International Journal of Advanced Technology & Engineering Research (IJATER)
International Conference on "Recent Advancement in Science & Technology" (ICRAST 2017)

KINETICS AND MECHANISTIC INVESTIGATION OF OXIDATION OF L-THREONINE BY N-BROMOSACCHARIN

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Abstract

The kinetics of oxidation of amino acid L-Threonine by *N*- bromosaccharin in aqueous acetic acid medium and in the presence of Hg (II) acetate has been investigated.. The reaction has been found to be first order with respect [oxidant] under pseudo first order condition. The kinetic results for dependence on substrate concentration indicates intermediate complex formation between oxidant and substrate species. Addition of saccharin ,has a retarding effect on the rate of oxidation .Increase in the concentration of perchloric acid retards the reaction rate. The effect of temperature is studies and activation parameter are determined. On the basis of kinetic results a probable mechanism is proposed.

Keywords: Kinetics, Oxidation, L - Threonine, *N*-Bromosaccharin

[I] Introduction

In the present investigation N-bromosaccharin has been employed as an oxidant . During the oxidation by N-bromosaccharin ,bromine is liberated. The liberated bromine may be oxidise amino acid,therefore, formation of bromine is suppressed by the addition of Hg (II) acetate[1]which trape Br^- and forms an unionized $HgBr_2$ or $HgBr_4^-$.

Oxidation kinetics of amino acids have been carried out using different oxidants viz. chloramines-T[2-4] in alkaline medium ,Bromine[5] in acetate buffer of pH -6 ,N-bromotoluene sulphonamide[6] ,sodium hypochorite[7] ,Co(III)[8], Ce(IV[9]), Mn(III)[10].A survey of the literature reveals that oxidation of amino acid follows different modes yielding either nitrile or aldehydes as products depending upon the medium and nature of oxidant.

[II] Experimental

N-Bromosaccharin was prepared by the method suggested by Bacchawat and Mathur[11] and was standardized by iodometric method [12].Amino acid L - Threonine solution was prepared by dissolving in perchloric acid. Solution of mercuric acetate was prepared by dissolving it in acetic acid – water mixture.

Stoichiometry and molecularity of the reaction

Stoichiometry of the reaction was carried out under the conditions [NBSA]>>[L–Threonine]. The reaction mixture containing10^2 [NBSA] =1.0M, 10^3[L- Threonine] = 1.0M, [$HClO_4$]=3.0M , $10^3[Hg(OAc)_2]$ = 5.0×10^{-3}M, HOAc-H_2O = 40%(v/v) was taken 36 h at35 ^{0}C,the concentration of NBSA was (after completion of the reaction) estimated at regular intervals of time iodometrically using as starch as indicator till the values was obtained. It has been observed that

$$C_4H_9O_3N + C_6H_4COSO_2NBr + H_2O \text{ ----------> } C_3H_6O_2 + CO_2 + NH_3 + C_6H_4COSO_2NH + HBr$$

The product of oxidation of amino acid L – Threonine was lactaldehyde , tested by preparing 2,4-dinitrophenyl hydrozone derivative.

[III]Results and Discussion

The kinetics of L - Threonine oxidation by N-bromosaccharin was carried out under the condition [L - Threonine] and [Hg(II)] >> [NBSA].

Dependence of rate on oxidant concentration-:

On the variation of initial concentration of N-bromosaccharin the pseudo first order rate constant decreases with the increase in the concentration of oxidant (Table-1). Such a decrease in rate constant value suggests that N-bromosaccharin is involved in a pre-equilibrium with some nucleophilic species (probably H2O) to form some intermediate with lower reactivity. Similar results were reported in the oxidation of benzhydrols[13], primary aliphatic alcohols[14], benzyl alcohol[15] and α- hydroxyl acids[16-18]

Table 1. Dependence of rate on the concentration of oxidant

S.N.	[NBSA]10^3M	[$HClO_4$]M	10^3 k min^{-1}
1	0.40	3.0	32.16
2	0.50	3.0	30.67
3	0.66	3.0	23.56
4	1.00	3.0	19.19
5	1.25	3.0	16.99
6	2.00	3.0	14.59
7	0.50	2.75	32.45
8	0.50	4.0	22.52
9	0.50	5.0	18.70
10	0.50	5.5	16.48

[L - Threonine] =1.0×10 $^{-2}$M, [$Hg(OAc)_2$] =5.0×10 $^{-3}$M ,HOAc-H_2O =40% (v/v),
Temperature = 35 ^{0}C

Dependence of rate on substrate concentration-:

The effect of substrate was investigated by varying the initial concentration of substrate from 1.25 X 10-3M to 10.0 X 10-3M .The pseudo first order rate constant increases with increase in the concentration of amino acid. However, the value of second order rate constant, k2 (k2 = k1 /[L-Threonine]) does not show constancy (Table 2).The plot between k1 and [L- Threonine] is initially (at lower concentration) linear passing through origin and then bends towards x-axis at higher concentration of amino acid (Figure 1). It suggests that the order with respect to substrate varies from 1 to 0. The double reciprocal plot between k1 and [amino acid] is linear with positive intercept on y-axis giving a kinetic evidence for complex formation.

