

## Adsorption of reactive yellow BF-3R dye by CTABr modified zeolite NaY

Adsorção do corante amarelo BF-3R reativo por zeólita NaY modificada com CTABr

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### Abstract

Textile industries generate effluents composed of organic salts and complexes from dyes not fixed on fabrics, or not degraded by the inefficiency of conventional treatment processes, which represents a high potential for environmental impact due to inadequate disposal of the generated effluent. Zeolites are porous materials that have a three-dimensional structure containing tetrahedrals of AlO<sub>4</sub> e SiO<sub>4</sub> which can be modified to improve its properties. The adsorption process using zeolites as adsorbents can be considered an excellent economic physical treatment to solve or minimize such a problem. This work presents an experimental study focusing on the preparation and characterization of zeolite NaY and modified with organic surfactant cetyltrimethylammonium bromide (CTABr) intended to be used as adsorbent in the process of removing yellow dye BF-3R in dye-water system batch system. The samples were characterized by X-ray diffraction (XRD), Infrared spectroscopy (IR) and thermogravimetry (TG). The effect of process parameter such as pH was studied. Results revealed that even though the modified cetyltrimethylammonium bromide organic surfactant (CTABr) did not cause alterations on the zeolite NaY structure. The IR results revealed that CTABr was successfully incorporated to zeolite NaY structure. The best conditions were established with respect to pH to saturate the available sites located on the zeolite NaY and NaY\_CTABr surface. The maximum adsorption capacities were 3.35 mg/g for dye 5.35 using as-synthesized zeolite NaY and CTABr modified zeolite NaY. Modified zeolites are excellent adsorbents for removing reactive dyes from industrial wastewater.

**Keyword:** Zeolite Y; Surfactant modified zeolite; Adsorption; Yellow dye BF-3R; Dyes removal.

### Resumo

As indústrias têxteis geram efluentes compostos por sais orgânicos e complexos a partir de tintas não fixadas nos tecidos, ou não degradadas pela ineficiência dos processos convencionais de tratamento, o que representa um alto potencial de impacto ambiental devido ao descarte inadequado do efluente gerado. Zeólitas são materiais porosos que possuem uma estrutura tridimensional contendo tetraédricos de AlO<sub>4</sub> e SiO<sub>4</sub> que podem ser modificados para melhorar suas propriedades. O processo de adsorção utilizando zeólitas sintéticas e modificadas como adsorventes pode ser considerado um excelente tratamento físico econômico para solucionar ou minimizar tal problema. Este trabalho apresenta um estudo experimental com foco na preparação e caracterização da zeólita NaY e modificada com surfactante orgânico brometo de cetiltrimetilâmônio (CTABr) destinado a ser utilizado como adsorvente no processo de remoção do corante amarelo BF-3R em sistema batelada sistema corante-água. As amostras foram caracterizadas por difração de raios X (XRD), espectroscopia de infravermelho (IV) e termogravimetria (TG). O efeito do parâmetro do processo, como o pH, foi estudado. Os resultados revelaram que o surfactante orgânico brometo de cetiltrimetilâmônio modificado (CTABr) não causou alterações na estrutura da zeólita NaY. Os resultados de IV revelaram que o CTABr foi incorporado com sucesso à estrutura da zeólita NaY. As melhores condições foram estabelecidas com relação ao pH para saturar os sítios disponíveis localizados na superfície da zeólita NaY e NaY\_CTABr. As capacidades máximas de adsorção foram 3,35 e mg/g para o corante 5,35 usando zeólita NaY como sintetizada e zeólita NaY modificada por CTABr. As zeólitas modificadas são excelentes adsorventes para a remoção de corantes reativos de águas residuais industriais.

**Palavras-chave:** Zeólita Y; Zeólita Y modificada com surfactante; Adsorção; Corante amarelo BF-3R; Remoção de corantes.

## Resumen

Las industrias textiles generan efluentes compuestos por sales orgánicas y complejos a partir de tintes no fijados en los tejidos, o no degradados por la ineeficiencia de los procesos de tratamiento convencionales, lo que representa un alto potencial de impacto ambiental por disposición inadecuada del efluente generado. Las zeolitas son materiales porosos que tienen una estructura tridimensional que contienen tetraédricos de AlO<sub>4</sub> y SiO<sub>4</sub> que pueden modificarse para mejorar sus propiedades. El proceso de adsorción que utiliza zeolitas sintéticas y modificadas como adsorbentes puede considerarse un excelente tratamiento físico económico para resolver o minimizar dicho problema. En este trabajo se presenta un estudio experimental centrado en la preparación y caracterización de zeolita NaY y modificada con tensoactivo orgánico bromuro de cetiltrimetilamonio (CTABr) destinado a ser utilizado como adsorbente en el proceso de remoción del tinte amarillo BF-3R en el sistema por lotes del sistema colorante-agua. Las muestras se caracterizaron por difracción de rayos X (XRD), espectroscopia infrarroja (IR) y termogravimetría (TG). Se estudió el efecto de parámetros del proceso como el pH. Los resultados revelaron que aunque el tensioactivo orgánico de bromuro de cetiltrimetilamonio modificado (CTABr) no provocó alteraciones en la estructura de la zeolita NaY. Los resultados de IR revelaron que CTABr se incorporó con éxito a la estructura de la zeolita NaY. Se establecieron las mejores condiciones con respecto al pH para saturar los sitios disponibles ubicados en la superficie de la zeolita NaY y NaY\_CTABr. Las capacidades máximas de adsorción fueron 3.35 y mg/g para el tinte 5.35 usando zeolita NaY sintetizada y zeolita NaY modificada con CTABr. Las zeolitas modificadas son excelentes adsorbentes para eliminar los tintes reactivos de las aguas residuales industriales.

