

ELECTROCHEMICAL PROPERTIES OF ACTIVE CARBON IN ACID AND ALKALINE ELECTROLYTES

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Summary

A comparative study of active carbon in 1 *N* H₂SO₄ and in 1 *N* KOH using chronovoltammetry and cyclic chronopotentiometry has been carried out. Chronovoltammetric curves of active carbon in both electrolytes are analogous with those of other forms of carbon. At potentials exceeding 0.8 V/reversible hydrogen electrode two oxidation processes probably take place on the carbon surface. One of them leads to the formation of oxygen containing redox surface groups on the carbon and the other to oxygen adsorbed on the surface in a form which can be reduced only at much lower potentials.

Introduction

The electrochemical properties of surfaces of various forms of carbon have recently been studied by many authors [1 - 7]. Chronovoltammetric curves obtained in various acid electrolytes for various forms of carbon are similar to each other and contain one anodic and one cathodic maximum [1 - 4] (with the exception of graphite for which two anodic and two cathodic maxima were observed [5]). According to the majority of authors these are due to the presence of certain redox surface groups containing oxygen on the carbon surface [2 - 5].

Chronovoltammetric curves of various forms of carbon in alkaline electrolytes [1, 6, 7] are also similar to each other but they are different from the curves obtained in acid electrolytes and they have been not interpreted up to now.

The hypothesis regarding the redox surface groups has been put forward on the basis of chronovoltammetric studies of various forms of carbon in acid electrolytes, but active carbon was not included in these studies. In contradiction to this hypothesis stands the hypothesis of oxygen adsorption [8, 9]. This last hypothesis was put forward on the basis of investigations of active carbon only; these investigations were carried out by means of different methods. The measurements were carried out in isoelectric conditions in

electrolytes of low and high pH and also by simple chronopotentiometric method.

It was therefore of interest to carry out comparative studies on active carbon in acid and alkaline electrolytes using the same measuring methods. In the present work cyclic chronovoltammetry (the potential sweep method) and cyclic chronopotentiometry were used. The purpose of this study was to find out whether chronovoltammetric curves of active carbon in acid electrolytes are similar to the corresponding curves of other forms of carbon, which would indicate that the redox surface groups hypothesis is valid also in the case of active carbon. Another aim was the interpretation of chronovoltammetric curves of active carbon in alkaline electrolytes.

Experimental

The active carbon used in the investigation was Norit SX IG having a BET specific surface area of $880 \text{ m}^2/\text{g}$. The test solutions consisted of $1 \text{ N H}_2\text{SO}_4$ and 1 N KOH prepared from analytical grade chemicals. The electrolytes were deaerated by means of prolonged argon bubbling. Experiments were conducted at 30°C . The electrolytic cell used has been described previously [10]. The counter electrode consisted of a platinum wire. Working electrodes were prepared [10] from 65 mg samples of active carbon with 3% of PTFE emulsion; the electrode potential was measured with respect to a reversible hydrogen electrode (RHE) in the same electrolyte. In the paper all the potentials are given *vs.* RHE.

In chronovoltammetric experiments, the samples were subjected to a triangular potential wave at a scan rate $0.3 \times 10^{-3} \text{ V/s}$. In chronopotentiometric experiments the samples were charged many times using in turn equal anodic and cathodic currents in selected potential ranges (Fig. 1). The principal measurements were carried out at a charging current of $50 \times 10^{-3} \text{ A/g}$ of carbon, *i.e.* at 3.25 mA , which approximately corresponded to the mean current recorded during the chronovoltammetric experiments in H_2SO_4 (Fig. 2(a)). The jumps in potential observed immediately after the changes of current direction were assumed to be the measure of the ohmic

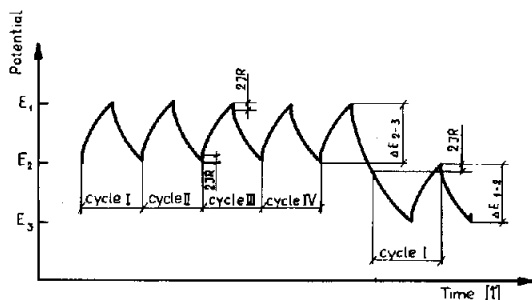


Fig. 1. Schematic plot of cyclic chronopotentiometric measurements.

polarization of the sample (2IR in Fig. 1); the width of the given potential range was corrected for this value. On the basis of these measurements the mean electrical capacity of the samples was determined for the given range and was recalculated for unit BET surface area of the carbon.

The unit electrical capacity determined by this method was assumed to be the sum of the double layer and faradaic capacities. Its further analysis is outside the scope of the present work.

