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VOLTAMMETRIC INVESTIGATION OF NITROFURAZONE

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ABSTRACT

This paper presents a detailed study of the voltammetric behaviour of nitrofurazone in nonaqueous solutions using platinum and ruthenium electrode.

INTRODUCTION

5-nitrofuran derivatives have become very popular as chemotherapeutic agents possessing an extremely wide spectrum of activity against various bacteria, protozoa, fungi, large viral agents etc., as well as showing antitumour activity (Stradins et al 1971). Nitrofurazone (5-nitro-2-furaldehyde semicarbazone), a member of this group, has broad spectrum antibacterial activity against a number of Gram-negative and Gram-positive micro-organisms (Mishra and Gode 1985).

However, the biochemical nature of antibacterial activity of 5-nitrofuran series still has been the subject of investigations.

The results of investigations have revealed that the potentials of the first stage of nitrofuran electroreduction depend on the properties of medium and the structure of the derivative (Stradins et al 1971). The primary electrochemical process being of interest from the point of view of biochemistry, in aqueous soutions consists in a 4e reduction of nitro group to hydroxylamino group; at more negative potentials a further electroreduction to amino group and at considerably more cathodic potentials reductive cleavage of azomethine bond is possible. The 4e process consists of some successive stages which, according to the structure of derivative and solvent, have a different character. Nitrofuran molecules are strongly adsorbed a the charged electrode (Stradins et al 1971).

Regarding to the data mentioned above the electroreduction mechanism of nitrofurans has been found to depend markedly on solvent, supporting electrolyte and electrode material (Cadle et al 1967, Kemula and Zawadowska 1975).

In this study the electroreduction of nitrofurazone was investigated using platinum and ruthenium electrodes in N,N-dimethylformamide by voltammetric technique.

EXPERIMENTAL

Materials: Nitrofurazone (pharmaceutical grade) was a kind gift of Eczacıbaşı İlaç Sanayi ve Ticaret A.Ş. (İstanbul, Turkey).

Commercially available N,N-dimethylformamide (DMF) was purified and dried by the method described by Moe, 1967.

Sodium nitrate used as supporting electrolyte in this study was obtained in reagent grade quality from Merck.

During the measurements the solutions were shielded from light.

Apparatus: All electrochemical experiments were performed on a PRG-3 Polarograph (Tacussel). An EPL-2 recorder (Tacussel) was used for recording the curves.

A three electrode system was used. The working electrodes were stationary platinum and ruthenium wire with a surface area of 0.61 cm^2 and 0.57 cm^2, respectively. Electrode pre-tretament consisted of allowing them to stand at –0.10 V for 15 min in nitrofurazone solutions being studied. The auxiliary electrode was platinum wire. Potentials were measured against a saturated calomel electrode (SCE) separated from the working electrode compartment by a glass frit and a bridge containing 1 M solution of $NaNO_3$ in dimethylformamide.

All solutions were deaerated prior to each measurement by passing purified nitrogen stream.

RESULTS AND DISCUSSION

Figure 1 presents voltammetric curves of nitrofurazone solution in DMF containing 1 M $NaNO_3$ on platinum electrode at different scan rates. At a scan rate of 10 mVs^{-1}, the two cathodic peaks at —0.8 V and —0.95 V and the anodic one at —0.7 V could be observed. The peak potentials were shifted to more negative values by increasing the