**Palabras clave:** Zeolita Y; Zeolita Y modificada con tensioactivo; Adsorción; Eliminación de tinte.

## 1. Introduction

With the advance of industrial production, dyes have been widely applied in various sectors, such as: textiles, inks, pharmaceuticals, cosmetics, plastics, paper, etc. (Radoor et al., 2021). The textile sector is considered one of the largest industrial water consumers in the world, being also responsible for inappropriately disposing of large amounts of effluents in water bodies and, thus, leading to the decline of ecosystem biodiversity, due to its high concentrations, strong toxicity, and low biodegradability (Radoor et al.; 2020; Ma et al., 2020).

Dyes are a major contributor to water source pollution, and textile industries worldwide are reported to be the main sources of dye effluent disposal (Nupearachchi et al., 2017; Wanyonyi et al., 2014). There are more than 100.000 commercially available dyes with more than  $7 \times 10^5$  tons of dyes produced annually (Jose et al., 2018). These materials have complex aromatic structures and exhibit great structural diversity, their properties are enhanced to resist fade, improve tissue distribution, and have a variety of shades, which makes them highly resistant to degradation (Kabra et al., 2011).

These organic compounds have three essential groups in their molecules: the chromophore, the autochrome and the matrix (Laurent et al., 2010). The chromophore is the active site of the dye and can summarize the spatial location of the atoms that absorb light energy, the most common groups of atoms in chromophores are nitro ( $-NO_2$ ), azo ( $-N=N-$ ), nitrous ( $-N=O$ ), thiocarbonyl ( $-C=S$ ), carbonyl ( $-C=O$ ), as well as the alkenes ( $-C=C-$ ) (Azzopardi et al., 2017; Benkhaya, Rabet, & Harfi, 2020). Reactive dyes are the most used because of their favorable characteristics of brilliant color, water resistance, simple application techniques and low energy consumption. Because they have different chemical structures, they are not easily biodegradable, therefore, even after extensive treatments, the color can remain in the effluent (Ahmad, & Rahman, 2011).

Adsorption is a physicochemical treatment method, in which an adsorbent material will remove specific molecules (adsorbate) from a liquid medium by physisorption and chemosorption interactions, which depends on several factors, such as: temperature, pressure, concentration of the medium reaction, physical and chemical characteristics of the adsorbent, as well as the surface area of it (Cooney, 1999; Ruthven, 1984; Ngulube et al., 2017). Different effective and low-cost adsorbents for dye removal were synthesized by different researchers, such as clay, magnetic nanoparticles, agricultural residues, and zeolites (Radoor et al., 2021; Sivalingam, & Sen, 2018).

Zeolites are hydrated microporous crystalline aluminosilicates with alternating tetrahedral units of SiO<sub>4</sub> and AlO<sub>4</sub> that are covalently joined by oxygen atoms to form well-defined structures, large surface area, wide channels, pore diameter with larger openings, in addition to exhibiting a large capacity for adsorption with good cation exchange properties (Johnson, & Arshad, 2014;

Lo et al., 2018). These materials have a negative charge due to isomorphic substitution by Al atoms in some Si places in their structure, which must be compensated by other cations, mainly from the 1A and 2A families (Khaleque et al., 2020).

To improve the properties of zeolites and obtain better adsorption efficiency in removing dyes, these materials must be modified. One of the methods of modification is the use of surfactants that are structurally composed with a small positive hydrophilic head that results in the occupation of only one site and has a hydrophobic hydrocarbon tail which helps to adsorb organic molecules in aqueous solution. (Zagho et al., 2021). The best-known cationic surfactants, used due to their efficiency in modifying porous materials, are cetyltrimethylammonium bromide, chloride, or hydroxide (CTABR, CTACL e CTAOH, respectively), mainly due to the low cost of these reagents (Martins et al., 2021).

Our research group has published some papers on the production of adsorbents and membranes for separation dyes (Barbosa et al., 2019; Barbosa et al., 2015; Barbosa, Rodrigues, & Rodrigues, 2019; Barbosa, Rodrigues, & Rodrigues, 2019; Lima et al., 2014; Lima, Paula, & Rodrigues, 2014; Nogueira et al., 2020; Oliveira et al., 2020; Paula, Paula, & Rodrigues, 2020; Rocha, Barbosa, & Rodrigues, 2016; Rocha, Barbosa, & Rodrigues, 2016; Rocha et al., 2017; Rocha et al., 2017; Rocha et al., 2015; Rodrigues, Barbosa, & Rodrigues, 2020; Rodrigues, Barbosa, & Rodrigues, 2020; Silva et al., 2019; Silva et al., 2019; Silva et al., 2019; Silva et al., 2019; Silva et al., 2020; Silva et al., 2020; Tomaz et al., 2019).

