Review Paper

Oxidative behavior of *N*-bromophthalimide for organic compounds: a review

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Abstract
Organic compounds receive from industries as effluents are highly toxic and hazardous for the environment. Conventional oxidation process for the oxidation of organic compounds through use of *N*-bromophthalimide (NBP) is one of the significant process for conversion of organic compounds into environmental friendly or less harmful substances. The main scenario of this review is oxidation and kinetics of different organic compounds by NBP with different experimental methods—iodometric and potentiometric along with uncatalyzed, and catalyzed system. In addition to this we also summarize synthesis, properties and reactive species of NBP. Oxidation products obtained by oxidation of various organic compounds by NBP were acetic acid, aldehyde, carbon dioxide, ammonia, cyanide, aldonic acid etc. Present review, first time offers all aspects of NBP as an oxidizing agent for oxidation of organic compounds.

Keywords *N*-Bromophthalimide · Oxidation · Kinetics · Organic compounds

Abbreviations

NBP	*N*-Bromophthalimide
NBS	*N*-Bromosuccinimide
NBA	*N*-Bromoacetamide
TP	Tetrapeptide
AA	Amino acid
Gly	Glycine
BAT	Bromamine-T
SDS	Sodium dodecylsulphate
CTAB	Cetyltrimethylammonium bromide
Alanine	Ala

1 Introduction

Organic compounds contain mainly carbon, and hydrogen as the backbone of the structure. It also consist some other elements, i.e. oxygen, nitrogen, sulphur etc. and its oxidation are carried out by either addition of oxygen or loss of electron. It includes remediation of pollutants or combustion process. Nowadays, study of oxidation of organic compounds present in environment is of immense importance and there are several oxidants reported for degradation processes [1–3]. With the passage of time, detailed study of the kinetics and mechanism of redox reaction has draw much attention, and mechanisms of various oxidation reactions have been neatly explained [4, 5]. Among various oxidants, *N*-halocompounds broadly used as powerful oxidizing agent in both catalyzed [6–8], and uncatalyzed reactions [9–11]. These are also the source of halogen and act as halogenating agent [12]. It has great properties sometimes it behaves like a base, nucleophile, hypohalite species etc. [13, 14].

Oxidation of ketones [15, 16], D-arabinose and mannose [17], reducing sugar [18] by NBA were reported. While, Singh et al. [19] reported that the reaction followed fractional order dependence on [NBA], first order on [Ru(III)], zero order on [glycerol and glycol] and positive effect of [H^+] was observed. Mathiyalagan and Sridharan [20] studied the kinetics of oxidation of benzyl ether by NBS. The reaction followed first order kinetics with respect to both [NBS] and [benzyl ether]. There are several reports

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also available in the literature on the oxidation of organic compound by NBS [21, 22]. Gowda et al. studied the oxidation of hydrophobic tetrapeptide [TP] sequences of elastin. The reaction was followed identical kinetics, first order each in [NBS], [AA] and [TP], no effect on the rate of [H^+] was observed [23]. Tiwari et al. [24] studied the kinetics and mechanism of the oxidation of Gly by NBS. Reaction followed first order kinetics on both [NBS] and [Gly] and inverse first order on [H^+].

Oxidation of different organic compounds by *N*-chlorobenzenesulphonamide [25], bromate [26], diperiodatonickelate [27], have been also reported. NBP is also among one of *N*-haloimides, as an oxidizing compound.