Table 2. Dependence of rate on the concentration of amino acid L – Threonine

SN	[L - Threonine] 10^3M	10^3 k_1 min^{-1}	3+log [L-Threonine]	3+log k_1	$k_2 = k_1$ /[L-Threonine]
1	1.25	8.26	0.069	0.916	6.60
2	1.66	10.25	0.220	1.010	6.17
3	2.22	13.45	0.346	1.128	6.05
4	2.50	15.66	0.397	1.194	6.26
5	3.53	20.36	0.522	1.508	6.11
6	5.00	25.88	0.968	1.412	5.17
7	6.66	28.58	0.825	1.456	4.29
8	10.0	30.67	1.000	1.486	3.06

[NBSA] =1.0×10 $^{-4}$M, [$HClO_4$]=3.0M ,[$Hg(OAc)_2$] = 5.0×10 $^{-3}$M, HOAc-H_2O = 40%(v/v), Temperature =35 ^{0}C

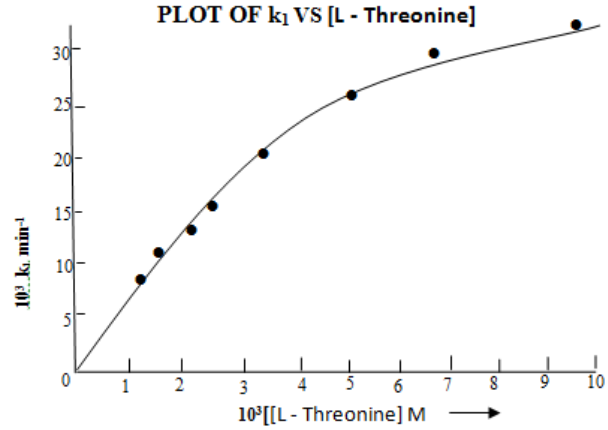


Figure1

Dependence of rate on perchloric acid concentration

Table-1 reveals that the pseudo first order constant decreases with increase in the concentration of perchloric acid. The linear plot of k_1 versus [$HClO_4$] passing through origin suggest that the reaction follows only acid dependent path. The slope value of log-log plot between k_1 and [$HClO_4$] is -1 indicates that the order is reverse unit order in acid.

Dependence of rate on solvent composition

The effect of dielectric constant of the medium on the rate was examined by varying the percentage composition of acetic acid - water binary mixture. Table-3 shows that the value of pseudo first order rate constant increases with increase in the composition of acetic acid in the binary mixture. The plot of log k_1 and inverse of dielectric constant of the medium is linear with positive slope suggesting dipole-dipole interaction.

Table 3. Dependence of rate on the dielectric constant of the medium

SN	HOAc-H_2O%(V/V)	[Saccharin] 10^3M	10^3 k_1 min^{-1}
1	20	0.00	23.66
2	30	0.00	26.57
3	40	0.00	30.67
4	50	0.00	40.59
5	60	0.00	54.59
6	40	1.00	28.54
7	40	1.66	25.78
8	40	2.00	22.14
9	40	2.50	19.95
10	40	3.33	15.63

[NBSA] $=1.0\times10^{-4}$M, [L - Threonine] $=1.0\times10^{-2}$M,[$Hg(OAc)_2$]$=5.0\times10^{-3}$M,[$HClO_4$]=3.0M, Temperature =35 ^{0}C

Dependence of rate on saccharin concentration

The effect of saccharin was investigated by varying the concentration of saccharin at constant concentration of other reactants. Table -3 shows the reaction rate decreases with increase concentration of saccharin. The plot of inverse of k_1 against [saccharin] is linear suggesting that saccharin is involved in some pre-equilibrium step. The effect of neutral salt was investigated by adding varying concentrations of sodium perchlorate at constant concentration of other reactants which shows negligible effect on the rate.

Under the concentration used for the present investigation mercuric acetate acts as scavenger for bromide ion. The reaction was studied at different temperatures and activation parameters were evaluated (Table 4).

