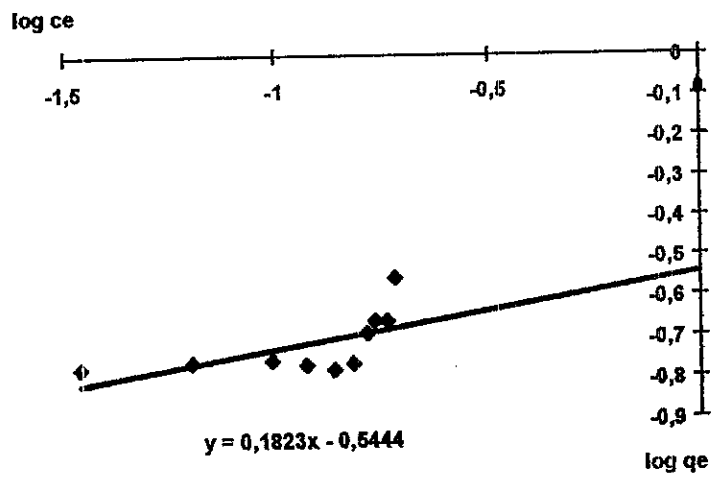
Grafik 2. 3a₂. Isoterm Langmuir untuk Karbon Aktif MKRb

b. INDb

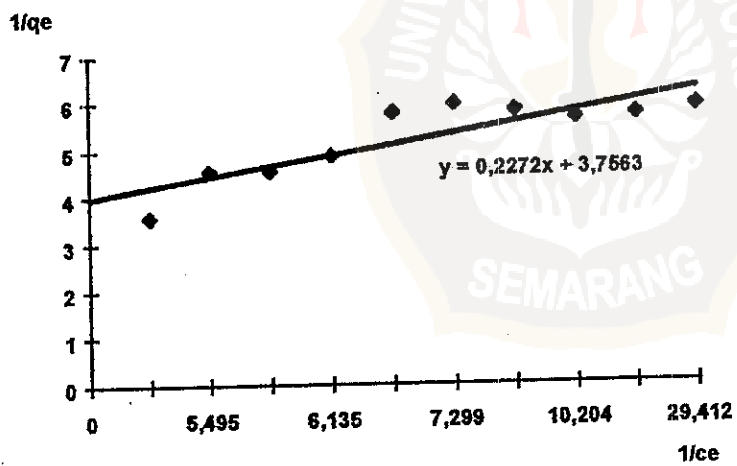
$C_0 = 0,204 \text{ g/L}$

Tabel 2. 3b. Hasil Proses Adsorpsi o-Kresol untuk Karbon Aktif INDb

Berat KA(g)	C_e (g/L)	$C_0 - C_e$ (g/L)	m/v (g/L)	q_e (g/g)	$1/C_e$ (L/g)	$1/q_e$ (g/g)	$\text{Log } C_e$	$\text{Log } q_e$
0,005	0,190	0,014	0,05	0,028	5,263	3,571	-0,721	-0,553
0,01	0,182	0,022	0,1	0,22	5,495	4,545	-0,740	-0,658
0,015	0,171	0,033	0,15	0,22	5,848	4,545	-0,768	-0,658
0,02	0,163	0,041	0,2	0,205	6,135	4,878	-0,787	-0,688
0,03	0,152	0,052	0,3	0,173	6,579	5,780	-0,819	-0,761
0,04	0,137	0,067	0,4	0,168	7,299	5,952	-0,863	-0,776
0,05	0,118	0,086	0,5	0,172	8,475	5,814	-0,928	-0,764
0,06	0,098	0,106	0,6	0,177	10,204	5,650	-1,008	-0,753
0,08	0,064	0,14	0,8	0,175	15,625	5,714	-1,116	-0,757
0,10	0,034	0,17	1,0	0,170	29,412	5,882	-1,463	-0,770



Grafik 2. 3b₁. Isoterm Freundlich untuk Karbon Aktif INDb



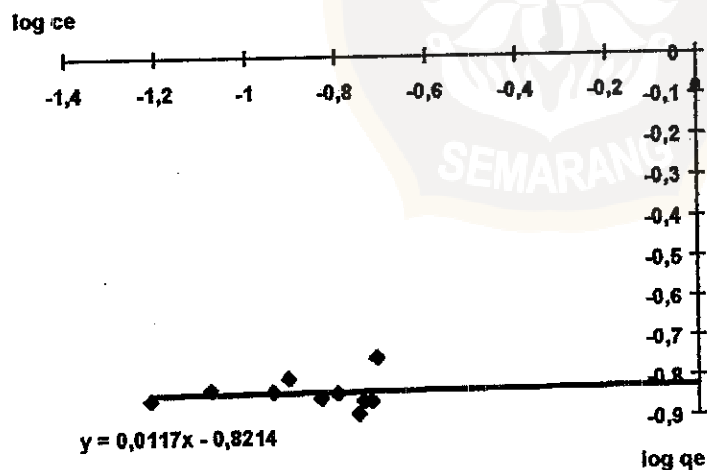
Grafik 2.3b₂. Isoterm Langmuir untuk Karbon Aktif INDb

