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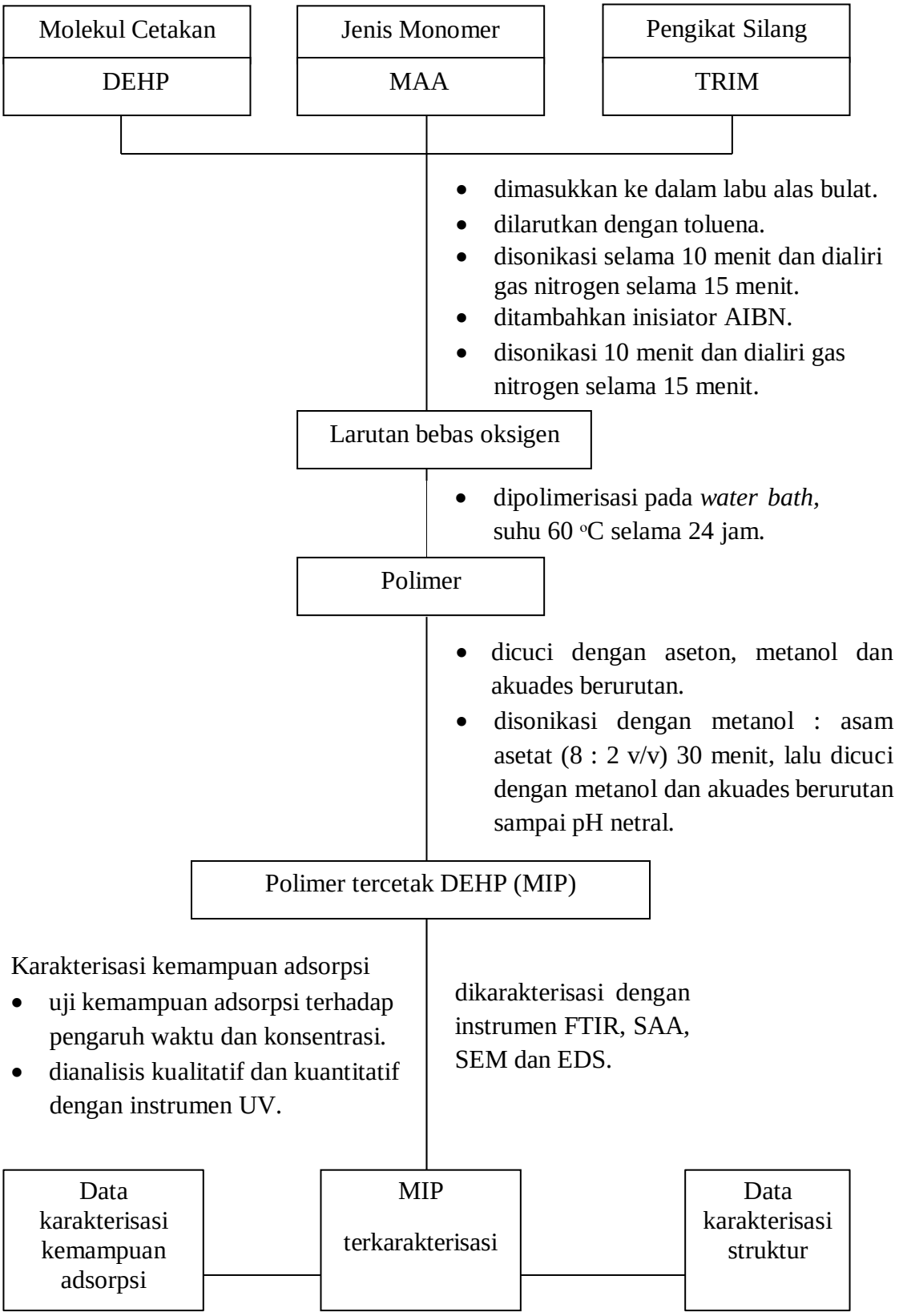
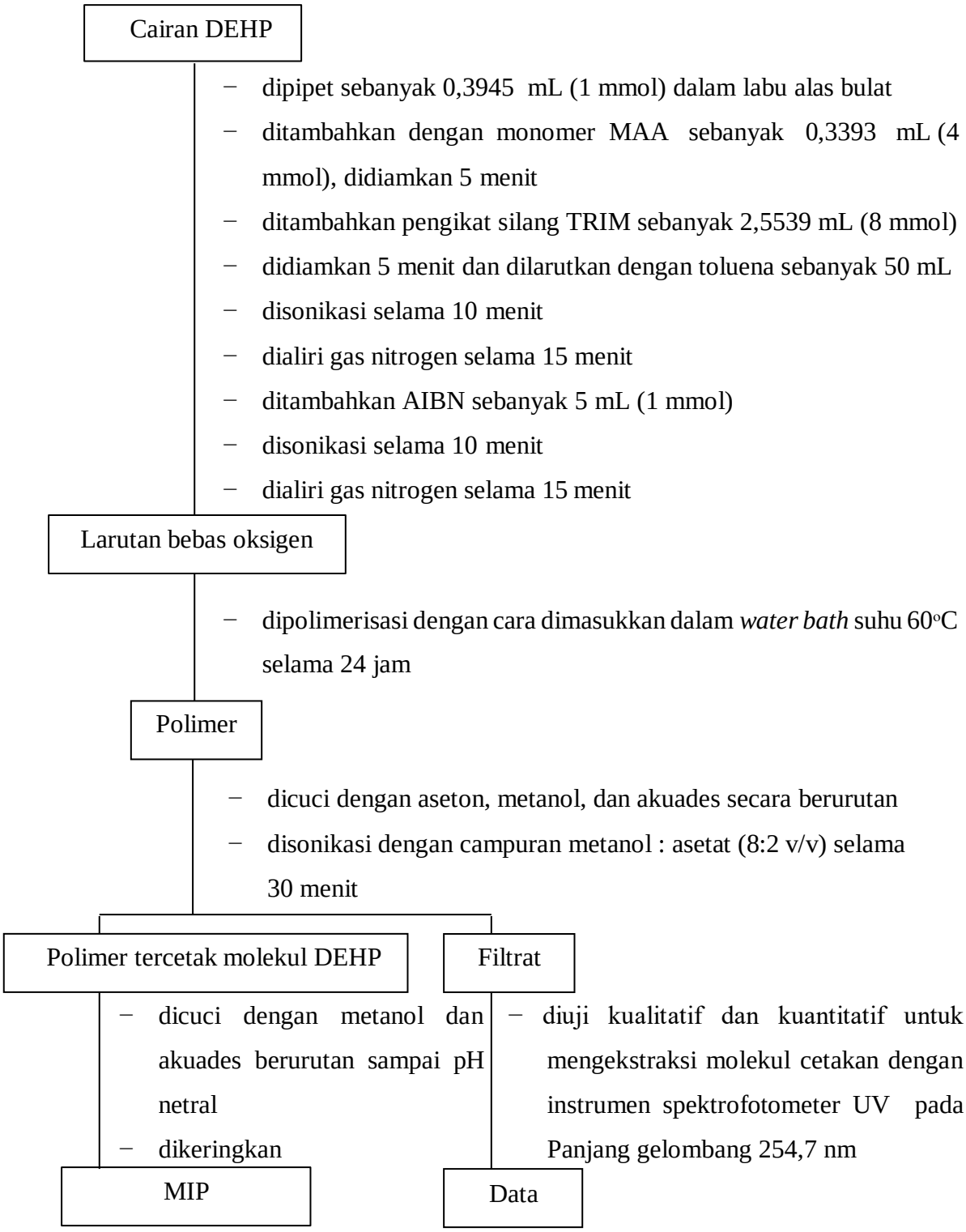
Lampiran 1. Skema Sintesis Polimer Bercetakan Molekul DEHP menggunakan Metode Polimerisasi Presipitasi



Catatan: Sintesis NIP dibuat dengan metode yang sama dengan MIP, tapi tanpa DEHP dan proses ekstraksi.

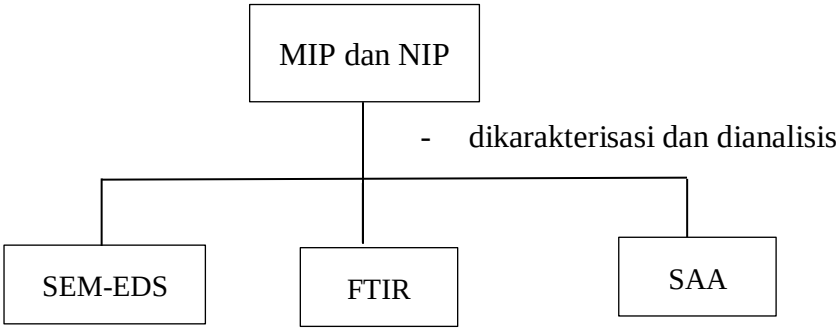
Lampiran 2. Bagan Alir Prosedur Penelitian

1. Sintesis MIP dan NIP

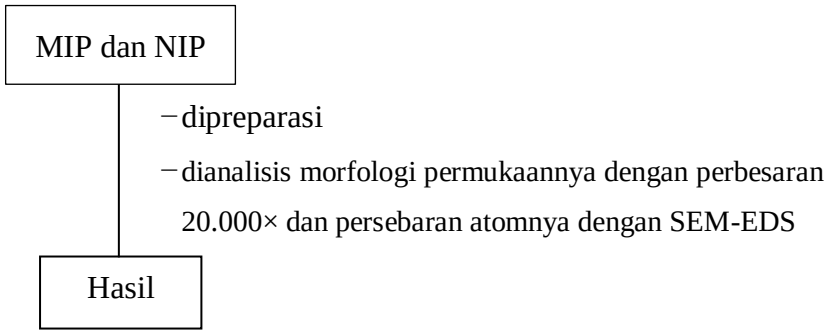


Catatan : Sintesis NIP dibuat dengan metode yang sama, tetapi tanpa menggunakan molekul cetakan (DEHP).

