Theoretical Study of Solvent Effects on 1,3-Dipolar cycloaddition Reaction

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(NJC)

(Received on 6/5/2014) **(Accepted for publication 26/6/2014)**

Abstract

The correlation between solvents parameters and rate constant (k) of 1,3-dipolar cycloaddition of benzonitrile oxide and N-ethylmaleimideorcyclopentene(k collected from literature) in different hydroxylic and non hydroxylic solvents were studied. Single parameter correlations were found to be poor(R^2< 0.9) except for σ* and α; R^2=0.903,0.914respectively.Avery good multiparameters correlation was found for the reaction of N-ethylmaleimide(logk=-0.145 +0.719+0.0336 $E_{T(30)+}$0.844α; R^2=0.995.sig:=0.091,F=65.131.

While excellentdual parametric correlation was shown when the dipolarophile was cyclopentene (logk=-0.0721,-0.895α-0.0148B ;)R^2=0.999, sig: =0.035, F=412.438. Which strongly indicates that protic solvents(HBD solvents) facilitate reactions with HBA dipolarophiles. These results may be useful as priori predictions for these reactions.

Keywords: 1, 3-Dipolar Cycloaddition,Solvent effects,SPSS Regression analysis,Solvent parameters.

الخلاصة

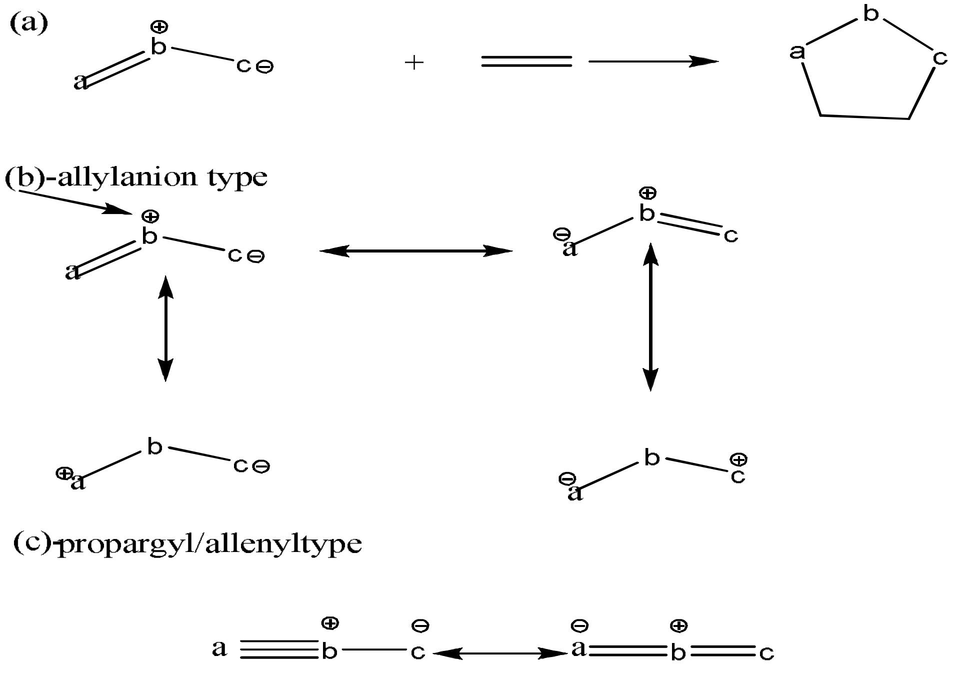
ان العلاقة بين تاثيرات المذيبات ومعدل ثابت سرعة التفاعل لتفاعلات 1،3 تفاعلات الاضافة الحلقية ثنائية القطبية لمركبات اوكسيد بنزونترايل ومركب ن- اثيل مالياميدورسايكلوبنيتين تم دراستها في الادبيات باستعمال مذيبات مائية وغير مائية.

