

## MODIFICATION OF ACTIVE CARBON BY OXIDATIVE TREATMENTS IN SOLUTION

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### ABSTRACT

Oxidation of active carbon surface may be achieved either by oxidizing gases or by oxidizing agents from aqueous solutions. Oxidation of active carbon was carried out at room temperature using  $H_2O_2$ ,  $(NH_4)_2S_2O_8$ ,  $K_2Mn_2O_7$  and  $HNO_3$ , at room temperature. Oxidation with  $HNO_3$  was also made at its boiling point. Oxidation of the carbon surface, at room temperature was associated with slight decrease in surface area and total pore volume and slight increase in the mean pore radius. However, reflux of active carbon in boiling concentrated  $HNO_3$  caused a destruction of the texture associated with a tremendous increase in the pore dimension and a drastic decrease in surface area. Oxidation of active carbon by oxidizing agents in solution brought about significant changes in the chemistry of the surface. Thus it increased the oxygen content and created surface carbon-oxygen complexes of acidic type. The changes in the chemistry of the carbon surface increased its hydrophilicity, its water vapor adsorption capacity and probably its adsorption of polar adsorbates.

### INTRODUCTION

The adsorption properties of carbon materials depend on their textural characteristics and on their chemical surface functionalities. The former is described by the surface area and porosity, and the latter mainly consist of the surface oxygen containing chemical groups, which can be acidic, basic or neutral [Kinoshita (1988) and Domingo-Garcia et al., (2000)]. The surface chemistry of carbons is determined to a large extent

by the number and the nature of the surface functional groups or complexes, mineral admixtures present in activated carbons can influence the surface chemistry of these carbons [Radovic et al., (1983)]. Carbon-oxygen surface compounds are by far the most important in influencing surface reactions, surface behavior, hydrophilicity and electrical and catalytic properties of carbons [Ryan and Stacy (1984)]. Cationic or anionic exchange capacities have been observed for carbons depending on surface functionality [Boehm (1994)]. Surface charge and zeta potential of carbon particles in aqueous suspensions are also conditioned by the nature of the surface functional groups in a given environment [Corapicoglu & Huang (1987)]. In a similar way, the adsorption properties of activated carbons can be controlled by modification of their surface groups. In addition, the solution chemistry (i.e., pH, added electrolyte, temperature, dissolved gases, mechanical agitation, etc) conditions the actual chemical response of any surface functional group present on the carbon-solution interface.

Oxidation is one of the most popular treatments of active carbons performed in order to increase their surface functionality and, consequently, to improve their sorption and ion exchange properties towards various adsorbates, as well as to enhance their adsorption and catalytic selectivity [Choma et al., (1999)]. This process can be carried out in the gas phase by using oxygen, ozone and nitrogen oxides, or in the liquid phase by means of hydrogen peroxide, nitric acid, potassium permanganate, ammonium persulphate, and other oxidizing agents. The degree of activation of an active carbon and the type of the surface groups created during the oxidation process depend on many factors such as the chemical composition of a given carbon, its surface properties and porosity [Choma & Jaroniec (1998) and Moreno-Castilla et al., (1998)]. Due to their high sorption capacity and their strong affinity for organic vapors, activated carbons are widely used in filtration techniques [Abdel-Raheim (2001)]. In such processes water vapor is also present at relative pressure above 0.5 and its influence on mixed sorption depends strongly on the amount of oxygen present on the surface, i.e., on the carbon oxygen functionality. Typical and untreated activated carbons contain less than 1.5 mmol of oxygen per gram [Lopez Ramon et al., (2000)], which corresponds to small fraction of the real surface area of the microporous walls [Fernandez et al., (2003)]. Under these circumstances water vapor adsorption exhibits relatively low effect on the sorption of different adsorbates from their aqueous solutions.

However, for carbons with higher oxygen content, water vapor adsorption is expected to exhibit a pronounced effect on the adsorption of different adsorbates from aqueous solutions [Stoecli (2000) and Shashi et al., (2004)].

The aim of the current work is to present the change in water vapor adsorption of activated carbon due to oxidation with different oxidizing agents. A special emphasis was put on monitoring changes in the carbon-oxygen functional groups and their contribution to the chemistry of the surface.