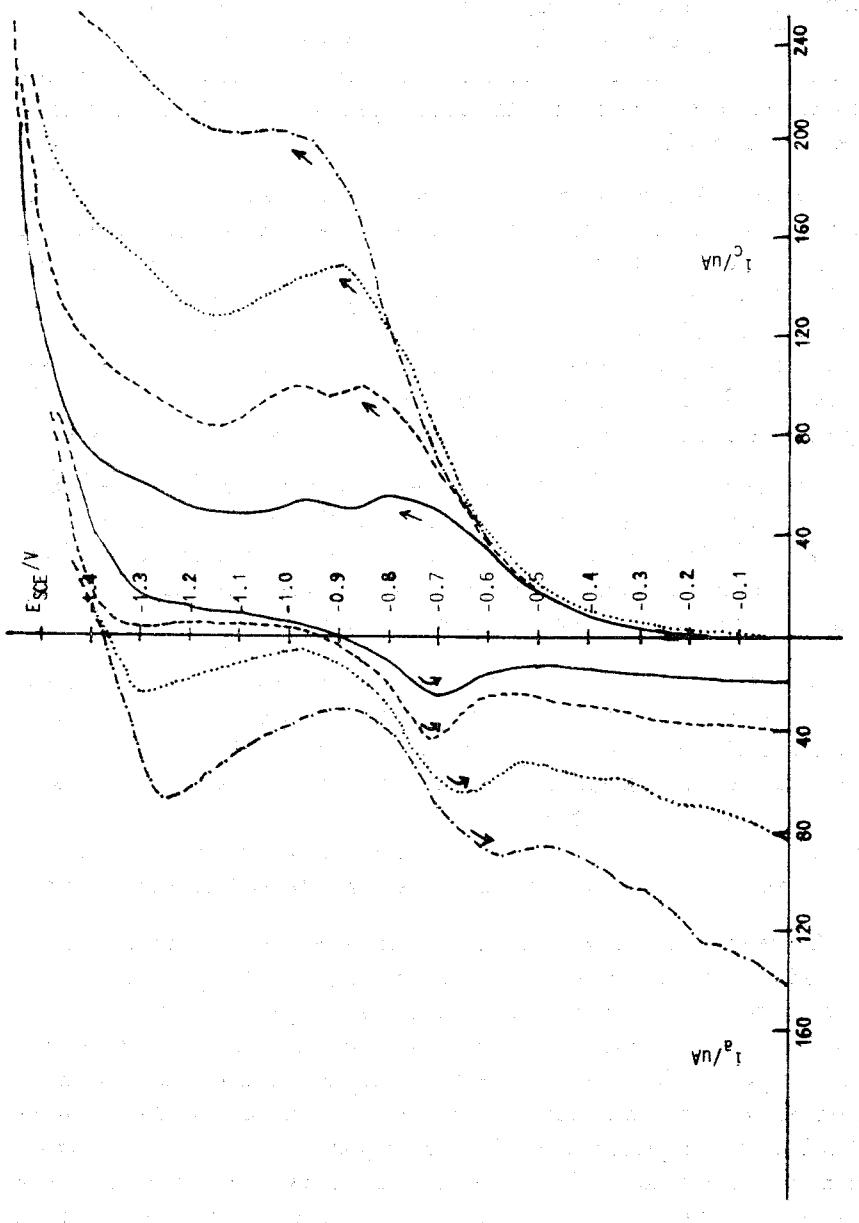

Figure 1. Voltammograms obtained in 8.4×10^{-4}M nitrofurazone containing DMF+1M $NaNO_3$ on platinum electrode at different scan rates. Scan rates (——), 10 mVs^{-1} ;(– – – –), 12.5 mVs^{-1}; (. . . . .), 50 mVs^{-1}; (-.-.-.-), 100 mVs^{-1}.

scan rate. At scan rates higher than 50 mVs^{-1}, the second peak at —0.95 V disappeared and the first one became sigmoid. In addition, the increase in scan rate caused an increase in the number of anodic peaks. And it also caused the shift of the anodic peak at —0.7 V towards more positive potential.

In Figure 2, the voltammetric curves obtained in DMF+1 M $NaNO_3$ with various concentrations of nitrofurazone are shown. An increase in the concentration of nitrofurazone determined the character of the two peaks. Only one peak was observed at about —0.9 V in the concentration of $4x10^{-4}$M. When the concentration was increased to $9x10^{-4}$M, a new cathodic peak appeared at about —1 V. If the concentration exceeded 10^{-3} M, the first peak became smaller and the second one became bigger. We observed the third one at —1.35 V on all of the curves.

