

Adsorption of 1,1,1,2-Tetrafluoroethane on Activated Charcoal

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This paper presents adsorption isotherms for HFC-134a on activated charcoal, in the temperature range of 273–353 K and for pressures up to 0.65 MPa, measured using the volumetric method. Three samples of charcoals with widely varying surface areas were chosen. The shapes of the isotherms obtained from the experimental data were similar in all cases and comparable to those reported in the literature. Adsorption parameters were evaluated from the isotherms using the Dubinin–Astakhov (DA) equation. The concentration dependence of the isosteric enthalpies of adsorption is extracted from the data.

Introduction

The present study on adsorption characteristics of 1,1,1,2-tetrafluoroethane (HFC-134a) on activated carbon was motivated by two factors. First, there is a need to switch to ozone-friendly working fluids for refrigeration in the wake of the ratification of the Montreal Protocol by several countries. The second factor is the thrust toward thermally driven cooling systems, which has gathered momentum in light of the Kyoto Protocol through which several countries have agreed to reduce the greenhouse gas emissions. Experimental determination of adsorption characteristics of the activated charcoal–HFC-134a system would be a precursor to practical system design and simulation with this adsorbate as the working fluid.

Adsorption data are seldom available from manufacturers of activated charcoal. At best, the commercial data are on the surface area, which is inadequate to gauge the throughput from the thermal (adsorption) compressor at various pressures and temperatures. Further, in view of numerous activated charcoal samples available in the market, it is seldom possible to extrapolate the data from one sample to another. Some experimental data exist for the adsorption of HFC-134a on activated carbon. Experimental results for Sutcliffe Speakman powdered activated carbon 208CP (commonly known as AX-21) were presented by Jones.¹ Lin and Lin² studied the gas-phase adsorption characteristics of HFC-134a on two types of activated carbon [granule (GAC) and pellet (EAC)] with the purpose of their eventual use in refrigeration and HFC recovery by an adsorption process. The work of Riffat³ pertains to adsorption of blends of HFC-32, HFC-125, and HFC-134a (refrigerants R-407a and R-407b) and HFC-32 by AX-21. The present article is complementary to the ongoing efforts toward generating experimental adsorption isotherm data for more samples of activated carbon. Adsorption isotherms over a temperature range of 273–353 K and for pressures up to 0.65 MPa were measured using the volumetric method for three specimens, namely, Chemviron, Fluka, and Maxsorb. This measurement range was chosen so as to cover typical operating limits in refrigeration. The choice

of specimens was based on a wide range of adsorption surface areas offered and their achievable packing densities. The adsorption parameters were evaluated using the Dubinin–Astakhov (DA) equation. Further, the enthalpy of adsorption data were extracted, and correlations are provided for the three specimens investigated.

Experimental Section

Materials. The HFC-134a sample used is of high purity grade, as supplied by the manufacturer. No additional analysis was made. All properties of HFC-134a used in this paper were evaluated from the data on the Internet site <http://webbook.nist.gov/chemistry/fluid>, which is based on the generalized equation of state proposed by Tillner-Roth and Baehr.⁴ Activated charcoal from three suppliers, namely, Chemviron (Chemviron Carbon GmbH, D-63232 Neu-Isenburg, Germany), Fluka (Fluka Chemie AG, CH-9471 Buchs, Switzerland), and Maxsorb (The Kansai Coke and Chemical Co. Ltd., 660-0861 Amagasaki, Japan) were chosen so that a wide range of adsorption surface areas and achievable packing densities was covered. The first specimen is granular, while the other two are in powder form. From our previous measurements, the surface area for the Fluka specimen was found to be 1143 m² g⁻¹.⁵

Apparatus and Procedure. The activated charcoal specimen was loaded into a stainless steel adsorption cell, 19 mm (i.d.) × 21 mm (o.d.) × 220 mm long having an internal volume (V_{cell}) of 49.9 mL. A large aspect ratio was chosen for fast thermal equilibration during measurements. During filling of the cell, the charcoal was pressed with a rod of suitable diameter to achieve a high packing density. It was possible to pack 37.55 g of Chemviron charcoal, 19.51 g of Fluka charcoal, and 14.01 g of Maxsorb charcoal into the cell.

