

# Kinetics of hydrolysis of Mono-4-methyl-2-nitro aniline phosphate ester in Buffer medium

Bhawana Bairagi, R.A.Banjara and S.A. Bhoite\*

School of studies in Chemistry, Pt. Ravi Shankar Shukla University, Raipur-492 010, India.

\*Corres.author: sa.bhoite10@gmail.com

**Abstract:** The kinetics of hydrolysis of Mono-4-methyl-2-nitroaniline phosphate has been carried out in buffer solution at 50°C in the pH range 0.00 to 7.46. The rate of reaction increases with increase in pH up to 4.17. The maximum value at pH 4.17 is due to hydrolysis via mononegative and neutral species. The neutral and monoanion have been found to be reactive. The experimental and theoretical rate values are in good agreement. The nature of molecularity of hydrolytic reaction has been decided on the basis of temperature and solvent effect. The monoester involves P-N bond fission, which is strengthened by comparative kinetic rate data.

**Key words:** Kinetics, Buffer medium, Mono-4-methyl-2-nitroaniline.

## Introduction

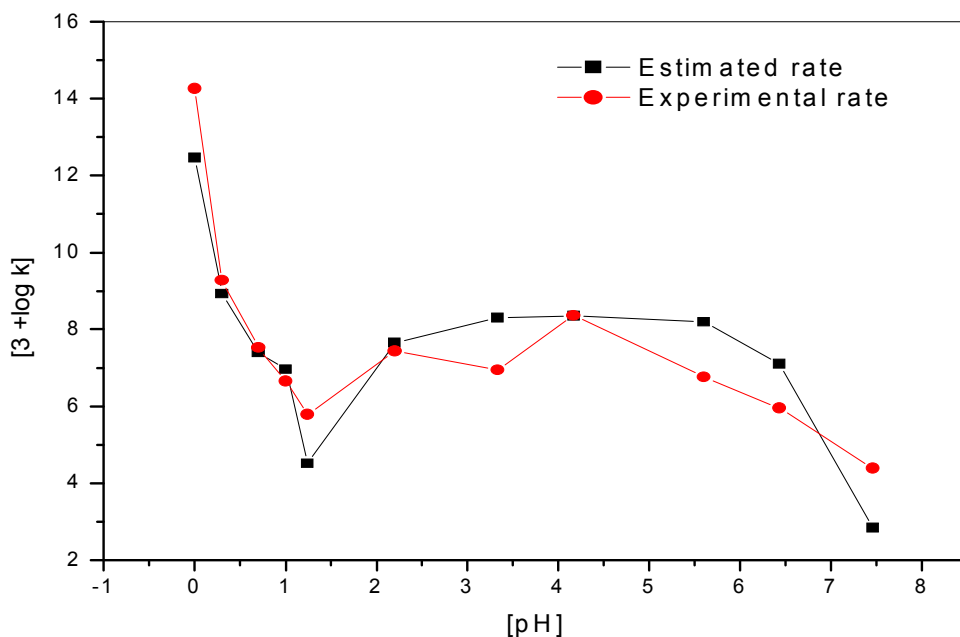
Organophosphates esters are the derivatives of orthophosphoric acid. An infinite ramifications are possible by making changes in subsistent groups through specific linkages such as C-N-P, C-O-P. Therefore they constitute a large family, which display a great role in the biological,<sup>1</sup> industrial,<sup>2</sup> academic, agricultural<sup>3</sup> and medicinal<sup>4</sup> fields. They play a vital role in photosynthesis and conversion of sugar into starch in plants and also involved in nitrogen fixation<sup>5</sup>. Many organophosphorus compounds are commonly used as insecticides even though they display extreme toxicity to humans<sup>6,7</sup>. Organophosphorus compounds are utilized as flame-retardants<sup>8</sup>, plasticizer<sup>9</sup> and also used to manufacture leather cloths such as seat covers, other utility articles viz footwears, raincoats handbags etc. Phosphates and phosphoramidates are widely used as prodrug moieties to enhance water solubility or therapeutic

potential of a parent drug<sup>10</sup>. Recently two nucleoside analogues 3-azidothymidine (AZT) and 2-3-dideoxycytidine (DDC), have been therapeutically used for the treatment of acquired immune deficiency syndrome (AIDS) patients<sup>10</sup>.