c. MRC

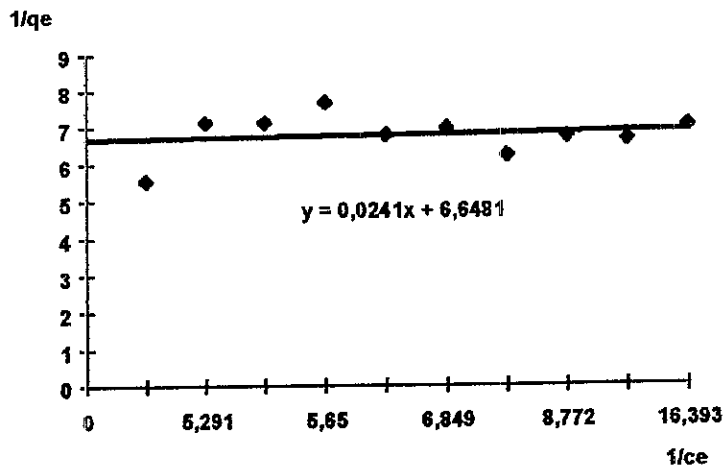
$$C_o = 0,203 \text{ g/L}$$

Tabel 2. 3c. Hasil Penentuan Adsorpsi o-Kresol untuk Karbon Aktif MRC

Berat KA (g)	C_e (g/L)	$C_o - C_e$ (g/L)	m/v (g/L)	q_e (g/g)	$1/C_e$ (L/g)	$1/q_e$ (g/g)	$\text{Log } C_e$	$\text{Log } q_e$
0,005	0,194	0,09	0,05	0,18	5,155	5,556	-0,712	-0,745
0,01	0,189	0,014	0,1	0,14	5,291	7,143	-0,724	-0,854
0,015	0,182	0,021	0,15	0,14	5,495	7,143	-0,741	-0,854
0,02	0,177	0,026	0,2	0,13	5,650	7,692	-0,753	-0,886
0,03	0,159	0,044	0,3	0,147	6,289	6,803	-0,799	-0,834
0,04	0,146	0,057	0,4	0,143	6,849	6,993	-0,836	-0,846
0,05	0,123	0,08	0,5	0,16	8,130	6,25	-0,909	-0,796
0,06	0,114	0,089	0,6	0,148	8,772	6,757	-0,994	-0,829
0,08	0,083	0,12	0,8	0,15	12,048	6,667	-1,082	-0,824
0,1	0,061	0,142	1,0	0,142	16,393	7,042	-1,215	-0,848



Grafik 2. 3c1. Isoterm Freundlich untuk Karbon Aktif MRC



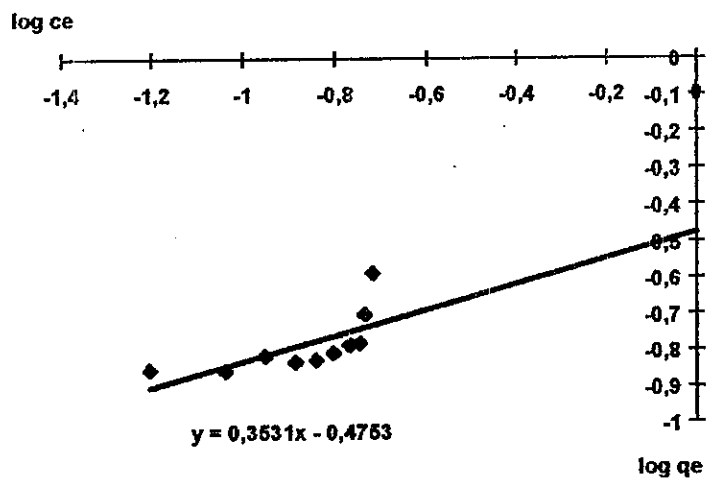
Grafik 2. 3c₂. Isoterm Langmuir untuk Karbon Aktif MRC

d. MKRg

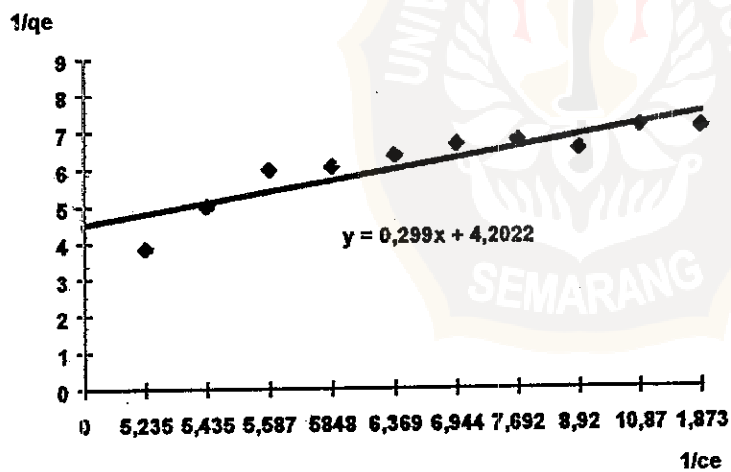
$C_o = 0,204$ g/L

Tabel 2. 3d. Hasil Penentuan Adsorpsi o-Kresol untuk Karbon Aktif MKRg

Berat KA (g)	C_e (g/L)	$C_o - C_e$ (g/L)	m/v (g/L)	q_e (g/g)	$1/C_e$ (L/g)	$1/q_e$ (g/g)	Log C_e	Log q_e
0,005	0,191	0,013	0,05	0,26	5,235	3,846	-0,719	-0,585
0,01	0,184	0,02	0,1	0,2	5,435	5,000	-0,736	-0,699
0,015	0,179	0,025	0,15	0,167	5,587	5,988	-0,747	-0,778
0,02	0,171	0,033	0,2	0,165	5,848	6,061	-0,768	-0,783
0,03	0,157	0,047	0,3	0,157	6,369	6,369	-0,805	-0,805
0,04	0,144	0,06	0,4	0,15	6,944	6,667	-0,841	-0,824
0,05	0,13	0,074	0,5	0,148	7,692	6,757	-0,886	-0,830
0,06	0,112	0,092	0,6	0,153	8,929	6,536	-0,952	-0,814
0,08	0,092	0,112	0,8	0,14	10,870	7,143	-1,038	-0,854
0,10	0,063	0,141	1,0	0,141	15,873	7,092	-1,204	-0,851



