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Low-Temperature Adsorption of Hydrogen on Activated Carbon

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NOTE

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Abstract

The adsorption isotherm of pure hydrogen on activated carbon (coconut shell) was determined at −186°C over a pressure range of 1 to 772 mm Hg. A McBain balance apparatus with a modified refrigerant thermostat was used.

The purpose of this work was to determine a low-temperature isotherm for hydrogen on a commonly used activated carbon down to low pressures. This data is useful for various gas purification applications.

Grant and Manes (*1*) determined a hydrogen adsorption isotherm on two coal type activated carbons at −195.8°C (liquid nitrogen bp). For our work we used a coconut shell activated carbon at −186°C over a pressure range of 1 to 772 mm Hg, which is slightly less than that of Grant and Manes. The isotherms for the three different carbons are compared.

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EXPERIMENTAL METHOD

The adsorption isotherm was determined on a McBain balance apparatus. Liquid nitrogen was used as the refigerant. The glass tube holding the McBain balance was designed with a thin wrapping of Nichrome ribbon inside a surrounding vacuum jacket 0.5 in. wide. The liquid nitrogen bath in a separate dewar vacuum flask surrounded this apparatus on the outside of the thin vacuum jacket. Thus the vacuum jacket acts as an insulator between the liquid nitrogen and the adsorption tube, and heat can be applied by the resistance Nichrome ribbon wound around the outside wall of the adsorbent tube. It was found that this experimental method allowed maintaining very stable temperatures in the liquid nitrogen and higher region. A copper–Constantan thermocouple was placed adjacent to the bucket holding the carbon sample. A beryllium-copper spring was used for suspending the bucket and the elongation was measured with a cathetometer. This spring elongated linearly at 0.3910 g/cm over the experimental range. The possible error in precision of the measured quantities were as follows: pressure, less than 0.1 mm Hg; temperature less than 0.2°C; and weight adsorbed less than 0.0001 g. The adsorbent used was activated carbon, Columbia grade 6-G, 12-32 mesh. This was obtained from National Carbon Division, Union Carbide Corporation. The hydrogen was dry electrolytic grade which was dried further in a liquid nitrogen trap. The weight of the adsorbent carbon was obtained by putting a measured amount of dry carbon in the bucket and then evacuating to a pressure of 0.1 μ for 2 hr at a temperature of 170°C. Approximately 5 to 7% of the weight of the adsorbent was lost during the 2-hr evacuation period. This loss in weight of the sample was observed by measuring the spring elongation with the cathetometer. The weight of the adsorbent after the 2-hr evacuation and heating period was taken as the weight of the experimental sample. After each cycle of adsorption and desorption, the adsorbent sample was evacuated at a pressure of 0.1 μ or less and brought to a temperature of 170°C for 1 hr and then allowed to cool to room temperature while at the high vacuum. This reactivation method gave good reproducible results.

DISCUSSION

The experimental results of this work are given in Table 1. They cover the pressure range from 1 to 772 mm Hg. The temperature of −186°C

was picked for these experiments because it is the boiling point of liquid air at 1 atm and is a commonly encountered temperature in low-temperature applications. It should be noted that in this work liquid nitrogen was used as the cooling medium, and the adsorbent temperature was maintained by a balancing method using a Nichrome ribbon heater in the adsorption apparatus.

There is only a small amount of low-temperature hydrogen adsorption data available on other activated carbon adsorbents and on silica gel (*1*). These data obtained from the literature together with the data from our work are plotted in Fig. 1. The two curves at −195.8°C were obtained

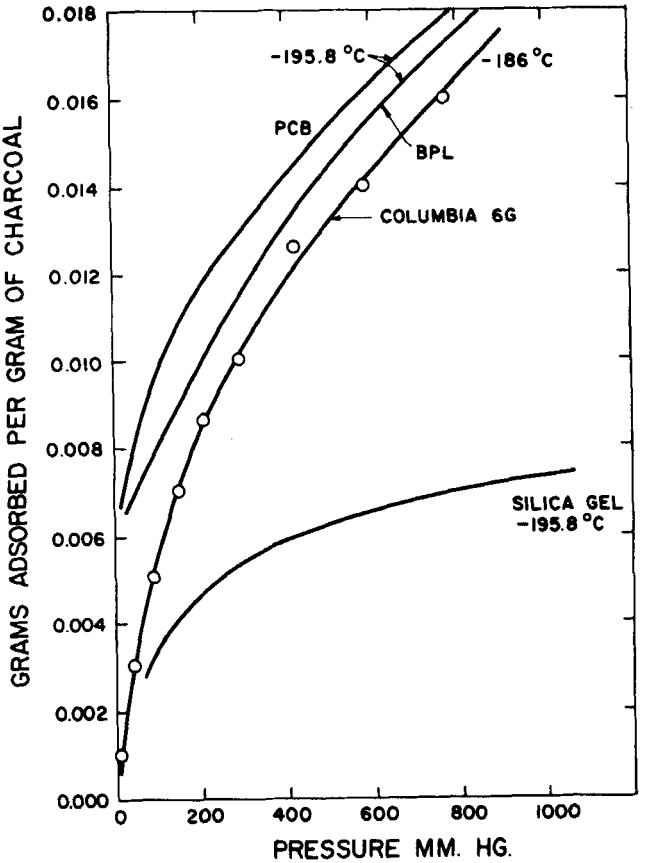

FIG. 1. Adsorption isotherms of hydrogen.

TABLE 1

Adsorption Isotherm of Hydrogen on Activated Carbon

Temperature (°C)	Pressure (mm Hg)	Grams adsorbed per gram carbon
−186	1	0.0015
	40	0.0030
	89	0.0051
	148	0.0069
	202	0.0086
	290	0.0102
	424	0.0126
	582	0.0140
	772	0.0163

on two different kinds of activated carbons derived from coal. These are Pittsburgh Chemical Company Grade PCB and Grade BPL activated carbons size 4 to 10 mesh, respectively. The silica gel isotherm at the same temperature was determined by Grant and Manes with a Davison Chemical Company Grade 03 silica gel.

It can be seen from Fig. 1 that the data of our work at −186°C agrees very well with the adsorption data on the other activated carbons. Although the Pittsburgh Chemical Company activated carbons are derived from coal while the activated carbon used in our work is derived from coconut shells, very similar Langmuir adsorption isotherm curves are obtained for these materials, and they seem to have almost the same adsorption capacity.

REFERENCE

1. R. J. Grant and M. Manes, *Ind. Eng. Chem. Fundam.*, *3*, 221 (1964).

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