ABSTRACT: The adsorption of p-nitrophenol (an electrolyte) and nitrobenzene (a non-electrolyte) on activated carbon was carried out at 301 K under controlled pH conditions. The experimental isotherms were fitted to the homogeneous Langmuir model and the binary Langmuir model. Variation of the model parameters with solution pH was studied. The fitted parameters obtained from the Langmuir equations (homogeneous and binary models) showed that both the maximum amount of solute adsorbed ($Q_{\text{max}}$) and the adsorption affinity of the carbon ($K_1$) towards the electrolytic adsorbate exhibited the more significant decrease. Under pH conditions below the $pK_a$ value of p-nitrophenol (when the adsorbate existed in a molecular form), both the solubility of the adsorbate and the electron density of its aromatic ring were significant factors affected the extent of London dispersion interactions. At higher solution pH values, electrostatic forces had a significant impact on the extent of adsorption. The influence of pH must be considered in terms of its combined effect on the carbon surface and on the solute molecules. It was confirmed that the uptake of the molecular forms of the aromatic solutes was dependent on the substituents attached to the aromatic ring. The adsorption of p-nitrophenol at higher pH values depended on the concentration of the anionic form of the solute present in the aqueous solution.

INTRODUCTION

The adsorption of dissociating aromatic compounds onto the surface of carbonaceous materials is affected by the properties of both the adsorbate and the adsorbent. Activated carbons are known to possess a heterogeneous physical and chemical structure, the former arising from the existence of micro-, meso- and macro-pores of different sizes (Derylo-Marczewska and Marczewski 1999), while the latter arises from the variety of functional groups (mainly carbon–oxygen) present on the adsorbent surface. The traditional use of activated carbon in both water and wastewater treatment is well known (Mattson et al. 1969; Halhouli et al. 1995).

The chemical nature of the adsorbate, its solubility, molecular size, shape and the types of functional groups contained all affect its adsorption behaviour significantly (Nouri 2002a,b; Nouri et al. 2002a). However, theoretical approaches, which could provide a quantitative explanation of the effects of solution pH and the chemistry of the carbon surface on the adsorption process, have been developed to only a small extent.
In the present work, the adsorption behaviours of two aromatic compounds (p-nitrophenol — a weak electrolyte, and nitrobenzene — a non-electrolyte) on a commercially available activated carbon (F100) under various solution conditions have been investigated systematically. Isotherms of these compounds were obtained under different pH conditions and the results discussed in terms of the two major forces involved in the adsorption process.

The experimental isotherms were fitted to the Langmuir models (homogeneous and binary) and the variation of the model parameters with solution pH studied and employed to gain further insight into the adsorption process.

THEORETICAL SECTION

In our previous work (Nouri 2002a; Nouri and Haghseresht 2002a,b; Nouri et al. 2002b; Haghseresht et al. 2002), activated carbon F100 was used in both an untreated and treated form. Analysis of the corresponding adsorption data was achieved using the Langmuir homogeneous [equation (1)] and binary [equation (4)] models as the local isotherm equations to obtain the corresponding parameters.

The Langmuir homogeneous model may be written as:

\[ \theta = \frac{K_1 C_e}{1 + K_1 C_e} \]  

(1)

where \( \theta = q/Q_{\text{max}} \), with the corresponding linear Langmuir equation being expressed as:

\[ \frac{C_e}{q} = \frac{1}{K_1 Q_{\text{max}}} + \frac{1}{Q_{\text{max}}} C_e \]  

(2)

In equation (2), \( K_1 \) is a constant (the adsorption affinity), \( C_e \) is the equilibrium solution concentration and \( Q_{\text{max}} \) is the maximum amount of solute adsorbed per g carbon. The quantity \( Q_{\text{max}} \) corresponds to complete coverage, whereas \( \theta \) is the fractional coverage as determined from the equilibrium solid concentration (q) and \( Q_{\text{max}} \). The equilibrium constant may be related to the adsorption energy by equation (3):

\[ K_1 = K_{10} \exp(-E) \]  

(3)

where \( K_{10} \) is the pre-exponential factor and \( E = e/RT \) is the reduced adsorption energy.