Grafik 2. 3d₁. Isoterm Freundlich untuk Karbon Aktif MKRg



Grafik 2. 3d₂. Isoterm Langmuir untuk Karbon Aktif MKRg

III. Penentuan Volume Rongga

3. 1 Volume Rongga Sebelum Adsorpsi

a. MKRb

$$\text{Piknometer kosong} = 19,3713 \text{ g}$$

$$\text{Piknometer + Aquadest} = 45,8540 \text{ g}$$

$$\text{Berat jenis Aquadest} = 1,0593 \text{ g/ml}$$

$$a = 45,8482 \text{ g}$$

$$b = 46,0395 \text{ g}$$

$$V_R = \frac{(a + 0,5) - b}{BJ}$$

$$V_R = \frac{(45,8482 + 0,5) - 46,0395}{1,0593}$$

$$V_R = 0,2914 \text{ ml}$$

b. INDb

$$a = 45,8513 \text{ g}$$

$$b = 46,0128 \text{ g}$$

$$BJ = 1,0593 \text{ g/ml}$$

$$V_R = \frac{(45,8513 + 0,5) - 46,0128}{1,0593}$$

$$V_R = 0,3195 \text{ ml}$$



c. MRC

$$a = 42,2030 \text{ g}$$

$$b = 42,3921 \text{ g}$$

$$BJ = 0,9948 \text{ g/ml}$$

$$V_R = \frac{(42,2020 + 0,0) - 42,3921}{0,9948}$$

$$V_R = 0,3125 \text{ ml}$$

d. MKRg

$$a = 45,8500 \text{ g}$$

$$b = 45,9709 \text{ g}$$

$$BJ = 1,0593 \text{ g/ml}$$

$$V_R = \frac{(45,8500 + 0,5) - 45,9709}{1,0593}$$

$$V_R = 0,3578 \text{ ml}$$

3. 2 Volume Rongga Setelah Proses Adsorpsi

$$\text{Piknometer kosong} = 19,3185 \text{ g}$$

$$\text{Piknometer + Aquadest} = 45,8402 \text{ g}$$

$$\text{Berat Jenis} = 1,0609 \text{ g/ml}$$



a. MKRb

$$a = 45,8402 \text{ g}$$

$$b = 46,0439 \text{ g}$$

$$V_R = \frac{(45,8402 + 0,5) - 46,0439}{1,0609}$$

$$V_R = 0,2793 \text{ ml}$$

b. INDb

$$a = 45,8402 \text{ g}$$

$$b = 46,0518 \text{ g}$$

$$V_R = \frac{(45,8402 + 0,5) - 46,0518}{1,0609}$$

$$V_R = 0,2718 \text{ ml}$$

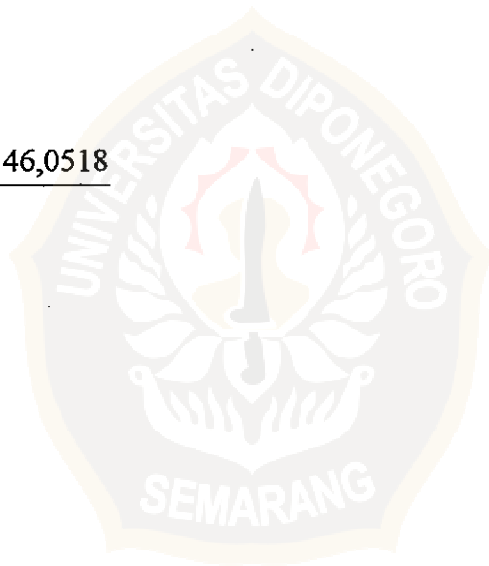
c. MRC

$$a = 45,8402 \text{ g}$$

$$b = 46,0191 \text{ g}$$

$$V_R = \frac{(45,8402 + 0,5) - 46,0191}{1,0609}$$

$$V_R = 0,3027 \text{ ml}$$



d. MKRg

$$a = 45,8402 \text{ g}$$

$$b = 45,9865 \text{ g}$$

$$V_R = \frac{(45,8402 + 0,5) - 45,9865}{1,0609}$$

$$V_R = 0,3334 \text{ ml}$$

Tabel 3. 1 Volume Rongga Sebelum dan Sesudah Proses Adsorpsi

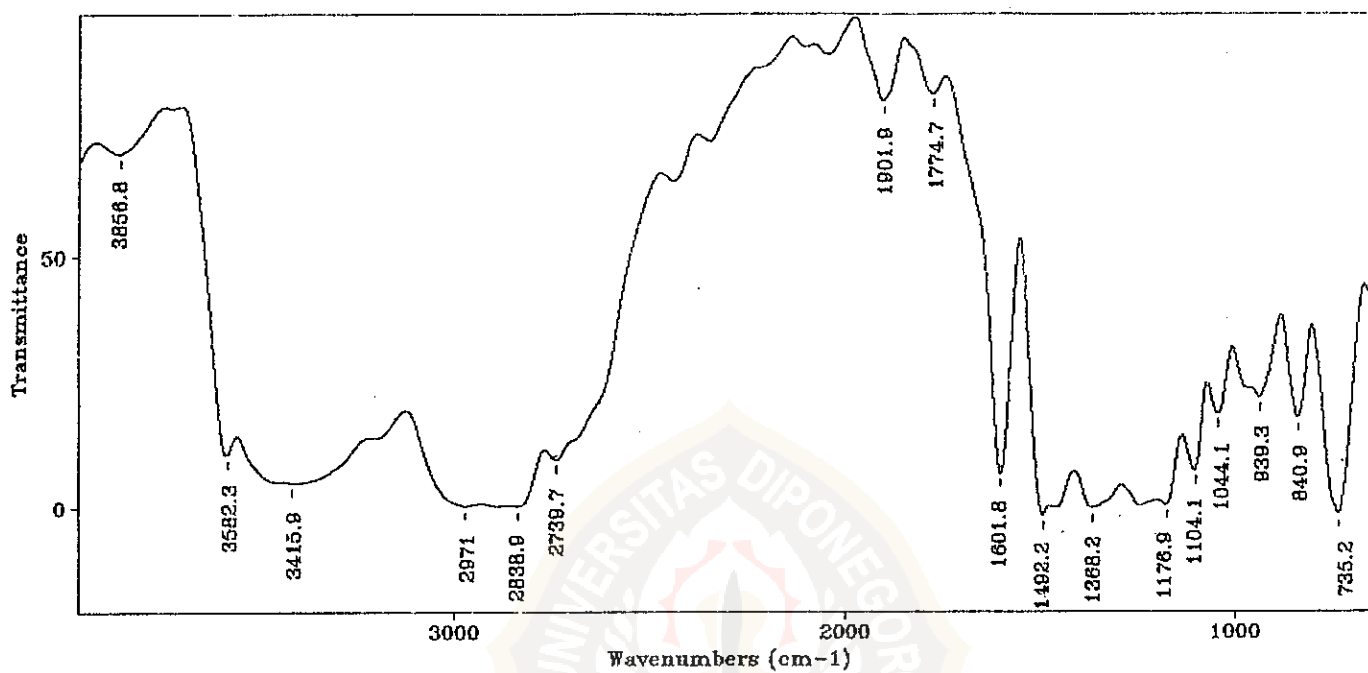
Jenis Karbon Aktif	V_{R1}	V_{R2}	$\Delta V_R (\%)$
MKRb	0,2914	0,2793	4,15
INDb	0,3195	0,2718	14,93
MRC	0,3125	0,3027	3,14
MKRg	0,3528	0,3334	6,92

Tabel 3. 2 Berat Jenis Karbon Aktif Sebelum dan Sesudah Proses Adsorpsi

Jenis Karbon Aktif	BJ_1	BJ_2
MKRb	1,69	1,79
INDb	1,55	1,83
MRC	1,65	1,65
MKRg	1,38	1,50

LAMPIRAN II :

