

Kinetics and Thermodynamics Interaction Between Bentonite Inserted Organometallic Compounds $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ With Methylene Blue Dye In Aqueous Medium

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Kinetics and Thermodynamics Interaction Between Bentonite Inserted Organometallic Compounds $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ With Methylene Blue Dye In Aqueous Medium

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Abstract. Bentonite insertion was conducted with organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ and then tested its stability at various pH, then its interaction between bentonite inserted by organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3]$ with methylene blue dye. The interaction between organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3]$ with methylene blue showed an adsorption rate of 15.49 min^{-1} at the concentration of methylene blue 25 mg/L . The adsorption capacity and adsorption energy (ΔE) were 2.74 mol/g and 5.58 kJ/mol , respectively, at temperature 70°C where visible trends of enthalpy (ΔH°) and entropy (ΔS°) values decrease with increasing concentration of methylene blue.

Keyword: bentonite, adsorption, methylene blue, organometallic, $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$

1. Introduction

Bentonite is a type of mineral smectite composed by an aluminosilicate, forming a layered structure and is a good cation exchanger. The main content of bentonite is montmorillonite. Montmorillonite has a cavity which causes a very large surface area of up to $700\text{-}800 \text{ m}^2/\text{g}$ [1]. This specific surface area is exposed to water dispersion, due to its high expansion ability and causes montmorillonite to accept organic compounds and metal ions.

The ability of bentonite as an adsorbent or catalyst can be improved by widening the distance between layers through insertion process that will produce a pillared or inserted bentonite [2]. Many researchers have made modifications through bentonite insertion. Characterize modified bentonite with Al as a polycation, performs inserted bentonite process using Aluminum metal. The results showed an increase in the surface area of bentonite when the addition of micro cation solution of Al



into the suspension of Ca-bentonite[3]. However, microcations that have been developed have not been effectively used as adsorbents or catalysts, since the obtained surface area is still small. The layer of bentonite increased when the ammonium salt is added to the bentonite simultaneously with microcation Al. However, the results obtained are still not effectively used as adsorbents, since they only have small surface area. Therefore in order to produce bentonite which has a large surface area requires a large positively charged compound (macrocation) [4]. This macrocation is derived from the synthesis results performed in the laboratory through a process of chemical synthesis.

In this study, bentonite macrocation is inserted with an organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ and subsequently used as adsorbents to adsorb methylene blue dye. The inserted bentonite is characterized using XRD analysis, and identified of their functional group by a spectrophotometer FTIR. The parameters tested in the dye adsorption process are: the influence of adsorption time, the effect of initial concentration of adsorbate and adsorption temperature.

2. Methodology

Materials used in this research were natural bentonite, chromium nitrate, formic acid, hydrochloric acid, sodium hydroxide, nitrogen gas, methylene blue and distilled water, while instrumentation applied for analysis were X-ray diffractometer Shimadzu lab X-type 6000, spectrophotometer FTIR Shimadzu Prestige-21, and UV-Vis Spectrophotometer Thermo Scientific Genesis 20.

2.1 Preparation of Bentonite and Characterization

Natural bentonite samples were heated using a furnace at a temperature of 400 °C. Next, a 100 g bentonite product was immersed in 500 mL of H_2SO_4 0,5 M and stirred using magnetic stirrer for 2 h. then filtered and dried. Bentonite acidification that has been dried and was mashed with crushed and characterized using XRD diffraction, FTIR spectrophotometer analysis.

2.2 Synthesis of Organometallic Compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ and its characterization

Organometallic compounds $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ synthesized by mixing $\text{Cr}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ (40 g) in 50 mL of distilled water and stirred using a magnetic stirrer. 100 ml of NaOH 3 M was added to the solution for 10 minutes to obtain a solution with green color. The obtained solution was filtered using filter paper. 12.5 mL of formic acid was added into the residue and refluxed for 2 hours, then allowed to stand at room temperature a few minutes and was filtered to obtain green color crystals [5]. The dried green crystals product was analyzed using a FT-IR Spectrophotometer.

