Kinetics and Mechanism of Oxidative Conversion of 5-Hydroxyindole to 2-Oxo-5-hydroxyindole by Chloramine-B in Basic Solutions

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Abstract   The conversion of 5-hydroxyindole (Indole) to 2-oxo-5-hydroxyindole is an important oxidative transformation in synthetic organic and biochemistry. Under pseudo first-order conditions of $[\text{Indole}]_o \gg [\text{chloramine-B or CAB}]_o$, the indole oxidation reaction in a basic solution follows the following experimental rate law: rate $= k'[\text{CAB}]_o[\text{Indole}]_o[\text{OH}^-]^x/[\text{BSA}]^y$, where BSA represents benzenesulfonamide and x and y are fractional orders. The retarding effect of BSA on the rate indicates its involvement in a fast pre-equlibrium in the mechanism of oxidation. Activation parameters have been determined. The variation of $[\text{OH}^-]$ at constant $[\text{BSA}]$ was performed to evaluate the equilibrium and decomposition constants. Based on the mechanism proposed, a rate law has been derived. Furthermore, the methodology developed could be adopted in the synthesis of 2-oxo-5-hydroxyindole. Advantages of the method include: mild reaction conditions, short reaction time, ease of isolation of products, cost effectiveness, and the use of eco friendly reagents.

Keywords   5 – Hydroxyindole, 2 - Oxo - 5 – Hydroxyindole, Chloramine – B, Benzenesulfonamide, Oxidation Kinetics, Mechanism

1. Introduction

Heterocyclic compounds such as indoles are known for their various biological activities and some of them are pharmaceutically important[1]. The oxidative metabolism of indoles in cells is an essential pathway for their detoxifica-tion[2]. The oxidation of indoles leads to a number of products depending on the nature of substituents on the in-dole nucleus and more particularly on the pyrrole moiety. Indoles, which are metabolites of the neurotransmitter, se-rotonin, found in brain act as precursors[3]. Furthermore, the nature of oxidizing agents and reaction conditions play an important role in the oxidation of indoles[4-5]. The oxidation of indoles to the oxoindole stage is an important transfor-mation in organic as well as in biochemistry[6]. There are several methods available in the literature for the conversion of indoles to oxoindoles; but they are complex in nature and require vigorous conditions[4-5]. Mechanisms of oxidation of 5-substituted indole derivatives (viz, 5-H, -OCH_3, -Br and −Cl) to the corresponding oxoindoles by alkaline chloramine-T and chloramine-B have been studied kineti-cally in the presence of OsO_4 catalyst[7-8]. The presence of

hydroxyl group at position-5 in indole makes it biologically significant as it plays a vital role in functions of the central nervous system (CNS)[9]. The literature survey indicates that there is no report on the oxidation of 5-hydroxyindole by aromatic N-haloamines from the viewpoint of its kinetic and mechanistic aspects. In the present kinetic study, 5- hy-droxyindole is oxidized to 2-oxo-5-hydroxyindole, which is biologically and pharmaceutically important. It is also a precursor in the synthesis of natural products[10].

Organic sulfonyl-N-haloamines are mild oxidants con-taining a strongly polarized N- bonded halogen in its +1 oxidation state. Kinetics and mechanisms of oxidation by these reagents have attracted the attention of chemists due to their diverse properties to act as halonium cations (X^+), hy-pohalites and N-anions[11]. They interact with a wide range of functional groups in aqueous, partially aqueous, and non-aqueous media in the presence of an acid or a base. As a result, these reagents have been used as mild and selective oxidizing agents in synthetic organic chemistry[12]. The prominent member of this group, sodium N-chloro-p- tolu-enesulfonamide, commonly known as chloramine-T (CAT), is a known analytical reagent and the kinetic and mechanistic aspects of many of its reactions have been well docu-mented[12-16]. Chloramine-B is the benzene analog of CAT, which can be easily prepared from the reaction of benzene-sulfonamide and chlorine in basic solutions[17]. Chlora-mine-B is a stable compound with slightly higher active

chlorine content than CAT. It liberates iodine from acidified aqueous KI solutions and undergoes two-electron reductions to form benzenesulfonamide and sodium chloride. Though the literature shows several reports on the kinetic and mechanistic aspects of CAT, a similar information with CAB is lacking[18-20]. Our preliminary experiments have revealed that CAB acts as an efficient oxidant as compared to CAT for the smooth and efficient conversion of 5-hydroxyindole to 2-oxo-5-hydroxyindole in basic solutions. Hence, the investigation on the indole-CAB redox reaction has been chosen in the present work.

