Adsorption of Styrene Monomer on Activated Carbon

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Styrene is discharged particulary from the factories of styrene resin and synthetic rubber, and it was listed as one of the offensive odor substances by the Offensive Odor Control Law in Japan at 1976. Styrene vapor has stimulating action on eye (STEWART et al. 1968) and membrana of nose and trachea (STEPHENSON & FOSDICK 1960). It has toxic effects on blood cells and liver (KATZ 1962), and nervous system (BOURNE & MILNER 1963). Concentration admissible of styrene in the working environment is restricted within 1.2 ppm at the Soviet Union and Bulgaria, 50 ppm at Japan, or 100 ppm at Great Britain, Western Germany, Switzerland, and America (SPECIAL COMMITTEE OF JAPANESE TRANSLATION OF FOREIGN LITERATURE 1976).

In the present work, adsorption isotherms of styrene monomer on activated carbon were obtained at 30°C by the gravimetric method using B.E.T. apparatus with a spring balance in order to find out the activated carbon suitable for the removal of styrene. Relation to exist between the amount adsorbed at equilibrium concentration 4000 ppm and the physicochemical properties such as pH, basic amount, pore volume, and pore size distibution of activated carbon was investigated to elucidate the mechanism of adsorption of styrene on activated carbon.

EXPERIMENTAL

Materials: Styrene, commercially purified material, was purified by vaccum distillation. Activated carbon used was commercial product, and its particle size was 4-16 mesh.

Procedure of Adsorption: Activated carbon was dried at 110°C for 1 h at 1×10^{-3} mmHg before use. Equilibrium amount adsorbed at equilibrium concentrations up to 4000 ppm was measured by a gravimetric method using B.E.T. apparatus with a spring balance at 30°C.

Surface pH and Basic Amount: The method for measuring pH and basic amount of activated carbon was given by URANO et al. (1976).

Measurement of Pore Size Distribution: The pore size distribution of activated carbon in the range of pore radii 6.5 to 100 Å was obtained by the method of DOLLIMORE & HEAL (1964). The pore size distribution in the range of pore radii 100-10000 Å was obtained by means of mercury prosimeter (Prosimeter Series 200, Carlo Erba, Italy).

RESULTS AND DISCUSSION

Adsorption Isotherm of Styrene on Activated Carbon:
In order to find out the activated carbon suitable for the
removal of styrene, adsorption isotherms of styrene on
activated carbon were obtained at 30°C in the range of
equilibrium concentrations about 50 to 4000 ppm as shown
in Fig. 1. Adsorption isotherms were broadly classified
into three types, type 1 showing a large amount adsorbed
and a plateau in the range of about 50 to 4000 ppm (Nos.2,
3, and 5), type 2 showing a gradual increase in amount
adsorbed with equilibrium concentration (No.1), and type 3
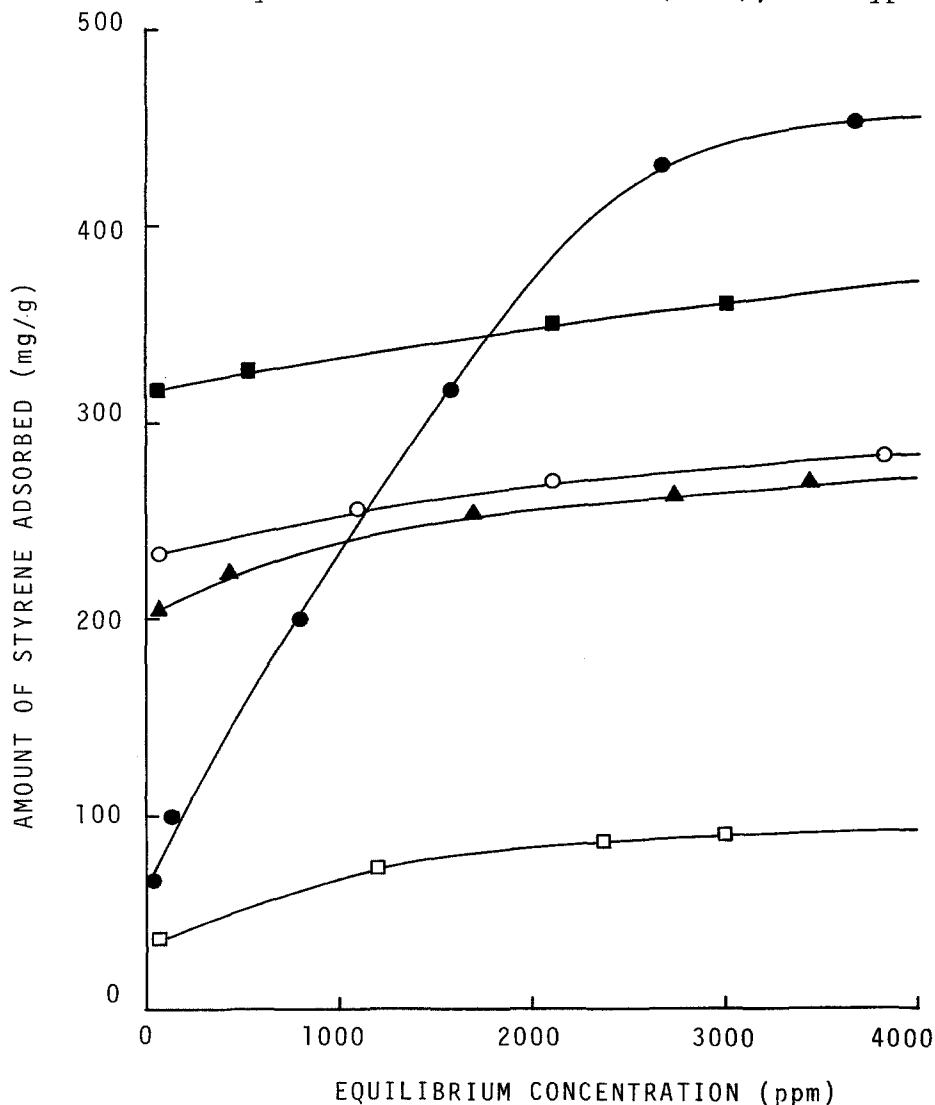
Fig. 1. Adsorption Isotherms of Styrene on Activated
Carbon at 30°C. ●No.1, ○No.2, ■ No.3, □ No.4, ▲ No.5