Figure 3 shows the voltammograms recorded with the same conditions in Figure 2 using ruthenium electrode. The reduction steps observed with platinum also appeared with ruthenium but the peak shape became as limiting current. On some of the curves, a new and ill-defined reduction step was observed at about —0.05 V.

Voltammetric curves presented in Figure 4 and Figure 5 were obtained by returning from different potentials using platinum and ruthenium electrodes, respectively. In the first cycle, the current was bigger than the following ones. As seen on the curves, the anodic peak at —1.2 V corresponds to the cathodic one at about —1.3 V which characterizes the reversibility of the investigated system. But according to the peaks in the range of less negative potentials, system is irreversible.

Cadle et al 1967 have found that in the absence of the proton donor, the reduction of aromatic nitro compounds proceeds by a simple one-electron step to produce radical anion and a new peak at —1.3 V corresponding a further reduction of the radical anion. And a many electron wave at potentials more positive than the one-electron wave has been observed with the hanging-drop electrode. Kemula and Zawadowska 1975 have also reported this reduction step at rather positive potentials for nitrofurans with the hanging-drope electrode. For their idea, it is a new redox system appeared on mercury electrode due to the substition of mercury cation in furan ring. Nevertheless Lipsztajn et al 1977 have found this concept not too probable as the concentration of mercury cation too low in the range of reduction potentials of nitrofurans. In the case of platinum in tetraethylammonium bromide containing N, N-