Table 4. Thermodynamic parameters

Ea kJ mol^{-1}	A $\times10^{10}$sec^{-1}	ΔH kJ mol^{-1}	ΔG* kJ mol^{-1}	ΔS* JK^{-1} mol^{-1}
79.6	1.6	79.45	83.2	-12.01

[IV]Reactive Species and Mechanism:

N-bromosaccharin get reduced to saccharin according to half cell reaction

$$C_6H_4COSO_2NBr + H^+ + 2e^- \text{----------}> C_6H_4COSO_2NH + Br^-$$

Indrasenan and Mohan Das[19] reported the formal potential of the couple [$C_6H_4COSO_2NBr$]/ [$C_6H_4COSO_2NH$] in anhydrous acetic acid at 30^{0}C as +1.308V which indicates that NBSA is moderately strong oxidant. Like other haloamides and imides N-bromosaccharin exists in various active forms such as the molecular species NBSA and the hydrolytic form HOBr, their protonated forms NBSAH$^+$,H_2O^+Br and Br^+ .

$$NBSA + H^{\oplus} \longrightarrow Sac + Br^{\oplus}$$

$$NBSA + H_2O \longrightarrow Sac + HOBr$$

$$HOBr + H^{\oplus} \longrightarrow H_2OBr^{\oplus}$$

The effect of hydrogen ion concentration and effect of addition of varying concentration of saccharin on the oxidation rate play a key role in deciding the active oxidant and substrate species. Our kinetic result show that retardation of reaction rate with added saccharin which excludes free or protonated form of oxidant. Hence the involvement of H_2O^+Br , Br^+ or HOBr as active species of oxidant may be considered.

$$NBSA + H_2O \longrightarrow Sac + HOBr$$

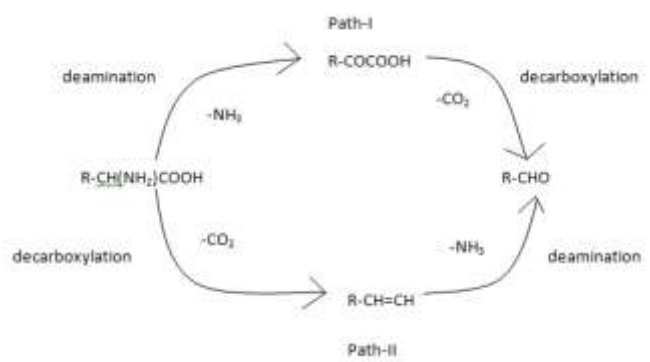
The linearity of plot of inverse of k_1 versus [saccharin] supports HOBr as active oxidant. The reactions are acid catalysed suggesting involvement of some protonated species viz. H_2O^+Br or Br^+.

$$HOBr + H^{\oplus} \rightleftharpoons H_2OBr^{\oplus} \quad \text{.....(1)}$$

$$NBSA + H^{\oplus} \rightleftharpoons Br^{\oplus} + Sac \quad \text{.....(2)}$$

The above equation (2) explains both acid catalysis and inverse dependence of reaction rate on saccharin concentration but it is well established that H_2O^+Br is more effective electrophile than Br^+ although it is very difficult to distinguish between the two in aqueous solution. The formation and participation of hypobromous acidium ion H_2O^+Br is well documented in several oxidation reactions involving haloamides and imides as oxidants.

The nature of plot of k_1 versus [perchloric acid] suggests that the oxidation follows an acid dependent. Accordingly unprotonated hydrolytic product HOBr [20-21]and its protonated form H_2O^+Br may be considered as active oxidant species involved in the oxidation. Amino acids are bi-functional compounds, capable of reacting at –COOH as well as –NH_2 function and the choice of mechanistic route for the oxidation of amino need acid more consideration . Oxidation of amino acid to aldehyde by two possible path-



Path –I incorporates deamination followed by decarboxylation while in path-II the steps are reversed .In the present investigation attempts to identify qualitatively the intermediate keto acid failed .This points out that oxidation of amino acid follows decarboxylation - deamination path.

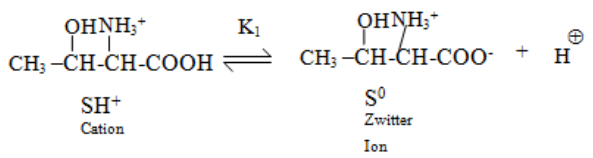
In acidic medium amino acid exists in the cationic form which changes to zwitter ion according to the following equilibrium. Hydrogen ion effect points to the involvement of zwitter ion species in the rate determining step.

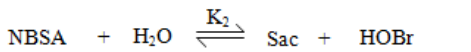
$$S + H^{\oplus} \rightleftharpoons S\overset{\oplus}{H} \rightleftharpoons S^{0} + H^{\oplus}$$

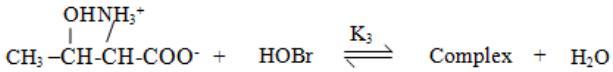
Medium effect studies also help in deciding the nature of active oxidant and substrate species .The effect of adding neutral salts shows no effect on the rate suggesting the reaction involve an interaction between neutral molecules in the slow step. The retarding effect of added perchloric acid and added saccharin points to HOBr as active oxidant species.

