The effect of structural parameters of biporous packing with an impermeable core on the gas separation efficiency

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The effect of the structural parameters of granules of biporous sorbent with an adsorbing surface layer and inert core on the gas separation efficiency has been studied. The adsorbent has some advantages over sorbents with the bulk volume accessible for an adsorbate.

Key words: adsorption, chromatography, biporous sorbent with adsorbing layer and impermeable core, HETP, retention time.

The search for ways to increase the efficiency of separation on adsorption columns is the main challenge of gas chromatographic studies.[1,2] The development of various methods of modification, including adsorption, ion exchange, and chemical treatment of inorganic adsorbents, considerably extends the area of these studies. We have previously performed[3] a theoretical study of chromatographic separation of gases in a column packed with biporous sorbent (Fig. 1), in which only the peripheral layer possesses adsorbing properties, and the core is inert. This improves the kinetic properties of sorbents, whereas the overall sizes of grains or fibers remain unchanged, *i.e.*, without detrimental effect on the permeability of their layer operating in an adsorption column. A similar structure is common to the surface-layered ion exchangers that are widely used for analysis and separation of biologically active substances. The mathematical model has previously[3–5] been described, and the general problem has been formulated. The analytical equations for the retention time (t_R) and the height equivalent of a theoretical plate (HETP — H) were obtained:

$$t_R = L(1 + \Gamma)/v, \qquad (1)$$

$$H = 2D_L/v + 2v(1 - \varepsilon)\varepsilon_t[\tau_t(1 + \varepsilon_a k_a/\varepsilon_t)^2 f(x) + k\tau_a(1 - x^3)]/15, \qquad (2)$$

where $\tau_t = R_0^2/D_t$ and $\tau_a = r_0^2/D_a$ are the characteristic intervals of time for diffusion in ordinary pores and microzones of the biporous sorbent granules; D_t and D_a are the diffusion coefficients for the conventional porous system and microzones; v is the flow rate of the carrier gas; r_0 and R_0 are the radii of the microzone and granule; L is the length of the chromatographic column; D_L is the molecular diffusion coefficient of the sample in the column; ε is the packing porosity of the column; $x = b/R_0$; b is the size of the impermeable core of the granule; $k = \varepsilon_t(1 + \varepsilon_a k_a/\varepsilon_t)$; $f(x) = (1 - 5x^3 + 9x^5 - 5x^6)$; $\Gamma = (1 - \varepsilon)k(1 - x^3)/\varepsilon$ is the distribution coefficient for a sample between the gas and adsorption phases; ε_a and ε_t are the porosities of the conventional porous systems and microporous zones; and k_a is Henry's constant in microporous zones.

Results and Discussion

Taking into account the earlier results,[2,3] we attempted to analyze how the structural parameters of the surface layer in the biporous sorbent granule and its thickness affect the separating power of the chromatographic column. From Eqs. (1) and (2) we obtain the equation describing resolution of two adjacent peaks[5] K:

$$K = 0.424(\Gamma_1 - \Gamma_2)(L)^{1/2}/(\Gamma_1(H_1)^{1/2} + \Gamma_2(H_2)^{1/2}), \qquad (3)$$

where Γ_1, Γ_2 and H_1, H_2 are the distribution coefficients for the sample between the gas and adsorption phases and HETP of two adjacent chromatographic peaks, respectively.

This equation makes it possible to study the influence of the structural parameters and the surface layer

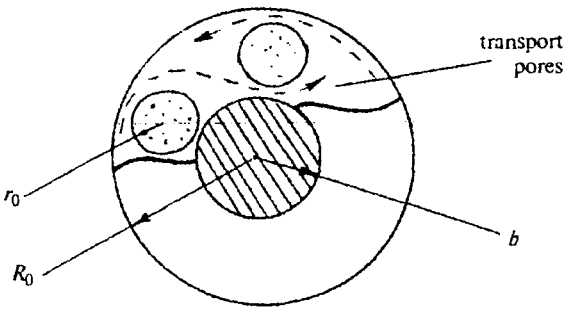

Fig. 1. Surface biporous sorbent: R_0 is the radius of granule, r_0 is the microporous formation radius, and b is the impermeable core radius.

Translated from *Izvestiya Akademii Nauk. Seriya Khimicheskaya*, No. 6, pp. 1193—1195, June, 1999.