Main objectives of the present study are to: (i) determine reaction stoichiometry and characterize the oxidation products; ii) determine the kinetic and activation parameters; (iii) elucidate a plausible mechanism; (iv) derive a consistent kinetic rate law; (v) ascertain the reactive species; and (vi) optimize the reaction conditions for the efficient conversion of 5-hydroxyindole to 2-oxo-5-hydroxyindole, which can be used as a method in organic synthesis. The latter methodology has several advantages including the simplicity with short reaction time, ease of isolation of products, cost effectiveness, and the use of relatively environmentally benign reagents.

2. Experimental

The purity of CAB (Aldrich Chemical Co.) was checked by determining the amount of active chlorine present in the compound. A stock aqueous solution of CAB was standardized iodometrically and preserved in brown bottles to prevent its photochemical deterioration[21]. An aqueous solution of 5-hydroxyindole (Aldrich Chemical Co.) was prepared and used. Heavy water (D_2O, 99.2%) was obtained from Bhabha Atomic Research Center (Mumbai, India). All other reagents used were of analytical grades of purity. Double distilled water was used in all solutions.

Kinetic procedure

Reactions were carried out under pseudo-first order conditions, ($[Indole]_o >> [CAB]_o$), in stoppered Pyrex glass boiling tubes whose outer surface was coated black to prevent photochemical effects. Appropriate amounts of solutions of 5-hydroxyindole and NaOH and water (to keep the total volume of 50 mL constant for all runs), were taken in the boiling tube and thermostated at $25 \pm 0.1\ ^0C$. A measured amount of CAB solution, also thermosated at the same temperature, was rapidly added with stirring to the mixture in the boiling tube. The progress of the reaction was monitored by withdrawing 5-mL aliquots from the reaction mixture at different time intervals and iodometrically determining the unreacted CAB concentration using a standard thiosulfate solution with starch indicator. The course of the reaction was followed for two half-lives. Pseudo-first-order rate constants, k', calculated from plots of log (titer) or[CAB] vs. time were reproducible within ±5%.

3. Results

Stoichiometry. Reaction mixtures with varying CAB-to-indole compositions in the presence of 8.0 mM NaOH were equilibrated at 298 K for 24 h. The iodometric determination of the residual oxidant showed that one mole of indole consumed one mole of CAB. The 1:1 stoichiometry obtained can be represented as in eq. (1).

$$+ Na^+ + Cl^- \tag{1}$$
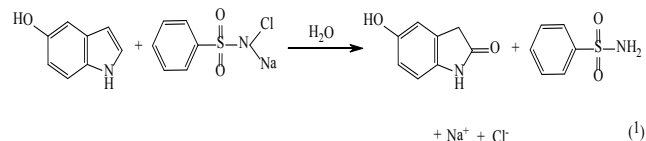
Product analysis

The reaction mixture of indole and CAB in NaOH solution was stirred for 24 h at 298 K. After completion of the reaction (monitored by thin-layer chromatography (TLC)), the reaction mixture was neutralized with dilute HCl and the products were extracted thrice with ethyl acetate. The products in the combined organic layer were identified by TLC) and separated and purified by column chromatography. The compounds were further purified by recrystallizing them in MeOH. The identity of the oxidation product, 2-oxo-5-hydroxyindole, was confirmed by gas the chromatography-mass spectral technique. The mass spectrum showed a parent molecular ion peak at 149 amu (Fig. 1) confirming 2-oxo-5-hydroxyindole. The reduction product of CAB, benzenesulfonamide (BSA), was identified by TLC with petroleum ether-chloroform-n-butanol (2:2:1, v/v/v) as the mobile phase and iodine as the detection reagent (R_f = 0.88)[18].
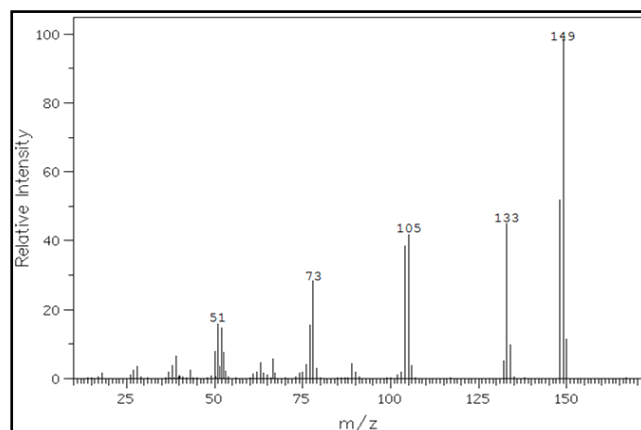

