Removal of a Bisoprolol drug from Aqueous Solutions onto Graphene Oxide/ Carboxymethyl cellulose sodium /Acryl acid polymer Composite by Adsorption

1 Masar A. Awad * and Layth S. Jasim Al-Hayder
Department of Chemistry, College of science, University of Al-Muthanna, Iraq
2 Department of Chemistry, College of Education, University of Al-Qadisiyah, Iraq
masara32@yahoo.com

Abstract
A polymer-based composite hydrogel was synthesized through chemical crosslinking by a free radical polymerization of acryl acid as a monomers and GO. GO /P (CMC -co- AA) was prepared. This composite hydrogel, were synthesized by using potassium persulfate as initiator and N, N –methylene bisacrylamide as cross-linker, X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), field-emission scanning electron microscopy (FE-SEM) , thermo gravimetric analysis (TGA) . Moreover, GO/P(CMC-co-AA) -structures were studied to show (BSP) adsorption from aqueous solution. The adsorption isotherms of Bisoprolol on the GO/P(CMC-co-AA) composite could be illustrated well by the Freundlich and Langmuir model. The thermodynamic factors (ΔG° , ΔH° and ΔS°) estimated, from the temperature-dependent isotherms revealed that the adsorption reaction of Bisoprolol on the GO/P(CMC-co-AA) composite was an exothermic and spontaneous process, obtaining an increase in the thermodynamic stability of the adsorption system . Finally, the results indicated that adsorption process followed two models and demonstrated that intraparticle diffusion plays a significant role in the adsorption mechanism.

Keywords: adsorption, Graphene oxide, hydrogels, Beta Blocker, Bisoprolol.

1.1-Introduction
Pharmaceuticals have been classified as one of the most significant groups and an emerging contaminants in wastewater .The concern for pharmaceuticals as toxic and hazardous substances not only for human life but also for the environmental [1]. This emerging contaminant arises from direct disposal of over plus drugs in hospitals and households, excretion from feces or urine after Pharmaceutical administration to animals and humans or from emission from production sites [2]. Furthermore, these emerging contaminants (drugs) may cause irreversible changes, long-term to the micro-organisms genome, which therefore increases their resistance bacteria life [3]. On the other hand, some drugs cause harmful effects on the human endocrine system[4]. Fair and Stumm-Zollinger in 1965 were the first to express concerns about the adverse effects of drugs found in municipal wastewater, by revealing that several drugs were poorly removed by typical wastewater treatment processes [5]. Because the removal of drugs can vary during wastewater
treatment depending on their physicochemical properties, including charge, size, shape, pKa, hydrophobicity and functional group[5]. Among numerous drugs commonly detected in wastewater effluents, bisoprolol (BSP) is representative contaminant that is readily released into the water environment[7]. Bisoprolol (BIS), is a selective β-adrenoreceptor antagonist (β1-bloker) drug used for secondary prevention of cardiac failure, myocardial infarction, angina pectoris and treat arterial hypertension[8]. Many researches have been shown that the applicability of biological and physical treatment methods for the removal of drug contamination from wastewater effluent by carbon nanotubes (CNTs) adsorption [9], membrane process[10], ultrasound processes [11], graphene oxides [12], and Sonophotolytic degradation [13]. Unlike widely known advanced oxidation techniques such as photocatalysis (UV/TiO₂), ultraviolet (UV/H₂O₂), ozonation (O₃/H₂O₂), Fenton/photo-Fenton treatment has recently been recognized as an advanced treatment process for the removal of drugs in wastewater, to protect the human health and environment at a very low concentration but their generally due to bioaccumulation may cause chronic effect, subtle on ecosystems,[15,14]. Over the last decade, many studies have shown the removal of drugs by adsorption treatments. Thus, a comprehensive study of drug removal by adsorption treatment is important, because adsorption of drugs is influenced significantly by their unique properties, including shape, size, pKa, hydrophobicity (octanol-water partition coefficient, KOW), functional groups, as well as water quality[16]. Adsorption process with a high-binding adsorbent is one of the most widely used to removal various pollutants from contaminated aqueous media. It is preferred over other methods because, its relatively simple operation, design, cost energy efficiency and effectiveness, the importance of adsorption for wastewater and water treatment is growing in view of the presence of emerging contaminants, such as personal care products (PPCPs) and pharmaceuticals [18,17].

