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Observation on the Fragmentation of Some Tosylhydrazones Using Electrochemically Generated Superoxide Ion

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Superoxide ion ($O_2^{\overline{\cdot}}$) generated in situ by electrochemical reduction of molecular oxygen in dimethylformamide (DMF) at mercury cathode, behaves as a mild effective base to deprotonate the acidic hydrogen from tosylhydrazones of benzophenone (**1**), benzaldehyde (**2**), cyclohexanone (**3**), benzoin (**4**), acetophenone (**5**), and benzil (**6**) finally affording tetraphenylethene (**1a**), *trans*-stilbene (**2a**), cyclohexene (**3a**), deoxybenzoin (**4a**), acetophenone azine (**5a**), and 4,5-diphenyl-1-tosylamino-1,2,3-triazole (**6a**) respectively in good to excellent yield.

Superoxide ion is one of the novel reactive intermediates and may be advantageously generated electrochemically in a milder and purer form by the reduction of molecular oxygen in aprotic medium.[1] Its transient existence as one of the most important activated forms of molecular oxygen in biological systems is known.[2–4] Fridovich[5] showed that all aerobic organisms possess a defence mechanism against superoxide ion in the form of superoxide dismutase. These biological findings have generated a great deal of interest to investigate the chemical behavior of this unique oxygen anion radical with simple organic molecules.[6] Superoxide ion acts as an effective nucleophile, base, oxidant, reductant, and free radical[7–16] depending upon the nature of the organic molecule and presence of other affectors. Recently, we have reported the superoxide-initiated oxidation of some secondary alcohols to ketones.[17]

The synthetic use of the base behavior of superoxide ion is further extended in the present study for achieving the fragmentation of tosylhydrazones of a variety of carbonyl compounds. There exists a reasonable number of chemical methods and regents[18–24] to accomplish the decomposition of tosylhydrazones leading to afford the follow up products. A survey of literature reveals that only one such report exists in which Tissot[25] has described the fragmentation of some tosylhydrazones of cycloalkanones with electrochemically generated superoxide ion and obtained cycloalkenes in all cases. Since they have taken organic substrates of same structural features, not much could be assessed of the scope of this novel fragmentation. With a view to investigate the behavior of simple organic molecules towards $O_2^{\overline{\cdot}}$ which is of importance in itself and further to assess the synthetic scope of the reported fragmentation, we undertook to study the reaction of electrochemically generated superoxide ion with tosylhydrazones of carbonyl compounds having variant structural features.

Experimental

Melting points were determined in an open capillary tube in a Büchi apparatus and are uncorrected. IR spectra were recorded with a Perkin-Elmer 783 grating spectrophotometer. The ^{1}H NMR was run with a JEOL FT-NMR spectrometer FX-90 Q. Chemical shifts are reported in ppm from TMS as an internal standard and are given in δ units. Elemental microanlyses were obtained using CHN analyzer, Perkin-Elmer 240C.

p-Tolylsulfonylhydrazine ($TsNHNH_2$) mp 105 °C, (lit,[26] 104—107 °C), was synthesized according to the reported method. Tosylhydrazones (**1**—**6**) were prepared according to the reported method[18] and were characterized by their physico-chemical, spectroscopic studies, and elemental analyses. These were reacted with electrochemically in situ generated superoxide ion. The reaction seems to be exothermic; the temperature in entry **6** reaches ca. 50 °C. All the products isolated were fully characterized by their physicochemical and spectral studies.

The electrochemical cell consisted of a glass cell, in which the anodic and cathodic chambers were separated by a medium porosity glass frit. Mercury (surface area 23.76 cm^2) was used as a cathode while a platinum disc (3.78 cm^2) was used as an anode. Saturated Calomel Electrode (SCE) served as a reference electrode. Wenking Potentioscan POS 73 (Bank Electronik, West Germany) was used for constant potential macro electrolysis. Cyclic voltammogramms were recorded on an X-Y recorder (Servoger type 733) using platinium electrode in DMSO-containing 0.1 M (1 M=1 mol dm^{-3}) of tetrabutylammonium perchlorate (TBAP) as supporting electrolyte. The quantity of electricity passed was measured using coper coulometer. Dimethylformamide (DMF) was used after dried over Molecular Sieves (3A), oxygen was dried by passing it through a packed column of anhydrous $CaSO_4$, sodium hydroxide pellets and Molecular Sieves (3A).