Figure 1. GC-MS spectrum of 2-oxo-5-hydroxyindole with a parent molecular ion peak at 149 amu.

Kinetic orders

The oxidation of 5-hydroxyindole with CAB was kinetically investigated at different initial concentrations of reactants in basic solutions at 298 K. Kinetic runs were carried out under pseudo-first-order conditions with a large excess of the substrate over the oxidant. Under these conditions, at constant$[Indole]_o$,[NaOH] and temperature, plots of log[CAB] vs. time were linear ($R^2 > 0.9834$) indicating a first-order dependence of the reaction rate on$[CAB]_o$. Pseudo-first-order rate constants are presented in Table 1. Furthermore, the rate constants are unaltered with the varia-

tion of $[CAB]_o$, confirming the first-order dependence on $[CAB]_o$. When the $[indole]$ was varied by keeping all other conditions the same, the rate increased with an increase in $[indole]_o$ (Table 1). A plot of log k' *vs.* log$[indole]_o$ was linear (Fig. 2; $R^2 = 0.9987$) with a slope of unity indicating a first-order dependence of the rate on $[indole]_o$. Also, a plot of k' *vs.*$[indole]$ gave a straight line ($R^2 = 0.9995$) passing through the origin, further confirming the first-order dependence on $[indole]_o$. It indicates that the oxidant-substrate has a transient existence. Furthermore, second-order rate constants, $k'' = k'/[indole]_o$ are nearly constant (Table 1), supporting the first-order dependence on $[indole]_o$.

Table 1. Effect of varying concentrations of CAB, indole and NaOH on the reaction rate at 298 K.

$10^4[CAB]_o$ (M)	$10^3[Indole]_o$ (M)	$10^3[NaOH]$ (M)	$10^4 k'$ (s^{-1})
2.00	6.00	8.00	7.55
3.00	6.00	8.00	7.40
4.00	6.00	8.00	7.48
5.00	6.00	8.00	7.50
6.00	6.00	8.00	7.58
4.00	2.00	8.00	2.42 (0.12)[a]
4.00	4.00	8.00	4.50 (0.11)[a]
4.00	6.0	8.00	7.48 (0.12)[a]
4.00	10.0	8.00	12.9 (0.13)[a]
4.00	16.0	8.00	20.6 (0.13)[a]
4.00	6.00	2.00	3.55 (3.31)[b]
4.00	6.00	4.00	5.10 (4.90)[b]
4.00	6.00	8.00	7.48 (6.32)[b]
4.00	6.00	12.0	9.20 (8.65)[b]
4.00	6.00	20.0	13.1 (12.2)[b]

a: Values in parentheses refer to second-order rate constants.
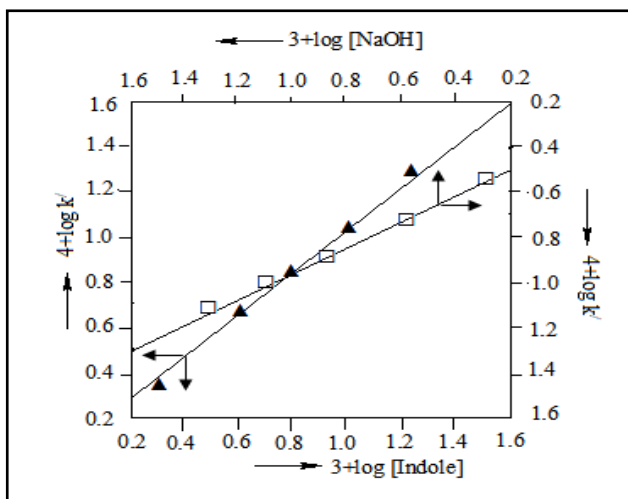b: Rate constants in parentheses refer to the variation of$[OH^-]$ in the presence of 1.00 mM benzenesulfonamide.