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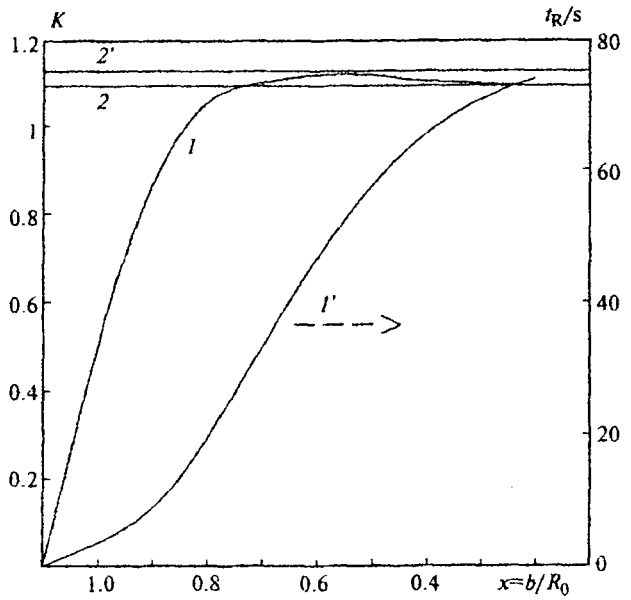

Fig. 2. Resolution (K) and retention time (t_R) as a function of the thickness of the porous layer (x): *1* and *1'*, for the biporous sorbent with the impermeable core, and *2* and *2'*, for conventional biporous sorbent ($b = R_0$).

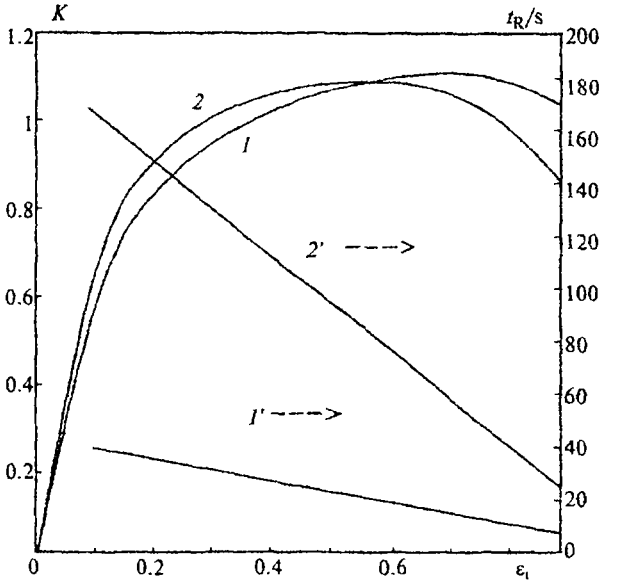

Fig. 3. Resolution (K) and retention time (t_R) as a function of the layer porosity (ε_i): *1* and *1'*, for the biporous sorbent with the impermeable core, and *2* and *2'*, for conventional biporous sorbent ($b = R_0$).

thickness on the efficiency of separation of two adjacent peaks which differ in sorption capacity ($\Gamma_1 > \Gamma_2$). As follows from Fig. 2, the resolution of the peaks increases as the thickness of the porous layer increases, and the complete separation of two adjacent peaks ($K > 1$) is already achieved at $x = 0.85$. Analysis of this system requires a noticeably shorter time than that for the analysis of the biporous sorbent active over the whole bulk volume. We found in the search for the extreme of function (3) that K achieves its maximum value at $x = 0.62$, corresponding to the point of the golden section of a unity segment (since $0 < x < 1$), and the resolution K of the biporous sorbent with the impermeable core near the vicinity of this point exceeds this value for the conventional sorbent. A similar dependence for K (Fig. 3) is observed when the layer porosity changes and reaches a maximum also near the golden section point on the unity segment (since $0 < \varepsilon_i < 1$). During the search for the extreme of the target function, the golden section of the indeterminacy interval is chosen in such a fashion that the ratio of the longer segment to the whole interval becomes equal to the ratio of the shorter segment to the longer segment.[6]

According to the data yielded from the analysis performed, changes in the characteristic parameters of the sorbent (D_i, D_a, and others) have a sufficiently weak effect on the variations of K.

Thus, the study performed showed that surface-layered biporous sorbent makes it possible within a short time to carry out chromatographic analysis of a gas mixture and retain a high resolution.

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Received July 21, 1998;
in revised form February 5, 1999