Results

Figures 2(a) and (b) show selected chronovoltammetric curves obtained for fresh samples of carbon polarized four times successively in the ranges 0.1 - 0.7 (curves I), 0.1 - 0.9 (curves II) and 0.1 - 1.1 V (curves III); curves IV were obtained in the range 0.1 - 0.9 V for the same sample previously maintained at 1.5 V.

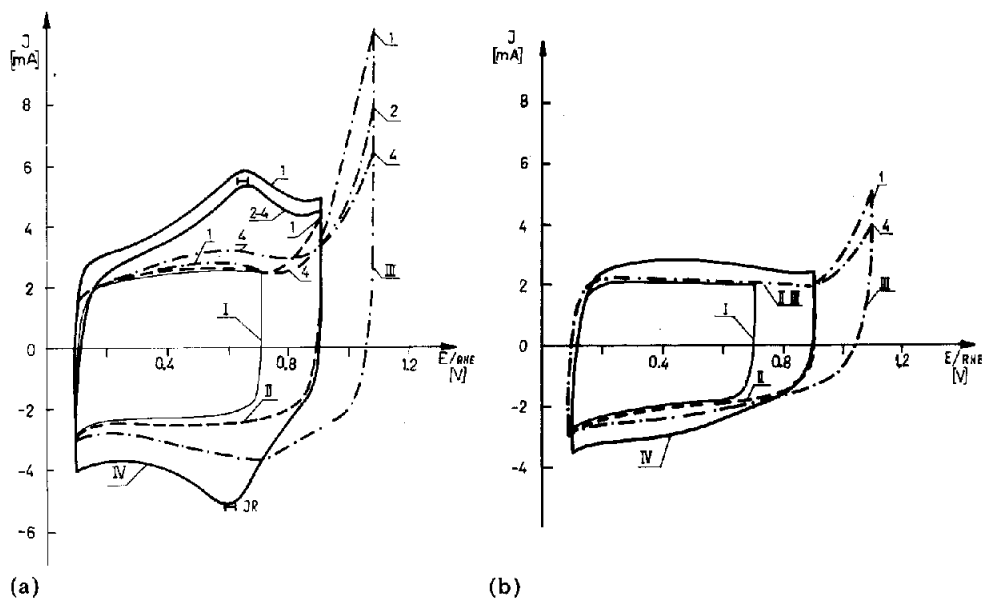


Fig. 2. Chronovoltammetric curves of active carbon in (a) 1 N H_2SO_4 and (b) 1 N KOH. I: 0.1 - 0.7 V; II: 0.1 - 0.9 V; III: 0.1 - 1.1 V; IV: 0.1 - 0.9 V after oxidation of the sample at 1.5 V. 1, 2 and 4: order of curves over given potential region.

The same samples were then cathodically reduced applying increasingly cathodic potentials up to -1.5 V. The curves obtained in both electrolytes in the range 0.1 - 0.9 V for the samples prepared by this method were in principle identical with those obtained before the reduction; the slight differences were due to some decrease in the size of the electrodes resulting from removal of a part of the samples by hydrogen evolving at strongly cathodic potentials.

The chronovoltammetric curves obtained for active carbon in 1 *N* H₂SO₄ (Fig. 2(a)) are very similar to those obtained by Laser and Ariel [4] for glassy carbon in 0.1 *N* HClO₄, by Kinoshita and Bett [3] for carbon black in 0.1 *N* H₂SO₄ and by Tarasevich *et al.* [1] for pyrographite in 1 *N* H₂SO₄. The shape of anodic sections of the curves shown in Fig. 2(a) indicates that at potentials exceeding 0.8 - 0.85 V some oxidation process was taking place at a rate increasing with increasing potential and decreasing with successive cycles. This oxidation process was followed by some increase of anodic and cathodic currents in the potential region 0.1 - 0.9 V and a gradual formation of a pair of broad maxima in the potential region 0.5 - 0.7 V. The potential difference between the two maxima was about 80 mV.

These observations are about in agreement with the results obtained by Laser and Ariel [4] for glassy carbon in 0.1 *N* HClO₄. However, the potential difference between the two maxima observed by these authors was much larger (about 400 mV). Laser and Ariel were using a several times higher scan rate (50×10^{-3} V/s as compared with 0.3×10^{-3} V/s in the present work), which should favour an increase in the potential difference, but their sample was a compact material having a smooth surface, whereas our active carbon had a very large surface area and was very porous. For pyrographite cycled at several volts per second Tarasevich *et al.* [1] observed anodic and cathodic maxima at potentials about 640 and 600 mV respectively, a potential difference smaller than that observed in the present work.