Figure 2. Plots of log k' versus log[Indole] and log k' *vs.* log[NaOH]. Experimental conditions are the same as in Table 1.

When the[NaOH] was varied, the rate increased with an increase in[NaOH] (Table 1). A plot of log k' *vs.* log[NaOH] was linear ($R^2 = 0.999$) with a slope of 0.55, indicating a fractional-order dependence

of the rate on[NaOH]. The effect of the reduction product, BSA or $PhSO_2NH_2$, was followed by externally adding it to the reaction mixture. This retarded the reaction and the rate constants (10^{-4}, s^{-1}) for[BSA] (mM): 1.00, 2.00, 4.00 and 6.00 were 6.32, 5.40, 4.25 and 3.58, respectively. A plot of log k' *vs.* log$[PhSO_2NH_2]$ was linear (Fig. 3; $R^2 = 0.9984$) with a slope of -0.33, suggesting an inverse-fractional-order dependence of the rate on$[PhSO_2NH_2]$. It indicates that BSA is involved in a fast pre-equilibrium to the rate determining step in the proposed scheme.
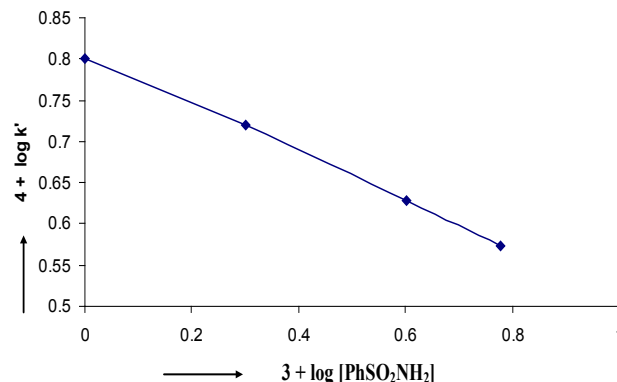

Figure 3. A Plot of log k' *vs.* log$[PhSO_2NH_2]$. Experimental conditions:$[CAB]_o = 4.00 \times 10^{-4}$ M;$[Indole]_o = 6.00 \times 10^{-3}$ M;$[NaOH] = 8.00 \times 10^{-3}$ M; T = 298 K.

In order to elucidate the nature of reactive species, the dielectric constant (D) of the solvent was varied by adding MeOH (0-30% v/v) to the reaction mixture, while the other experimental conditions were kept constant. The rate constants k' (10^{-4},s^{-1}), determined at D values of 76.73, 72.37, 67.48 and 62.79 were 7.48, 6.62, 5.50 and 4.35, respectively. Furthermore, a plot of log k' *vs.* 1/D was linear (Fig. 4; $R^2 = 0.9980$) with a negative slope. Values of D for MeOH-H_2O mixtures reported in the literature[22] were employed. Data show that the rate of oxidation increases with the increase in D of the medium, which parallels the solvent polarity. This effect is attributed to the formation of a relatively more polar transition state as compared to the ground state. The polar solvent stabilizes the transition state and increases the rate. Blank experiments performed showed that MeOH was not oxidized significantly by CAB under the prevailing experimental conditions. The addition of Cl^- ions in the form of NaCl (5.0 mM) to the reaction mixture had no effect on the rate, indicating that no interhalogen or free chlorine was formed in the reaction sequence. Also, the variation of the ionic strength of the medium by adding $NaClO_4$ (0.2 M) did not alter the rate significantly. Hence, the ionic strength of the reaction mixture was not fixed constant for all other kinetic runs. The reaction rate was studied at different temperatures (293-303 K) while keeping other experimental conditions constant. From the linear Arrhenius plot of log k' *vs.* 1/T (Fig. 5; $R^2 = 0.9995$), activation parameters such as energy of activation (E_a), enthalpy of activation ($\Delta H^{\neq}$), entropy of activation ($\Delta S^{\neq}$), and free energy of activation ($\Delta G^{\neq}$) for the overall reaction have been computed. The rate constants and the activation parameters are presented in Table 2. The solvent isotope effect was studied in the D_2O medium. The reaction was more accelerated with k' $=9.10 \times 10^{-4}$ s^{-1} in