2.3 Insertion of Organometallic Compounds $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ into Bentonite and its Characterization

Bentonite insertion process was made in several weight ratio of activated bentonite: organometallic compounds $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ at (2.5:1), (1:1), (1:2), (1:3), respectively. A 2.5 g of activated bentonite was dissolved in 200 mL of distilled water into different flasks. 100 mL of NaOH 1 M was added into the flasks containing 1; 2.5; 5, and 7.5 g of organometallic compounds $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$. Next, the mixtures were poured into the flask which already contains activated bentonite and stirred for 24 hours using a magnetic stirrer at room temperature under nitrogen air condition [6]. The results obtained were then filtered and dried at room temperature. Results of bentonite inserted by organometallic compounds $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ at every weight ratio subsequently characterized using XRD diffraction, FT-IR Spectrophotometer analysis.

2.4 Adsorption of methylene blue dye by Activated Bentonite and Bentonite inserted Organometallic Compounds $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$

2.4.1 Effect of Adsorption Time and Kinetics Parameters

The methylene blue adsorption kinetics was studied by performing the adsorption process at constant room temperature by varying the contact time to monitor the effect of the time change on the adsorption percent. Amount of 0.01g activated bentonite, and 0.05 g of bentonite inserted organometallic compounds $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ added into 50 mL of 25 mg/L methylene blue solution then homogenized with a horizontal shaker at a predetermined interval time. The adsorption time varied from 10; 20; 30; 40; 50; 60; 70; 80, and 90 min. After adsorption process the

methylene blue concentration in solution was measured by using a UV-Vis Spectrophotometer at a wavelength of 665 nm.

2.4.2 Effect of Initial Concentration and Temperature and Thermodynamics Parameters

Thermodynamic parameters of adsorption of methylene blue by activated bentonite and bentonite inserted organometallic compounds $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ through various initial concentrations of methylene blue and adsorption temperature. Amount of 0.01g activated bentonite and 0.05 g of bentonite inserted organometallic compounds $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ each adsorbent interacted with 50 mL of methylene blue solution at various concentrations of 10; 15; 25; 30 and 40 mg/L and then homogenized using a horizontal shaker for 30 min at various temperatures 30; 40; 50; 60 and 70 °C. The mixture then measured using a UV-Vis Spectrophotometer at a maximum wavelength of 665 nm to determine the residual concentration of the methylene blue.

3. Results and Discussions

3.1 Synthesis and Characterization of Organometallic Compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ Using FT-IR Spectrophotometer

Synthesis of organometallic compounds $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ based on the procedures carried out by Lesbani [7]. At the end of the synthesis process obtained green colored crystals had formed indicating the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ were then characterized using FT-IR spectrophotometer to identify functional groups of the organometallic compound.

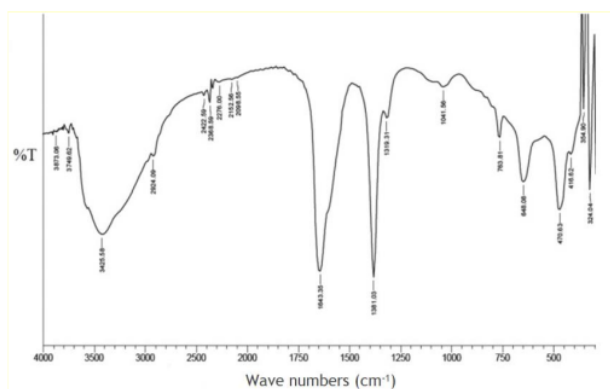


Figure 1. The FT-IR spectra of Organometallic Compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$

The FT-IR spectra in Figure 1. shows the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ have a distinctive vibration at wave number 648 cm^{-1} ($\text{Cr}_3\text{-O}$), and broadband at wave number 3428 cm^{-1} which is stretching vibration of -OH group of molecules of H_2O were detected in the solid organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$. The existence of a formic acid group that serves as a ligand contained in the wave number 2800-2950 cm^{-1} and the cluster of NO_3^- appears at wave number 1381 cm^{-1} which is a counterion [5]. Furthermore, the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ used in the process of insertion into the bentonite activation results that the product will be applied as an adsorbent in the adsorption process of methylene blue dye.