## EXPERIMENTAL

Preparation of the carbons: The raw material (date pits) was first thoroughly washed with doubly distilled water to remove adhering dirt and then oven-dried at 383K. The dried pits were crushed to 1-5 mm size fraction. The crushed date pits were carbonized at 773K in nitrogen atmosphere. The carbonization product was demineralized before gasification with steam at 1173K to a burn-off = 36%. This activated carbon was designated "C".

Oxidation of carbon samples: Thirty percent  $\text{H}_2\text{O}_2$ ,  $(\text{NH}_4)_2\text{S}_2\text{O}_8$  or  $\text{K}_2\text{Mn}_2\text{O}_7$  were used to oxidize three carbon samples. The oxidation process was carried out at room temperature (298K) for 6h by adding 100  $\text{cm}^3$  of the selected oxidizing solution to 10 g of the active carbon "C" which was placed in a glass flask. After finishing the oxidation process, the mixture was decanted, the carbon sample was washed with doubly distilled water until to a constant pH and dried at 383K. These oxidized carbon samples were designated COX1, COX2 and COX3, respectively. Other three oxidized carbons COX4, COX5 and COX6 were prepared by oxidation with 20, 40 and 65%  $\text{HNO}_3$ , respectively. An additional oxidized carbon COX7 was prepared as follows: 100  $\text{cm}^3$  of  $\text{HNO}_3$  were added to 10 g of the activated carbon contained in a glass flask. In this case this flask was connected with a reflux condenser ended with two absorption bulbs filled with NaOH solution. The carbon-nitric acid mixture was kept at its boiling point temperature for 3h. The released nitrogen oxides were absorbed in the absorption bulbs. After oxidation the mixture was cooled to room temperature, washed and dried as described above.

**Techniques:**

The textural properties (surface area and porosity) were determined from the adsorption of nitrogen at 77K, using conventional volumetric apparatus. Prior to any adsorption measurement, the carbon sample was degassed at 473K under a reduced pressure of  $10^{-5}$  Torr. The FTIR spectra of the carbons were determined using Mattson FTIR spectrometer. Discs were prepared by first mixing 1 mg of the powdered carbon with 400 mg of KBr (Merck for spectroscopy), in agate mortar then pressing the resulting mixture successively under pressure of 5 ton/cm<sup>2</sup> for 5 min and at 10 ton/cm<sup>2</sup> for 5 min under vacuum. The spectra of the samples were recorded between 4000 and 400 cm<sup>-1</sup>. The pH measurements were carried out by means of PYE pH meter in 1 g carbon suspended in 20 ml CO<sub>2</sub>-free doubly distilled water.

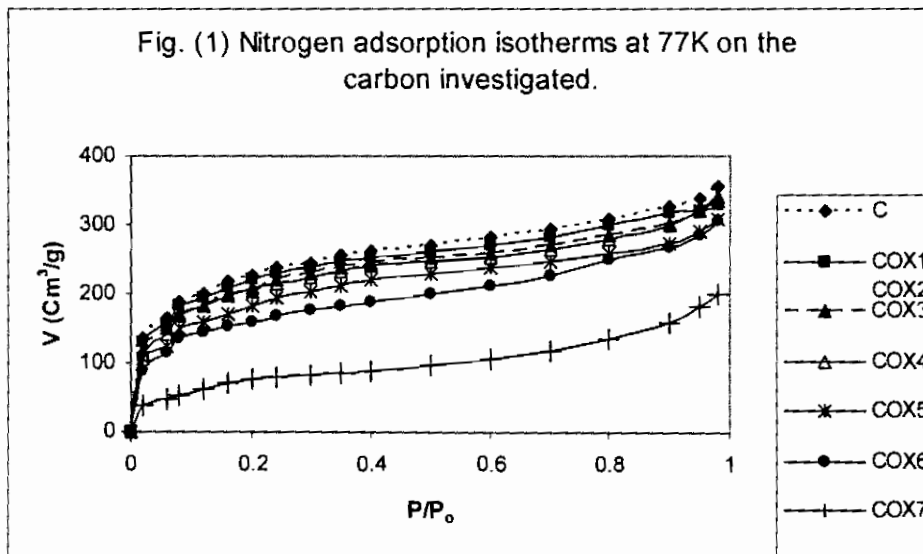
The base neutralization capacities were carried out by neutralization of 0.1 mol/dm<sup>3</sup> NaHCO<sub>3</sub>, Na<sub>2</sub>CO<sub>3</sub> and NaOH by the carbon. Thus 0.2 g of the carbon sample was mixed with 50 ml of the respective solution in 100 ml Quickfit polyethylene bottles. The suspensions were flushed with nitrogen. Mechanical shaking was continued for 48 h. The residual concentration of each solution was determined by titration against 0.1 mol/dm<sup>3</sup> HCl. For the determination of the acid neutralization capacity 0.2 g of the carbon sample was mixed with 50 ml 0.1 mol/dm<sup>3</sup> HCl in 100 ml Quickfit glass bottle for 48h while continuous shaking. The residual concentration of HCl was determined by titrating the supernatant against standard 0.1 Na<sub>2</sub>CO<sub>3</sub>. Estimation of the combined oxygen was made by means of an apparatus consisting of 50 cm<sup>3</sup>-capacity high purity silica reactor leading into two (10 dm<sup>3</sup>) reservoirs connected to a calibrated McLeod gauge to measure the pressure of degassed CO and CO<sub>2</sub>.