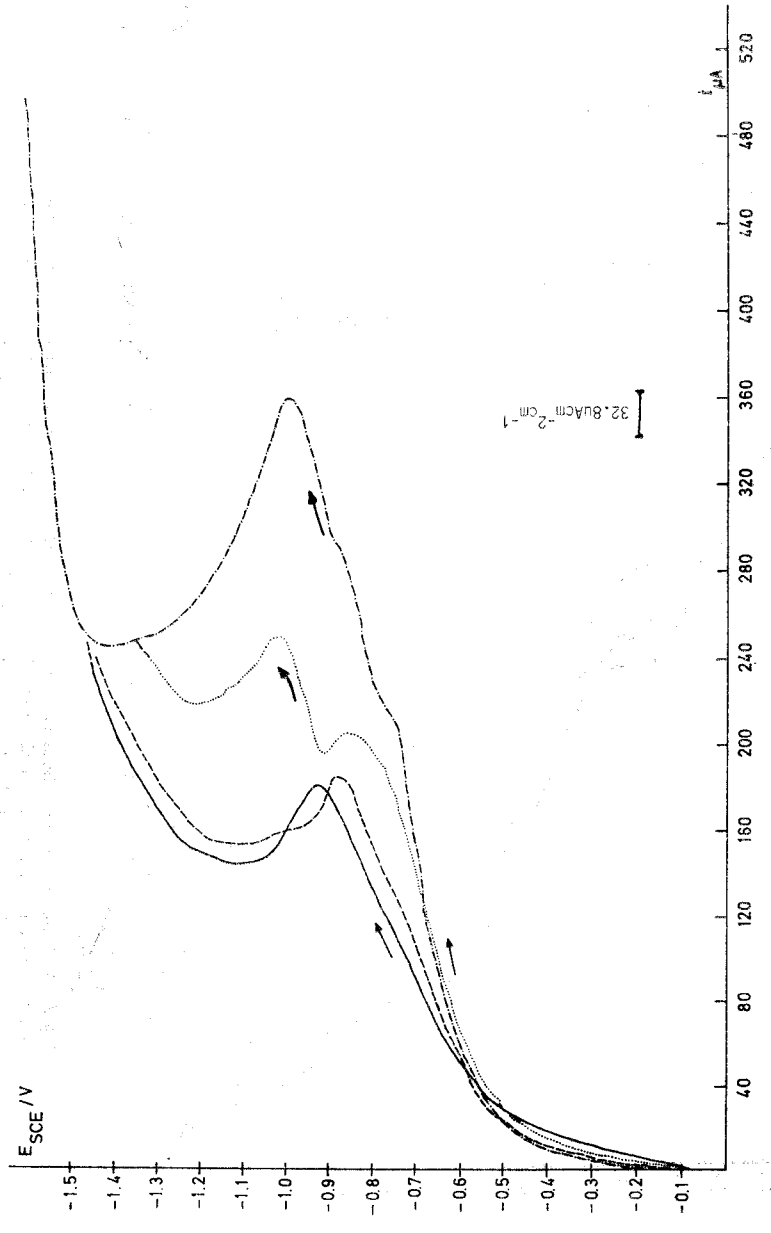

Figure 2. Voltammograms obtained in DMF+1M $NaNO_3$ containing various concentrations of nitrofurazone on platinum electrode. Scan rate, 50 mVs^{-1} Solutions: (——), $4x10^{-4}M$; (–·–·–), $9x10M^{-4}$; (……), $2x10^{-3}M$; (–·–·–·–) $4x10^{-3}M$.

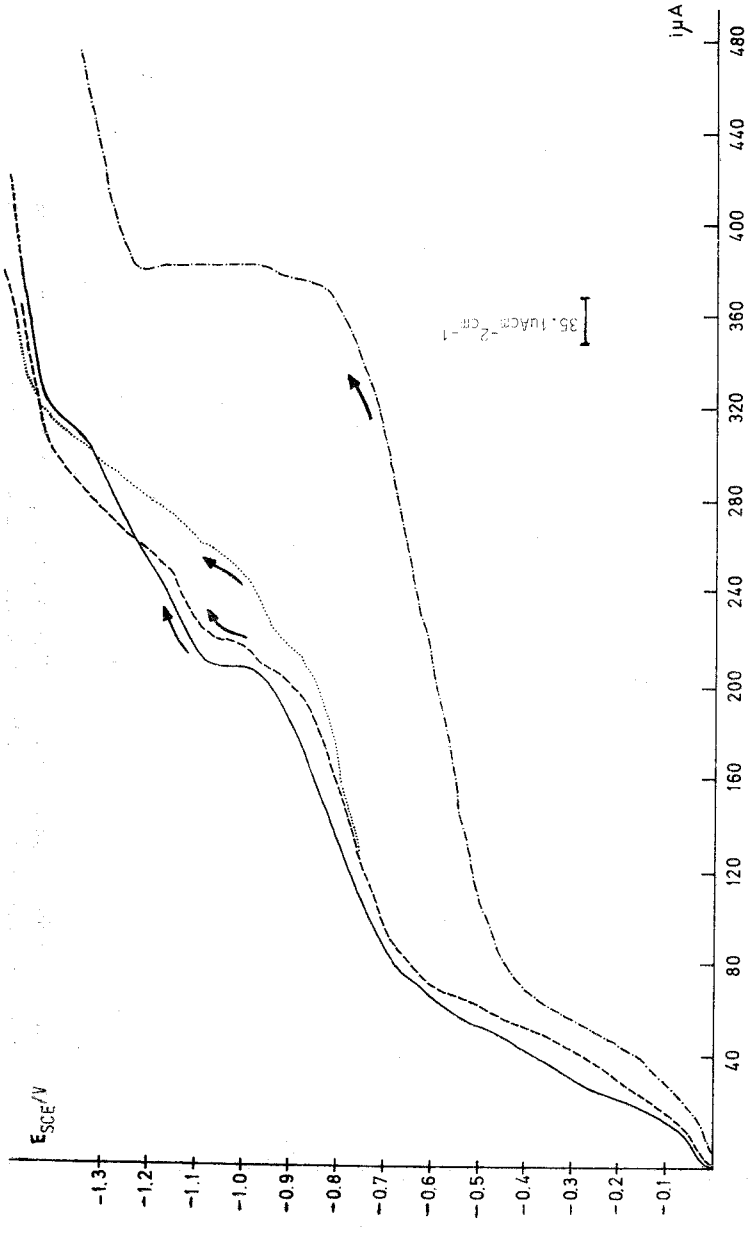

Figure 3. Voltammograms obtained in DMF+1M $NaNO_3$ containing various concentrations of nitrofurazone on ruthenium electrode. Scan rate, 50 mVs^{-1} Solutions: (———), $4x10^{-4}M$; (– – – –), $9x10^{-4}M$; (. . . . .), $2x10^{-3}M$; (–.–.–.–.–.–), $4x10^{-3}M$.