Hydrogels are class of soft and wet materials, highly water swellable, hydrophilic, polymer networks, constituted by weakly cross-linking. Hydrogels offer high chemical, mechanical and stability physical in their swollen state [19]. The hydrogels can to be applied as biocompatible materials for a variety of biomedical applications including wound dressing [20], and controlled drug delivery systems [21]. Graphene oxide was obtained by treating graphite with strong oxidizing agents [23]. The incorporation of oxygen groups into graphene makes its structure more hydrophobic and it can be dispersed in water solution, Furthermore, having excellent mechanical and thermal properties [24], Additionally, the amphiphilic nature of GO due to the existence of oxygenated groups including carbonyl, hydroxyl, epoxides and carboxyl results in good dispersion of GO in protic solvents [25]. The large variety of methods to synthesize graphene oxide, such as Hummers Method, Brodie, Staudenmaier [26], Where it was prepared GO/P(CMC−co−AA) composite by using N,N’ methylene bisacrylamide (MBA). It has proved its ability to remove the drugs. The polymer composite after the adsorption process is easily collected from the drug solution by filtration.
2. Materials and experimental procedure

2.1. Materials:

Graphite powders were obtained from Fluka, concentrated hydrochloric acid from B.D.H Company and used directly without primary purification, acryl acid (AA), Carboxymethyl cellulose sodium salt (CMC) from Scharlau, potassium persulfate (KPS) and N,N--methylene-bisacrylamide (MBA) from Kemiou Chemical Reagent Co, Ltd, China, Bisprolol and Sodium hydroxide were purchased from Merck. All the reagents used were analytical grade pure and used without further purification.

2.2. Preparation of GO

Graphene oxide (GO) was synthesized according to modified Hummers method [23]. Briefly, take 1.0 g of sodium nitrate and stir with 1.0 g of graphite in an ice-water bath for 15 minutes. Once the mixture was very well-mixed, 45 mL of sulfuric acid (H$_2$SO$_4$) was added gradually into the mixture. The mixture was kept in 0°C by using the ice-water bath as a safety precaution. While maintaining vigorous agitation, 6.1 g of potassium permanganate was added gradually into the mixture contain the suspension solution under stirring condition. This mixture was stirred for 2 hours with the temperature of the ice-water bath kept at ≤5°C, after overnight stirring, the mixture gradually thickened, the mixture became brownish grey in color and pasty. Thereafter, to eliminate excess of KMnO$_4$, 10 mL of hydrogen peroxide (30%) was added dropwise and stirred for 10 minutes, to reduce the residual manganese dioxide and permanganate to colorless soluble manganese sulfate. The exothermic reaction occurred and let it to cool down, after the filtration of the mixture; the residue was washed with (10% HCl) and centrifuged using Eppendorf Centrifuge 5430R at 5000 rpm for 4 minutes solution five times. The product was washed with deionized water for several times. Then, it was dried at 70°C and stored for further use.

2.3. Preparation of GO cross-linked P(CMC-co-AA) composite

For the preparation of P(CMC-co-AA) hydrogel, there are a number of steps that begin with the preparation of the hydrogel, (2% w/v) of CMC, and (8% w/v) of AA were prepared in distilled water, then 80% and 20% of AA and CMC were mixed, respectively. The mixture is
stirred very well by using incubator shaker, and then is added the cross-linker agent, MBA (0.15 mole/L), while still stirring, is then added the initiator KSP (0.0371 mole/L), and passed the nitrogen gas for 15 minutes after placed the solution in polyethylene test tubes. The tubes are then placed in a water bath where the temperature is gradually increased from 40°C to 70°C. The temperature increase is as follows: 40°C for 1 hour, 50°C for 2 hours, 70°C for 2 hours. The prepared hydrogel is cut into small pieces about 8mm long and then washed with distilled water and ethanol for a several time to remove all non-reactive monomers. Then dry by an electric oven at 50 °C until Get a constant weight [27].

To prepare the GO/P(CMC-co-AA) composite we will use a similar method to prepare the P(CMC –co- AA) hydrogel, but with the addition (0.8% w/v) of GO by ratio, (1:10) of the mixture hydrogel.

2.4 . Characterization of composite

Field emission scanning electron microscopic (FE-SEM, JEOL, JSM-6701F, Japan) was used to investigate the morphology of the obtained surface material. The average particle size was prepared using Microstructure measurement software. X-ray diffraction (XRD) measurement of the powder was performed using a D/Max 2550 V diffractometer with monochromatic Cu Ka radiation (k = 1.54056 Å), and collected at a scanning rate of 0.03°s⁻¹ for 20 in a range from 3° to 80°. Fourier transform infrared (FTIR) spectroscopy was recorded with a FTIR Bruker, vector 22, spectrometer with using KBr tablets as sample holders in the (400–4000 cm⁻¹) range. The thermogravimetric analysis (TGA) diagrams of the samples were recorded with a Mettler– Toledo TGA 851e with 3-20mg samples at a heating rate of 10 °C min⁻¹ under a nitrogen atmosphere by heating the composite from 30 °C to 904 °C.