## RESULTS AND DISCUSSION

**Textural Properties:**

The adsorption of nitrogen at 77K on the carbons investigated proved to be rapid with the equilibrium attained in 20 min. However 30 min intervals were allowed between successive adsorption measurements to ensure equilibrium conditions. The adsorption of nitrogen, in all cases, was found also to be reversible with the desorption points lying on the same adsorption isotherm. These adsorption characteristics may be taken as evidences for the accessibility of the total pores to nitrogen molecules.

Fig.1 shows the nitrogen adsorption isotherms which are characterized by steep initial portions, well developed rounded knee bends (B points) and rising plateau beyond the knee bend. The nitrogen adsorption isotherms of carbons C, COX1, COX2, COX3, COX4 and COX5 are of type I according to BDDT classification [Brunauer et al., (1940)], whereas those of COX6 and COX7 are similar to type II of the same classification. The rising plateau in some isotherms and the tendency to exhibit type II isotherm may refer to the existence of a considerable fraction of mesoporosity. Satisfactory straight lines in the relative pressure range 0.05 – 0.30 were obtained (not illustrated), on applying the BET equation [Brunauer et al., (1938)].



The surface areas as calculated by applying the BET equation to the adsorption isotherms  $S^{BET}$  ( $m^2/g$ ), were calculated adopting the value of  $0.162 \text{ nm}^2$  for the molecular area of nitrogen [Gregg & Sing (1982)]. The total pore volume  $V_T$  ( $ml/g$ ) was estimated by converting the volume adsorbed at the relative pressure of 0.97-0.98 to the volume of liquid nitrogen.  $S^{BET}$  and  $V_T$  were used to calculate the mean pore radius  $r_m$  (nm) assuming cylindrical pore model, using the relationship:  $2V_T \times 10^3 / S^{BET}$  [Youssef et al., (2004)].  $S^{BET}$ ,  $V_T$  and  $r_m$  are listed in Table 1. The volume of liquid nitrogen taken at relative pressure  $P/P_0 = 0.1$  was assumed to represent the micropore volume  $V_m^{0.1}$  ( $ml/g$ ) column 5 of Table 1. Another independent method, namely the  $\alpha$ -method [Sing