3.2 Characterization of Bentonite and Bentonite Inserted Organometallic Compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ using XRD Diffraction, FTIR Spectrophotometer Analysis

Bentonite has a distinctive basal spacing in the range of diffraction angle 2θ between 2-6° [7]. It is characterized by the diffraction angle (2θ) in natural bentonite, bentonite heating to 400 °C, and bentonite results of acidification using sulfuric acid are diffracted at 1°; 3.3 °; and 4.1 ° with basal spacing by 21.2 Å; 26.2 Å; and 21.2 Å, respectively. Diffractogram of natural bentonite, bentonite

heated at a temperature of 400 °C, and bentonite acidification using sulfuric acid results shown in Figure 2.

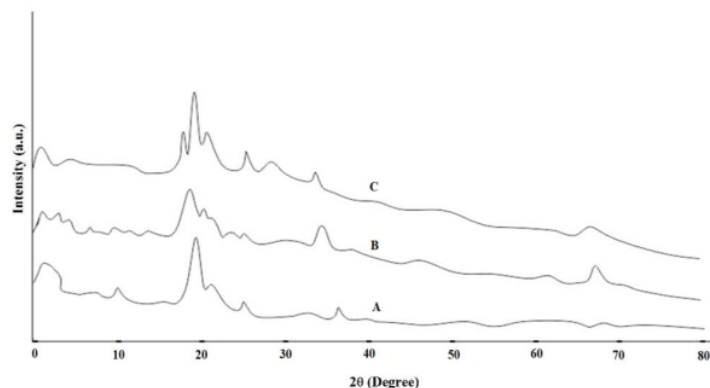


Figure 2. The XRD pattern in (a) Natural bentonite, (b) Bentonite heated at a temperature of 400 °C, and (c) Bentonite acidification results using sulfuric acid 0.5M

Based on data from the XRD measurement results of the analysis in Figure 2 shows the large diffraction angles appear on the area diffraction angle of 19°, 20°, and 34° which indicates the bentonite is a class of layered material that contains several minerals including mineral illite, montmorillonite, and quartz [8]. Diffraction typical of natural bentonite, bentonite heating to 400 °C and acid bentonite showed that the bentonite has a high crystallinity.

Bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ further characterized using XRD as shown in Figure 3.

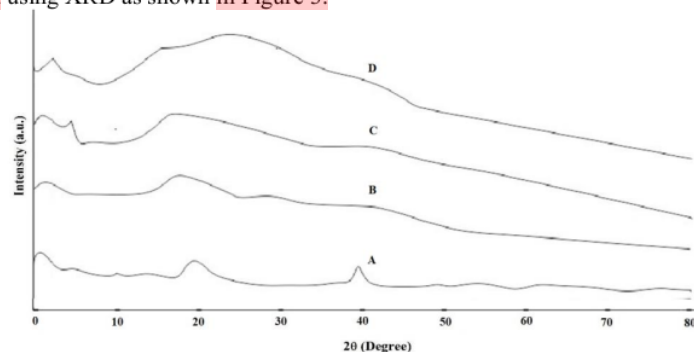


Figure 3. The XRD pattern of bentonite inserted organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ in the ratio of (A) 2.5:1; (B) 1:1; (C) 1:2 and (D) 1:3

The results of XRD measurements on bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ change in the angle of diffraction 2θ agree. The bentonite and the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ ratio (2.5:1), (1:1), (1:2) and (1:3) shows a typical diffraction angle on bentonite which appeared in the area that is 3.3° 2θ with basal spacing of 26.4 Å to Figure 3.A, 26.5 Å in Figure 3.B, 26.2 Å in Figure 3.C, while in Figure 3.D. 26.2 Å, respectively. In the insertion bentonite, the diffraction tends to widen which decrease of crystallinity due to the presence of water molecule in the organometallic compound. The FT-IR spectrophotometer data shows the presence of hydroxyl groups caused by water molecules

absorbed OH on the surface of the octahedral layer and Si-O-Si groups in the tetrahedral layer[9]. FT-IR spectra of natural bentonite, bentonite heating to 400 °C, and a sulfuric acid activated bentonite is shown in Figure 4.

