

## KINETIC STUDY ON THE PREPARATION REACTION OF CARBANION MONOSUBSTITUTED PHTALAZINIUM YLIDES

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We report here a kinetic study on the preparation reaction of monosubstituted 1-methylphtalazinium ylides carbanion. It is confirmed that ylides, both stable and unstable, are obtained through a simple unilateral successive reaction of the first order. Here, the inactivation process is a dimerization reaction of the second order. Calculated rate constants confirmed the increase in elimination of proton acidity and stabilization of the carbanion by electron attractive groups. In addition, electron repulsive groups were shown to increase carbanion nucleophilicity and promote the inactivation reaction.

### INTRODUCTION

Phtalazinium ylides are compounds having a zwitterionic structure included in the cycloimmonium ylides class, in which, the carbanion is bound at a positive nitrogen atom from the heterocycle (Fig. 1).

Cycloimmonium salts halogen acid elimination reaction is the most usual preparation method for cycloimmonium ylides, as the literature shows.<sup>1</sup>

In this respect, Dima *et al.*<sup>2,3</sup> obtained 1-methylphtalazinium ylides using as a production method the  $K_2CO_3$  or triethylamine treatment of 1-methylphtalazinium salts (Fig. 1).

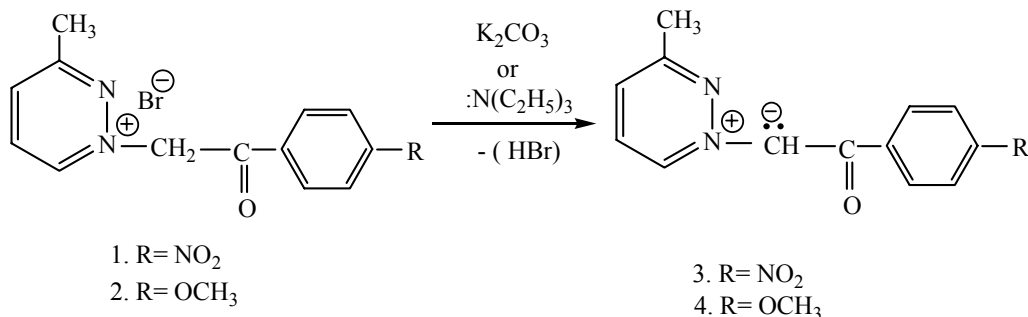


Fig. 1 – Preparation reaction of 1-methyl-phtalazinium ylides.

Studies regarding 1-methylphtalazinium ylide structure and reactivity showed that the stability of these compounds is assured by many factors, *i.e.*, the transfer degree of positive charge on the heterocyclic structural ensemble, and negative charge on ylide carbanion substitutes.

Investigating the preparation reaction of phtalazinium ylides from cycloimmonium salts, Petrovanu *et al.*<sup>1,2,4</sup> showed that some of the isolated ylides have a poor stability, as they are inactivated due to a dimerization process.

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Experimental results proved theoretical estimations concerning ylide inactivation; moreover, 1-methylphtalazinium-phenacylides, which possess electron attractive groups in the *para* benzene ring ( $-\text{NO}_2$ ), were shown to be more stable than those having electron repulsive groups in the same position ( $-\text{OCH}_3$ ).

An explanation is that electron attractive effect groups facilitate a transfer of negative charge from the ylide carbanion, and electron repulsive ones increase the carbanion nucleophilic reactivity, encouraging the dimerization reaction.

## RESULTS AND DISCUSSION

Our research is focused on the kinetic characterization of the ylide preparation reaction by treatment of 1-methylphtalazinium salts with triethylamine.

According to the literature citations,<sup>5</sup> cycloimmonium ylides preparation consists of proton removal from the carbon atom that is directly linked to the heterocyclic nitrogen. The process is encouraged by the presence of electron attractive groups, which increase the expelled proton acidity.

Kinetic parameters for the preparation reaction of 1-methyl-phtalazinium ylides were varied depending on cycloimmonium salt type and ylide structure.

Experimental data show that the **3** ylide is formed in the absence of the dimer due to its stability. The **4** ylide is obtained together with the **5** dimer that results from the inactivation process (Fig. 2).

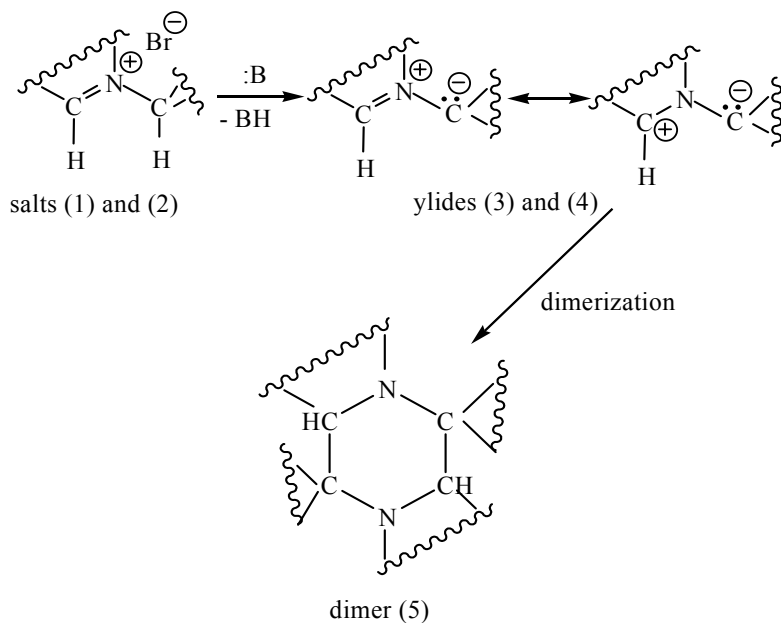
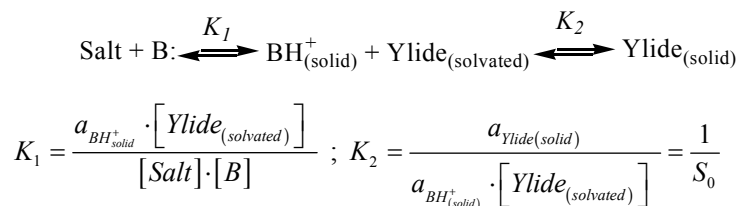


Fig. 2 – Dimerization reaction of *para*-nitro-phenacyl-1-methyl-phtalazinium ylide **4**.