2 Synthesis of NBP

Initial molecule for the synthesis of NBP is phthalimide, (7.36 g, 50.0 mmol, 1.0 eq), Na_2CO_3 (3.98 g, 37.6 mmol, 0.75 eq), and KBr (5.95 g, 50.0 mmol, 1.0 eq) were mixed in a 500 ml round bottom flask followed by addition of doubly distilled water (200 ml). Then flask was cooled on an ice water bath for 10 min, afterward potassium peroxymonosulfate (30.8 g, 50.1 mmol, 1.0 eq) drape in 75 ml water, with an intense stirring (700 rpm), for 10 min. Next the addition of the oxidant resulted in intense liberation of bromine gas, and thus the flask was capped with a glass stopper between additions. The mixture rapidly turned into an orange lather suspension with visible bromine gas above it. The suspension was kept for continuous 24 h stirring, at which point it had become a yellow solution with a white precipitate. Stirring was continued another 24 h, until the solution above the precipitate was almost clear. The suspension was filtered on a Büchner-funnel and the filter cake sucked dry for a period of 30 min. The white precipitate was dissolved in boiling toluene (150 ml), hot filtered into a beaker and left to cool slowly to ambient temperature, covered with an aluminum foil. Lastly, upon reaching ambient temperature, precipitation had begun and the beaker was placed in a refrigerator at 4 °C for a period of 17 h, before filtering the precipitate on a Buchner-funnel. The filter cake was washed with n-pentane (30 ml) to give 6.52 g (57%) of small white crystals. The mother liquor was concentrated, filtered and the filter cake washed with toluene, and n-pentane. And it was grind with mortar to obtain fine powder of NBP [28].

3 Properties of NBP

(a) It is turbulent in front of sun light but stable when placed in dark. Because it shows photochemical activity and get auto degrade in the presence of light [29].
(b) It is sparingly soluble in water but easily soluble in organic solvent i.e. acetic acid, acetonitrile etc. [30].
(c) After oxidation it generally oxidized into phthalimide which is non-toxic compound and sometime its reaction with organic compounds give carbonyl and cyanide compounds [31, 32].
(d) It contains very polar N–Br bond, so it easily relieve bromine ion for bromination [33] (Fig. 1).
(e) It has different oxidizing species in acidic and basic medium, so it oxidized various organic compounds [34, 35].

4 Reactive species of NBP

N-bromophthalimide was known as powerful oxidizing, and brominating agent. There are five possible reactive species of NBP is reported i.e. free NBP, protonated NBP, Br^+, HOBr, $(H_2OBr)^+$ [82–85], as per the following equilibria:

$$NBP + H_2O \rightleftharpoons HOBr + NHP \quad (1)$$

$$NBP + H^+ \rightleftharpoons NHP + Br^+ \quad (2)$$

$$NBP + H^+ \rightleftharpoons (NBPH)^+ \quad (3)$$

$$HOBr + H^+ \rightleftharpoons \left(H_2OBr\right)^+ \quad (4)$$

Selection of reactive species of NBP was mainly depend on kinetic behavior of medium (acid/base), and phthalimide. Reactive species, leads to a rate law capable of explaining all the kinetics observations and other effects. If phthalimide only showed negative effect on reaction kinetics then HOBr will be possible reactive species (Eq. 1). And acid (H^+) shows first order and phthalimide has negative effect, than possible reactive species for the reaction will be Br^+ (Eq. 2). If phthalimide did not show any effect and acid followed positive fractional order then NBP or protonated NBP will be reactive species for the oxidation process (Eqs. 3, 4).

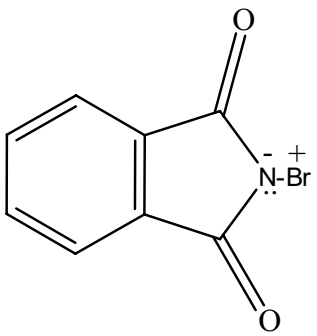

Fig. 1 Structure of *N*-bromophthalimide

5 Overview of earlier work done

NBP has very polar N–Br bond which easily relive bromine for bromination reaction and easily oxidized organic compounds, it is unstable in the presence of sunlight. Researcher managed to set oxidation of organic compounds brick by brick and crafting a formidable pathway from un-catalyzed to catalyzed (transition metal ions and surfactants) oxidation process, and we summarize all report below.

5.1 Oxidation of organic compounds by NBP (uncatalyzed)

As we already know that un-catalyzed reaction required more activation energy to react together. Various reports available in literature for un-catalyzed oxidation of organic compound [36, 37]. It needs more time and energy to complete the reaction, so ultimately increases the cost of the reactions. We found only few reports for oxidation of organic compounds by NBP, e.g. Benzhydrols [38], aspirin [39], substituted oxo-butonic acids [40] in acidic medium.