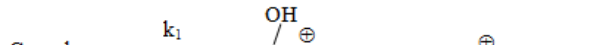
The participation of intermediate complex in the reaction mechanism can be evaluated from kinetic data. The nature of double reciprocal plot between k_1 and [substrate] gives kinetic evidence for the formation of transient complex, the hypobromite, between the oxidant species and zwitter ion of the substrate. The complex yields an intermediate carbocation in a slow, rate determining step via decarboxylation. The resulting carbocation forms imine in a fast step by deammination.

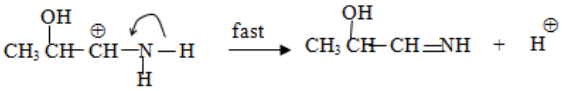
The proposed mechanism is well supported by the moderate values of energy of activation and thermodynamic parameter (Table-4). Stoichiometry and product analysis are also supported.

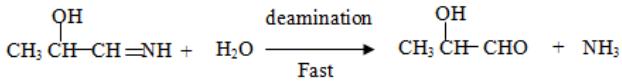












$$\text{Rate} = k_1\,[\text{Complex}]$$

$$= k_1\,K_2\,K_3\,[S^0]\,[\text{NBSA}]\,/\,[\text{Sac}]$$

$$[\text{NBSA}] = \frac{[\text{Sac}]\,[\text{NBSA}]_T}{[\text{Sac}] + K_2 + K_2K_3\,[S^0]}$$

$$k_{obs} = \frac{\text{Rate}}{[\text{NBSA}]_T} = \frac{k_1K_1K_2K_3\,[S\overset{\oplus}{H}]}{[\text{Sac}]\,[\overset{\oplus}{H}] + K_2\,[\overset{\oplus}{H}] + K_1K_2K_3\,[S\overset{\oplus}{H}]}$$

[V]Conclusions

The kinetic oxidation studies of L - Threonine by N-bromosaccharin reveal that the amino acid degrades into aldehyde through decarboxylation-deamination process whearas nitrile are obtained by decarboxylation. Kinetic evidence also supports for the formation of intermediate complex between active oxidant and substrate species.

[VI]References

[1] J.C. Bailar " The Chemitry Of Coordination Compounds", Reianhold, New York 1956,p6
[2] A.K.Boss , R.M. Mahrotra and S.P. Mushram , Indian J Chem,9793,11,896
[3] A. Kumar, A.K. Boss and S.P. Musram , J.Indian Chem. Soc., 1976,53,755
[4] J. Sharma , L. Pandey and S.P. Musram, Indian J Chem,1980,19,475
[5] D.S. Mahadevappa , S. Ananda , A.S.A. Murty and K.S. Rangappa, Indian J Chem 1984,23,17
[6] D.S. Mahadevappa , S. Ananda, M.B.M. Gowda and K.S. Rangappa, J.Indian Chem. Soc. 1984,61,323
[7] Rausch, Thomas, F.Hofmann and W.Hillgenberg, Z.Naturforach., B.Anorg., Chem,1981.36.359
[8] A. Meenakshi and M.Santappa, Curr. Sci., 1968,37,313
[9] M. Adinarayana , B. Setheram and T. Navneet Rao. J.Indian Chem. Soc.1976,53,877
[10] M.A. Beg and Kamaluddin Indian J Chem, 1975,13,1167
[11] J.M. Bacchawat andN.K. Mathur, Indian J Chem., 1971, 9, 1335-1336
[12] M.Z. Barkat and M.F. Abd-el-Wahab , Anal Chem.,1954, 26, 55
[13] V. Manoharan and N. Venkatasubramanian., Indian J Chem., 1984, 23, 389
[14] V.K. Sharma., K.Sharma and A. Singh., Oxid Commun.,1990, 13(4), 251.
[15] K. Vijaymohan., P.Manikyamba,P. Raghunath Rao and E.V. Sundram, Proc Natl AcadSci., India, 1988, 58(A), 57
[16] U. Mishra ,K. Sharma and V.K.Sharma., J Indian Chem Soc.,1986, 63, 586
[17] V.K.Sharma,K. Sharma and U. Mishra , Oxid Commun.,1988,11(3-4), 275
[18] U Shukla,K. Sharma and V.K.Sharma , Oxid Commun.,1992, 15, 219
[19] C. Mohandas and P. Indrasenan ,Indian J Chem, 1987,26,55
[21] K.Vijay Mohan , P. Raghunath Rao and E.V. Sundram, J.Indian Chem. Soc.1984,61,876
[22] J. Mukherjee and K.K. Banerji ,J.Org.Chem. 1981,46,262