A schematic arrangement of the experimental set up is shown in Figure 1, which is similar to that used by Prasad et al.⁵ The adsorption cell was immersed in a constant-temperature circulation bath (Julabo FP-80). A mixture with a volumetric composition of 35% ethylene glycol and 65% demineralized water was used as the bath liquid. The unit can be operated in the temperature range of –15 to 90 °C with a stability of ±0.1 °C, which was achieved by the use of a PID controller with a platinum resistance thermometer as a sensor. The uncertainty in temperature measurement is expected to be ±0.1 °C. In view of the

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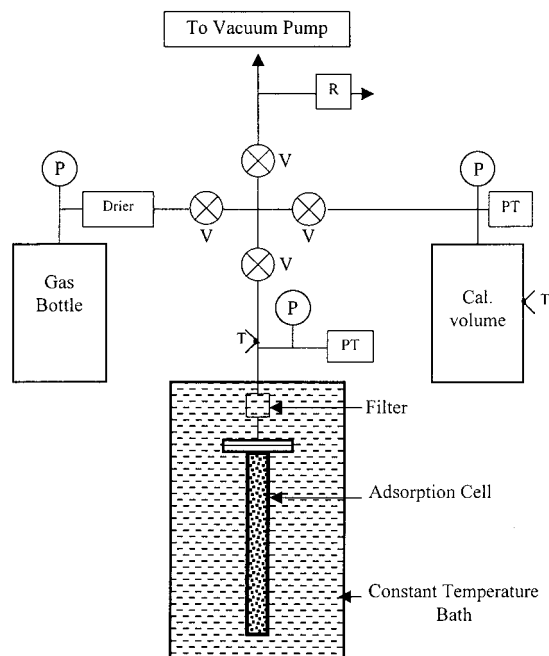


Figure 1. Schematic of experimental setup: P, pressure gauge; PT, pressure transducer; V, valve; R, relief valve; T, temperature sensor.

measurement range and the uncertainty, the differences between IPTS-68 and ITS-90 were ignored. The cell was connected to a 901-mL calibrated volume through a capillary whose volume was 5.84 mL. To account for the gas in the capillary, its volume was divided into one segment of 4.44 mL at the temperature of the capillary and another of 1.4 mL at an average temperature of the cell and the capillary. The pressures of HFC-134a in the calibrated volume and in the cell were measured using two 0–1 MPa Entran pressure transducers (EPNM-38-150A) whose accuracy is 0.25% of full scale. A redundant secondary indicator of a 0–1 MPa range Bourdon tube pressure gauge was also employed. The temperatures of the calibrated volume and the capillary, which are nearly at ambient temperature, were recorded using T-type thermocouples and a thermocouple monitor (Stanford Systems SRS630). Because of the continuous circulation of the bath fluid, the slenderness of the cell, the cell's total immersion into the bath liquid, and the adequate time allowed for thermal stabilization, it was assumed that no gradients of temperature would occur within the cell. Hence, the bath temperature was taken to be the temperature at which the isotherms were obtained.

Prior to the isotherm measurements, the entire assembly was evacuated for at least 50 h using a rotary vacuum pump to an ultimate vacuum level of 10^{-2} mbar. During evacuation, the cell with charcoal was maintained at 100–110 °C to desorb any residual gas in the cell.

The evacuated calibrated volume was pressurized with HFC-134a from its source through a drier so that any trace of moisture could be eliminated. After sufficient time for stabilization was allowed, the initial pressure and temperature of the calibrated volume were noted. A small quantity of gas was allowed into the evacuated adsorption cell. Again, the pressure and temperature of calibrated volume were noted. These two readings play a role in determining the amount of gas present in the adsorption cell. Then, the adsorption cell was allowed to stabilize at a given temperature. The pressure and temperature of the adsorption cell, as well as the temperature of the capillary, were recorded.