However, as described in our previous work (Nouri and Haghseresht 2002b; Nouri 2002b), the adsorption isotherm for dissociating compounds is best represented by the binary Langmuir model [equation (4)]:

\[ \theta = \frac{C_m K_m + C_i K_i}{1 + C_m K_m + C_i K_i} \]  

(4)

where \( K_m = K_{0m} \exp(-E_m/RT) \) and \( K_i = K_{0i} \exp(-E_i/RT) \). In equation (4), the subscripts i and m represent the ionic and molecular species in the system, respectively. The other symbols C, K and E represent the bulk concentration, equilibrium constant and adsorption energy of the species.
At a given pH, the dissociating species will be in equilibrium, i.e. \( \text{HA} \leftrightarrow \text{H}^+ + \text{A}^- \), where HA refers to the neutral species, A\(^-\) refers to the ionized species and the equilibrium constant, \( K_a \), may be expressed as:

\[
K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]} \quad (5)
\]

We can then use relationship (5) to express the solution concentrations of the individual species in terms of the measured equilibrium concentrations:

\[
C_m = \left( \frac{C_e}{1 + \alpha} \right) \quad (6)
\]

\[
C_i = \left( \frac{C_c \alpha}{1 + \alpha} \right) \quad (7)
\]

where \( \alpha = C_i/C_m \), \( \log \alpha = \text{pH} - \text{p}K_a \) and \( C_e = C_i + C_m \).

The relationships shown in equations (6) and (7) allow equation (4) to be re-arranged in a linear form:

\[
\frac{C_e}{q} = \frac{(1 + \alpha)}{(K_m + K_i\alpha)Q_{max}} + \frac{1}{Q_{max}} C_e \quad (8)
\]

A plot of \( C_e/q \) versus \( C_e \) for an adsorption system where the molecular species are dominant would lead to determination of \( Q_{max} \) and \( K_i \), i.e. the equilibrium constant for the molecular species. However, when adsorption is undertaken at a solution pH where both molecular and ionic species are present, the fitted equilibrium constant \( K_1 \) would be a composite parameter containing \( K_m \), \( K_i \) and \( \alpha \) as shown in equations (9) and (10):

\[
K_1 = \frac{K_m + K_i \alpha}{1 + \alpha} \quad (9)
\]

\[
(K_i + K_i\alpha) = K_m + K_i \alpha 
\]

Equation (10) allows the determination of \( K_1 \) in the following situations:

1. At low pH, where the molecular species are dominant, \( \alpha \approx 0 \). Therefore \( K_1 \approx K_m \).
2. When \( \text{pH} = \text{p}K_a \), the quantity \( \alpha \) is equal to unity. The value of \( K_1 \) then becomes the average of \( K_m \) and \( K_i \).
3. In highly alkaline solution, where the solute is highly ionized, \( K_1 \approx K_i \).

**Characterization of activated carbon**

Nitrogen and carbon dioxide adsorption studies were undertaken to characterize the activated carbon (see below). The nitrogen adsorption data were used to determine the BET surface area \( (S_{BET}) \), the total pore volume \( (V_{tot}) \) and the micropore volume \( (V_{mic}) \) of the activated carbon. The BET surface area was obtained by applying the BET equation to the adsorption data obtained
over the $P/P_0$ range 0.10–0.1, $V_{\text{tot}}$ was obtained from the total adsorption measured at $P/P_0 = 0.96$ while the micropore volume, $V_{\text{mic}}$, was obtained using the t-plot method (Gregg and Sing 1983). The ultramicropore volume ($V_{\text{ulmic}}$) of the carbon was obtained by applying the Dubinin–Radushkevich (D–R) equation to the CO$_2$ adsorption isotherms obtained at 273 K (Marsh 1987).

The water adsorption data were analyzed by fitting the corresponding isotherms to equation (11), the so-called DS-2 equation (Barton et al. 1991):

$$c(Q_0 - q)(1 - kq) = q/(P/P_0^0)$$

where $q$ is the measured adsorption per g carbon, $P/P_0^0$ is the relative pressure, $c$ is a kinetic parameter, $k$ is a constant associated with decreasing active site concentration and $Q_0$ is the concentration of primary sites. The toluene pore volume of the carbon was determined using the plateaux of the toluene isotherms.

In the present work, the linear forms of the Langmuir homogeneous equation [equation (2)] and binary equation [equation (8)] were used to determine the fitted parameters for the adsorption of two aromatic compounds, i.e. $p$-nitrophenol (a weak electrolyte) and nitrobenzene (a non-electrolyte), on the untreated activated carbon (F100) to compare the fitted parameters and confirm the relationship between $K_m$ and $K_i$. The effect of functional groups on the affinity and adsorption capacity was also studied.