لقد تم ايجاد معامل ارتباط منفرد ضعيف (R^2‹0.9) لانتقالات σ^*و α وكذلك تم ايجاد معاملي ارتباط
(R^2= 0.903) وكذلك (R^2= 0.914) على التوالي.

بالنسبة لتفاعل اثيل مالياميد تم ايجاد معامل ارتباط جيد (logk=−0.145 +0.719+0.0336
$E_{T(30)}$+0.844α) R^2=0.995.sig:=0.091,F=65.131). تم ايجاد معامل ارتباط ثنائي بارامتري ممتاز
للمركبات ثنائية القطبية مثل السايكلوبنتين (logk=−0.0721,−0.895α−0.0148B) (R^2=0.999,
sig: =0.035, F=412.438). هذه النتائج تدل على ان المذيب الهيدروجيني يسهل التفاعل مع المركبات
ثنائية القطبية وهذه العملية تعتبر مفيدة عند توقع احتمالية حصول التفاعل مسبقا.

Introduction

1, 3-Dipolar cycloaddition (13DC) is a chemical reaction involves the addition of an unsaturated compound to a 1, 3-dipole to form a five-membered ring. Their usefulness arises from their versatility and their stereospecific creation of chiral centers in organic molecules. The 1, 3- dipoles can be classified into two types; the allylanion type and the propargyl/allenyl type (Scheme I).



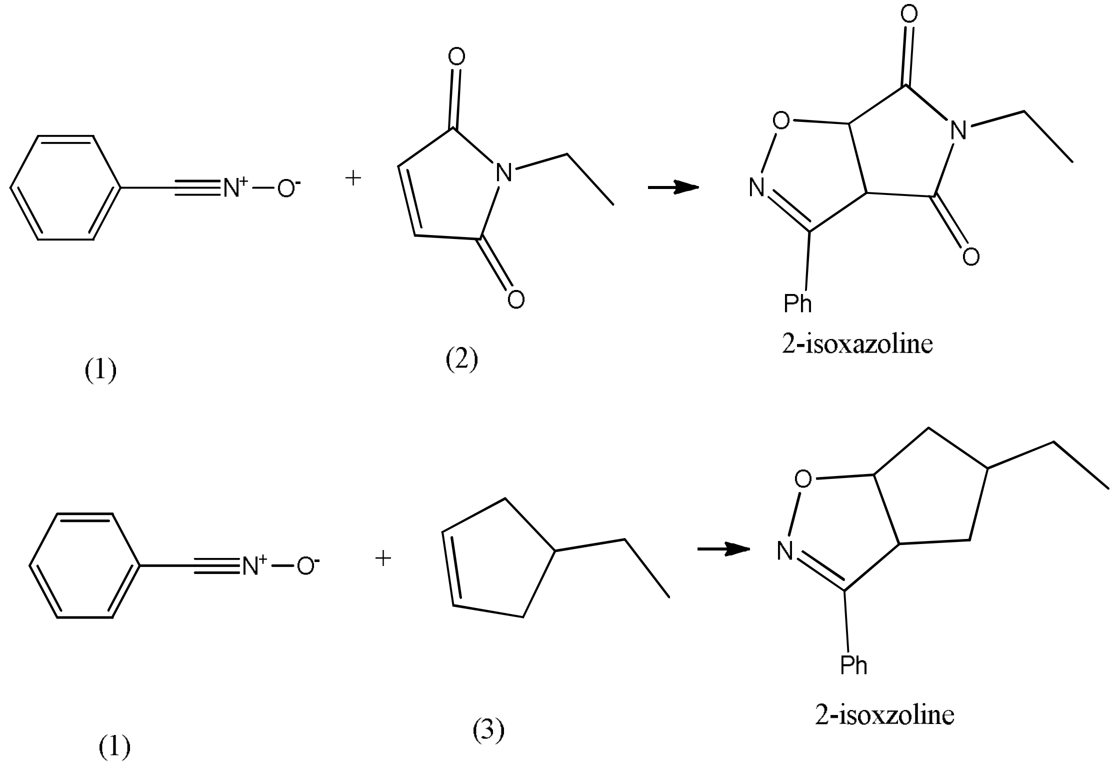
Scheme I

According to Woodward – Hoffmann rule[2] 13DC is a thermally allowed $[_{\pi}4_{s} + _{\pi}2_{s}]$ concerted reaction. Thus the transition state (T.S.) is controlled by the frontier orbitals of the reactants[3]. Accordingly 13DC additions contain three types of interactions:

