

## Preparation of synthetic carbon adsorbents by polyvinyl chloride (PVC) carbonization

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Preparation of synthetic carbon adsorbents by carbonization of polyvinyl chloride (produced by Anwil, Włocławek, Poland) is described in the paper. The influence of polyvinyl chloride (PVC) carbonization conditions on the porous structure of the obtained carbon was studied. Part of the prepared carbonizates was activated in the atmosphere of in water vapour and carbon dioxide (600 – 800 °C). The influence of individual processes on structural properties of the obtained synthetic carbons was studied. Structural characteristics were determined by means of nitrogen adsorption (-196°C, BET method) and relative isotherms adsorption  $\alpha_s$ .

### 1. INTRODUCTION

Carbon adsorbents are widely applied in many techniques. Microporous carbon adsorbents called active carbons are applied in various adsorption processes from the gas and liquid phases for purification of gases or liquids or for separation of their components. Such materials are also used as catalysts and their supports as well as in the medical sorption therapy. Then various active carbons characterized by significantly differentiated specific surface areas and micro- and mesopore volumes are required. Carbon adsorbents used in analytical chemistry are another group. In this case depending on the problem there are applied active carbons characterized by strongly developed porous structure e.g.

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for chromatographic separation of low-boiling gases, removal of some substances from the studied matrices etc. as well as mesoporous carbon adsorbents in technology of sample preparation for their analysis etc. As follows from the above, ability of preparation and modification of carbon adsorbents of the desired porous structure is very important from the practical point of view.

Also porous polymers are widely applied. They can be used for preparation of ultra pure water applied in electronic industry as well as for purification of drinking water and wasted waters. Polymers are commonly used as packings of columns in chromatography and for to the solid phase extraction. The advantage of porous polymers is the fact that they can be used as thin films, membranes and fibers. Therefore the interest in porous polymers has been increasing during the last years.

After carbonization and then activation of polymers there is obtained synthetic carbon material possessing better structural properties than polymers (larger specific surface area and pore volume), high thermal stability and chemical inertness. Synthetic carbon adsorbents are characterized by high degree of purity, good electric conductivity, hardness and resistance to corrosion. As for application in adsorption or chromatography adsorbents should possess sorption properties not only as far as sorption capacities are concerned but also textures of carbonized material.

Special properties of the carbons prepared by polymer carbonization allow for their specific application in which they are indispensable. The example can be the method of organic polymer carbonization described by the authors of paper [1]. They also discussed application of synthetic, spherical carbon adsorbents obtained in this way for blood hemoperfusion i.e. sorption of toxins directly from the patient's blood.

Active carbons are prepared by carbonization of organic materials. After carbonization non-porous or weakly porous material is usually prepared therefore carbonizates is physically or chemically activated [2] due to which microporous structure develops mainly in the carbon material. During physical activation consisting in partial gasification of carbon material, water vapour, carbon dioxide and air or their combination is most frequently used as the medium. In chemical activation the reaction of partial gasification is carried out in the presence of salts, alkalies or acids like:  $ZnCl_2$ ,  $K_2S$ ,  $KCNS$ ,  $KOH$ ,  $Fe(NO_3)_3$ ,  $FeCl_3$ ,  $NH_4Cl$ ,  $H_3PO_4$ , or metallic catalysts. The above mentioned methods are also used for modification of porous structure of carbon adsorbents. A main disadvantage of the physical and chemical activation processes is the fact that in application of oxidizing agents in the form of water vapour, carbon dioxide etc., high temperatures cause large burring-out from several to several dozen per cent by weight on the exterior parts of carbon material grains which decreases effectiveness of the starting material application. Moreover, with the

increase of burning-out, mechanical resistance of the modified active carbon decreases [2] which is unfavorable for its further application in adsorption technique, particularly on the commercial scale.