**METHODS AND MATERIALS**

**Materials**

Prior to all experiments, a sample of activated carbon (F100 as obtained from the Calgon Carbon Co.) was ground and sieved to a particle size in the range 400–800 μm. The chemicals used were as follows: $p$-nitrophenol (PNP) (99.9% purity), nitrobenzene (NB) (99.7% purity), both obtained from Merck Chemicals, and HCl and NaOH (AR grade) as obtained from Ajax Chemicals.

**Methods**

**Point of zero charge (PZC) measurements**

The pH value corresponding to the point of zero charge, $pH_{(PZC)}$, of the carbon was determined as described in our previous work (Nouri 2002; Nouri and Haghseresht 2002). Figure 1 shows the variation of pH relative to the amount of activated carbon employed. The limiting pH was taken as being the value of $pH_{(PZC)}$. This was found to be 7.8 for F100.

**Equilibrium adsorption experiments**

Such adsorption experiments were carried out by placing 45 mg activated carbon in solutions (50 ml in each case) containing different concentrations of the adsorbates. The pH value of each solution was adjusted by adding dilute solutions of NaOH or HCl as appropriate. All solutions were then maintained in a temperature-controlled shaking bath for 4 d at 301 K to reach equilibrium. At this stage, the residual concentrations of the solutes were measured spectrophotometrically
using a JASCO-V550 spectrophotometer, employing wavelengths of 260 nm and 275 nm for PNP and 310 nm for NB, respectively.

**Vapour adsorption**

Toluene and water adsorption experiments were carried out gravimetrically using an in-house adsorption apparatus equipped with quartz springs, an MKS transducer capable of measuring the absolute pressure to a precision of ± 1 mTorr and a temperature-controlled oven capable of being heated to 473 K. Prior to adsorption experiments, all samples were degassed overnight at 423 K, i.e. at a lower degassing temperature than used for the gas adsorption experiments (see below). Such conditions were employed to maintain the integrity of any surface oxides present, since such functional groups affect the observed water adsorption behaviour quite significantly. During the adsorption measurements, the samples were subjected to a step change in the adsorbate pressure from an initial zero value to the saturation pressure. The adsorption isotherms obtained for toluene and water are depicted in Figures 2(a) and (b), respectively.

**Gas adsorption experiments**

Nitrogen adsorption/desorption experiments were carried out volumetrically at 77 K using an Autosorb (Quantachrome Corp.) instrument. Carbon dioxide adsorption experiments were also carried out volumetrically at 273 K using a NOVA 1200 (Quantachrome Corp.) instrument. Samples of F100 activated carbon (20–30 mg) were employed for the nitrogen adsorption experiments while 90–100 mg of the activated carbon was used for the carbon dioxide adsorption experiments. All samples were outgassed overnight at 473 K prior to such experiments. The corresponding CO$_2$ and N$_2$ adsorption isotherms are depicted in Figures 3(a) and (b), respectively.
The N\textsubscript{2} and CO\textsubscript{2} adsorption data were employed to calculate the values of $S_{\text{BET}}$, $V_{\text{tot}}$, $V_{\text{mic}}$ and $V_{\text{ulmic}}$ for the activated carbon. These are listed in Table 1, which indicates that the pore volume as determined via toluene adsorption measurements ($V_{\text{toluene}}$) was substantially less that the $V_{\text{tot}}$ value measured from gas adsorption data. This may be attributed to the relative size of the nitrogen and toluene molecules, with the smaller N\textsubscript{2} molecules being capable of penetrating micropores which were inaccessible to the toluene molecules.

| $S_{\text{BET}}$ (m\textsuperscript{2}/g) | $V_{\text{tot}}$ (cm\textsuperscript{3}/g) | $V_{\text{mic}}$ (cm\textsuperscript{3}/g) | $V_{\text{ulmic}}$ (cm\textsuperscript{3}/g) | $V_{\text{ulmic}}/V_{\text{tot}}$ | $V_{\text{toluene}}$ (cm\textsuperscript{3}/g) |
|--------------------------------------|-----------------------------------------|------------------------------------------|--------------------------------------|---------------------------------|----------------------------------|
| 957                                 | 0.5260                                  | 0.3811                                   | 0.207                                 | 0.393                          | 0.21                             |

**Figure 2.** Adsorption isotherms: (a) toluene; (b) water.

**Figure 3.** Adsorption isotherms: (a) carbon dioxide; (b) nitrogen.

**TABLE 1.** Pore Structure Characteristics of F100 Activated Carbon
The corresponding value of the primary adsorption site concentration, $Q_0$, of the activated carbon, as calculated via equation (11), is listed in Table 2.