The $HOMO_{dipde}$ – $LUMO_{alkene}$ (type I), the HOMO – LUMO of both reactants (type II) and the LUMO $_{\text{dipole}}$ – HOMO $_{\text{alkene}}$ (type III) interactions.

Nitrile oxides are 1, 3-dipoles belong to the propargyl / allenyl type.

The 13DC addition of nitrile oxides to alkenes yield 2- isoxazolines (Scheme II), which are useful intermediate in organic synthesis.[4]



Scheme II

The literature contains many examples of 1, 3-DC nitrile oxides to alkenes [1a,5]but few studies of solvent effects on this reaction[6].

However solvation is the disappearance of the solute in the bulk of the solvent. Two viewpoints have been shown to be valid for the solvation process. In the first the solvent is considered as homogeneous continuum, exerts non-specific interactions. The strength of these long - range interactions are measured in terms of bulk properties of the solvent such as the dielectric function $f(\varepsilon)$ and refractive index function $f(n^2)$.[7]In the second view point the solvent is considered as inhomogeneous medium possess short – range, specific and chemical forces. These interaction forces are expressed in terms of the solvents specific properties; Lewis basicity (nucleophilicity) B[7c], Lewis acidity (electrophilicity) E[7c], hydrogen – bonding interactions, hydrogen – bonding donor ability (HBD) α[8] and hydrogen – bonding acceptor ability (HBA)β[8]. The literature contains many empirical solvent parameters some measure single property and others measure mixed properties. However, when solvent interacts in specific manner with solute, correlation with parameters which assume no direct interaction will fail. Eventually, for a reaction the solvent stabilizes the reactants and the T.S. and hence the rate of the reaction is dependent on the extent and mode of solvation.

The aim of this work is to obtain linear solvation relationship between the rate constant(k,collected from literature) for the reaction of benzonitrile oxide (1) ethylmaleimide (2) or ethylcyclopentene(3) into two sets of hydroxylic solvents and solvent parameters.These parameters are Lewis basicity B^{7c} , Lewis acidity E^{7c}, polarity/ polarizability scale $E_T(30)^8$,Taft's polar substituent constant of alcohol σ^{*9},basisity as indicated by solubility of hydrogen chloride in alcohol(L)[10],steric subsituent constant Es^9,HBD ability α^8,HBA ability β^8 dielectric constant $f(\epsilon)$ [7],refractive index function $f(n^2)^7$, solvatochromic polarity scale π^{*8},and Gutmann donor DN and Gutmann acceptor AN numbers[8].

The all mentioned parameters for the corresponding solvents together with the rate constant logk were shown in tables1,2,3 and ,4.

The correlations of rate constant (log k) with single and multiparameters linear regression were examined using SPSS VERSION 11.

Correlation coefficient R^{211} and significant value p ($p < 0.05$) were used as measure for the significance of the regression. While F-test was used to test the validity of the multiparametric regression.