There are also other ways of preparation of porous carbon adsorbents or modification of their porous structure. One of them [3] consists in thermal treatment of active carbons in the temperature range 1800 – 2800 °C. This procedure leads to preparation of meso- and microporous carbon adsorbents whose serious disadvantage is small specific surface area and very small volume of pores. To increase the specific surface area, the authors of paper [3] suggest that the carbon material heated at 1800 – 2600 °C should be subjected to partial gasification with the H<sub>2</sub>/H<sub>2</sub>O mixture at 1000 °C in the presence of ferric salts as the catalyst of this reaction and then the salt should be removed and finally adsorbent reduced with hydrogen at 400 °C. This procedure allows for preparation of carbon adsorbents characterized by small pore volume.

Increase in active carbon pore volume can be attained by their activation with water vapour in the presence of calcium catalyst which is described, among others, in the Polish patent No. 159527 or by thermal treatment of carbon material in the presence of metallic iron or nickel catalyst in the hydrogen atmosphere (Polish patent No. 164212). However, only mesopores develop in the above processes which is not sufficient for the practical application of such adsorbents. Similar results are obtained using modification of carbon adsorbent texture described in the Polish patent No. 150976 in which porous structure of active carbon is modified in the high-temperature pyrolysis process of organic substances on its surface which decreases significantly the quantities of primary porous structure parameters.

One of the first papers on carbonization of polymers dealt with preparation of special porous carbons (molecular sieve type) obtained by polyvinylidene chloride (PVDC) carbonization [4,5]. Polyvinyl chloride (PVC) is one of the most extensively applied polymer materials. It is worth noting that it is so widely applied despite its high thermal instability which was overcome by using additives stabilizing thermally a polymer or changing its properties as required in a given field of application. Owing to its technological stability and significant importance in industry, thermal degradation and stabilization of PVC is the subject of many investigations [6-11]. The studies of polyvinyl chloride degradation make use of knowledge of the decomposition process in order to stabilize the material, which results in prolongation of polymer life and stability, and on the other hand its aim is to determine favorable conditions of useless material degradation. Both aspects are important taking into account growing requirements for stability and strength of the materials as far as new applications are concerned and problems concerning waste material utilization.

The aim of our research was to prepare synthetic carbon adsorbents by carbonization of polyvinyl chloride (PVC produced by ANWIL, Włocławek, Poland) impregnated with the salts of iron ( $\text{Fe}^{3+}$ ), zinc ( $\text{Zn}^{2+}$ ) and ammonium ( $\text{NH}_4^+$ ). The obtained carbonizates were modified with water vapour in the presence of  $\text{Ca}^{2+}$  ions as a catalyst and with carbon dioxide ( $\text{CO}_2$ ) at 800 °C in order to develop their porous structure.

## 2. EXPERIMENTAL

### 2.1. Preparation of synthetic active carbons

A series of synthetic carbon adsorbents was prepared by carbonization of polyvinyl chloride (PVC) polymer with the addition of catalysts. The polymer (100 g) was boiled in the aqueous solution  $\text{NH}_4\text{Cl}$  (7% by weight),  $\text{FeCl}_3$  (13% by weight),  $\text{ZnCl}_2$  (7% by weight) for 48 h. The impregnated polymer was dried at 90 – 110 °C for 24 h. Carbonization of polymer (10 g) was carried out with gradual increase of heating temperature (5 °C/min) in the atmosphere of nitrogen or nitrogen and carbon dioxide mixture (1:1). The sample was kept in the fluidal reactor at 275 °C for 3 h. The final temperature and time of sample carbonization were different (600 – 800 °C). After taking the carbonizates from the oven, it was washed with 6 M HCl in the Soxhlet apparatus. After washing with hydrochloric acid the carbonizates was washed with distilled water till  $\text{Cl}^-$  ions disappeared (tested by means of the reaction with  $\text{AgNO}_3$ ).