2.5. Calculate the quantity adsorbed

Stock solutions of BIS of 1000 mg.L⁻¹ was prepared by dissolving 1 g of drug in 1 L of distilled water. The effects of contact time, adsorbent dose, solution pH, initial drug concentration, and temperature of the drug adsorption process using the prepared material were investigated. Desired temperature was controlled by using a temperature-controlled water bath shaker. Solution pH were adjusted using 0.1 M NaOH and 0.1 M HCl. All pH measurements were carried out using a pH meter.

At a certain time, the supernatant was filtered, and the final drug concentration was determined using UV–Vis spectrometer at the wavelength of 223.5 nm drug. The following formula was used to determine the adsorbed drug amounts per gm of the prepared hydrogel (m) either at equilibrium (Qe) [28].

\[ Q_e = \frac{x}{m} = \frac{V (C_0 - C_x)}{m} \]

............... (1)
Where; \( Qe \) or \((x/m)\) (mg g\(^{-1}\)) is the amounts of drug adsorbed per unit weight of the adsorbent at equilibrium; \( C_0 \) and \( C_e \) (ppm = mg L\(^{-1}\)) are the drug concentrations at initial, and equilibrium, respectively; \( V \) (L) is the volume of drug solution; and \( m \) (g) is the weight of the surface adsorbent.

2.8. Drug sorption isotherms

The drug sorption capacity of the prepared surface material at different initial and equilibrium concentrations can be illustrated by the adsorption isotherms. Adsorption isotherms describe how the BIS drug (adsorbate) interacts with surface material (adsorbent) and give a thorough understanding of the nature of interaction between drug and polymer composite. Several isotherm equations have been employed for such analysis and the two important isotherms of Freundlich and Langmuir isotherms were applied.

2.8.1. Langmuir isotherm model

Langmuir’s isotherm was used for monolayer adsorption on a surface hydrogel containing a negligible interaction with finite number of identified sites between assumes uniform energies of adsorption and (drug) adsorbed molecules and on the surface. In addition, the maximum adsorption of drug depends on the saturation level of monolayer [29]. The Langmuir isotherm was represented by the following equation:

\[
q_e = \frac{q_m.K_L.C_e}{(1+K_L.C_e)} \quad \ldots \quad (2)
\]

Where the Linear equation:

\[
\frac{C_e}{q_e} = \frac{1}{q_m.K_L} + \left(\frac{1}{q_m}\right) \cdot C_e \quad \ldots \quad (3)
\]

Where; \( C_e \) was the liquid-phase concentration with \( q_e \) is the solid-phase drug concentration in equilibrium with expressed in mole L\(^{-1}\), \( K_L \) was an equilibrium constant (L mol\(^{-1}\)) and \( q_m \) was the maximum monolayer adsorption capacity (mg g\(^{-1}\))

. A straight line with intercept of \( 1/q_m.K_L \) and slope of \( 1/q_m \) is obtained when \( C_e/q_e \) is plotted against \( C_e \).

2.8.2. Freundlich isotherm model

Drug Adsorbent that follow the Freundlich isotherm equation was assumed to have a different adsorption potential with heterogeneous surface consisting of sites [30] and each type of site is assumed to adsorb drug molecules, as in the Langmuir linear equation:

\[
\ln q_e = \ln K_f + \frac{1}{n} \cdot C_e \quad \ldots \quad (4)
\]

Where; \( n \) was a constant, related to adsorption intensity and \( K_f \) was constant a function of the energy of temperature and adsorption, which gave a straight line by plotting (\( \ln q_e \)) versus (\( \ln C_e \)) with intercept of \( \ln K_f \) and slope of \( 1/n \).
2.8. Adsorption thermodynamics

Adsorption thermodynamics experiment was performed at the optimum condition obtained for various temperatures (10, 15, 20 and 25 °C). Thermodynamic parameters were determined by the following equations, where $K_D$ (q_e/C_e) was the equilibrium partition constant, $\Delta G$ (kJ mol$^{-1}$) was the Gibbs free energy change, $\Delta H$ (kJ mol$^{-1}$) was the enthalpy change, $\Delta S$ (kJ mol$^{-1}$ K$^{-1}$) was the entropy change, $R$ (8.314 J mol$^{-1}$ K$^{-1}$) was the universal gas constant, and $T$ (K) was the temperature [29].