Correction for ohmic polarization (segments IR in curves IV in Fig. 2(a)) showed that the anodic and cathodic maxima observed in the present work occurred at nearly the same potential 625 mV.

The chronovoltammetric curves obtained for active carbon in 1 *N* KOH (Fig. 2(b)) are similar in general to those obtained by Gagnon [7] for active carbon and carbon black in 6 *N* KOH, by Mrha *et al.* [6] for active carbon in 1 *N* KOH, and by Tarasevich *et al.* [1] for pyrographite in 1 *N* KOH. However, these authors did not investigate systematically the effect of anodic oxidation of the sample on the shape of the curves. In contrast to the curves obtained in the present work the anodic sections of chronovoltammetric curves obtained by Mrha *et al.* [6] and by Tarasevich *et al.* [1] contain a maximum at about 0.1 V. This maximum was not interpreted by the above authors. In chronovoltammetric measurements carried out in the present work the potential of 0.1 V was one of the two limits of the measurement regions. This fact explains the lack of a similar maximum in curves shown in Fig. 2(b). This maximum will be discussed later.

A characteristic feature of the curves shown in Fig. 2(b) is the difference in the shape of the anodic and cathodic sections in the potential region 0.1 - 0.8 V. The anodic sections can be approximated to straight lines parallel to the potential axis, whereas the cathodic sections can be approximated to straight lines which are at a distinct angle to the potential axis.

The shape of the anodic sections of the curves shown in Fig. 2(b) indicates that, at potentials exceeding 0.8 - 0.85 V some oxidation process was taking place at a rate increasing with increasing potential and decreasing

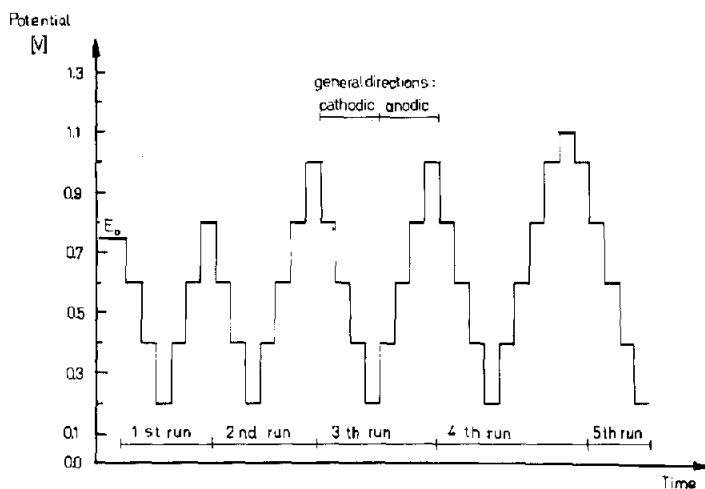


Fig. 3. General course of chronopotentiometric measurements in H_2SO_4 . E_0 , open circuit potential; —, middle potentials of multiple charging at 0.2 V amplitude (see Fig. 1).

in successive cycles. The oxidation process was followed by some increase of anodic and cathodic currents in the potential range 0.1 - 0.9 V. In contrast to the experiments carried out in H_2SO_4 , in KOH no formation of maxima was observed.

Chronopotentiometric measurements were carried out in successive neighbouring potential ranges (see Fig. 1), 0.2 V wide. For a new sample these ranges were shifted in the region 0.1 - 0.9 V and then the region was gradually extended in the anodic direction. The detailed course of these measurements in H_2SO_4 is shown schematically in Fig. 3. The influence of such treatment on the measured properties of carbon in KOH electrolyte was relatively small (see curves 1 and 5 in Fig. 5(b)). For this reason the programme realized in KOH was extended: the sample was additionally oxidized at a potential of +1.5 V and re-examined also at potentials more cathodic than 0.1 V.

In chronopotentiometric measurements in both electrolytes, the charges due to anodic and cathodic sweeping became constant only after several cycles in the given potential range. In the region 0.3 - 0.9 V the charges were already stabilized during the second cycle. Outside this region the stabilization of charges required a larger number of cycles which depended on the sample history. Selected relationships are shown in Fig. 4.