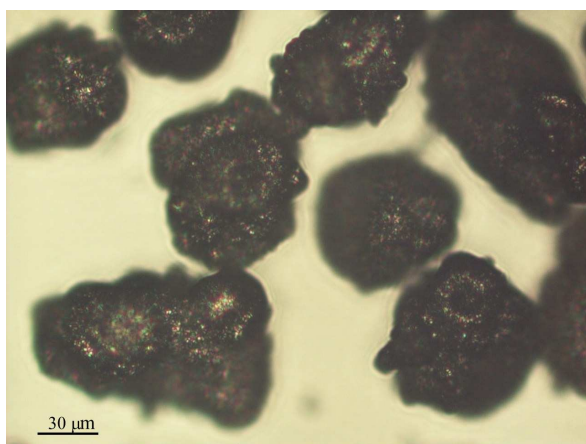


Fig. 1. Micrograph of synthetic carbon adsorbent PCV2 (magn. 200x)

Part of the obtained carbons was activated with water vapour (800 °C) in order to develop a suitable porous structure in them. Before activation with

calcium salts, the carbon material was impregnated using calcium acetate ( $\text{Ca}(\text{CH}_3\text{COO})_2$ ) spreading about 2% Ca on 1g of carbon. After activation the catalyst was removed from the adsorbent surface washing with hydrochloric acid and distilled water. The washed carbon was dried at 150 °C and designated with the symbol PCV1P-5P

The other kind of active carbon was obtained from the same carbonizates after its high-temperature treatment in the carbon dioxide atmosphere at 600 °C (PCV11), 800 °C (PCV2C, 4C, 5C) in the quartz reactor in the fluidal bed and in the  $\text{CO}_2$  stream (180 ml/min) for 6 h. The obtained carbon adsorbents were designated with the symbols PCV11, PCV2C, 4C, 5C. Table 2 presents the surface and structural properties of modified carbon adsorbents.

## 2.2. Nitrogen adsorption

Figure 2 presents exemplary isotherms of adsorption-desorption of the initial carbon (PCV-4) and the adsorbents activated with water vapor (PCV4P) and  $\text{CO}_2$  (PCV4C) registered at  $-196^\circ\text{C}$  using the adsorption analyser Micromeritics ASAP 2405N. The structural characteristics of the adsorbents: specific surface area  $S_{\text{BET}}$ , pore volume  $V_p$  and the average pore size  $R_p$  (for the cylindrical model of pores) were determined using the software Micromeritics (Tables 1 and 2).

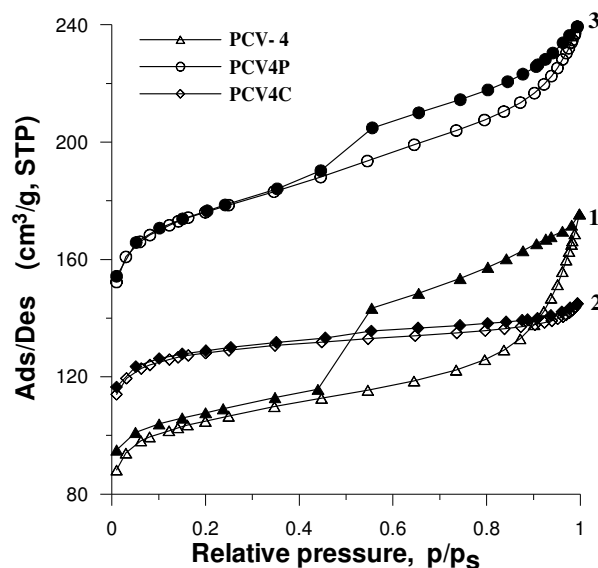


Fig. 2.  $\text{N}_2$  adsorption-desorption isotherm ( $-196^\circ\text{C}$ ) of chosen adsorbents: 1. PCV-4, 2. PCV-4P (activated with  $\text{H}_2\text{O}$  steam); 3 PCV-4C (activated with  $\text{CO}_2$ ) (Tabs 1 and 2).

Tables 1 and 2 present structural characteristics for the non-modified initial active carbon and that modified by the catalytic and vapor-gas ways.

Tab. 1. Characteristics of porous structure of initial polymer (PC) and synthetic carbon adsorbents estimated behind assistance BET method.