5.2 Oxidation of organic compounds by NBP (surfactant catalyzed)

Surfactants act as catalyst by making micelles when dissolved in water [41]. It aggregates above certain concentration called critical micelle concentration (CMC) to form micelles. And shapes of micelles i.e. rod like, spherical, bilayers, reverse are responsible for its catalytic activity. Each surfactant has its specific CMC value i.e. CTAB = 8×10^{-4} mol/l, SDS = 8×10^{-3} mol/l. It has both hydrophobic and hydrophilic portion. The rate of reaction has been altered by adding surfactants; it can either increase or decrease the rate of reaction. There are two types of surfactants i.e. cationic and anionic. So, micellar catalyzed reactions have evinced prodigious interest because of their application in many industrial processes. It has some other application like wetting agents, solubilizers, preservatives etc. Normally catalytic activity of the substances is depends on its reaction with substrate, nature of oxidant and conditions (Table 1). Various literature available for micellar catalyzed oxidation of organic compounds with different oxidant, such as chloramines-T, NBS, NBP etc. [42–44].

5.3 Oxidation of organic compound by NBP (transition metal ions catalyzed)

As we all know that transition metal ions have incompletely filled d-orbital, and it easily form one or more stable ions. And have variable oxidation state. As catalyst mainly platinum group among transition metal ions are selected i.e. ruthenium(III), iridium(III), palladium(II) etc. [70]. It is the key material for various industrial processes and can be recycled with less energy and time [71–75]. By literature, we found several articles on the oxidation of several organic compounds NBP in transition metal catalyzed system in acidic and alkaline medium, i.e., D-glucose [76, 77], D-fructose [78], glycine [79, 80], valine [81–83], β-alanine [84], leucine [85], D-arabinose [86].

Overall, it can be said that oxidation efficiency of NBP can be increased up by the used up of catalyst. And from above table, it is very clearly understand that *N*-bromophthalimide is act as active oxidant for the oxidation of organic–inorganic compounds, but still this needs more attention to use as an oxidant. In light of the available information, and of our continued interest in the chemistry of *N*-bromophthalimide, the potential applications of these compounds still remain largely untouched as evident by the scant information available in the literature.

6 Factors affecting oxidation of organic compounds by NBP

6.1 Temperature

The rate of a reaction always increases on increasing temperature, irrespective of the reaction being endothermic or exothermic, because of an increase in the number of activated molecules. In general, the rate of a reaction is doubled on increase in temperature by ten degrees. An examination of the rate expression in the form

$$\text{Reaction rate} = \text{Rate constant} \times (\text{Reactant concentration})^{\text{order}}$$

It shows that the rate constant is a temperature dependent term, but reactants concentrations and the reaction order are eventually not affected by temperature. Thus, rate constant is independent of reactant concentration, it varies with temperature. The activation energy for a reaction is experimentally determined through the Arrehenius equation and Eyring equation.

6.2 Catalyst

Activating effect of certain substance exert a special catalytic force upon the reactants, but in simple manner, catalysis is the process in which alter the rate of a chemical reaction is increased by means of a chemical substances known as a catalyst or a substance that modifies the transition state to lower the activation energy. Unlike other reagents that participate in the chemical reaction, a catalyst is not consumed. Thus, the catalyst may participate in multiple