dimethylformamide and dimethylsulphoxide, this step has been reported at 0.1-0.2 V more negative potentials (Cadle et al 1967). Our observation for ruthenium was in accordance with this step. The electrochemical investigations of aromatic nitro compounds in DMF using hanging-drope electrode performed by Lipsztajn et al 1974, 1977 have showed that Na^+ used in the supporting electrolyte effects the peak heights and the peak numbers. This effect is interpreted as the adsorption of cation. In our study the concentration of Na^+ ($NaNO_3$) was constant but the changes in concentration of nitrofurazone effected the degree of the adsorption of Na^+. And the reduction products of nitrofurazone seemed to be adsorbed on the electrode (Figure 4,5). As a result of this competitive adsorption, the peak heights at —0.8 and —0.95 V changed with the concentration of nitrofurazone as explained in Figure 2.A similar change in peak heights has been reported by Smith and Bard 1975 in the paper concerning the electroreduction of nitrofurazone in liquid ammonia with some solid electrodes. This behaviour has been explained as the effect of the proton donor concentration. We observed three steps on the reduction branch of nitrofurazone. The first step at about —0.8 V corresponds to the reduction of nitrofurazone to its radical anion which is stable in nonaqueous media and the second step at about —0.95 V corresponds to the reduction of the radical anion to dianion; a similar phenomenon takes place in the case of nitrobenzene (Smith and Bard 1975). The reductive cleavage of the <C=N— bond was observed as the third step at —1.35 V (Stradins et al 1971). In some of the papers, the first and second steps have been observed together (Kemula and Zawadowska). In our study the electroreduction of nitrofurazone was found to be somehow different on ruthenium and on platinum. The first difference was the additional reduction step at about —0.05 V on ruthenium. The second one was the higher current density on ruthenium than on platinum which revealed that ruthenium was better electrocatalyst for nitrofurazone reduction in DMF.

According to the peak current concentration relationship for the first and second peak, this method seems to be probable for the quantitative determination of nitrofurazone (Figure 6). The studies for obtaining the optimal conditions are being carried out in detail in our lab.

