

# "Effect of aquo T.H.F. (Solvent medium) on the Kinetics and Mechanism of Hydrolysis of Biologically Active Ester Ethylnicotinate"

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## ABSTRACT:

The hydrolysis of ethylnicotinate in water-T.H.F. solvent mixture was investigated volumetrically for kinetic studies. The composition varying from 20-80% (v/v) at different temperatures range from 20°C – 40°C. The rate of reaction decreases continuously with decreasing concentration of water at all varying temperatures. The iso-composition activation energy ( $E_C$ ) rises with increasing the proportion of solvent. The kinetics of the reaction was also investigated in term of solvent composition, dielectric constant and the concentration of water. The thermodynamic activation parameters were also calculated. There is Increase in the numerical value of free energy of activation ( $\Delta G^*$ ) with simultaneous decrease in entropy of activation ( $\Delta S^*$ ) and enthalpy of activation ( $\Delta H^*$ ), of the reaction mixture.

**Keywords :** Solvolysis effect, aquo-T.H.F. mixture, ethylnicotinate, specific rate constant, iso-composition and iso-dielectric activation energy, activated complex, transition state and the effect of the addition of ZnO-nanoparticles.

## 1. Introduction :

The effect of T.H.F. solvent on the rate and the mechanism of base catalyzed hydrolysis of ethylnicotinate have received continued attention over the time period<sup>[1-6]</sup>, but the effect of T.H.F. (solvent) on the rate of reaction, mechanism of the reaction and

thermodynamic activation parameter of solvolysis of ethylnicotinate (ester) and solvent solute interaction in the reaction media consisting of T.H.F. and also addition of ZnO nanoparticles have not been reported so far. The main conclusion from these studies is that the reactivity is influenced by solvolysis, transition state through specific and non-specific solvent solute interaction.

Hence, in present investigation the above untouched works, it has been proposed to make a comprehensive studies of base catalyzed solvent effect of biologically active esters, for study in detail because esters of nicotinic acid and nicotinamide derivatives are useful pharmacologically active molecule are used, since long as pro drug. Thus the present investigation is quite interesting and important from point of kinetic study.

## 2. Experimental :

The quality of Ethylnicotinate of fluke AG grade and T.H.F. of high quality grade were used. The A ZnO nanoparticles was used. All other chemicals used were either of BDH or Merck grades. The strength of the Solution was kept N/5 N with respect to NaOH and N/5 N with respect to ester, in the reaction mixture. The reaction was found to obey second order kinetics and the evaluated value of specific rate constant is recorded in table-1. The variation of log k with mole % is shown in table-2 with the help slop of Arrhenins plot of log k verses  $1/T$  (table-3) the iso-composition activation energy ( $E_0$ ) was calculated and inserted in table-4 The values of iso-dielectric activation energy ( $E_C$ ) were calculated of different dielectric constants. The variation of log k with log ( $H_2O$ ) is also mentioned in table-5.

The thermodynamic activation parameter, i.e., ( $\Delta G^*$ ), ( $\Delta S^*$ ) and ( $\Delta H^*$ ) values calculated with the help of Wynne-Jons and Eyring<sup>[6]</sup> equation and has been Tabulated in table.

### 3. Result and Discussion :

**3.1. Solvent Effect on Specific Rate :** The second order kinetics, the rate constants for base catalyzed hydrolysis of ethylnicotinate in water T.H.F. mixture were calculated, and also with ZnO nanoparticles were calculated at 20°C, 30°C and 40°C. From the slope of linear plot of log k against time (t). The rate constant at different temperature and composition are collected in table. The log k value is also plotted against the mole % of added solvent (T.H.F.) in the reaction media (tabulated in table and Fig.-1). The valued are found to be decreasing trend with the increasing composition of the solvent. The trend of variation in the values of specific rate constant (Table.) can be discussed in the light of Hughes and Ingold<sup>[7]</sup> theory. In alkali catalyzed hydrolysis of ethylnicotinate, the dielectric constant value of reaction media increase with gradual addition of organic co-solvent.