\[
K_D = \frac{q_e}{C_e} \quad \text{.........(5)}
\]

\[
\Delta G = -RT \ln K_D \quad \text{.........(6)}
\]

\[
\ln K_D = \frac{\Delta S}{R} - \frac{\Delta H}{RT} \quad \text{.........(7)}
\]

The value of $\Delta G$ was calculated from the $K_D$ values for each temperature, the values of $\Delta S$ and $\Delta H$ were calculated from the intercept and slope of the plot of ln $K_D$ versus 1/T, respectively.

3. Results and discussion

3.1. Characterization

3.1.1. Fourier transform infrared (FTIR) analysis

Figure (2) : The FTIR spectrum of graphite sheets (G) exhibits no characteristic peak for the functional groups. It only shows two peaks at approximately 1668 and 3444 cm$^{-1}$ is attributed to the O-H stretching vibration for adsorbed water molecules, and the skeletal vibrations from graphite domains, the sp$^2$ aromatic C=C, respectively. After treating with oxidizing agents, yield the graphene oxide, the FTIR spectrum of GO represents the intense and broad bands at 1731 and 3405 cm$^{-1}$ corresponding to C = O stretching vibrations (from carboxylic and carbonyl groups) and the O–H stretching vibrations (hydroxyl) [30]. the bands at 1338 and 1080 cm$^{-1}$ can be assigned to C–O and C–OH stretching vibrations, while, the residual (sp$^2$) skeletal vibration of (un-oxidized) graphitic sheets (C=C) at 1623 cm$^{-1}$ [23].

![Figure (2): FTIR spectra of graphene Oxide and graphite](image)
The formation of copolymer hydrogel (CMC-co-AA) was investigated using FT-IR spectrum of the precursor CMC, AA and the prepared GO/(CMC-co-AA) composite hydrogel as shown in Figure (3A). The (CMC/AA) hydrogel is observed to show at Lower frequencies and to give a strong absorption band at 3321.53 cm\(^{-1}\) due to its (O–H) stretching. The absorption band of P(CMC-co-AA) at 1031.95, 1109.11, 1450.52 cm\(^{-1}\) are due to the (C–O) stretching of its alcohol. Similarly, the absorption band of P(CMC-co-AA) at 1209.41 cm\(^{-1}\) corresponds to the (C–O) stretching of its ether linkage. The absorption band at 1516.10, 1411.80 cm\(^{-1}\) is due to its (C=N) stretching vibration in MBA and (CH\(_2\)) scissoring, while the (C=O) stretching vibration of carboxylate group of (CMC) that interaction with the groups of (AA) is showed at 1610.61 cm\(^{-1}\) of P(CMC-co-AA) hydrogel [42,41]. The FTIR spectra of the (GO/P(CMC-co-AA)) composite is studied the (O–H) stretching vibration carboxylate group of CMC, AA and GO overlapping of bands at (3417.63) cm\(^{-1}\) and (C–H) stretching at 2931.60, 2869.88 cm\(^{-1}\), while the (C–H) bending is showed at 2785.02 cm\(^{-1}\), and observed the (C–N) bending at 1319.22 cm\(^{-1}\), and C-H bending at 594.03 cm\(^{-1}\). The FT-IR for GO/P(CMC-co-AA) is showed the shift of the groups bands (C=O) reveals the interactions between the carboxylic groups of CMC with O-H groups on AA and GO platelets is given at 1650.95 cm\(^{-1}\) [31].

Figure (3): FT-IR spectra of P(CMC-co-AA), (GO/P(CMC-co-AA)), and Bis-(GO/P(CMC-co-AA))