Sample	BET surface area $S_{\text{BET}}$ [m <sup>2</sup> /g]	Micropore surface area $S_{\text{mi}}$ [m <sup>2</sup> /g]	Total pore volume $V_{\text{por}}$ [cm <sup>3</sup> /g]	Average pore radius $R_{\text{por}}$ [Å]	Micropore volume $V_{\text{micr}}$ [cm <sup>3</sup> /g]	Per cent of micropore [% <sub>mic</sub> ]
PC	4.7	-	0.008	68	-	-
PCV-1	4.9	-	0.004	30	-	-
PCV-2	6.7	-	0.009	53	-	-
PCV-3	368	269	0.26	22	0.12	46
PCV-4	208	159	0.10	16	0.07	70
PCV-5	6.8		0.013	78	-	-
PCV-6	6.8		0.009	53	-	-
PCV-7	9.7		0.013	55	-	-
PCV-8	6.5	-	0.009	54	-	-

To obtain more complete characteristics of porous structure of the obtained carbon materials there was used the method  $\alpha_s$  [12-14] consisting in comparison of the experimental adsorption isotherm on the porous solid and the adsorption isotherm on the standard non-porous adsorbent [12,13]. Using this method the total surface area of active carbons ( $S_t$ ), micropore volume ( $V_{mi}$ ) and mesopore specific surface areas ( $S_{me}$ ) were determined (Figs 3-5). The graphitized soot Carbpac F, whose experimental isotherm of nitrogen adsorption at  $-196$  °C is presented in paper [15] was used as the reference adsorbent.

### 3. RESULTS AND DISCUSSION

As generally known active carbons are homogeneous in respect of geometrical structure of pores (their sizes and shape). Therefore the characteristics in Table 1-3 show only average properties of active carbon synthetic data. Figures 2-5 provide more detailed characteristics of meso- and microporous structure of the prepared adsorbents.

Tab. 2. Characteristics of porous structure of modified synthetic carbon adsorbents estimated behind assistance method of BET.

Sample	BET surface area $S_{\text{BET}}$ [m <sup>2</sup> /g]	Micropore surface area $S_{\text{mi}}$ [m <sup>2</sup> /g]	Total pore volume $V_{\text{por}}$ [cm <sup>3</sup> /g]	Average pore radius $R_{\text{por}}$ [Å]	Micropore volume $V_{\text{micr}}$ [cm <sup>3</sup> /g]	Per cent of micropore [% <sub>mic</sub> ]
PCV11	422	341	0.20	15	0.15	75
PCV1P	313	127	0.51	65	0.06	11
PCV2P	509	399	0.33	20	0.18	54
PCV4P	617	473	0.36	19	0.21	58
PCV5P	483	357	0.31	21	0.16	51
PCV2C	345	230	0.25	23	0.10	46
PCV4C	448	373	0.22	16	0.17	75
PCV5C	293	181	0.23	25	0.08	35

Tab. 3. Characteristics of porous structure of initial and modified (with H<sub>2</sub>O or CO<sub>2</sub>) carbon adsorbents estimated behind assistance  $\alpha_s$ -method.

Sample	Total surface area $S_t$ [m <sup>2</sup> /g]	Mesopore surface area $S_{\text{me}}$ [m <sup>2</sup> /g]	Total pore volume $V_t$ [cm <sup>3</sup> /g]	Micropore volume $V_{\text{mi}}$ [cm <sup>3</sup> /g]	Specific adsorption of nitrogen $a_{\text{mi}}^0$ [mmol/g]
PCV-3	447	22	0.26	0.16	4.6
PCV-4	246	2.5	0.10	0.09	2.7
PCV-5	17	0.7	-	0.004	0.12
PCV-6	20	1.3	-	0.006	0.18
PCV-7	23	1.0	-	0.005	0.15
PCV11	469	1.7	0.20	0.19	5.6
PCV1P	287	52	0.51	0.09	2.7
PCV2P	492	18	0.33	0.22	6.4
PCV4P	584	13	0.36	0.30	8.4
PCV5P	451	23	0.31	0.20	5.8
PCV2C	303	32	0.25	0.12	3.6
PCV4C	431	3.7	0.22	0.20	5.8
PCV5C	267	33	0.23	0.09	2.7

The shape of the prepared carbon adsorbents was determined by means of the Nikon Microscope. Figure 1 shows exemplary microscopic pictures of the carbon adsorbent PCV-2 enlarged 200x. As follows from the studies none of the prepared synthetic active carbons possesses a spherical structure but that close to it (Fig. 1).

