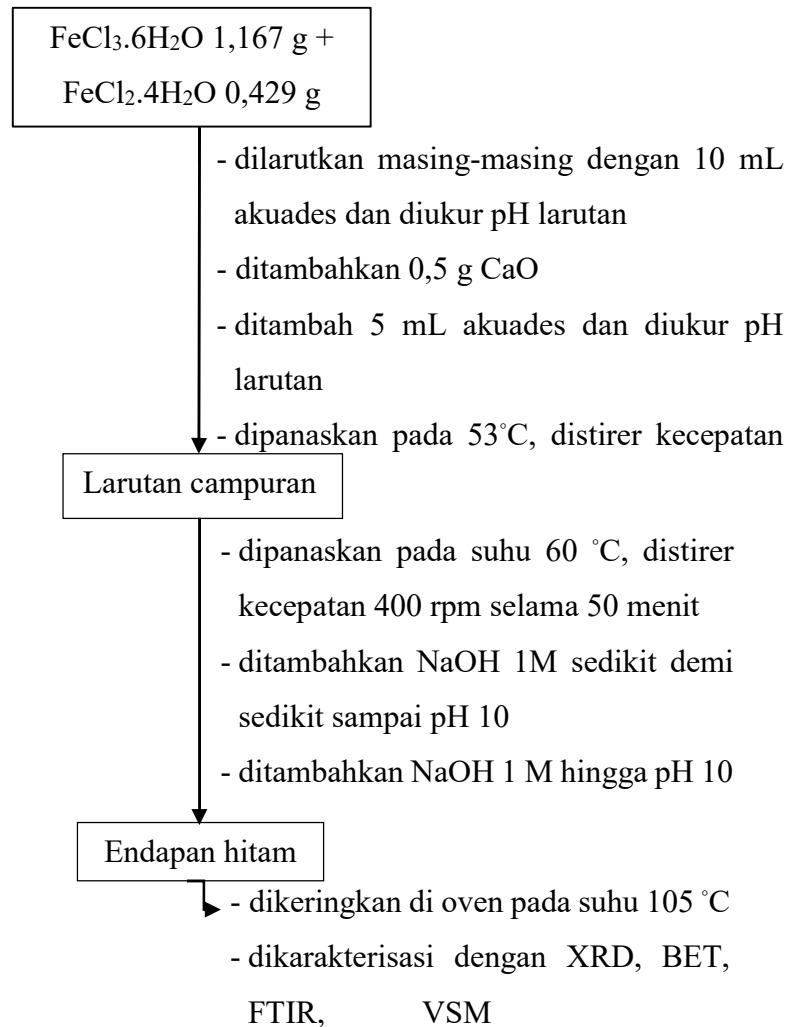


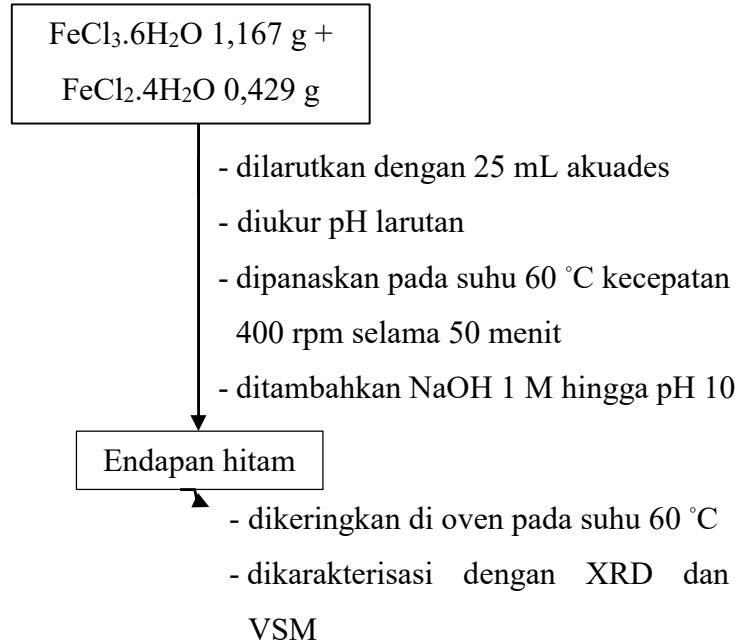
LAMPIRAN

Lampiran 1. Diagram Alir Prosedur Penelitian

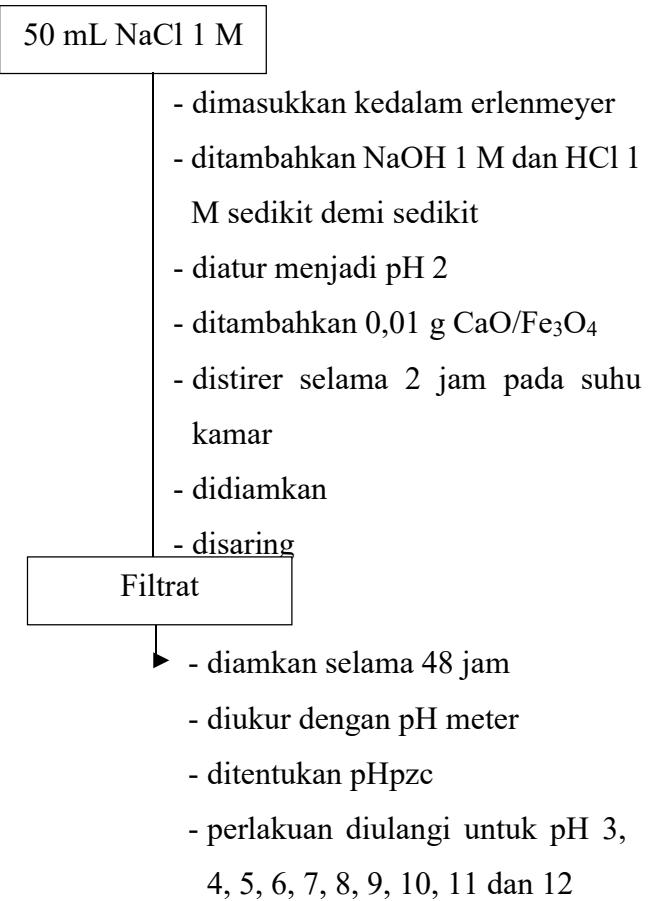
A. Sintesis komposit CaO/Fe₃O₄



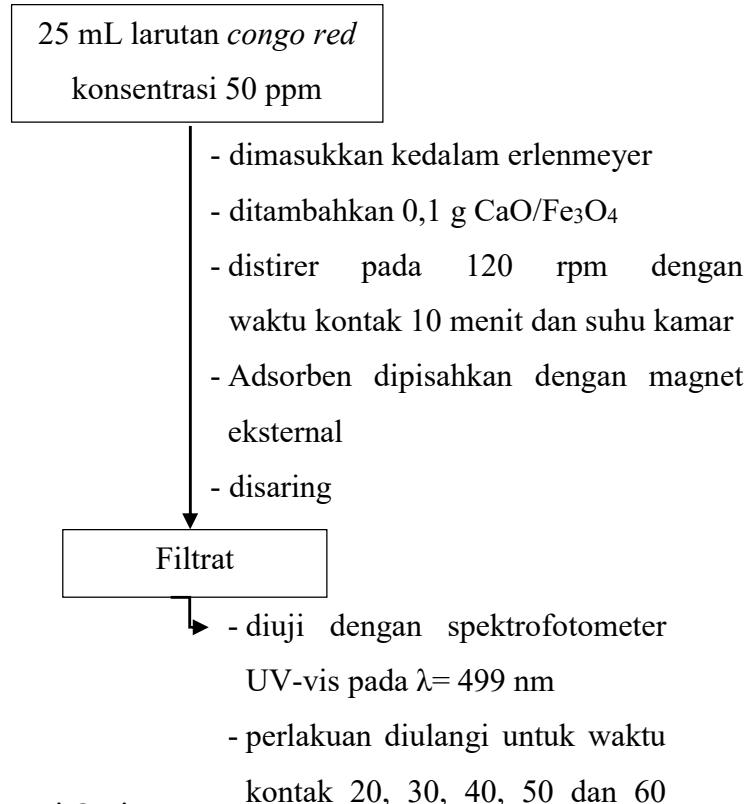
B. Sintesis Fe₃O₄



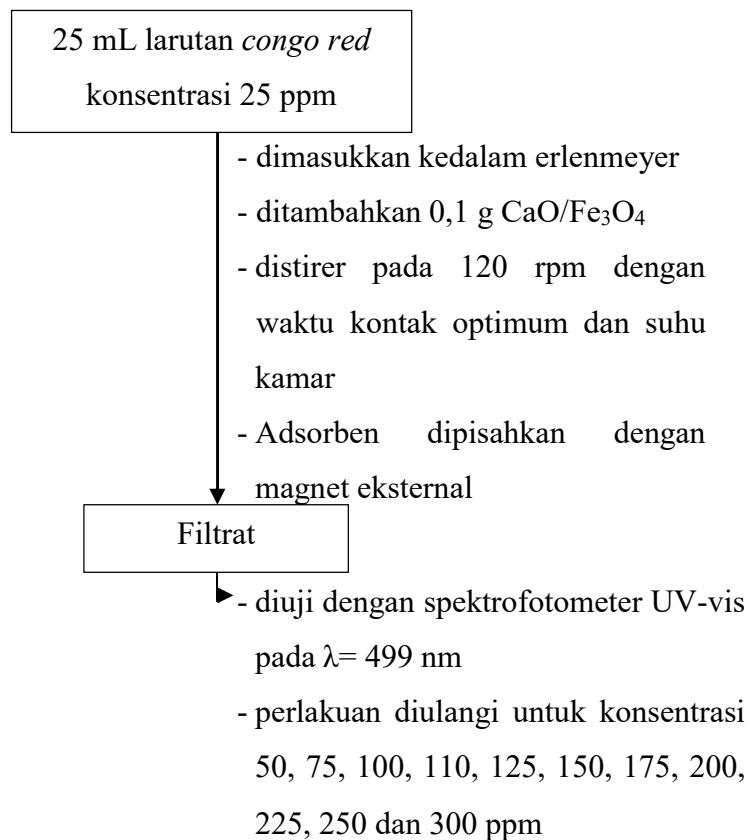
C. Penentuan pH_{pzc}



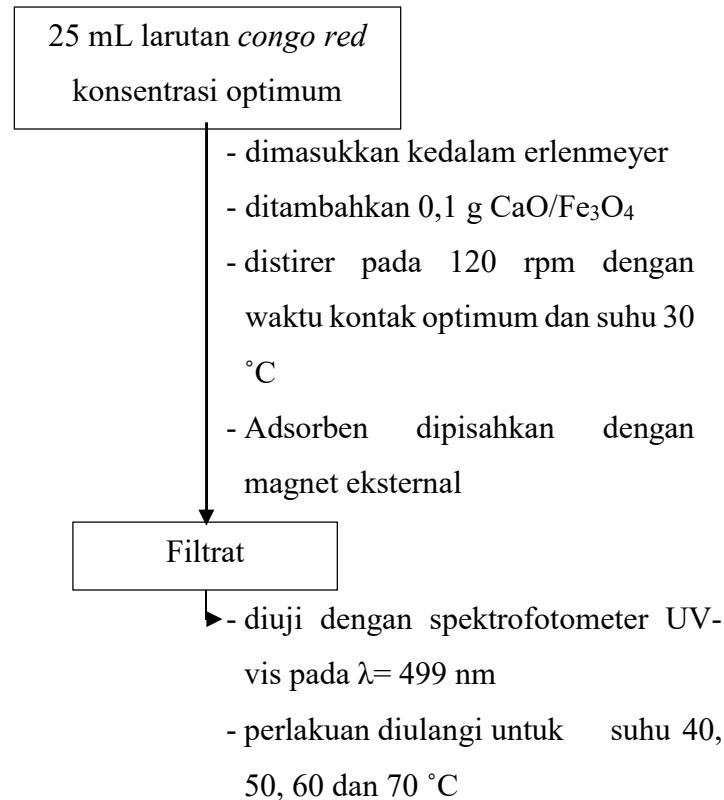
D. Penentuan Waktu Kontak Optimum



E. Penentuan Konsentrasi Optimum



F. Penentuan Suhu Optimum



Lampiran 2. Perhitungan Perbandingan Massa Pembentukan komposit CaO/Fe₃O₄



Diketahui:

$$\text{BM Fe}_3\text{O}_4 = 231,5 \text{ g/mol}$$

$$\text{BM FeCl}_3 \cdot 6\text{H}_2\text{O} = 270,2 \text{ g/mol}$$

$$\text{BM FeCl}_2 \cdot 4\text{H}_2\text{O} = 198,75 \text{ g/mol}$$

Sintesis CaO/Fe₃O₄ (1:1) sebanyak 10 g

$$0,5 \text{ g Fe}_3\text{O}_4 \times 10 \text{ g} = 5 \text{ g Fe}_3\text{O}_4$$

$$\text{mol Fe}_3\text{O}_4 = \frac{5 \text{ g}}{231,5 \text{ g/mol}} = 0,0216 \text{ mol}$$

$$\begin{aligned} \text{mol FeCl}_3 \cdot 6\text{H}_2\text{O} &= 2 \times \text{mol Fe}_3\text{O}_4 \\ &= 2 \times 0,0216 \text{ mol} \\ &= 4,32 \cdot 10^{-2} \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{Berat FeCl}_3 \cdot 