

Investigation of Adsorption of Gluconic Acid from Aqueous Solutions by Activated Carbon

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The separation of gluconic acid from aqueous solutions using activated carbon was examined. Experiments were carried out in the system of aqueous gluconic acid solutions (0.75, 1.5, 3, 5 and 8%, w/w) and different amounts of activated carbon (0.001, 0.002, 0.003, 0.004, 0.005, 0.006, 0.007 and 0.008 g) as adsorbent. The equilibrium distributions of gluconic acid were measured. Adsorption experiments were carried out at 298 K. The adsorption of gluconic acid was found to be appreciable in activated carbon. The percentage removal of gluconic acid was 94.14%. The equilibrium data fit well within the Freundlich isotherms.

Key words: Adsorption, Gluconic acid, Activated carbon, Freundlich isotherm

INTRODUCTION

Among the available methods for removing organic acids, adsorption is one of the most preferred methods. The traditional use of activated carbon in both water and wastewater treatment is well known. These materials are very versatile adsorbents due to their high surface area, a well developed pore structure and surface properties. In spite of their huge application in removing organic substances, however, the mechanism of the adsorption process is not yet fully understood and much confusion exists in the literature regarding these mechanisms. Activated carbons are known to have a heterogeneous physical and chemical structure. The former arises from the existence of micro, meso and macropores of different sizes and the latter arises from the variety of functional groups (mainly in the form of carbon-oxygen) that exist in the surface. The significance of the carbon surface chemistry in the adsorption process was first raised by Hassler¹ and Nouri *et al.*² A decade later, other authors have investigated the effects of surface carbon-oxygen groups and the sorbate-sorbent π - π interactions on the adsorption mechanism of organic compounds. Since then, theoretical and experimental approaches have come a long way, as demonstrated by various reviews in the last twenty years.

Adsorption phenomenon is largely governed by the physico-chemical characteristics of the adsorbent and adsorbate. In liquid phase adsorption, it has been established that the adsorption capacity of an adsorbent carbon depends on the

following factors. Firstly, it is the nature of the adsorbent, such as its pore structure, ash content and functional groups. Secondly, the nature of adsorbate (e.g., its functional groups, polarity, molecular weight and size). Finally, the solution conditions, referring to its ionic strength and adsorbate concentrations.

Gluconic acid has a large number of different industrial usages due to some exceptionally useful properties. These include its extremely low toxicity and corrosiveness, and its ability to form water-soluble complexes in different metal ions, and to plastify concrete and retard the setting process.

In this work the adsorption behaviour of gluconic acid on the activated carbon was investigated. All experimental data were then fitted into the Freundlich isotherm equation to obtain the corresponding factors^{3, 4}.

Theoretical

The analysis of the isotherm data is important to develop an equation which accurately represents the results and which could be used for design purposes. Out of the several isotherm equations available, Freundlich isotherm equations were found most suited for the present equilibria. The Langmuir isotherm is valid for monolayer adsorption onto a surface containing a finite number of identical sites. The model assumes uniform energies of adsorption onto the surface and no transmigration of adsorbate in the plane of the surface. Langmuir equation is represented in the following equation:

$$(C_e / Q_e) = (K_f / Q^0) + (C_e / Q^0) \quad (1)$$

where C_e is the equilibrium concentration (mg/L), Q_e is the adsorbed at equilibrium (mg/g) and K_f , Q^0 can be related to the equilibrium constant and sorption maxima respectively. The plot of C_e / Q_e vs. C_e gives a straight line showing the applicability of Langmuir isotherm. The values of K_f and Q^0 at different concentrations have been determined from the slope and intercept of the plot.

The Freundlich equation is used for heterogeneous surface energies in which the energy term in the Langmuir equation varies as a function of the surface coverage strictly due to variation in the heat of adsorption. The Freundlich equation has the general form,

$$Q_e = K_f C_e^{1/n} \quad (2)$$

A logarithmic plot linearizes the equation enabling the exponent n and the constant K_f to be determined⁵⁻⁸.

$$\log Q_e = \log K_f + (1/n) \log C_e \quad (3)$$

The constants are listed in Table-3 for the batch system. The values of K_f and $1/n$ at different concentrations were determined from the slope and intercept of the linear plots of Q_e vs. $\log C_e$.

EXPERIMENTAL

The granular activated carbon used in this work was supplied by Merck Co. Gluconic acid was also supplied by Merck Co.