Figures 5(a) and (b) show the dependence of the electrical capacity of active carbon samples in both electrolytes on potential and sample history; this dependence was determined by cyclic chronopotentiometry. The arithmetical mean values of anodic and cathodic capacities shown in the graphs were calculated from the charges measured during the fourth charging cycle, *i.e.* after certain stabilization of the charges. In order to simplify the graphs the capacities determined as the mean values for 0.2 V wide ranges

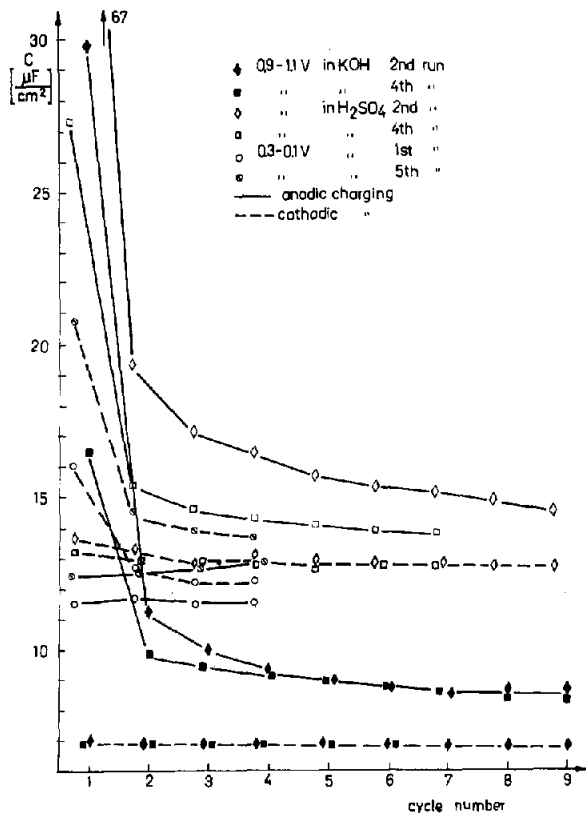
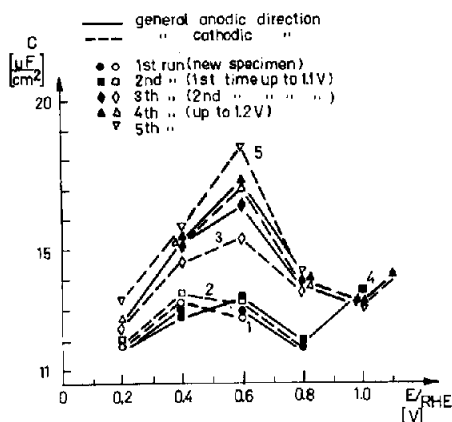


Fig. 4. Selected electrical capacities of active carbon as function of the number of cycles in chronopotentiometric measurements in 1 N H_2SO_4 and in 1 N KOH; $I = 50 \text{ mA/g}$.

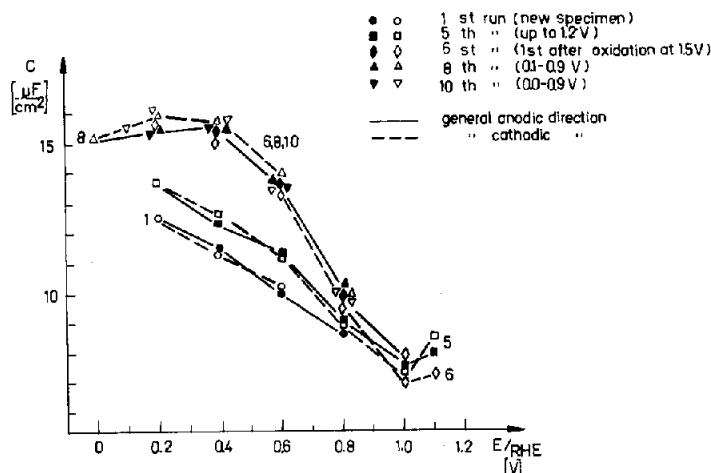
were ascribed to the middle potential of each range (see Fig. 3). In the region 0.1 - 0.9 V the difference between the anodic and cathodic capacities did not exceed the error of the determination (about 5%); at higher potentials this difference was greater and the anodic charges were considerably larger than the cathodic ones.

The results of chronopotentiometric measurements carried out in H_2SO_4 (Fig. 5(a)) are in agreement with those of chronovoltammetric ones (Fig. 2(a)). They confirm the occurrence of the oxidation process at potentials exceeding 0.8 V. At these potentials, a rapid increase of anodic charges, decreasing in successive cycles was observed. As a result of the oxidation process the electrical capacity over the whole potential region 0.1 - 0.9 V was increasing; at the same time the formation of the broad capacity maximum was observed in the potential region corresponding to the two maxima in chronovoltammetric curves. Unlike chronovoltammetric curves the chronopotentiometric curves indicated that this maximum, although small, was also present in the case of fresh samples which were not anodically oxidized.