D_2O medium as compared to $k' = 7.48 \times 10^{-4}$ s^{-1} in H_2O, leading to a solvent isotope effect, $k'(H_2O) / k'(D_2O) = 0.82$. The reaction mixture failed to initiate polymerization of aqueous acrylamide solutions, indicating the absence of free radicals.

Table 2. Rate constants at different temperatures and activation parameters for the oxidation of 5-hydroxyindole by CAB in basic medium.

Temperature (K)	$10^4 k'$ (s^{-1})
293	5.32
298	7.48
303	9.84
308	13.2
E_a (kJ mol^{-1})	49.2
$\Delta H^{\neq}$ (kJ mol^{-1})	46.6
$\Delta G^{\neq}$ (kJ mol^{-1})	91.5^a
$\Delta S^{\neq}$ (JK^{-1} mol^{-1})	-148
log A	5.48

Conditions:$[CAB]_o = 4.00 \times 10^{-4}$ M;$[Indole]_o = 6.0 \times 10^{-3}$ M; $[NaOH] = 8.0 \times 10^{-3}$ M; ^{a} 298 K

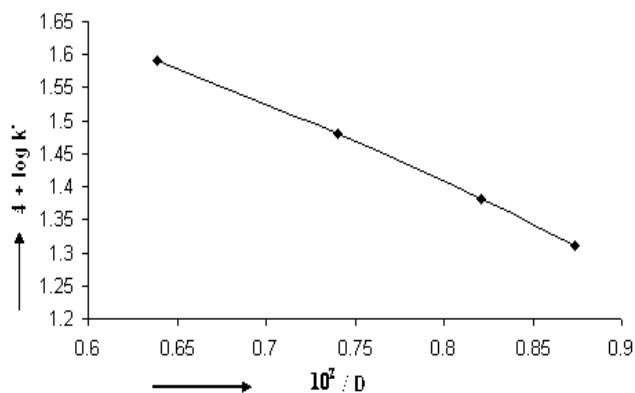**Figure 4.** A plot of log k' *vs.* 1/D. Experimental conditions:$[CAB]_o = 4.00 \times 10^{-4}$ M;$[Indole]_o = 6.00 \times 10^{-3}$ M;$[NaOH] = 8.00 \times 10^{-3}$ M; T = 298 K.
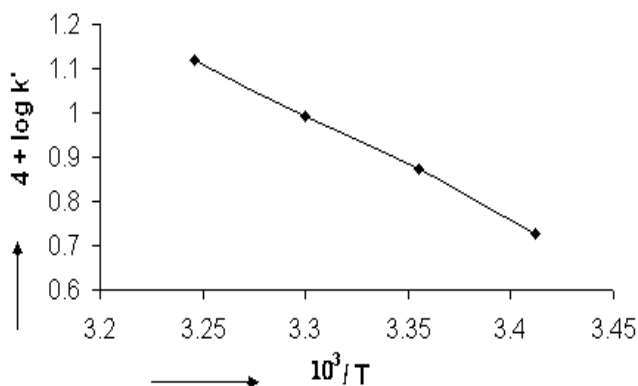
Figure 5. An Arrhenius plot of log k' *vs.* 1/ T. Experimental conditions:$[CAB]_o = 4.00 \times 10^{-4}$ M;$[Indole]_o = 6.00 \times 10^{-3}$ M;$[NaOH] = 8.00 \times 10^{-3}$ M; T = 298 K.
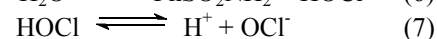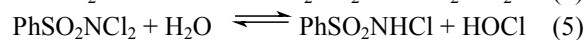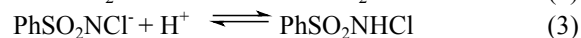
4. Discussion