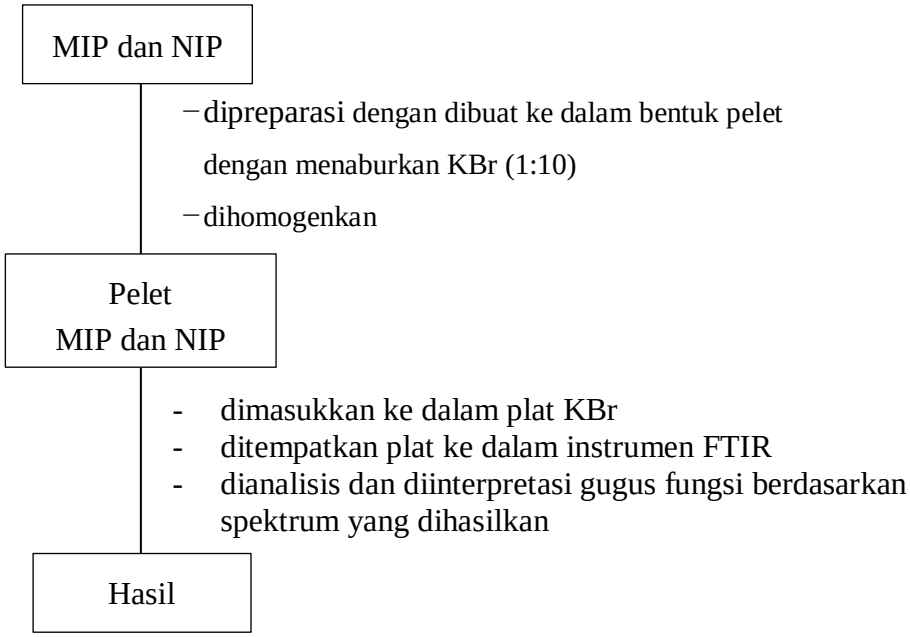
2. Karakterisasi MIP_DEHP_MAA dan NIP_MAA



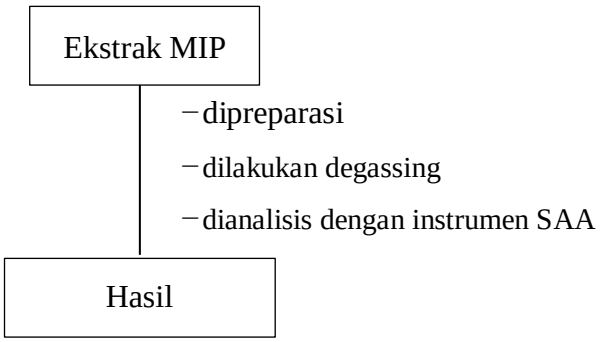
3. Karakterisasi MIP dan NIP menggunakan SEM-EDS



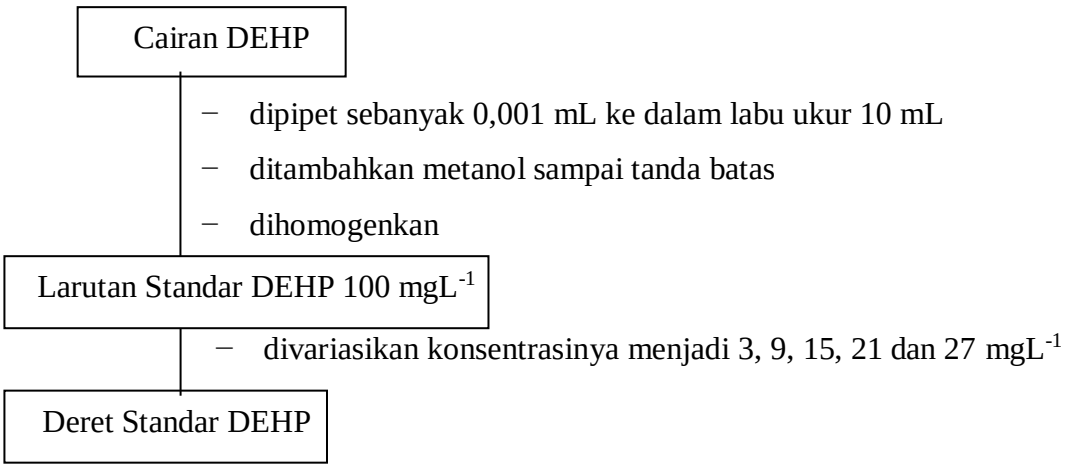
4. Karakterisasi MIP dan NIP menggunakan FTIR



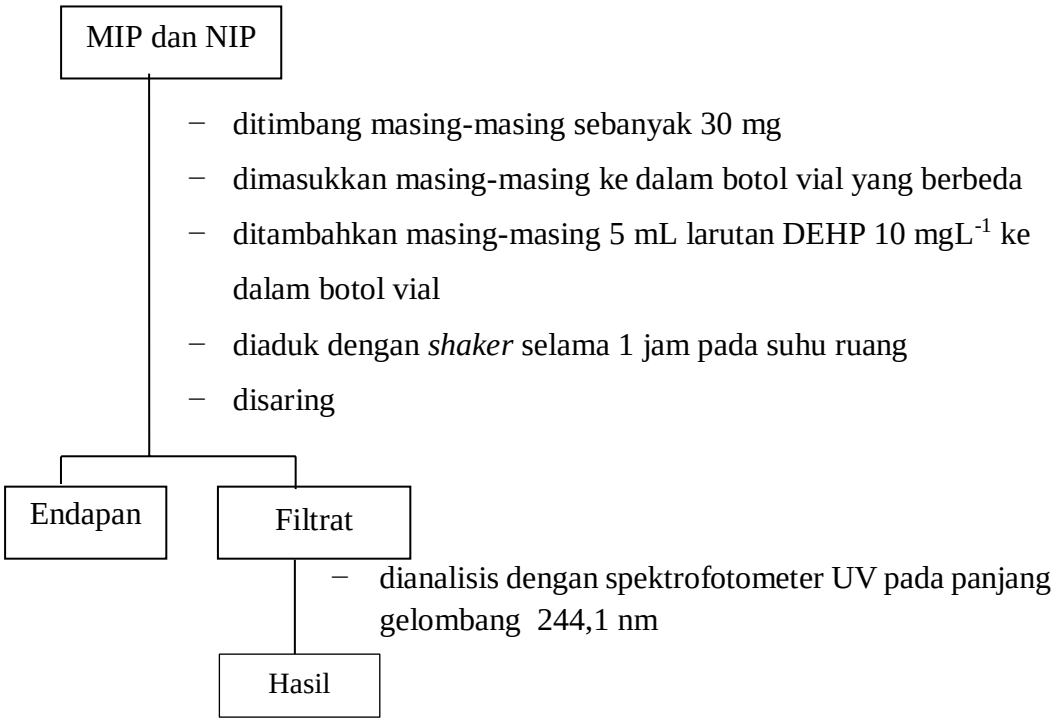
5. Karakterisasi MIP Menggunakan SAA



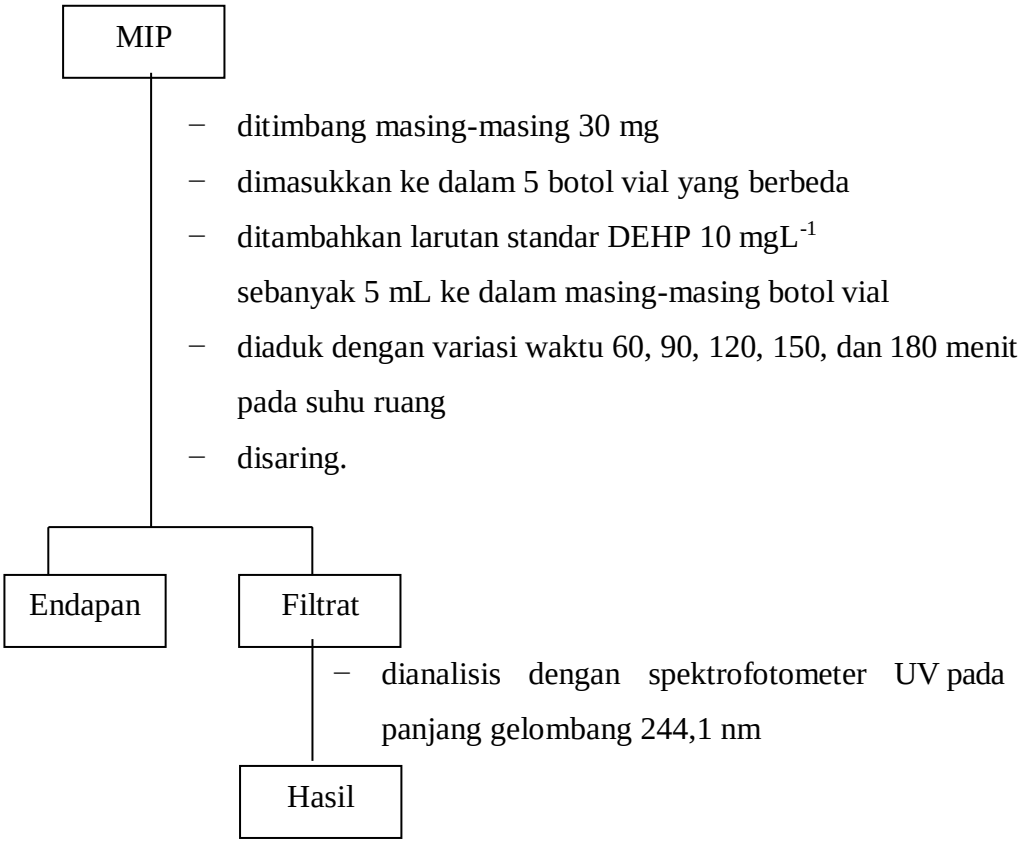
6. Pembuatan Larutan Standar DEHP 100 mgL^{-1}



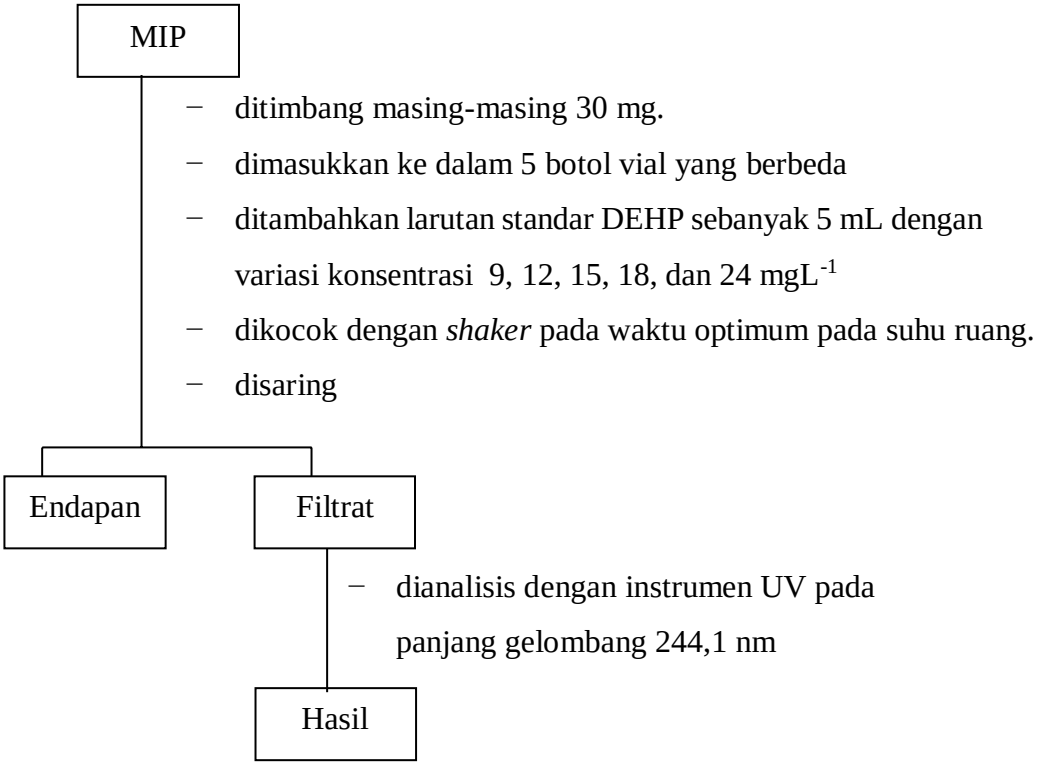
7. Uji Kemampuan Adsorpsi MIP dan NIP



8. Pengaruh Waktu terhadap Kemampuan Adsorpsi DEHP oleh MIP



9. Pengaruh Konsentrasi terhadap Kemampuan Adsorpsi MIP

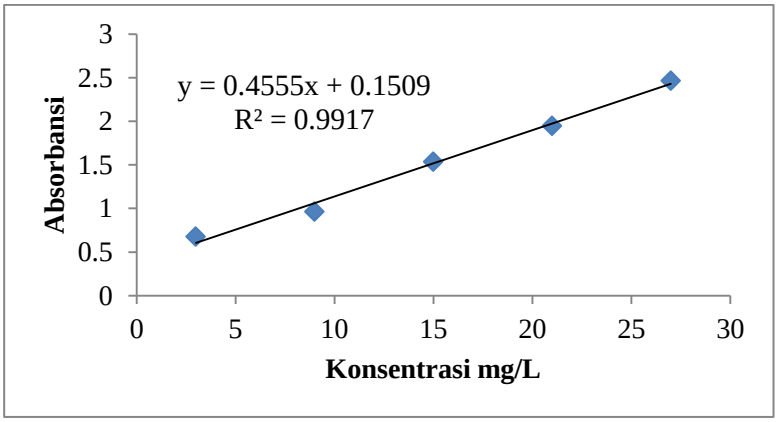


Lampiran 3. Data Spektrofotometer UV-Vis

1. Data absorbansi larutan standar DEHP

No.	Sampel	Konsentrasi (mg/L)	Absorbansi
1	DEHP 1	3	0,678
2	DEHP 2	9	0,962
3	DEHP 3	15	1,537
4	DEHP 4	21	1,947
5	DEHP 5	27	2,463