Table 1 Surfactants catalyzed oxidation of organic compounds by NBP

No.	Organic compounds (substrate)	Reaction conditions	Results	References
1	Dextrose	Dextrose had been oxidize by NBP in the presence and absence of surfactant	The rate of reaction followed first order dependence on [NBP], fractional on [dextrose] and inverse fractional order on $[H^+]$. Stoichiometric ratio showed one mole of NBP was require for complete oxidation of 1 mol of dextrose	[45]
2	DL-Serine	Reaction had been carried out in micellar system using SDS at 308 K in perchloric acid medium, with $[NBP] = 1 \times 10^{-4}$ M, $[serine] = 1 \times 10^{-3}$M, $[H^+] = 0.005$ M, $[SDS] = 8.3 \times 10^{-3}$M	The rate of reaction was first order dependence on NBP, fractional order on serine and inverse fractional for acid. While added mercuric acetate, phthalimide and ionic strength of the medium did not have any significant effect	[46]
3	L-Threonine	Oxidation of L-threonine had been carried out in the presence of CTAB in micellar system in 308 K	Kinetic study revealed that rate of reaction followed first, fractional, and negative fractional order on [NBP], [L-threonine], and $[H^+]$. Salt, phthalimide had no effect on the reaction rate	[47]
4	L-Lysine	Oxidation of L-lysine by N-bromophthalimide (NBP) had been studied at 308 K in the presence of cationic surfactant CTAB on the	The reaction exhibited first order dependence on both [NBP] and [L-lysine], and negative fractional order dependence on acid. CTAB positively catalyzed the reaction The various activation parameters in presence and absence of CTAB had been also evaluated	[48]
5	Lactose	Oxidation of lactose were studied in the catalyzed and uncatalyzed SDS/CTAB by the NBP in acid medium under pseudo first order condition	Rate of reaction followed first, fractional, and negative fractional-order kinetics in NBP, lactose, and sulfuric acid, respectively. Anionic micelles have negative effect on oxidation	[49]
6	Acetaldehyde	Organic compound acetaldehyde was oxidize by NBP in the presence of cationic micelle catalyzed system at 308 K	The order of the reaction with respect to substrate (acetaldehyde) and oxidant (NBP) is first and positive fractional with respect to the $[H^+]$. The rate of the reaction decreased with increase in dielectric constant of the medium. The rate constant first increased with increasing concentration of CTAB and after attaining peak, this rate constant decreased with increase in CTAB concentrations, on further increasing the concentration, it became almost constant. Addition of the inorganic salts, that is, $[Cl^-]$ and $[Br^-]$ rate of the reaction increased. CH_3COOH was identified as the main oxidation product of the reaction	[50]
7	L-leucine	L-leucine had been oxidized by NBP in the presence of cationic micelle CTAB at 308 K and $[NBP] = 1 \times 10^{-4}$M, $[Leucine] = 1 \times 10^{-3}$ M, $[CTAB] = 4 \times 10^{-4}$ M used for the oxidation process	Reaction kinetics followed first order kinetics with respect to [NBP], [leucine] and negative fractional order depend on [acid]. And stoichiometric ratio showed that for oxidation of 1 mol of leucine 1 mol of NBP was required and main oxidation product was identified as aldehyde	[51]
8	L-Alanine	L-alanine (1×10^{-4}M) was oxidize by NBP (5×10^{-4}M) in micellar catalyzed system (8.1×10^{-3}M) at 308 K in acidic medium (5×10^{-3}M)	The rate of reaction followed first, fractional and inverse fractional order for [NBP], [alanine] and $[H^+]$ respectively, mercuric acetate and ionic strength of the medium had no significant effect while phthalimide had inhibitory effect on reaction velocity, CMC values are lower than reported value and main oxidation product of the reaction was methyl cyanide	[52]

Table 1 (continued)