3.1.2. Field emission-scanning electron microscopy (FE-SEM) analysis

FE-SEM observation was used for characterization of the surface morphology of the polymer composite and its hydrogel. FE-SEM image of graphite, GO, P(CMC-co-AA) and GO/P(CMC-co-AA) is shown in figure (4 a-c): As can be seen from the figure, graphite sheets be stack as layer thick and explain a closely aligned layered structure. It also exhibits flaky appearance for the strong sp\(^2\) carbon to carbon bonding in the plane. After oxidation process by using hummer method (23), FE-SEM image of GO nanosheets appear wavy frizzy appearance, the surface has the edges of the sheet is foggy. Furthermore, the surface of GO sheet looks coarse carpet which can due to the link of residual (water molecules), hydroxyl and carboxyl groups with the sheets [32] given in Figure. (4). It could be seen that the fracture surface
morphology of the (GO/P(CMC-co-AA) polymer composite containing the GO sheets exhibited an undulant, rough and coarse surface and becoming more easily identified on the surface adsorbent. Furthermore, the pores is became more uniform and more smaller comparing with the P(CMC-co-AA) hydrogel (Figure. 3c). Also, it can be seen, that the GO platelets were well dispersed throughout the polymer composite matrix as individual platelets.[25]

![Figure (4) : FE-SEM images of (a)Graphite, (b)GO, (c,d)(GO/P(CMC-co-AA) and (E,F) BIS-(GO/P(CMC-co-AA)](Image)

3.2.3- X-ray diffraction (XRD)

X-ray diffraction (XRD) as an important tool is used to investigate crystal structure of surface materials. The crystal structures of prepared P(CMC-AA) hydrogel and GO/P(CMC-co-AA) composite were obtained by XRD measurements Figure (5): P(CMC-AA) and GO/P(CMC-co-AA) composite had a peak at the angle range of 10°–80°. According to Bragg’s law, The XRD pattern of the P(CMC-AA) and GO/P(CMC-co-AA) composite showed a broad non crystalline diffraction peak centered at (2θ = 22.677°), (2θ = 20.783°), corresponding to an interlayer d-spacing of (d= 3.9180Å), (d= 4.2706Å), Respectively [33].
Figure (5): XRD spectra of GO/P(CMC-co-AA) composite and P(CMC-AA) hydrogel

3.2.4. Thermogravimetric analysis (TGA) analyses

In order to evaluate the thermal stability of the (GO/P(CMC-co-AA) composite, the TGA/DTA analysis is performed and the diagrams were exhibited in Figure 6. Scanning the weight loss percent from (30 to 904 °C) appeared three distinct steps for all samples prepared. That the weight loss percent was the highest for the mat GO/P(CMC-AA) composite % F. (3.059%) but it was the lowest for the GO/P(CMC-AA) % F. mat (4.568%) indicating the highest thermal stability of the latter. Considering the weight loss amount, it can be stated that addition of GO to the P(CMC-co-AA) leads in decreasing the weight loss. Indeed, strong electrostatic interactions and intermolecular hydrogen bonding between the functional groups of the two GO and P(CMC-co-AA) polymers as well as with that of bisoprolol drug result a strong network leading to higher thermal stability for the polymer composite relative to the pure GO [34].
3.2. Adsorption Study:

3.2.1: Calibration Curves of BIS drug

Solutions of different concentrations of BIS drug prepared by serial dilutions. Absorbance values of BIS solutions are measured at the selected ($\lambda_{\text{max}} = 223.5$ nm) and plotted against the concentration values BIS in Figure (7). The calibration curves in the concentration range for BIS drug that falls in the region of applicability of Beer-Lambert’s law are employed.

![Calibration curves of the BIS drug.](image)

Figure 7: Calibration curves of the BIS drug.

3.2.2. Effect of contact time on drug adsorption

The effect of the contact time on the adsorption of BIS drug was showing (Figure.8) for the GO/P(CMC-co-AA) polymer composite at a solution pH of 8.0. It is observed that initially the drug adsorption data increases at a rapid rate and followed by a slow rate of adsorption experimental till it reaches the equilibrium process. At the beginning of the adsorption process, the functional groups of GO/P(CMC-co-AA) polymer composite are available for these interactions, when the rate of adsorption process is very high. As adsorption experimental continues, the functional groups of the fixed amount of the GO/P(CMC-co-AA) polymer composite present in the aqueous solution exhaust and thus the rate of adsorption data decreases, and finally the adsorption of BIS on GO/P(CMC-co-AA) reaches a dynamic equilibrium and gives a maximum adsorption value ($q_{\text{max}}$), when the rate of adsorption and desorption process equals from the polymer composite (35).

