In Eq. (5), v_B and k'_s are invariable while ρ_B takes distinct values for different mixtures. Hence, according to Eq. (5), surface rate constant k_s should vary corresponding to the molar density of B in each particle. With insertion of Eq. (5), Eq. (4) is therefore rewritten as

$$\tau = \frac{R}{bk'_s v_B C_{A0}} \quad (6)$$

This is now independent of the particle molar density of B, as is seen in experimental observations. Consequently, one may understand that the rate constant k'_s based on the effective surface area given by Eq. (5) must be used instead of k_s based on the geometrical surface area in representing the rate equation for a solid reactant in the mixture with an inert.

Nomenclature

C_{A0}	= concentration of A in bulk phase	[mol/m ³]
k_s	= apparent surface rate constant	[m/min]

k'_s	= rate constant based on unit area of effective surface	[m/min]
R	= radius of a particle	[m]
r_c	= radius of an unreacted core	[m]
t	= reaction time	[min]
v_B	= molar volume of B	[m ³ /mol]
X_B	= extent of conversion of B in a particle	[—]
ρ_B	= molar density of B in a particle	[mol/m ³]
τ	= complete reaction time of a particle	[min]

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RESPONSE OF CIGARETTE SMOKE PARTICLES TO CHANGE IN HUMIDITY

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Do particles in cigarette smoke grow larger in humid air? Results of our study indicate that condensation of water vapor on cigarette smoke particles takes place only under supersaturation conditions.

Size distributions of smoke particles generated with filters (Wakaba brand, the Japan Tobacco and Salt Public Corporation) were measured by the apparatus shown in Fig. 1. The experimental set-up consisted mainly of an ultramicroscopic sedimentation size analyser⁴⁾, a smoking device, two humidifiers and a psychrometer. Each humidifier consisted of a silica gel bed, a bubbler, and two control valves. The relative humidity of the air stream from each humidifier was controlled by adjusting the flow rates of the air streams through the bubbler and the silica gel bed. Supersaturation conditions can be obtained by heating the water in the bubblers⁵⁾.

The apparatus was first tested by experiments with sodium chloride particles, generated by atomizing saline solutions and subsequently drying the droplets

in a silica gel bed (not shown in Fig. 1). Figure 2 shows the measured geometric mean diameter (number median diameter) of NaCl particles as a function of relative humidity at 25°C. The results indicate that NaCl particles have a deliquescent point at about 76% relative humidity, which is in agreement with the value reported in the literature (see, for example, (2)).

Particles in cigarette smoke can grow by either Brownian coagulation³⁾ or condensation. To mini-

Fig. 1 Experimental apparatus

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Fig. 2 Relation between geometric mean diameter of NaCl particles and relative humidity

Fig. 3 Particle size distribution of cigarette smoke at various relative humidities

Fig. 4 Particle size distribution of exhaled cigarette smoke

mize the effect of coagulation, the cigarette smoke was diluted about 100-fold by filtered, humid air. The diluted smoke contained approximately 10^6 par-

ticles/cm³.

Figure 3 shows the measured size distributions of cigarette smoke particles at various relative humidities at 25°C and one supersaturation condition (the degree of supersaturation was not determined). The residence time of particles in the experimental system ranged from 10 to 30 seconds. Although marked increase in particle size took place under supersaturation conditions, no appreciable growth was seen at 100% or lower relative humidities. Under subsaturation and saturation conditions, the number median diameter of the log normally distributed particles is 0.44 μm. Carter and Hasegawa¹⁾ reported a mean diameter of 0.4616 μm for particles generated from cigarettes with a conventional filter, but did not state the relative humidity.

Figure 4 shows the measured size distribution of particles exhaled from a human subject, following inhalation of cigarette smoke. The smoke was diluted about 100-fold before inhalation. The size distribution of exhaled particles differs only slightly from those shown in Fig. 3 for relative humidities up to 100%.

It is concluded, therefore, that the change in size of cigarette smoke particles in the respiratory system is caused mainly by Brownian coagulation and, possibly, by condensation of water vapor under supersaturation conditions, which may be induced by a drop in temperature of inhaled smoke.

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