6\text{H}_2\text{O} &= \text{mol FeCl}_3 \cdot 6\text{H}_2\text{O} \times \text{BM FeCl}_3 \cdot 6\text{H}_2\text{O} \\ &= 4,32 \cdot 10^{-2} \text{ mol} \times 270,2 \text{ g/mol} \\ &= 11,67 \text{ g} \end{aligned}$$

$$\text{mol FeCl}_2 \cdot 4\text{H}_2\text{O} = \text{mol Fe}_3\text{O}_4$$

$$\begin{aligned} \text{Berat FeCl}_2 \cdot 4\text{H}_2\text{O} &= \text{mol FeCl}_2 \cdot 4\text{H}_2\text{O} \times \text{BM FeCl}_2 \cdot 4\text{H}_2\text{O} \\ &= 2,16 \cdot 10^{-2} \text{ mol} \times 198,75 \text{ g/mol} \\ &= 4,29 \text{ g} \end{aligned}$$

Lampiran 3. Perhitungan Rendemen CaO/Fe₃O₄

Data perhitungan CaO/Fe₃O₄

No.	FeCl ₃ .6H ₂ O (g)	FeCl ₂ .4H ₂ O (g)	CaO (g)	CaO/Fe ₃ O ₄ eksperimen (g)	CaO/Fe ₃ O ₄ teori (g)
1.	11,6981	4,2949	5,0187	5,8681	10

Cara menghitung %Rendemen:

$$\begin{aligned}
 \% \text{Rendemen I} &= \frac{\text{berat eksperimen}}{\text{berat teori}} \times 100\% \\
 &= \frac{5,8681}{10 \text{ g}} \times 100\% \\
 &= 58,681\%
 \end{aligned}$$

Lampiran 4. Perhitungan Rendemen Fe₃O₄

Data perhitungan Fe₃O₄

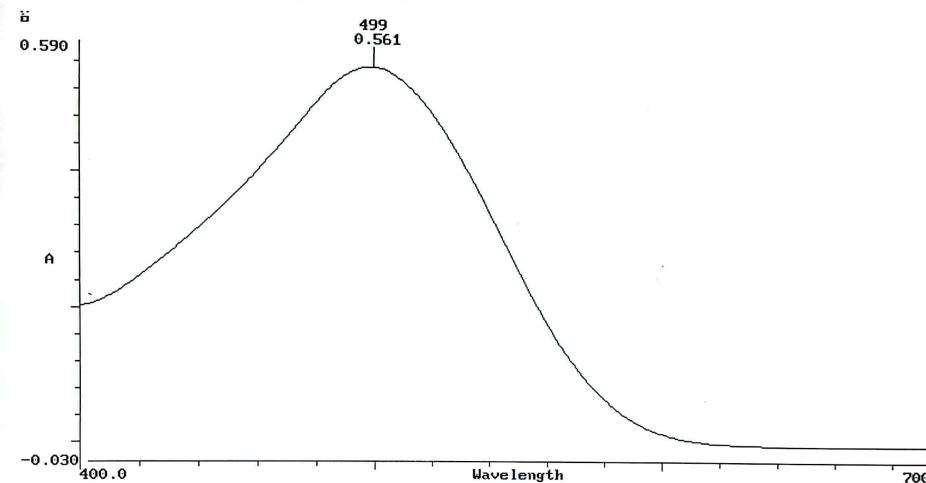
No.	FeCl ₃ .6H ₂ O (g)	FeCl ₂ .4H ₂ O (g)	CaO/Fe ₃ O ₄ eksperimen (g)	CaO/Fe ₃ O ₄ teori (g)
1.	11,6842	4,3012	2,6417	5

Cara menghitung %Rendemen:

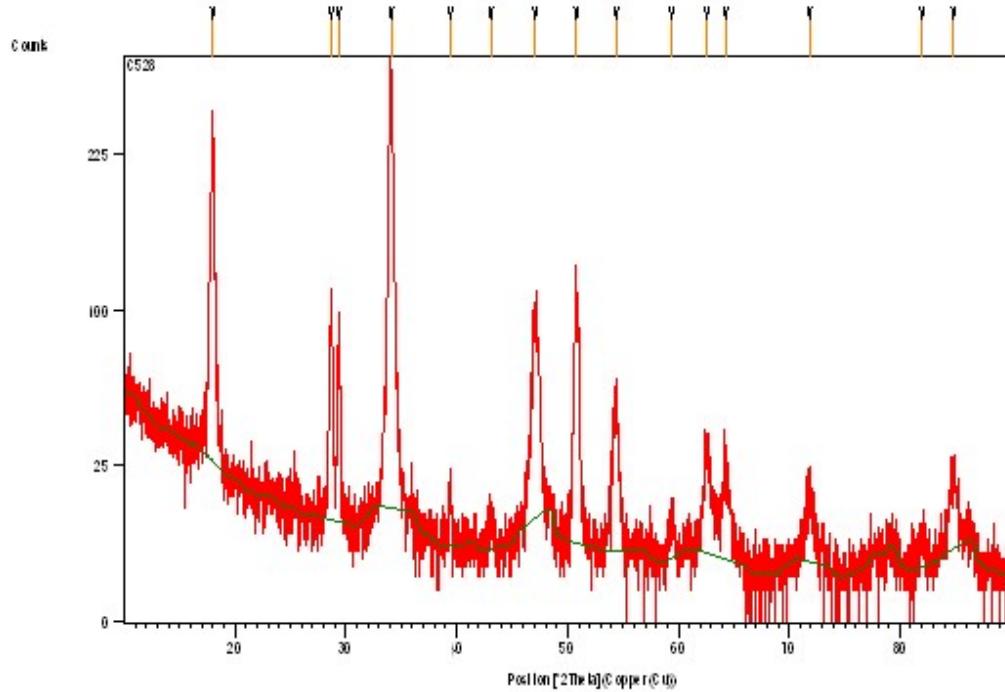
$$\begin{aligned}
 \% \text{Rendemen I} &= \frac{\text{berat eksperimen}}{\text{berat teori}} \times 100\% \\
 &= \frac{2,6417}{5 \text{ g}} \times 100\% \\
 &= 52,83\%
 \end{aligned}$$

Lampiran 5. Panjang Gelombang Maksimum Congo Red

Larutan *congo red* 15 mg/L diukur serapannya pada panjang gelombang 400–700 nm. Panjang gelombang maksimum didapatkan pada 499 nm dengan adsorbansi 0,561.



Lampiran 6. Hasil Karakterisasi CaO Murni dengan Menggunakan XRD



Peak List

Pos. [$^{\circ}$ 2Th.]	Height [cts]	FWHM [$^{\circ}$ 2Th.]	d-spacing [Å]	Rel. Int. [%]
17.9723	227.35	0.3936	4.93570	77.52
28.6576	97.52	0.2362	3.11508	33.25
29.3688	74.44	0.1574	3.04123	25.38
34.0630	293.29	0.2755	2.63210	100.00
39.4156	12.22	0.2362	2.28613	4.17
43.1158	6.85	0.4723	2.09812	2.34
47.0962	86.58	0.6298	1.92967	29.52
50.7797	109.73	0.1968	1.79800	37.41
54.3642	46.23	0.4723	1.68762	15.76
59.3677	7.58	0.4723	1.55678	2.58
62.5547	26.74	0.3936	1.48491	9.12
64.2875	20.19	0.4723	1.44901	6.89
71.8263	17.04	0.7872	1.31434	5.81
81.9911	3.23	0.9446	1.17521	1.10
84.8050	16.48	0.9600	1.14231	5.62

Hasil karakterisasi XRD CaO murni didapatkan pola difakrogram dari CaO murni dan Ca(OH)₂, sehingga dapat ukuran kristal CaO murni dan Ca(OH)₂ dapat dihitung

- Perhitungan ukuran kristal CaO murni menggunakan persamaan *Debye Scherer*

$$D = \frac{K \lambda}{\beta_{co}}$$

1. Untuk $2\theta = 64,287$

Diketahui: $\lambda = 1,5406 \text{ \AA} = 0,15406 \text{ nm}$

$$\begin{aligned}
K &= 0,5 \text{ nm} \\
\beta &= 0,4723 \text{ deg} \\
&= \left(0,4723 \times \frac{\pi}{180} \right) \text{ rad} \\
&= \left(0,4723 \times \frac{\frac{22}{7}}{180} \right) \text{ rad} \\
&= 0,0082 \text{ rad} \\
2\theta &= 64,287 \\
\theta &= \frac{64,287}{2} \\
\theta &= 32,144 \\
\theta &= \left(32,144 \times \frac{\pi}{180} \right) \text{ rad} \\
\theta &= \left(32,144 \times \frac{\frac{22}{7}}{180} \right) \text{ rad} \\
\theta &= 0,5612 \text{ rad}
\end{aligned}$$

Sehingga,

$$\begin{aligned}
D &= \frac{K \lambda}{\beta \cos \theta} \\
D &= \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0082 \text{ rad})(\cos 0,5612 \text{ rad})} \\
D &= \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0082 \text{ rad})(0,9999 \text{ rad})} \\
D &= \frac{0,07703 \text{ nm}}{0,0082 \text{ rad}} \\
D &= 9,39 \text{ nm}
\end{aligned}$$

Sehingga didapatkan ukuran kristal CaO murni 9,39 nm

- Perhitungan ukuran kristal Ca(OH)₂ menggunakan persamaan *Debye Scherer*

$$\begin{aligned}
D &= \frac{K \lambda}{\beta \cos \theta} \\
1. \text{ Untuk } 2\theta &= 34,063 \\
\text{Diketahui: } \lambda &= 1,5406 \text{ Å} = 0,15406 \text{ nm} \\
K &= 0,5 \text{ nm} \\
\beta &= 0,2755 \text{ deg} \\
&= \left(0,2755 \times \frac{\pi}{180} \right) \text{ rad}
\end{aligned}$$

$$= \left(0,2755 \times \frac{\frac{22}{7}}{180} \right) rad$$

$$= 0,0048 \text{ rad}$$

$$2\theta = 34,063$$

$$\theta = \frac{64,287}{2}$$

$$\theta = 17,0315$$

$$\theta = \left(17,0315 \times \frac{\pi}{180} \right) rad$$

$$\theta = \left(17,0315 \times \frac{\frac{22}{7}}{180} \right) rad$$

$$\theta = 0,2973 \text{ rad}$$

Sehingga,

$$D = \frac{K \lambda}{\beta \cos \theta}$$

$$D = \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0048 \text{ rad})(\cos 0,2973 \text{ rad})}$$

$$D = \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0048 \text{ rad})(0,9999 \text{ rad})}$$

$$D = \frac{0,07703 \text{ nm}}{0,0048 \text{ rad}}$$

$$D = 16,05 \text{ nm}$$

2. Untuk $2\theta = 50,779$

Diketahui: $\lambda = 1,5406 \text{ \AA} = 0,15406 \text{ nm}$

$$K = 0,5 \text{ nm}$$

$$\beta = 0,1968 \text{ deg}$$

$$= \left(0,1968 \times \frac{\pi}{180} \right) rad$$

$$= \left(0,1968 \times \frac{\frac{22}{7}}{180} \right) rad$$

$$= 0,0034 \text{ rad}$$

$$2\theta = 50,779$$

$$\theta = \frac{50,779}{2}$$

$$\theta = 25,3895$$

$$\theta = \left(25,3895 \times \frac{\pi}{180} \right) rad$$

$$\theta = \left(25,3895 \times \frac{\frac{22}{7}}{180} \right) rad$$

$$\theta = 0,4433 \text{ rad}$$

Sehingga,

$$D = \frac{K \lambda}{\beta \cos}$$

$$D = \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0034 \text{ rad})(\cos 0,4433 \text{ rad})}$$

$$D = \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0034 \text{ rad})(0,9999 \text{ rad})}$$

$$D = \frac{0,07703 \text{ nm}}{0,0034 \text{ rad}}$$

$$D = 22,65 \text{ nm}$$

3. Untuk $2\theta = 28,657$

Diketahui: $\lambda = 1,5406 \text{ \AA} = 0,15406 \text{ nm}$

$$K = 0,5 \text{ nm}$$

$$\beta = 0,2362 \text{ deg}$$

$$= \left(0,2362 \times \frac{\pi}{180} \right) rad$$

$$= \left(0,2362 \times \frac{\frac{22}{7}}{180} \right) rad$$

$$= 0,0041 \text{ rad}$$

$$2\theta = 28,657$$

$$\theta = \frac{28,657}{2}$$

$$\theta = 14,3285$$

$$\theta = \left(14,3285 \times \frac{\pi}{180} \right) rad$$

$$\theta = \left(14,3285 \times \frac{\frac{22}{7}}{180} \right) rad$$

$$\theta = 0,2502 \text{ rad}$$

Sehingga,

$$D = \frac{K \lambda}{\beta \cos \theta}$$

$$D = \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0041 \text{ rad})(\cos 0,2502 \text{ rad})}$$

$$D = \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0041 \text{ rad})(0,9999 \text{ rad})}$$