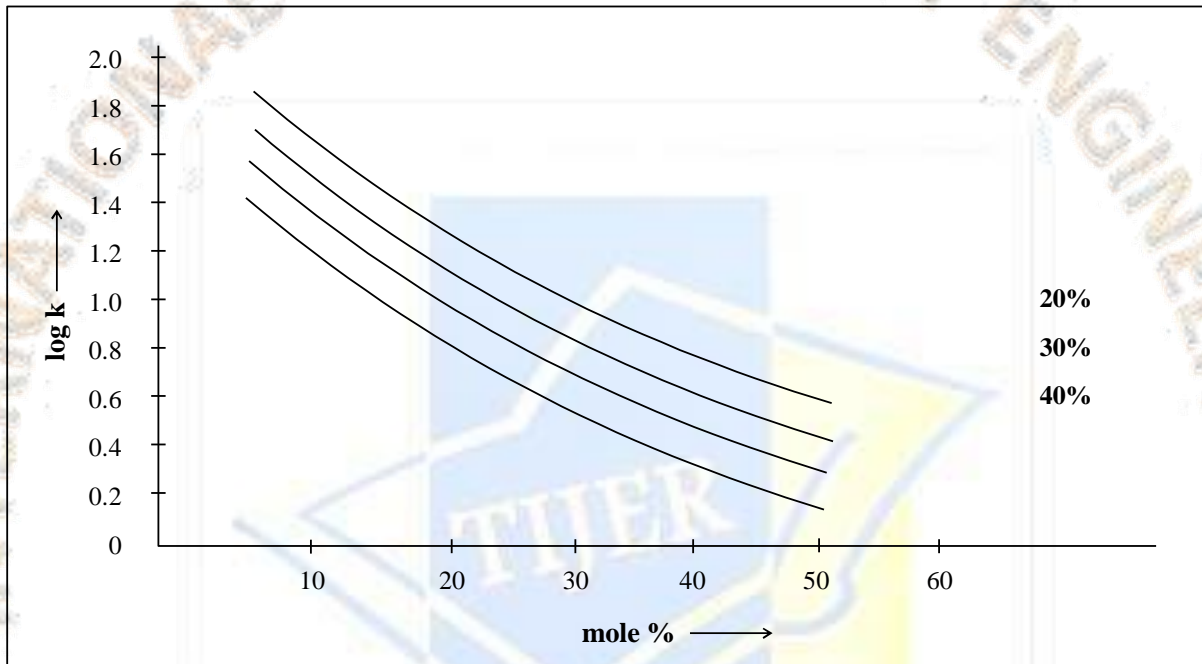
- a. The depletion in rate is due to the decrease in the polarity of the reaction media by adding less polar T.H.F. or decrease in bulk dielectric constant value of medium.
- b. The decrease in the polarity due to addition of less polar solvent and also decrease in bulk dielectric constant, is in good agreement with the theory of Hughes and Ingold. Such decrease in rate constant with increasing proportion of organic co-solvent like methanol was also reported by Elsemongy<sup>[8]</sup> and recently by A.K. Singh.<sup>[9]</sup>

**Table 1 : Specific rate constant K values of alkalicatalyzed hydrolysis of ethylnicotinate in water-T.H.F. System**

Tem. in °C	% of T.H.F.			
	20%	40%	60%	80%
20°C	17.84	14.37	11.78	9.24
30°C	34.98	29.31	21.27	17.99
40°C	68.70	54.87	37.87	28.32

**Table 2 : Variation of log k value against + mole %  
(water-T.H.F. System)**

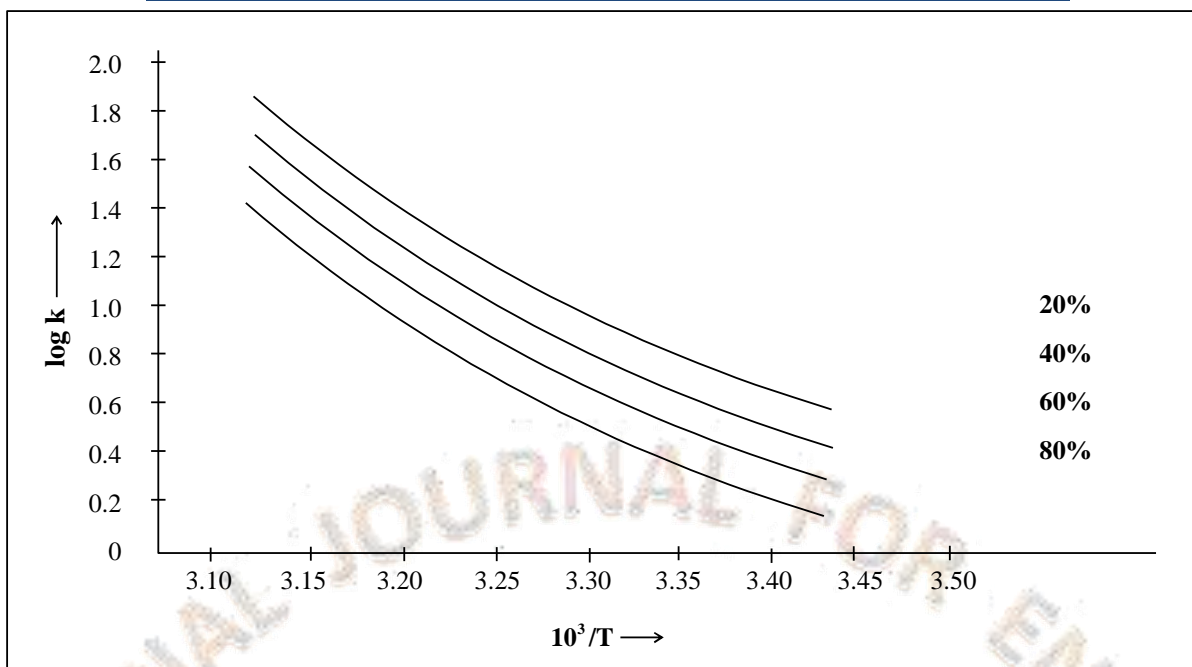
% of T.H.F.	log k			
	mole %	20°C	30°C	40°C
20%	5.25	1.251	1.543	1.836
40%	12.87	1.157	1.467	1.739
60%	25.00	1.071	1.327	1.578
80%	47.06	0.965	1.255	1.452