Table 1 Reaction of benzonitrile oxide (1) with N-ethylmaleimide (2) in alcohols. (a.ref.7 b.ref.9 c.ref.6 d.ref.10 e.ref.11 f.ref.12)

Solvent	$K_2{}^a$	Log k	B^b	E^b	$E_{T(30)}{}^c$	σ^{*d}	$E_s{}^d$	L^e	$f_{(\epsilon)}{}^f$	π^{*c}	$\propto^c$	β^c	$E_T{}^{Nc}$
MeOH	0.196	-0.7077	114	14.9	55.5	0.00	0.00	0.857	0.477	0.60	0.98	0.66	0.762
1-propanol	0.320	-0.4949	119	10.6	50.7	-0.36	-0.36	0.957	0.464	0.52	0.84	0.90	0.617
2-propanol	0.289	-0.5391	122	8.7	45.6	-0.47	-0.47	1.029	0.460	0.48	0.76	0.84	0.546
t-BuOH	0.254	-0.5952	125	5.2	43.9	-1.54	-1.54	1.115	0.441	0.41	0.42	0.93	0.389
1-butanol	0.310	-0.5086	119	10.3	50.2	-0.39	-0.39	0.965	0.457	0.47	0.84	0.84	0.586

Table 2 Reaction of benzonitrile (1) with cyclopentene in alcohols. (a.ref.7 b.ref.9 c.ref.6 d.ref.10 e.ref.11 f.ref.12)

Solvent	$K_4{}^a$	Log k	B^b	E^b	$E_{T(30)}{}^c$	σ^{*d}	$E_s{}^d$	L^e	$f_{(\epsilon)}{}^f$	π^{*c}	$\propto^c$	β^c	$E_T{}^{Nc}$
MeOH	$22.9*10^{-4}$	-2.6402	114	14.9	55.5	0.000	0.00	0.857	0.477	0.60	0.98	0.66	0.762
EtOH	$26.5*10^{-4}$	-2.5768	117	11.6	51.9	-0.100	-0.07	0.943	0.469	0.54	0.86	0.75	0.654
1-propanol	$259*10^{-4}$	-2.5867	119	10.6	50.7	-0.115	-0.36	0.957	0.464	0.52	0.84	0.90	0.617
2-propanol	$27.4*10^{-4}$	-2.5622	122	8.70	48.6	-0.190	-0.47	1.029	0.460	0.48	0.76	0.84	0.546

Table 3 Reaction of benzonitrile (1) with N-ethylmaleimide (2) in non-hydroxylic solvents. (a.ref.7 b.ref.6 c.ref.12 d.ref.13)

Solvent	K_2^a	Log k	$E_{T(30)}^b$	$\propto^b$	β^b	π^{*L}	$f_{(n)}^{2c}$	$f_{(s)}^c$	E_T^{Nb}	AN^d	DN^d
CCl_4	0.210	-0.6778	32.4	0.00	0.10	0.21	0.125	0.222	0.052	8.6	0.0
THF	0.100	-1.0000	37.4	0.00	0.55	0.55	0.197	0.405	0.207	8.0	20.0
$CHCl_3$	0.059	-1.2291	39.1	0.20	0.10	0.10	0.210	0.356	0.259	23.1	4.0
CH_3CN	0.100	-1.0000	45.6	0.19	0.40	0.40	0.175	0.481	0.460	18.9	14.1
n-Hexane	0.330	-0.4815	31.0	0.00	0.00	0.00	0.186	0.188	0.009	0.0	0.0

Table 4 Reaction of benzonitrile oxide (1) with cyclopentene (3) in non-hydroxylic solvents. (a.ref.7 b.ref.6 c.ref.12 d.ref.13)

Solvent	K_4^a	Log k	$E_{T(30)}^b$	$\propto^b$	β^b	π^{*b}	$f_{(€)}^c$	$f_{(n^2)}^{c}$	E_T^{Nb}	AN^d	DN^d
CCl_4	26*10-4	-2.5955	32.4	0.000	0.10	0.21	0.222	0.125	0.052	8.60	0.00
Dioxane	17*10-4	-2.7696	36.0	0.000	0.37	0.49	0.223	0.203	0.164	10.30	14.30
$CHCl_3$	13*10-4	-2.8962	39.1	0.200	0.10	0.69	0.356	0.210	0.259	23.10	4.00
CH_2Cl_2	12*10-4	-2.9066	45.6	0.190	0.40	0.66	0.481	0.175	0.460	18.90	14.10
n-Hexane	33*10-4	-2.4776	31.0	0.000	0.00	-0.11	0.188	0.186	0.009	0.00	0.00
CH_3CN	12*10-4	-2.9208	40.7	0.130	0.10	0.73	0.420	0.204	0.309	20.40	1.00