This work aims to examine the adsorption capacities of as-synthesized zeolite NaY and CTABr modified zeolite NaY for the sorption of reactive yellow dye BF-3R from aqueous solutions. The adsorption of reactive yellow dye BF-3R onto zeolite was studied by performing batch kinetic experiments. The effect of parameter such as pH was analyzed for the purpose of understanding the adsorption behavior of dye onto zeolites.

## 2. Methodology

This work was carried out at the Laboratório de Desenvolvimento de Novos Materiais (LABNOV), belonging to the Unidade Acadêmica de Engenharia Química, located at the Centro de Ciências e Tecnologia of the Universidade Federal de Campina Grande (UAEQ/CCT/UFCG).

### 2.1 Materials and Chemical

Deionized water, Sodium Aluminate ( $\text{NaAlO}_2$ ), Sodium Silicate ( $\text{Na}_2\text{SiO}_3$ ), Sodium Hydroxide ( $\text{NaOH}$ ), Cetyltrimethylammonium Bromide ( $\text{C}_{19}\text{H}_{42}\text{NBr}$ ) were purchased from Sigma-Aldrich (Merck).

Reactive Yellow BF-3R was supplied by Texpal Quím., São Paulo, Brazil. BF-5G is bifunctional dye, which is composed of a system of chromophores, linked to two reactive systems: a vinyl sulfone group and another chlorine triazine group. The main properties of Reactive Yellow BF-3R dye are summarized in Table 1.

**Table 1.** Properties of reactive yellow BF-3R dye.

Name	Dye	Molecular formula	CAS	Molecular mass (g.mol <sup>-1</sup> )
Reactive Yellow BF-3R dye	Reactive Yellow 145	$\text{C}_{28}\text{H}_{20}\text{ClN}_9\text{Na}_4\text{O}_{16}\text{S}_5$	93050-80-7	1024.89

Source: Authors.

### 2.2 Synthesis of the Zeolite NaY

A zeolite was synthesized according to the procedure reported in the literature (IZA (International Zeolite Association).

### Synthesis Gel (A)

The sodium hydroxide ( $\text{NaOH}$  - 4.07 g) was dissolved in deionized water ( $\text{H}_2\text{O}$  - 19.95 g) and the sodium aluminate ( $\text{NaAlO}_2$  - 2.09 g) was slowly added under constant stirring until total dissolution (solution 1). Then, 8.55 g of sodium silicate ( $\text{Na}_2\text{SiO}_3$ ) and 14.25 g of deionized water were added to the solution (1) and left under stirring for a period of 24 h at room temperature (synthesis gel A).

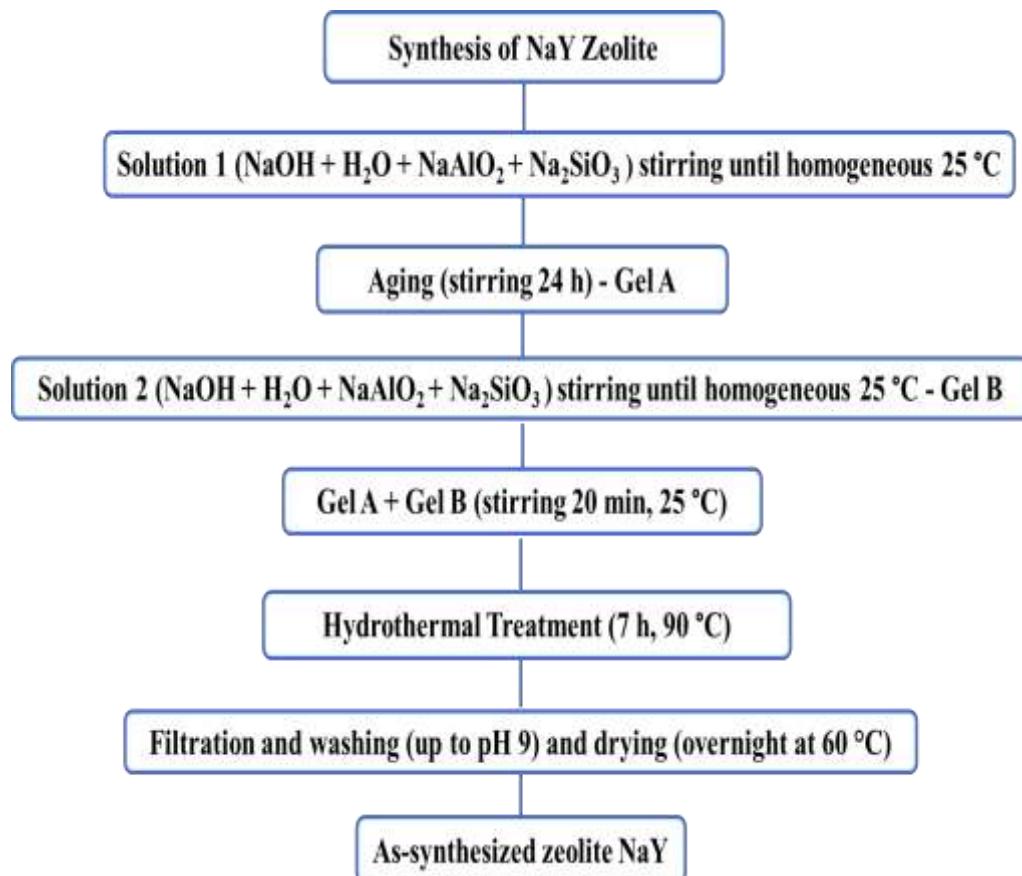
### Synthesis Gel (B)