2. Kurva hubungan antara absorbansi vs konsentrasi larutan standar DEHP



3. Data absorbansi larutan DEHP setelah adsorpsi oleh MIP dan NIP

No.	Sampel	Absorbansi	q_e (mg/g)	Δq_e (mg/g)
1	Adsorpsi DEHP oleh MIP	2,651	0,7518	0,510
2	Adsorpsi DEHP oleh NIP	1,256	1,2623	

4. Data absorbansi larutan DEHP setelah adsorpsi oleh MIP terhadap pengaruh waktu

No.	Sampel	Waktu (menit)	Absorbansi
1	DEHP	60	2,953
2	DEHP	90	2,836
3	DEHP	120	2,679
4	DEHP	150	2,623
5	DEHP	180	2,679

5. Data penentuan kinetika adsorpsi orde satu semu dan orde dua semu

No.	Waktu	C_e (mgL^{-1})	q_t (mg/g)	q_e-q_t	Log (q_e-q_t)	t/q_t
1.	0	0	0	0,4654	-0,3321	0
2.	60	6,1517	0,6413	0,1207	-0,9181	93,54784
3.	90	5,8948	0,6841	0,0779	-1,1083	131,5418
4.	120	5,5501	0,7416	0,0205	-1,6884	161,8037
5.	150	5,4272	**0,7621**	**0**	0	196,8169
6.	180	5,5501	0,7416	0,0205	-1,6884	242,7056

Catatan:

q_t adalah q_e pada waktu t

q_e adalah q_t pada waktu optimum

6. Data absorbansi adsorpsi DEHP oleh MIP terhadap pengaruh konsentrasi

No.	Sampel	Konsentrasi (mg/L)	Absorbansi
1	DEHP	9	0,414
2	DEHP	12	0,585
3	DEHP	15	0,603
4	DEHP	18	0,687
5	DEHP	24	0,903

7. Data persamaan isotermal adsorpsi Langmuir dan Freundlich

No.	Sampel	Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	Log C_e	Log q_e	$1/C_e$	$1/q_e$
1	MIP_DEHP	9	0,5776	1,4037	-0,2384	0,1473	1,7313	0,7124
2	MIP_DEHP	12	0,9530	1,8412	-0,0209	0,2651	1,0493	0,5431
3	MIP_DEHP	15	0,9925	2,3346	-0,0033	0,3682	1,0075	0,4283
4	MIP_DEHP	18	1,1769	2,8038	0,0708	0,4478	0,8497	0,3567
5	MIP_DEHP	24	1,6511	3,7248	0,2178	0,5711	0,6056	0,2685

8. Data kurva non linear untuk persamaan isotermal adsorpsi Langmuir

No.	Co	1/qm	1/Ce	1/qmKL	1/Ce x 1/qmKL	1/qe	qe
1	9	0,0458	1,731	0,3967	0,687	0,733	1,365
2	12	0,0458	1,049	0,3967	0,416	0,462	2,164
3	15	0,0458	1,008	0,3967	0,400	0,445	2,245
4	18	0,0458	0,850	0,3967	0,337	0,383	2,612
5	24	0,0458	0,606	0,3967	0,240	0,286	3,496

9. Data kurva non linear untuk persamaan isotermal adsorpsi Langmuir

No.	Co	Log Kf	1/n	Log Ce	1/n x Log Ce	Log qe	qe
1	9	0,3549	0,9569	-0,238	-0,228	0,127	1,339
2	12	0,3549	0,9569	-0,021	-0,020	0,335	2,162
3	15	0,3549	0,9569	-0,003	-0,003	0,352	2,248
4	18	0,3549	0,9569	0,071	0,068	0,423	2,646
5	24	0,3549	0,9569	0,218	0,208	0,563	3,658

Lampiran 4. Perhitungan

1. Konsentrasi Larutan DEHP

a. Massa DEHP dalam 1000 mL

$m = \rho \times V$

$= 0{,}984 \text{ g/mL} \times 1000 \text{ mL}$

$= 984 \text{ g}$

$\text{massa DEHP } 99{,}5\% = \frac{99{,}5}{100} \times 984 \text{ g}$

$= 979{,}08 \text{ g}$

b. Konsentrasi DEHP dalam 1 L

$M = \frac{\text{massa}}{Mr} \times \frac{1}{V}$

$= \frac{979{,}08 \text{ g}}{390{,}556 \text{ g/mol}} \times \frac{1}{1 \text{ L}}$

$= 2{,}5068 \text{ mol/L}$

$\text{ppm (m/v)} = M \times Mr$

$= 2{,}5068 \text{ mol/L} \times 390{,}556 \text{ g/mol} \times 1000 \text{ mg/g}$

$= 979046{,}0315 \text{ mg/L}$

2. Pembuatan Larutan Induk DEHP 100 mg/L dalam 10 mL

$V_1 \times C_1 = V_2 \times C_2$

$V_1 \times 979046{,}0315 \text{ mg/L} = 100 \text{ mg/L} \times 10 \text{ mL}$

$V_1 = 0{,}001 \text{ mL}$

3. Pembuatan Larutan Standar DEHP

Konsentrasi 3 mg/L

$V_1 \times C_1 = V_2 \times C_2$

$V_1 \times 100 \text{ mg/L} = 5 \text{ mL} \times 3 \text{ mg/L}$

$V_1 = 0{,}15 \text{ mL}$

Konsentrasi 9 mg/L

$V_1 \times C_1 = V_2 \times C_2$

$V_1 \times 100 \text{ mg/L} = 5 \text{ mL} \times 9 \text{ mg/L}$

$V_1 = 0{,}45 \text{ mL}$

Konsentrasi 15 mg/L

$$V_1 \times C_1 = V_2 \times C_2$$

$$V_1 \times 100 \text{ mg/L} = 5 \text{ mL} \times 15 \text{ mg/L}$$

$$V_1 = 0{,}75 \text{ mL}$$

Konsentrasi 21 mg/L

$$V_1 \times C_1 = V_2 \times C_2$$

$$V_1 \times 100 \text{ mg/L} = 5 \text{ mL} \times 21 \text{ mg/L}$$

$$V_1 = 1{,}05 \text{ mL}$$

Konsentrasi 27 mg/L

$$V_1 \times C_1 = V_2 \times C_2$$

$$V_1 \times 100 \text{ mg/L} = 5 \text{ mL} \times 27 \text{ mg/L}$$

$$V_1 = 1{,}35 \text{ mL}$$

4. Pembuatan Larutan Standar DEHP 10 mg/L dalam 100 mL

$$V_1 \times C_1 = V_2 \times C_2$$

$$V_1 \times 100 \text{ mg/L} = 100 \text{ mL} \times 10 \text{ mg/L}$$

$$V_1 = 10 \text{ mL}$$

5. Nilai konsentrasi adsorpsi DEHP oleh MIP dan NIP

$y = 0{,}4555x + 0{,}1509$

a. Adsorpsi DEHP oleh MIP

$y = 1{,}256$

$y = 0{,}4555x + 0{,}1509$

$1{,}256 = 0{,}4555x + 0{,}1509$

$$x = \frac{1{,}256 - 0{,}1509}{0{,}4555}$$

$x = 2{,}4261$ mg/L

b. Adsorpsi DEHP oleh NIP

$y = 2{,}651$

$y = 0{,}4555x + 0{,}1509$

$2{,}651 = 0{,}4555x + 0{,}1509$

$$x = \frac{2,651 - 0,1509}{0,4555}$$

$$x = 5,4887 \text{ mg/L}$$

6. Nilai Kemampuan Adsorpsi DEHP oleh MIP dan NIP

$$q_e = \frac{(C_o - C_e)\, V}{W}$$

Diketahui: C_o = 10 mg/L W = 0,03 g

V = 0,005 L C_e = Konsentrasi setelahadsorpsi

a. Kemampuan Adsorpsi DEHP oleh MIP

$$q_e = \frac{(10 - 2,426)\, 0,005}{0,03}$$

$$q_e = 1,2623 \text{ mg/g}$$

b. Kemampuan Adsorpsi DEHP oleh NIP

$$q_e = \frac{(10 - 5,488)\, 0,005}{0,03}$$

$$q_e = 0,7518 \text{ mg/g}$$

7. Nilai konsentrasi adsorpsi dan kemampuan adsorpsi DEHP oleh MIP terhadap pengaruh waktu

Waktu (menit)	y (absorbansi)	x (Konsentrasi) (mg/L)	q_e (mg/g)
60	2,953	6,1517	0,6414
90	2,836	5,8948	0,6842
120	2,679	5,5502	0,7416
150	2,623	5,4272	**0,7621**
180	2,679	5,5502	0,7416

Contoh perhitungan konsentrasi adsorpsi dan kemampuan adsorpsi DEHP oleh MIP terhadap pengaruh waktu:

a. Konsentrasi Adsorpsi DEHP oleh MIP 60 menit

y = 0,4555x + 0,1509

y = 2,953

y = 0,4555x + 0,1509

2,953 = 0,4555x + 0,1509

$$x = \frac{2,953 - 0,1509}{0,4555}$$

x = 6,1517 mg/L

b. Kemampuan Adsorpsi DEHP oleh MIP 60 menit

$$q_e = \frac{(C_o - C_e)\ V}{W}$$

Diketahui: C_o= 10 mg/L W = 0,03 g

C_e= Konsentrasi setelah adsorpsiV = 0,005 L

$$q_e = \frac{(10 - 6,1517)\ 0,005}{0,03}$$

q_e = 0,6414 mg/g

8. Nilai konsentrasi adsorpsi dan kemampuan adsorpsi DEHP oleh MIP terhadap pengaruh konsentrasi

Konsenrasi awal (mg/L)	y (absorbansi)	x (konsentrasi) (mg/L)	q_e (mg/g)
9	0,414	0,5776	1,4037
12	0,585	0,9530	1,8412
15	0,603	0,9925	2,3346
18	0,687	1,1769	2,8038
24	0,903	1,6511	3,7248

