INVESTIGATION OF THE KINETICS OF SORPTION OF WATER VAPOR FROM A GAS-CARRIER STREAM ON TYPE A ZEOLITES

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The intensive drying of gas mixtures is one of the main fields of application for type A zeolites. It is therefore of interest to investigate the kinetics of water vapor sorption from a gas-carrier stream on granular zeolites. These investigations should give the kinetic characteristics necessary for the design of a sorption apparatus and information on its optimal operating conditions. The investigations, to some extent, should also throw light on the role of secondary porosity in the kinetics of the process, knowledge of which is necessary in order to be able to granulate zeolites efficiently under large scale technological conditions. In this work we were not able to consider all these problems. Instead we limited ourselves in the investigation to the determination of the water vapor diffusion coefficients in type A zeolites which were adsorbing water vapor from a stream of nitrogen. The results obtained were compared with results obtained from vacuum measurements.

EXPERIMENTAL

Type 4A and 5A zeolites, particle diameter 3 mm, made by the Linde Company, and also similar diameters and zeolites to those used by Ya. V. Mirskil (NaA-296 and CaA-297) with an increased secondary porosity voidage, were used in the investigation. The grains were carefully trimmed from the face ends and ground to the shape of a cylinder, with its length equal to the diameter.

The adsorption kinetics were investigated by the method of sorption weighings under vacuum and dynamic conditions. The method of measurement under vacuum conditions has been described in [1]. The sketch of the apparatus for investigating the kinetics of sorption under dynamic conditions is given in Fig. 1. The main part of the apparatus is a sorption tube in which a grain of the sorbent is suspended on a quartz spiral. The gas-carrier (nitrogen) is supplied from a cylinder. After removing the impurities from the mixtures in columns 1 and 2 with active carbon and phosphorus pentoxide, a part of the stream is led through the manometer 3 into the evaporator containing water 8 and the other (main) part is led through the manometer 4 into the mixer 5. From the mixer the gas stream either flows into the wet and dry bulb hygrometer 6 or into the sorption tube 7. The relative moisture $\varphi$ of the gas was assumed equal to 0.1 as a consequence of using the two-stage principle of drying, i.e., the usual drying agents (silica-gel and alumino-gel) for removing high moisture contents, and using zeolite to complete the removal of the reduced concentrations of water vapor. The concentration of water vapor was estimated by weighing the amount of water absorbed by a U-tube containing either phosphorus pentoxide or a fine fraction of zeolite. The wet and dry bulb thermometer was used to keep the conditions constant when carrying out the tests. The evaporator, containing water, was placed in a sensitive thermostat and maintained at 20°C. The specific flow rate in the sorption tube was 1-21/min·cm².

The experiment was carried out in the following order. The sorbent particle, allowed to reach equilibrium with the moisture in an atmosphere of air, was weighed on an analytical balance to 0.1 mg and placed in the sorption tube. A high vacuum was then established in the tube or, if the dehydration was carried out in the gas-carrier stream, nitrogen was passed through the tube at a low flow rate and the temperature was increased to 350°C. The particles were evacuated for 3 hours. The electric furnace was then removed, the sorption tube cooled to room temperature, dry nitrogen was admitted into the tube (by evacuating from a vacuum line) and after waiting 5 to 10

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minutes, the test commenced, i.e., the gas mixture containing water vapor was admitted. After a definite interval of time the expansion of the spiral was measured. The readings were carried out with the help of a cathetometer with the graticule scale of the eye-piece graduated at intervals of 0.02 mm. The sensitivity of the spiral was 0.03 mg/scale division.

The coefficient of internal diffusion \( D \) was calculated from the experimental results from the equation for a cylinder of finite dimensions [2]:

\[
\gamma = 1 - \sum_{n=1}^{\infty} \sum_{m=1}^{\infty} B_n B_m \exp \left[ - \left( \frac{4 \pi^2 n^2}{k^2} \right) \tau \right], 
\]

where \( \gamma = \frac{a}{a_\infty} \) is the relative adsorption value, \( a \) is the adsorption value at the moment of time \( t \), \( a_\infty \) is the limiting adsorption value, \( B_n \) and \( B_m \) are the coefficients determined from the equations

\[
B_n = \frac{4B_i^2}{\mu_n^2 (\mu_n^2 + B_i^2)} \\
B_m = \frac{2B_i^2}{\mu_m^2 (\mu_m^2 + B_i^2 + \mu_m^2)},
\]

where \( \mu_n \) is the root of the Bessel function equation \( \frac{I_0 (\mu_n)}{I_1 (\mu_n)} = \frac{\mu_n}{B_i} \); \( \mu_m \) is the root of the equation \( \cot \mu_m = \frac{\mu_m}{B_i} \); \( Bi_1 \) and \( Bi_2 \) are Biot moduli on the side surface and on the particle end faces; \( k = \frac{L}{R} \); \( \tau = \frac{Dt}{R^2} \); \( R \) and \( L \) are the radius and length of the particle.

If we designate \( t_{0.5} \) as the time in which the adsorption value \( \gamma \) becomes equal to 0.5 then equation (1) may be converted to the form

\[
D = \alpha \frac{R^2}{t_{0.5}},
\]

where \( \alpha \) is a constant depending on the value of \( k \), i.e., the ratio of the length and radius of the particle (in our case \( k = 2 \)) and on the Biot modulus. The Biot moduli, expressing the conditions of mass-exchange on the surface of the grain depend on the internal diffusion coefficient and are found by the method of successive approximations.