(1968)] was also used to analyze the nitrogen adsorption isotherms. This method allows the determination of very interesting textural parameters. These are the total surface area  $S^{\alpha}$ , the surface of non-micropores  $S_n^{\alpha}$  and consequently the surface located in micropores  $S_m^{\alpha}$ . Also the volume of non-micropores  $V_n^{\alpha}$  and the micropore volume  $V_m^{\alpha}$  are frequently calculated from the  $\alpha$ -method. Representative  $\alpha$ -plots of the nitrogen isotherms are shown in Fig. 2, based on standard data previously reported [Selles-Perez and Martin -Martinez (1991)]. Each plot show two straight portions (one from  $\alpha=1$  and another for  $\alpha > 1$ ). These two straight portions have been found when it is assumed that  $\alpha = 1$  for a relative pressure of 0.4, a value at which it is reasonable to propose that the micropores are completely filled and the capillary condensation in the mesopores has not yet started. Thus the extrapolation from  $\alpha > 1$  still gives the micropore volume and the non-microporous surface area of the carbon. The straight portion passing through point of  $\alpha < 1$  to the origin determine the total surface area  $S^{\alpha}$ . The textural parameters determined from this method are listed in Table 1.

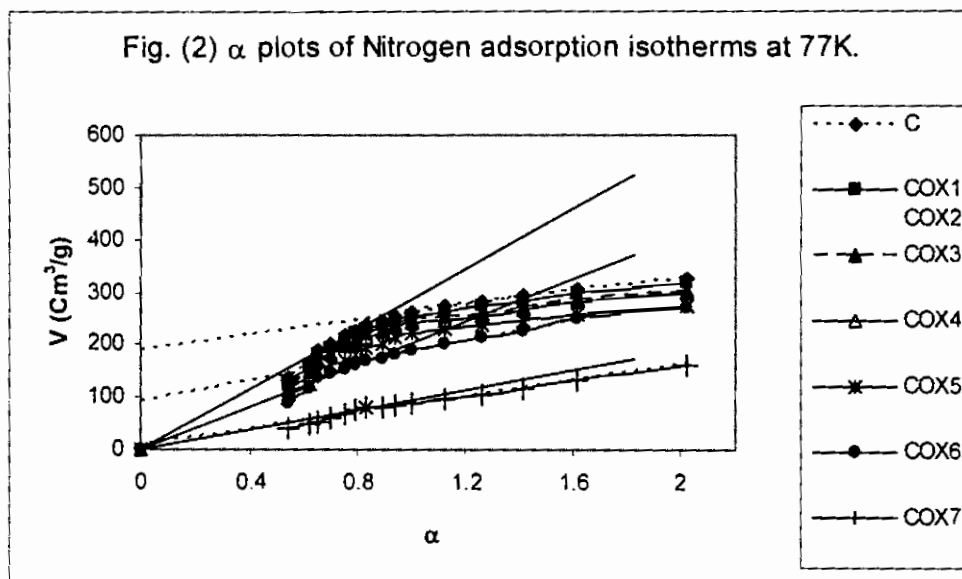
**Table (1):** Textural properties as determined by the BET-method and the  $\alpha$ -method.

Sample	$S^{BET}$ m <sup>2</sup> /g	$V_T$ ml/g	$r_m$ nm	$V_m^{0.1}$ ml/g	$S^{\alpha}$ m <sup>2</sup> /g	$S_n^{\alpha}$ m <sup>2</sup> /g	$S_m^{\alpha}$ m <sup>2</sup> /g	$V_n^{\alpha}$ ml/g	$V_m^{\alpha}$ ml/g
C	789	0.550	1.39	0.297	798	215	583	0.255	0.295
COX1+	758	0.540	1.41	0.285	756	220	538	0.260	0.280
COX3	724	0.514	1.42	0.270	728	220	508	0.249	0.265
COX4	683	0.520	1.52	0.260	675	235	440	0.257	0.263
COX5	646	0.509	1.57	0.240	644	255	389	0.309	0.200
COX6	547	0.494	1.78	0.200	560	218	342	0.331	0.163
COX7	290	0.342	2.36	0.075	280	180	100	0.302	0.040

COX1+ means that the data are the same for COX2 also.