Reaction mechanism

In general, both CAB and CAT, which undergo a two-electron change in their reactions, exhibit similar equilibria in aqueous solutions[23]. The redox potential of the CAB/PhSO$_2$NH$_2$ system is dependent on pH of the medium. Chloramine-B in aqueous solutions behaves as a strong electrolyte and, depending on the pH of the medium, it furnishes the following species in several equilibria[21,23-25]:

$$PhSO_2NClNa \rightleftharpoons PhSO_2NCl^- + Na^+ \quad (2)$$
$$PhSO_2NCl^- + H^+ \rightleftharpoons PhSO_2NHCl \quad (3)$$
$$2PhSO_2NHCl \rightleftharpoons PhSO_2NH_2 + PhSO_2NCl_2 \quad (4)$$
$$PhSO_2NCl_2 + H_2O \rightleftharpoons PhSO_2NHCl + HOCl \quad (5)$$
$$PhSO_2NHCl + H_2O \rightleftharpoons PhSO_2NH_2 + HOCl \quad (6)$$
$$HOCl \rightleftharpoons H^+ + OCl^- \quad (7)$$
$$HOCl + H^+ \rightleftharpoons H_2OCl^+ \quad (8)$$
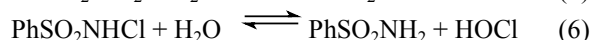
The possible oxidizing species present in acidified CAB solutions are PhSO$_2$NHCl, PhSO$_2$NCl$_2$, HOCl and possibly H$_2$O$^+$Cl. In alkaline solutions, PhSO$_2$NCl$_2$ and HOCl do not exist[24]. Calculations of Hardy and Johnston[25] have indicated that there exist considerable concentrations of PhSO$_2$NCl$^-$ and its conjugate acid, PhSO$_2$NHCl, even in alkaline chloramine solutions. Furthermore, the retardation of the rate by OH$^-$ ions, observed in reactions of CAT, has been attributed to the equilibrium[eq. (9)], where a similar species, p-Me-C$_6$H$_4$SO$_2$NHCl, is assumed to be the reactive species.

$$p\text{-Me-}C_6H_4SO_2NCl^- + H_2O \rightleftharpoons p\text{-Me-}C_6H_4SO_2NHCl + OH^-$$
$$(9)$$
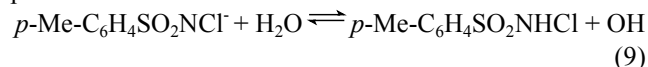
In view of the similarity in properties of CAB and CAT, the observed fractional-order dependence of the rate on[OH$^-$] and the rate retardation by added PhSO$_2$NH$_2$, Scheme 1 is proposed to represent the reaction mechanism for the oxidation of 5-hydroxyindole by CAB in basic solutions.
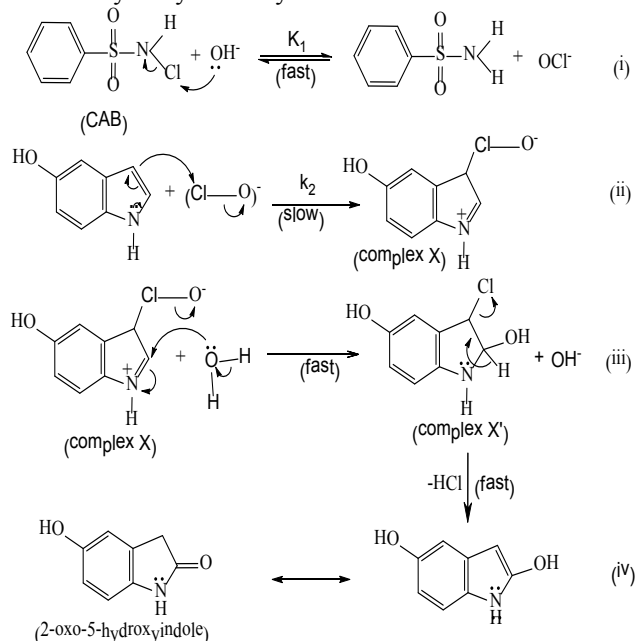
Scheme 1. Detailed mechanistic scheme for the oxidation of 5- hydroxyindole by CAB in basic solutions.