$$D = \frac{0,07703 \text{ nm}}{0,0041 \text{ rad}}$$

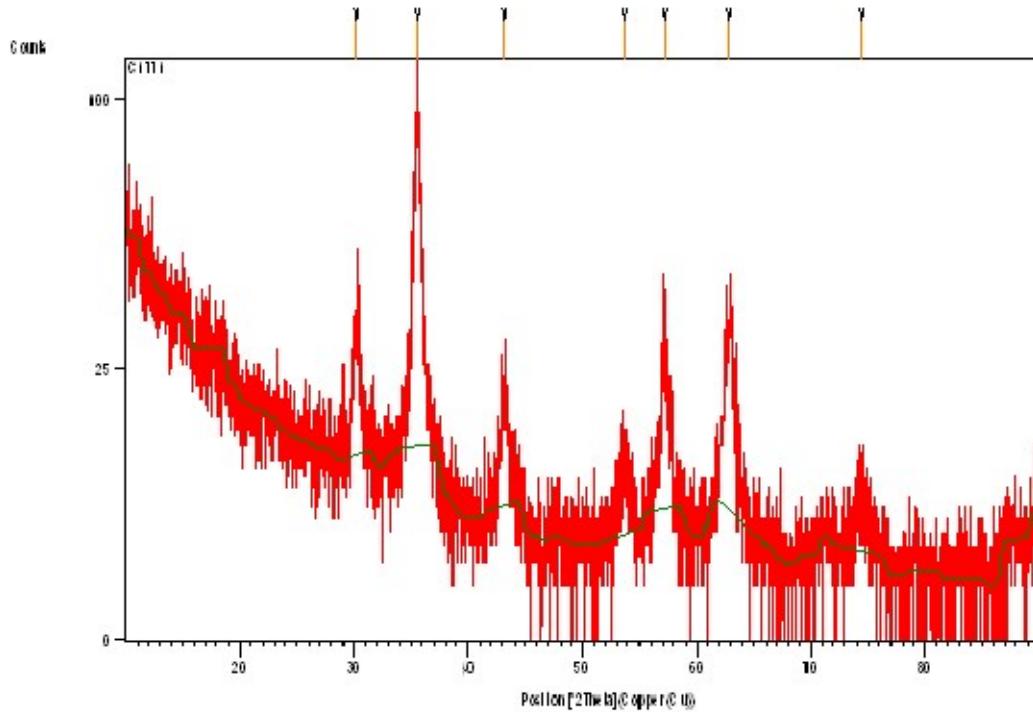
$$D = 18,78 \text{ nm}$$

Maka,

$$\text{Ukuran kristal rata-rata} = \frac{16,05 + 22,65}{3},78 = 19,16 \text{ nm}$$

Sehingga ukuran kristal Ca(OH)_2 sebesar 19,16 nm

Lampiran 7. Hasil Karakterisasi Fe₃O₄ dengan Menggunakan XRD



Peak List

Pos. [°2Th.]	Height [cts]	FWHM [°2Th.]	d-spacing [Å]	Rel. Int. [%]
30.1992	22.95	0.6298	2.95948	27.42
35.5816	83.70	0.4723	2.52318	100.00
43.2157	13.83	0.9446	2.09350	16.53
53.7364	5.93	0.9446	1.70584	7.09
57.2040	21.14	0.6298	1.61041	25.26
62.8123	28.58	0.9446	1.47944	34.14
74.4095	4.79	1.1520	1.27393	5.72

- Perhitungan ukuran kristal Fe₃O₄ menggunakan persamaan *Debye Scherer*

$$D = \frac{K \lambda}{\beta \cos \theta}$$

1. Untuk $2\theta = 35,581$

Diketahui: $\lambda = 1,5406 \text{ Å} = 0,15406 \text{ nm}$

$$K = 0,5 \text{ nm}$$

$$\beta = 0,4723 \text{ deg}$$

$$= \left(0,4723 \times \frac{\pi}{180} \right) \text{ rad}$$

$$= \left(0,4723 \times \frac{\frac{22}{7}}{180} \right) \text{ rad}$$

$$= 0,0082 \text{ rad}$$

$$\begin{aligned}
 2\theta &= 35,581 \\
 \theta &= \frac{35,581}{2} \\
 \theta &= 17,790 \\
 \theta &= \left(17,790 \times \frac{\pi}{180}\right) rad \\
 \theta &= \left(17,790 \times \frac{\frac{22}{7}}{180}\right) rad \\
 \theta &= 0,3106 \text{ rad}
 \end{aligned}$$

Sehingga,

$$\begin{aligned}
 D &= \frac{K \lambda}{\beta \cos \theta} \\
 D &= \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0082 \text{ rad})(\cos 0,3106 \text{ rad})} \\
 D &= \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0081 \text{ rad})(0,9999 \text{ rad})} \\
 D &= \frac{0,07703 \text{ nm}}{0,0080 \text{ rad}} \\
 D &= 9,62 \text{ nm}
 \end{aligned}$$

2. Untuk $2\theta = 62,812$

Diketahui: $\lambda = 1,5406 \text{ \AA} = 0,15406 \text{ nm}$

$$\begin{aligned}
 K &= 0,5 \text{ nm} \\
 \beta &= 0,9446 \text{ deg} \\
 &= \left(0,9446 \times \frac{\pi}{180}\right) rad \\
 &= \left(0,9446 \times \frac{\frac{22}{7}}{180}\right) rad \\
 &= 0,016 \text{ rad}
 \end{aligned}$$

$$\begin{aligned}
 2\theta &= 62,812 \\
 \theta &= \frac{62,812}{2} \\
 \theta &= 31,406 \\
 \theta &= \left(31,406 \times \frac{\pi}{180}\right) rad \\
 \theta &= \left(31,406 \times \frac{\frac{22}{7}}{180}\right) rad \\
 \theta &= 0,5483 \text{ rad}
 \end{aligned}$$

Sehingga,

$$\begin{aligned}
 D &= \frac{K \lambda}{\beta \cos \theta} \\
 D &= \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,016 \text{ rad})(\cos 0,5483 \text{ rad})} \\
 D &= \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,016 \text{ rad})(0,9999 \text{ rad})} \\
 D &= \frac{0,07703 \text{ nm}}{0,0016 \text{ rad}} \\
 D &= 4,67 \text{ nm}
 \end{aligned}$$

3. Untuk $2\theta = 30,199$

Diketahui: $\lambda = 1,5406 \text{ \AA} = 0,15406 \text{ nm}$

$$\begin{aligned}
 K &= 0,5 \text{ nm} \\
 \beta &= 0,6298 \text{ deg} \\
 &= \left(0,6298 \times \frac{\pi}{180} \right) \text{ rad} \\
 &= \left(0,6298 \times \frac{\frac{22}{7}}{180} \right) \text{ rad} \\
 &= 0,011 \text{ rad}
 \end{aligned}$$

$$\begin{aligned}
 2\theta &= 30,199 \\
 \theta &= \frac{30,199}{2} \\
 \theta &= 15,0995 \\
 \theta &= \left(15,0995 \times \frac{\pi}{180} \right) \text{ rad} \\
 \theta &= \left(15,0995 \times \frac{\frac{22}{7}}{180} \right) \text{ rad} \\
 \theta &= 0,2636 \text{ rad}
 \end{aligned}$$

Sehingga,

$$\begin{aligned}
 D &= \frac{K \lambda}{\beta \cos \theta} \\
 D &= \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0011 \text{ rad})(\cos 0,2636 \text{ rad})} \\
 D &= \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,011 \text{ rad})(0,9999 \text{ rad})} \\
 D &= \frac{0,07703 \text{ nm}}{0,011 \text{ rad}}
 \end{aligned}$$

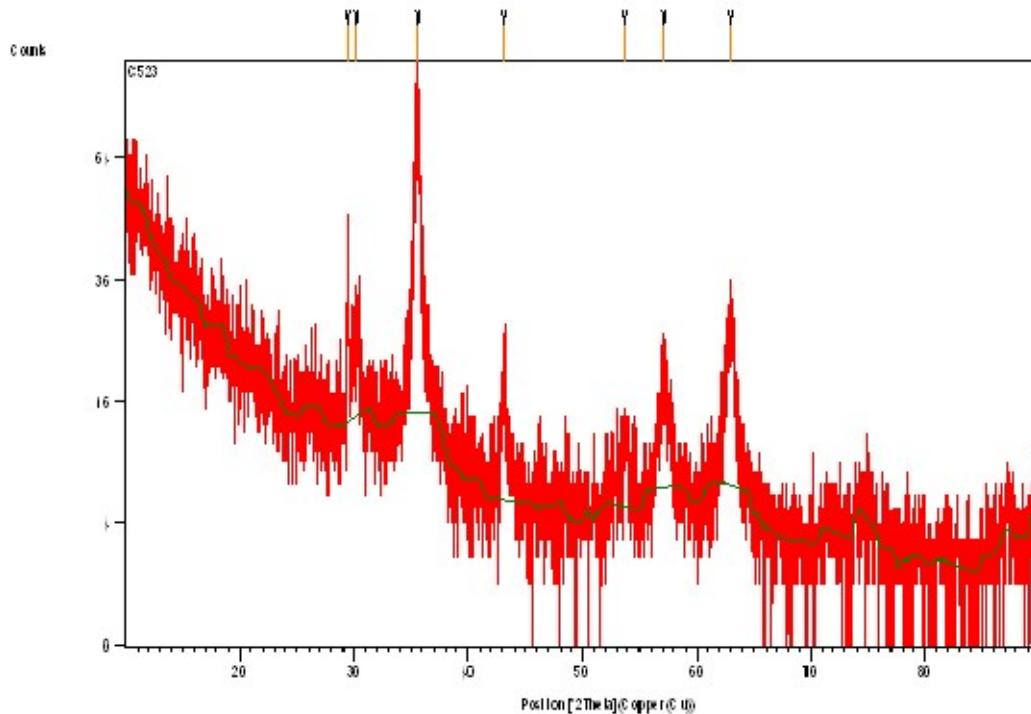
$$D = 7,003 \text{ nm}$$

Maka,

$$\text{Ukuran kristal rata-rata} = \frac{9,62 + 4,67 + 7,003}{3} = 7,09 \text{ nm}$$