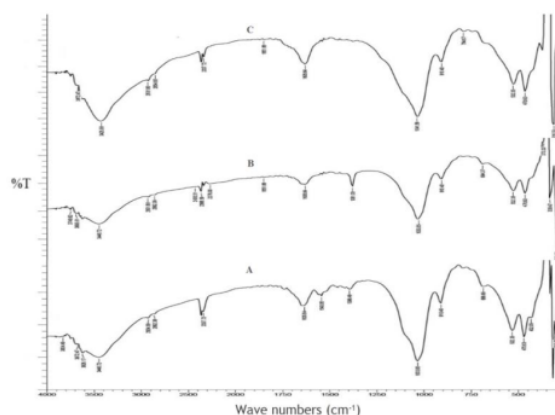


Figure 4. The FT-IR spectra of (a) Natural bentonite, (b) Bentonite heated at a temperature of 400 °C, and (c) Bentonite results in acidification using sulfuric acid 0.5M

The activation process by heating causes reduces the intensity at the area of wave numbers 3448.7 cm⁻¹ and 1635.6 cm⁻¹ indicate the water content in bentonite was reduced. At the OH bending vibration of water molecules was observed at 1635.6 cm⁻¹ region which is an OH vibration of water molecules trapped within the silicate framework (water of crystallization). The comparison data of wavenumber FT-IR spectra of natural bentonite, bentonite heating at a temperature of 400 °C, and bentonite acidification using sulfuric acid 0.5 M results outlined in Table 1.

Table 1. Data of wave number of natural bentonite, bentonite heated at a temperature of 400 °C, and bentonite results acidification by sulfuric acid 0.5 M

Functional group	Wavelength (cm ⁻¹)		
	Natural bentonite	Bentonite heated at 400 °C	Bentonite acidification
Stretching Si-O-Si	1033.8	1033.8	1041.5
Stretching HOH	3448.7	3448.7	3425.5
Buckling Al-O-Al	910.4	910.4	910.4
Buckling HOH	1635.6	1635.6	1635.6
Buckling Al-O-Si	532.3	532.3	532.3
Buckling Si-O-Si	470.6	470.6	470.6

Based on Table 1 shows that the shift of wavenumber of 1033.8 cm⁻¹ to 1041.5 cm⁻¹ that indicates the vibrational stretch from the group Si-O-Si was observed as a broad absorption peak with a sharp intensity indicating a high content of montmorillonite on bentonite[10]. The wave numbers 3626.1 cm⁻¹ indicates stretching vibration of the OH group in the Al layer octahedral Al-OH or Mg-Al.

The product of the insertion process is then characterized using a FT-IR spectrophotometer. Figure 5 shows the absorption peaks in the insert of the organometallic compound bentonite [Cr₃O(OOCH)₆(H₂O)₃](NO₃) with multiple comparisons. The Cr-O vibration of the organometallic compound that inserted into bentonite indicated by absorption band at 640-700 cm⁻¹ region and can also be seen that there is a shift wavenumber 1635.6 cm⁻¹ to 1597 cm⁻¹ in buckling vibration of OH in bentonite resulting from insertion of organometallic compounds by comparison

(1:2) and (1:3). The shift wavenumbers also occur in the bending vibration of Si-O-Si on bentonite the insert of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ with a ratio (1:3) the wave number of 470.6 cm^{-1} to 478.6 cm^{-1} .

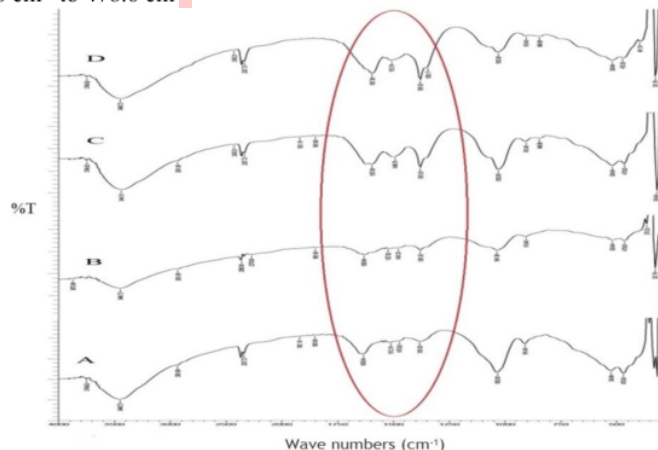


Figure 5. FT-IR spectra bentonite inserted organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ in the ratio of (A) 2.5: 1, (B) 1:1, (C) 1:2, and (D) 1:3

Based on the FT-IR spectra the insertion process is shown in the ratio (1:2) and (1:3) with sharp spectrum compared to a ratio (2.5:1) and (1:1). Therefore, the optimal insertion was in the ratio (1:2) and (1:3). The FT-IR wavenumber data of Figure 5. are summarized in Table 2.