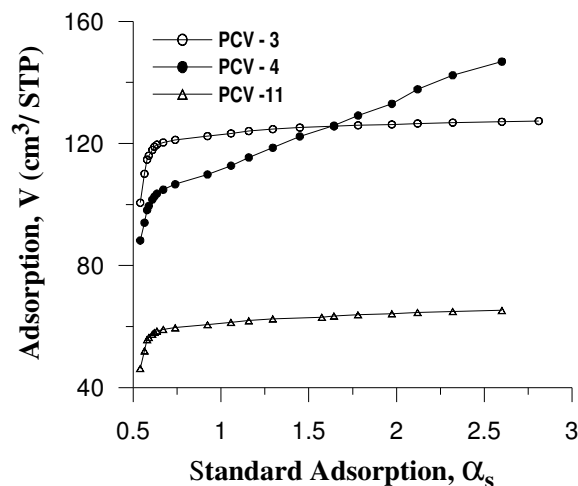


Fig. 3.  $\alpha_s$ -plots for nitrogen adsorption isotherm on carbon adsorbents (PCV-3,4 and 11).

Tables 1 and 2 present the structural characteristics obtained by carbonization of polyvinyl chloride with and without various catalysts ( $\text{FeCl}_3 + \text{ZnCl}_2 + \text{NH}_4\text{Cl}$ ) at 600 – 800 °C and then by activation in the  $\text{CO}_2$  atmosphere at 600 and 800 °C as well as activation with water vapor at 800 °C with different values of burning-out “ $\gamma$ ” degree measured by determination of apparent density of the adsorbents before and after activation (Tab. 4).

Apparent density was measured by determination of dried weighed carbon volume (at 120 °C for 12 h). The obtained results of weighing were substituted into the formula:

$$\rho_a = \frac{m}{V_a} \quad (1)$$

where:  $\rho_a$  – the apparent density of carbon  
 $m$  – weight of carbon  
 $V_a$  – apparent volume of carbon



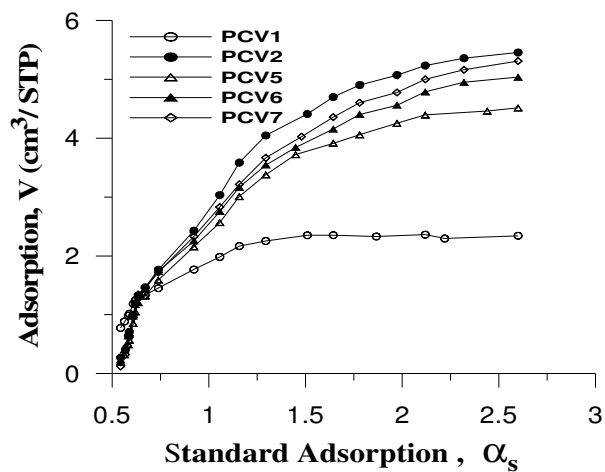


Fig. 4.  $\alpha_s$ -plots for nitrogen adsorption isotherm carbon adsorbents (PCV-1,2 and 5-7).