Sehingga ukuran kristal Fe₃O₄ sebesar 7,09 nm

Lampiran 8. Hasil Karakterisasi CaO/Fe₃O₄ dengan Menggunakan XRD



Peak List

Pos. [°2Th.]	Height [cts]	FWHM [°2Th.]	d-spacing [Å]	Rel. Int. [%]
29.3780	26.41	0.1574	3.04030	40.09
30.1918	13.48	0.4723	2.96018	20.46
35.6294	65.86	0.5510	2.51990	100.00
43.1931	12.33	0.4723	2.09455	18.73
53.7291	5.87	0.9446	1.70606	8.91
57.1870	13.22	0.7872	1.61084	20.08
62.8818	21.60	0.9600	1.47675	32.79

- Perhitungan ukuran kristal CaO dan Fe₃O₄ pada komposit CaO/Fe₃O₄ menggunakan persamaan *Debye Scherer*

$$D = \frac{K \lambda}{\beta \cos \theta}$$

1. Untuk $2\theta = 35,629$

Diketahui: $\lambda = 1,5406 \text{ \AA} = 0,15406 \text{ nm}$

$$K = 0,5 \text{ nm}$$

$$\beta = 0,5510 \text{ deg}$$

$$= \left(0,5510 \times \frac{\pi}{180} \right) \text{ rad}$$

$$= \left(0,5510 \times \frac{\frac{22}{7}}{180} \right) rad$$

$$= 0,0096 \text{ rad}$$

$$2\theta = 35,629$$

$$\theta = \frac{35,629}{2}$$

$$\theta = 17,8145$$

$$\theta = \left(17,8145 \times \frac{\pi}{180} \right) rad$$

$$\theta = \left(17,8145 \times \frac{\frac{22}{7}}{180} \right) rad$$

$$\theta = 0,3110 \text{ rad}$$

Sehingga,

$$D = \frac{K \lambda}{\beta \cos \theta}$$

$$D = \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0096 \text{ rad})(\cos 0,3110 \text{ rad})}$$

$$D = \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0096 \text{ rad})(0,9999 \text{ rad})}$$

$$D = \frac{0,07703 \text{ nm}}{0,0080 \text{ rad}}$$

$$D = 8,02 \text{ nm}$$

2. Untuk $2\theta = 29,378$

Diketahui: $\lambda = 1,5406 \text{ \AA} = 0,15406 \text{ nm}$

$$K = 0,5 \text{ nm}$$

$$\beta = 0,1574 \text{ deg}$$

$$= \left(0,1574 \times \frac{\pi}{180} \right) rad$$

$$= \left(0,1574 \times \frac{\frac{22}{7}}{180} \right) rad$$

$$= 0,0027 \text{ rad}$$

$$2\theta = 29,378$$

$$\theta = \frac{29,378}{2}$$

$$\theta = 14,689$$

$$\theta = \left(14,689 \times \frac{\pi}{180} \right) rad$$

$$\theta = \left(14,689 \times \frac{\frac{22}{7}}{180} \right) rad$$

$$\theta = 0,2564 \text{ rad}$$

Sehingga,

$$D = \frac{K \lambda}{\beta \cos}$$

$$D = \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0027 \text{ rad})(\cos 0,2564 \text{ rad})}$$

$$D = \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0027 \text{ rad})(0,9999 \text{ rad})}$$

$$D = \frac{0,07703 \text{ nm}}{0,0016 \text{ rad}}$$

$$D = 28,53 \text{ nm}$$

3. Untuk $2\theta = 62,881$

Diketahui: $\lambda = 1,5406 \text{ \AA} = 0,15406 \text{ nm}$

$$K = 0,5 \text{ nm}$$

$$\beta = 0,9600 \text{ deg}$$

$$= \left(0,9600 \times \frac{\pi}{180} \right) rad$$

$$= \left(0,9600 \times \frac{\frac{22}{7}}{180} \right) rad$$

$$= 0,0016 \text{ rad}$$

$$2\theta = 62,881$$

$$\theta = \frac{62,881}{2}$$

$$\theta = 31,4405$$

$$\theta = \left(31,4405 \times \frac{\pi}{180} \right) rad$$

$$\theta = \left(31,4405 \times \frac{\frac{22}{7}}{180} \right) rad$$

$$\theta = 0,5489 \text{ rad}$$

Sehingga,

$$D = \frac{K \lambda}{\beta \cos \theta}$$

$$D = \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0016 \text{ rad})(\cos 0,5489 \text{ rad})}$$

$$D = \frac{(0,5 \text{ nm})(0,15406 \text{ nm})}{(0,0016 \text{ rad})(0,9999 \text{ rad})}$$

$$D = \frac{0,07703 \text{ nm}}{0,0016 \text{ rad}}$$

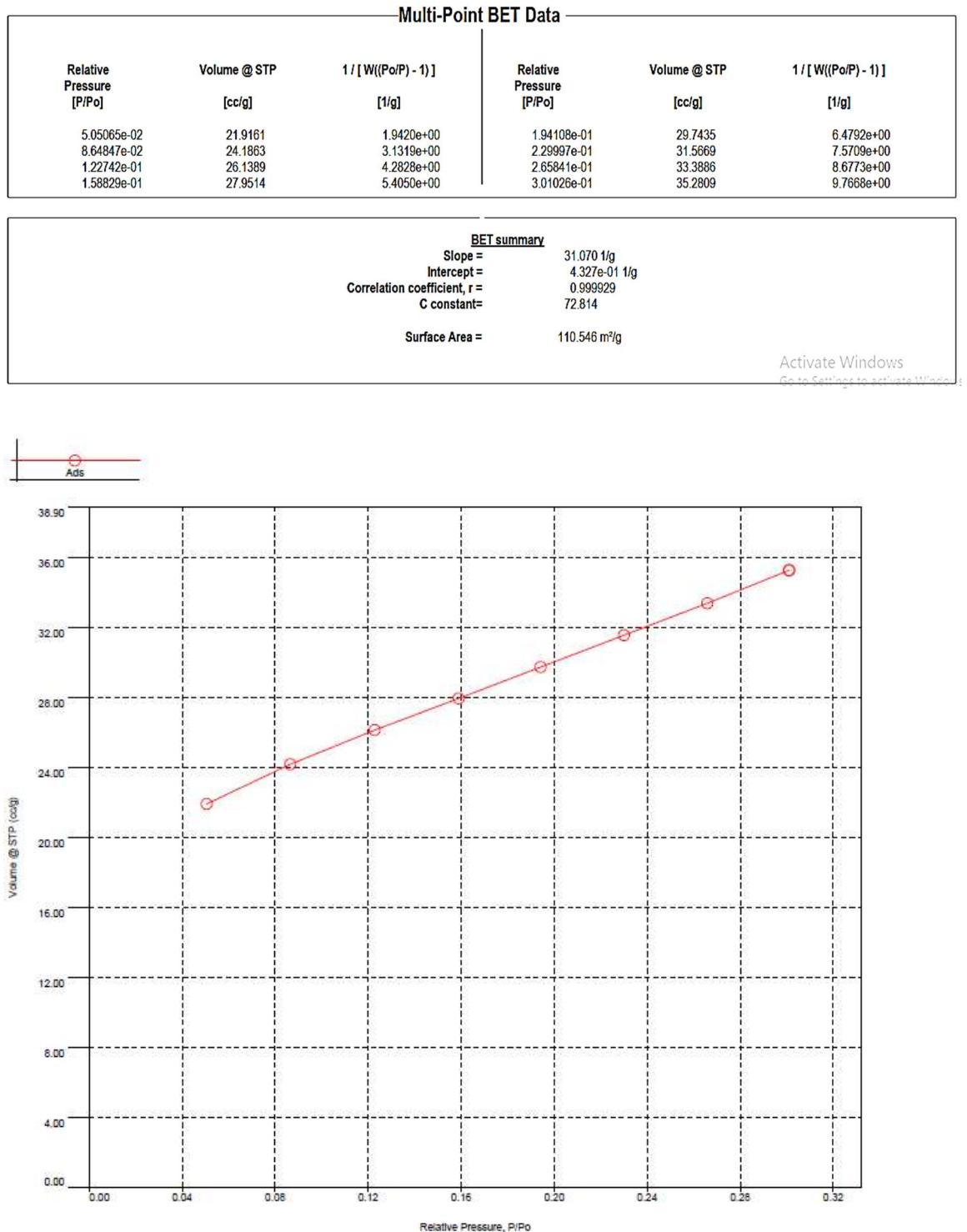
$$D = 48,14 \text{ nm}$$

Maka,

$$\text{Ukuran kristal rata-rata} = \frac{8,02 + 28,53 + 48,14}{3} = 28,23 \text{ nm}$$