![Effect of contact time on drug absorption of the GO/P(CMC-co-AA) polymer composite.](image)

Figure 8: Effect of contact time on drug absorption of the GO/P(CMC-co-AA) polymer composite.
3.2.3. Adsorption isotherms

The analysis of the isotherm experiment was improving to extend an equation which represents the results utilized for the design. Adsorption equilibrium was traditionally estimated by adsorption isotherms. It was acquired from experimental data using Freundlich and Langmuir adsorption isotherm models at different temperatures (10, 15, 20 and 25 °C) and different initial concentrations. According to the parameter values and the correlation coefficients which summarized in Table 1, the $R^2$ of Langmuir model is very larger than Freundlich model which suggests that the adsorption is an experimental which occurred in a homogeneous surface. But in general, adsorption of Bisoprolol on GO/P(CMC-co-AA) composite actualizes according to Langmuir isotherm; which includes the following postulates: (i) adsorption process occurs as a monolayer (ii) the adsorbent's surface was energetically homogeneous, (ii) desorption rate was only related to adsorbed amount. For Bisoprolol, the theoretical adsorption capacity is found as 6.7751 mg. g$^{-1}$ at 293 K as given in Table 4. In addition, the values of $R^2$ at high temperatures are higher than those at low temperatures as shown in (Figure 9). It can be deduced that the adsorption processes behavior is more effective at high temperatures [36]

Table 1: Isotherm models' parameters for adsorption of Bisoprolol on (GO/P(CMC-co-AA).

| Isotherm models' parameters | Freundlich isotherm parameters | Langmuir isotherm parameters |
|----------------------------|--------------------------------|----------------------------|
|                           | $n$ | $K_f$ | $R^2$ | $q_m$ | $K_L$ | $R^2$ |
| Bisoprolol                | 3.9857 | 2.3383 | 0.7298 | 6.7751 | 0.2010 | 0.9848 |

Figure 9: Isotherm models for adsorption of Bisoprolol on GO/P(CMC-co-AA) : (a)Freundlich isotherm. and (b)Langmuir isotherm.
3.3. Adsorption thermodynamics

The adsorption thermodynamics are provided some useful information on energy changes of the adsorption experiments. Thermodynamic parameters for adsorption process are collected by performing set of experiments at different temperatures. The thermodynamic results of Bisoprolol adsorption onto GO/P(CMC-co-AA) are summarized in Table 2. Adsorption thermodynamics of BIS on GO/P(CMC-co-AA). At temperatures (293 K), The $\Delta G$ value was -35648.6 kJ/mol. The negative values of $\Delta G$ showed that drug adsorbent system was spontaneous in nature. Furthermore, the increase in the values of $\Delta G$ with the decreasing temperature showed clearly that the adsorption process was more spontaneous at lower temperatures. It was also noticed that the $\Delta G$ enhanced with lower temperature which revealed the improvement of adsorption process due to activation of more adsorption sites within GO/P(CMC-co-AA) particles in cooled solution. Also, high negative $\Delta G$ indicated high degree of adsorption favorability. The values of $\Delta S$ and $\Delta H$ were 2.2916.71 kJ/mol.K and 90.3806 J/mol., respectively. The positive $\Delta H$ value confirmed the endothermic adsorption nature. On the other hand, the positive value of $\Delta S$ reflected the increase affinity of GO/P(CMC-co-AA) towards Bisoprolol. [37].

Table 2: Thermodynamic parameters of Bisoprolol adsorption onto GO/P(CMC-co-AA).

| Parameter | $\Delta S^\circ$ KJ/mole.K | $\Delta H^\circ$ KJ/mol | Adsorption nature | $-\Delta G^\circ$ KJ/mol |
|-----------|---------------------------|------------------------|------------------|-------------------------|
| Bisoprolol | 90.3806                   | 22916.71               | endothermic      | 283 288 293 298 |

4. Conclusions

This study involved the preparation of P(CMC-co-AA) and GO/P(CMC-co-AA). The results revealed that the prepared GO/P(CMC-co-AA) has a microspore volumes and relatively high surface area and it was found out to be a promising adsorbent for drug removal from wastewater and aqueous solutions. The adsorption efficiency of Bisoprolol is increase with increasing the solution temperature and increased with increasing the dose of adsorbent and initial drug concentration. While the amount of Bisoprolol drug adsorbed was increased with increasing contact time at all initial drug concentrations. Furthermore, the adsorption processes reached equilibrium within 120 min. for Bisoprolol. All equilibrium data calculated at different temperatures fit perfectly with Langmuir isotherm model. The negative values of $\Delta G$, positive values of $\Delta H$ and $\Delta S$ indicate that the drug adsorption process was spontaneous, endothermic and a decrease in randomness occurs at the solid. The overall results showed that the prepared composite GO/P(CMC-co-AA) was low-cost adsorbent and an effective for the removal of Bisoprolol drug from aqueous solutions.
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