## Experimental

Mono-4-methyl-2-nitroaniline phosphate (Ba-Salt) has been prepared from 4-methyl-2-nitro aniline and phosphorus pentoxide by the method described earlier<sup>11</sup>. Kinetic study of the hydrolysis of Mono-4-methyl-2-nitroaniline phosphate has been carried out 50°C employing  $5 \times 10^{-4}$  mol dm<sup>-3</sup> solution of the monoester in aqueous medium. The buffer solutions were maintained using appropriate mixture of KCl, COOH, C<sub>6</sub>H<sub>4</sub>.COOH, NaOH and H<sub>3</sub>BO<sub>3</sub>. Allen's modified method<sup>12</sup> was used for spectrophotometric determination of inorganic phosphate. All the chemical used during work were of A.R. grade.

Fig :- 1: pH log rate profile for the hydrolysis of mono-4-methyl-2-nitroaniline phosphate at 50°C



**Results and Discussion**

Hydrolysis of Mono-4-methyl-2-nitroaniline phosphate has been studied at 50°C in the pH range 0.00 to 7.46 using suitable buffers. Fig. 1 shows the pH log rate profile in which theoretical rates are closely agreed with those observed rates. The rate of reaction increases with the increase in pH up to 4.17. The maximum value at pH 4.17 is due to hydrolysis via mononegative species and dissociation of neutral species. After pH 4.17 the fall in rates is due to the inertness of the dinegative species<sup>13</sup>. A slight deviation of the experimental rate in pH range 0.00 to 2.00 has been found to be due the incursion of the neutral species. Similar nature of hydrolysis was observed in the case of ortho and p-methoxy phenyl dihydrogen phosphate<sup>14</sup>, p-ethoxy phenyl dihydrogen phosphate<sup>14</sup>, 2,3-dimethoxy phenyl dihydrogen phosphate monoester<sup>15</sup>. Neutral & mononegative rates can be represented as :

$$k_N = k_{N_0} \frac{N}{N + M} \dots\dots\dots(1)$$

$$k_M = k_{M_0} \frac{M}{M + N} \dots\dots\dots(2)$$

where  $k_{N_0}$  is specific neutral rate,  $k_{M_0}$  (specific mononegative rate) is experimental rate at pH 4.17 and  $N/N + M$  and  $M/M + N$  are the fraction of neutral and mononegative species respectively. The

results summarized in Table -1 show that there is close agreement between calculated and experimental rates. The value of specific neutral rates ( $k_{N_0}$ ) was determined from the relation:

$$k_e = k_{M_0} \cdot \frac{M}{M + N} + k_{N_0} \cdot \frac{N}{N + M} + k_H^+ \cdot C_H^+ \dots\dots\dots (3)$$

Where  $k$  is experimental rate. There is a good agreement between values of specific neutral rate  $k_{N_0}$  determined by equation (3) is  $6.633 \times 10^{-3} \text{ min}^{-1}$  at different pH from 0.00 to 1.00 and from ionic strength data is  $6.57 \times 10^{-3} \text{ min}^{-1}$ .

It is clear from Table -1 that in the pH range 0.00 to 1.00; hydrolysis governs by neutral conjugate and mononegative species. In the pH range 1.00 to 1.24, the reactions are via neutral and mono negative species. In the pH range 1.24 to 7.46 only mononegative species are reactive.