HASIL SPEKTRA INFRA MERAH

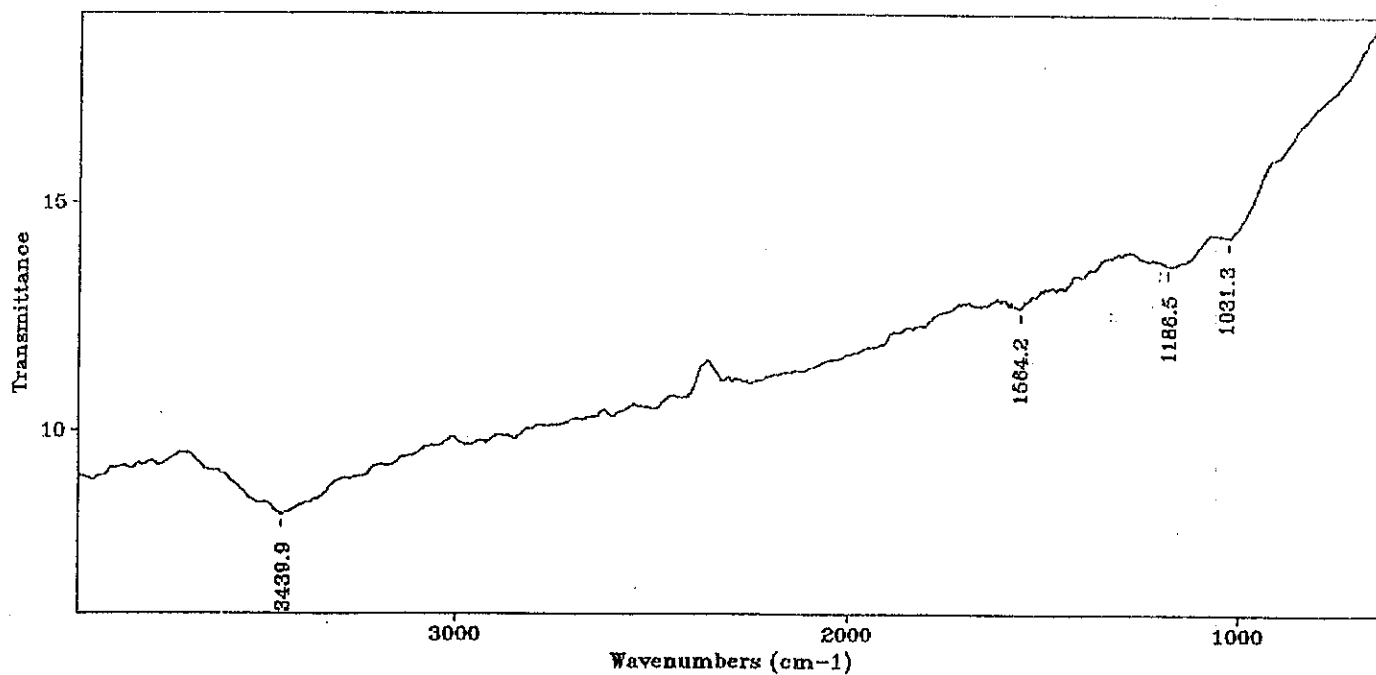


OCRE
Buck Scientific Inc. M500

Res= 6 cm⁻¹

06/19/97 13:05

Grafik 2. 1. Spektra Infra Merah o-Kresol



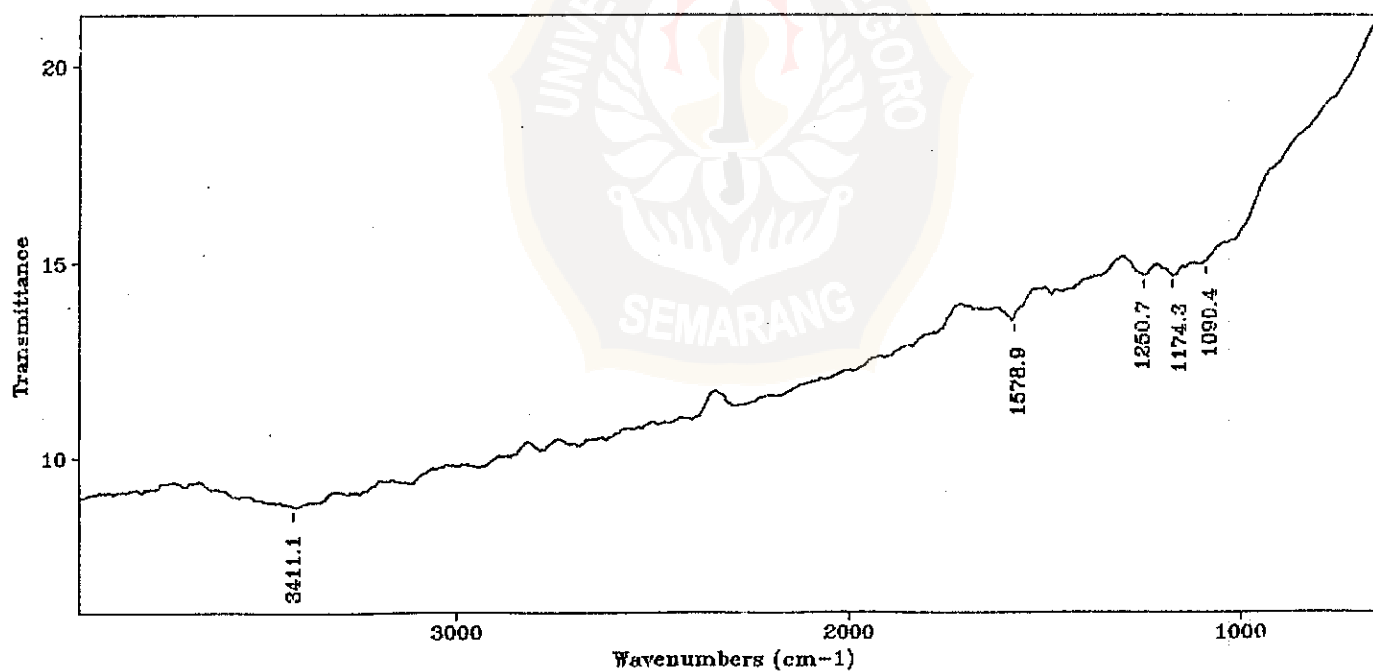
MRC1

Res= 6 cm⁻¹

06/19/97 13:12

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Grafik 2. 2. Spektra Infra Merah Karbon Aktif MRC Sebelum Proses Adsorpsi