After a period of 24 hours, another gel was prepared through the following steps: in a beaker, sodium hydroxide ( $\text{NaOH}$  – 0.04 g) was dissolved in deionized water ( $\text{H}_2\text{O}$  - 32.85 g) and then 3.28 g of aluminate was added, sodium, stirred until homogeneous, (solution 2). Then, 22.24 g of deionized water and 13.39 g of sodium silicate were added to solution (2), stirred in a beaker until dissolved (gel B). After the synthesis gel preparation process, 4.16 g of the gel (A) were mixed with the gel (B) and left under stirring for a period of 20 min. Then it placed in a stainless steel autoclave where the hydrothermal synthesis occurred at 90 °C for 7 h. The molar composition of the reaction mixture was 4.6  $\text{Na}_2\text{O}$ :  $\text{Al}_2\text{O}_3$ : 10 $\text{SiO}_3$ : 180 $\text{H}_2\text{O}$ .

After the hydrothermal treatment was completed, the autoclave was removed from the oven and cooled to room temperature. Subsequently, the sample was washed with distilled water until pH 9 and dried in overnight at 60 °C.

Figure 1 show the flow diagram synthesis of zeolite NaY.

**Figure 1.** Flow diagram synthesis of zeolite NaY.



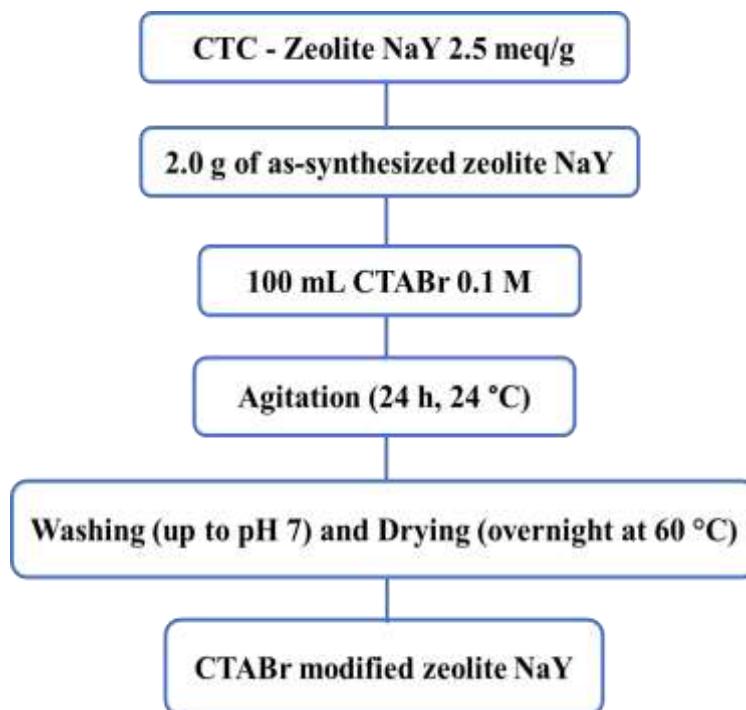
Source: Authors.

### 2.3 Modification of the zeolite NaY

The cation exchange capacity of zeolite Y is 2.5 meq/g (Hashemi et al., 2019). Modification of the zeolite NaY, according to the procedure described by authors (Shinzato, 2008), considering an ion exchange percentage of 100 %, a mixture of 2.0 g of zeolite NaY with a solution of 100 mL of CTABr 0.1 M was carried out using a magnetic stirrer at room temperature for 24 h.

Figure 2 show the flow diagram of the modification of zeolite NaY with CTABr.

**Figure 2.** Flow diagram of the CTABr modified zeolite NaY.



Source: Authors.

### 2.4 Characterization

#### 2.4.1 X-rays diffraction (XRD)

For the characterization of samples synthesized by XRD (X-rays diffraction), a Shimadzu XRD-6000 diffractometer with CuK $\alpha$  radiation was used. voltage of 40 KV, a current of 30 mA, a step size of 0.020 and a time per step of 0.60 seconds, with a sweep speed of 2° per minute and a 2θ angle ranging from 3° to 50°.

#### 2.4.2 Infrared spectroscopy (IR)

For to obtain the infrared, the IR MAGNA 560 ESPS Nicolet equipment was used. The samples in the form of tablets were previously oven dried and placed in the sample holder. IR spectra were obtained at wavelengths in the range 400-4000 cm<sup>-1</sup> with a 4 cm<sup>-1</sup> resolution.

#### 2.4.3 Thermogravimetry (TG)

Thermogravimetric analysis was performed in a TGA/SDTA 851 equipment in a nitrogen atmosphere with a gas flow of 250 mL·min<sup>-1</sup>. The sample was heated from room temperature up to 900 °C, at a heating rate of 10 °C·min<sup>-1</sup>.

### 2.5 Batch adsorption

Dye adsorption kinetic was determined from batch experiments with constant stirring (Tien, 1994).

The tests started with a solution of 1000 mg.L<sup>-1</sup> of the dyes, from which dilutions were made, whose absorbances were analyzed in a spectrophotometric device to obtain the calibration curve.

