ANODIC VOLTAMMETRY OF PYRAZOLONE DERIVATIVES WITH THE HELP OF THE SELF-CLEANING ROTATING ELECTRODE

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Nine pyrazolone derivatives have been studied by anodic voltammetry using gold self-cleaning rotating electrode (SRE). Voltamograms of good reproducibility are presented. On the basis of voltammetric data a mechanism is proposed for the electrochemical oxidation of sodium 1-phenyl-2,3-dimethyl-4-(N-methyl amino)pyrazol-5-one-N-methansulphonate and 1-phenyl-2,3-di-methyl-4-(dimethylamino)pyrazol-5-one in protic medium.

Voltammetric method has been used for the analytical study of 1-phenyl-2,3-dimethyl-4-(dimethylamino)pyrazol-5-one in protic medium[1] and cyclic voltammetry has been applied for the electrochemical study of 1-phenyl-2,3-dimethyl-4-(methylamino)pyrazol-5-one, 1-phenyl-2,3-dimethyl-4-(methylamino)pyrazol-5-one, 1-phenyl-2,3-dimethyl-4-aminopyrazol-5-one, and 1-phenyl-2,3-dimethyl-pyrazol-5-one to establish the mechanism of electrooxidation of 1-phenyl-2,3-dimethyl-4-(dimethylamino)pyrazol-5-one in aprotic medium.

However, a systematic study of the pyrazolone group has not been carried out in protic media in view of establishing the mechanism of electrooxidation, influence of substituent groups and pH of the medium on their electrochemical behaviour.

In the present paper results and some theoretical considerations are presented for the electrochemical oxidation of nine pyrazolone derivatives using gold self-cleaning electrode (SRE)[3]. The studied compounds are presented in Table I and shall be denoted henceforth in the text by roman figures as in Table I.

EXPERIMENTAL

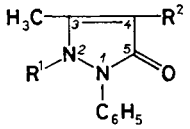
Reagents. All chemicals used are of analytical grade. In the preparation of the solutions bi-distilled water was used. It was found out that ordinary distilled water is also suitable. For every sample a stock solution of $1 . 10^{-3}$ mol l^{-1} concentration was prepared immediately before the experiment. The supporting electrolyte was Britton–Robinson buffer. The pH of the buffer was adjusted with NaOH of 2 mol l^{-1} concentraiton. The pyrazolone derivatives listed in Table I were obtained from Pharmachim, Sofia, except for *III* which was obtained from the Bulgarian Academy of Sciences.

Apparatus. The experiments were carried out in a three compartment glass cell. The working electrode was gold SRE[3]. Saturated calomel electrode (SCE) was used as reference electrode. As counter electrode a large platinum wire was used. The volume of the glass cell was 150 ml. However, the same results can be obtained by using a common laboratory glass *e.g.* of 50 ml. This makes the method easily applicable in serial analysis. The anodic potentials were applied by Radelkis OH-405 (Hungary) potentiostat-galvanostat. The potential sweep rate was 10 mV/s. The voltammograms were recorded by a Philips PM 8120 X–Y recorder. The working electrode

TABLE I

Compounds examined

Basic structure ($R^1 = R^2 = H$) 1-phenyl-3-methylpyrazol-5-one



Compound	Substituents		Half-wave potential, $E_{1/2}$, V
	R^1	R^2	
I	$-CH_3$	$-H$	1·200
II	$-H$	$-H$	0·695
III	$-CH_3$	$-CH(CH_3)_2$	1·050
IV	$-CH_3$	$-NH_2$	0·560
V	$-CH_3$	$-NHCH_3$	0·410
VI	$-CH_3$	$-NHCHO$	0·920
VII	$-CH_3$	$-N(Na)-CH_2OSO_2Na$	0·590
VIII	$-CH_3$	$-N(CH_3)-CH_2OSO_2Na$	0·400
IX	$-CH_3$	$-N(CH_3)_2$	0·560

rotation rate in most of the cases was 50 Hz. The voltammograms were taken at room temperature.

Procedure. To obtain reliable data 100·0 mg of the studied substance were taken and dissolved in 100·0 ml of distilled water. By voltammetric determination of the studied substance in five different aliquots of the above solution the quantity of the studied substance in this solution was found.

Coulometric studies. Firstly the voltammogram of the sample was recorded in Britton–Robinson buffer pH 2. Then the potential corresponding to the wave plateau was applied to the SRE. The current passing through the cell was recorded by a *X–t* recorder. After integrating the area of the current-time curve the quantity of electricity that passed through the cell was calculated. At the end of the experiment a voltammogram was recorded to determine the quantity of the remaining compound.