**Fig. 1: Variation of log k with mole %**

**Table 3 : Variation of log k values against  $10^3/T$ , water-T.H.F. System**

Temp. in °C	log k				
	$10^3/T$	20%	40%	60%	80%
20°C	3.412	1.251	1.157	1.071	0.965
30°C	3.300	1.543	1.467	1.327	1.255
40°C	3.194	1.836	1.739	1.578	1.452


 Fig. 2: Variation of log k with  $10^3/T$ 
**Table 4 : Values of Iso-composition Activation Energy with Increasing Percentage of Solvent (water-T.H.F. Media)**

% of T.H.F.	20%	40%	60%	80%
$E_{\text{exp.}}$ in J/mole	52.92	49.13	45.33	35.58

### 3.2 Evaluated Values of iso-composition Activation Energy ( $E_C$ ) of the Reaction :

The value of iso-composition activation energy ( $E_C$ ) of the reaction has been evaluated from Arrhenins plot of log k values of the reaction against  $10^3/T$ . The plot are shown in figure and the numerical values of  $E_C$  of the reaction are listed in table-3. The value of  $E_C$  decrease with increasing the concentration of T.H.F. has been established that changes the value of activation energies and this is noticeable only when the salvation changes take place in either initial state level or at transition state level or both levels. The decrease in activation energy of the reaction with decrease in specific rate constant values may seem to be quite natural. The following three possibilities can be hold responsible for depletion in the values of  $E_C$ .

- Transition state is more solvated than initial state.
- The transition state is less desolvated than initial state, and

- (c) The transition state is solvated and the initial state is desolvated.

Out of the these three factors, the third seems to be applicable in our case, as this factor is by decrease in the values of entropy of activation ( $\Delta S^*$ ) and enthalpy of activation ( $\Delta H^*$ ) with gradual addition of organic co-solvent (T.H.F.) in the reaction media.

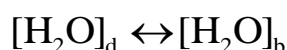
This conclusion is also supported recently by Singh R.T. et al.<sup>[10]</sup>

**3.3. Effect of Solvent on Iso-dielectric Activation Energy :** The value of Iso-dielectric activation energy ( $E_D$ ) is calculated by plotting Arrhenius plot of  $\lg K_D$  values against  $1/T$  and evaluated values are recorded. This shows that  $E_D$  value goes up with increasing dielectric value in the reaction media. This interpretation was supported by past view of Woford<sup>[11]</sup> and recently it is supported by Singh R.T. et al.<sup>[12]</sup>

**3.4. Effect of Solvent on Solvation Number and Mechanistic Path of the Reaction :** Salvation number ( $n$ ) that is the number of water molecule associated with activated complex is evaluated by using Robertson<sup>[13]</sup> relation.

$$\log K = \log K_0 + n \log [H_2O]$$

The salvation number ( $n$ ) is determined by plotting  $\log K$  against  $\log [H_2O]$ . The slope of plot give the number of water molecule associated with activated complex. By the observation of the value of slope, it is indicated that the value of slopes increases from to which attributes to the fact that equilibrium of water molecule by addition of T.H.F. is shifted from dense form to bulky form with rise of temperature.