Ukuran kristal Fe_3O_4 pada komposit $\text{CaO}/\text{Fe}_3\text{O}_4$ sebesar 28,23 nm

Lampiran 9. Karakterisasi BET



Grafik isotherm

Lampiran 10. Karakterisasi FTIR

Gugus Fungsi	CaO/Fe ₃ O ₄ Sebelum	CaO/Fe ₃ O ₄ Setelah
	Adsorpsi (cm ⁻¹)	Adsorpsi (cm ⁻¹)
-OH	3408,22	3388,93
Fe-O	561,29	582,50
	584,43	
Ca-O	873,75	873,75
S-O	-	1174,65
C-N	-	1226,73
O-C-O	1409,96	1409,96
	1444,68	1612,49
	1625,99	

Lampiran 11. Pengukuran pH *Point Zero Charge* (pHpzc)Data pengukuran pH *Point Zero Charge* (pHpzc)

Komposit CaO/Fe ₃ O ₄		
pH awal	pH akhir	ΔpH
2.07	7.96	5.89
3.1	8.16	5.06
4.06	8.35	4.29
5.03	8.49	3.46
6.12	8.51	2.39
7.09	8.44	1.35
8	8.6	0.6
9.1	8.66	-0.44
10.08	8.69	-1.39
11.02	8.71	-2.31
11.98	10.37	-1.61

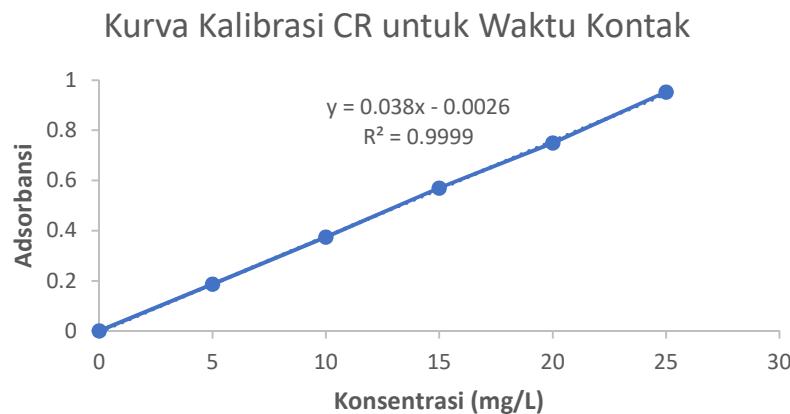
Lampiran 12. Pengaruh Variasi Waktu Kontak Terhadap Adsorpsi *Congo Red*

a. Kurva Kalibrasi *Congo Red*

Larutan standar *congo red* 5, 10, 15, 20 dan 25 mg/L diukur absorbansinya pada panjang gelombang 499 nm.

Data pembuatan kurva kalibrasi larutan zat warna *congo red*

A ₁	A ₂	A ₃	Ā	konsentrasi awal (mg/L)	konsentrasi terukur (mg/L)
0	0	0	0	0	0
0,189	0,179	0,192	0,187	5	4,98
0,373	0,375	0,375	0,374	10	9,92
0,571	0,564	0,572	0,569	15	15,04
0,737	0,758	0,755	0,750	20	19,81
0,94	0,954	0,962	0,952	25	25,12



b. Data Pengaruh Variasi Waktu Kontak

t (menit)	A ₁	A ₂	A ₃	Ā	FP	C _e (mg/L)	C _o - C _e (mg/L)	%efisiensi penyerapan	Q _t (mg/g)
0	0,378	0,379	0,378	0,378	5	50,07	0	0	0
10	0,172	0,171	0,191	0,178	1	4,75	45,32	91	11,33
20	0,161	0,164	0,161	0,162	1	4,33	45,74	91	11,43
30	0,102	0,115	0,157	0,125	1	3,35	46,72	93	11,68
40	0,058	0,058	0,058	0,058	1	1,59	48,47	97	12,12
50	0,040	0,040	0,040	0,040	1	1,12	48,95	98	12,24
60	0,066	0,067	0,066	0,066	1	1,81	48,26	96	12,06

Contoh perhitungan:

Persamaan regresi : $y = 0,038x - 0,0026$

- Perhitungan konsentrasi tak terserap (x) variasi waktu kontak 50 menit, dengan absorbansi 0,040

$$y = 0,038x - 0,0026$$

$$0,040 = 0,038x - 0,0026$$

$$x = \frac{0,040 + 0,0026}{0,038}$$

$$x = 1,12$$

sehingga, konsentrasi tak terserap (x) adalah 1,12 mg/L

- Perhitungan %efisiensi penyerapan waktu kontak 50 menit

$$\% \text{efisiensi penyerapan} = \frac{\text{konsentrasi awal} - \text{konsentrasi tidak terserap}}{\text{konsentrasi awal}} \times 100\%$$

$$= \frac{50,07 - 1,12}{50,070}$$

$$= 98\%$$

- Perhitungan daya serap waktu kontak 50 menit

$$Q_e = \frac{\text{konsentrasi terserap} \times V}{W}$$

$$= \frac{48,95 \text{ mg/L} \times 0,025 \text{ L}}{0,1 \text{ g}}$$

$$= 12,24 \text{ mg/g}$$

Lampiran 13. Data Kinetika Adsorpsi

Data perhitungan kinetika adsorpsi komposit CaO/Fe₃O₄ terhadap *congo red*

t (menit)	\bar{A}	C_o (mg/L)	C_e (mg/L)	$C_o - C_e$ (mg/L)	Q_t (mg/g)	$Q_e - Q_t$	t/Q_t	$\log(Q_e - Q_t)$
0	0,378	50,07	50,07	0	0	0	0	0
10	0,178	50,07	4,753	45,317	11,329	0,908	0,883	-0,042
20	0,162	50,07	4,332	45,738	11,435	0,802	1,749	-0,096
30	0,125	50,07	3,349	46,721	11,680	0,557	2,568	-0,254
40	0,058	50,07	1,595	48,475	12,119	0,118	3,301	-0,928
50	0,04	50,07	1,121	48,949	12,237	0,000	4,086	0
60	0,066	50,07	1,814	48,256	12,064	0,173	4,973	-0,762

$$Q_e = 12,237 \text{ mg/g}$$

$$\text{Untuk mencari } Q_e = \frac{(C_o - C_e) \times V(L)}{W_{\text{adsorben}}(\text{g})}$$

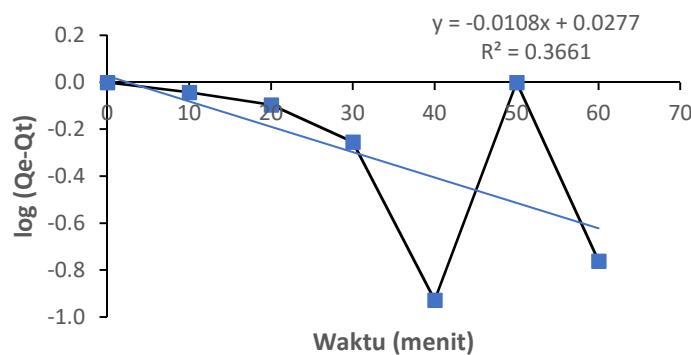
Keterangan: C_o = Konsentrasi awal zat warna *congo red* (mg/L)

C_e = Konsentrasi sisa zat warna *congo red* (mg/L)

Q_t = Kapasitas adsorpsi tiap waktu (mg/g)

Q_e = Kapasitas adsorpsi pada kesetimbangan (mg/g)

Grafik persamaan pseudo orde satu



Persamaan pseudo orde satu

$$\log(Q_e - Q_t) = \log Q_e - \left(\frac{k_1}{2,303} \right) t$$

Persamaan linear

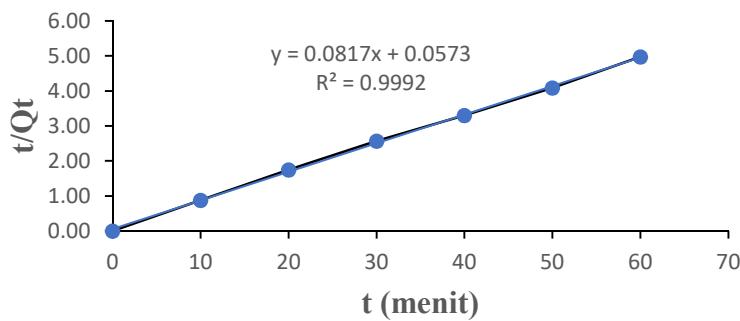
$$y = ax + b$$

$$y = -0,0108x + 0,0277$$

sehingga dapat dinyatakan sebagai berikut,

$$\begin{aligned}
 \text{Slope (a)} &= -\left(\frac{k_1}{2,303}\right) \\
 k_1 &= -(2,303 \times (-0,0108)) \\
 &= 0,02 \text{ menit}^{-1} \\
 \text{Intersept (b)} &= \log Q_e \\
 Q_e &= 10^{0,0277} \\
 &= 1,07 \text{ mg/g}
 \end{aligned}$$