Kinetic rate laws for the hydrolysis of Mono-4-methyl-2-nitroaniline phosphate may be represented as :

(1) In the pH range 0.00 to 1.00  
 $k = k_H^+ \cdot C_H^+ + 8.363 \times 10^{-3} \frac{M}{M + N} + 6.633 \times 10^{-3} \frac{N}{N + M}$

(2) In the pH range 1.00 to 1.24  
 $k = 8.363 \times 10^{-3} \frac{M}{M + N} + 6.633 \times 10^{-3} \frac{N}{N + M}$

**(3)** In the pH range 1.24 to 7.46

A change over from water to aqueous dioxane increases the rate showing dispersion of changes in the transition state <sup>(16)</sup> as shown in Table -1. Arrhenius parameter for hydrolysis via neutral and mononegative species summarized in Table-2 are in favour of a bimolecular reaction. A comparative kinetic rate data for the hydrolysis of some phosphate monoesters

$$k = 8.363 \times 10^{-3} M / M + N$$

via neutral and mononegative species as shown in Table - 3 and 4 also supports the bimolecular nature of hydrolysis involving P-N bond fission. The probable reaction mechanism for the hydrolysis of mononegative species and neutral species of Mono-4-methyl-2-nitroaniline phosphate has been represented.

**Table -1: Estimated and Experimental Rates of the Hydrolysis of Mono-4-methyl-2nitroaniline Phosphate (Ba-Salt) via Neutral and Mononegative Species at Different pH values at 50°C**

pH	M/M+N	N/N+M	$k_M 10^3$ (min <sup>-1</sup> )	$k_N 10^3$ (min <sup>-1</sup> )	$k_H^+ C_H^+ 10^3$ (min <sup>-1</sup> )	$k 10^3$ (min <sup>-1</sup> ) (Estd.)	$k 10^3$ (min <sup>-1</sup> ) (Expt.)	3+logk (Estd.)	3+logk (Expt.)
0.00	0.063	0.937	5.268	6.156	8.368	12.458	14.256	1.096	1.153
0.30	0.119	0.881	9.951	5.788	6.713	8.929	9.268	0.9508	0.9669
0.70	0.253	0.747	2.115	4.907	6.141	7.396	7.529	0.8689	0.8767
1.00	0.403	0.597	3.370	3.922	4.829	6.965	6.654	0.8429	0.8230
1.24	0.540	0.450	4.516	2.956		4.516	5.784	0.6547	0.836
2.20	0.915	0.085	7.652	5.584		13.843*	7.439	0.8837	0.87155
3.33	0.993	0.007	8.304	4.599		15.914+	6.945	0.9192	0.8416
4.17	0.999	0.001	8.354	6.572		18.322**	8.363	0.9218	0.9223
5.60	0.980	-	8.195			7.652	6.760	0.9135	0.8299
6.43	0.850	-	7.108			8.304	5.954	0.8517	0.7741
7.46	0.340	-	2.843			8.354	4.385	0.4537	0.6419
						14.551*			
						16.197+			
						21.314**			
						8.195			
						7.108			
						2.843			

\*10 % dioxane, +20% dioxane, \*\*30 % dioxane

**Table-2: Arrhenius Parameter for the Hydrolysis of Mono-4-methyl-2-nitroaniline Phosphate (Ba-salt) via Neutral and Mononegative Species at 50°C**

pH	E (Kcal/mole)	A (Sec <sup>-1</sup> )	-ΔS <sup>‡</sup> (e.u.)
1.24	10.98	1.10 x10 <sup>6</sup>	35.85
4.17	9.609	1.57x10 <sup>7</sup>	31.78