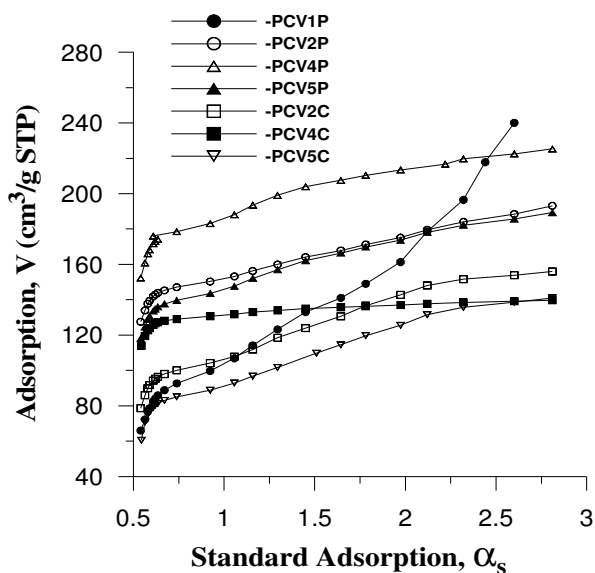


Fig. 5.  $\alpha_s$ -plots for nitrogen adsorption isotherm on modified carbon adsorbents (PCV-2,4,5-P and -C).

The activation process yield was estimated from the loss of apparent density value calculated from the formula:

$$\gamma = \frac{\rho_k - \rho_w}{\rho_k} \cdot 100\% \quad (2)$$

where:  $\gamma$  – the value of the burning-out of the modified carbon adsorbent  
 $\rho_k$  – the apparent density of carbon after modification  
 $\rho_w$  – the apparent density of carbon before modification

As follows from the comparison of the data in Tables 1 and 2, the catalytic activation of adsorbents with the catalyst ( $\text{ZnCl}_2$ ) leads to formation of the microporous system of small mesopore volume whereby  $\text{ZnCl}_2$  amount increase does not affect the adsorbent textural characteristics. Additional activation in the  $\text{CO}_2$  atmosphere causes additional increase in micropore volume (1.2 – 2 times) without distinct changes in their diameter. The comparison of the results with those obtained in series II (Tab. 2) indicates that gaseous activation causes the increase of mesopore sizes and some surface burning-out due to high activation temperature in the  $\text{CO}_2$  atmosphere (Tab. 2, Fig. 2). In this series of experiments micropores appear already at minimal burning-out. However, with further increase of burning-out value, their volume does not practically increase. In preparation of microporous carbon materials from PVC, the addition of  $\text{FeCl}_3$  as an oxidizing catalyst causes formation of tunnel macropores not affecting microporosity.

Application of alkali metals or other catalysts being Levis acids leads to significant increase of the adsorbent specific surface area and its microporosity. The specific surface area of synthetic active carbons without a catalyst was 4 – 10  $\text{m}^2/\text{g}$  (Tab. 1) and that of carbon in the presence of three catalysts ( $\text{FeCl}_3$  (13%) +  $\text{ZnCl}_2$  (7%) +  $\text{NH}_4\text{Cl}$  (7%)) – 208 to 368  $\text{m}^2/\text{g}$ . Moreover, the addition of catalyst increases the final product yield, true density and crystalline structure arrangement extent.

As follows from Table 1 (adsorbents PCV-3, PCV-4) and Table 2 (adsorbents PCV1P, PCV2C, PCV5C) active carbons prepared from the polymer PVC due to the catalytic activation have as good adsorption (and micro textural) properties as those of carbons obtained as a result of vapour-gas activation. With the activation temperature increase in the range 600 – 800 °C the specific surface area changes insignificantly but losses of products (volatile products of carbon oxidization) are larger and therefore a temperature 700 °C is recommended as optimal.

Tab. 4. The apparent density of synthetic active carbon and the calculated activation process yield.

Sample	The apparent density $\rho_a$ [g/ml]	The calculated yield of activation process [% w/w]
PCV 1	0.575	--
PCV 1p	0.425	26.22
PCV 2	0.649	--
PCV 2p	0.430	33.74
PCV 2c	0.598	7.82
PCV 4	0.605	--
PCV 4p	0.580	4.10
PCV 4c	0.570	5.79
PCV 5	0.596	--
PCV 5p	0.573	3.84
PCV 5c	0.534	10.39

As follows from the data describing porous structure of the carbons prepared from the polymer PVC with different heating rates (PCV-3 and PCV-4 samples), active carbons of larger micropore structure homogeneity and distinct sieve – molecular properties are obtained with a small heating rate (Tabs 1 and 2; Figs 2-5).