The adsorbed quantity of dye was calculated using the following equations (Wu et al., 2009):

$$\% \text{ Rem} = \left( \frac{C_i - C_f}{C_i} \right) * 100 \quad (1)$$

$$q_e = \frac{V}{m} (C_i - C_f) \quad (2)$$

Where: %Rem = Removal percentage and q<sub>e</sub> = Adsorption capacity (mg dye/g zeolite); C<sub>i</sub> = Initial concentration (mg.L<sup>-1</sup>); C<sub>f</sub> = Final concentration (mg.L<sup>-1</sup>); V = Volume of solution (L); m = mass of zeolite (g).

## 2.6 Influence of pH

The adsorption of reactive yellow BF-3R dye solution over varying pH (from 1.0 to 14.0) was studied under the following experimental conditions: reactive yellow BF-3R dye with an initial concentration (50 mg/L); zeolite (0.5 g); 200 rpm stirring at 25 °C and 120 min.

## 2.7 Adsorption kinetics

Reactive yellow BF-3R dye adsorption kinetics were acquired in batch experiments.

Based on reports from the reviewed literature, the ideal temperature for adsorption of dye is room temperature (Barbosa et al., 2019). Most authors reported a time of 1-3 h for adsorption process in the laboratory (Paula, Paula, & Rodrigues, 2020; Barbosa et al., 2019).

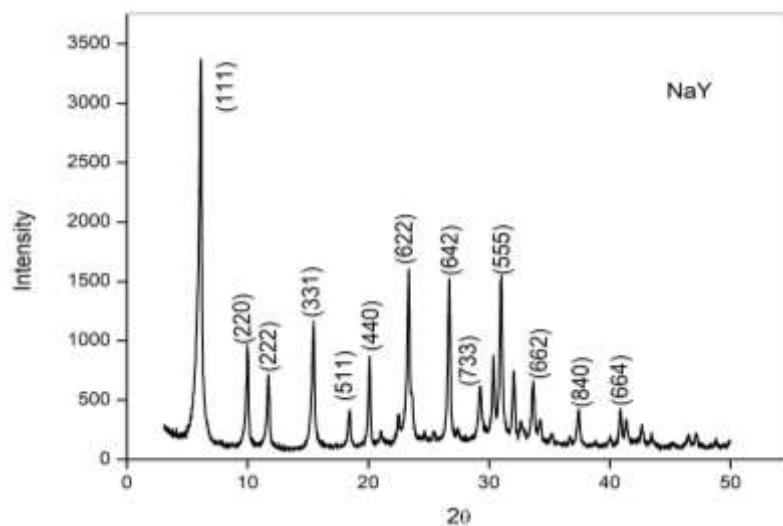
These experiments were performed at room temperature using a solution of 50 mg.L<sup>-1</sup> of reactive yellow BF-3R dye, which was put in contact with 0.5 g of zeolite. Adsorption experiments were conducted in erlenmeyer flasks at controlled pH 1 for zeolite NaY and pH 8 for CTABr modified zeolite NaY and under mechanical stirring at 200 rpm (Certomat MO). Aliquots from the solution were collected at different time intervals between 0 and 180 min. Afterward, the solutions were filtered and analyzed for residual reactive yellow BF-3R dye concentration with a UV-VIS 1600 (Pro-Analysis) absorption spectrophotometer in the region of ultraviolet-visible.

## 3. Results and discussion

### 3.1 X-ray diffraction (XRD)

The diffractograms of as-synthesized zeolite NaY and CTABr modified zeolite NaY are shown in Figures 3 and 4.

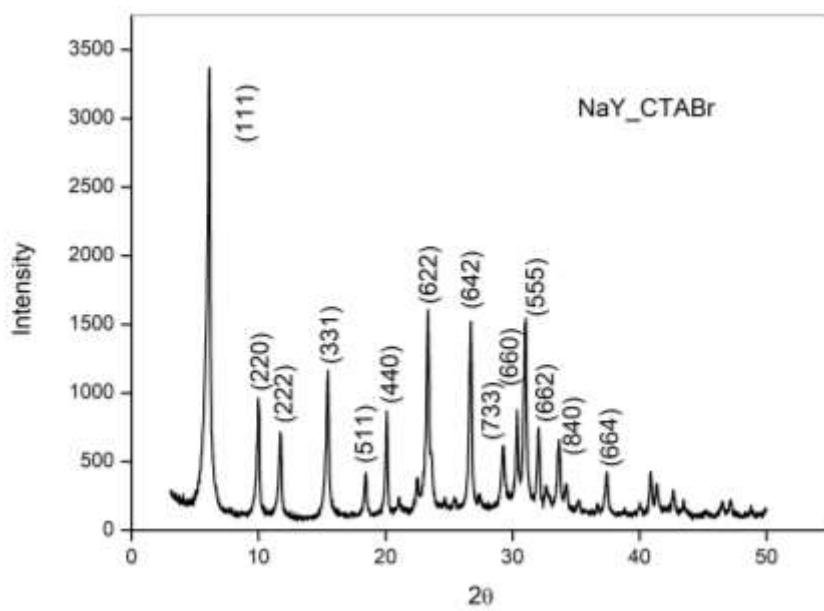
**Figure 3.** XRD pattern of as-synthesized zeolite NaY.