Fragmentation of Benzil Bis(tosylhydrazone) (6) to 4,5-Diphenyl-1-tosylamino-1,2,3-triazole (6a). Typical Procedure: A solution of tetrabutylammonium bromide (3.22 g; 0.1 M) in DMF (100 cm^3) was used as electrolyte. The cathodic chamber containing 50 cm^3 of the electrolyte was purged with nitrogen for 5 min. The electrolytic solution was pre-electrolyzed at −1.9 V vs. SCE until the background current drops to about 2 mA. Now 2 cm^3 of cyclohexene was added to anolyte to absorb the liberated bromine. Catholyte was saturated with oxygen for 30 min, tosylhydrazone (**6**; 0.5 g; 9×10^{-4} M) was added to the cathodic chamber, oxygen was bubbled through the solution during the course of electrolysis carried out at constant potential of −1.0 V vs. SCE, until the loss of starting material was indicated by thin layer chromatography and current falls appreciably (Table 1). Upon completion of the reaction, catholyte was taken in 100 cm^3 of cold water. As ether (25 cm^3×3) was added to the above solution, compound **6a** precipitated which was collected by filtration, dried and recrystalized from ethanol to yield pure product **6a**. This was identified by its physicochemical and spectral data as; 4,5-diphenyl-1-*p*-tosylamino-1,2,3-triazole mp 126 °C.

IRν: 3210, 1630, 1600, 1550, 1500, 1350, and 1150 cm^{-1}; ^{1}H NMR (CDCl$_3$) δ=2.54 (s, 3H, CH$_3$), 7.33—8.81 (ArH+ 1NH proton).

For the isolation of products **1a**—**5a** the following work-up procedure was adopted. Catholyte was poured into 100 cm^3 of cold water, extracted with ether (25 cm^3×3), dried (Na$_2$SO$_4$), filtered and evaporated to yield the products **1a**—**5a**. Compounds **1a**, **2a**, **4a**, and **5a** were recrystallized and identified by their physicochemical and spectral data. For isolating product **3a**, electrolysis was repeated 4 times and product obtained after removing the organic solvent was distilled on a Kugelrohr apparatus to yield pure compound.

Results and Discussion

Fragmentation of tosylhydrazones (**1**—**6**) under mild condition viz., by electrochemically generated superoxide ion is based on its capability to abstract acidic proton.[9—11] The result of fragmentation indicates that the corresponding products (**1a**—**6a**) are obtained in good yield (80—85%). The decomposition of tosylhydrazone of carbonyl compounds was first investigated by Bamford and Stevens[18] with sodium in boiling ethylene glycol. This procedure has since been widely exploited from synthetic and mechanistic consideration and is widely reviewed by Shapiro.[27] Friedman and Shecter[28] have investigated that protic and aprotic solvents frequently give rise to totally different reaction products.

Cyclic Voltammetry: Typical voltammogram of superoixide ion (O_2^{-}) formation is shown in Fig. 1 by full line (—), the C.V. of oxygen reduction in presence of substrate **5** is shown by dotted line (---).