The results of chronopotentiometric measurements carried out in KOH (Fig. 5(b)) are also in general agreement with those of chronovoltammetric



(a)



(b)

Fig. 5. Dependence of electrical capacity of active carbon on potential and sample history in (a) 1 N H_2SO_4 and (b) 1 N KOH; determined by cyclic chronopotentiometry; $I = 50$ mA/g.

ones (Fig. 2(b)) and they confirm the occurrence of the oxidation process at potentials exceeding 0.8 V. As a result of this process the electrical capacity over the whole potential region between 0.1 and 0.9 V was increasing (Fig. 5(b)); this corresponds to the increase of current in chronovoltammetric measurements (Fig. 2(b)). Unlike the chronovoltammetric ones, in the chronopotentiometric curves of oxidized samples a broad maximum of electrical capacity was observed at the potential near 0.3 V (Fig. 5(b)). The existence of this maximum was verified in additional chronopotentiometric measurements of an oxidized sample at various charging currents (25, 50, 100 and 200 mA/g).

This maximum cannot be identified with the previously mentioned maximum at about 0.1 V in chronovoltammetric curves obtained by Mrha *et al.* [6] for active carbon and by Tarasevich *et al.* [1] for pyrographite in KOH. These authors obtained the anodic maximum in dynamic conditions, immediately after the period in which considerable cathodic currents had been observed. In these conditions the anodic maximum was probably due to oxidation of cathodic reaction products which had been formed at lower potentials. In the present work the maximum was observed in cyclic measurements carried out in relatively narrow potential ranges, after almost complete equilibration of anodic and cathodic charges in these ranges (Fig. 4).

As mentioned above, the charges due to anodic and cathodic chargings were stabilized in both electrolytes only after a certain number of cycles. During the initial cycles in a given potential range considerable differences between the anodic and cathodic charges were observed (Fig. 4). In successive cycles these differences decreased in magnitude, in many cases almost to zero. However, always in a given potential range an excess anodic or cathodic charge was in sum flowing out during successive cycles. The excess charges, calculated as differences between the anodic and cathodic charges measured in the initial four cycles in the individual potential ranges, are shown in Figs. 6(a) and (b). These relationships were practically the same when a larger number of cycles was taken into account.

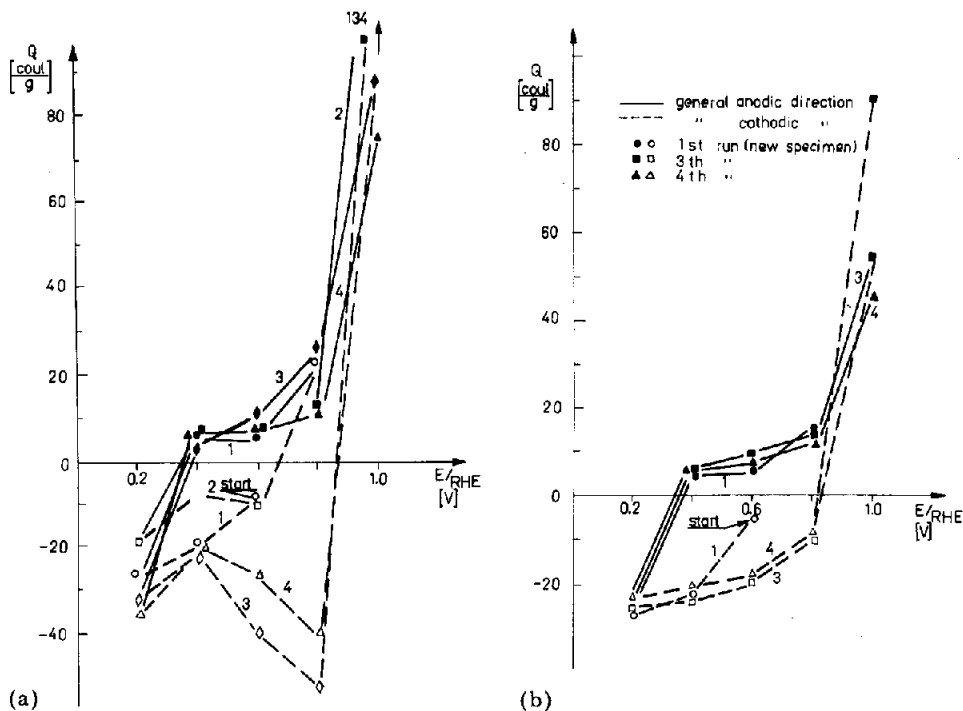


Fig. 6. Dependence of excess charge of active carbon on potential and sample history in (a) 1 N H_2SO_4 and (b) 1 N KOH; $I = 50$ mA/g.