**TABLE 2.** Surface Chemical Characteristics of F100 Activated Carbon

| pH(PZC) | C (atom%) | O (atom%) | Si (atom%) | $S^{2-}$ (atom%) | $Q_0$ (mg/g) |
|---------|-----------|-----------|------------|-----------------|-------------|
| 7.8     | 94.3      | 4.9       | 0.57       | 0.20            | 23.8        |

X-Ray photoelectron spectroscopic (XPS) studies

XPS measurements were conducted using a Perkin-Elmer PHI model 560 ESCA system which employed a model 25-270 AR cylindrical mirror analyzer. All spectra were acquired at a basic pressure of $2 \times 10^{-7}$ Torr using Mg KR excitation at 400 W power.

Survey (wide) scans were recorded using a pass energy of 100 eV while multiplex (narrow) scans, over selected elemental regions, were measured at 50-eV pass energy. All binding energies were referenced to that of C1s at 285 eV because of sample charging (Perry and Grint 1983). Elemental concentrations were calculated after correction of the peak areas for atomic sensitivity factors (Ward and Wood 1992). Details of the surface elemental analysis of the activated carbon as determined by XPS are listed in Table 2.

![Figure 4. PNP and NB isotherms at pH 2.0: (a) equilibrium; (b) normalized.](image)

**TABLE 3.** Properties of Solutes Studied

| Solute | Molecular weight | $pK_a$ | Solubility (g/l) |
|--------|------------------|--------|------------------|
| PNP    | 139.11           | 7.2    | 16               |
| NB     | 123.11           | –      | 2                |
RESULTS AND DISCUSSION

The equilibrium isotherms for the two solutes at pH = 2.0 are shown in Figures 4(a) and (b), the isotherms being plotted using a mass-based solid concentration, $q$ (mg of solute adsorbed per g carbon), versus the liquid concentration, $C_e$ (in ppm), obtained under equilibrium conditions. Since the $pK_a$ value of PNP is 7.2, both solutes were in their molecular form at the pH value chosen for the experiments.
The results depicted in Figure 4(a) show that the adsorption capacity of the carbon for PNP was greater than that for NB. This observation is contrary to that to be expected from the solubility data for these solutes (Table 3). The affinities of the solutes for the solvent suggest that NB would be adsorbed to the greater extent, as it is less soluble in water. It seems, therefore, that the observed adsorption pattern was not governed solely by the affinity of the solute for the solvent. To take this into account, the corresponding reduced concentrations ($C_e/C_s$) were calculated. The use of such values normalizes the amount of energy required to bring a molecule of the solute

![Figure 7. PNP isotherms at different pH values based on initial concentration of sorbate in solution.](image)

![Figure 8. Experimental data fitted with homogeneous Langmuir isotherm: (a) PNP; (b) NB.](image)
from the bulk onto the surface of the solution (Muller et al. 1985; Radovic et al. 1997). However, the normalized values of the adsorption data given in Figure 4(b) show that the adsorption capacity of the carbon for the adsorbates still followed the same trend, i.e. PNP > NB.

A comparison of the functional groups associated with the solutes can provide some explanation for this trend, since the hydroxy group of PNP is electron-donating while the NO$_2$ group of NB is electron-withdrawing. This indicates that the electron density of the aromatic ring in the solutes follows the order PNP > NB, i.e. the same as the observed adsorption pattern. In other

| Solute | pH  | $Q_{\text{max}}$ (mmol/g) | $K_1$ (mmol/l) |
|--------|-----|-----------------|---------------|
| NB     | 2.0 | 1.97            | 10.2          |
|        | 8.0 | 1.97            | 16            |
|        | 10.0| 2.01            | 21.4          |
|        | 12.0| 1.94            | 25.8          |
| PNP    | 2.0 | 1.7             | 18.9          |
|        | 8.0 | 1.3             | 9.1           |
|        | 10.0| 0.6             | 10.1          |
|        | 12.0| 0.5             | 7.9           |

**Figure 9.** Variation of $Q_{\text{max}}$ with pH for PNP and NB.
words, when the electron density of the aromatic ring in the solute is higher, its affinity towards a carbon surface is also higher. Furuya et al. (1997) have also observed that an increase in the electron density of an adsorbate led to an increase in its uptake on activated carbon.

Several reviews state that the influence of pH on adsorption must be considered from the viewpoint of its combined effect on the carbon surface and the solute molecules (Radovic 1999). Thus, it has been found that the adsorption capacity of carbon towards solutes in their molecular form was dependent on the electron density of the solutes. This is because the main forces involved in the adsorption process are dispersion interactions between the aromatic ring of the solutes and the carbon surface. However, when the solutes were ionized, a different situation arose, as discussed below.