As follows from the data in Table 1, the effective diameter of micropores is about 0.46–0.56 nm (estimated from the data about nitrogen adsorption). Such pores occupy up to 80% of total pore volume of the tested adsorbents. For the adsorbents including over 90% carbon, main part of pore volume comes from micropores. However, all kinds of pores occur in the carbons of average degree of metamorphism.

As follows from the analysis of the results obtained for the adsorbents, for which special conditions of PVC pyrolysis were used, the adsorption isotherms possess distinct hysteresis loops of capillary condensation which indicate formation of network consisting of large size spacings and furrows (Fig. 2 for the sample PCV4C). All adsorption-desorption nitrogen isotherms are IV – type with the hysteresis loops H3. Their course does not depend on conditions of stage I carbonization (occurring in the temperature range 90–110 °C) whereby the width of hysteresis loop decreases when the polymer temperature approaches the melting point. However, for the samples not impregnated with the above salts both isotherm shape and hysteresis loop width depend on the conditions of stage I realization. Desorption branches on the isotherm determined for the samples

PC, PCV-1, 2, 4–8 under the incomplete saturation conditions and also the adsorption branch obtained after incomplete desorption are parallel to main branches of hysteresis loop (Fig. 2). The results indicate that during PVC pyrolysis without catalysts, the additional network of spacings and furrows is formed. Moreover, an ordinary network of narrow-pores (in the area before hysteresis) is formed in all examples.

According to the earlier analysis of carbon adsorbent texture formation during pyrolysis of thermoplastic material, it can be assumed that large furrows could be formed in the sites of weaker local bonds between primary polyvinyl chloride crystallites. In the plasticization stage of the material these furrows can grow reaching relatively large sizes. PVC melting causes removal of such local heterogeneities and therefore temperature increase of I-stage of the process decreases the action of this mechanism.

As follows from the shape of isotherms presented in Figures 2-5 a higher temperature of stage I can increase microporosity of the carbonizates (change of hysteresis loop shape) which may result in plastic deformation of the polymer skeleton in the process of heating.

Table 4 presents the percentage values of burning-out and apparent density of the obtained carbon adsorbents. Modification of carbonizates changes the apparent density of adsorbents which changes their porous structure. These changes, their direction and value depend on several factors: temperature of carbonization, its time, presence and kind of a catalyst, gas atmosphere etc.

Figure 6 presents the differential distribution of pore volume of the studied adsorbents in relation to their radius size. This figure shows that there are pores of a dominant diameters which contribute to the volume in a maximal way. Their values are given in Tables 1 and 2.

The course of the dependence  $dV/d(\log R)$  with the increase of "R" size above the value of dominant radius is mild. The second maximum occurs only for the sample PCV1P. The differential curves shown in Figure 6 are asymmetric which indicates some heterogeneity of pore geometric structure of these adsorbents. Moreover, the initial fast growth of the value  $dV/d(\log R)$  with the change of size "R" indicates occurrence of significant number of transition micropores (ultra-micropores – super-micropores transition) in these adsorbents. This is due to large contribution of the adsorbent specific surface area falling to the pores of this kind. Figure 6 shows that only fraction of the total volume and the surface area of active carbons falls to mesopores i.e. the pores of radii  $R \sim 30-78 \text{ \AA}$ .

