

ELECTROLYTIC OXIDATION OF TETRA-HYDROCARBAZOLE

Inam-ul-Haque^{*ab}

^aDepartment of Chemistry, University of Engineering and Technology, Lahore - 54890, Pakistan

^bJ-263, Defence Housing Authority Lahore-54792 Pakistan

(Received June 6, 2002; accepted January 1, 2004)

Electro-oxidation of THC in a strong base, potassium methoxide in methanol, produces a series of dehydromers having interesting stereochemistry and ¹³C dynamic N.M.R. properties (Bobbitt *et al* 1986a). Electro-oxidation of 1-carbomethoxy THC yields its 1-methoxy derivative in 44% yield (Bobbitt 1989). In aqueous acetonitrile containing LiClO₄, THC can be oxidized to a dehydrodimer in 60 - 90% yield. A two compartment cell at + 0.7 V vs. SCE having graphite anode is used (Bobbitt *et al* 1986b). Preparative anodic hydroxylation of 1-carbomethoxy THC and its 7-methoxy derivative have been reported (Rusling *et al* 1984). Related mechanistic investigations were also carried out (Rusling *et al* 1986). Characteristics of anodic normal pulse voltammograms for the monomeric indole alkaloids such as catharanthine, vindoline, THC, its N-methyl derivative, aniline, *p*-chloroaniline, and *m*-dimethylaminoanisidine, were described (Haque 1990).

The mechanisms of electro-dimerization of THC and N-methyl THC were investigated using cyclic, linear sweep, normal pulse and reverse pulse voltammetry at carbon paste and platinum electrodes in 10% aqueous - acetonitrile (Kulkarni *et al* 1982). Adsorptive / extractive accumulation of THC at carbon paste electrode was used to improve the subsequent voltammetric determination with respect to the sensitivity and selectivity (Wang and Bonakdar 1985).

2,2,6,6-Tetramethylpiperidine-1-oxonium tetrafluoroborate was shown to react with THC to give, in the presence of water, the 4-keto derivative (Bobbitt *et al* 1988). In the absence of water, the oxidation of THC gave a mixture of dimers, probably derived from the Diels - Alder self condensation of 2,3-dihydro-1*H*-carbazole (Bobbitt *et al* 1990).

A saturated solution of solid sodium bicarbonate containing 0.2M lithium perchlorate in equivolume aqueous - acetonitrile was investigated as an electrolyte for the electrochemical oxidation of 2,3,4,9-tetrahydro-1*H*-carbazole, THC, to its 4a-7'

dehydrodimer. THC was oxidized by a similar mechanism in the presence and absence of bicarbonate. A Bioanalytical Systems BAS-100 Electrochemistry System was used for voltammetry. The three-electrode cells used carbon paste working electrodes ($A = 0.08 \text{ cm}^2$), a platinum counter electrode and, as reference a Ag / Ag⁺ (0.001 M acetonitrile solutions) was used. All working electrodes were disks surrounded by an outer layer of insulating material. All potentials are reported vs SCE. Acetonitrile (ACS reagent - grade or spectrograde), and THC (Aldrich) were used as received. Solutions were purged with purified nitrogen for 8 - 10 min prior to the beginning of an experiment carried out at an ambient temperature of the laboratory, $25 \pm 2^\circ \text{C}$ (Haque 1989).

For the electrochemical oxidation of THC, a saturated solution of solid NaHCO₃ containing 0.2M lithium perchlorate in equivolume aqueous - acetonitrile was investigated as an electrolyte, to determine whether THC is oxidized by a similar mechanism in the presence and absence of sodium bicarbonate. From voltammetric and preparative runs, it appears that THC is oxidized by a similar mechanism in the presence and absence of sodium bicarbonate. There is a substantial increase in the amount of dimeric product formed when sodium bicarbonate is present; this is probably due to the decreased acid catalyzed decomposition of dimeric product.

This is suggested by examination of the voltammograms obtained during the electrochemical oxidation of THC. Fig 1(a) shows cyclic voltammogram of 1mM THC at carbon paste electrode in an equivolume aqueous-acetonitrile containing 0.2M lithium perchlorate but no sodium bicarbonate. Two peaks appear in this voltammogram; first peak appears at a potential of 0.51 V with peak current 25.0 μA. Fig 1(b) shows the voltammogram obtained for THC when sodium bicarbonate is added to the background electrolyte. A single peak appears in this voltammogram at a potential of 0.39V and 25.0μA peak current. Time single peak suggests that electrolysis of the dimer is suppressed in the presence of sodium bicarbonate. The cyclic voltammetric values of E_p for the first peak, for the electro-oxidation of tetrahydrocarbazole, shifted to more negative values as the concentration of the carbonate was increased, with $dE_p / d \log [\text{bicarbonate}] = -17.9 \text{ mV}$. Since neither a reliable acidity scale nor a suitable range of buffer is available in the equivolume aqueous - acetonitrile used, qualitative information can be obtained by the assumption that bicarbonate is acting as a proton acceptor. A value of -17.9 mV / pH would be expected (Nadjo and Saveant 1973).

