A Kinetic Study of the Solvent Effect of Aquo-Protic Solvent media on the Medicinal Efficiency of a Heavy Caprylate Ester

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ABSTRACT

The hydrolysis product of Caprylate ester is Caprylic acid, which has antibacterial, antiviral, antifungal and anti-inflammatory properties. It is used to prevent urinary tract infections and bladder infections.

With a view to highlight the solvent effect of aquo-protic solvent media the kinetic of alkali catalysed hydrolysis of butyl caprylate has been studied in different aquo-glycerol media containing 20 to 80% glycerol (v/v) and at 5 different temperatures ranging from 20 to $40^0 C$.

The specific rate constants of the reaction were found to decrease with increasing concentration of glycerol and thus prediction of Parker has not been found applicable. The numerical values of ISO-composition activation energy (E_C) and ISO-dielectric activation energy (E_D) of the reaction were found to increase and decrease respectively, which were interpreted by solvation and desolvation of initial and transition state of the reaction to different extent.

KEYWORDS: Medicinal Efficiency, Aquo-protic, Heavy Caprylate, Moblile Transition State, Electrostatic Effect, Iso-Composition and Iso-dielectric, Solvation and Desolvation, Barclay, Butler Rule, Iso-kinetic Temperature.

INTRODUCTION

The effect of solvent on the alkali catalysed hydrolysis of esters have received a large number of attention from time to time[1-2], but the explanations put forward for them are not satisfactory. Considering ester hydrolysis as ion-dipole type and assuming the predominance of electrostatic effect, Ingold[3] as well as Laidler[4] have predicted a decrease in rate with decreasing dielectric constant of the medium, for which there is general experimental evidence. However, on the basis of solvation phenomenon, Parker[5] predicted a rate enhancement in case of ester hydrolysis by dipolar-aprotic solvent like DMSO etc. and this view has been supported by Reberts[6]. However, the decrease in rate of ester hydrolysis upon addition of these solvents has also been observed in recent years by Ojha & Singh[7] and Hafizee & Singh et. al.[8] and therefore, more works are needed to establish the mechanism of solvation and the effect of dielectric constant. Among the esters studied thoroughly so far, the esters having medicinal efficiency like caprylates appear to have received very

little attention in this regard. Therefore, it is thought worthwhile to study the effect of dipolar protic solvent, glycerol on the rate as well as on the various activation parameters of alkali catalysed hydrolysis of Butyl caprylate at different temperatures to arrive at some definite conclusions regarding the effect of protic solvent, glycerol on the medicinal efficiency of caprylate.

EXPERIMENTAL

All the chemicals used were either of BDH (AnalR) or Merck (CP) grade and all were purified before their use. The kinetics of alkali catalysed hydrolysis of Butyl caprylate was studied in water-glycerol media having varying concentration of glycerol from 20 to 80% (v/v) at five different temperatures ranging from 20 to 40^0C. The strength of reaction mixture was fixed 0.1 M and 0.05 with respect to alkali (NaOH) and ester respectively.

The reaction was found to obey 2nd order kinetic equation and the evaluated value of specific rate constants of the reaction have been recorded in Table – I. The value of Iso-composition activation energy (E_C), Iso-dielectric activation energy (E_D) and thermodynamic activation parameters of the reaction have been enlisted in Table – II,III and IV respectively.

Results and Discussion:

Solvent Effect on the rate of reaction:

From Table - 1, it is obvious that rate constant value are markebly decreasing with the progressive addition to glycerol at all the temperatures. Since glycerol has a lower dielectric constant value than water, the bulk dielectric constant of the medium will be found to decrease and this will disfavor the formation of higher polar transition state.

Glycerol being a poor anion solvent[9], its increase in the aqueous mixture will facilitate the desolvation of ions already solvated by water, forming a glycerol-water associated species[10]. Since the initial and the transition states (all being anions differing in size and charge) cannot be equally desolvated, the rate will naturally be affected by such specific solvation changes. Experimentally it has been observed that the rate decreases with increasing glycerol in the medium and thus, it appears that the phenomenon of desolvation is more dominant in the transition state than that in the initial state and that is why the activation energy has been found to increase. Similar findings have also been reported earlier by Singh & Kumari[11] and Singh and Singh[12] and also in recent years by Anjana & Singh et. al.[13] and Atulit[14].

Effect of temperature and Solvent on the composition Activation Energy of the reaction

Rate constant values of the reaction were found to increase with increasing temperature in accordance to the Arrhenius law, yielding a good straight line for the plots of log k against 1/T as shown in fig – 1. The E_{exp} or E_C (Iso-composition activation energy) values are shown in Table – II. The E_C values increase from 92.37 to 128.33 kJ/mol with increasing proportion of

glycerol from 20 to 80% (v/v) in the reaction media.

The probable cause for enhancement in the value of Iso-composition activation energy of the reaction is desolvation and solvation of the transition and initial states respectively, which is also supported by the increase in the values of entropy of activation as recorded in Table – IV. Such findings and their interpretations have also been reported earlier by Singh et. al.[15] and recently by Dubey[16].

