DIFFERENTIAL ENTHALPY OF HYDROGEN SULFIDE ADSORPTION IN ACTIVATED SORBENT FROM HYBRID TOMENTOSA TREE

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Abstract: *In the present article, the regularities of the adsorption differential enthalpy of hydrogen sulfide molecules on an activated carbon adsorbent obtained from the bark of the Paulownia tomentosa tree at a temperature of 303 K, depending on the adsorption value, as well as the mechanism of the sorption process, were investigated. From the stepwise change of the adsorption differential enthalpy of hydrogen sulfide molecules on the activated carbon adsorbent from the bark of the Paulownia tomentosa tree, it was determined that the number of active sites with respect to hydrogen sulfide is 0.25 mmol/g, and the formation of a pentamer complex of adsorbate/adsorbent in the ratio of $5H_2S$:adsorbent was established.*

Keywords: *adsorption, adsorbent, isotherm, relative pressure, enthalpy, microcalorimeter, hydrogen sulfide.*

INTRODUCTION

In many branches of industry, in the production of different assortments of activated adsorbents, mainly carbonaceous materials with an initial carbon content above 76.0–86.0%, as well as stems and branches of plants, fruit pits recycled as waste (including apricot, peach, and walnut), clay minerals and other related raw material residues are used. In order to employ them as adsorbents, extensive scientific research is being carried out to improve their physicochemical properties and adsorption capacity, since the application of efficient adsorbents in various branches of industry is of great importance.

During the activation process, when carbon monoxide and hydrogen are released from the system into the atmosphere, the activation process of thermally

active adsorbents can be significantly accelerated, while a decrease in the rate of reaction of steam with carbon in these products is observed [1].

The transportation and storage of wood waste may cause many problems. Due to the high moisture content of wood waste, its direct use as fuel is not feasible. Therefore, the pyrolysis method is considered a more efficient way of processing them [2-4]. In addition, millions of tons of walnut shell waste accumulate worldwide. Walnut shell contains (in %): 25.8–51.9% cellulose, 16.8–47.6% lignin, 8.7–17.9% hemicellulose, 0.2–3.1% ash, and 3.8–10.41% moisture. When walnut shell is activated with H_3PO_4 at 170°C for 0.5–1.0 hours, the process is carried out in the presence of nitrogen and 12 other inert gases [5-8].

METHODOLOGY AND MATERIALS

In this article, the adsorption differential enthalpy of hydrogen sulfide at 303 K on activated carbon derived from the bark of the Paulownia-Tomentosa tree are presented.

The adsorption isotherm was measured using a universal high-vacuum apparatus. The principle of operation and characteristics of this device are fully described in the authors' works [9-13]. This apparatus makes it possible to comprehensively determine the regular change of the sorption differential enthalpy with respect to the adsorption capacity, the number, strength, and nature of active centers of the activated carbon adsorbent obtained from Paulownia-Tomentosa tree bark waste by conventional (thermal–pyrolysis and steam–gas conditions) methods, as well as to clarify the sorption mechanism.

RESULTS AND DISCUSSION

The regular relationship between the adsorption differential enthalpy of hydrogen sulfide molecules on the activated carbon adsorbent obtained from the bark of the Paulownia Tomentosa tree at a temperature of 303 K, as well as the mechanism of the sorption process, was determined.

The differential enthalpy of hydrogen sulfide molecule adsorption on the activated adsorbent obtained from the bark of the Paulownia tomentosa tree is presented in Figure 1.