RESULTS AND DISCUSSION

In Fig. 1 voltammograms of $2{\cdot}3 \cdot 10^{-4}$ mol l^{-1} of *VIII* recorded one after the other without pretreatment of the electrode are presented to demonstrate good reproducibility of the waves. The same reproducibility (without the need of electrode pretreatment) was obtained also for the other compounds studied. Linear dependence is obtained between the wave height and the square root of the SRE rotation rate, $n^{1/2}$, which is an indication for the diffusion character of the obtained waves. The depedence between the concentration of the substance (pH 2) and their wave height is linear in a wide concentration range ($10^{-5}-10^{-3}$ mol l^{-1}); the half-wave potentials, $E_{1/2}$, of the studied substances do not change with concentration.

In Fig. 2 $E_{1/2}$ of *VIII* and *IX* as a function of the pH of the medium are shown. Well formed voltammograms of *VIII* could be obtained up to pH about 7·3 while for *IX* up to pH about 8·6. With the increase of pH above 3 for *IX* and 3·9 for *VIII* splitting of their waves is observed. The second wave of amidophen with the more positive $E_{1/2}$ disappears at about pH = 6·5 and only the first wave remains. At pH = 3 the $E_{1/2}$ – pH plot of *IX* having a slope of 0·064 V/pH unit changes after a discontinuity into a line of 0·047 V/pH unit and of 0·020 V/pH at pH = 4·9. From pH = 6·5 the $E_{1/2}$ of *IX* is independent of pH which indicates that in this pH region its oxidation proceeds without the participation of protons. Protons participate in the oxidation of *VIII* in the whole pH range where its oxidation can take place. Since our coulometric investigations showed one electron oxidation of both *VIII* and *IX* in acidic medium (pH = 2) fractional numbers for the protons participating in the reaction are obtained. This fact might be an indication of the irreversibility of the obtained voltammograms. Even more complicated is the explanation of the obtained $E_{1/2}$ – pH dependences at higher pH values; additional data are necessary which are not available now. It should be stated here that the $E_{1/2}$ – pH line of *V* (not presented in Fig. 2) showed a slope similar to that of *VIII*.

From the voltammetric data obtained we made some conclusions concerning the mechanism of the electrochemical oxidation of *VIII* and *IX*. We also studied some

of the intermediate products during their synthesis and also some substances having a structure that can help us in evaluating the mechanism. In Table I the half-wave potentials, $E_{1/2}$, of the studied nine pyrazolone derivatives in Britton–Robinson buffer (pH = 2) at 50 Hz rotation rate of the gold SRE are shown. It is seen that a close relation exists between the strcture of the pyrazolone derivatives and their electrochemical oxidation. It should be noted that the existence of a substituent on C-4 in the pyrazolone ring plays the main role. If there is no substituent on C-4 (*I*) a wave of high positive $E_{1/2}$ value appears (1·2 V). With the introduction of an alkyl group the electrochemical reactivity does not increase significantly. Thus, the compound with the isopropyl group on C-4 (*III*) has the $E_{1/2}$ value 1·050 V which is only 0·150 V lower as compared with *I*. From the $E_{1/2}$ values in Table I it follows that amino group substituents on C-4 increase the electrochemical reactivity of pyrazolones. In the case of a primary amino group on C-4 (*IV*) the $E_{1/2}$ = 0·560 V, *i.e.* about half of the $E_{1/2}$ value of *I*. The substituents in the amino group are of important significance with respect to the electroreactivity. If the substituent has a positive induction effect as it is in the case of V, $E_{1/2}$ has a lower value (about 0·150 V lower) than that of *IV*. Disubstituted *IV* (*IX*) has the same value of the half-wave potential as that of *IV*. Probably due to steric effect the $E_{1/2}$ of *IX* is higher than that of *V*.

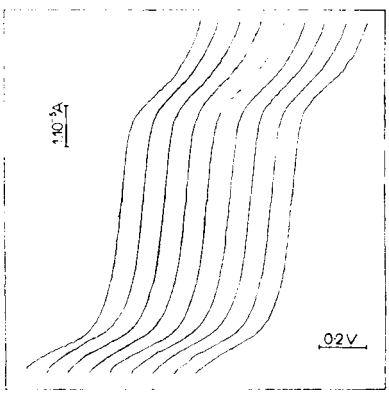


FIG. 1

Voltammograms of sodium 1-phenyl-2,3-dimethyl-4-(N-methylamino)pyrazol-5-one-N-methansulphonate in Britton–Robinson buffer on gold SRE taken successively one after the other. Starting potential 0·0 V *vs* SCE