Excess charges observed in both electrolytes in the ranges 0.3 - 0.5 and 0.5 - 0.7 V during the shifting of potential ranges in the anodic direction and the excess charge observed in KOH in the range 0.9 - 0.7 V during the shifting of ranges in the cathodic direction can be neglected as due to experimental error (such small charges were due to the method of measurements; the neighbouring potential ranges had common limits but as a result of ohmic polarization they were in fact separated by $2IR$ — see Fig. 1). The anodic excess charges observed in both electrolytes in the range 0.9 - 1.1 V were large, which confirms the existence of the oxidation process taking place at a rate decreasing in successive measuring cycles (Fig. 4) and in successive measurements (Figs. 4 and 5).

Figures 6(a) and (b) also show the existence of considerable cathodic excess charges in wide potential regions during the shifting of potential in the cathodic direction. In H_2SO_4 this excess charge was observed in the region 0.9 - 0.1 V, with a minimum in the vicinity of 0.4 V (Fig. 6(a)); in KOH the excess charge was observed in a narrower region, 0.7 - 0.1 V (Fig. 6(b)). It should be remembered that these charges were determined for several initial cycles in a given potential range. In successive cycles the difference between the anodic and cathodic charges in these ranges was rapidly decreasing to zero and a prolonged cycling, *e.g.* in the range 0.9 - 0.7 V had no observable effect on the excess charge measured next in the neighbouring range 0.7 - 0.5 V.

Figure 7 shows the dependence of electrical capacity of oxidized samples of active carbon in 1 N KOH on charging current in chronopotentiometric measurements for the individual 0.2 V wide potential ranges. It has been found [11] that the values of charge and of electrical capacity of active carbon measured by the methods used also in this work strongly depend on the rate of measurement. These values decrease with increasing rate of potential change and with increasing charging current. Similar relationships have been observed for graphite [5, 12], pyrographite [1, 13] and glassy carbon [13]. This has been explained as due to the dependence of the depth of penetration of the measuring signal into the pores of the sample on its speed [1, 12] or to the faradaic character of the charge [5].

In the case of a considerable contribution by the second factor the dependence of the results of measurement on its rate should be different in different potential ranges. The results given in Fig. 7 show that in all potential ranges over the whole region 0.1 - 0.9 V the dependence of electrical capacity on charging current was similar (the slopes of the straight lines are the same). This indicates that the factor determining the dependence of the measured electrical capacity of the material on the rate of measurement was the dependence of the depth of penetration of the measuring signal into the pores on its speed.

Here it is proper to return to the above mentioned work of Gagnon [7] who compared the behaviour of carbon black and active carbon in 6 N KOH. For these two materials he obtained analogous chronovoltammetric curves but their electrical capacities calculated for the potential of 0.9 V on the

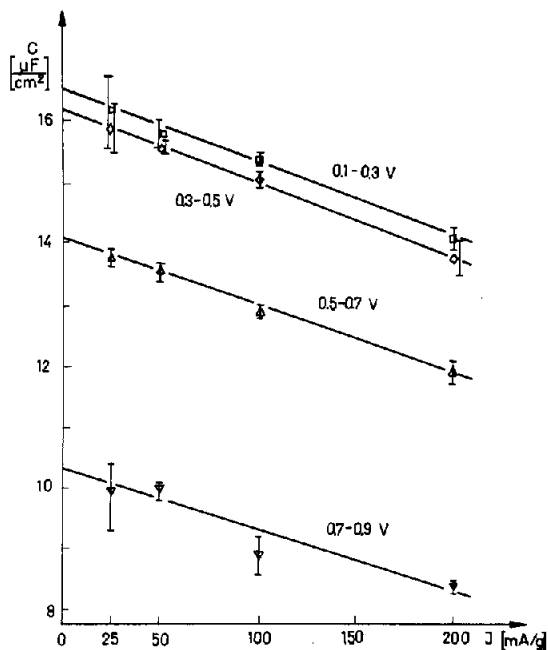


Fig. 7. Dependence of electrical capacity of anodically oxidized active carbon on the rate of measurement for various potential ranges in chronopotentiometric experiments, in 1 *N* KOH.

basis of these measurements (Gagnon called them "double layer capacities") were different: 10 and $4.5 \mu\text{F}/\text{cm}^2$ respectively. The results presented in Fig. 7 show that when the rate of measurement is sufficiently small the capacity of active carbon in the vicinity of the 0.9 V potential is similar to that obtained by Gagnon for carbon black. Gagnon [7] was carrying out the measurements at only one, relatively high rate (6×10^{-3} V/s). Carbon black is much less porous than active carbon and for this reason the dependence of the measured electrical capacity on the measurement rate should be stronger in the case of active carbon than in the case of carbon black. Hence, the conclusion reached by Gagnon that there is a considerable difference between the wetting of carbon black and of active carbon by the electrolyte seems to be unjustified.