Inspection of tale 1 reveals that : (i) Comparable surface areas were obtained from the BET-method and the  $\alpha$ -method. (ii) The total surface area slightly decreased whereas the mean pore radius slightly increased upon oxidation of activated carbon with 30% H<sub>2</sub>O<sub>2</sub>, (NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub>, K<sub>2</sub>Mn<sub>2</sub>O<sub>7</sub>, or with 20 and 40% HNO<sub>3</sub>, at room temperature. However, oxidation with 65% HNO<sub>3</sub> at room temperature was found to be associated with about 31% decrease in the total surface area and with

28% increase in  $r_m$ . The drastic change in the textural properties was found upon oxidation of activated carbon with 65%  $\text{HNO}_3$  at its boiling point. Thus  $S^{\text{BET}}$  decreased from 780 to 290  $\text{m}^2/\text{g}$ ,  $V_T$  decreased by about 28% whereas  $r_m$  increased by 70%. (iii) The  $\alpha$ -method revealed that for the activated carbon C,  $S_m^a/S_n^a$  and  $V_m^a/V_n^a$  are 2.71 and 1.16, respectively whereas these ratios decreased to 0.59 and 0.13 for COX7. Less oxidized carbons exhibited intermediate values.



#### Chemistry of Carbon Surfaces:

The chemistry of the surface of a carbon is equally important to its textural properties in determining its adsorption properties and its use, particularly in aqueous solutions. The chemistry of the carbon surface is attributed to the existence of carbon-oxygen functional groups of acidic or basic nature. The pH of the aqueous slurry of the carbon material provides a qualitative indicator of the nature of the surface groups. The FTIR spectra of the carbons may give also another qualitative indicator. The quantitative measure of the type and amount of the surface groups, particularly those of the carbon-oxygen type are conventionally obtained by measuring the acid-base neutralization capacities. FTIR spectra of the carbons are shown in Fig. 3. The bands at  $1073\text{-}1591\text{ cm}^{-1}$  (composed band) are attributed to carbonate and carboxylic structure, highly stable cyclic ether containing COCOC groups or ether bridges between cycles

[Figueiredo et al., (1999)]. The bands at 1000-1220  $\text{cm}^{-1}$  may be assigned to C-OH stretching [Fanning & Vannice (1993)], whereas those at 1154  $\text{cm}^{-1}$  are characteristic of O-H bending. The band centered at 1692  $\text{cm}^{-1}$  is ascribed to C=O stretching, whereas that centered at 3444  $\text{cm}^{-1}$  is characteristic of O-H stretching [Shindo & Izumino (1994)]. Slight differences are shown when the spectra of COX1, COX2, COX3, COX4 and COX5 were compared with the spectrum of carbon C. However, the situation is different with COX6 and COX7 where considerable increase in the intensities of the spectral bands with this increase more pronounced in case of COX7. It is worth-mentioning that spectroscopic methods have not yield comparable results and the entire amount of combined oxygen has not been accounted for [Bansal et al., (1988)].

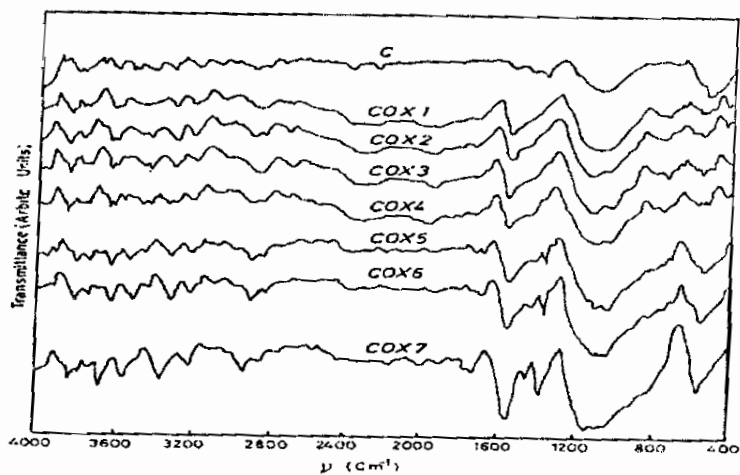


Fig.(3) FT-IR spectra of the carbons investigated.