To show the effect of initial gluconic acid concentrations on the adsorption, 0.003 g activated carbon was agitated with 5 mL of gluconic acid solution at five different concentrations: 0.75, 1.5, 3, 5 and 8% (w/w). At the second stage, to show the effect of shaking times on the adsorption, aqueous solutions of gluconic acid (= 3% w/w) and 0.003 g activated carbon were agitated in a shaking bath for 1, 2, 3 and 4 h. Lastly, aqueous solutions of gluconic acid (= 3% w/w) and activated carbon at 8 different amounts (0.001, 0.002, 0.003, 0.004, 0.005, 0.006, 0.007 and 0.008 g) was agitated in the shaking bath for 4 h. All the solutions were left in a temperature controlled shaking bath at 298 K. After adsorption experiments, the residue concentrations of the gluconic acid after filtration were determined by titration with 0.1 N aqueous sodium hydroxide. Acid analysis was checked against a material balance.

RESULTS AND DISCUSSION

Initially, the adsorption of gluconic acid on the activated carbon was investigated. The isotherm of gluconic acid is shown in Fig. 1 and Table 1. The isotherm is plotted using a mass based acid concentration, Q_e (in mg of the solute adsorbed per g of the carbon) vs. the liquid concentration (C_e) at equilibrium conditions. The liquid concentration at equilibrium (C_e) increases from 0.71 g/L to 9.50 g/L with increasing the initial concentration of gluconic acid.

TABLE- 1
EXPERIMENTAL RESULTS OF THE ADSORPTION OF GLUCONIC ACID
INTO ACTIVATED CARBON

Initial concentration (g/L)	Initial concentration (% w/w)	Amount of Activated carbon (mg)	Equilibrium concentration C_e (g/L)	Removal of acid (%)
7.54	0.75	0.003	0.71	91.40
15.23	1.50	0.003	1.25	91.79
30.92	3.00	0.003	7.50	75.74
52.63	5.00	0.003	7.90	84.98
86.95	8.00	0.003	9.50	89.07
30.92	3.00	0.001	18.95	38.71
30.92	3.00	0.002	13.17	57.41
30.92	3.00	0.003	9.18	70.31
30.92	3.00	0.004	5.22	83.11
30.92	3.00	0.005	1.81	94.14
30.92	3.00	0.006	1.29	95.82
30.92	3.00	0.007	1.18	96.18
30.92	3.00	0.008	0.78	97.48

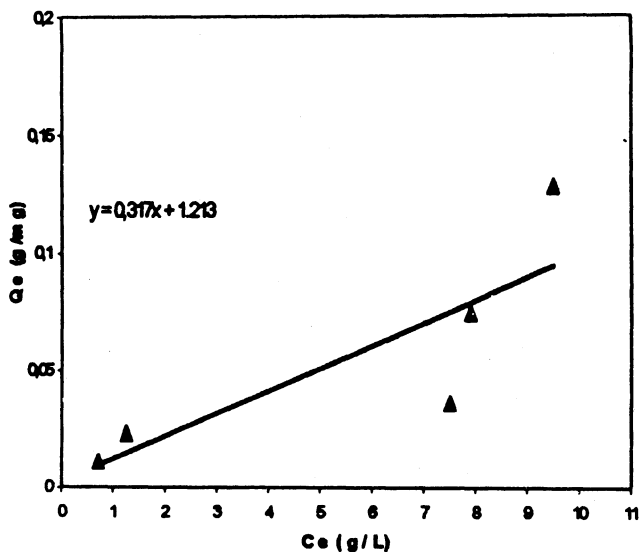


Fig. 1. Adsorption of gluconic acid

Fig. 2 demonstrates the influence of the amount of activated carbon on the adsorption of gluconic acid. It can be seen that the adsorption of gluconic acid increases with increasing amount of activated carbon. With increase in amount of activated carbon from 0.001 g to 0.008 g sorption of gluconic acid increases from 38.71 to 97.48%.