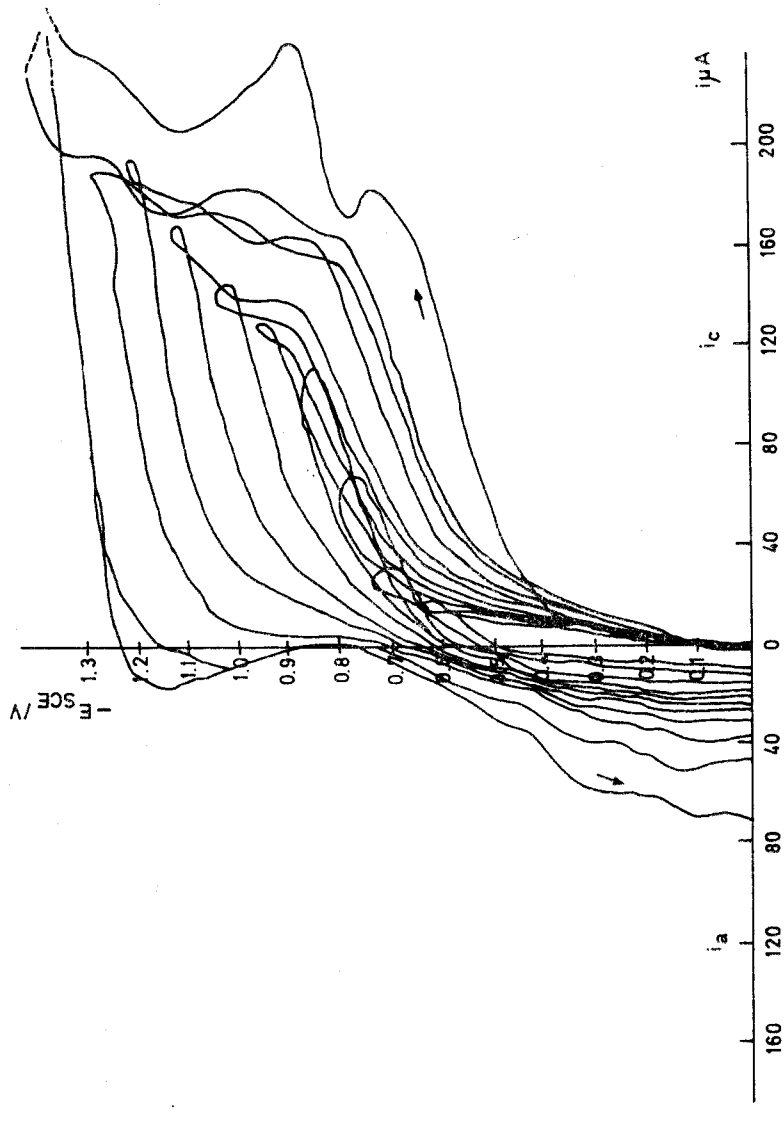

Figure 4. Voltammetric curves obtained in $2x10^{-3}$M nitrofurazone containing DMF+1M $NaNO_3$ by returning from different potentials using platinum electrode. Scan rate, 50 mVs^{-1}.