Examination of Fig. 1 reveals that in the presence of organic substrate **5** the reduction current remains approximately the same but the peak potential has shifted anodically from −1.0 V to −0.9 V. Further, the superoxide oxidation peak has disappeared and a new peak has appeared at +0.4 V. As there is no change in reduction current the reaction seems to be one electron process. The absence of superoxide oxidation peak indicates that superoxide is rapidly destroyed in a fast subsequent chemical reaction between

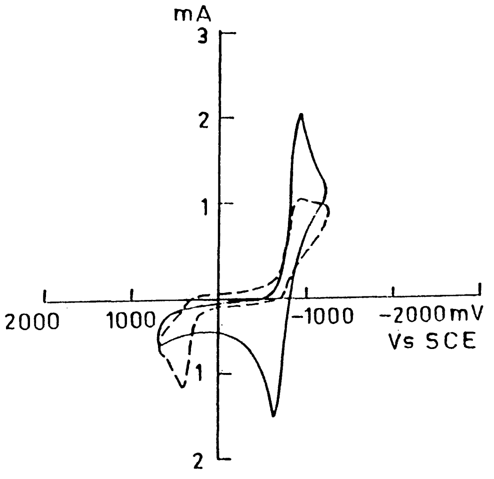
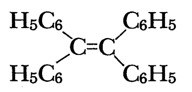
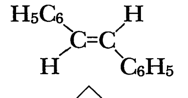
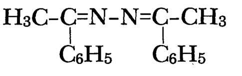
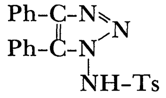


Fig. 1. Cyclic voltammogram for oxygen reduction (—) and in the presence of tosylhydrazone of acetophenone (**5**), (----).
Solvent: DMSO+0.1 M TBAP. *T*: 20 °C.
Scan rate: 200 mV s^{-1} at Pt.

Table 1. Reaction of Electrochemically Generated Superoxide Ion in DMF with Tosylhydrazones (**1**—**6**); Mercury Pool: Cathode, Platinum Disc: Anode at −1.0 V (vs. SCE); Temp: 25—30 °C

Tosyl hydrazone (**1**—**6**)	Current/mA		Products (**1a**—**6a**)	Yield	Mp (bp)/°C	
	Initial	Final		%	Obs.	Reported
1	100	22		81	222	224—226
2	85	15		82	118	124
3	110	22		85	(81)	(81)
4	125	20	C$_6$H$_5$COCH$_2$C$_6$H$_5$	86	50	54—56
5	105	20	 $H_3C\text{-}\underset{C_6H_5}{C}\text{=N-N=}\underset{C_6H_5}{C}\text{-}CH_3$	71	119	124
6	100	30		95	126	—

superoxide and tosylhydrazone effecting the fragmentation process of tosylhydrazone. The fragmentation pattern can be rationalized as:

$$O_2 \underset{\text{0.1 M TBAP in DMSO}}{\overset{-1.0\text{ V vs. SCE}}{\rightleftarrows}} O_2^{\bar{\cdot}}$$

$$O_2^{\bar{\cdot}}+\underset{\mathbf{I}}{R_1R_2C{=}N\text{-}NH\text{-}Ts} \rightarrow \underset{\mathbf{II}}{R_1R_2C{=}N\text{-}\bar{N}\text{-}Ts}+H\dot{O}_2$$

The $H\dot{O}_2$ may possibly undergo bimolecular disproportionation as reported earlier.[25]

The intermediate **II** readily loses sulfinate ion to furnish the reactive diazo compound **III**, which after necessary regrouping of electrons undergoes fission to produce nitrogen and the alkene.

1a—**3a** are supposed to be formed via possible carbene intermediate.[29,30]

$$\underset{\mathbf{II}}{R_1R_2C{=}N\text{-}\bar{N}\text{-}Ts} \rightarrow \underset{\mathbf{III}}{[R_1R_2C{=}\overset{+}{N}{=}\bar{N}]}+Ts^-$$