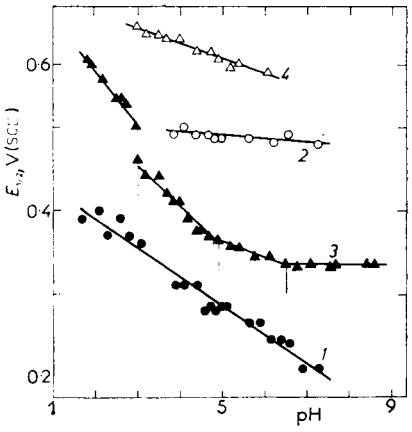
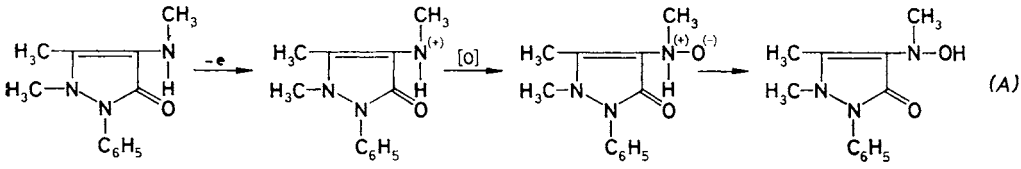


FIG. 2

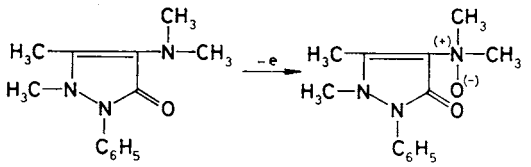
Half-wave potential, $E_{1/2}$, of some pyrazolone derivatives as a function of pH. The substances are denoted with roman figures as in Table I. *1* first wave of *VIII*; *2* second wave of *VIII*; *3* first wave of *IX*; *4* second wave of *IX*. Concentration of *VIII* $1{\cdot}7 \cdot 10^{-4}$ mol l^{-1} and of *IX* $2{\cdot}6 \cdot 10^{-4}$ mol $\cdot l^{-1}$

Similar to $E_{1/2}$ of *V* is the $E_{1/2}$ of *VIII*. The reason for this is probably the hydrolysis of *VIII* in acidic medium leading to the formation of *V*. The latter is oxidized electrochemically showing an $E_{1/2}$ similar to that when pure *V* is oxidized. In ref.[2] a mechanism is proposed for the electrooxidation of *IX* in aprotic medium (acetonitrile). Unlike the results reported in ref.[2] our studies revealed that the $E_{1/2}$ of the tertiary amine *IX* is more negative than that of the secondary amine *V* but equal to that of the primary amine *IV*. However, when the substituent in the amino group is exerting negative induction effect (*VI*) the oxidation is hindered and the $E_{1/2}$ has a relatively very high positive value (0·920 V) compared to that of *VIII*, *IX*, and *V*. On the other hand the $E_{1/2}$ of *VI* is relatively less positive as compared to $E_{1/2}$ of *I*. Similar observation was made for *VII* ($E_{1/2}$ = 0·590 V) due to the negative induction effect of sodium. Interesting was the electrochemical oxidation of *II*. Its oxidation is much easier and compared to *I* its $E_{1/2}$ is almost twice as low. It is to be noted that in its pyrazolone ring there is a secondary nitrogen where the oxidation can take place.

From the relations established between the structure and the electrochemical oxidation of the pyrazolone derivatives it can be concluded that the latter takes place in a different way compared to the chemical oxidation. For instance, it is known that during the oxidimetric determination of *IX* the double bond in its pyrazolone ring is broken and dioxopyramidon is obtained. However, it is known also that the chemical oxidation of the pyrazolone ring at the —C=C— bond needs four electrons[1,4-6]. This mechanism is improbable here because according to the mentioned coulometric investigations in the electrochemical oxidation of both *VIII* and *IX* only one electron participates. Analysis of the slopes of the voltammograms points also to a one electron electrooxidation. Furthermore, during the oxidimetric determination of *VIII* it is the sulphite anion which is oxidized. In our studies we did not observe the wave of the oxidation of the sulphite anion in *VIII* which indicates that this anion is not oxidized electrochemically. Therefore, unlike the chemical oxidation of *VIII*, the voltammogram of this substance only reveals the oxidation of *V* remaining after its hydrolysis. Probably the mechanism of the electrochemical oxidation of *VIII* and *IX* is similar to the mechanism of the chemical oxidation of amino groups with H_2O_2 in which one electron and one proton participate[7,8]. Therefore, we propose the following mechanism for the electrochemical oxidation of *VIII* (*A*) and *IX* (*B*):



(*A*)



(B)

The method of anodic voltammetry using gold SRE has been observed to be favourably applicable for routine determination of pyrazolone derivatives.

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