Solvent Effect on the Iso-dielectric Activation Energy of the Reaction:

The values of Iso-dielectric Activation Energy of the reaction at different desired dielectric constant values of the media have been evaluated by the process reported by Elsemongy et. al.[17] and are recorded in Table - III.

From the values recorded in Table – III, it is obvious that E_D values are found to decrease from 129.74 to 93.60 kJ/mol with increasing D values from 50 to 75 respectively of the reaction media. This trend of change (depletion) in E_D values is in harmony with the enhancement in E_C values with increasing concentration of glycerol in the reaction media.

Such findings are quite natural and are found in support of the report of Dubey and Singh[18] and also by recent researchers of Sushma & Singh et. al.[19].

Obeyancy of Barclay-Butler Rule and Solvent-Solute interaction in the water glycerol Reaction Media:

As recorded in Table – IV, both the values of ΔH^* and ΔS^* are found increasing and the increase being smooth. Iso-kinetic relationship between ΔH^* and ΔS^* are obeying Barclay and Butler rule[20] giving an excellent straight line as shown in Fig. – 2 when ΔH^* is plotted against ΔS^*. The numerical value of slope of the plots which determine the value of ISO-kinetic temperature is found to be 322.0

The increase in ΔH^* and ΔS^* values suggests the formation of more mobile transition state which supports the contention of desolvation of the transition state. On the guidelines of Leffler[21], from the evaluated values of Iso-kinetic temperature of the reaction which is greater than 300 (322.0), it is inferred that there is appreciable change in the structure of the reactant or in the solvent or in both the reactant and the solvent due to much stronger interaction between solvent and solute present in the water glycerol reaction media.

Similar observations and inferences have also been reported earlier by Singh & kumari et. al.[22] and in recent years by Ojha & Singh et. al.[23].

Effect of Ionic strength on the rate of reaction

There is negligible influence of the ionic strength on the reaction rate. This suggest that the reaction is not ion-ion, but ion-molecular in nature.

References:

1. Elsemongy, M. M.: Z. Physik, Chem., (Neue Folge), **95**, 215, 1975
2. Singh Lallan, Singh, R. T., and Jha, R. C.: J. Indian Chem. Soc. **55**, 375, 1978
3. Ingold, C. K.: Structure and Mechanism in Organic Chemistry, Bell, London, 1953
4. Laidler, K. J. and Lanskroener, P. A.: Trans. Faraday Soc., **52**, 200, 1956
5. Parker, A. J.: Chem. Rev., **69**, 1, 1960
6. Roberts, D. D.: J. Org. Chem., **31**, 4037, 1966
7. Ojha, R., Singh, Y. P. and Singh, R. T.: Wutan Huatan Jisuan Jishu, XVIII, No. (III), 108-118, March, 2022
8. Hafizee, N. K. and Singh, R. T.: GIS Science Journal, **9**, No. (7), 417-424, 2022
9. Parker, A. J.: Quartz. Rev., **16**, 163, 1962
10. Wolford, R. K.: J. Phys. Chem., **68**, 3392, 1964
11. Singh, R. T., Kumari, A., Kumari, R. and Kumari, P.: NIRJ Sci., **10**, 87-97, 2012
12. Singh, R. T., Singh, P. K., Singh, S. M. and Singh, U. C.: ARJ Phys. Sci., **15**, No. (1-2), 129-139, 2012
13. Anjana, Singh, R. I. and Singh, R. T.: IJESM, **6**, No. (7), 558-568, Nov. (2017)
14. S. Atulit: Wutan Huatan Jisuan Jishu, **XVI**, No. (XI), 354-358, Nov. 2020
15. Singh, R. T., Singh, S. N., Singh, P. and Singh, R. I.: NIRJ Sci., **8**, 133-138, 2012
16. Dubey, R. B.: SR Journal, **8**, No. (61), 14372-14378, Sept. 2020
17. Elsemongy, M. M, Elamayam, M. S. and Moussa, M. N. H.: Z. Physik. Chem. (Neue Folge), **95**, 215, 1975
18. Dubey, R., Singh, A. K., Singh, P. and Singh, R. T.: NIRJ Sci., **4**, 121-126, 2010
19. K. Sushma, A. Ashutosh and Singh, R. T.: IJAEMA, XII, No. (I), 3345-3363, Jan. 2020
20. Barclay, I. M. and Butler, J. A. V.: Trans. Faraday Soc., **34**, 1445, 1938
21. Leffler, J. E.: J. Org. Chem., **20**, 1201, 1955
22. Singh, R. T., Singh, D. K., Puja and Kumari, M: NIRJ Sci., **12**, 77-87, 2013
23. Ojha R, Singh Y. P. and Singh R. T.: Strad. Research Journal, **9**, No. (6), 276 – 289, 2022