Figure 5 shows the adsorption isotherms of the solutes at pH values of 8.0, 10.0 and 12.0, respectively. The carbon surface was negatively charged at such high pH values since the solution pH was much higher than the pH_{PZC} of the carbon (7.8). These pH values were also well above the pK_a value of PNP (Table 3), indicating that under such circumstances it was mainly in the ionic form. Figure 5 also shows that the adsorption capacity of the carbon for NB was still high (NB > PNP) at all pH values studied. This means that even at these high pH values much less PNP was in the molecular form than NB. In other words, due to the high electrostatic repulsive forces involved in adsorbent–adsorbate and adsorbate–adsorbate interactions, the adsorption capacity of the carbon towards PNP was lower than when the solute was in its molecular form.

Figure 6 shows the adsorption isotherms for NB at different pH values in the range 2.0–12.0 while Figure 7 depicts those for PNP over the same pH range. In both figures, the mass-based solid concentration, q (mg solute adsorbed per g carbon) has been plotted against the initial liquid concentration, C_i (in ppm). It will be noted from the data depicted in Figure 6 that the adsorption capacity of the carbon towards NB (a non-electrolyte) was the same irrespective of the pH value of the solution. However, in the case of PNP (a weak electrolyte), as the solution pH increased the concentration of the anionic form of the solute increased, leading to a greater degree of electrostatic repulsion with a consequent lowering of the adsorption capacity of the carbon adsorbent.

All the isotherms obtained experimentally were fitted by the linear form of the Langmuir isotherm [equation (1)] as depicted in Figure 8. The corresponding fitting parameters (Q_{max}^*, the maximum adsorption capacity, and K_1, the Langmuir constant) for NB and PNP as obtained from the homogeneous model are listed in Table 4. The change in the value of Q_{max}^* with pH determined from the homogeneous Langmuir model for the two solutes is depicted in Figure 9. That observed for PNP appeared to the much more significant than that for NB. The pK_a value for PNP listed in Table 3 indicates that this solute dissociates in aqueous media. Hence, the increasing presence of PNP ions in solution at higher pH values would lead to a greater degree of electrostatic repulsion and a consequent decrease in the adsorption capacity of the carbon towards this solute.

The data depicted in Figure 9 also indicate that when pH_{eq} was ca. 8.0 (the pH_{PZC} value of the carbon), the adsorption capacity of the carbon towards PNP diminished quite significantly while that towards NB remained relatively unchanged. This behaviour is in contrast to that reported in the literature. A number of authors (Radovic et al. 1997; Muller et al. 1980) have suggested that the adsorption capacity of a neutral carbon surface towards both ionic and molecular forms of a solute should be the same. Hence, in those cases where the solute pK_a is less than pH_{PZC}, the magnitudes of Q_{max}^* for the molecular and ionic forms of the solute at pH_{PZC} should not differ significantly.

A possible reason for our observations is that, in our experimental procedure, no adjustment was made to the ionic strength of the solutions by the addition of sodium chloride as suggested by a number of other authors (Muller et al. 1985; Derylo-Marcewksa 1993). The presence of such an inorganic salt should lead to an enhancement in the adsorption of organic anions in alkaline solutions. This results from charge neutralization on the carbon surface and the attraction of the
salt cation to the organic anions (Rosene and Manes 1977; Jaroniec and Madey 1988) leading to better surface packing. However, our results suggest that the repulsive forces between the anions led to a poorer adsorption capacity.

The following equation is proposed for demonstrating the variation of $Q_{\text{max}}$ with pH:

$$Q_{\text{max}} = q + A \cdot \text{pH}$$

(12)

with $q$ being 2.02 and 1.98 for PNP and NB, respectively, with the corresponding values of $A$ being $-0.12$ and $-7.151 \times 10^{-4}$.