All measurements were made only when equilibrium existed in the cell, which was found to be after 0.5 h per experiment. Subsequently, the temperature of the bath was changed, and the next data point along an isochore was obtained. Measurements were made over the range 0–80 °C at 20 °C intervals. The same procedure was repeated with a different quantity of gas in the adsorption cell, to cover a pressure close to the saturation pressure at the respective temperature. However, for 40, 60, and 80 °C, the upper pressure was limited to about 0.65 MPa, as the saturation pressure at an ambient of 25 °C is 0.665 MPa. This precaution was necessary to avoid the possibility of condensation of HFC-134a in the capillary and the associated errors in the estimation of adsorbate present in the capillary. Isotherm measurements for the entire temperature range were repeated for each charcoal sample.

Results

Data Reduction. The amount of gas adsorbed had to be calculated for the generation of isotherms. From among the various definitions in common use for the amount of gas adsorbed,⁶ the Gibbs definition is adopted here because it is independent of the intergranular structure and the packing pattern of the charcoal.⁷ As per this definition, the adsorbed quantity is the excess of HFC-134a present in the pores over and above what would be present under equilibrium conditions if adsorption were absent. Based on this definition, the mass of the gas in the void (m_{void}) is given by

$$m_{\text{void}} = \rho_{\text{cell}} [V_{\text{cell}} - V_{\text{ch}}] \quad \text{at } T_{\text{cell}} \quad (1)$$

where ρ_{cell} is the density of gas in the cell, V_{cell} is the volume of the adsorption cell, and V_{ch} is the volume occupied by charcoal in the cell, which is calculated from the mass of the charcoal filled into the cell and the solid density of charcoal, 2200 kg m^{-3} . T_{cell} is the temperature of the cell. In a strict sense, the solid volume of the charcoal has to be evaluated by high-temperature helium expansion experiments. However, the uncertainties arising from the ash content of the specimens and the use of the solid density are unlikely to affect the data significantly.^{8,9}

The mass of gas leaving the calibrated volume (Δm_{cv}) can be calculated from the difference in densities of the adsorbate in the calibrated volume (ρ_{cv}) at two successive pressure and temperature readings (i and f). This quantity is given by

$$\Delta m_{\text{cv}} = \Sigma(\rho_{\text{cvi}} - \rho_{\text{cvf}}) V_{\text{cv}} \quad (2)$$

where V_{cv} is the calibrated volume.

The amount adsorbed (m_{ad}) can then be calculated from

$$m_{\text{ad}} = \Delta m_{\text{cv}} - m_{\text{cap1}} - m_{\text{cap2}} - m_{\text{void}} \quad (3)$$

where

$$m_{\text{cap1}} = V_{\text{cap1}} \rho_{\text{cap1}} \quad \text{at } T_{\text{cap}} \quad (4)$$

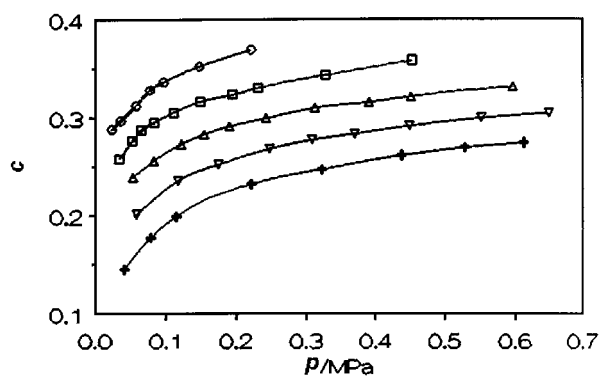
$$m_{\text{cap2}} = V_{\text{cap2}} \rho_{\text{cap2}} \quad \text{at } T_{\text{avg}} \quad (5)$$

where V_{cap1} and V_{cap2} are the volumes of HFC-134a in the capillary at the capillary temperature (T_{cap}) and at average temperature (T_{avg}), respectively. ρ_{cap1} is the density of the adsorbate at T_{cap} , and ρ_{cap2} is the density of the adsorbate at T_{avg} . The specific adsorbance, c , can then be calculated as