Reaction of benzonitrile oxide with N-ethylmaleimide in alcohols: In case of the reaction of 1 with 2 in alcohols table 1 ,single correlations between log k and the parameters shown in table 1 were found to be poor ($R^2<0.556$). However the best multiparameteric equations obtained were :

$$\log k = -3.782 + 0.914\beta + 0.577\alpha + 0.0676B \qquad (1)$$

R^2 =0.966	sig. = 0.232	F= 9.61	n =5

$$\log k = -1.428 + 0.747\beta + 0.72\alpha - 0.0327E \qquad (2)$$

R^2= 0.988	sig.=0.138	F=27.8	n =5

$$\log k = -1.272 + 0.892\beta + 0.537\alpha - 0.914\pi^* \qquad (3)$$

R^2=0.991	sig.=0.122	F= 35.724	n =5

$$\log k = -0.145 + 0.719\beta + 0.0336E_{T\,(30)} + 0.844\alpha \qquad (4)$$

R^2= 0.995	sig. = 0.091	F_{cal} = 65.131	n =5

F_{table}= 53.593

As shown in equation 1-4 above the correlation coefficients were fair to be satisfactory[11]but,the significance of the correlation is low $p>0.05$.However these equations(1-4) showed also that the solvation of the reaction can be described by the solvation parameters HBD α,HBA β, ET(30), π*,and B. For the HBD acidity it seems that the alcohol solvate the nitrile oxide through H-bonding with the negatively charged oxygen hence retards the reaction. Since the cycloaddition required naked oxygen.While the maleimide was solvated through hydrogen bonding with carbonyl groups of the maleimide which in turn polarize the double bond(schem2,5) and make it more available for addition(accelerate the reaction).Thus the solvation of the two reactants oppose each other but the solvation of maleimide seems to overwhelm the solvation of the 1,3 dipole and the net is acceleration of the reaction(positive sign of α coefficients in allequation 1-4).This interpretation is also confirmed by the negative coefficient of α(equation 6) for the reaction of benzonitrile oxidewith cyclopentene where the carbonyl group is absent . Therefore the solvation via hydrogen bonding acidity HBD, operates only for the 1,3-dipole.

For the solvation by HBA basicity (β)(equations 1-4),it is believed that hydrogen of the alkene double bond in solids can form hydrogen- bonding of the type C-H….O[13].This may permit the surmise that alcohol form hydrogen –bonding with olefinic protons of maleimide in solution which will polarize the double bond and make it more available for cycloaddition .And such polarization imply nucleophilic solvation (B) of the double bond as shown by equation 1and Scheme III[12]. The correlation of $E_{T(30)}$ and π*parameter (equation 3and 4,negative sign) indicate the negative solvaton via dipolarity, which is in accord with less polar T.S than the reactants.

Reaction of benzonitrile oxide with cyclopentene in alcohols:

The rate constants of the reaction of 1 of 3 in non hydroxylic solvent were shown in table 2 together with solvent parameters. The linear regression of logk with single parameter were shown in table 5.The fair correlation of both parameter σ* and ∝ (equations5-6)reflect that thehydroxylicsolvent strongly solvate the 1,3-dipole through HBD acidity and retard the reaction.The opposite signs shown by σ*and ∝ upon their inclusion in adual parametric equation may be attributed to the very high collinearly between them ($R^2=0.99$).However improvements were shown when a second parameter was introduced to each correlation of σ*and ∝ (eqauation 7-22).Contrary to the reaction of maleimide,all correlations (equation 7-22) reflect a negative solvation by HBD acidity ,polarity and,polarizability. The 1,3-dipole is highly solvated by these factors and dominates the solvation process.The best dual parametric correlation was shown by HBD acidity ∝ and basicity (B)(R2=0.999,sig.0.035(F=422.4)

Table 5 Single linear regression of log K with solvents parameters of the reaction of 1 with 3 in alcohols.