No.	Organic compounds (substrate)	Reaction conditions	Results	References
9	Mannose	Oxidation of mannose ($5x10^{-2}$M) was carried out by NBP ($2x10^{-4}$M) in sulphuric acid medium in micellar catalyzed (SDS, CTAB) system at 313 K	From the kinetic data obtained it was concluded that CTAB enhance the rate of reaction, and SDS retard the rate of reaction. Oxidation kinetics followed first, fractional, and inverse negative order [NBP], [mannose] and [H^+] respectively. Berzin's model has been applied for catalytic role of surfactant and various activation parameters had been calculated on the basis of temperature variation.	[53]
10	Diethylene glycol	Diethylene glycol was oxidize by NBP in the presence of cationic surfactant i.e. CTAB with [diethyl glycol] = 4×10^{-2}M, [NBP] = 2×10^{-4}M, [CTAB] = 1×10^{-3}M, [H^+] = 1×10^{-4}M at 20% acetic acid	Reaction kinetics followed first, fractional, and negative fractional order for [NBP], [diethylene glycol], and [H^+]. While, phthalimide and mercuric acetate had no effect. CTAB increase the rate of oxidation diethylene glycol, and stoichiometric analysis showed that 1 mol of NBP required for the complete oxidation of 1 mol of diethylene glycol and hydroxyaldehyde was found oxidation product	[54]
11	Acetone	Oxidation of acetone had been done in the presence of both cationic and anionic micelles at 308 K, under pseudo first order condition by iodometric determination method, and [NBP] = 2×10^{-4}M required for the oxidation of [acetone] = 3×10^{-3}M,	Rate of reaction showed first order and fractional order dependence on [NBP] & [acetone], CTAB positively influenced the rate of reaction, and SDS had no significant effect. Ionic strength of the medium had positive effect; binding constant was also evaluated. And from above result a mechanism for the oxidation of acetone had been proposed	[55]
12	Lactic acid	Oxidation kinetics of lactic acid ($3x10^{-2}$M) by NBP ($2x10^{-4}$M) had been studied at 318 K in acidic medium ($5x10^{-3}$M) catalyzed by CTAB ($9x10^{-4}$M)	Kinetic study of lactic acid followed first, fractional and inverse fractional order for [NBP], [lactic acid] and [H^+] respectively, CTAB firmly catalyzed the oxidation process, product analysis test showed formation of acetaldehyde and carbon dioxide	[56]
13	β-Alanine	β-alanine ($1x10^{-3}$M) had been oxidized by NBP ($1x10^{-4}$M) at 313 K in the presence CTAB ($9.8x10^{-4}$M) surfactant at 313 K with 50% acetic acid	Kinetics of oxidation of alanine followed first order with respect to [Oxidant], fractional order of [Ala] and inverse fractional order of [acid]. While addition of solvent decreases the rate of reaction. CTAB had positive effect. Increasing [$Hg(OAc)_2$] and inorganic salts i.e. chloride & bromide increased the rate of reaction, whereas a change in ionic strength of the medium had no effect on oxidation velocity. Main oxidation product was identify as Methyl Cyanide	[57]
14	Malic acid	Oxidation kinetics of malic acid by NBP had been studied at 313 K in micelles i.e. [CTAB] = $9X10^{-4}$M, [SDS] = $8X10^{-3}$M	Oxidation of malic acid followed first order kinetics with respect to [Oxidant], fractional order of [malic acid] and inverse fractional order of [acid]. CTAB firmly catalyzed reaction, and SDS had inhibiting effect on oxidation of malic acid	[58]

Table 1 (continued)