Fig. 2(a) shows large amplitude pulse voltammogram for THC at carbon paste electrode in equivolume aqueous-acetonitrile containing 0.2M lithium perchlorate. In this voltammogram

*Author for correspondence

b.Present address

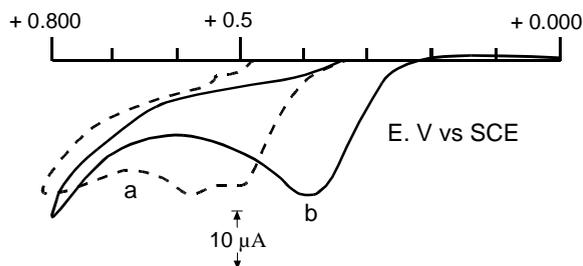


Fig 1. Cyclic voltammogram of 1 mM THC at carbon paste electrode in equivolume aqueous acetonitrile containing 0.2M lithium perchlorate (a) without (---) and (b) saturated with (—) sodium bicarbonate.

single wave appears with half-wave potential at 0.47V, and 53.0 μ A limiting current. Fig. 2(b) shows large amplitude pulse voltammogram for THC when sodium bicarbonate was added to the previous solution Fig. 2(a).

This voltammogram also shows a single wave at $E_{1/2}$ 0.31 V, and 49.0 μ A limiting current. As revealed by cyclic voltammetry Fig. 1(a), the difference between peak potential for the formation of dimer (510 mV, Table 1) and peak potential for subsequent oxidation of dimer (570 mV, Table 1) is only 60 mV. This difference is too small to be manifest as two distinct plateaux in the large amplitude pulse voltammogram Fig. 2(a) in the present solvent mixture of equivolume aqueous acetonitrile. However, when the proportion of acetonitrile is increased to 90% in the electrolyte and 0.002 M tetra-*t*-butylammonium hydroxide is added in place of sodium bicarbonate, two separate $E_{1/2}$ values were reported earlier (Haque 1989) for the corresponding large amplitude pulse voltammogram.

Large amplitude pulse voltammetry (LAPV) gives only one anodic wave in the presence and absence of sodium bicarbonate. The height of this wave was nearly the same regardless of whether sodium bicarbonate was present or not. The wave height in LAPV is directly proportional to number of electrons transferred (Bond 1980) which did not increase in the presence of bicarbonate. Furthermore, there was no change in the height of the wave as compared with that in the electrolytic solution containing 90% acetonitrile and 10% water (Kulkarni *et al* 1982). LAPV shows there was no change in the number of electrons transferred Fig. 2(b) when bicarbonate is added to the electrolytic solution.

Fig. 3(a) shows differential pulse voltammogram for 1mM THC at carbon paste electrode in aqueous - acetonitrile containing 0.2M lithium perchlorate, when no sodium bicarbonate was added. This voltammogram shows three distinct summits. First summit appears at a potential of 0.43V and 15.3 μ A summit current. The second and third electro-oxidation summits were not investigated further. Fig 3(b) shows differential pulse voltammogram of 1mM THC. This was obtained when

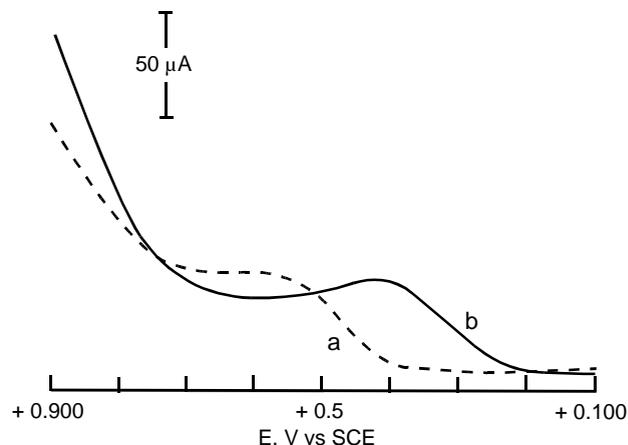


Fig 2. Large amplitude pulse voltammogram of 1 mM THC at carbon paste electrode in equivolume aqueous acetonitrile containing 0.2M lithium perchlorate (a) without (---) and (b) saturated with (—) sodium bicarbonate.