The results of chemical surface groups titrations are collected in Table 2, included also in this table are the surface pH values. It was assumed that  $\text{NaHCO}_3$  neutralizes carboxylic groups whereas those neutralized by  $\text{Na}_2\text{CO}_3$  but not by  $\text{NaHCO}_3$  were believed to be lactones. The weakly acidic groups neutralized by  $\text{NaOH}$  but not by  $\text{Na}_2\text{CO}_3$  were postulated as phenols. The total basicity (m equiv./g) was determined from neutralization with 0.1M HCl. The total amount of the surface carbon-oxygen complexes could be determined by degassing the carbon sample at high temperatures up to 1273K. The amount of the complex which is out-gassed as CO could be followed with the rise of the out-gassing temperature from 573 to 1273K, by measuring the pressure exerted by the out-gassed CO by means of a McLeod gauge. The amount of  $\text{CO}_2$  could be determined at the end of the experiment assuming that the complex consisted of one oxygen atom [Youssef et al., (1982)]. The CO and  $\text{CO}_2$  evolved are given in Table 2.

Inspection of Table 2 reveals that: (i) Carbon C exhibits basic surface pH and contains approximately the same amount of the total surface acid groups and surface basic groups. (ii) The total number of surface acid groups increased whereas the basic groups decreased upon oxidation, with these changes depending on the oxidizing agent and are more pronounced with nitric acid oxidation. Although the degree of oxidation with nitric acid is related to its concentration, however the temperature of oxidation with nitric acid is more effective. Thus tremendous increase in the surface acidity and drastic decrease in the surface basicity could be depicted when COX7 is compared with any of the other oxidized carbons. (iii) The changes in the type and amount of the carbon–oxygen groups is always associated with a change in the surface pH. (iv) Phenolic groups predominate on the surface of the investigated carbons except with COX7 where carboxylic groups predominate. (v) Evidently, the total amount of surface acid groups (m equiv/g) is always comparable with the amount of oxygen degassed as  $\text{CO}_2$ . Also, the amount of surface basic groups were found to be equal to the amount of oxygen degassed as CO, both are expressed in the same units. This is in good agreement with previous work [Barton et al., (1984)].

**Table (2):** Surface pH, Chemical surface groups content and out-gassed CO and CO<sub>2</sub> (m equiv/g).

Sample	PH	Carboxyl	Lactone	Phenol	Total	Basic	CO	CO <sub>2</sub>
C	8.1	0.08	0.12	0.14	0.34	0.37	0.35	0.32
COX1	6.8	0.14	0.15	0.19	0.48	0.21	0.20	0.45
COX2	6.7	0.15	0.15	0.24	0.54	0.20	0.22	0.55
COX3	6.8	0.15	0.16	0.28	0.57	0.20	0.21	0.56
COX4	6.5	0.20	0.17	0.32	0.69	0.18	0.17	0.67
COX5	6.1	0.24	0.21	0.34	0.79	0.18	0.17	0.78
COX6	5.5	0.35	0.26	0.37	0.98	0.10	0.10	0.96
COX7	4.4	0.48	0.32	0.44	1.24	----	0.04	1.20

**Water Vapor Adsorption:**

Study of the mechanism of adsorption of water vapor on activated carbons and interpretation of the respective adsorption isotherms have been undertaken by many groups of investigators for the last decades. Nonetheless, several ambiguities remain unsolved. The principal points generally raised and argued concern the role of associated oxygen and capillary condensation in determining the adsorption of water vapor on active carbon. The disagreement between the groups interesting in studying water vapor adsorption on active carbons may be attributed to the different nature of carbons, oxidizing agents used, methods and conditions of preparation and possibly other reasons. Regardless of this conflict, more investigations are required to improve the adsorption properties of active carbons and their applications particularly in solution chemistry [Hu et al., (1999), Guwarth et al., (2000), Okolo et al., (1995) and Ania et al., (2002)].