Source: Authors.

The NaY zeolite synthesized shown in Figure 3 showed well-defined and narrow peaks indicating that the zeolites obtained are characterized by high crystallinity and purity characteristic of the structure of this aluminosilicate in the range of  $2\theta=5$  to  $50^\circ$ , according to with the standard catalog card JCPDS 43-0168. This result agrees with the literature (Dabbawala et al., 2018).

**Figure 4.** X-ray diffraction pattern of the CTABr modified zeolite NaY.



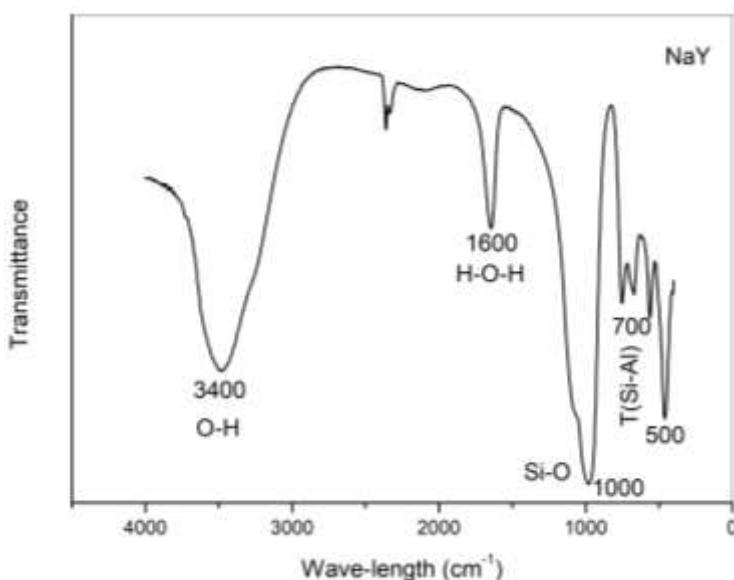
Source: Authors.

According to Figure 4, the XRD patterns of the CTABr modified zeolite NaY did not change, that is, the modification process did not change the structure of the NaY zeolite, maintaining its crystallinity due to its non-alteration of the Si/Al ratio (Lutz, 2014; Mirzaei et al., 2016; Hashemi, Eslami, & Karimzadeh, 2019). The peak intensity remained at, suggesting that the surfactant (CTABr) was adsorbed in the inner region of the zeolite NaY (Pukcothanung, Siritanon, & Rangsriwatananon, 2018). These results are similar using the mordenite zeolite and the ZSM-5 zeolite reported in the literature (Silva et al., 2019).

### 3.2 Infrared spectroscopy (IR)

The IR Spectroscopy of the as-synthesized zeolite NaY and CTABr modified zeolite NaY- which are given in Figure 5 and Figure 6.

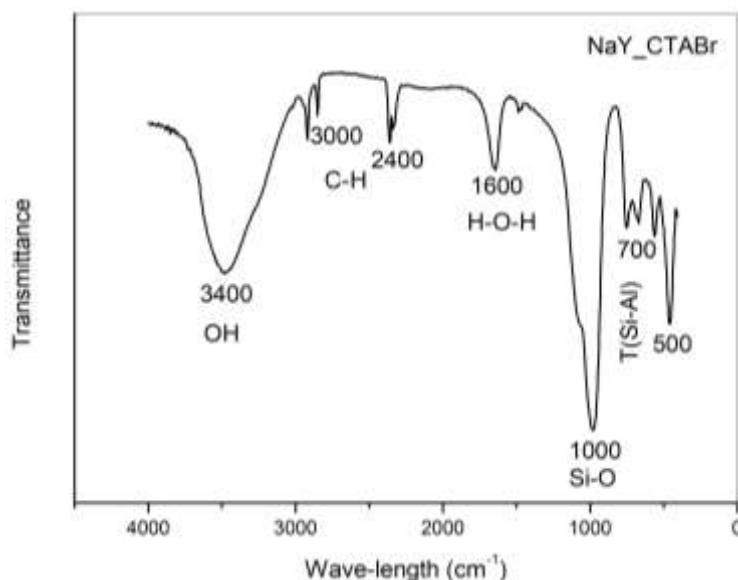
**Figure 5.** IR spectra of as-synthesized zeolite NaY.



Source: Authors.

Figure 5 illustrates typical infrared spectra of as-synthesized zeolite NaY. It is possible to observe the characteristic bands of the structure of this aluminosilicate that is found in the region of  $1100 - 450\text{ cm}^{-1}$  corresponding to the Si-O and Al-O groups. The primary  $\text{TO}_4$  units are combined in different ways to form different types of polyhedra and consequently different structures. The band in the region of  $1100 - 1000\text{ cm}^{-1}$  is attributed to the internal vibrations of asymmetrical stretching of the T(Si-Al)-O bonds and the band in the region between  $500$  and  $700\text{ cm}^{-1}$  is attributed to the symmetrical narrowing of the external tetrahedrons of the zeolite Y T-O (Taufiqurrahmi, Mohamed, & Bhatia, 2011; Oliveira et al., 2014; Huo, 2013). The band at  $1600\text{ cm}^{-1}$  refers to the angular deformation of the hydroxyl group at  $3400\text{ cm}^{-1}$  corresponding to the hydroxyl groups OH from the water molecules present in their cavities (Kulprathipanja, 2010).