Solvent parameter	Sign of coefficient	R^2	Sig. value P
$\propto$	-	0.914	0.044
B	+	0.773	0.121
B	+	0.521	0.278
E	-	0.894	0.054
$\mathbf{E_s}$	-	0.513	0.284
$\mathbf{E_{T(30)}}$	-	0.886	0.059
$\boldsymbol{\pi^*}$	-	0.876	0.064
$\boldsymbol{\sigma}$	-	0.903	0.050

$\log k = -2.633 - 0.413\sigma *$ (5)		
$R^2 = 0.903$	sig. = 0.05	n = 4

$\log k = -2.284 - 0.357\alpha$ (6)		
$R^2 = 0.914$	sig.= 0.044	n = 4

$\log k = -2.629 - 0.404\sigma * -0.0281E$ (7)		
$R^2 = 0.903$	sig. = 0.311	n = 4

$\log k = -2.829 - 0.543\sigma * +0.0035E_{T(30)}$ (8)		
$R^2 = 0.904$	sig. = 0.309	n = 4

$\log k = -3.725 - 0.623\sigma * +2.289f(\varepsilon)(9)$		
$R^2 = 0.914$	sig. = 0.293	n = 4

$\log k = -2.986 - 0.945\sigma * +0.463E_T^N$ (10)		
$R^2 = 0.917$	sig. = 0.289	n = 4

$$\log k = -3.188 - 1.003\sigma * + 0.026\pi^{*} \qquad (11)$$

$R^2 = 0.918$	sig. = 0.287	n = 4

$$\log k = -2.23 - 0.389\alpha + 0.0346\beta \qquad (12)$$

$R^2 = 0.918$	sig. = 0.286	n = 4

$$\log k = -0.948 - 1.591\sigma * + 1.723\alpha \qquad (13)$$

$R^2 = 0.932$	sig. = 0.261	n = 4

$$\log k = -2.752 - 0.965\alpha + 0.0192E_{\mathrm{T(30)}} \qquad (14)$$

$R^2 = 0.933$	sig. = 0.26	n = 4

$$\log k = -0.281 - 1.319\alpha - 1.242L \qquad (15)$$

$R^2 = 0.947$	sig. = 0.23	n = 4

$$\log k = -2.064 - 1.419\alpha + 1.075E_{\mathrm{T}}^{\mathrm{N}} \qquad (16)$$

$R^2 = 0.964$	sig. = 0.189	n = 4

$$\log k = -2.636 - 0.618\sigma * + 0.0803E_{\mathrm{S}} \qquad (17)$$

$R^2 = 0.967$	sig. = 0.18	n = 4

$$\log k = -2.419 - 1.52\alpha + 2.12\pi^{*} \qquad (18)$$

$R^2 = 0.968$	sig. = 0.178	n = 4

$$\log k = 0.367 - 3.58\sigma * - 3.509L \qquad (19)$$

$R^2 = 0.969$	sig. = 0.176	n = 4

$\log k = -2.108 - 0.54\alpha + .0838E_S$ (20)		
$R^2 = 0.984$	sig. = 0.128	n = 4

$\log k = -0.891 - 1.062\sigma * -0.0153B$ (21)		
$R^2 = 0.985$	sig. = 0.121	n = 4

$\log k = -0.0721 - 0.895\alpha - 0.0148B$ (22)			
$R^2 = 0.999$	sig. = 0.035	n = 4	$F_{cal} = 412.438$

$F_{table} = 199.5$

Reaction of benzonitrile oxide with N-ethylmaleimide in polar and apolar aprotic solvents