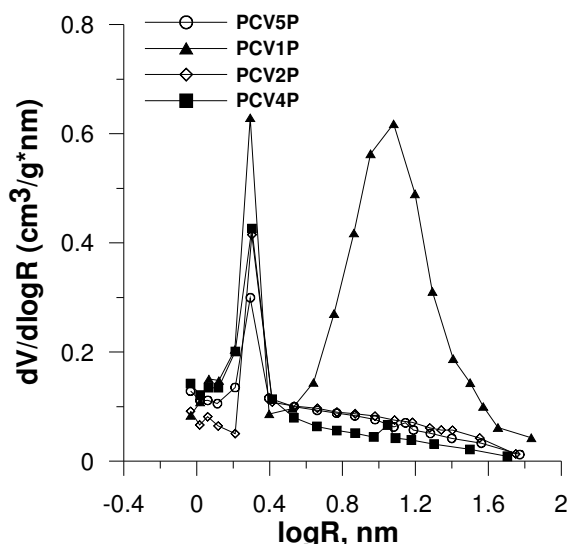


Fig. 6. Differential pore size distribution for selected modified (with  $\text{H}_2\text{O}$ ) carbon adsorbents calculated from nitrogen adsorption at  $-196^\circ\text{C}$ .

All curves for active carbons modified in the catalytic as well as vapour-gas ways in this picture have a similar course i.e. show rapid growth of the specific surface area falling to the pores of the radius  $R < 20 \text{ \AA}$ .

One of the parameters determining structural properties of active carbons prepared by their catalytic activation is the way of spreading the catalyst (which affects its dispersion). As follows from the data, catalytic activation using a property chosen catalyst and under suitable conditions allows to prepare a large assortment of active carbons of given textural characteristics. Addition of a catalyst on the carbon adsorbent surface allows to decrease the process temperature, increase the final product yield and combine dehydrochlorination and carbonization.

The synthetic active carbons prepared by us possess differentiated pores. Catalytic and vapour-gaseous treatment of carbons causes on one hand formation of small size pores of the micropore size order characterized by very small adsorption capacity compared to water vapour as the adsorbate and on the other hand narrowing of transition pore diameters. In sorption of weakly adsorbing vapours of the substance, the pores of the smallest sizes in which these substances are to be adsorbed should play a significant role. However, macropores are of less importance in adsorption of these substances and will play a role of transport arteries.

Another problem very important from a practical point of view is getting to know the mechanisms of processes causing changes in the geometrical structure

of internal pores of active carbons and in their disordered structure. These studies are very important in determination of the conditions necessary to prepare the adsorbent of proper structural parameters. For example choosing suitable conditions of modification i.e. kind of modifier and treatment temperature it is possible to decrease or increase porosity of active carbons prepared by polymer carbonization several times as in our experiments. Therefore the detailed studies of the influence of individual treatment conditions discussed in this paper on the surface properties and structure are carried out.

#### 4. CONCLUSIONS

The studies of the effect of polyvinyl chloride (PVC) carbonization parameters on applicability of the obtained synthetic active carbons were carried out. Great influence of the catalysts ( $\text{FeCl}_3$ ,  $\text{ZnCl}_2$ ,  $\text{NH}_4\text{Cl}$ ) on carbonization and properties of the obtained carbons was observed. In the case of polymer carbonization with catalysts the synthetic active carbons are characterized by large pore volume, mainly micropores. Carbonization of the polymer without the presence of the mentioned catalysts leads to preparation of smaller porosity carbon. Porous structure of the obtained carbons can be developed additionally by their activation in water vapour and carbon dioxide (800 °C). More detailed studies of porous structure of the obtained carbon adsorbents were made using the method  $\alpha_s$  which showed that the adsorbents have first of all microporous structure and in some cases similar to molecular sieve structure.

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## CURRICULA VITAE



**Andrzej Gierak** was born in 1951, Lublin Poland. Graduated from Maria Curie-Skłodowska University in Lublin in 1976. Since 1975 as a student he was employed in the Department of Physical Chemistry as an assistant. In 1986 obtained Ph.D. degree on the basis of dissertation entitled: "The preparation and investigation on chromatographic properties of carbon adsorbents obtained on inorganic support" In 2002 he obtained D.Sc. after the presentation of the dissertation: "The preparation of carbon adsorbents and investigation on its application in environmental analysis". At present he is Assistant Professor in the Department of Chemical Physics and Physico-Chemical Method Separation, Faculty of Chemistry, UMCS Lublin.

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