Scheme 1 presents a detailed electronic mechanistic picture for the oxidative conversion of 5-hydroxyindole to 2-oxo-5-hydroxyindole. In the fast pre-equilibrium (step (i)), the conjugate acid of CAB, PhSO$_2$NHCl, interacts with OH$^-$

ions to form the active oxidizing species, which is hy-pochlorite ion or OCl^-. In the slow step (or rate determining step (ii)), an electrophilic attack by the chlorine end of hy-pochlorite ion at negative position-3 of the indole moiety forms the intermediate, complex X. In fast step (iii), complex X undergoes intramolecular rearrangements, as indicated by arrows, leading to a nucleophilic attack by a water molecule at position-2 to form complex X', 3-chloro-2,5-dihydroxyindole. In the next fast step, complex X', after intramolecular rearrangements, eliminates a mole-cule of HCl to form the end product, 2,5-dihydroxyindole. The enolic form of this diol finally tautomerizes to form the end oxidation product, 2-oxo-5-hydroxyindole.

Derivation of rate law

The total effective concentration of CAB, from Scheme 1, is given by eq. (10) as,

$$[CAB]_{total} = [PhSO_2NHCl] + [OCl^-] \qquad (10)$$

From step (i) of Scheme 1,

$$[PhSO_2NHCl] = \frac{[PhSO_2NH_2] [OCl^-]}{K_1 [OH^-]} \qquad (11)$$

The substitution for $[PhSO_2NHCl]$ from eq. (11) into eq. (10) leads to eq. (12 for $[OCl^-]$.

$$[CAB]_{total} = \frac{[PhSO_2NH_2] [OHCl^-] + K_1 [OH^-][OCl^-]}{K_1 [OH^-]}$$

$$[OCl^-] = \frac{K_1 [CAB]_t [OH^-]}{[PhSO_2NH_2] + K_1[OH^-]}$$

or $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (12)$

From the slow step of Scheme 1,

$$rate = k_2[OCl^-][Indole] \qquad (13)$$

By combining eq. (12) with eq. (13), the following rate law is obtained.

$$rate = \frac{K_1 k_2 [CAB]_t [Indole] [OH^-]}{[PhSO_2NH_2] + K_1 [OH^-]} \qquad (14)$$

The derived rate law[eq. (14)] is in agreement with the experimental data, including a first-order dependence each on $[CAB]_o$ and $[indole]_o$, a fractional-order dependence on $[OH^-]$ and a negative fractional-order dependence on $[PhSO_2NH_2]$.

Since rate = $k'[CAB]_t$, under pseudo-first-order conditions of $[indole]_o >> [CAB]_o$, rate eq. (14) can be transformed into eqs. (15) and (16).

$$k' = \frac{K_1 k_2 [Indole] [OH^-]}{[PhSO_2NH_2] + K_1 [OH^-]} \qquad (15)$$

$$\frac{1}{k'} = \frac{[PhSO_2NH_2]}{K_1 k_2 [Indole][OH^-]} + \frac{1}{k_2 [Indole]} \qquad (16)$$

To test the validity of eq. (16), the reaction was studied at varying $[OH^-]$ with a constant 1.00 mM BSA at 298 K (Table 1). From the slope and intercept of the linear double recip-rocal plot of $1/k'$ *vs.* $1/[OH^-]$ (Fig. 6; $R^2 = 0.9863$), the values of equilibrium constant K_1 and decomposition constant k_2 determined are 1.11 and 0.175 $M^{-1}s^{-1}$, respectively.