showing a low amount adsorbed in the range of about 50 to
4000 ppm (No.4). Activated carbon No.3 and activated
carbon No.1 were found to be most suitable for the removal
of styrene at low equilibrium concentrations up to about
1000 ppm and high equilibrium concentrations above about
2000 ppm, respectively.
      Relation Between Amount Adsorbed And Physicochemical
Properties of Activated Carbon: Amount of styrene ad-
sorbed on activated carbon seems to be determined by chem-
ical properties and porous structure of activated carbon.

TABLE 1

Physicochemical Properties of Activated Carbon Used

Activated Carbon No.	pH	Basic Amount (eq/g)	Micropore Volume (mL/g)
1	6.68	71.67×10^{-7}	0.6216
2	6.95	81.05×10^{-7}	0.3924
3	6.32	56.67×10^{-7}	0.2665
4	4.68	47.39×10^{-7}	0.1529
5	9.91	118.60×10^{-7}	0.4319

Micropore volume is integral pore volume below pore radius
15 Å.

Amount of ammonia adsorbed on activated carbon was decided
mainly by its surface pH and basic amount (MIYOSHI et al.
1976). However, there was no appreciable interaction be-
tween the amount adsorbed at a equilibrium concentration
4000 ppm and the chemical properties such as pH and basic
amount (Fig.1 and TABLE 1). In order to elucidate the re-
lation to exist between the amount adsorbed and the porous
structure, pore size distribution of activated carbon was
obtained in the range of radii 6.5 to 10000 Å as shown in
Fig.2. The pore structure of activated carbon is custom-
arily divided into three classes, micropores (radius<15 -
16 Å), transitional pores (15 - 16 Å <radius <1000 -
2000 Å), and macropores (radius > 1000 - 2000 Å) (DUBININ