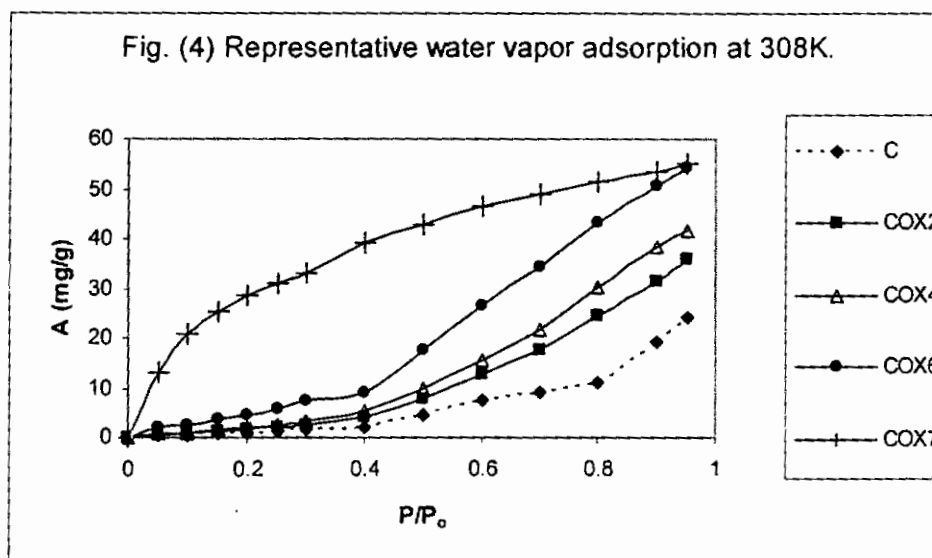
Representative water vapor adsorption isotherms are shown in Fig.(4). It is evident that the adsorption of water vapor on carbons oxidized by H<sub>2</sub>O<sub>2</sub>, (NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub>, K<sub>2</sub>Mn<sub>2</sub>O<sub>7</sub> and 20% and 40% HNO<sub>3</sub>, at room temperature was not influenced so much by this oxidation. On the other hand, oxidation of active carbon with concentrated HNO<sub>3</sub> influenced significantly the process of water vapor adsorption as in COX6. The influence is very pronounced upon oxidation with this acid at its boiling point as in COX7. The amount of water vapor adsorption on unmodified carbon C is relatively small in the range of relative pressure below 0.4, in which the isotherm exhibits type III according to IUPAC classification [Sing et al., (1985)]. This isotherm is observed because of

weak interaction between water molecules and the carbon surface due to a small amount of primary sites, i.e., oxygen surface groups, available for adsorption. The treatment of carbon with different oxidizing agents at room temperature did not change the type of the isotherm indicating that this type of oxidation did not create sufficiently large number of oxygen groups. Although this mild oxidation did not cause a change in the type of the isotherm, a noticeable difference in the amount of water vapor adsorbed is visible, especially when oxidation was achieved with 65% HNO<sub>3</sub> at room temperature. For strongly oxidized carbon COX7 the amount of adsorbed water vapor in the range of relative pressure below 0.4 is much greater than that for non-oxidized carbon or any mild-oxidized one. The water vapor adsorption of COX7 is of type II according to IUPAC classification, which is characteristic of strong adsorbent-adsorbate interaction, which was achieved by creating a significant amount of primary active sites (Table 2). The S<sup>BET</sup>-nitrogen surface area of COX7 is considerably lower than the surface area of any of the carbons investigated (Table 1), this implies high concentration of the active sites, i.e., large number of active adsorption sites per unit surface area. This probably enhanced the adsorption of water vapor on this particular sample and meanwhile indicates that the chemistry of the carbon surface rather than the texture is the prominent factor in determining the adsorption capacity of the carbon for water vapor adsorption.

The BET equation was applied to the water vapor adsorption isotherms to determine the monolayer adsorption capacity and consequently the area covered by water vapor, adopting 0.106 nm<sup>2</sup> for the cross sectional area of water molecule [Youssef et al., (1982)]. This equation allowed also the determination of the BET-C constant which is a measure of the adsorbent-adsorbate interaction and its value determines the type of the adsorption isotherm particularly at low relative pressure. Table 3 lists the monolayer capacities expressed in mg/g, the S<sup>BET</sup> values. The BET-C constants. Included also in this table are the ratios A<sub>0.4</sub>/A<sub>0.95</sub> where A<sub>0.4</sub> and A<sub>0.95</sub> are the amount of water vapor adsorbed at relative pressures of 0.4 and 0.95, respectively. Table 3 depicts that the BET-constant of the unmodified carbon equals 6.0, those of mild-oxidized carbon range between 6 and 7 whereas the BET-C constant of COX6 equals 10 and that of COX7 equals 20. This explains why type II water vapor adsorption isotherm was exhibited by the sample COX7. The ratio A<sub>0.4</sub>/A<sub>0.95</sub> of unmodified carbon is very small (0.09)

whereas it amounts to 0.71 for COX7, i.e., 8-fold increase of this ratio is brought about by strong oxidation. For other oxidized samples this ratio ranged between 0.11 and 0.18.