**Figure 6.** IR spectra of CTABr modified zeolite NaY.



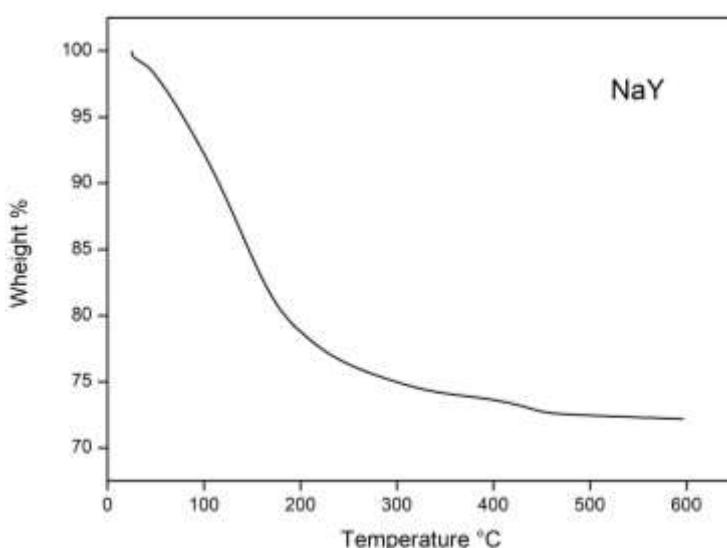
Source: Authors.

It can be observed that after modification of the zeolite NaY with the CTABr, changes occur (Figure 6). The bands in the 2400 - 3000 cm<sup>-1</sup> region arise from the symmetric and asymmetric elongation of C-H belonging to the surfactant, indicating that the modification with CTABr was efficient. (Pukcothanung, Siritanon, & Rangsriwatananon, 2018). The main characteristic bands of zeolite were maintained in the range of 480 to 1000 cm<sup>-1</sup> which are associated with Si-O and Al-O vibrations. The band referring to the hydroxyl group was maintained in the region of 3400 cm<sup>-1</sup>, showing that the structures of zeolites are stable after modification (Lin, & Zhan, 2012).

### 3.3 Thermogravimetry (TG)

The thermogravimetric analysis of the as-synthesized zeolite NaY and CTABr modified zeolite NaY are shown in Figures 7 and 8, respectively.

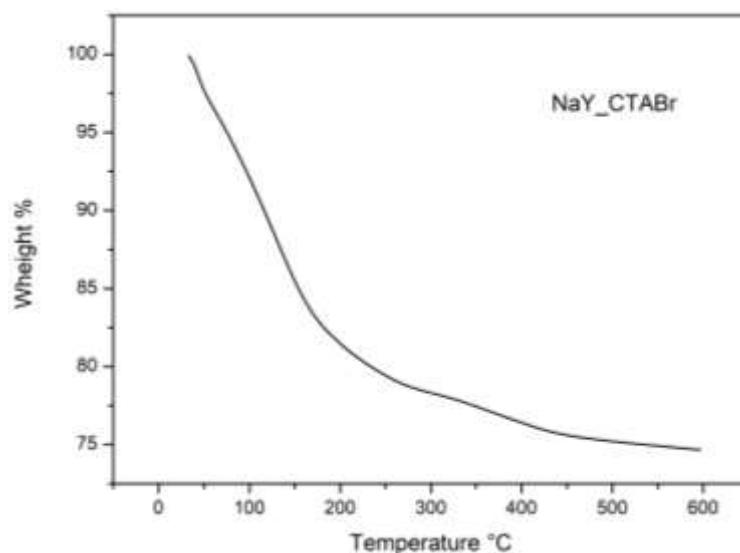
**Figure 7.** TG curve of as-synthesized zeolite NaY.



Source: Authors.

From the thermogravimetric curves of the samples of the as-synthesized zeolite NaY represented in Figure 7, that the most accentuated loss of mass is observed between approximately 25 and 250 °C, corresponding to 21.53 %, which corresponds to the elimination of physiosorbed water from the pores and the dehydration of sodium cations. The rest of the water present in the zeolites' cavities is gradually eliminated with the increase in temperature, resulting in gradual dehydration. The total mass loss for as-synthesized zeolite NaY was 25.09 %, from 400 °C onwards, no significant mass loss is observed. These results are like those found in the literature for NaY zeolites by other authors (Raharjo et al., 2019; Liu et al., 2003).

**Figure 8.** TG curve of CTABr modified zeolite NaY.



Source: Authors.

The thermogravimetric curve of the CTABr modified zeolite NaY (Figure 8) indicate a greater loss of mass regarding the desorption of water molecules adsorbed inside the structure of the materials up to a temperature of approximately 200 °C, which corresponds to 22.07 %, in the sequence, a second mass loss process related to the thermal decomposition of the CTABr surfactant, which occurs between 230 and 500 °C, was observed. After a temperature of 500 °C there is no significant mass loss, resulting in a total mass loss of 26.07 %. These results agree with those found in the literature by other researchers (Pukcothanung, Siritanon, & Rangsriwatananon, 2018).

### 3.4 Influence of pH

Table 2 shows the values of total removal percentage of reactive yellow BF-3R dye (% Rem) and adsorption capacity ( $q_e$ ) of as-synthesized zeolite NaY and CTABr modified zeolite NaY.