No.	Organic compounds (substrate)	Reaction conditions	Results	References
15	Hydroxy acids (tartaric & malic acid)	Tartaric acid {[tartaric acid] = $3x10^{-2}$M, [$Hg(OAc)_2$] = $1x10^{-3}$M, [H^+] = $1x10^{-2}$M} and malic acid {[malic acid] = $3x10^{-2}$M, [$Hg(OAc)_2$] = $7.5x10^{-4}$M, [H^+] = $5x10^{-3}$M} were oxidizing by NBP ($2x10^{-4}$M) in the presence CTAB ($9x10^{-4}$M) at 313 K in perchloric acid medium.	The oxidation of TA and MA by NBP in the presence of CTAB is faster than in the absence of surfactant. The rate of oxidation of hydroxy acids was found to be in the order: TA > MA. First order kinetics with respect to NBP was observed in the oxidation of both hydroxy acids. The kinetics results indicate that the first order kinetics in hydroxy acids at lower concentrations tends towards a zero order at its higher concentrations. Inverse fractional order in [H^+] and [phthalimide] were noted throughout its tenfold variation. With a progressive increase in [CTAB], Variation of [$Hg(OAc)_2$] and ionic strength (μ) of the medium did not bring about any significant change in the rate of reaction.	[59]
16	Glycine	SDS ($8.1x10^{-3}$M) catalyzed oxidation of glycine ($5x10^{-4}$M) by NBP ($1x10^{-4}$M) was studied at 308 K under pseudo first order condition	The rate of reaction was found to have first-order dependence on [NBP] and fractional-order on [glycine] and [H^+]. The addition of phthalimide had no significant effect on the rate of reaction. While increasing $Hg(OAc)_2$ and bromide ion increased the rate of reaction, whereas a change in ionic strength of the medium had no effect on oxidation velocity. HCN was found as the oxidation product of the reactions.	[60]
17	Citric acid	Citric acid (2×10^{-2}M) was oxidize by NBP ($2x10^{-4}$M) with CTAB ($9x10^{-4}$M) at 308 K	Oxidation kinetics followed first & fractional order dependence on [NBP], [citric acid] respectively, the main oxidation product of the reaction was acetone dicarboxylic acid and stoichiometric analysis revealed that 1 mol of NBP required for the oxidation of 1 mol of citric acid	[61]
18	Acetophenone	Oxidation of acetophenone was studied iodometrically in the presence of two different cationic and anionic surfactant at 308 K and [CTAB] = 9.8×10^{-4}M, [SDS] = 8.3×10^{-3}M	Cationic micelle CTAB strongly oxidized acetophenone as compare to SDS and mercuric acetate and phthalimide had negligible effect on rate of oxidation, and $(NBPH)^+$ was the reactive species of NBP	[62]
19	Oxalic acid	Oxidation of oxalic acid by NBP was studied at 308 K and catalyzed by cationic surfactant CTAB in micellar system	The rate of reaction followed fractional, first and negative fractional order [Oxalic acid], [oxidant] and [H^+] and on the basis of results obtained a plausible mechanism has been proposed	[63]
26	Glycolic acid	Glycolic acid was oxidized in micellar system catalyzed by cationic micelles CTAB at 318 K.	The oxidation kinetics followed first, fractional and inverse fractional orders with respect to [NBP], [glycolic acid] [H^+] respectively and critical micelle concentration of CTAB was found to be lower than those reported in the literature, and it positively increased the rate. And on the basis of results a plausible mechanism had been proposed	[64]
27	Dextrose	Dextrose ($5x10^{-2}$M) was oxidize by NBP ($2x10^{-4}$M) in CTAB ($1x10^{-3}$M) catalyzed micellar system at 313 K (high temperature)	The reaction followed first order and fractional-order kinetics, with respect to [NBP] and [dextrose], respectively. Addition of CTAB increased the rate of reaction. And mercuric acetate and phthalimide had negative effect.	[65]

Table 1 (continued)

No.	Organic compounds (substrate)	Reaction conditions	Results	References
28	Galactose	Oxidation of galactose had been done in the presence of cationic surfactant cetylpyridinium chloride (CPC) in acidic medium at 308 K.	Oxidation kinetics of galactose showed fractional, first, and negative fractional order with respect to [galactose], [NBP], and $[H^+]$. The rate of reaction decreased with an increase in dielectric constant of the medium. The effect of cationic surfactant cetylpyridinium chloride (CPC) has been studied. CPC retards the rate of reaction. Various activation parameters have been also evaluated	[66]
29	DL-aspartic acid	Oxidation of DL-aspartic acid had been carried out at 308 K in the presence of anionic surfactant SDS in acidic medium	The rate of reaction was found to follow first-order kinetics dependence on [NBP], fractional order dependence on [aspartic acid] and inverse fractional order dependence on $[H^+]$. Effect of chloride ion, ionic strength, of the medium and mercuric acetate had no significant effect on reation rate but addition of Phthalimide has decreased the rate of reaction. Main oxidation product was found $COOH\text{-}CH_2\text{-}CN$.	[67]
30	D-fructose	$[NBP] = 2\times10^{-4}$ M, [D-fructose] $= 2\times10^{-2}$M, $[CTAB] = 9.2\times10^{-4}$ M, $[SDS] = 8.3\times10^{-3}$M at 303 K used for the oxidation of D-fructose	Oxidation of D-fructose showed first, fractional order kinetics with respect to [NBP], [D-fructose], there is no effect of mercuric acetate while CTAB increases and SDS decreased the rate of reaction and a suitable mechanism was propose to explain all results obtained	[68]
31	D-sucrose	$[NBP] = 2\times10^{-4}$ M, [D-sucrose] $= 1\times10^{-3}$M, $[CTAB] = 1.2\times10^{-3}$ M, $[SDS] = 1.0\times10^{-2}$M at 308 K are the reaction conditions for the oxidation process	Oxidation of D-sucrose showed first, fractional order kinetics with respect to [NBP], [D-sucrose], there is no effect of mercuric acetate and stoichiomertic ratio for NBP and sucrose 1:2 and major oxidation product was aldonic acid	[69]