It remains now to explain the significant increase in the water vapor adsorption capacity beyond relative pressure = 0.4. At or just before this relative pressure, the primary adsorption sites are covered with water molecules which may be considered as secondary sites for further adsorption of water vapor via hydrogen bonding.



**Table (3):** Some water vapor adsorption parameters.

Sample	A <sub>m</sub> (mg/g)	S <sup>BET</sup> (m <sup>2</sup> /g)	BET-C constant	A <sub>0.4</sub> /A <sub>0.95</sub>
C	1.15	4.0	6.0	0.09
COX1	1.86	6.5	6.0	0.11
COX2	2.00	7.1	7.0	0.11
COX3	2.90	10.3	7.0	0.12
COX4	3.20	11.4	7.0	0.13
COX5	4.20	14.8	6.0	0.14
COX6	6.10	21.4	10.0	0.18
COX7	27.4	97.0	20.0	0.71

### CONCLUSION

Mild oxidation of active carbon with oxidizing agent from solution is associated with slight decrease in the surface area and total pore volume and slight increase in the mean pore radius. Drastic increase in the surface area and considerable increase in the pore size is associated with strong oxidation with concentrated nitric acid at its boiling point. Oxidation of active carbon creates carbon-oxygen complexes at the surface with the type and number of the complexes depending on the oxidizing agent, its concentration as well as on the temperature of oxidation.

Oxidation of active carbon with oxidizing agents from solution increases the hydrophilicity of the carbon as well as its capacity for water vapor adsorption. These changes are related to the changes in the chemistry of the surface rather than to the changes in the texture. Surface carbon-oxygen groups are the primary sites for water vapor adsorption. The adsorbed water molecules may act as secondary sites for further adsorption of water molecules via hydrogen bonding.

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تحويل الكربون المنشط بواسطة المعالجة بالأكسدة في المحاليل.

شيخة سعود عاشور

المملكة العربية السعودية - مكة المكرمة ص. ب ١٨٤٧

رقم الهاتف ٠٠٩٦٦٥٠٤٥٣٢٠٨٦ - رقم الفاكس ٠٠٩٦٦٢٥٦١٤٠٠٣

من أكثر الصفات المهمة التي تحدد استعمال الكربون النشط هي الخواص النسجية وكيمياء السطح . كيمياء السطح للكربون النشط ناتج عن وجود مجموعات وظيفية خاصة من نوع C-O ، ويمكن أكسدة سطح الكربون النشط بواسطة الغازات المؤكسدة أو العوامل المؤكسدة في المحاليل المائية.

وقد أجريت أكسدة الكربون النشط عند درجة حرارة الغرفة باستعمال منجنات البوتاسيوم، حمض النيتريك وكبريتات الأمونيوم المائية كما أجريت الأكسدة بواسطة حمض النيتريك عند درجة الغليان أيضاً.

ولوحظ أن أكسدة الكربون النشط عند درجة حرارة الغرفة يصحبها انخفاض بسيط في مساحة السطح وحجم المسام وزيادة بسيطة في متوسط قطر المسام.

إن إجراء عمليه (reflux) للكربون النشط في حمض نيتريك مركز مغلي يسبب هدم لخواص الكربون النسجية ومصاحبه بزيادة في أبعاد المسام وانخفاض شديد في مساحة السطح.

إن أكسدة الكربون النشط بواسطة العوامل المؤكسدة في المحاليل المائية تسبب تغيير واضح في كيمياء السطح، حيث أنها تزيد من محتوى الأكسجين وتخلق متراكب من سطح الكربون ومجموعات CO لها خواص حمضية.

كما أن هذه التغيرات الكيميائية تجعل سطح الكربون محب للماء وله القدرة على إمتزاز بخار الماء إضافة إلى المواد القطبية.