Different solvent interactions were found in the reaction of 1 with 2 in non-hydroxylic solvents.Poor correlations were found for single paramtric equations. R^2Were < 0.9 for Gutmanns acceptor (A.N.) and Donor (D.N.) numbers[13], Kirkwood dielectric function f (ε) refractive index function f (n^2), Dimorth-Reichardt ET(30) and normalized $E_T(30)$ ET^N, but R^2wasSatisfactoryfor solvatochromic parameters π*R^2= 0.933. Upon introduction of a second parameter satisfactory correlations were obtained(equations 23, 27a,28a,29a,30a).Further both single and multi-parameter correlations were improved on exclusion of $CHCl_3$ from regressions(equations 24.25,26,and 27b,28b,29b,30b).Besides the sign of the parameters f(ε),DN,AN,β were changed when $CHCl_3$ was excluded from the regression.This may be inferred by the high anomaly of $CHCl_3$where the rate is the slowest among other solvent table 3(k=0.059, ref.6b table 1) since CHCl3 has the ability to form hydrogenbonding.However,the solvation of the reaction is best described byπ*,AN,DN , f(ε),and β parameters ,through negative solvation of the 1,3-dipole. Also less polar T.S. than the reactants is less sensitive to polar interactions.

$\log k = -0.553 - 1.061\pi * +0.505E_T^N$ (23)	
R^2=0.985	sig.=0.042

$\log k = -0.233 - 1.72f(\varepsilon)$ (24)	
R^2=0.907	sig.=0.047

$\log k = -0.539 - 0.957\beta$		(25)
R^2= 0.921	sig.=0.04	

$\log k = -0.552 - 0.725\pi*$		(26)
R^2=0.979	sig.=0.011	

$\log k = -0.726 - 1.123\pi* + 0.901f(\varepsilon)$		(27a)
R^2=0.962	sig.=0.038	

$\log k = -0.526 - 0.673\pi* - 0.134f(\varepsilon)$		(27b)
R^2=0.979	sig.=0.144	F_{cal}=23.702

$\log k = -0.549 - 0.915\pi* + 0.0049DN$		(28a)
R^2=0.946	sig.=0.054	F_{cal}=17.53

$\log k = -0.55 - 0.553\pi* - .0069DN$		(28b)
R^2=0.999	sig.=0.045	F_{cal}=240.596

F_{table}=199.5

$\log k = -0.533 - 0.718\pi* - 0.0049AN$		(29a)
R^2=0.938	sig.=0.062	F_{cal}=15.136

$\log k = -0.577 + 0.0096AN - 0.91\pi*$		(29b)
R^2=1.0	sig.=0.022	F_{cal}=1015.203

F_{table}=799.5

$\log k = -0.559 - 0.933\pi* + 0.239\beta$		(30a)
R^2=0.955	sig.=0.045	F_{cal}=21.206

$\log k = -0.537 - 0.494\pi * - 0.347\beta$(30b)		
R^2=1.0	sig.=0.007	F_{cal}=9584.413

F_{table}=4999.5

Reaction of benzonitrile oxide with cyclopentene in polar and apolar aprotic solvents:

On linear regression of logk of the reaction of 1 and 3 in non hydroxylicsolvents,with single solvent parameters(table 4) only π*among all other parameters showed asatisfactory correlation with a high significance p> 0.001.This indicates that the reaction are mainly solvated by non-specific interactions the dipole interactions i.e. negative solvation of the 1,3-dipole.When another parameter introduced no mentioned changes in correlations were found(equations 32a,33a,34a,35a,36a,37a and,38a) . Also on exclusion of CHCl3 from the regression, no improvements were seen(equations 31b,32b,33b,34b,35b,36b,37b and,38b)

$\log k = -2.514 - 0.555\pi *$		(31a)
R^2=0.983	sig. <0.001	F_{cal}=231.78

$\log k = -2.513 - 0.556\pi *$		(31b)
R^2=0.981	sig. =0.001	F_{cal}=151.403

$\log k = -2.513 - 0.553\pi * -0.012\beta$		(32a)
R^2=0.983	sig.=0.002	F_{cal}=87.245