$$c = m_{\text{ad}}/m_{\text{ch}} \quad (6)$$

Table 1. Isotherm Data and Results for R-134a on Chemviron Charcoal

T (°C)	p (MPa)	Δm_{cv} (g)	m_{ad} (g)	c (kg kg ⁻¹)	
0	0.023	10.87	10.83	0.288	
	0.036	11.22	11.16	0.297	
	0.057	12.10	12.00	0.312	
	0.077	12.47	12.33	0.328	
	0.096	12.8	12.63	0.336	
	0.147	13.47	13.20	0.352	
	0.221	14.28	13.87	0.369	
20	0.034	9.74	9.68	0.258	
	0.052	10.45	10.37	0.276	
	0.065	10.87	10.77	0.287	
	0.083	11.22	11.08	0.295	
	0.110	11.63	11.44	0.305	
	0.148	12.10	11.85	0.316	
	0.194	12.47	12.14	0.323	
	0.231	12.80	12.41	0.330	
	0.327	13.47	12.89	0.343	
	0.453	14.28	13.45	0.358	
40	0.053	9.04	8.96	0.239	
	0.082	9.74	9.61	0.256	
	0.121	10.45	10.26	0.273	
	0.154	10.87	10.63	0.283	
	0.190	11.22	10.91	0.291	
	0.242	11.63	11.24	0.299	
	0.312	12.10	11.59	0.310	
	0.390	12.47	11.82	0.315	
	0.451	12.80	12.05	0.321	
	0.596	13.47	12.43	0.331	
	60	0.058	7.63	7.54	0.201
		0.117	9.04	8.87	0.236
		0.174	9.73	9.48	0.252
0.247		10.45	10.08	0.268	
0.308		10.87	10.40	0.277	
0.369		11.22	10.64	0.283	
0.449		11.63	10.92	0.291	
0.551		12.10	11.22	0.299	
0.649		12.47	11.41	0.304	
80		0.041	5.52	5.46	0.145
	0.078	6.76	6.65	0.177	
	0.114	7.63	7.46	0.199	
	0.221	9.04	8.72	0.232	
	0.322	9.74	9.27	0.247	
	0.437	10.45	9.81	0.261	
	0.528	10.87	10.08	0.269	
	0.612	11.22	10.29	0.274	

**Figure 2.** Isotherms of HFC-134a on Chemviron charcoal: ○, 0 °C; □, 20 °C; △, 40 °C; ▽, 60 °C; +, 80 °C.

where m_{ch} is the mass of the charcoal in the cell. Tables 1–3 list the isotherm data for the Chemviron, Fluka, and Maxsorb charcoals, respectively. The overall uncertainty in c was estimated to be not more than 1%, which is made up of contributions from the uncertainties in the volume of the capillary, the calibrated volume, the pressure, the temperature, and the calculation of the density using the equation of state.

Discussion

Figures 2–4 show the isotherms for the three charcoals investigated on a pressure–concentration–temperature

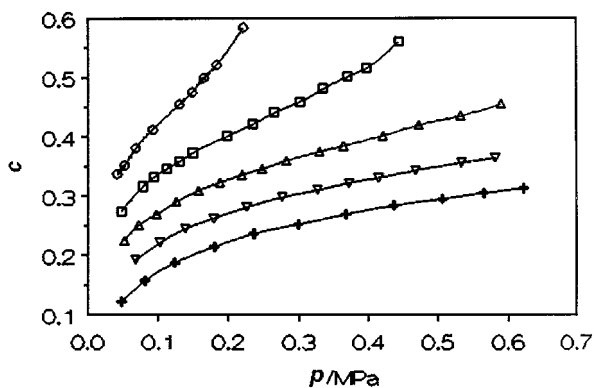
Table 2. Isotherm Data and Results for R-134a on Fluka Charcoal