Table 2. Data of wave number of bentonite inserted organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ in the ratio of (A) 2.5: 1, (B) 1:1, (C) 1:2, and (D) 1:3

Functional group	Ratio of Bentonite : $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$			
	2.5:1	1: 1	1: 2	1: 3
	Wave number (cm^{-1})			
Stretching HOH	3448.7	3448.7	3441	3448.7
Buckling HOH	1635.6	1635.6	1597	1597
Stretching Si-O-Si	1033.8	1041.5	1033.8	1033.8
Buckling Al-O-Al	910.4	910.4	910.4	910.4
Buckling Al-O-Si	524.6	524.6	524.6	524.6
Buckling Si-O-Si	470.6	470.6	470.6	478.6
Cr-O	670	700	673	673

3.3 Effect of Adsorption Time of Methylene Blue adsorption by bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$

Effect of adsorption time of methylene blue adsorption was conducted to determine the optimum time interaction between methylene blue with an adsorbent activated bentonite and bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$. An equilibrium state characterizes the optimum interaction between the concentration of the methylene blue and the adsorbent. The duration of adsorption time affects the absorption process [11]. This is because the longer the adsorbent interaction with the adsorbate allows the number of collisions to occur. According to the theory of collision, the reaction rate takes place on the number of collisions of the unity of time, the more collisions that occur, the faster the reaction takes place. Chart the influence of time methylene blue adsorption to the adsorption capacity of the adsorbent activated bentonite and bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ shown in Figure 6.

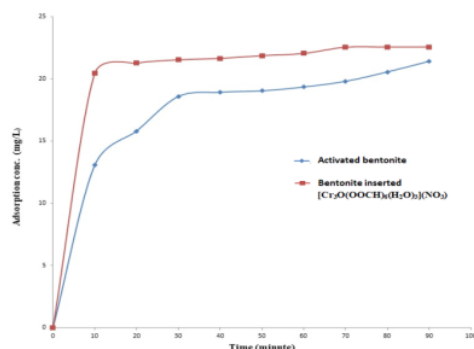


Figure 6. Effect of adsorption time of methylene blue by activated bentonite and bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$

Based on Figure 6, seen on activated bentonite (control) the amount of methylene blue that adsorbed at first 10 minutes relatively slow and increase gradually and then to stable adsorption at an additional time. Adsorption of methylene blue on bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ is high absorption rate and close to stable. According to Jankowska (1991), if the adsorbate has filled all the pores of the adsorbent will occur resulting in saturation of adsorption decreased reactivity.

Adsorption Kinetics is used to determine the adsorption rate occurring in the adsorbate to the adsorbent and is affected by time [12]. The rate of adsorption kinetics parameter obtained from Langmuir equations

$$\frac{\ln \frac{C_0}{C}}{C} = k_1 \frac{t}{C} + K \quad (1)$$

where:

- C_0 = Initial concentration (mg/L)
- C = Conc. after interaction time (mg/L)
- t = Adsorption time (minute)
- k_1 = Adsorption rate (menit^{-1})
- K = Adsorption equilibrium constant.