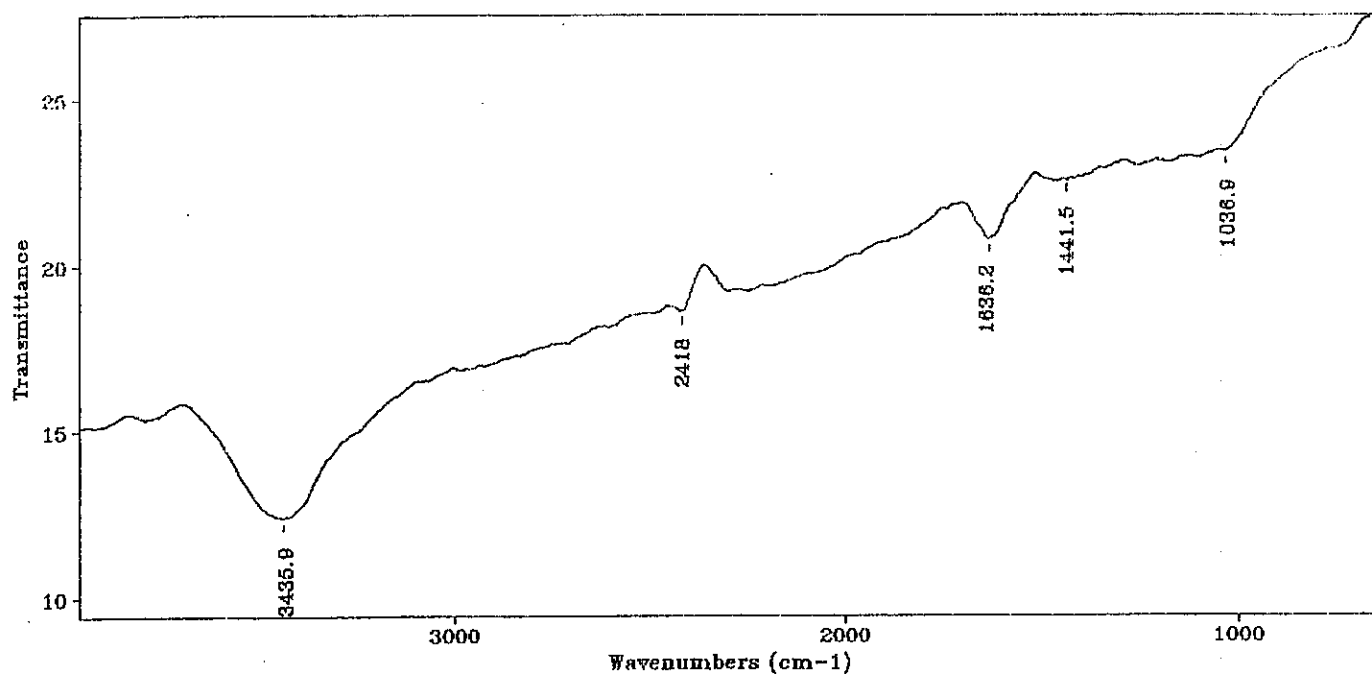
MRC2

Res= 6 cm⁻¹

06/19/97 13:34

Buck Scientific Inc. M500

Grafik 2. 3. Spektra Infra Merah Karbon Aktif MRC Setelah Proses Adsorpsi



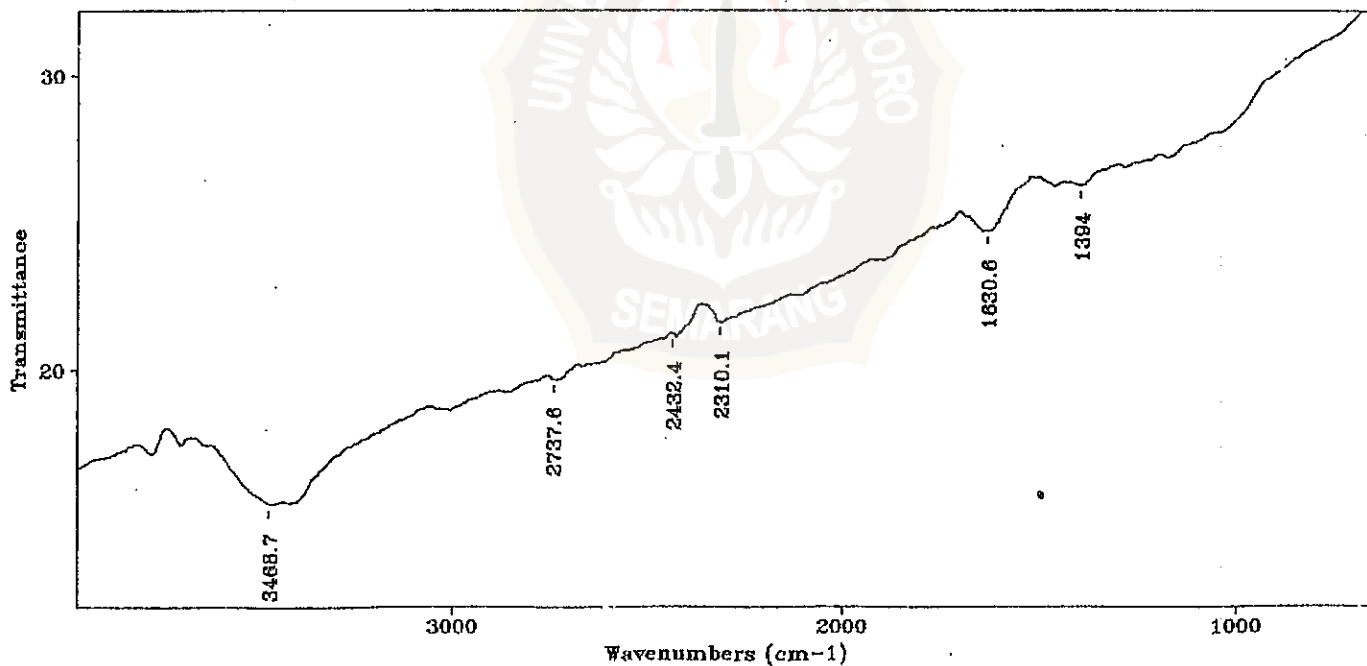
MKRG1

Res= 6 cm⁻¹

06/19/97 13:21

Buck Scientific Inc. M500