Grafik persamaan pseudo orde dua



Persamaan pseudo orde dua

$$\frac{t}{Q_t} = \frac{1}{k_2 Q_e^2} + \frac{1}{Q_e} t$$

Persamaan linear

$$y = ax + b$$

$$y = 0,0817x + 0,0573$$

sehingga dapat dinyatakan sebagai berikut,

$$\begin{aligned}
 \text{Slope (a)} &= \frac{1}{Q_e} = 0,0817 \\
 Q_e &= \frac{1}{0,0817} \\
 &= 12,24 \text{ mg/g} \\
 \text{Intersept (b)} &= \frac{1}{k_2 Q_e^2} = 0,0573 \\
 k_2 &= \frac{1}{Q_e^2 \times 0,0573} \\
 &= \frac{1}{(12,240)^2 \times 0,0573} \\
 &= 0,12 \text{ g/mg.menit}
 \end{aligned}$$

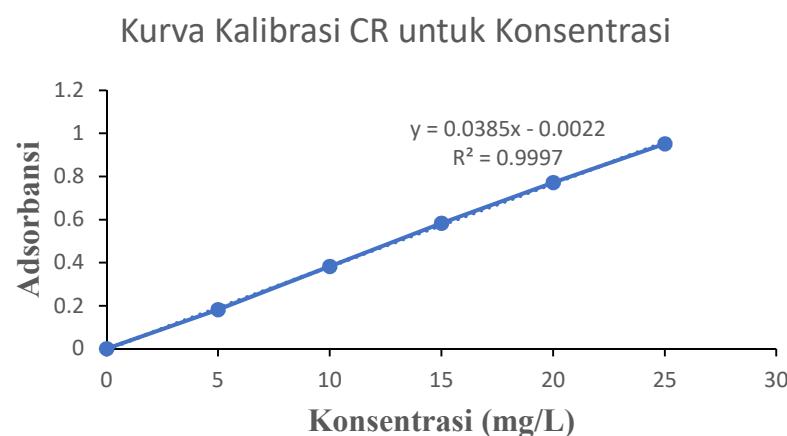
Lampiran 14. Pengaruh Variasi Konsentrasi Terhadap Adsorpsi Congo Red

a. Kurva Kalibrasi *Congo Red*

Larutan standar *congo red* 5, 10, 15, 20 dan 25 mg/L diukur absorbansinya pada 499 nm.

Data pembuatan kurva kalibrasi larutan zat warna *congo red*

A ₁	A ₂	A ₃	\bar{A}	Konsentrasi Awal	Konsentrasi Terukur
0	0	0	0	0	0
0,182	0,182	0,182	0,182	5	4,78
0,382	0,382	0,383	0,382	10	9,99
0,581	0,582	0,584	0,582	15	15,18
0,771	0,772	0,774	0,772	20	20,12
0,95	0,952	0,953	0,952	25	24,78



b. Data Perhitungan Pengaruh Variasi Konsentrasi

Variasi konsentrasi (mg/L)	C_o (mg/L)	A_1	A_2	A_3	\bar{A}	FP	C_e (mg/L)	$C_o - C_e$ (mg/L)	%efisiensi penyerapan	Daya serap (mg/g)
0	0	0	0	0	0	0	0	0	0	0
25	25,71	0	0	0	0	1	0,06	25,65	99,78	6,41
50	49,37	0,047	0,047	0,048	0,047	1	1,29	48,08	97,39	12,02
75	74,40	0,194	0,193	0,192	0,193	1	5,07	69,33	93,19	17,33
100	101,71	0,341	0,34	0,34	0,340	1	8,90	92,81	91,25	23,20
110	109,25	0,330	0,330	0,331	0,330	1	8,64	100,61	92,09	25,15
125	125,33	0,379	0,378	0,378	0,378	1	9,88	115,45	92,11	28,86
150	149,92	0,697	0,694	0,694	0,695	1	18,11	131,81	87,92	32,95
175	174,51	0,729	0,729	0,729	0,729	1	18,99	155,52	89,12	38,88
200	200,66	0,243	0,243	0,243	0,243	5	31,84	168,82	84,13	42,20
225	225,07	0,34	0,34	0,34	0,340	5	44,44	180,63	80,25	45,16
250	250,61	0,559	0,559	0,559	0,559	5	72,88	177,73	70,92	44,43
300	300,54	0,472	0,472	0,472	0,472	10	123,17	177,37	59,02	44,34

Contoh perhitungan:

Persamaan regresi: $y = 0,0385x - 0,0022$

- Perhitungan variasi konsentrasi 225 mg/L, dengan absorbansi sebesar 0,559 sehingga konsentrasi tak terserap (x) adalah:

$$y = 0,0389x - 0,0029$$

$$0,559 = 0,0389x - 0,0029$$

$$x = \frac{0,559 + 0,0029}{0,0389}$$

$$x = 44,44$$

Jadi, konsentrasi tak terserap (x) adalah 44,44 mg/L

- Perhitungan %efisiensi penyerapan untuk variasi konsentrasi 225 mg/L

$$\begin{aligned} \text{\%efisiensi penyerapan} &= \frac{\text{konsentrasi awal} - \text{konsentrasi tidak terserap}}{\text{konsentrasi awal}} \times 100\% \\ &= \frac{225,07 - 44,44}{225,07} \times 100\% \\ &= 80,25\% \end{aligned}$$

- Perhitungan daya serap (Q_e) untuk variasi konsentrasi 225 mg/L

$$\begin{aligned} Q_e &= \frac{\text{konsentrasi terserap} \times V}{W} \\ &= \frac{180,63 \text{ mg/L} \times 0,025 \text{ L}}{0,1 \text{ g}} \\ &= 45,16 \text{ mg/g} \end{aligned}$$

Lampiran 15. Data Isoterm Adsorpsi

Data perhitungan isoterm adsorpsi komposit CaO/Fe₃O₄ terhadap *congo red*

Konsentrasi (mg/L)	C _e (mg/L)	Q _e (mg/g)	C _e /Q _e	log C _e	log Q _e
0	0	0	0	0	0
25	0,06	6,41	0,0094	-1,222	0,807
50	1,29	12,02	0,1073	0,111	1,080
75	5,07	17,33	0,2926	0,705	1,239
100	8,9	23,2	0,3836	0,949	1,365
110	8,64	25,15	0,3435	0,937	1,401
125	9,88	28,86	0,3423	0,995	1,460
150	18,11	32,95	0,5496	1,258	1,518
175	18,99	38,88	0,4884	1,279	1,590
200	31,84	42,2	0,7545	1,503	1,625
225	44,44	45,16	0,9841	1,648	1,655
250	72,88	44,43	1,6403	1,863	1,648
300	123,17	44,34	2,7779	2,091	1,647