It shows that, with addition of T.H.F. to water the mechanism path of reaction is changed from bimolecular to unimolecular. The similar way is observed by Parker and Tomillinson<sup>[14]</sup> and recently by Singh A.K.<sup>[15]</sup>

**Table 5 : Variation of  $2 + \log k$  with  $\log [H_2O]$  (water-T.H.F.)  
at different temperature.**

% of T.H.F.	% of H <sub>2</sub> O	$\log [H_2O]$	$2 + \log k$		
			20°C	30°C	40°C
20%	80%	1.65	2.251	3.543	3.836
40%	60%	1.52	3.157	3.467	3.739
60%	40%	1.32	3.071	3.327	3.578
80%	20%	1.16	2.965	3.255	3.452

#### 4. Conclusion :

In the alkaline hydrolysis of ethylnicotinate, the decrease in rate constant with mole percentage of co-solvent either decrease in bulk dielectric constant value or it decreases in polarity of reaction media by the addition of less polar T.H.F. to it.

Decreasing trend of activation energy ( $E_C$ ) with increase co-solvent inferred the salvation in transition state and desolvation in initial state. The increasing number of water molecule associated with activated complex with increasing temperature shows that the mechanism of reaction media changes from bimolecular kinetics to unimolecular kinetics with the addition of solvent (T.H.F.). Same trend is obtained with the addition of ZnO nanoparticles.

#### 5. References :

1. Sing A.K., Kinetics and solvent effect on activation parameter of aqua-propanol solvent system for acid catalyzed solvolysis of propyl formate. International Journal of Chemic Science 2019; 3(4) : 85-88.
2. Singh A.K. Solvent effect and kinetics on solvolysis of propyl formate in water propanol solvent mixture, International Journal of Chemical Science. 2019 : 3(4) : 82-84.

3. Singh A.K., Activation parameters and solvent effect on solvolysis of ethylbenzoate in aqno-organic solvent system, Asian Journal of Research in Chemistry 2019 : 12(2) : 99-102.
4. Bano Arjuman, Singh A.K., A kinetic Study of Solvent Effect of aqno-ethanol solvent system on thermodynamic activation parameters of the catalyzed solvolysis of ethynicotinate. Journal of Ultra Chemistry 2019 : 13(5) : 121-124.
5. Singh A.K. Solvent effect on enthalpy and entropy of activation for the hydrolysis ethylcinnamate in mixed solvent system, Journal of Phy. Chem. Biophys, 2017, 7(7).
6. Singh A.K, the influence of solvent on solvolysis of ethyl cinnamate in water acetone mixed solvent system, Chemical Sciences Journal, 2017, Idoi : 10. 4172/2150 3494.1000150, Volume-8, Issue 1, 1000150.
7. Wynne Jone WFK, Eyring H. Theory of rate of Rate process McGraw Hill, New York, 1941.
8. Hughes ED., Ingold CK, Mechanism of substitution at saturated carbon atom part IV, A discussion of constituent and solvent effect on mechanism, kinetics, velocity and orientation of substitution, J. Chem. Soc. 1935, 244-255.
9. MM Elsemongy Abu, Elamayn MS, Moussa Z. Phys. Chem. 1973; 84-294.
10. Singh A.K., A kinetics study of solvent effect on thermodynamics activation parameter on alkali catalyzed solvolysis of methyl salicylate in water DMF media, Inter, Journal of Adv. Research and Innovation, 2015; 3(3) : 547-549.
11. Singh A.K., The influence of solvent on solvolysis of ethcinnamate in water acetone mixed solvent system. Chemical Sciences Journal 2017. Idoi;10.4172/2150-3494.1000150. Volume 8. Issue 1.1000150.



12. Wolford R.K., Kinetics of the acid catalyzed hydrolysis of acetal in dimethyl sulfoxide water solvents at 15, 25 and 35°, J. Phys. Chem. 1964; 68(11) : 3392-3398, J. Phys. Chem. 68, 3392, 1964.
13. Singh R.T., A kinetic study of the effect of solvent on biochemical efficiency of aliphatic hexanoate ester, Aryabhat Research Journal of Physical Science. (ARJPS), 2014; 17(1-2) : 173-185.
14. Robertson R.E., A survey of thermodynamic parameter for solvolysis in water. Prog. Phy. org. chem. 1967; 4 : 213.
15. Parker K.J. Tomillinson DJ, Trans Farady Soc. 1971; 67 : 1302.
16. Singh A.K., Solvent effect on solvolysis rate of ethylacetate in water methanol and water ethanol mixed solvent system. Inter.J for Res. in Applied Science & Engg. Tech. (IJRASET), 2016 : 4(9) : 505-509.