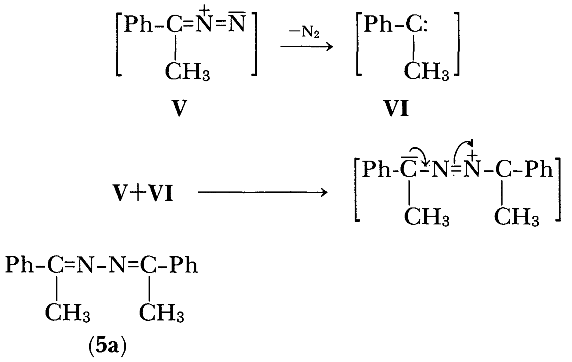
$$[R_1R_2C{=}\overset{+}{N}{=}\bar{N}] \rightarrow [R_1R_2C{:}] + N_2$$

$$[R_1R_2C{:}] \rightarrow \text{Alkene } (\mathbf{1a}\text{—}\mathbf{3a})$$

where R_1, R_2=alkyl or aryl group, Ts=p-$CH_3C_6H_4SO_2$.

In case of **2**, Bamford and Stevens[18] have isolated two fractions 2-benzyloxyethanol and benzyl-*p*-tolylsulfone, but in our case we get exclusively the *trans*-stilbene (**2a**) in excellent yield.

A possible route for the formation of acetophenone azine (**5a**) can be given as:



$$\underset{\mathbf{V}}{\left[\begin{array}{l}Ph\text{-}C{=}\overset{+}{N}{=}\bar{N}\\ \quad\; CH_3\end{array}\right]} \xrightarrow{-N_2} \underset{\mathbf{VI}}{\left[\begin{array}{l}Ph\text{-}C{:}\\ \quad\; CH_3\end{array}\right]}$$

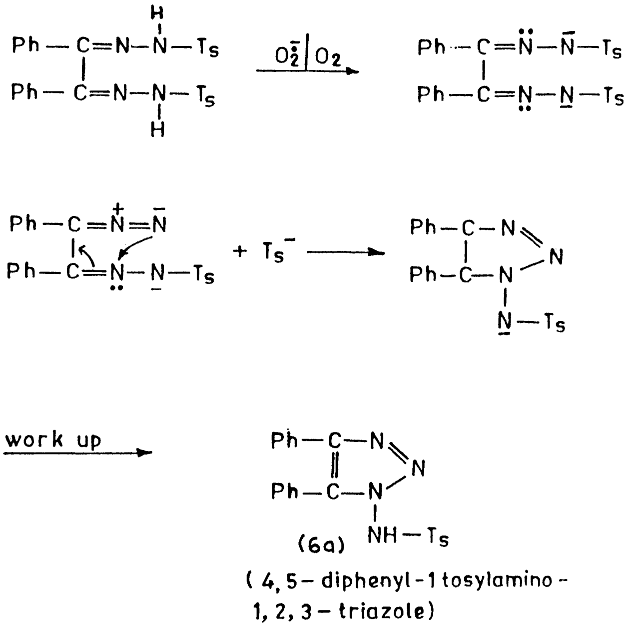
$$\mathbf{V}+\mathbf{VI} \longrightarrow \left[\begin{array}{l}Ph\text{-}\bar{C}\text{-}N{=}\overset{+}{N}\text{-}C\text{-}Ph\\ \quad\; CH_3 \qquad\quad CH_3\end{array}\right]$$

$$\begin{array}{l}Ph\text{-}C{=}N\text{-}N{=}C\text{-}Ph\\ \quad\; CH_3 \qquad CH_3\end{array}$$

(**5a**)

Under similar set of reaction conditions tosylhydrazone of benzoin (**4**) gave deoxybenzoin (**4a**).

The benzil bis(tosylhydrazone) (**6**) has an interesting fragmentation behavior. While Bamford and Stevens[18] reported the formation of diphenylacetylene on heating it under basic protic conditions, Freeman and Johnson[23] under photochemical conditions obtained isomeric α-methoxystilbene when **6** was irradiated in methanol containing sodium methoxide. The latter authors also obtained 25% of triazole (**6a**). However, we observed that electrochemically generated superoxide ion reacted with **6** to afford exclusively 4,5-diphenyl-1-tosylamino-1,2,3-triazol (**6a**) as the only product. A possible pathway for triazole formation is provided in Scheme 1.



Scheme 1.

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