Table – I

Specific rate constant values of Alkali Catalysed Hydrolysis of Butyl Caprylate in Water Glycerol media

$$k \times 10^2 in \ (dm)^3 mol^{-1} \ min^{-1}$$

Temp in ⁰C	% of Glycerol (v/v)						
	20%	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**
20⁰C	107.01	92.28	77.00	64.09	52.34	41.65	29.96
25⁰C	199.02	175.91	152.12	131.19	111.84	95.36	71.63
30⁰C	377.75	337.99	302.20	269.34	238.67	212.23	171.51
35⁰C	672.82	623.39	576.90	531.13	486.63	444.73	389.85
40⁰C	1206.15	1165.20	1095.97	1044.48	991.29	941.46	882.06

Table – II

Iso-dielectric Activation Energy (E_C or E_{exp}) of the reaction

% of Glycerol(v/v)	20%	30%	40%	50%	60%	70%	80%
E_{exp} values of kJ/mol	92.37	96.67	100.31	104.57	110.80	116.20	128.33

Table – III
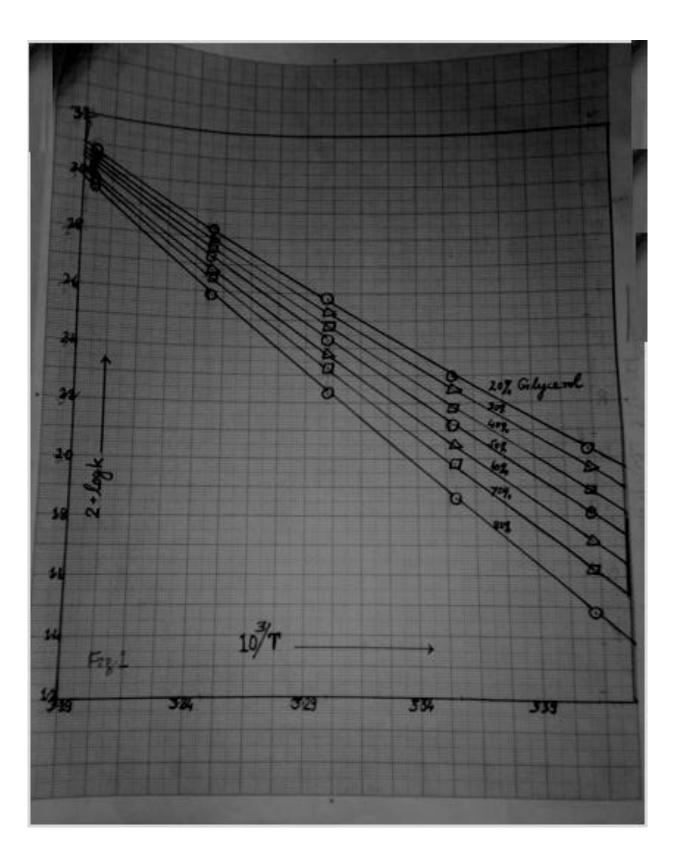
Iso-composition Activation Energy (E_D) of the reaction

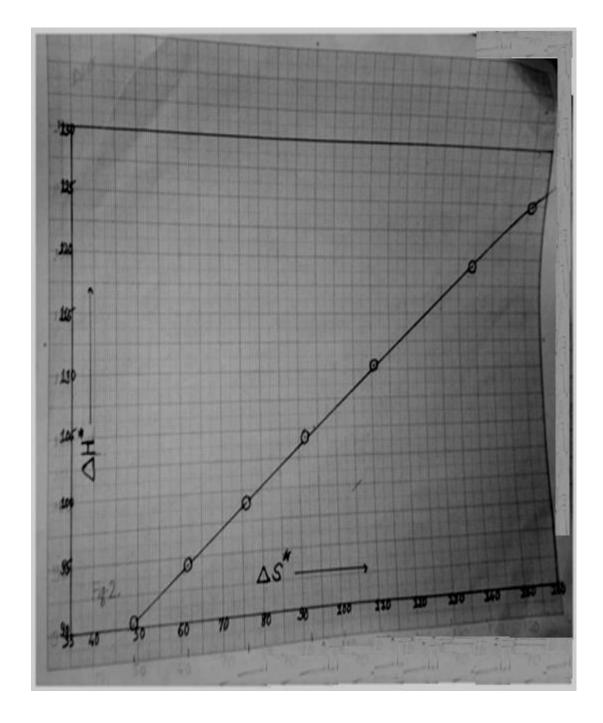| % of Glycerol(v/v)	D=50	D=55	D=60	D=65	D=70	D=75
E_{exp} values of kJ/mol	129.74	126.76	121.63	109.55	100.47	93.60

Table – IV

Activation Parameters of Alkali Catalysed Hydrolysis of Butyl Caprylate in Water-Glycerol Solvent System

ΔH^* and ΔG^* in kJ/mol, ΔS^* in J/K/mol

% of Glycerol (v/v)	Mole% of Glycerol	ΔH^* in kJ/mol	30^{0}C	
			ΔG^*	ΔS^*
20%	05.81	90.37	75.57	48.84
30%	09.56	94.55	75.85	61.72
40%	14.12	99.10	76.13	75.85
50%	19..79	104.25	76.42	91.85
60%	27.01	110.27	76.72	110.73
70%	36.54	119.13	77.02	138.98
80%	49.67	124.72	77.68	155.25

Fig 1

Fig.2.