Contoh perhitungan konsentrasi adsorpsi dan kemampuan adsorpsi DEHP oleh MIP terhadap pengaruh konsentrasi:

a. Konsentrasi Adsorpsi DEHP oleh MIP 9 mg/L

$y = 0,4555x + 0,1509$

$y = 0,414$

$y = 0,4555x + 0,1509$

$0,414 = 0,4555x + 0,1509$

$$x = \frac{0,414 - 0,1509}{0,4555}$$

$x = 0,5776$ mg/L

b. Kemampuan Adsorpsi DEHP oleh MIP 9 mg/L

$$q_e = \frac{(C_o - C_e)\, V}{W}$$

Diketahui: C_o = konsentrasi awal W = 0,03 g

C_e = Konsentrasi setelah adsorpsi V = 0,005 L

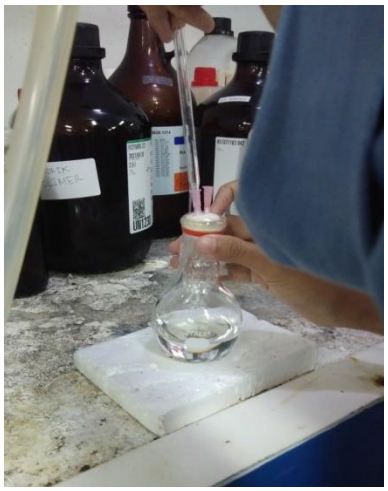
$$q_e = \frac{(9 - 0,5776)\, 0,005}{0,03}$$

$q_e = 1,4037$ mg/g

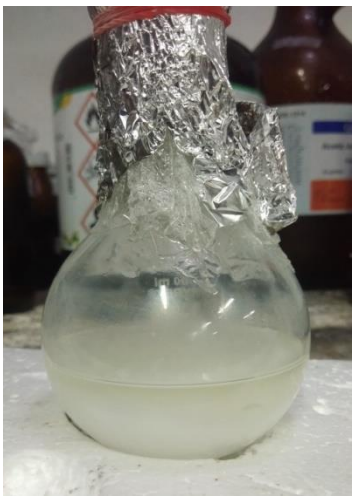
Lampiran 5. Foto Hasil Penelitian

Proses pencampuran bahan dan prapolimerisasi

Sonikasi



Pengaliran gas nitrogen untuk menghilangkan gas oksigen



Polimer terbentuk berwarna putih

Pencucian polimer dengan akuades

Pengeringan polimer

Proses pencucian polimer dengan aseton, metanol, dan akuades agar bersih dari pengotor

Hasil ekstraksi polimer

Pengocokan dengan alat *shaker*untuk pengaruh waktu dan konsentrasi terhadap adsorpsi DEHP

Lampiran 6. Karakterisasi EDS

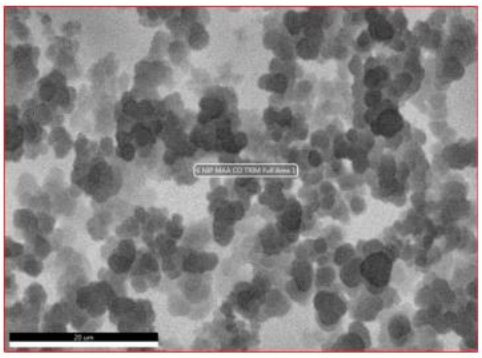
1. NIP_MAA-co-TRIM

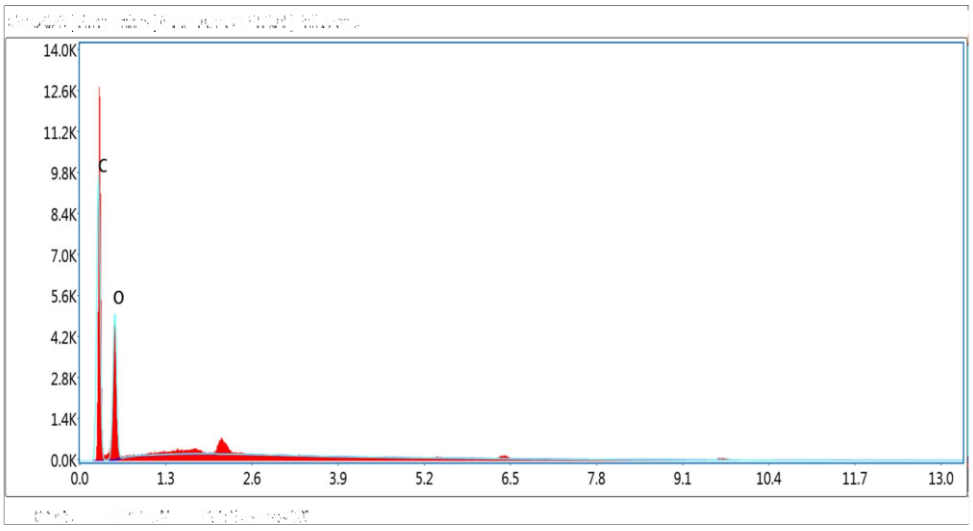
EDAX APEX

03042023

Author: Teknik Mesin ITS
Creation: 04/30/2023 3:33:41 PM
Sample Name: Firna Unhas

6 NIP MAA CO TRIM





Element	Weight %	Atomic	%Net Int.	Error%	Kratio	Z	A	F
C K	51.16	58.25	628.92	5.45	0.3068	1.0216	0.5872	1.0000
O K	48.84	41.75	355.64	9.65	0.0886	0.9761	0.1858	1.0000

2. MIP-DEHP-co-TRIM$_{(BE)}$

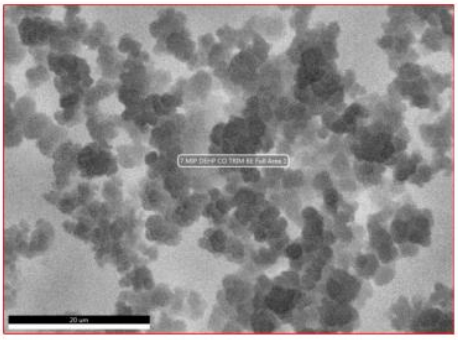
EDAX APEX

03042023

Author: Teknik Mesin ITS
Creation: 04/30/2023 3:36:45 PM

Sample Name: Firna Unhas

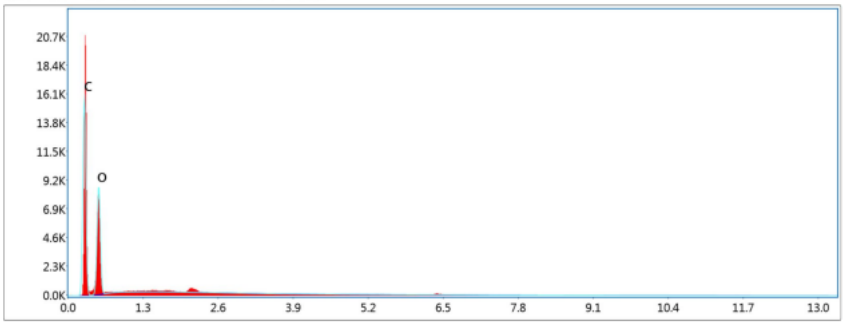
7 MIP DEHP CO TRIM BE



EDAX APEX

Full Area 1

kV:20 Mag: 2000 Takeoff: 30 Live Time(s): 98.2 Amp Time(μs): 3.84 Resolution:(eV) 133.6



Smart Quant Results

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	A	F
C K	50.30	57.41	1023.69	5.40	0.2994	1.0220	0.5827	1.0000
O K	49.70	42.59	613.92	9.47	0.0917	0.9765	0.1889	1.0000

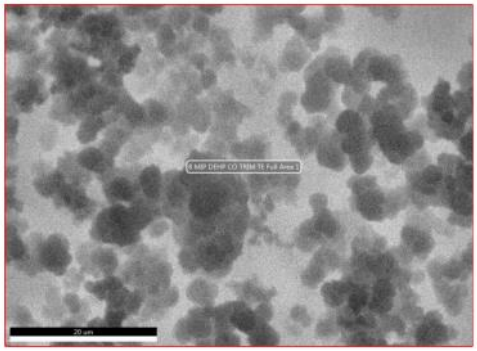
3. MIP-DEHP-co-TRIM$_{(TE)}$

03042023

Author: Teknik Mesin ITS
Creation: 04/30/2023 3:39:37 PM

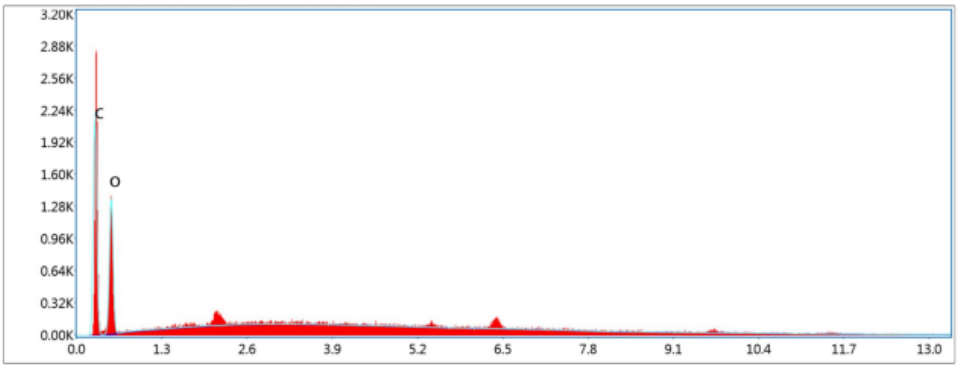
Sample Name: Firna Unhas

8 MIP DEHP CO TRIM TE



Full Area 1

kV:20 Mag: 2000 Takeoff: 30 Live Time(s): 97.1 Amp Time(µs): 3.84 Resolution:(eV) 133.6

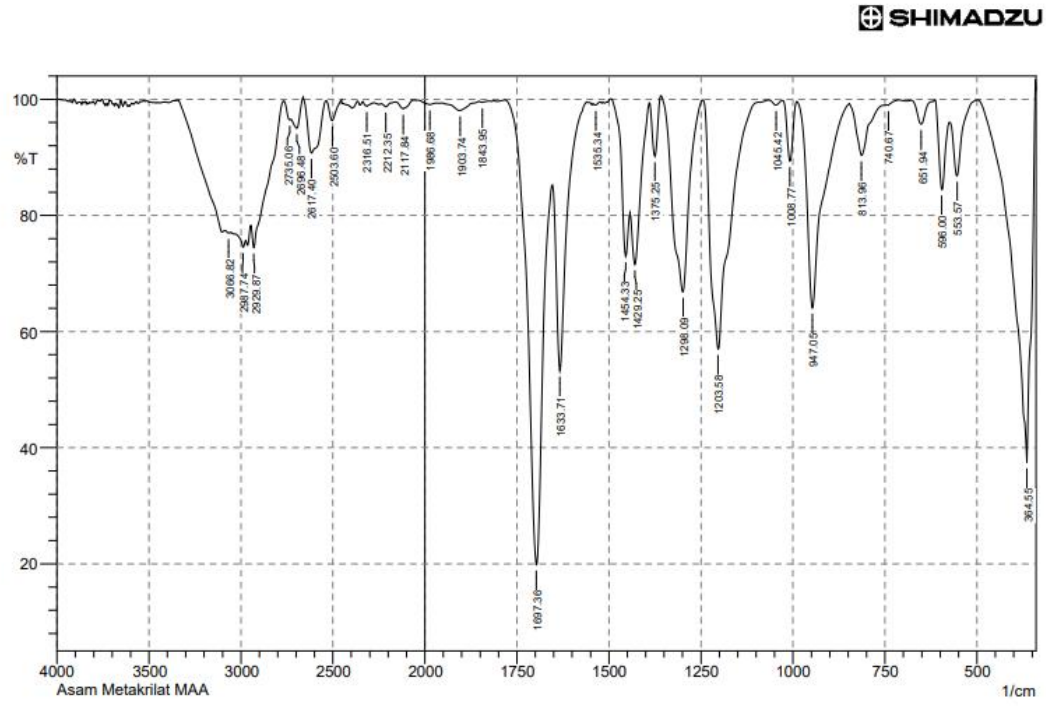


Smart Quant Results

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	A	F
C K	48.46	55.60	143.15	6.11	0.2845	1.0228	0.5738	1.0000
O K	51.54	44.40	97.10	10.12	0.0985	0.9773	0.1955	1.0000