Persamaan Langmuir

$$\frac{C_e}{Q_e} = \frac{C_e}{Q_m} + \frac{1}{Q_m K_L}$$

Persamaan linear

$$y = ax + b$$

$$y = 0,0213x + 0,1124$$

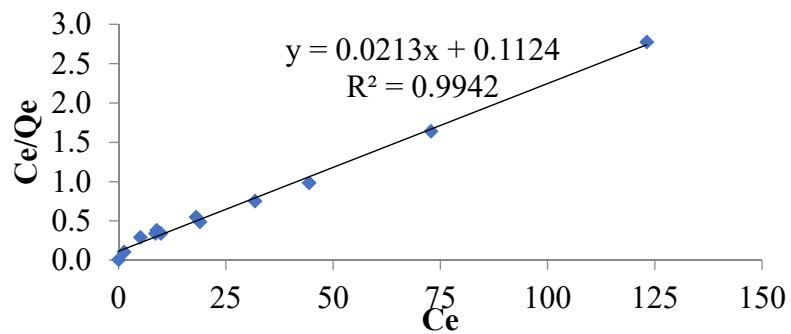
dimana,

$$\text{Slope (a)} = \frac{1}{Q_m} = 0,0213$$

$$Q_m = \frac{1}{0,0213} \\ = 46,948 \text{ mg/g}$$

$$\text{Intersept (b)} = \frac{1}{Q_m K_L} = 0,1124$$

$$K_L = \frac{1}{54,054 \times 0,1124} \\ = 0,164 \text{ L/mg}$$



Persamaan Freundlich

$$\log Q_e = \log K_r + \frac{1}{n} \log C_e$$

Persamaan linear

$$y = ax + b$$

$$y = 0,291x + 1,1258$$

dimana,

$$\text{Slope (a)} = \frac{1}{n} = 0,291$$

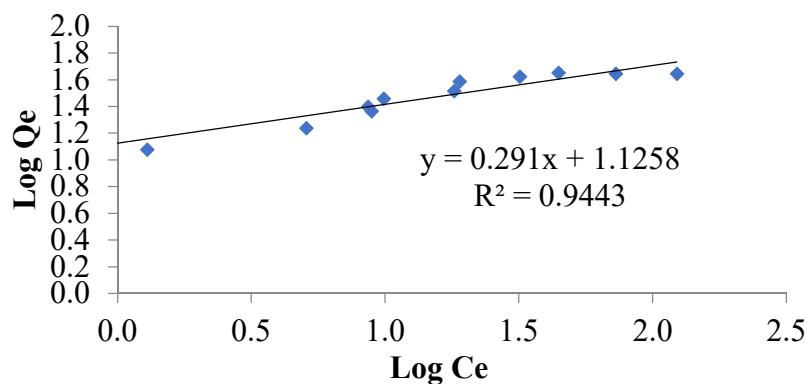
$$n = \frac{1}{0,291}$$

$$= 3,43$$

$$\text{Intersept (b)} = \log K_r = 1,1258$$

$$K_r = 10^{1,1258}$$

$$= 13,359 \text{ mg/g}$$



Lampiran 16. Pengaruh Variasi Suhu Terhadap adsorpsi Congo Red

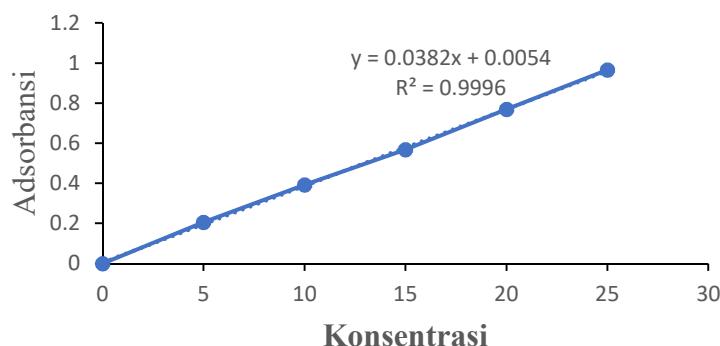
a. Kurva Kalibrasi Congo Red

Larutan standar *congo red* 5, 10, 15, 20 dan 25 mg/L diukur absorbansinya pada panjang gelombang 499 nm.

Data pembuatan kurva kalibrasi larutan zat warna *congo red*

A ₁	A ₂	A ₃	\bar{A}	konsentrasi awal	konsentrasi terukur
0	0	0	0	0	0
0,206	0,206	0,206	0,206	5	5,25
0,391	0,392	0,392	0,392	10	10,11
0,575	0,556	0,575	0,569	15	14,75
0,763	0,771	0,773	0,769	20	19,99
0,964	0,966	0,966	0,965	25	25,13

Kurva Kalibrasi CR untuk Suhu



b. Data Perhitungan Pengaruh Variasi Suhu

T (°C)	A ₁	A ₂	A ₃	\bar{A}	FP	C _e (mg/L)	C _o - C _e (mg/L)	%efisiensi penyerapan	Daya serap (mg/g)
0	0,862	0,867	0,867	0,865	10	225,29	0	0	0
30	0,322	0,321	0,321	0,321	1	8,27	217,02	96,33	54,26
40	0,202	0,205	0,206	0,204	1	5,21	220,08	97,69	55,02
50	0,124	0,128	0,129	0,127	1	3,18	222,11	98,59	55,53
60	0,514	0,518	0,517	0,516	1	13,38	211,91	94,06	52,98
70	0,643	0,642	0,642	0,642	2	33,35	191,94	85,20	47,99

Contoh perhitungan:

Persamaan regresi: $y = 0,0382x + 0,0054$

- Perhitungan variasi suhu 50°C, dengan absorbansi sebesar 0,127 sehingga konsentrasi tak terserap (x) adalah:

$$y = 0,0382x + 0,0054$$

$$0,127 = 0,0382x - 0,0054$$

$$x = \frac{0,127 + 0,0054}{0,0382}$$

$$x = 3,18$$

Jadi, konsentrasi tak terserap (x) adalah 3,18 mg/L

- Perhitungan %efisiensi penyerapan untuk variasi suhu 50°C

$$\begin{aligned}\% \text{efisiensi penyerapan} &= \frac{\text{konsentrasi awal} - \text{konsentrasi tidak terserap}}{\text{konsentrasi awal}} \times 100\% \\ &= \frac{225,29 - 3,18}{225,29} \times 100\% \\ &= 98,59\%\end{aligned}$$

- Perhitungan daya serap (Q_e) untuk variasi suhu 50°C

$$\begin{aligned}Q_e &= \frac{\text{konsentrasi terserap} \times V}{W} \\ &= \frac{222,11 \text{ mg/L} \times 0,025 \text{ L}}{0,1 \text{ g}} \\ &= 55,53 \text{ mg/g}\end{aligned}$$

Lampiran 17. Data Termodinamika

Data perhitungan termodinamika komposit CaO/Fe₃O₄ terhadap *congo red*

T (K)	C _e (mg/L)	Q _e (mg/L)	Q _e /C _e	ln (Q _e /C _e)	1/T	ΔH (kJ/mol)	ΔS (J/K.mol)	ΔG (kJ/mol)
303	8,271	54,26	6,560	1,881	0,0033			-4,72
313	5,208	55,02	10,565	2,358	0,0032			-6,19
323	3,183	55,53	17,445	2,859	0,0031	39,769	0,147	-7,65
333	13,375	52,98	3,961	1,377	0,0030			-9,12
343	33,347	47,99	1,439	0,364	0,0029			-10,59

Persamaan termodinamika sebagai berikut,

$$\ln \frac{Q_e}{C_e} = \frac{\Delta S}{R} - \frac{\Delta H}{RT}$$

Persamaan regresi linear:

$$y = ax + b$$

$$y = -4783,4x + 17,659$$

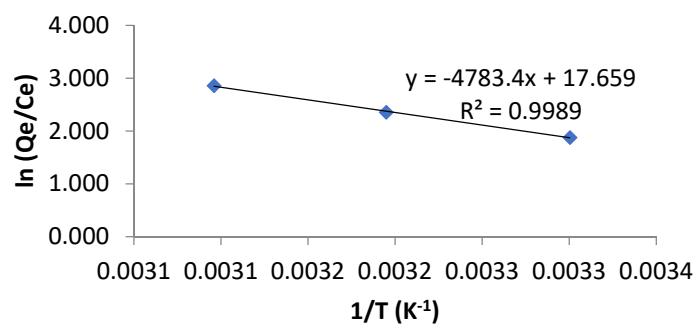
Sehingga,

$$\begin{aligned} \text{Slope} &= -\left(\frac{\Delta H}{R}\right) \\ \Delta H &= -(slope \times R)/1000 \\ &= -(-4783,4 \times 8,314 \text{ J/K.mol})/1000 \\ &= 39,769 \text{ kJ/mol} \end{aligned}$$

$$\begin{aligned} \text{Intersept} &= \frac{\Delta S}{R} \\ \Delta S &= (\text{intersept} \times R)/1000 \\ &= (17,659 \times 8,314 \text{ J/K.mol})/1000 \\ &= 0,147 \text{ J/K.mol} \end{aligned}$$

Suhu 30 °C (303 °K)

$$\begin{aligned} \Delta G &= \Delta H - (T \times \Delta S) \\ &= 39,769 - (303 \times 0,147) \\ &= -4,716 \text{ kJ/mol} \end{aligned}$$



Lampiran 18. Gambar Penelitian



Larutan
CaO/Fe₃O₄



Endapan CaO/Fe₃O₄



Komposit CaO/Fe₃O₄



Larutan *congo red* sebelum adsorpsi untuk penentuan waktu kontak kondisi optimum



Larutan *congo red* setelah adsorpsi untuk penentuan waktu kontak kondisi optimum (dari kiri ke kanan 10, 20, 30, 40, 50 dan 60 menit).



Larutan *congo red* setelah adsorpsi untuk penentuan konsentrasi pada kondisi optimum (dari kiri ke kanan 0, 25, 50, 75, 100 dan 110 mg/L).



Larutan *congo red* setelah adsorpsi untuk penentuan konsentrasi pada kondisi optimum (dari kiri ke kanan 125, 150, 175, 200, 225, 250 dan 300 mg/L).



Larutan *congo red* sebelum adsorpsi untuk penentuan suhu pada kondisi optimum



Larutan *congo red* setelah adsorpsi untuk penentuan suhu pada kondisi optimum (dari kiri ke kanan 30, 40, 50, 60 dan 70 °C).



a) Larutan *congo red* sebelum adsorpsi b) Larutan *congo red* setelah adsorpsi