As described in our previous work (Nouri and Hagseresht 2002b), the value of $Q_{\text{max}}$ for PNP at any pH value where the solute is reasonably well ionized ($\alpha > 20$) can be estimated from the following equation:

$$Q_{\text{max}} (\text{pH} > pK_a) = Q_{\text{max}} (\text{pH} \ll pK_a) \left(\frac{FQ_{pK_a}}{\ln(pH_{ave} - pK_a)} + \frac{FQ_{PZC}}{pH_{ave} - pH_{PZC}}\right)$$

(13)

where $FQ$ is a parameter which includes the contributions of the ion concentration and surface chemistry factors, symbolized by the subscripts $pK_a$ and PZC, respectively. The estimated $Q_{\text{max}}$ values, $Q_{\text{max}}$ (est), obtained from an application of equation (13) with those determined from the homogeneous Langmuir equation, $Q_{\text{max}}$ (Langmuir), are listed in Table 5. As can be seen, both sets of $Q_{\text{max}}$ values were very close to each other. However, it should be emphasized that this model can only be used when the degree of ionization of the solute is reasonably high ($\alpha > 10$).

Figure 10 shows the variation of $K_1$ for the two solutes and indicates that the value for NB increased with the pH value. This could arise because the electron density of the carbon basal layers might be expected to increase under such circumstances, allowing the London dispersion forces between the aromatic ring of the solute and the basal planes to increase. With PNP, increasing pH led to an increase in the concentration of the anionic form of the solute and an increase in the negative charge on the carbon surface. The mutual repulsion between solute and surface thus engendered led to a decrease in the degree of adsorption of the solute.

The relationship shown in equation (8) indicates that the molecular and ionic equilibrium constants, $K_m$ and $K_i$, cannot be optimized simultaneously if the binary Langmuir isotherm equation is applied. Furthermore, for $K_m$ to be constant for a given system, equation (8) must apply for a set of isotherms obtained under different solution conditions. Analysis of our results showed that a linear plot of $K_i + K_1 \alpha$ versus $\alpha$ could not be obtained for any of the experimental data. If it is considered that electrical charge is ‘smeared’ on the carbon surface as suggested by previous authors

| pH | $Q_{\text{max}}$ (Langmuir) | $Q_{\text{max}}$ (est) |
|----|-----------------------------|-------------------------|
| 2.0 | 1.71                        | 1.71                    |
| 8.0 | 1.3                         | –                       |
| 10.0| 0.6                         | 0.67                    |
| 12.0| 0.5                         | 0.49                    |

$FQ_{pK_a} = 0.45$

$FQ_{PZC} = 0$
(Muller et al. 1980), then the types of sites on the carbon surface differ considerably depending on the pH value of the solution. Table 6 lists the fitting parameters obtained from an application of the binary equation [equation (8)] to the data for PNP. It shows that the $Q_{\text{max}}$ values obtained from the binary equation were very close to the $Q_{\text{max}}$ values obtained from an application of the homogeneous model [equation (2)] to the same data. At low pH, where the molecular species were dominant ($\alpha \approx 0$), $K_1 \approx K_m$. In highly alkaline solution, where the solute was highly ionized, $K_1 \approx K_i$.

**TABLE 6.** Fitting Parameters for PNP from the Langmuir Binary Model
[Equation (8)]

| pH | $Q_{\text{max}}$ (mmol/g) | $K_m$ (mmol/l) | $K_i$ (mmol/l) |
|----|----------------|---------------|----------------|
| 2.0 | 1.61 | 19.5 | 278000 |
| 8.0 | 1.35 | 5.6 | 5.6 |
| 10.0 | 0.6 | 4170 | 9.7 |
| 12.0 | 0.5 | 26410 | 7.2 |

**CONCLUSIONS**

The adsorption capacity of a commercially available activated carbon towards two aromatic compounds, one being an electrolyte under certain pH conditions, were investigated. It was found
that the uptakes of the molecular forms of the aromatic solutes were dependent on the substituents on the aromatic ring. Electron-donating groups on the ring led to a higher uptake by the carbon. Adsorption of the solutes at higher pH values depended on the concentration of the anionic form of the solutes present, with a lower uptake being observed for electrolytic forms (lower pK_a). At higher anionic concentrations, the electrostatic repulsive forces between individual solute molecules and between the solute and carbon surface would be higher. The fitting parameters obtained from an application of the Langmuir equation (both homogeneous and binary models) showed that Q_max and the adsorption affinity of the carbon (K_m) decreased to a greater extent towards electrolytes. Where molecular species dominated at low pH, K_1 ≈ K_m. In contrast, at high pH where the solute was highly ionized, K_1 ≈ K_i. At pH ≈ pK_a, the adsorption affinity of the carbon assumed a value that was the average of K_m and K_i. The magnitude of Q_max varied as a function of pH (Q_max = q + ApH) and relative parameters were determined for the two solutes. The estimated Q_max values [Q_max (est)] for PNP were found to be very close to those obtained from the homogeneous model.

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