

# ADSORPTION KINETICS ON ACTIVE CARBONS

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## Introduction

Active carbons are widely used for the removal of gases and vapours from air. When carbon filters are used in practical applications, toxic material is removed from air containing water vapour. Hence there will be competitive adsorption between the material to be adsorbed and the air containing water vapour. Water vapour is known to have a detrimental effect on the adsorption of pollutants from air streams. Little work has been carried out on the adsorption/desorption kinetics of organic materials and water vapour on active carbons. However there is a growing interest in this area of competitive adsorption as the effect of water vapour which varies in concentration in air must be taken into consideration for prediction of optimum performance of active carbon filters.

The initial study has involved a comparison of the adsorption kinetics and equilibrium uptakes of water vapour and organic molecules on a highly microporous carbon. The objective of the study was to investigate the adsorption and desorption kinetics of water vapour and organic molecules as a function of relative pressure in order to understand the effect of changes in concentration and atmospheric conditions on the performance of active carbon in real situations.

## Experimental

### *Materials used*

The carbon used was derived from coconut shell carbon by activation in carbon dioxide at 1173K.

### *Micropore Size Distribution*

The micropore size distribution was determined by the molecular probe method<sup>1</sup> using the adsorption of CH<sub>2</sub>Cl<sub>2</sub>(400pm), CHCl<sub>3</sub>(460pm), i-pentane (490pm) and CCl<sub>4</sub>(600pm) at 301K and  $p/p_0 = 0.5$ .

### *Adsorption Kinetics*

The kinetic measurements were carried out using an Intelligent Gravimetric Analyser (IGA) supplied by Hiden Analytical. The instrument consists of a fully computerised microbalance which automatically records the weight of the carbon sample as a function of time with the vapour pressure and sample temperature under

computer control. After outgassing the sample at 10<sup>-8</sup> bar and 383 K; the vapour pressure and temperature were set to the desired value under computer control and the weight uptake measured as a function of time under isothermal conditions until equilibrium was attained. The approach to equilibrium was monitored in real time and a computer algorithm used to establish when 99% gas uptake was achieved. After equilibrium was achieved, the vapour pressure was increased to the next desired value and weight versus time recorded. The weight versus time data were used to calculate the kinetic data for each pressure step thereby providing adsorption kinetic data for different amounts of pre-adsorbed vapour.

## Results

The carbon dioxide(273K) and nitrogen(77K) adsorption isotherms were determined and both were type 1. The total pore volume calculated from the nitrogen adsorption data was 0.222cm<sup>3</sup>g<sup>-1</sup> while the micropore volume determined from the Dubinin Radushkevich graph was 0.212 cm<sup>3</sup>g<sup>-1</sup>. The effective micropore size distribution of the carbon was estimated by the molecular probe method. The results showed that there was a sharp decrease in adsorption capacity for probe molecules with sizes between 400 and 460pm which is consistent with ultramicroporosity being the part of the porous structure.

The adsorption of organic vapours such as dichloromethane, and chloroform also have type 1 isotherms whereas the adsorption of water vapour was a type V isotherm as shown in figure 1. The water vapour isotherm shows some adsorption/desorption hysteresis and consists of three regions 0 - 1.2 kPa, 1.2 - 1.8kPa and 1.8- 2.4kPa. The steepest part of the isotherm is associated with the gradual volume filling of porosity associated with the growth of water molecule clusters and bridging between these clusters. The adsorption kinetics for all three regions follow a linear mass transfer driving force model for typically > 90% of the uptake<sup>2</sup>. The rate constants are higher in the low pressure region (0-1.2kPa) and lowest in the pressure range (1.2 - 1.8kPa) before increasing again at higher

$p/p_0$  as shown in figure 2.