**Table 2.** Effect of pH on the adsorption of reactive yellow BF-3R dye in samples.

pH	% Rem	$q_e(\text{mg.g}^{-1})$	% Rem	$q_e(\text{mg.g}^{-1})$
1	61.1060	3.35	83.0147	4.52
2	45.5557	2.50	93.7316	5.10
3	46.3405	2.54	95.9007	5.22
4	43.9496	2.41	97.7297	5.32
5	45.8934	2.51	96.4981	5.25
6	42.4895	2.33	97.8492	5.32
7	44.3237	2.43	97.9503	5.33
8	43.4842	2.38	98.3915	5.35
9	43.3838	2.38	96.0937	5.23
10	44.8713	2.46	97.6378	5.31
11	42.4256	2.32	97.7022	5.32
12	41.6134	2.28	97.1966	5.29
13	49.6167	2.72	84.0165	4.57
14	24.7490	1.36	53.8786	2.93

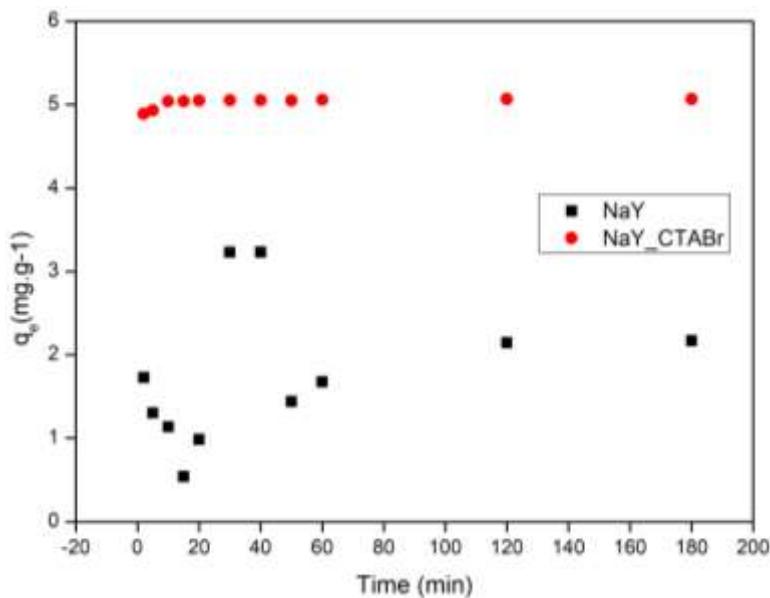
Source: Authors.

As shown in Table 1, the process showed low removal at basic pH for NaY zeolite without modification due to the properties of the adsorbent. as the pH value decreases. the removal percentage increases and consequently the adsorption capacity also increased. Changing the pH not only transforms the surface properties of the adsorbent. but also influences the existing shape of the adsorbent in the solution. changing both physical and chemical properties (Hayes, Leckie, & 1987). The process using CTABr-modified zeolite showed an excellent percentage of removal. where we can observe a significant removal at all pH. coming from two distinct regions in the same structure. a positive hydrophilic part that results in the occupation of only one location and has a tail length of hydrophobic hydrocarbon that helps to adsorb organic molecules in aqueous solution. which increases the interaction with effluents containing dyes (Salim, & Malek, 2016).

### 3.5 Adsorption Kinetics

The plots of  $q_e$  as a function of time at the initial reactive yellow dye BF-3R concentration are presented in Figure 9.

**Figure 9.** Reactive yellow BF-3R dye adsorption kinetics for samples.



Source: Authors.

Adsorption kinetics is mainly applied to portray the rate of adsorption between adsorbate by the adsorbent. In these experiments, since the experience time between the adsorbent and the adsorbate is quite short, it is necessary to consider the time and rate of adsorption necessary for the adsorption to reach equilibrium (Zou, Shi, & Deng, 2017; Cao et al., 2014). In Figure 7 it is possible to observe that equilibrium is reached after 2 hours for both materials, corresponding to 61.10 % removal for as-synthesized zeolite NaY and for CTABr modified zeolite NaY 98.39 % removal of the yellow dye BF-3R.

#### 4. Conclusions

In this work, zeolite NaY was synthesized from hydrothermal treatment, for the first time. Then, it was modified by CTABr surfactant (based on CEC of the synthetic zeolite NaY) in order to remove organic dye from wastewater.

The results indicated that the zeolite NaY and the modification process with the surfactant cetyltrimethylammonium bromide (CTABr) did not compromise the structure of the zeolite for adsorption of the yellow dye BF-3R.

The effect of process parameter such as pH was studied. The results of the adsorption tests showed a maximum value of adsorption capacity in acid medium for the synthesized zeolite NaY adsorbent, and for the CTABr-modified NaY zeolite the best results were found in the studied pH range, with greater removal, in the basic medium.

Finally, this study showed that dye removal zeolite capacity can be substantially improved by modifying its surface, with CTABr surfactant. According to the results obtained in this work, modified zeolite is an effective sorbent for the removal of yellow dye BF-3R from aqueous solutions.

The present study represents the development of suitable strategies to prepare zeolite with surfactant for current application in the removal of dyes, as well as future applications in the release of drugs.

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