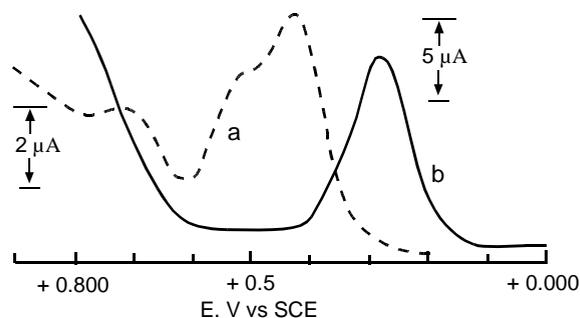


Fig 3. Differential pulse voltammogram of 1 mM THC at carbon paste electrode in equivolume aqueous acetonitrile containing 0.2M lithium perchlorate (a) without (---) and (b) saturated with (—) sodium bicarbonate.

solid sodium bicarbonate was added to the previous solution Fig 3(a). A single summit appears in this voltammogram at 0.28 V and 15.3 μ A summit current, corresponding presumably to the first summit in Fig. 3(a). The differential pulse voltammetry suggests that electrolysis of dimer is suppressed in the presence of sodium bicarbonate. There was no change in the identity (Bobbitt *et al* 1986a &b) of the dimeric product formed when sodium bicarbonate was added to the electrolyte solution, as confirmed by HPLC. Values of potentials, and currents for the three voltammetric techniques are summarized in Table 1.

Voltammetric and preparative runs indicate that THC is oxidized by a similar mechanism in the presence and absence of sodium bicarbonate. However, there is a substantial increase in the amount of dimeric product formed when bicarbonate is present. The yield of 4a-7'-dehydrodimer of THC in the presence of saturated sodium bicarbonate upon electrolysis in 0.2M $\text{LiClO}_4 + 1 : 1$ mixture of acetonitrile - water approached

Table 1

Anodic voltammetric characteristics of THC at carbon paste electrode in equivolume acetonitrile water containing 0.2M lithium perchlorate in the absence (A) and presence (B) of saturated sodium bicarbonate (1g 50ml)

Technique	Potential (mV) vs. SCE			Current (μ A) I
	E _{1x}	E _{x2}	E _{x3}	
CV at 100mVs ⁻¹				25.0
A	510	570	--	25.0
B	390	--	--	
DPV at 4mVs				15.3
A	430	510	720	15.3
B	280	--	--	
LAPV at 4mVs ⁻¹ A				
B	470	--	--	53.0
	310	--	--	49.0

nearly 25%. In the absence of bicarbonate, yield of the dimeric product was less than 16%. Sodium bicarbonate apparently suppresses the acid - catalyzed decomposition of the dimeric product.

Key words: Electrodehydrodimerization, Voltammetry, Tetrahydrocarbazole, Electrosynthesis.

References

- Bobbitt J M, Chou T T, Leipert T K 1986a Dynamic ¹³C N.M.R studies of electrochemically formed 4a-N and 4a-4a dehydrodimers of 1,2,3,4-tetrahydrocarbazole. *Heterocycles* **24** 687-696.
- Bobbitt J M, Scola P M, Kulkarni C L, Denicola Jr. A J, Chou T T 1986b Anodic dimerization of 1,2,3,4-tetrahydrocarbazole and some of its derivatives. *Heterocycles* **24** 669-678.
- Bobbitt J M, Cecile L, Flores M 1988 Organic nitrosonium salts as oxidants in organic chemistry. *Heterocycles* **27** 509-533.
- Bobbitt J M 1989 Anodic electroorganic chemistry and natural products. *ACS Symposium Series* **390** 176-195, in Stock J T, Orne M (Eds), *Electrochemistry, Past and Present*, American Chemical Society, Washington DC, USA.
- Bobbitt J M, Cecile L, Flores M, Guttermuth, Ma Z, Tang H 1990 Organic nitrosonium salts. II. Stability studies and oxidations of some indole derivatives. *Heterocycles* **30** 1131-1140.
- Bond A M 1980 *Modern Polarographic Methods in Analytical Chemistry*. Marcel - Dekker, New York, USA p. 267.
- Haque I U 1989 Anodic voltammetry of model compounds for anticancer drugs. *J Chem Soc Pak* **11** 232-236.
- Haque I U 1990 Pulse voltammetry of monomeric indole derivatives. *Bull Electrochem* **6** 743-744.
- Kulkarni C L, Scheer B J, Rusling J F 1982 Potential-sweep and pulse voltammetric investigations of the dimerization of tetrahydrocarbazoles. *J Electroanal Chem* **140** 57-74.
- Nadjo L, Saveant J M 1973 Electrodimerization VII. Role of proton transfer reactions in the mechanism of electrohydrodimerization. Formal kinetics for voltammetric studies (linear sweep, rotating disk, polarography). *J Electroanal Chem* **44** 327-366.
- Rusling J F, Scheer B J, Owlia A, Chou T T, Bobbitt J M 1984 Anodihydroxylation of 1-carbomethoxy-1,2,3,4-tetrahydrocarbazoles. *J Electroanal Chem* **178** 129-142.
- Rusling J F, Brooks M Y, Scheer B J, Chou T T, Shukla S S, Rossi M 1986 Analysis of ECE type electrode reactions by chrono-coulometry: anodic hydroxylation of tetrahydrocarbazoles. *Anal Chem* **58** 1942-1947.
- Wang J, Bonakdar M 1985 Adsorptive / extractive stripping voltammetry of 1,2,3,4 - tetrahydrocarbazole. *Anal Lett* **18** 2569-2579.