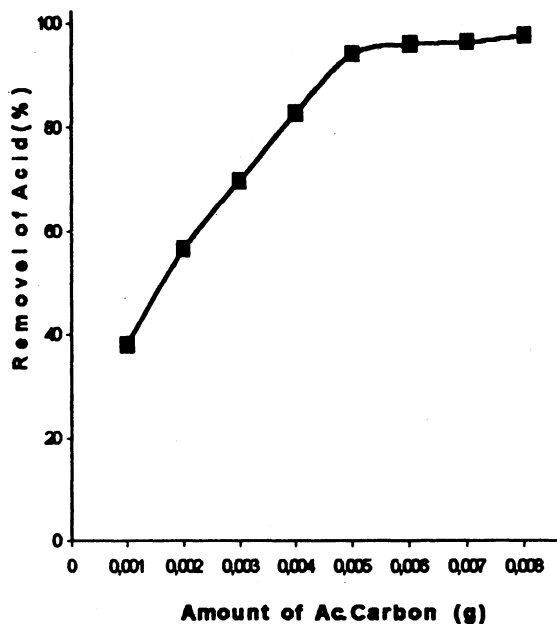


Fig. 2. Effect of activated carbon amount on gluconic acid adsorption

In Fig. 3, the effect of shaking time on adsorption of gluconic acid is shown. It can be seen from Fig. 3 that the adsorbed amount of gluconic acid increases with increasing shaking time. With increase in shaking time from 1 to 4 h, sorption

of gluconic acid increases from 2.29 to 70.31%. Adsorption isotherms were fitted into the Freundlich isotherm equations to calculate the isotherm parameters. The values of Freundlich parameters are given in Table 3.

TABLE-2
EFFECT OF SHAKING TIME ON THE ADSORPTION OF GLUCONIC ACID INTO ACTIVATED CARBON

Initial concentration (g/L)	Amount of Activated carbon (g)	Shaking time (h)	Equilibrium concentration (g/L)	Removal of acid (%)
30.92	0.003	1	30.23	2.23
30.92	0.003	2	18.28	40.88
30.92	0.003	3	11.41	63.09
30.92	0.003	4	9.18	70.31

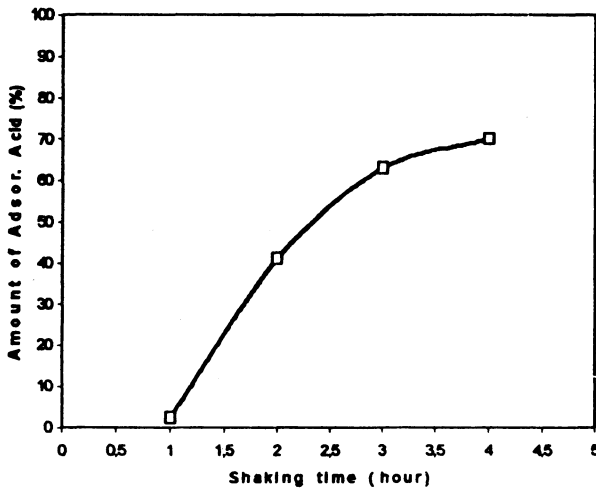


Fig. 3. Effect of shaking time on gluconic acid adsorption

TABLE-3
ADSORPTION ISOTHERM PARAMETERS OF GLUCONIC ACID BY ACTIVATED CARBON

Freundlich parameters	
K_f (mg/g)	$1/n$
2.075	1.214

In this work the adsorption capacity of commercially available activated carbon for gluconic acid, in different initial concentrations of acid and activated carbon, was investigated. It was found that the adsorption capacity of activated carbon was dependent on the amount of activated carbon and the initial

concentration of gluconic acid. On the basis of isotherm constants analysis it was confirmed that activated carbon exhibits promising adsorption characteristics for gluconic acid.

Symbols

- C_e = Equilibrium concentration, mg/L
 K_1 = Equilibrium constant
 Q_e = Adsorbed at equilibrium, mg/g
 Q^0 = Sorption maxima
 K_f = Constant
 n = Constant

REFERENCES

1. J.W. Hassler, Chemical Publishing Co., Inc., New York, p. 213 (1994).
2. S. Nouri, F. Hagsereeth and G.Q. Lu, *Inter. J. Engg. Sci.*, **12**, 67 (2001).
3. I. Langmuir, *J. Am. Chem. Soc.*, **40**, 1361 (1918).
4. H. Freundlich, *Z. Phys. Chem.*, **57**, 185 (1906).
5. Kalpana Rai and A. Maheshwari, *Asian J. Chem.*, **14**, 739 (2002).
6. S. Nouri, *Asian J. Chem.*, **14**, 934 (2002).
7. Kalpana Rai, A. Maheshwari and R. L. Shivhare, *Ultra Science*, **12**, 281 (2000).
8. S.S. Shastri and M.K.N. Yankie, *Asian J. Chem.*, **14**, 1009 (2002).

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