T (°C)	p (MPa)	Δm_{cv} (g)	m_{ad} (g)	c (kg kg ⁻¹)	
0	0.042	6.66	6.57	0.337	
	0.052	6.98	6.87	0.352	
	0.068	7.58	7.43	0.381	
	0.092	8.23	8.03	0.412	
	0.130	9.17	8.88	0.455	
	0.148	9.59	9.27	0.475	
	0.165	10.10	9.74	0.499	
	0.183	10.57	10.16	0.521	
	0.221	11.90	11.40	0.584	
	20	0.048	5.43	5.34	0.274
0.078		6.32	6.16	0.316	
0.094		6.66	6.47	0.332	
0.112		6.98	6.75	0.346	
0.130		7.24	6.98	0.358	
0.149		7.58	7.28	0.373	
0.198		8.23	7.83	0.401	
0.234		8.70	8.22	0.421	
0.265		9.17	8.61	0.441	
0.301		9.59	8.96	0.459	
0.334		10.10	9.39	0.481	
0.369		10.57	9.77	0.501	
0.396		10.91	10.05	0.515	
0.443		11.90	10.92	0.560	
40		0.052	4.49	4.39	0.225
		0.072	5.01	4.88	0.250
		0.097	5.43	5.25	0.269
	0.125	5.89	5.65	0.290	
	0.157	6.32	6.02	0.309	
	0.188	6.66	6.30	0.323	
	0.219	6.98	6.55	0.336	
	0.248	7.24	6.76	0.346	
	0.282	7.58	7.03	0.360	
	0.329	7.97	7.32	0.375	
	0.363	8.23	7.51	0.385	
	0.420	8.70	7.85	0.402	
	0.472	9.17	8.20	0.420	
	0.532	9.59	8.49	0.435	
	0.589	10.10	8.87	0.455	
	60	0.068	3.87	3.75	0.192
		0.102	4.49	4.30	0.221
0.138		5.01	4.77	0.244	
0.179		5.43	5.12	0.262	
0.226		5.89	5.48	0.281	
0.276		6.32	5.81	0.298	
0.326		6.66	6.05	0.310	
0.371		6.98	6.28	0.322	
0.414		7.24	6.46	0.331	
0.467		7.58	6.69	0.343	
0.533		7.97	6.95	0.356	
0.581		8.23	7.11	0.364	
80		0.048	2.47	2.39	0.122
		0.081	3.19	3.05	0.157
		0.123	3.87	3.66	0.187
		0.180	4.49	4.18	0.214
		0.236	5.01	4.60	0.236
	0.299	5.43	4.91	0.252	
	0.367	5.89	5.25	0.269	
	0.436	6.32	5.55	0.284	
	0.506	6.66	5.75	0.295	
	0.565	6.98	5.96	0.305	
0.622	7.24	6.11	0.313		

(p – c – T) plane. The shapes of the isotherms obtained from the experimental data are similar in all cases and also are comparable with those of Jones.¹ However, the specific adsorbance, c , for each specimen is considerably different at any given set of conditions. It is a maximum for Maxsorb charcoal and comparable to that of AX-21 charcoal.¹ In decreasing order of specific adsorbance, the Fluka and Chemviron charcoals stand second and third, respectively. However, the values obtained here are better than those reported by Lin and Lin² for GAC and EAC (0.133 kg kg⁻¹ at 25 °C and atmospheric pressure). This spread in the specific adsorbance can be attributed to the variability in the surface area and pore distribution. These observations confirm that a designer must have adsorption character-