Discussion

Comparison of the results obtained in the present work for active carbon in 1 *N* H_2SO_4 and in 1 *N* KOH by means of the same measuring methods indicates similarities as well as some differences between the behaviour of active carbon in these electrolytes. The principal similarities and differences are as follows:

(i) At potentials exceeding 0.8 V (RHE) in both electrolytes an oxidation process takes place at a rate increasing with increasing potential and decreasing in successive cycles. Comparison of numerical values characterizing this process (anodic currents) indicates that in the acid electrolyte it was taking place at a higher rate than in the alkaline medium.

(ii) As a result of this process the electrical capacity of carbon was increasing in the whole principal measuring region 0.1 - 0.9 V. At the same time in 1 N H₂SO₄ a distinct broad maximum of electrical capacity was growing; this maximum corresponds to two maxima observed in chronovoltammetric curves at a potential of about 625 mV. It should be emphasized that the chronopotentiometric method made it possible to notice the capacity maximum earlier than the chronovoltammetric method.

In 1 N KOH, the increase of the capacity due to the oxidation process was smaller than in the acid medium. Chronopotentiometric measurements made it possible to observe for a strongly oxidized sample an indistinct maximum of electrical capacity at about 300 mV.

(iii) Another effect of the oxidation process taking place in both electrolytes was the appearance of an excess cathodic charge in a wide potential region. In 1 N H₂SO₄ this charge was observed in the region 0.9 - 0.1 V and in 1 N KOH in the region 0.7 - 0.1 V.

The above data make it possible to propose a hypothesis that the behaviour of active carbon in 1 N H₂SO₄ and in 1 N KOH is determined by similar processes taking place on the carbon surface. Comparison of the results obtained for active carbon with those obtained by other authors for other forms of carbon suggests that analogous processes also take place on other forms of carbon such as carbon black, pyrographite and glassy carbon.

The results suggest that at potentials exceeding 0.8 V two oxidation processes were taking place in both 1 N H₂SO₄ and in 1 N KOH. One of them was responsible for the irreversible increase of anodic and cathodic currents as well as the electrical capacity in the wide potential region 0.1 - 0.9 V and the formation of the capacity maximum at the potential about 625 mV in 1 N H₂SO₄ and at the potential near 300 mV in 1 N KOH. The other oxidation process was leading to the formation of a product which was reducible in a wide range of lower potentials, which was observed in the form of an excess cathodic charge.

For the first process in 1 N H₂SO₄ the mechanism proposed by Laser and Ariel [4] and based on their studies on glassy carbon in HClO₄ can be accepted. According to these authors the oxidation leads to irreversible formation of oxygen containing readily reversible redox groups on the carbon surface. Thus, it appears that the redox surface groups hypothesis is valid also for active carbon. However, this mechanism implies in fact the independence of the redox potential (on the RHE scale) of the surface groups of the pH, whereas the results of the present work showed that the difference between these potentials in 1 N H₂SO₄ and in 1 N KOH was about 0.3 V. These data suggest that in 1 N KOH the first oxidation process also leads to the irreversible formation of readily reversible redox groups but these groups are probably different from those formed in acid media.

According to Tarasevich *et al.* [1] the existence of the two maxima in chronovoltammetric curves of pyrographite in 1 N H₂SO₄ is due to reversible adsorption of oxygen. The authors did not confirm their opinion and did not attempt to interpret similarly the corresponding curves which they obtained at the same time in 1 N KOH. The existence of irreversible adsorption of oxygen on carbon was proved in isotopic studies carried out by Strazhesko and Mackevich [14]. The results obtained in the present work and the results obtained by Laser and Ariel [4] for different forms of carbon indicate that in acids the maxima increase with increasing degree of irreversible oxidation of the surface. This would lead to the conclusion that the irreversible oxidation of the surface causes an intensification of the reversible adsorption process. However, for their oxidized pyrographite samples Tarasevich *et al.* [1] suggest that the reversible adsorption of oxygen did not exceed 1 - 2% of the monolayer, *i.e.* it was equal to that determined for non-oxidized carbon [9].