Grafik 2. 4. Spektra Infra Merah Karbon Aktif MKRg Sebelum Proses Adsorpsi



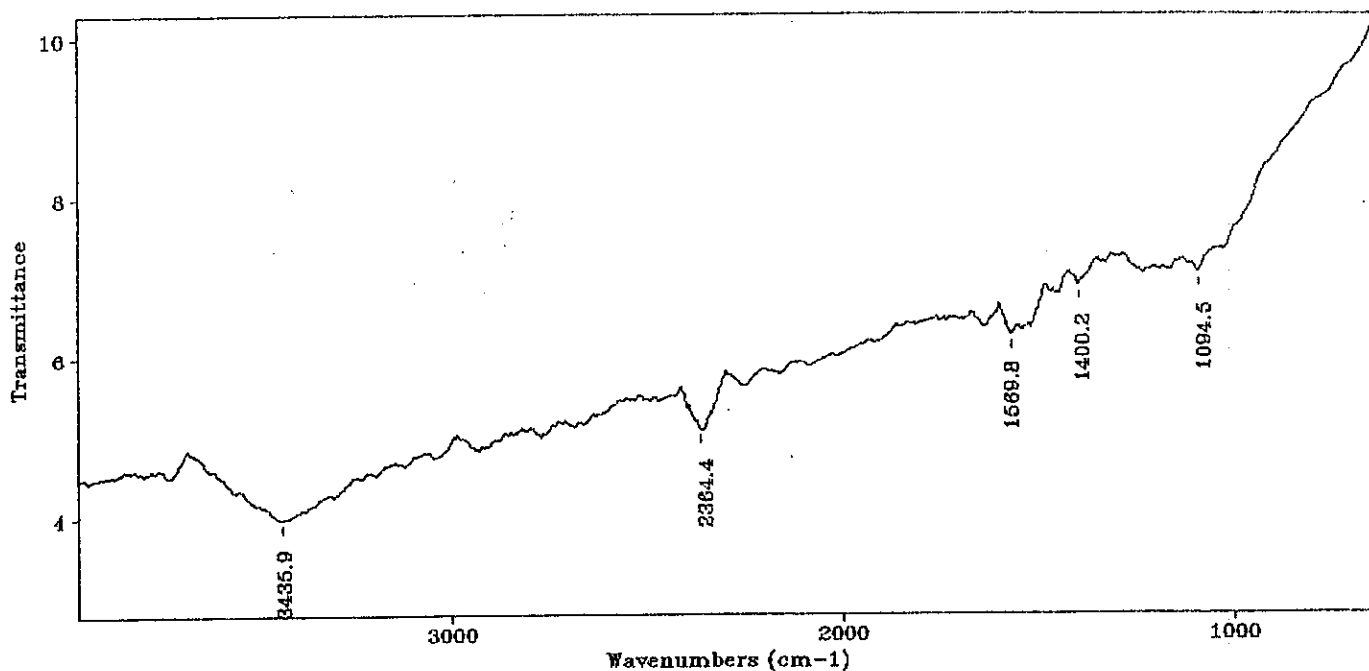
MKRG2

Res= 6 cm⁻¹

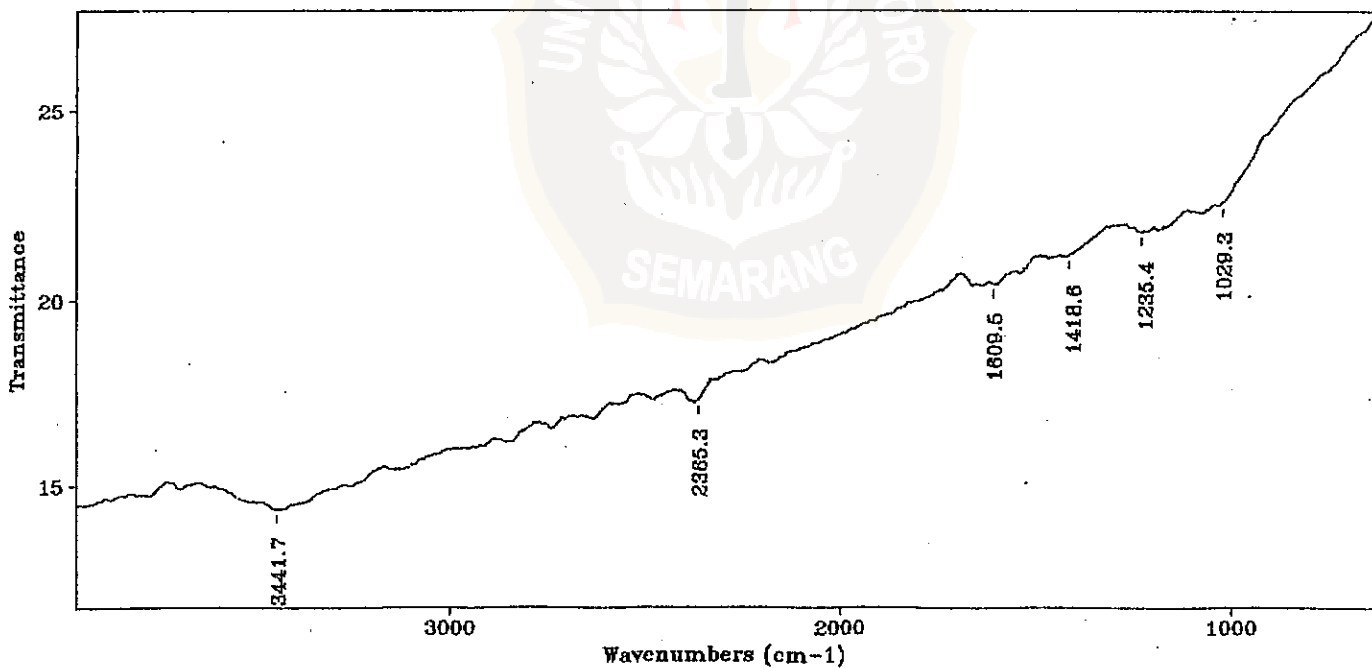
06/19/97 13:43

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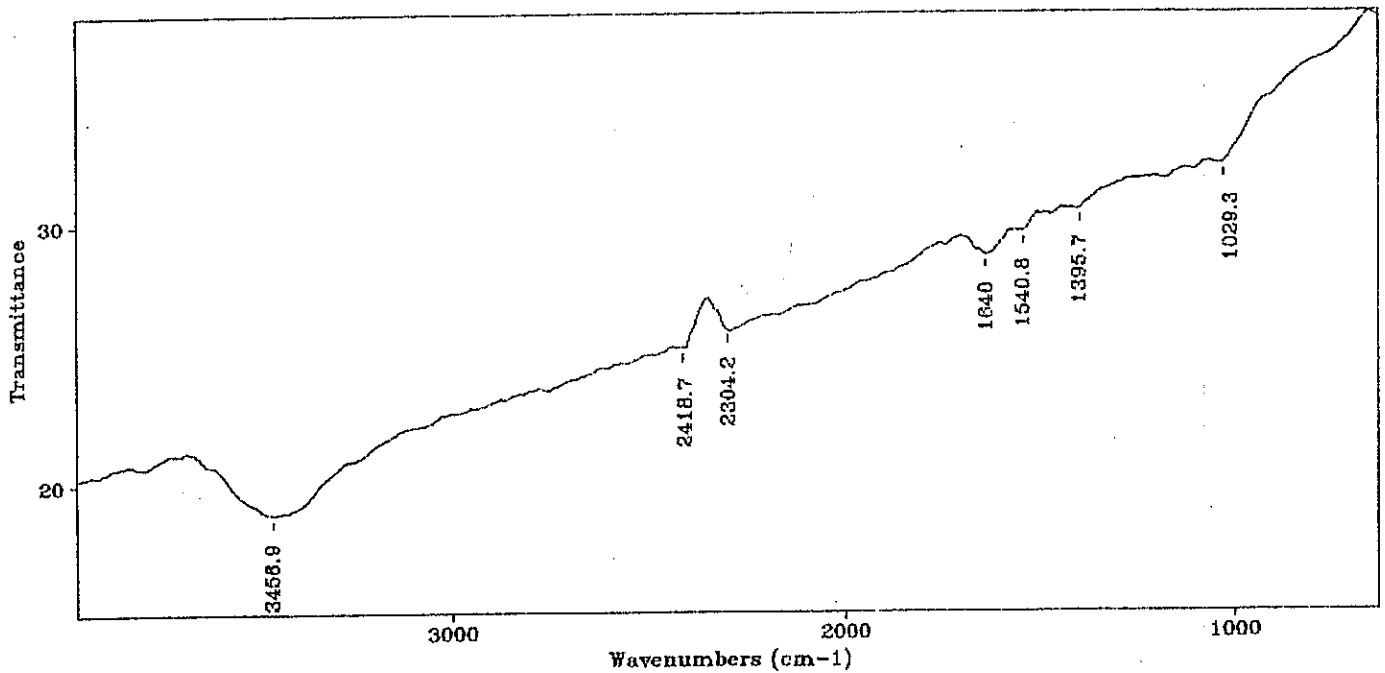