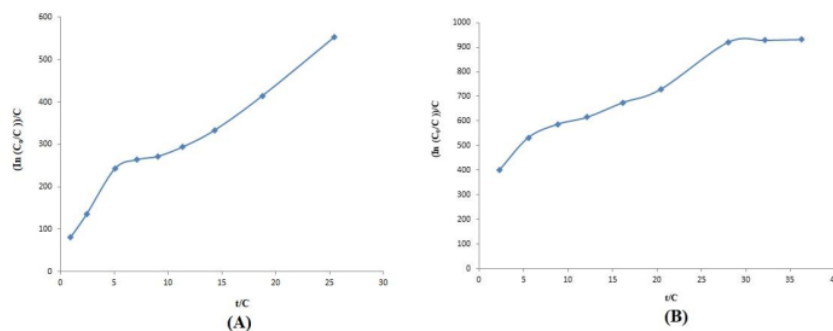


Figure 7. Kinetic parameters adsorption of methylene blue by (A) activated bentonite, and (B) bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$

The curve of kinetic parameters for the activated bentonite and bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ are presented in Figure 7. The rate of adsorption constants can be calculated from Langmuir equation by plotting $\ln(\text{C}_0/\text{C})/\text{C}$ versus t/C . The slope as a adsorption rate (k_1) and correlation coefficient (R^2) of the plot $\ln(\text{C}_0/\text{C})/\text{C}$ versus t/C in adsorption of methylene blue by activated bentonite (A), and bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ (B). The adsorption rate (k_1) where 1.25 min^{-1} and 15.49 min^{-1} , respectively. The correlation coefficient for both adsorbents about (> 0.9) indicates that the process of adsorption kinetics of methylene blue meets to Langmuir kinetics equation [13].

3.4 Effect of Temperature and Initial Concentration of Methylene Blue and the Determination of Thermodynamic Parameters

The effect of temperature in the adsorption process of methylene blue was studied at various temperature interaction of 30, 40, 50, 60, and 70 °C, respectively. The effect of the initial concentration of the methylene blue eq.10, 15, 25, 30, and 40 mg/L, respectively to adsorbents (A) activated bentonite, and (B) bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ as shown in Figure 8.

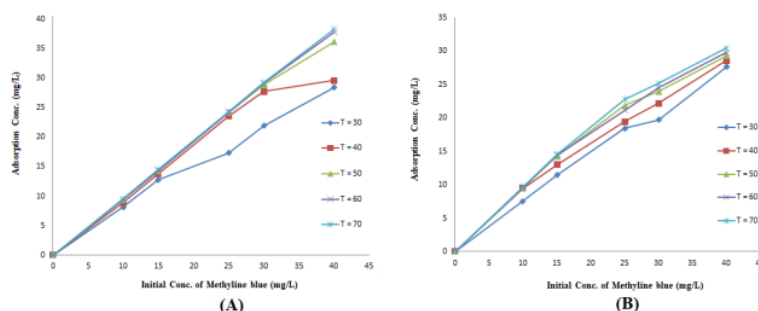


Figure 8. Effect of adsorption temperature and initial concentration of methylene dye by (A) activated bentonite, and (B) bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$

In Figure 8, shows the effect of temperature and initial concentration of methylene dye by (A) activated bentonite, and (B) bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$. It is seen that the higher the temperature and the concentration, it will increase the amount of methylene blue adsorbed. Based on the adsorption of methylene blue at various temperature and initial concentration give thermodynamic parameters in the adsorption system. Parameters such as adsorption capacity (b), the adsorption energy (E), enthalpy (ΔH) and entropy (ΔS) is presented in Table 3.

In Tabel 3. showed increased adsorption energy (E) as increased of temperature on activated bentonite, and bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$. The activated bentonite has adsorption energies of 10.69 kJ/mol and for bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ has adsorption energy of 5.58 kJ/mol, respectively at a temperature of 70 °C.

Thermodynamic parameters from the adsorption process methylene blue, such as enthalpy (ΔH) and entropy (ΔS) can be calculated from the slope and intercept of $1/T$ as the x-axis against $\ln K_d$ as the y-axis obtained from Equation 2.

$$\ln K_d = \frac{\Delta S}{R} - \frac{\Delta H}{RT} \quad (2)$$

Where:

ΔH = enthalpy

ΔS = entropy

K_d = coefisien distribusi of adsorbat (Q_e/C_e)

R = constanta of gas (8.314 J/mol K)

T = temperature

Table 3. The adsorption capacity (b), the adsorption energy (E), enthalpy (ΔH) and entropy (ΔS) of the adsorption of methylene blue by (A) activated bentonite, and (B) bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$