Lampiran 7. Karakterisasi FTIR

1. Spektrum Monomer MAA

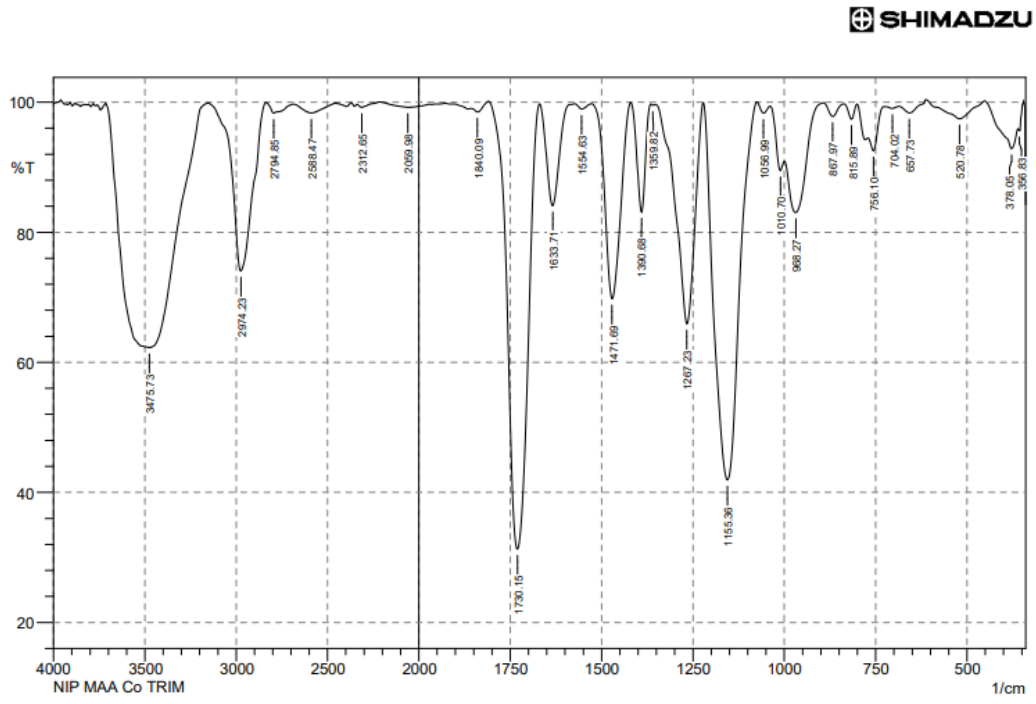


No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	364.55	37.47	65.39	493.78	341.4	19.55	20.61
2	553.57	86.81	10.26	572.86	503.42	1.65	1.04
3	596	84.46	13.71	613.36	574.79	1.54	1.18
4	651.94	95.73	4.15	678.94	613.36	0.48	0.44
5	740.67	98.97	0.17	746.45	711.73	0.08	-0.01
6	813.96	90.35	8.82	846.75	746.45	1.81	1.42
7	947.05	64.13	35.35	989.48	848.68	8.86	8.48
8	1008.77	89.38	10.33	1028.06	989.48	0.85	0.81
9	1045.42	99.01	0.82	1064.71	1028.06	0.09	0.06
10	1203.58	57	42.76	1244.09	1093.64	13.15	12.94
11	1298.09	66.84	33.37	1357.89	1246.02	8.01	8.12
12	1375.25	90.18	9.8	1390.68	1359.82	0.69	0.69
13	1429.25	71.59	12.75	1440.83	1390.68	3.85	1.43
14	1454.33	72.95	11.86	1494.83	1442.75	3.07	0.86
15	1535.34	99.02	0.33	1543.05	1523.76	0.07	0.01
16	1633.71	53.25	34.96	1653	1560.41	8.45	5.26
17	1697.36	19.89	70.19	1782.23	1654.92	25.87	21.37
18	1843.95	99.48	0.2	1853.59	1828.52	0.05	0.01
19	1903.74	98.08	1.43	1951.96	1853.59	0.48	0.27
20	1986.68	99.1	0.4	2031.04	1965.46	0.17	0.05
21	2117.84	98.38	1.28	2160.27	2054.19	0.41	0.28
22	2212.35	98.73	0.59	2237.43	2160.27	0.28	0.07
23	2316.51	98.83	0.71	2337.72	2276	0.23	0.1
24	2503.6	96.35	3.45	2536.39	2453.45	0.66	0.6
25	2617.4	90.76	9.42	2661.77	2536.39	2.98	3.02
26	2696.48	95.01	3.41	2729.27	2661.77	1	0.54
27	2735.06	96.46	0.54	2767.85	2729.27	0.37	0.05
28	2929.87	74.46	5.69	2945.3	2767.85	11.9	2.51
29	2987.74	74.55	1.3	3032.1	2976.16	6.73	0.13
30	3066.82	76.97	0.19	3086.11	3059.1	3.05	0.02

Comment;
Asam Metakrilat MAA

Date/Time; 3/27/2023 1:02:39 PM
No. of Scans;
Resolution;

2. Spektrum NIP_MAA-co-TRIM

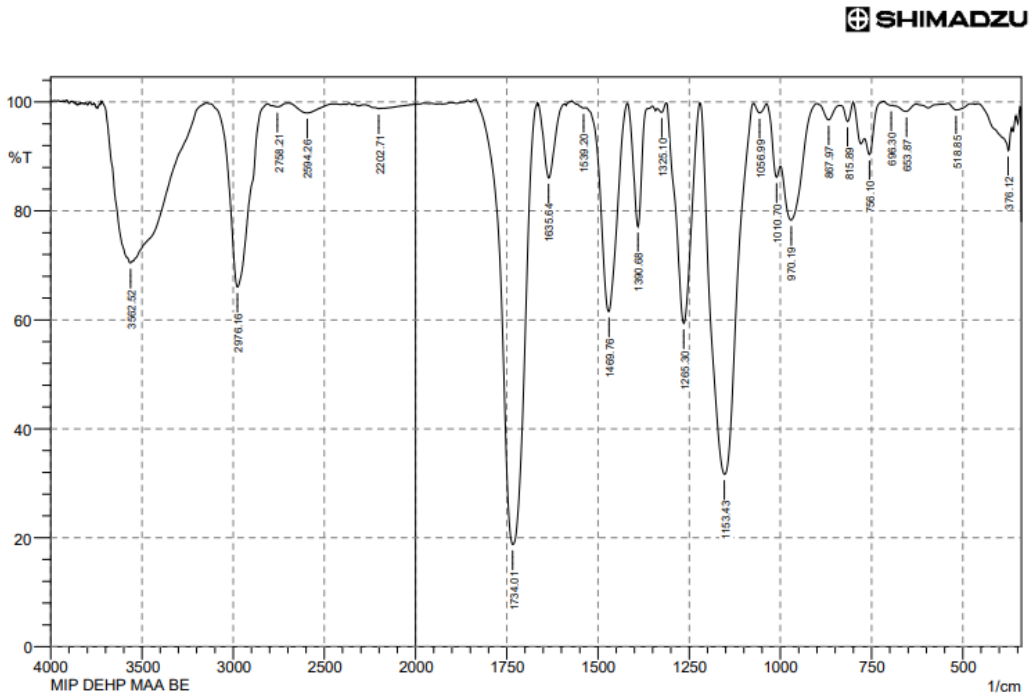


No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	356.83	95.634	1.316	360.69	345.26	0.171	0.035
2	378.05	92.843	3.681	451.34	362.62	1.589	0.772
3	520.78	97.444	2.823	611.43	451.34	0.845	1.038
4	657.73	98.342	1.401	686.66	611.43	0.288	0.242
5	704.02	99.042	0.307	725.23	686.66	0.134	0.024
6	756.1	92.534	3.579	771.53	725.23	0.901	0.266
7	815.89	97.365	2.373	837.11	800.46	0.216	0.175
8	867.97	97.797	2.037	894.97	837.11	0.274	0.231
9	968.27	83.023	10.555	999.13	894.97	4.385	2.315
10	1010.7	89.487	3.639	1037.7	1001.06	1.12	0.293
11	1056.99	98.309	1.406	1074.35	1039.63	0.16	0.117
12	1155.36	41.918	58.035	1220.94	1076.28	24.655	24.63
13	1267.23	65.938	33.859	1352.1	1222.87	9.526	9.391
14	1359.82	99.49	0.192	1365.6	1352.1	0.024	0.005
15	1390.68	83.108	16.721	1419.61	1365.6	1.926	1.886
16	1471.69	69.783	30.051	1527.62	1421.54	6.923	6.845
17	1554.63	98.942	0.815	1571.99	1527.62	0.128	0.081
18	1633.71	84.066	15.618	1668.43	1587.42	2.768	2.654
19	1730.15	31.265	68.64	1809.23	1670.35	25.919	25.878
20	1840.09	98.482	0.953	1857.45	1809.23	0.186	0.099
21	2059.98	99.224	0.073	2218.14	2046.47	0.33	0.062
22	2312.65	99.216	0.527	2339.65	2218.14	0.212	0.135
23	2588.47	98.351	1.41	2682.98	2459.24	0.969	0.75
24	2794.85	98.322	1.565	2835.36	2684.91	0.634	0.52
25	2974.23	74.059	25.858	3151.69	2837.29	15.187	15.066
26	3475.73	62.277	1.804	3491.16	3153.61	34.555	2.786

Comment;
NIP MAA Co TRIM

Date/Time; 3/27/2023 12:50:24 PM
No. of Scans;
Resolution;