As mentioned above, the second anodic oxidation process led to the formation of a product which was reducible in a wide range of lower potentials. In 1 N H₂SO₄ the cathodic excess charge was observed in the region 0.9 - 0.1 V, with a minimum of this charge at about 0.4 V. In 1 N KOH this charge was observed in the region 0.7 - 0.1 V and its values were practically identical with those observed in 1 N H₂SO₄ in the range of the minimum value and to the left of this range (between 0.5 and 0.1 V). It was suggested earlier [11] that the cathodic excess charge in acid electrolyte is due to molecular oxygen weakly bonded to the carbon surface, which during the decrease of the potential is reduced to hydrogen peroxide which in turn below about 0.4 V is reduced to water. This suggestion was based on the so far accepted scheme [6, 15, 16] of electroreduction of oxygen on carbon and some other materials. Recently Taylor and Humffray [17] published data showing that the second polarographic wave in the curves of reduction of oxygen on glassy carbon is also an oxygen reduction wave like the first one. These authors suggest that the reason for the existence of two oxygen waves is the existence of two types of active centres on carbon surface. They also state that the first wave is not always observed and that its presence depends on unspecified conditions of purity and preparation of the electrode surface [17].

In order to explain the existence of the cathodic excess charge it is necessary to assume that at potentials exceeding 0.8 V a process leading to adsorption of oxygen on carbon surface takes place and this oxygen is reduced in a wide range of lower potentials. The results suggest that in 1 N H₂SO₄ two types of adsorption centres were present on the carbon surface and that these centres were responsible for the excess charge in the potential regions above and below 0.5 V respectively, whereas in 1 N KOH there was only one type corresponding to low desorption potentials of the adsorbed oxygen. This desorption is responsible for the distinct slope with respect to the potential axis of the cathodic sections of the chronovoltammetric curves obtained in KOH.

Tarasevich *et al.* [1] observed a similar oxidation process in acid and alkaline electrolytes in the case of pyrographite at potentials exceeding 1 V. This process leads to the formation of a product whose reduction was observed in chronovoltammetric curves down to potentials lower than 0.5 V. Tarasevich suggested that this product was a difficult to reduce form of oxygen chemisorbed on the carbon surface. The opinion of Tarasevich *et al.* [1] that there exist on the carbon surface at the same time a reversibly adsorbed oxygen, which is responsible for the two maxima in acid media at the potential about 0.6 V, and another one, less reversibly adsorbed, which appears on the surface at high potential (above 1 V) and is desorbed at very low potentials (below 0.5 V), does not follow directly from the results of his measurements and is unconvincing.

Laser and Ariel [4] observed a similar process on glassy carbon in acid electrolyte and suggested that it is an "irreversible redox reaction of surface groups" which are formed on carbon surface as a result of its oxidation, in contrast to the simultaneously observed reversible redox reaction of surface groups, which is responsible for the existence of the two maxima in chronovoltammetric curves in the intermediate potential range.

In the present work the existence of the cathodic excess charge was observed also in the case of fresh samples of active carbon which had not been previously anodically polarized above 0.7 V. These excess charges determined in the potential region 0.5 - 0.1 V were similar to those determined in the same region for samples which were previously polarized at higher potentials. The excess charges observed for fresh samples could be due only to the earlier contact with atmospheric oxygen. These results can be explained either by assuming that on the surface of carbon which has not been anodically oxidized there is the same number of surface groups responsible for the "irreversible redox reaction" as on the surface of oxidized carbon, which is contrary to the results obtained in the present work and also by Laser and Ariel [4], or by accepting the hypothesis which was proposed above regarding the existence of oxygen adsorbed on carbon surface in a form, which is reducible only at relatively low potentials.

Conclusions

(1) Chronovoltammetric curves of active carbon in 1 N H₂SO₄ and in 1 N KOH are analogous to those obtained for other forms of carbon in low and in high pH electrolytes respectively. The curves of anodically oxidized active carbon in H₂SO₄ had two maxima, occurring at approximately the same potential, *i.e.* 625 mV/RHE. Chronopotentiometric measurements of anodically oxidized active carbon in KOH made it possible to observe an indistinct maximum of electrical capacity of this material at a potential of about 300 mV/RHE. The shape of chronovoltammetric curves in KOH is strongly influenced by a gradual reduction at low potentials of a product which was previously formed at much higher potentials.

(2) Similar processes determine probably the shape of chronovoltammetric curves and the dependence of the electrical capacity of the material on the potential for active carbon and for other forms of carbon, such as carbon black, pyrographite and glassy carbon, in acid and in alkaline electrolytes.

(3) Two oxidation processes take place on carbon surface in acid and alkaline electrolytes at potentials exceeding 0.8 V/RHE. One of them is an irreversible formation on the carbon surface of oxygen containing redox surface groups the presence of which is responsible for the maxima of electrical capacity at definite potentials; it is probable that the surface groups which are formed in acid electrolytes are different from those which are formed in alkaline ones. The product of the second oxidation process is probably oxygen adsorbed on carbon surface, and reducible gradually at lower potentials.

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