Adsorbent	T (°C)	b (mg/g)	E (kJ/mol)	C _o (mg/L)	R ²	ΔH (kJ)	ΔS (kJ/K)
Activated Bentonite	30	10.32	3.60	10	0.914	31.60	0.131
	40	16.23	3.40	15	0.916	32.39	0.136
	50	59.52	8.32	25	0.717	50.84	0.194
	60	158.73	10.66	30	0.833	51.02	0.194
	70	192.31	10.69	40	0.938	51.03	0.188
Bentonite Inserted $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$	30	1.57	5.15	10	0.660	42.49	0.155
	40	1.68	3.62	15	0.934	50.59	0.178
	50	2.09	4.97	25	0.859	26.04	0.094
	60	2.15	4.77	30	0.953	21.13	0.075
	70	2.74	5.58	40	0.987	7.29	0.031

Enthalpy value (ΔH) and entropy (ΔS) in the methylene blue adsorption by activated bentonite and bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ as presented in Table 3. increased with increasing concentrations of methylene blue. The entropy (ΔS) at a concentration of methylene blue 40 mg/L was decreased for the bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$. The enthalpy (ΔH) of activated bentonite with methylene blue concentration of 40 mg/ is 51.03 kJ, and the bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ with a concentration of 15 mg/L is 50.59 kJ, whereas the entropy (ΔS) the greatest on bentonite activation results in the concentration of the methylene blue 30 mg/L is 0.194 kJ/K and the bentonite inserted with a concentration of 15 mg/L is 0.178 kJ/K with adsorption capacity (ΔE) were 2.74 mol/g at temperature of 70 °C [5].

4. Conclusions

Bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ has been successfully synthesized in various proportions. Characterization using XRD analysis did not show that the optimal insertion occurs at a various weight ratio. Further characterization using FT-IR spectrophotometer showed that the optimal insertion process occurs on a comparison of (1:2) and (1:3) showed a wider spectrum and sharper compared with a ratio (2.5:1) and (1:1). Bentonite inserted of the organometallic compound $[\text{Cr}_3\text{O}(\text{OOCH})_6(\text{H}_2\text{O})_3](\text{NO}_3)$ absorption of methylene blue at various contact time and temperatures gave the adsorption rate at a concentration of 25 mg/L of 15.49 min⁻¹. The adsorption capacity (b) and the adsorption energy (E), the largest at a temperature of 70 °C with respective values of 2.74 mg / g and 5.58 kJ/mol and at variable concentrations showed enthalpy (ΔH), and entropy (ΔS) decreased with increasing concentrations of methylene blue.

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References

- [1] Bendou S and Amrani M 2014 *J. Miner. Mater. Charact. Eng.* **2** 404–13
- [2] Bergaya F, Jaber M and Lambert J-F 2012 (Springer, London) pp 41–75

- [3] Nagendrappa G 2011 *Appl. Clay Sci.* **53** 106–38
- [4] Zhou C H 2011 *Appl. Clay Sci.* **53** 87–96
- [5] Paluta Utami H and Marihot Siburian D 2016 *Sci. Technol. Indones.* **1** 20–4
- [6] Vitanesa L, Nardo Purba R, Lesbani A and Said M 2017 *Sci. Technol. Indones.* **1** 9–16
- [7] Lesbani A, Kawamoto R, Uchida S and Mizuno N 2008 *Inorg. Chem.* **47** 3349–57
- [8] Kouraichi S, El-Hadi Samar M, Abbessi M, Boudouh H and Balaska A 2015 *Catal. Sci. Technol.* **5** 1052–64
- [9] Uddin F 2008 *Metall. Mater. Trans. A* **39** 2804–14
- [10] Palin E J, Dove M T, Redfern S A T, Saniz-Diaz C I and Lee W T *Phys. Chem. Miner.* **30** 293–304
- [11] Mohadi R, Kurniawan C, Yuliasari N, Hidayati N and Lesbani A 2015 *Prog. Chem. Appl. Chitin its Deriv.* **20** 213–21
- [12] Taher T, Mohadi R, Rohendi D and Lesbani A 2017 p 20-28
- [13] Professor I, Moradi M, Dehpahlavan A, Rezaei Kalantary R, Ameri A, Farzadkia M and Izanloo H 2015 *Environ. Heal. Eng. Manag. J.* **2** 99–106

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