3. Spektrum MIP_DEHP_MAA-co-TRIM(BE)



No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	376.12	91.062	4.279	459.06	368.4	1.799	0.705
2	518.85	98.543	1.191	540.07	480.28	0.249	0.176
3	653.87	98.276	1.2	682.8	626.87	0.277	0.148
4	696.3	99.372	0.071	717.52	694.37	0.034	0.01
5	756.1	90.326	4.816	769.6	719.45	1.002	0.36
6	815.89	96.433	3.262	833.25	800.46	0.281	0.235
7	867.97	96.726	2.713	893.04	839.03	0.44	0.306
8	970.19	78.326	13.23	999.13	900.76	5.755	3.082
9	1010.7	86.174	4.999	1037.7	1001.06	1.434	0.382
10	1056.99	98.011	1.688	1074.35	1037.7	0.196	0.148
11	1153.43	31.63	68.094	1219.01	1074.35	32.863	32.691
12	1265.3	59.357	40.455	1311.59	1220.94	9.6	9.526
13	1325.1	98.113	1.196	1336.67	1313.52	0.137	0.067
14	1390.68	77.108	22.377	1417.68	1352.1	2.723	2.563
15	1469.76	61.545	37.848	1531.48	1419.61	9.53	9.218
16	1539.2	98.907	0.127	1546.91	1535.34	0.052	0.005
17	1635.64	86.064	13.656	1666.5	1593.2	2.129	2.035
18	1734.01	18.769	81.081	1834.3	1668.43	39.687	39.655
19	2202.71	98.782	0.155	2223.92	2173.78	0.248	0.013
20	2594.26	97.99	1.753	2696.48	2439.95	1.237	0.931
21	2758.21	99.12	0.388	2791	2696.48	0.245	0.071
22	2976.16	66.033	33.713	3145.9	2812.21	20.352	19.986
23	3562.52	70.474	0.519	3579.88	3554.81	3.77	0.055

Comment;

MIP DEHP MAA BE

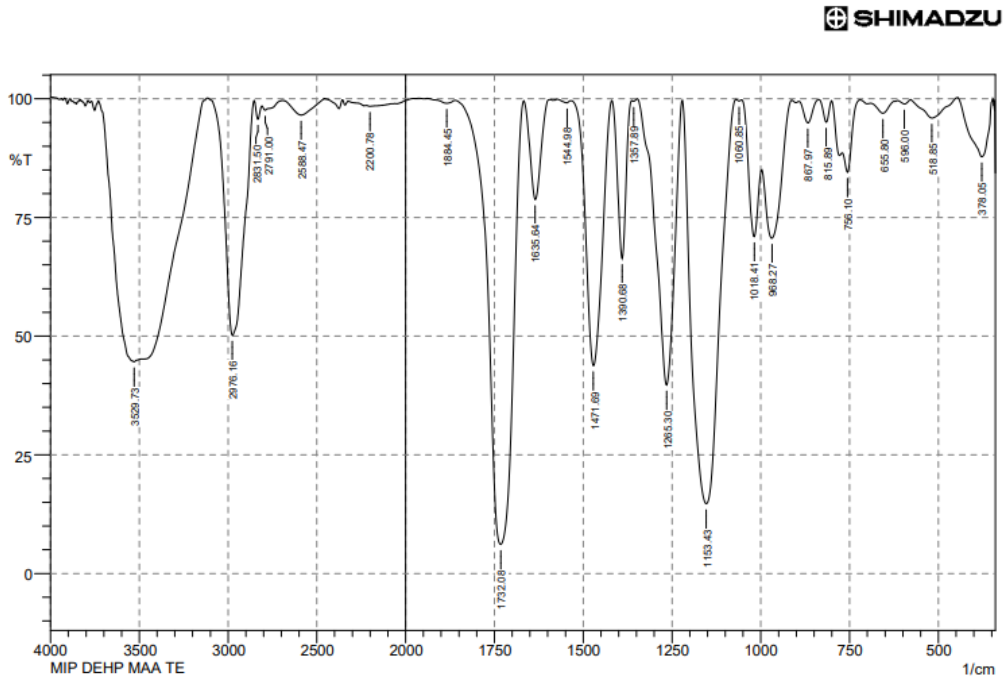
Date/Time; 3/27/2023 12:57:45 PM

No. of Scans;

Resolution;

Apodization;

4. Spektrum MIP_DEHP_MAA-co-TRIM(TE)



No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	378.05	87.756	12.345	445.56	347.19	3.14	3.203
2	518.85	95.932	4.022	576.72	447.49	1.211	1.199
3	596	98.914	0.817	615.29	578.64	0.115	0.071
4	655.8	96.947	2.314	690.52	623.01	0.542	0.323
5	756.1	84.538	7.135	769.6	721.38	1.762	0.591
6	815.89	95.046	4.633	837.11	800.46	0.393	0.345
7	867.97	94.906	4.722	893.04	837.11	0.628	0.542
8	968.27	70.619	19.53	997.2	914.26	7.551	4.644
9	1018.41	70.941	19.278	1053.13	999.13	4.595	2.597
10	1060.85	99.541	0.257	1070.49	1053.13	0.024	0.009
11	1153.43	14.709	85.044	1220.94	1070.49	54.892	54.736
12	1265.3	39.701	59.895	1346.31	1222.87	19.682	19.507
13	1357.89	99.463	0.302	1363.67	1348.24	0.024	0.011
14	1390.68	66.346	33.209	1417.68	1363.67	4.227	4.123
15	1471.69	43.774	55.832	1531.48	1419.61	16.091	15.899
16	1544.98	99.152	0.515	1573.91	1535.34	0.088	0.046
17	1635.64	78.779	20.894	1666.5	1595.13	3.337	3.242
18	1732.08	6.124	93.413	1859.38	1668.43	64.339	63.978
19	1884.45	99.049	0.74	1938.46	1861.31	0.16	0.116
20	2200.78	98.414	0.229	2222	2069.62	0.911	0.098
21	2588.47	96.57	3.218	2686.84	2459.24	1.915	1.736
22	2791	97.603	1.035	2808.36	2694.56	0.763	0.283
23	2831.5	95.677	3.385	2852.72	2808.36	0.519	0.332
24	2976.16	50.186	49.659	3115.04	2854.65	32.036	31.879
25	3529.73	44.596	8.985	3730.33	3493.09	51.342	10.739

Comment;
MIP DEHP MAA TE

Date/Time; 3/27/2023 12:43:02 PM
No. of Scans;
Resolution;
Apodization;

Lampiran 8. Karakterisasi SAA

micromeritics®

Started:	6/22/2023 1:58:12 PM	Analysis adsorptive:	N2
Completed:	6/22/2023 5:35:53 PM	Analysis bath temp.:	-195,850 °C
Report time:	6/23/2023 7:33:19 AM	Thermal correction:	No
Sample mass:	0,0414 g	Ambient free space:	11,1184 cm³ Measured
Analysis free space:	32,1601 cm³	Equilibration interval:	10 s
Low pressure dose:	None	Sample density:	1,000 g/cm³
Automatic degas:	No		

Summary Report

Surface Area

Single point surface area at P/Po = 0,299637710:	6,8503 m²/g
BET Surface Area:	6,9042 m²/g

Pore Volume

Single point adsorption total pore volume of pores less than 384,1792 nm diameter at P/Po = 0,995000000:	0,018022 cm³/g

Pore Size

Adsorption average pore diameter (4V/A by BET):	10,4411 nm
Desorption average pore diameter (4V/A by BET):	4,5417 nm
BJH Desorption average pore diameter (4V/A):	38,5760 nm

Started:	6/22/2023 1:58:12 PM	Analysis adsorptive:	N2
Completed:	6/22/2023 5:35:53 PM	Analysis bath temp.:	-195,850 °C
Report time:	6/23/2023 7:33:19 AM	Thermal correction:	No
Sample mass:	0,0414 g	Ambient free space:	11,1184 cm³ Measured
Analysis free space:	32,1601 cm³	Equilibration interval:	10 s
Low pressure dose:	None	Sample density:	1,000 g/cm³
Automatic degas:	No		

Isotherm Tabular Report

Relative Pressure (P/Po)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
			00:46	718.738525
0.062995495	45.278412	1.9048	00:56	718.756348
0.075256781	54.094330	1.9793	00:58	718.796753
0.090272293	64.888489	2.0445	01:00	718.808472
0.110046065	79.105415	2.1071	01:02	718.839111
0.135015225	97.056458	2.1486	01:04	718.855652
0.150032638	107.844200	2.1927	01:06	718.804932
0.174958316	125.758690	2.2156	01:08	718.792297
0.199863332	143.669006	2.2373	01:11	718.836243
0.224789161	161.594238	2.2446	01:13	718.870239
0.249734006	179.505035	2.2603	01:15	718.784912
0.274616213	197.421921	2.2581	01:17	718.901184
0.299637710	215.410965	2.2472	01:19	718.904724
0.340206542	244.564026	2.2118	01:21	718.869263
0.399631200	287.288879	2.1061	01:23	718.885010
0.440022454	316.319611	2.0551	01:25	718.871521
0.479917381	345.005646	2.0006	01:27	718.885498
0.519788189	373.689606	1.9528	01:29	718.926697
0.559694672	402.389587	1.9067	01:31	718.944824
0.599624199	431.103851	1.8564	01:33	718.956726
0.639488787	459.792633	1.8066	01:36	719.000305
0.679380629	488.475128	1.7930	01:38	719.000671
0.719301976	517.171448	1.7667	01:40	718.990723
0.759127378	545.820740	1.7887	01:42	719.010742
0.779076743	560.154419	1.8682	01:44	718.997742
0.818101422	588.222412	1.9587	01:46	719.009155
0.857753312	616.755310	2.1685	01:48	719.035767
0.888300274	638.724548	2.4745	01:50	719.041260
0.899510805	646.775391	2.6506	01:52	719.030151
0.909501273	653.976379	2.8387	01:54	719.049438

Started:	6/22/2023 1:58:12 PM	Analysis adsorptive:	N2
Completed:	6/22/2023 5:35:53 PM	Analysis bath temp.:	-195,850 °C
Report time:	6/23/2023 7:33:19 AM	Thermal correction:	No
Sample mass:	0,0414 g	Ambient free space:	11,1184 cm³ Measured
Analysis free space:	32,1601 cm³	Equilibration interval:	10 s
Low pressure dose:	None	Sample density:	1,000 g/cm³
Automatic degas:	No		

Isotherm Tabular Report

Relative Pressure (P/Po)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
0.919477552	661.142578	3.0653	01:56	719.041565
0.929434334	668.326538	3.3227	01:58	719.068054
0.939344853	675.496277	3.6413	02:00	719.114258
0.949265492	682.653931	4.0468	02:02	719.139099
0.954648458	686.580444	4.3208	02:05	719.197144
0.959673592	690.234863	4.6051	02:07	719.239197
0.964616581	693.788818	4.9896	02:09	719.237915
0.969657175	697.449951	5.4535	02:11	719.274780
0.974669799	701.021973	5.9229	02:13	719.240479
0.979468334	704.418274	6.5697	02:15	719.184326
0.982281081	706.481506	7.0893	02:17	719.225403
0.984867683	708.337769	7.6044	02:19	719.221252
0.987229489	710.035767	8.2027	02:21	719.220581
0.989684855	711.797729	8.9763	02:23	719.216553
0.991687096	713.264709	9.7705	02:25	719.243713
0.993663436	714.689636	10.7574	02:27	719.247192
0.994849683	715.541748	11.4836	02:30	719.246094
0.996764090	716.930481	13.6166	02:40	719.257935
0.980929472	705.546814	7.7751	02:44	719.263550
0.962531130	692.282715	5.7198	02:46	719.231506
0.941297246	677.025574	4.7356	02:48	719.247375
0.920636479	662.210999	4.2469	02:50	719.296936
0.900403908	647.666016	3.9672	02:52	719.306091
0.880240689	633.175598	3.7987	02:54	719.320984
0.860914220	619.277710	3.6917	02:56	719.325684
0.821777554	591.127808	3.5936	02:58	719.328247
0.761737452	547.946472	3.5749	03:01	719.337708
0.720661963	518.401611	3.6547	03:03	719.340881
0.680479467	489.515472	3.7480	03:05	719.368469
0.640394434	460.674561	3.8668	03:07	719.360657