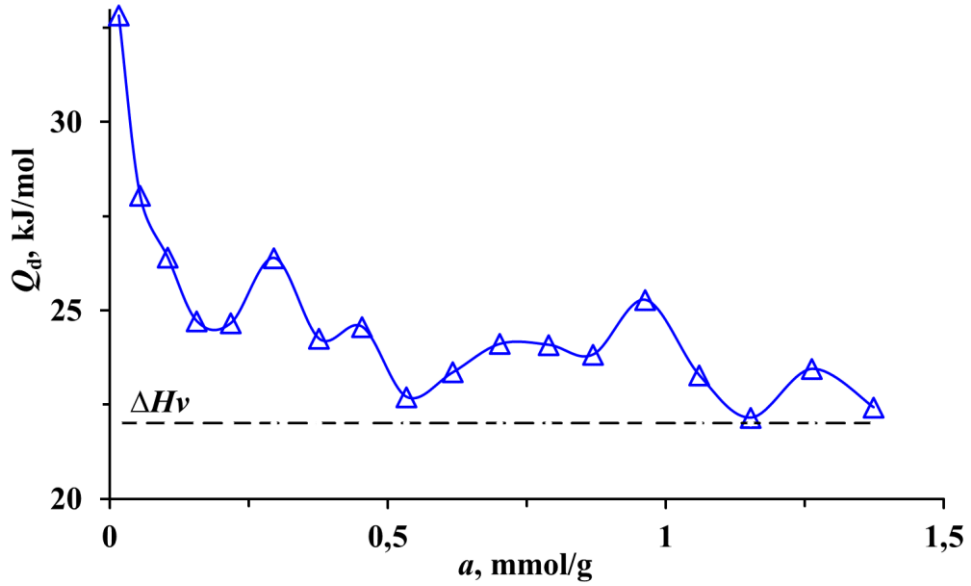

Figure 1. Differential enthalpy of hydrogen sulfide molecule adsorption on an activated adsorbent obtained from Paulownia tomentosa tree.

Based on differential enthalpy, the adsorption mechanism, i.e., the nature, strength, and number of zeolite active sites, corresponds to the sorption mechanism described above on the basis of the adsorption isotherm.

The differential enthalpy changes in a wave-like manner. This change corresponds to the complexes formed at the active sites of the adsorbent. At the initial stage, the differential enthalpy of adsorption equals ~33 kJ/mol at 0.02 mmol/g adsorption. With the saturation of sorption volume, at 0.22 mmol/g the enthalpy decreases almost linearly to 24.7 kJ/mol, forming the first minimum. This value corresponds to the sorption active site value (0.25 mmol/g) explained in the isotherm of the activated adsorbent obtained from Paulownia tomentosa bark, i.e., hydrogen sulfide molecules form a monomer $1H_2S$:adsorbent complex with the activated adsorbent.

After 0.25 mmol/g adsorption, the increase of adsorption enthalpy up to 26.4 kJ/mol is related to the relocation of the initial hydrogen sulfide molecules, as well as the release of additional energy caused by van der Waals interactions between adsorbate molecules.

At 0.45 mmol/g adsorption, the differential enthalpy forms a step, and at 0.5 mmol/g adsorption it decreases to 22 kJ/mol, forming the second minimum and creating a $2H_2S$:adsorbent dimer complex. With further saturation of the sorption volume, the enthalpy increases linearly up to 25 kJ/mol, forming a $3H_2S$:adsorbent trimer at 0.75 mmol/g adsorption, and rises to 26 kJ/mol at 1 mmol/g adsorption, forming a $4H_2S$\:adsorbent tetramer complex. During further adsorption of hydrogen sulfide molecules, the differential enthalpy first decreases to 22.5 kJ/mol,

then increases to 23.5 kJ/mol at 1.25 mmol/g adsorption, forming a $5H_2S$:adsorbent pentamer complex, thus completing the sorption process.

CONCLUSION. The differential enthalpy of adsorption of hydrogen sulfide molecules on an activated adsorbent obtained from the bark of the Paulownia tomentosa tree were studied by the adsorption–calorimetric research method. From the stepwise change of the adsorption isotherm and the differential enthalpy of hydrogen sulfide molecules on the activated carbon adsorbent from the bark of the Paulownia tomentosa tree, it was determined that the number of active sites with respect to hydrogen sulfide is 0.25 mmol/g, and the formation of a pentamer complex of adsorbate/adsorbent in the ratio of $5H_2S$:adsorbent was established.

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