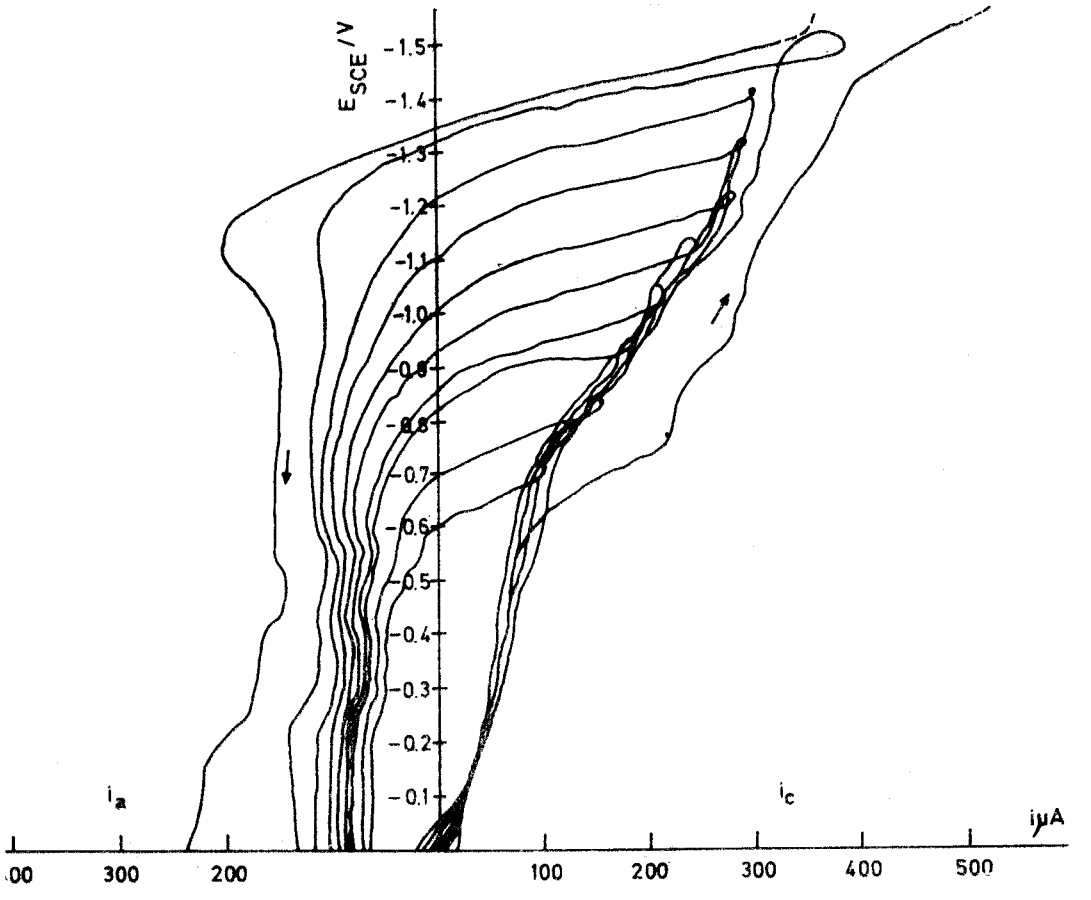

Figure 5. Voltammetric curves obtained in 2×10^{-3} M nitrofurazone containing DMF+1M $NaNO_3$ by returning from different potentials using ruthenium electrode. Scan rate, 50 mVs^{-1}.

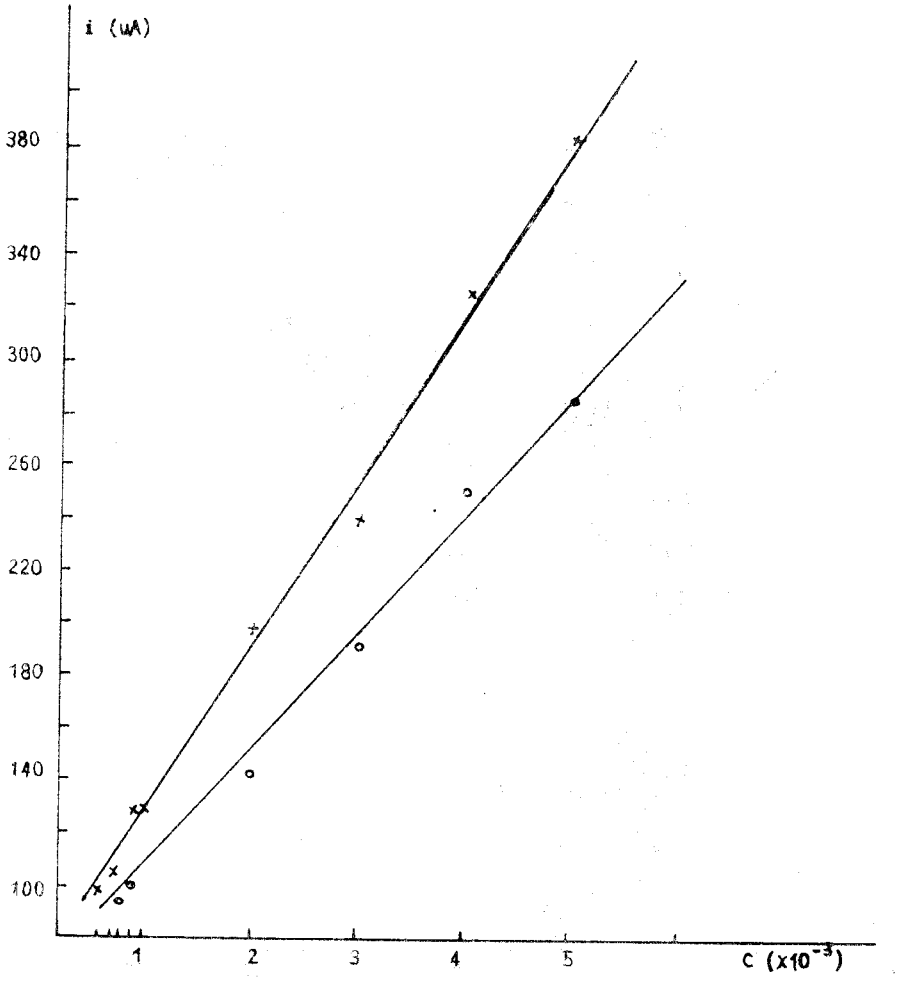

Figure 6. Dependence of the peak current at –1V on concentration of nitrofurazone in 1M $NaNO_3$ in DMF. x : Pt; o: Ru.

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