Started:	6/22/2023 1:58:12 PM	Analysis adsorptive:	N2
Completed:	6/22/2023 5:35:53 PM	Analysis bath temp.:	-195,850 °C
Report time:	6/23/2023 7:33:19 AM	Thermal correction:	No
Sample mass:	0,0414 g	Ambient free space:	11,1184 cm³ Measured
Analysis free space:	32,1601 cm³	Equilibration interval:	10 s
Low pressure dose:	None	Sample density:	1,000 g/cm³
Automatic degas:	No		

Isotherm Tabular Report

Relative Pressure (P/Po)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
0.600234943	431.810425	4.0069	03:09	719.402344
0.560124605	402.976868	4.1543	03:11	719.441467
0.520008585	374.116089	4.3131	03:13	719.442139
0.479960467	345.311401	4.4570	03:15	719.458008
0.439751503	316.401367	4.6068	03:17	719.500366
0.399777499	287.617218	4.7626	03:19	719.443237
0.359620668	258.739410	4.8972	03:21	719.478699
0.319482684	229.865646	5.0425	03:24	719.493286
0.279770969	201.300659	5.1761	03:26	719.519470
0.229959194	165.459808	5.2873	03:28	719.518127
0.181150715	130.341400	5.3846	03:30	719.519104
0.131792779	94.829071	5.4564	03:33	719.531616
0.096044099	69.105980	5.4532	03:36	719.523438

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TriStar II Plus 3.01 TriStar II Plus Version 3.01 Page 6 of 14
Serial # 1080 Unit 1 Port 1

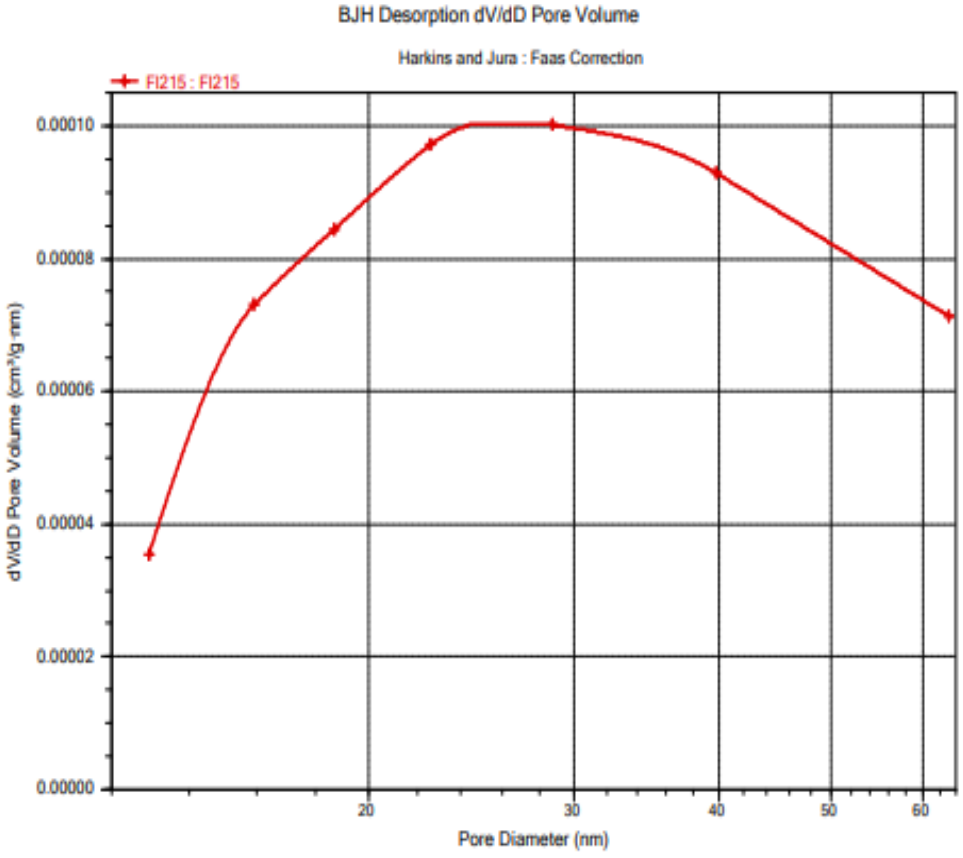
Started:	6/22/2023 1:58:12 PM	Analysis adsorptive:	N2
Completed:	6/22/2023 5:35:53 PM	Analysis bath temp.:	-195,850 °C
Report time:	6/23/2023 7:33:19 AM	Thermal correction:	No
Sample mass:	0,0414 g	Ambient free space:	11,1184 cm³ Measured
Analysis free space:	32,1601 cm³	Equilibration interval:	10 s
Low pressure dose:	None	Sample density:	1,000 g/cm³
Automatic degas:	No		

BET Report

BET surface area:	6,9042 ± 0,2127 m²/g
Slope:	0,641675 ± 0,019089 g/cm³ STP
Y-intercept:	-0,011252 ± 0,003568 g/cm³ STP
C:	-56,029599
Qm:	1,5862 cm³/g STP
Correlation coefficient:	0,9956044
Molecular cross-sectional area:	0,1620 nm²

Relative Pressure (P/Po)	Quantity Adsorbed (cm³/g STP)	1/[Q(Po/P - 1)]
0.062995495	1.9048	0.035296
0.075256781	1.9793	0.041117
0.090272293	2.0445	0.048534
0.110046065	2.1071	0.058684
0.135015225	2.1486	0.072646
0.150032638	2.1927	0.080500
0.174958316	2.2156	0.095713
0.199863332	2.2373	0.111645
0.224789161	2.2446	0.129189
0.249734006	2.2603	0.147266
0.274616213	2.2581	0.167654
0.299637710	2.2472	0.190385

Started:	6/22/2023 1:58:12 PM	Analysis adsorptive:	N2
Completed:	6/22/2023 5:35:53 PM	Analysis bath temp.:	-195,850 °C
Report time:	6/23/2023 7:33:19 AM	Thermal correction:	No
Sample mass:	0,0414 g	Ambient free space:	11,1184 cm³ Measured
Analysis free space:	32,1601 cm³	Equilibration interval:	10 s
Low pressure dose:	None	Sample density:	1,000 g/cm³
Automatic degas:	No		



Started:	6/22/2023 1:58:12 PM	Analysis adsorptive:	N2
Completed:	6/22/2023 5:35:53 PM	Analysis bath temp.:	-195,850 °C
Report time:	6/23/2023 7:33:19 AM	Thermal correction:	No
Sample mass:	0,0414 g	Ambient free space:	11,1184 cm³ Measured
Analysis free space:	32,1601 cm³	Equilibration interval:	10 s
Low pressure dose:	None	Sample density:	1,000 g/cm³
Automatic degas:	No		

BJH Adsorption Pore Distribution Report

Faas Correction

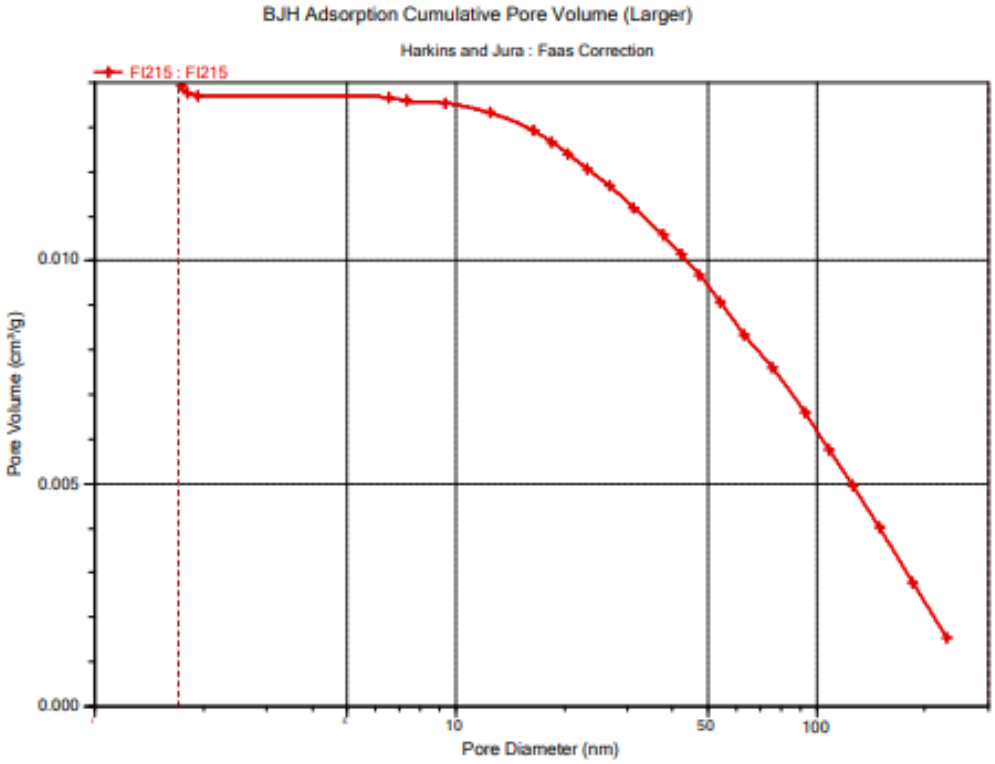
Harkins and Jura

$t = [13.99 / (0.034 - \log(P/Po))]^{0.5}$

Diameter range:	1,7000 to 300,0000 nm
Adsorbate property factor:	0,95300 nm
Density conversion factor:	0,0015468
Fraction of pores open at both ends:	0,00

Pore Diameter Range (nm)	Average Diameter (nm)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
301.5 - 229.9	256.2	0.001545	0.001545	0.024	0.024
229.9 - 185.4	202.9	0.001246	0.002792	0.025	0.049
185.4 - 149.8	163.8	0.001217	0.004009	0.030	0.078
149.8 - 126.4	136.1	0.000943	0.004952	0.028	0.106
126.4 - 108.0	115.8	0.000813	0.005765	0.028	0.134
108.0 - 93.2	99.5	0.000822	0.006587	0.033	0.167
93.2 - 75.5	82.5	0.001023	0.007610	0.050	0.217
75.5 - 63.0	68.2	0.000742	0.008352	0.044	0.260
63.0 - 54.0	57.8	0.000734	0.009086	0.051	0.311
54.0 - 47.3	50.2	0.000607	0.009693	0.048	0.360
47.3 - 42.0	44.3	0.000446	0.010139	0.040	0.400
42.0 - 37.5	39.5	0.000428	0.010567	0.043	0.443
37.5 - 31.2	33.8	0.000628	0.011195	0.074	0.517
31.2 - 26.7	28.6	0.000486	0.011681	0.068	0.585
26.7 - 23.3	24.7	0.000386	0.012067	0.062	0.648
23.3 - 20.6	21.7	0.000335	0.012402	0.062	0.709
20.6 - 18.4	19.3	0.000272	0.012673	0.056	0.766
18.4 - 16.4	17.3	0.000247	0.012921	0.057	0.823
16.4 - 12.5	14.0	0.000395	0.013316	0.113	0.936
12.5 - 9.4	10.5	0.000220	0.013535	0.083	1.020
9.4 - 7.3	8.1	0.000050	0.013585	0.024	1.044
7.3 - 6.6	6.9	0.000075	0.013660	0.043	1.087
6.6 - 1.9	2.0	0.000049	0.013709	0.099	1.186
1.9 - 1.8	1.9	0.000052	0.013761	0.111	1.297
1.8 - 1.7	1.8	0.000181	0.013942	0.407	1.704