Grafik 2. 5. Spektra Infra Merah Karbon Aktif MKRg Setelah Proses Adsorpsi



Grafik 2. 6. Spektra Infra Merah Karbon Aktif INDb Sebelum Proses Adsorpsi



Grafik 2. 7. Spektra Infra Merah Karbon Aktif INDb Setelah Proses Adsorpsi



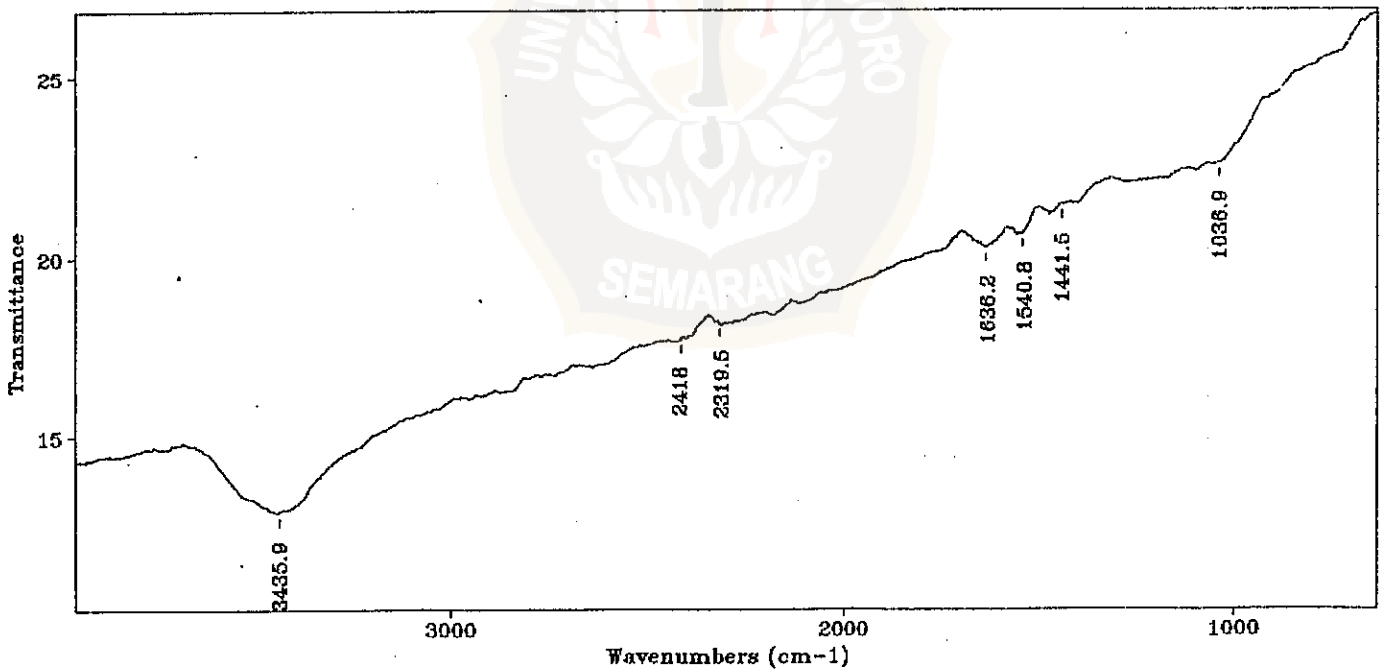
MKRB1

Res= 8 cm⁻¹

06/19/97 13:52

Buck Scientific Inc. M500

Grafik 2. 8. Spektra Infra Merah Karbon Aktif MKRb Sebelum Proses Adsorpsi



MKRB2

Res= 8 cm⁻¹

06/19/97 13:25

Buck Scientific Inc. M500

Grafik 2. 9. Spektra Infra Merah Karbon Aktif MKRb Setelah Proses Adsorpsi