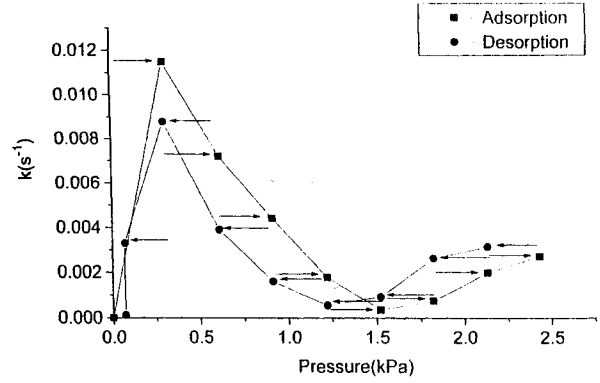
In contrast the adsorption isotherm for  $\text{CH}_2\text{Cl}_2$  is type 1 as shown in Figure 3. The adsorption kinetics for pressure increments of  $p/p_0$  in the range 0.01 - 0.1 followed a linear mass transfer driving force model. A typical graph of  $\ln(1 - M_t/M_e)$  is shown in figure 4. The rate constants for given pressure increments do not vary greatly for low surface coverage but increase dramatically when pore filling occurs.

### Conclusions

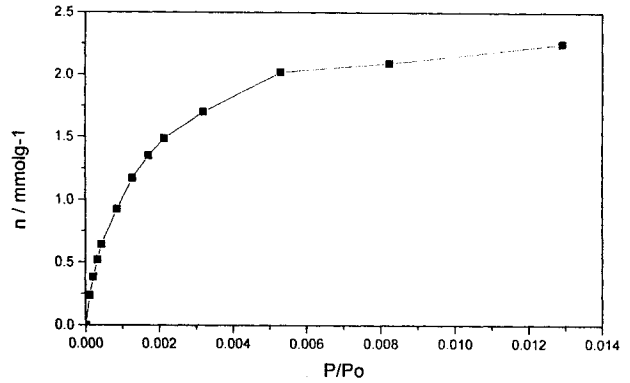
The presence of water vapour in air affects the performance of active carbons adsorbents. The kinetics of adsorption for both water vapour and dichloromethane for rapid changes in vapour pressure follow a linear mass transfer driving force model for > 90% of the uptake. The results clearly show that the rates of adsorption and desorption vary with the position on the isotherm and hence the mechanism of the adsorption process.

### References

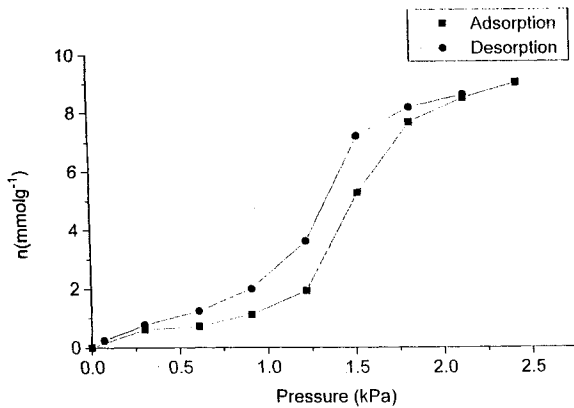
1. Braymer, T.A., Coe, C.G., Farris, T.S., Gaffney, T.R., Schork, J.M. and Armor, J.N., *Carbon*, 1994, **32**, 445.
2. Foley, N.J., Thomas, K.M., Forshaw, P.L., Stanton, D and Norman, P., *Langmuir* (in press).



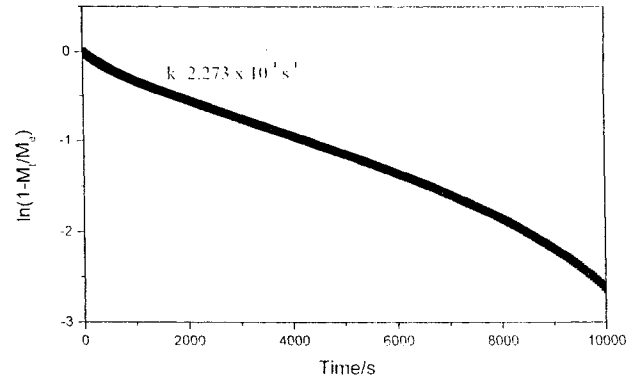
**Figure 2.** The Adsorption/Desorption Rate Constants over the Isotherm: Pressure increment 0.3kPa



**Figure 3.** Dichloromethane Adsorption Isotherm at 293K.



**Figure 1.** Water vapour adsorption isotherm of the carbon at 295K



**Figure 4.** A graph of  $\ln(1 - M_t/M_e)$  versus time for  $\text{CH}_2\text{Cl}_2$  adsorption on the active carbon at 293K Pressure Increment:  $p/p_0$  0-0.001)