chemical transformations, although in practice, catalysts are sometimes consumed in secondary processes. The catalyst increases rate of reaction by providing a different reaction mechanism to occur with lower activation energy. But sometime it decreased the rate of reaction. In present review transition metal ions and surfactants (CTAB, SDS) were use as catalyst, where anionic surfactants sometime retard the rate of reaction.

6.3 Ionic strength

The ionic strength (I), refer to the strength of electric field in the solution according to the theory of Bronsted and Bjerrum [87], which postulates the reaction through the formation of an activated complex. According to this theory, the effect of ionic strength on the rate for a reaction involving two ions:

$$\log k = \log k_0 + 1.02\, Z_A Z_B I^{1/2}.$$

where Z_A and Z_B are the valency of the ions A and B, k and k_0 are the rate constant in the presence and absence of the added electrolyte respectively. A plot of log k against $I^{1/2}$ should be linear with a slope of 1.02 $Z_A Z_B$. If $Z_A Z_B$ have similar signs, the quantity $Z_A Z_B$ are positive, and the rate increases with the ionic strength having positive slope, while if the ions have dissimilar charges, the quantity $Z_A Z_B$ are negative and the rate would decrease with increase in ionic strength, having negative slope.

6.4 Effect of dielectric constant

For the study of dielectric constant of the medium, various solvent i.e. acetic acid and acetonitrile etc. were generally used in different percentage (%). The effect of dielectric constant of the medium on the rate constant of a reaction between two ions has been described by the well known equation given below

$$\log k = \log k_0 - \frac{Z_A Z_B e^2 N}{2.303(4\pi\varepsilon) d_{AB} RT} \times \frac{1}{D}$$

where k_0 is the rate constant in a medium of infinite dielectric constant, Z_A and Z_B are the charges of reacting ion, d_{AB} refers to the size of activated complex, T is absolute temperature and D is dielectric constant of the medium. This equation shows that if a plot is made between log k versus 1/D, a straight line and—$Z_A Z_B$ and $e^2N/2.303(4\pi\epsilon o)$ $d_{AB}RT$ will be equal to slope. And with help of this equation we can also calculate the size of activated complex (d_{AB}).

7 Economics of the process

After oxidation of organic compounds, NBP gave phthalimide, carbonyl compound, which is non-toxic and after separation we can use it for another reaction. And it is environment favorable compound. If we used NBP in proper manner with precaution and by using catalyst we can decrease cost of reaction. And from above study we saw that these reactions did not required any type of costly instruments or chemicals. But still it need more focus because it's reported literature, available only in laboratory scale or pilot scale not for industrial purpose.

8 Conclusion

Use of NBP, as an oxidant is still field of experiment; we need more, to focus on its diverse behavior. In summary, *N*-bromophthalimide was successfully used to oxidize kinetically various organic compounds either catalyzed (micellar or transition metal) or un-catalyzed reaction. Mainly two experimental methods were use for the degradation process i.e. iodometric, and potentiometric. In present review catalyst with different active species gave various reactive species of NBP to oxidize various organic compounds. And NBP is unstable for more than 24 h, so we have to develop a method for its stability for long time. Thus, NBP could be used as promising oxidant for the oxidation of pollutants present in water.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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