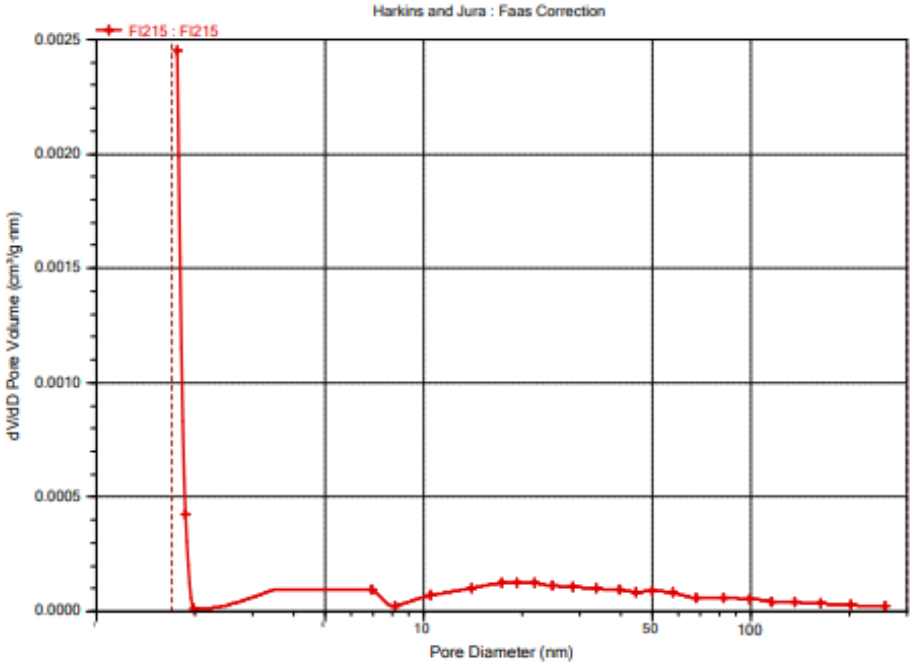
Started:	6/22/2023 1:58:12 PM	Analysis adsorptive:	N2
Completed:	6/22/2023 5:35:53 PM	Analysis bath temp.:	-195,850 °C
Report time:	6/23/2023 7:33:19 AM	Thermal correction:	No
Sample mass:	0,0414 g	Ambient free space:	11,1184 cm³ Measured
Analysis free space:	32,1601 cm³	Equilibration interval:	10 s
Low pressure dose:	None	Sample density:	1,000 g/cm³
Automatic degas:	No		



Started:	6/22/2023 1:58:12 PM	Analysis adsorptive:	N2
Completed:	6/22/2023 5:35:53 PM	Analysis bath temp.:	-195,850 °C
Report time:	6/23/2023 7:33:19 AM	Thermal correction:	No
Sample mass:	0,0414 g	Ambient free space:	11,1184 cm³ Measured
Analysis free space:	32,1601 cm³	Equilibration interval:	10 s
Low pressure dose:	None	Sample density:	1,000 g/cm³
Automatic degas:	No		

BJH Adsorption dV/dD Pore Volume

Harkins and Jura : Faas Correction



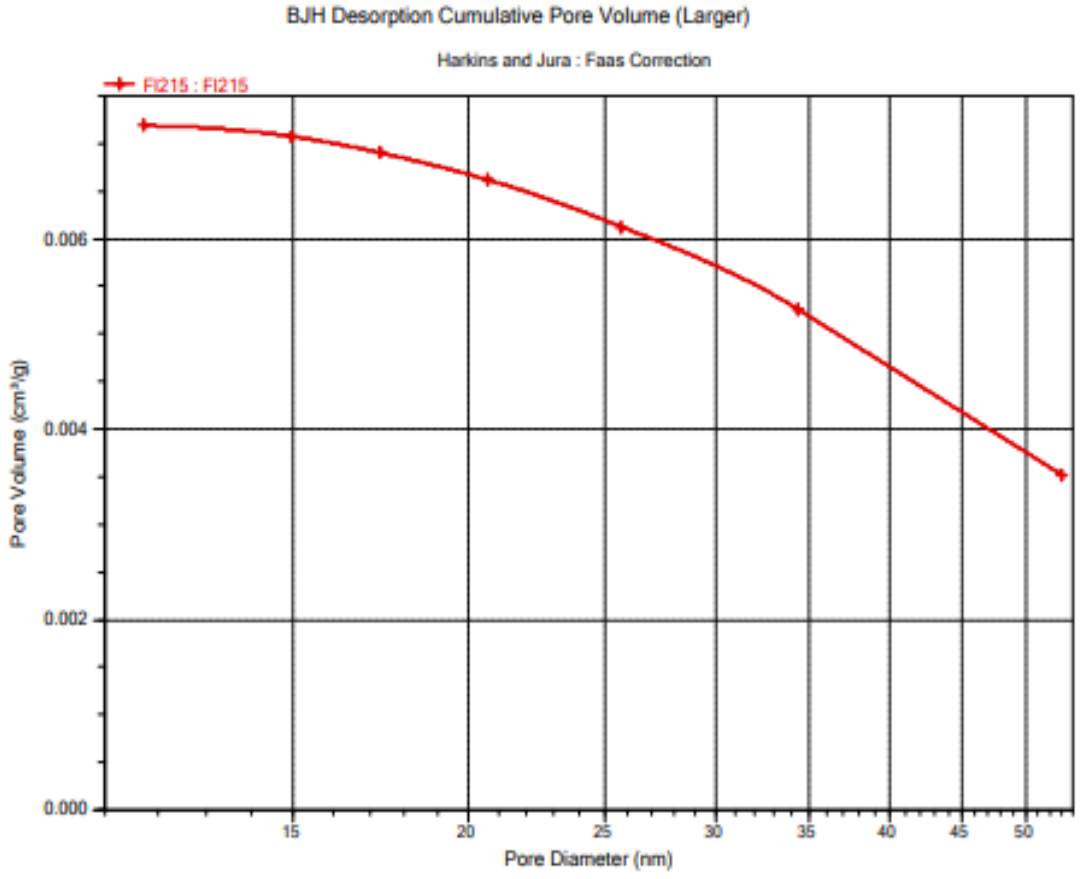
BJH Desorption Pore Distribution Report

Faas Correction
Harkins and Jura
t = [13.99 / (0.034 - log(P/Po))] ^ 0.5

Diameter range:	1,7000 to 300,0000 nm
Adsorbate property factor:	0,95300 nm
Density conversion factor:	0,0015468
Fraction of pores open at both ends:	0,00

Pore Diameter Range (nm)	Average Diameter (nm)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
102.5 - 53.1	63.1	0.003523	0.003523	0.223	0.223
53.1 - 34.4	39.7	0.001735	0.005258	0.175	0.398
34.4 - 25.7	28.7	0.000868	0.006127	0.121	0.519
25.7 - 20.7	22.6	0.000492	0.006618	0.087	0.606
20.7 - 17.3	18.6	0.000285	0.006903	0.061	0.667
17.3 - 14.9	15.9	0.000171	0.007074	0.043	0.710
14.9 - 11.7	12.9	0.000115	0.007189	0.036	0.745

Started:	6/22/2023 1:58:12 PM	Analysis adsorptive:	N2
Completed:	6/22/2023 5:35:53 PM	Analysis bath temp.:	-195,850 °C
Report time:	6/23/2023 7:33:19 AM	Thermal correction:	No
Sample mass:	0,0414 g	Ambient free space:	11,1184 cm³ Measured
Analysis free space:	32,1601 cm³	Equilibration interval:	10 s
Low pressure dose:	None	Sample density:	1,000 g/cm³
Automatic degas:	No		



Lampiran 9. Contoh Perhitungan Nilai K_1 dan K_2 berdasarkan Persamaan Orde Satu Semu dan Orde Dua Semu

1. Penentuan K_1 dari persamaan orde satu semu

Persamaan orde satu semu:

$$\log (q_e - q_t) = \log q_e - K_1\, t/2{,}303$$

- $\log q_e$ = Intercept
  q_e = Inv. log Intercept

  $\log q_e$ = -0,4
  q_e = 0,3981

- $-K_1/2{,}303$ = Slope
  K_1 = -Slope x 2,303
  K_1 = 0,0052 x 2,303
  K_1 = 0,012

2. Penentuan K_2 dari persamaan orde dua semu

Persamaan orde dua semu:

$$t/q_t = 1/K_2\, q_e^2 + t/q_e$$

- $1/q_e$ = Slope
  q_e = 1/Slope
  q_e = 1/1,3065
  q_e = 0,7654

- $1/K_2 q_e^2$ = Intercept
  K_2 = 1/Intercept x q_e^2
  K_2 = 1/7,0882 x $(0{,}7654)^2$
  K_2 = 0,241

Lampiran 10. Contoh Perhitungan Nilai Kapasitas Adsorpsi berdasarkan Model Persamaan Isotermal Adsorpsi Langmuir dan Isotermal Adsorpsi Freundlich

1. Isotermal Adsorpsi Langmuir

Persamaan:

$$\frac{1}{q_e} = \frac{1}{q_m K_L} x \frac{1}{C_e} + \frac{1}{q_m}$$

Keterangan:

C_e = Konsentrasi saat kesetimbangan (mg/L)
q_e = Jumlah zat teradsorpsi saat kesetimbangan (mg/g)
q_m = Kapasitas adsorpsi maksimum monolayer (mg/g)
K_L = Konstanta afinitas adsorpsi atau konstanta kesetimbangan (L/mg)

Berdasarkan model isotermal Langmuir diperoleh persamaan garis:

$$y = 0{,}3967x + 0{,}0458$$

$\frac{1}{q_m} = 0{,}0458$ maka, $q_m = \frac{1}{0{,}0458} = 21{,}834$

$\frac{1}{q_m K_L} = 0{,}3967$ maka, $K_L = \frac{1}{21{,}834 \text{ x } 0{,}3967} = 0{,}1155$

2. Isotermal Adsorpsi Freundlich

Persamaan:

$$\log q_e = \frac{1}{n} \log C_e + \log K_F$$

Keterangan:

C_e = Konsentrasi saat kesetimbangan (mg/L)
q_e = Jumlah zat teradsorpsi saat kesetimbangan (mg/g)
K_F = Kapasitas adsorpsi (mg/g)
$\frac{1}{n}$ = Konstanta Freundlich menyatakan faktor heterogenitas
n = Intensitas adsorpsi

Berdasarkan model isotermal Freundlich diperoleh persamaan garis:

$$y = 0{,}9569x + 0{,}3549$$

$\frac{1}{n} = 0{,}9569$ maka, $n = \frac{1}{0{,}9569} = 1{,}045$

$\log K_F = 0{,}3549$

$K_F = \text{Inv. log } (0{,}3549)$

$K_F = 2{,}264$