Table 3. Isotherm Data and Results for R-134a on Maxsorb Charcoal

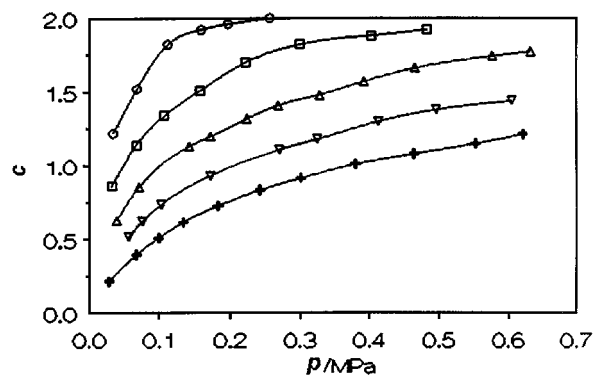
T (°C)	p (MPa)	Δm_{cv} (g)	m_{ad} (g)	c (kg kg ⁻¹)
0	0.034	17.22	17.14	1.220
	0.068	21.44	21.29	1.520
	0.112	25.70	25.44	1.820
	0.159	27.28	26.91	1.920
	0.197	27.97	27.51	1.960
20	0.256	28.73	28.12	2.010
	0.032	12.11	12.04	0.860
	0.067	16.06	15.92	1.140
	0.107	18.96	18.74	1.340
	0.158	21.44	21.10	1.510
40	0.222	24.28	23.80	1.700
	0.300	26.12	25.53	1.820
	0.403	27.28	26.36	1.880
	0.483	27.97	26.84	1.920
	0.039	8.86	8.78	0.627
	0.071	12.11	11.97	0.855
	0.142	16.06	15.77	1.130
	0.172	17.22	16.87	1.200
	0.223	18.96	18.51	1.320
	0.268	20.33	19.78	1.410
60	0.328	21.44	20.75	1.480
	0.392	22.88	22.05	1.570
	0.465	24.28	23.29	1.660
	0.576	25.70	24.43	1.740
	0.632	26.20	24.79	1.770
	0.056	7.30	7.20	0.514
	0.076	8.86	8.72	0.622
	0.103	10.49	10.03	0.735
	0.172	13.37	13.04	0.931
	0.270	16.06	15.54	1.110
80	0.325	17.22	16.58	1.180
	0.413	18.96	18.15	1.300
	0.496	20.33	19.34	1.380
	0.605	21.44	20.20	1.440
	0.028	3.08	3.03	0.216
	0.067	5.67	5.55	0.396
	0.099	7.30	7.12	0.509
	0.134	8.86	8.62	0.615
	0.183	10.49	10.16	0.726
	0.242	12.11	11.67	0.833
	0.301	13.37	12.81	0.915
	0.380	14.81	14.11	1.010
	0.464	16.06	15.19	1.080
	0.552	17.22	16.17	1.150
	0.621	18.13	16.94	1.213

**Figure 3.** Isotherms of HFC-134a on Fluka charcoal: ○, 0 °C; □, 20 °C; △, 40 °C; ▽, 60 °C; +, 80 °C.

istics of the specimen intended for use and that it is seldom possible to extrapolate from one sample to another.

Adsorption Parameters Using the D–A Equation.

Agarwal and Schwarz¹⁰ assessed the best combination of the empirical methods presented in the literature to evaluate the adsorption potential, the saturation vapor pressure, and the adsorbed-phase volume, both above and below the critical temperature of the adsorbate. They recommended the use of the Dubinin–Astakhov (DA) equation,¹¹ as it was found to provide the best representation of the adsorption data. The same was done in the

**Figure 4.** Isotherms of HFC-134a on Maxsorb charcoal: ○, 0 °C; □, 20 °C; △, 40 °C; ▽, 60 °C; +, 80 °C.

present analysis to obtain the temperature-independent characteristic curve. The Dubinin–Astakhov (DA) equation is

$$\ln(W) = \ln W_0 - (A/E)^n \quad (7)$$

where A is the adsorption potential, W is the adsorbed volume, W_0 is the limiting volume of adsorption space of the adsorbent, E is the characteristic energy of the adsorption system, and n is the structural heterogeneity parameter. W_0 , E , and n are also known as adsorption parameters or correlating parameters.