The proposed reaction mechanism and the derived rate law are supported by the following experimental facts: (i) Bronsted and Bjerrum[26] have explained the primary salt

effect on the reaction rates through the relation:

$$log\ k' = log\ k_o + 1.02\ Z_A Z_B\ \mu^{1/2} \qquad (17)$$

where μ is the ionic strength of the medium, A and B are the reacting ions, Z_A and Z_B are charges on the respective species, k' and k_o are rate constants in the presence and ab-sence of the added electrolyte, respectively. According to eq. (17), a plot of log k' *vs.* $\mu^{1/2}$ should be linear with a slope of 1.02 $Z_A Z_B$ and intercept of log k_o. As the slope of the line depends on $Z_A Z_B$, the reaction rate may increase, decrease or remain unaffected with the ionic strength variation in the reaction medium. In the present case, variation of ionic strength of the medium does not alter the rate, which signi-fies that at least one of the reactants species is a neutral molecule as shown in slow step (ii) of Schemes1. Hence, the observed ionic strength effect is consistent with the Bron-sted-Bjerrum concept[26] for the proposed mechanism; (ii) A negative MeOH effect also provides support for the pro-posed mechanism (Scheme 1). The effect of solvents on the reaction rates has been described by House[27], Entelis and Tiger[28], Amid[29], and Richardt[30]. For
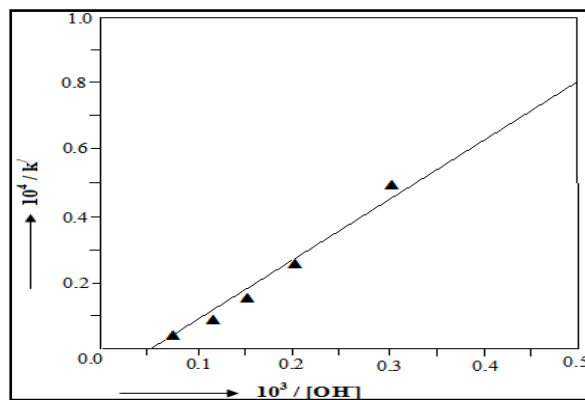

Figure 6. A plot of $1/k'$ *vs.* $1/[OH^-]$. Experimental conditions: $[CAB]_o = 4.00 \times 10^{-4}$ M; $[Indole]_o = 6.00 \times 10^{-3}$ M; $[PhSO_2NH_2] = 1.0 \times 10^{-3}$ M; T = 298 K.

the limiting case of a zero angle of approach between two dipoles or in an ion-dipole system, Amis[29] has shown that a plot of log k' *vs.* $1/D$ gives a straight line, with a negative slope for interactions between a negative ion and a dipole or between two diploes, while a positive slope results for the positive ion-dipole interactions. The negative dielectric ef-fect observed in the present study clearly supports the an-ion-dipole interactions in the rate determining step[step (ii) of Scheme 1]; (iii) Solvent isotope studies have shown that the rate of reaction is higher in D_2O medium. For a reaction involving a fast pre-equilibrium with H_3O^+ or OH^- ion transfer, the rate increases in D_2O medium since D_3O^+ and OD^- ions are stronger acid and stronger base than H_3O^+ and OH^- ions, respectively[31-32]. In the present case, the ob-served solvent isotope effect $k'(D_2O)/k'(H_2O) > 1$ is due to the greater basicity of OD^- ions as compared to OH^- ions. However, the magnitude of acceleration in D_2O is smaller than the expected value of 2 to 3 times greater which is re-flective of the fractional-order dependence of the rate on $[OH^-]$; (iv) The proposed mechanism is supported by the moderate values of energy of activation and other activation

parameters. The fairly positive values of free energy and enthalpy of activation indicate that the transition state is highly solvated. The observed negative $\Delta S^{\neq}$ may be interpreted as follows: as a fraction of collisions becomes more stringent, the decomposition of the rigid activated complex involves a slow process. This is suggestive of the fact that the redox reaction is relatively more controlled by entropy than enthalpy.

5. Conclusions

The kinetics of oxidation of 5-hydroxyindole by CAB in basic medium follows the experimental rate law: $-d[CAB]/dt = [CAB]_o[Indole]_o[OH^-]^{0.55}/[BSA]^{0.33}$. A suitable mechanism resulting in a derived rate law consistent with the experimental data is suggested. The present method for the oxidative conversion of 5-hydroxyindole to 2-oxo-5-hydrox yindole has the following advantages: simplicity of the method with a short reaction time and the use of cost-effective and environmentally benign reagents. Furthermore, this method could be adopted for the conversion of 5-hydroxyindole to 2-oxo-5-hydroxyindole in organic synthesis.

ACKNOWLLDGEMENTS

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