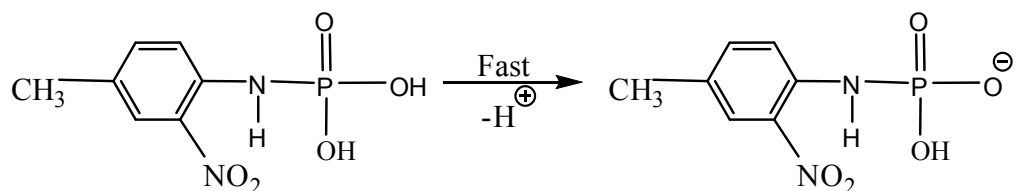
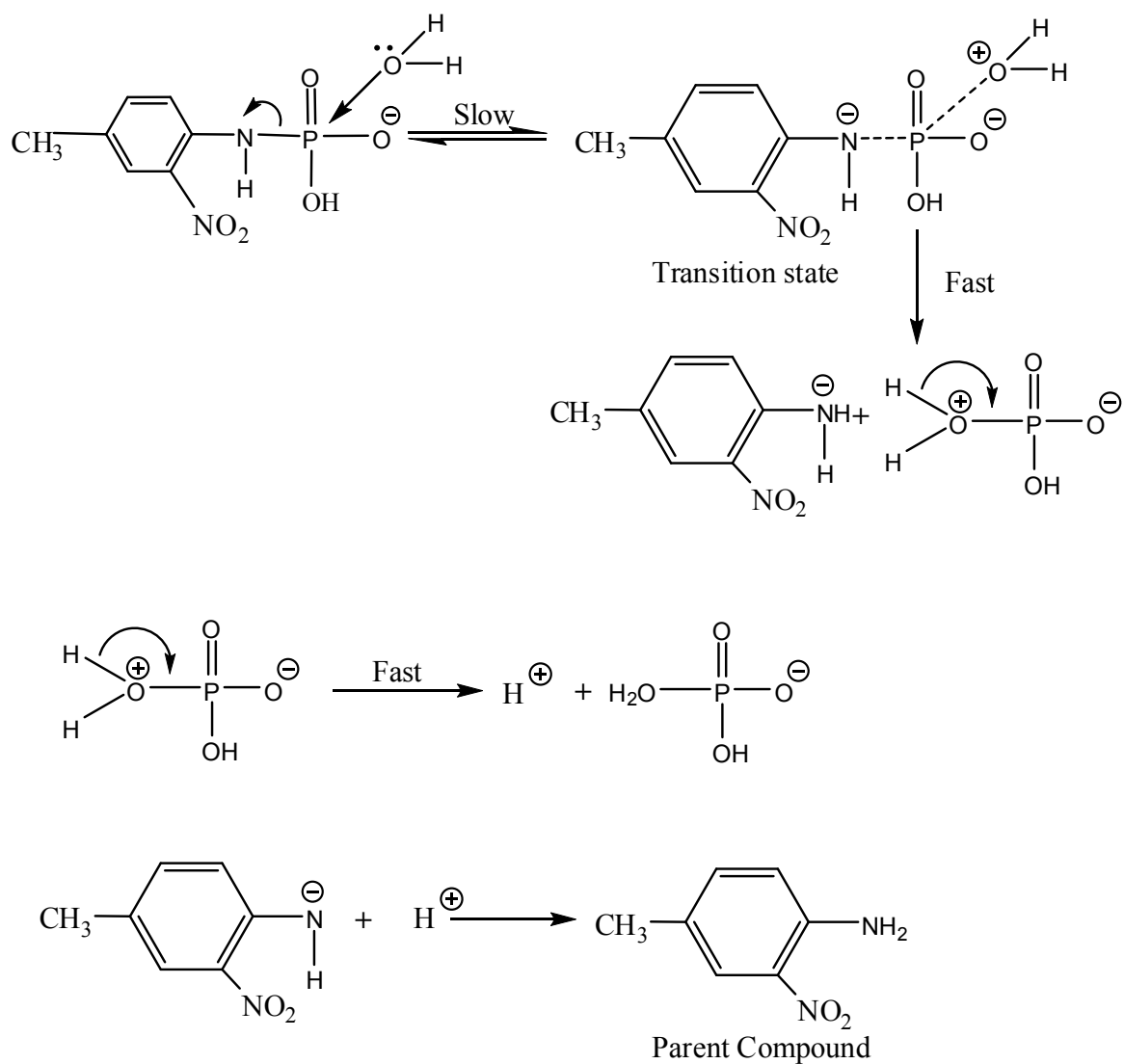
**Table – 3: Comparative Kinetic Rate Data for the Hydrolysis of Some Phosphate Monoesters via Neutral Species .**