The adsorption potential (A) is the work done in the isothermal compression of 1 mol of vapor from the equilibrium pressure (p) to the vapor pressure (p_s) and is given by

$$A = RT \ln(p_s/p) \quad (8)$$

The adsorbed volume (W) in eq 7 is given by

$$W = cv_a \quad (9)$$

where c is the specific adsorbance and v_a is the specific volume of the adsorbed phase of the adsorbate. The adsorbed-phase volume can not be measured directly, and as a consequence, its value is approximated. In general, for adsorption at or below the adsorbate saturation temperature, it is considered to be equivalent to the corresponding liquid specific volume. Above the saturation temperature, different approximations have been used. A comprehensive summary of the various methods, including a discussion of their strengths and weaknesses, is given by Agarwal and Schwarz.¹⁰ Among the three empirical relations considered to be superior, it was found that the method suggested by Dubinin¹¹ was the most appropriate one to represent the adsorption data for HFC-134a. Accordingly

$$v_a = v_b \exp[\Omega(T - T_b)] \quad (10)$$

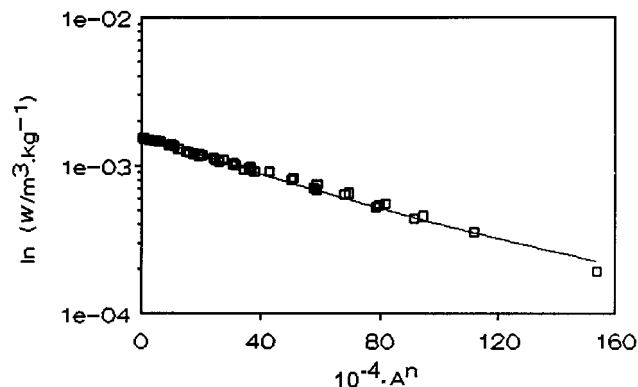
$$\Omega = \ln(b/v_b)/(T_c - T_b) \quad (11)$$

where v is the saturated specific volume and the subscripts a and b refer to the thermodynamic conditions of the adsorbate in the adsorbed state (T) and at its normal boiling point (T_b), respectively. T_c is the critical temperature of the adsorbate, and b is the van der Waals volume.

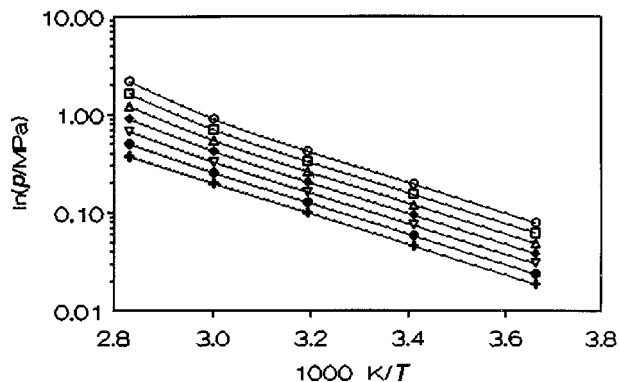
For HFC-134a, $T_b = 246.78$ K, $T_c = 374.21$ K, $v_b = 7.2643 \times 10^{-4}$ m³ kg⁻¹, and $b = 9.39 \times 10^{-4}$ m³ kg⁻¹. The values of the specific volume of the adsorbed phase calculated using eq 10 and the saturation pressures at the tempera-

Table 4. Adsorbed-Phase Volumes, v_a , and Saturation Pressures, p_s

T (°C)	v_a ($\text{m}^3 \text{kg}^{-1}$)	p_s (MPa)
0	0.0007657	0.2928
20	0.0007972	0.5717
40	0.0008301	1.0165
60	0.0008643	1.6817
80	0.0008999	2.6332