$\log k = -2.513 - 0.552\pi * -0.0121\beta$		(32b)
R^2=0.981	sig.=0.019	F_{cal}=50.671

$\log k = -2.511 - 0.522\pi * -0.0031AN$		(33a)
R^2=0.983	sig.=0.002	F_{cal}=88.585

$\log k = -2.57 - 0.493\pi * -0.0027AN$		(33b)
R^2=0.981	sig.=0.019	F_{cal}=52.666

$\log k = -2.512 - 0.549\pi * -0.0007DN$ (34a)		
R^2=0.984	sig.=0.002	F_{cal}=90.208

$\log k = -2.512 - 0.547\pi * -0.0008DN$ (34b)		
R^2=0.981	sig.=0.019	F_{cal}=52.516

$\log k = -2.444 - 0.537\pi * -0.425f(n^2)$ (35a)		
R^2=0.987	sig.=0.001	F_{cal}=115.472

$\log k = -2.436 - 0.54\pi * -0.468f(n^2)$ (35b)		
R^2=0.986	sig.=0.014	F_{cal}=69.58

$\log k = -2.518 - 0.493\pi * + 0.274\alpha$ (36a)		
R^2=0.991	sig.=0.001	F_{cal}=168.02

$\log k = -2.518 - 0.485\pi * +0.363\alpha$ (36b)		
R^2=0.993	sig.=0.007	F_{cal}=142.091

$\log k = -2.301 - 0.46\pi * -E_{T(30)}$ (37a)		
R^2=0.993	sig.=0.001	F_{cal}=229.107

$\log k = -2.276 - 0.44\pi * -0.0076E_{T(30)}$ (37b)		
R^2=0.994	sig.=0.006	F_{cal}=164.943

$\log k = -2.51 - 0.46\pi * -0.22E_T^N$ (38a)		
R^2=0.994	sig.=0.001	F_{cal}=229.568

$$\log k = -2.51 - 0.439\pi * -0.248ETN \qquad (38b)$$

R^2=0.994 sig.= 0.001 F_{cal}= 166..035

Conclusion

In summary it seems that there exist two modes of solvation one in favor of reaction and other slow down the reaction. As we mentioned earlier in the reaction of 1 and2 in alcohols, both reactants solvated by HBD acidity but the two processes opposing each other and the solvation of2 prevails (positive sign of αequation 1-4).Similarly the nucleophilic solvation (B) of 1 and 2 where the solvation of 2 prevails (positive sign of B equation1). On going from maleimide to cyclopentene the solvation by HBD acidity slows down the reaction (negative sign of α equations), since the dipolarophile lacks the ability of HBA ability. And this supports the above interpretation of 1 and 2 solvation in alcohols.

The solvation of 1and 2 in non-hydroxylic solvents can be mainly explained by non-specific dipolar solvation (π*) (negative solvation). On exclusion of$CHCl_3$ better correlations were obtained and the sings of parameters reversed. This indicates that $CHCl_3$deviates from the trend and has different impact of solvation on the reaction than in other solvents.

In case of the reaction of 1 and3 in non-hydroxylicsolvents, the reaction was mainly negatively solvated by dipolarity (π*) with little viaspecific solvation HBA (β).

Finally in this reaction three entities have to be solvated, the 1,3-dipole, the dipolarophile and the T.S.. The solvation of the dipolarophile by bipolarity – pdarizibility is in favor of the reaction. While the solvation of the 1,3-dipole and the T.S. by the same way are disfavored by reaction. In similar way the solvation by hydrogen bonding where solvation of dipdarophile by hydrogen bonding increase the rate of reaction.

The lack of HBA basicity on changing the dipolarophile from maleimide to cyclopentene makes the rate to dropped by 100 fold (ref.6b table1) amatter which support our interpretation.

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