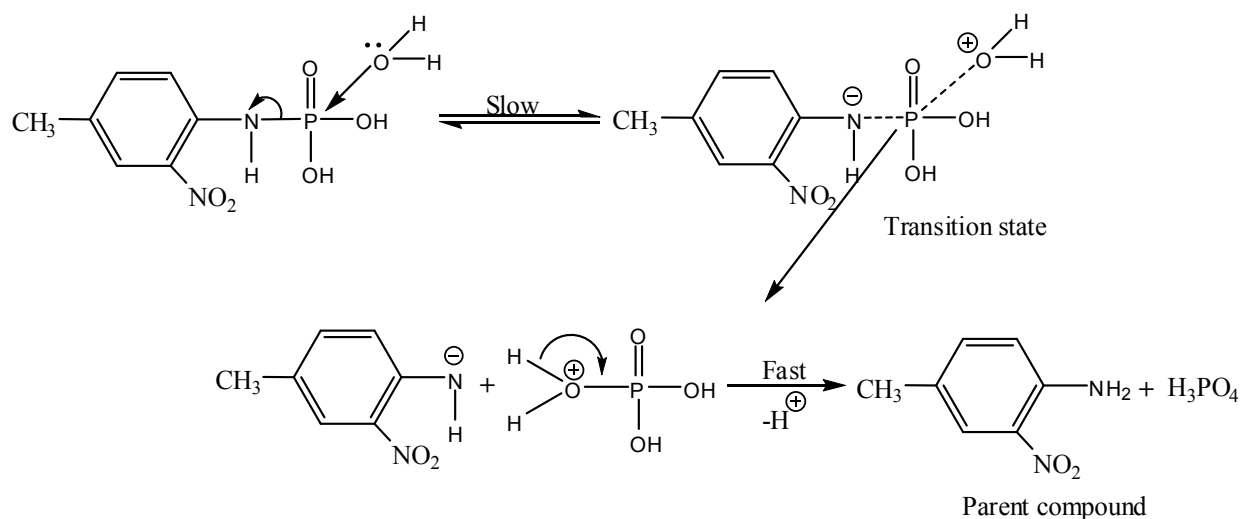
Sr. No.	Phosphate monoesters	Medium pH	E (Kcal/mole)	$-\Delta S^\ddagger$ e.u.	molecularity	Bond fission
1	p-nitro aniline	1.20	11.44	48.52	2	P-N
2	4-methyl-2-nitro aniline	1.24	10.98	35.85	2*	Present work
3	2-chloro-5-nitro aniline	1.24	3.38	69.57	2	P-N
4	Dinitro Diphenyl Amine	1.24	7.59	57.40	2	P-N
5	2,5-Dichloro aniline	1.24	5.03	64.77	2	P-N

**Table – 4: Comparative Kinetic Rate Data for the Hydrolysis of Some Phosphate Monoesters via Mononegative Species**

Sr. No.	Phosphate monoesters	Medium pH	E (Kcal/mole)	$-\Delta S^\ddagger$ e.u.	Molecularity	Bond Fission
1	2-4-Dinitro Aniline	4.17	13.30	44.40	2	P-N
2	p-toluidine	4.17	12.26	31.56	2	P-N
3	O-toludine	5.20	10.05	40.52	2	P-N
4	4-methyl- 2-nitro-aniline	4.17	9.609	31.78	2	Present Work
5	Diisopropyl aniline	4.17	8.69	54.74	2	P-N

## Formation of mononegative species

Bimolecular nucleophilic attack of water on phosphorus via mononegative species  $SN^2(P)$ 

**Mechanism via neutral species**Bimolecular attack of water on phosphorus atom of the neutral species  $SN^2$  (P)**References**

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