1966). The results of pore size distribution indicated
that the activated carbons used were mainly occupied by
micropores. The pore volume of No.1 increased remarkably
with pore radius in the range of radii 6.5 to 15 Å, but
pore volumes of Nos.2 - 5 increased gradually with pore
radius in the same range. Activated carbon No.1 with the
largest amount adsorbed at equilibrium concentrations
above about 2000 ppm showed a smaller pore volume than
those of Nos. 2 and 5 in the range of radii up to 10 Å,
but it showed a larger pore volume than those of Nos.2 and
5 at pore radii above 10 Å, and it also showed a significant
increase in pore volume in the range of radii 10 to 15 Å.
Adsorption isotherm of No.1 (Fig.1) resembled closely in
shape of its pore size distribution curve (Fig.2), and the
results of Figs.1 and 2 suggested that there was an inter-
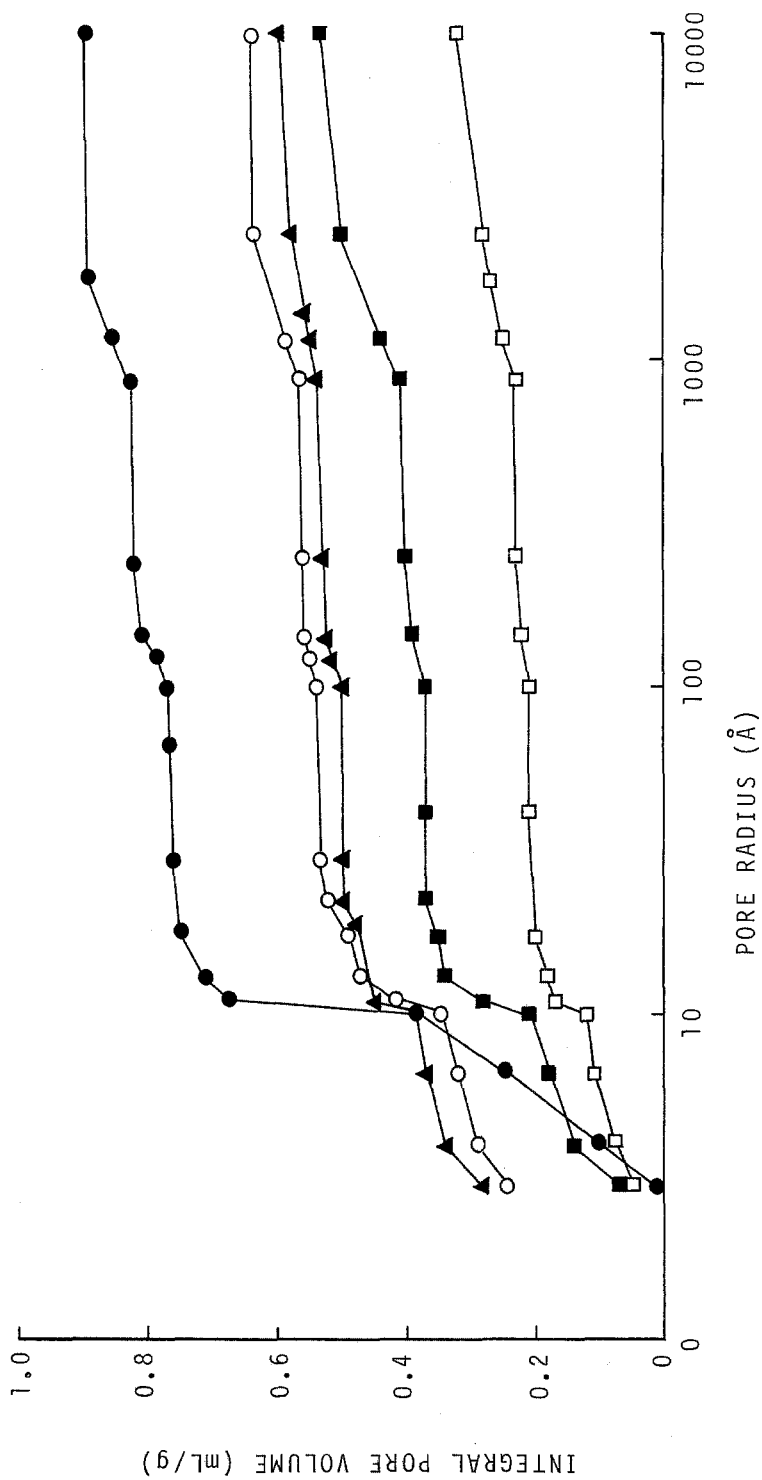action between pore volume and amount of styrene adsorbed.

Fig. 2. Pore Size Distribution Curves of Activated Carbon.
●No.1, ○No.2, ■No.3, □No.4, ▲No.5

Figure 3 shows the amount of styrene adsorbed at equilibrium concentration 4000 ppm vs. micropore volume of up to radius 15 Å. An approximately linear relationship existed between the two, and it was confirmed that the amount adsorbed was determined by their micropore volumes of less than 15 Å. The diameter of styrene is 6.50 Å (TANADA & BOKI), and therefore, it can easily enter into the micropore of activated carbon.
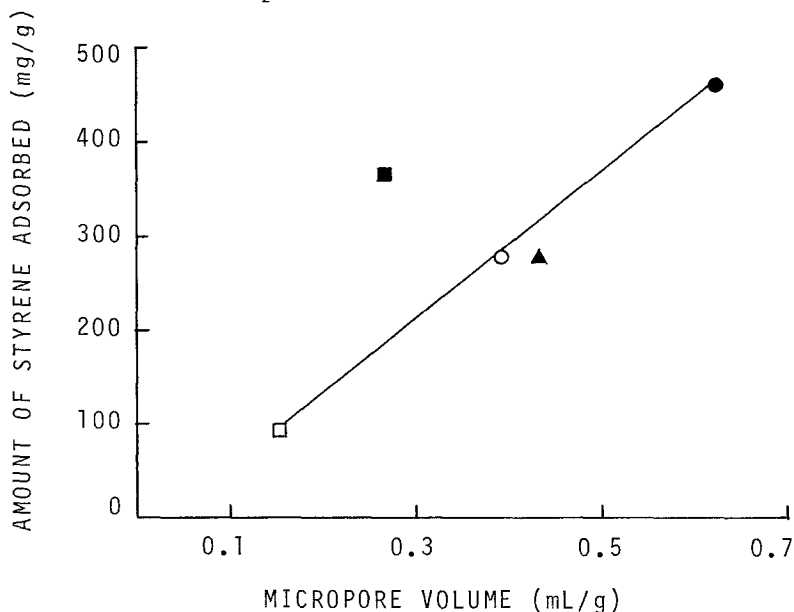

Fig. 3. Micropore Volume vs. Amount of Styrene Adsorbed. ●No.1, ○No.2, ■No.3, □No.4, ▲No.5

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