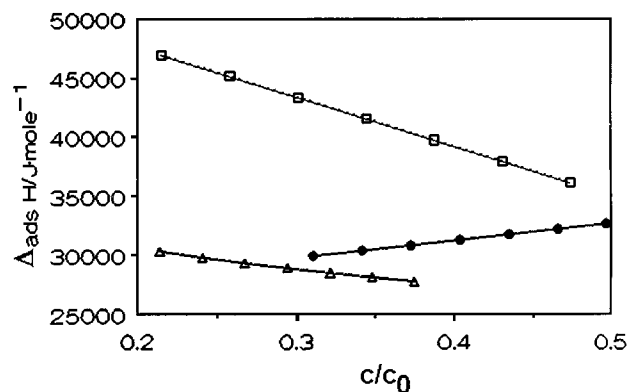
**Figure 5.** Characteristic curve of Maxsorb charcoal.**Table 5. Adsorption Parameters W_0 , E , and n and Deviations**

charcoal specimen	W_0 ($\text{m}^3 \text{kg}^{-1}$)	E (J mol^{-1})	n	$100(W - W_{\text{cal}})/W$	
				average (%)	maximum (%)
Chemviron	0.000279	14870	1.60	1.4	2.9
Fluka	0.000449	8897	0.95	3.1	7.5
Maxsorb	0.001548	8269	1.50	2.6	5.8

**Figure 6.** Isotherms of Maxsorb charcoal: O, $c = 1$; □, $c = 1.1$; △, $c = 1.2$; ◆, $c = 1.3$; ▽, $c = 1.4$; ●, $c = 1.5$; +, $c = 1.6$.

tures of interest are presented in Table 4. Using eqs 7–11, the characteristic curve $\ln(cv_a)$ vs A^n can be plotted. The value of n can be optimized from the least-squares fit, as linear behavior (on a semilog scale) is quite apparent. The intercept gives the value of W_0 , and the slope can be used to calculate E . A typical characteristic curve for Maxsorb charcoal is shown in Figure 5. Similar figures for the other specimens were also generated.¹² The adsorption parameters and the associated deviations from experimental data are given in Table 5.

Enthalpy of Adsorption ($\Delta_{\text{ads}}H$). To evaluate this property, the isotherms on the p - c plane had to be transformed into isosteres on the $(\ln p)$ - $(1/T)$ plane. A typical transformation for Maxsorb specimen is shown in Figure 6. The slopes of the isosteres were used to calculate the enthalpy of adsorption using the Clausius–Clapeyron equation.¹³ Figure 7 shows the relative loading (d/c_0) dependence of the isosteric enthalpy of adsorption for each

**Figure 7.** Loading dependence of enthalpy of adsorption: □, Chemviron; ●, Maxsorb; △, Fluka.**Table 6. Correlating Parameters for Enthalpy of Adsorption**

charcoal specimen	slope (S) (J mol^{-1})	intercept (I) (J mol^{-1})
Chemviron	-41847	55943
Fluka	-15649	33556
Maxsorb	14723	25340

of the specimens. c_0 is calculated from eq 9, with W_0 computed from Table 5 and v_a at 0 K ($0.00048 \text{ m}^3 \text{kg}^{-1}$).⁴ The linear dependence of the enthalpy of adsorption on the relative loading can be represented as

$$\Delta_{\text{ads}}H = S(d/c_0) + I \quad (12)$$

Table 6 lists the slope (S in J mol^{-1}) and intercept (I in J mol^{-1}) for the three charcoals. The Chemviron sample exhibits a stronger dependence on concentration than the other two. Second, the Maxsorb specimen shows a monotonically increasing trend compared to the others. It also emerges that the concentration dependence cannot be ignored in the case of the Fluka and Chemviron specimens. The magnitude of the enthalpy of adsorption is greater than that of the enthalpy of vaporization of HFC-134a in the range of experimental conditions studied. This aspect is important in the design of thermal compressors in which the coolant requirements for removing the enthalpy of adsorption have to be assessed. Bottani et al.¹⁴ proposed that a large micropore area leads to heterogeneous molecular interactions, which cause an increase in the enthalpy of adsorption with concentration. It can be concluded that the Maxsorb specimen is energetically more heterogeneous than the other samples.

Conclusion

Experimental isotherm data were obtained for three specimens of activated charcoal adsorbing HFC-134a. A mathematical description of the isotherms using the Dubinin–Ashtakov equation is provided. The isosteric enthalpy of adsorption was evaluated from the transformed isotherm data. Based on the variation of this property, qualitative characterization of micropore surfaces has been developed.

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