For a kinetic interpretation, it was taken into account that the very low solubility of the resulting ylides and dimers, experimentally stated by their solid-phase separation as early as the initial stage of the reaction, significantly shifts the equilibrium towards their formation.

In the process of the **3** ylide formation, the steps were:

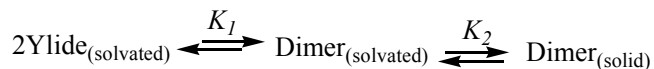


where  $S_0$  is the ylide intrinsic solubility, and  $a_{solid}$  the activity of the solid compounds.

The equilibrium constant of the global process is given by:

$$K = \frac{a_{Ylide(solid)}}{[Salt] \cdot [B]} = K_1 \cdot K_2 = K_1 \frac{1}{S_0}$$

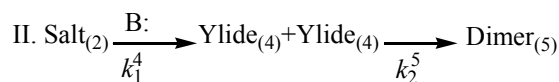
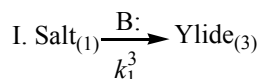
If the 4 ylide was obtained, the process was succeeded by dimerization:



in which:

$$K = K_1 \frac{1}{S_{0(Dimer)}}$$

As a conclusion, the existence of a heterophasic equilibrium characterized by a very high equilibrium constant determines the whole process to evolve beyond a state of equilibrium, which permits modeling (from a kinetics perspective) of the overall process as a simple unilateral reaction ( I ) or a successive unilateral reaction ( II ).<sup>6</sup>



Kinetic equations were presented in order to reveal the formation process of the 3 and 4 ylides:

$$v = - \frac{d[Salt_{(1)}]}{dt} = k [Salt_{(1)}]^n [B]^m$$

Considering the presence of a base excess (B), the differential kinetic equation becomes:

$$v = k_1^3 [Salt_{(1)}]^n$$

where:  $k_1^3 = k[B]^m$ , and  $[B]$  is the base concentration (triethylamine).

The 4 ylide preparation reaction is a successive one with a second order dimerization process.<sup>7</sup>

$$- \frac{d[Salt_{(2)}]}{dt} = k_1^3 [Salt_{(2)}]^n$$

$$\frac{d[Ylide_{(4)}]}{dt} = k_1^4 [Salt_{(2)}]^n - k_2^5 [Ylide_{(4)}]^2$$

$$\frac{d[Dimer_{(5)}]}{dt} = k_2^5 [Ylide_{(4)}]^2$$

Fig. 3 comprises the kinetic curves of both salt and dimer, ylide time dependence.

Concentrations of chemical compounds participating in the reaction are determined using a spectrophotometer, as all compounds are colored and present maximum absorbance in the visible domain at different wavelengths.

For the determination of kinetic parameters by the differential method, the fundamental kinetic equation was used in a logarithmic form:

$$\ln v = \ln k + n \ln c$$

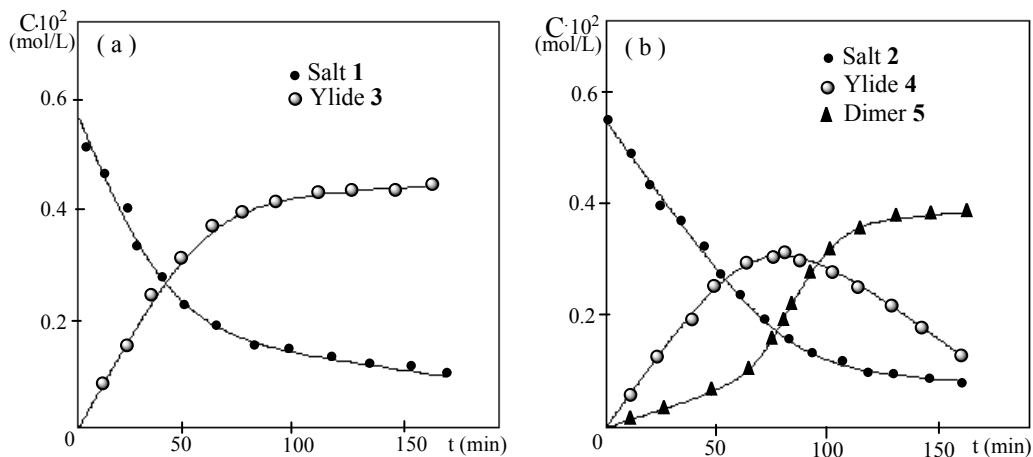


Fig. 3 – Kinetic curves of 1-methyl-phtalazinium ylides preparation reaction: (a) *para*-nitro-phenacyl-1-methyl-phtalaziniu ylide 3; (b) *para*-methoxy-phenacyl-1-methyl-phtalaziniu ylide 4.

The result of a  $v = f(c)$  dependence involved interpolating the  $c = f(t)$  experimental data using the *cspline* function in Mathcad 5.0 Plus, and numeric derivation of the revealing interpolation function.

Fig. 4 includes the plots for the  $\ln v = f(\ln c)$  dependence in the formation reaction of the 3 and 4 ylides, and the 5 dimer respectively, at 80°C.

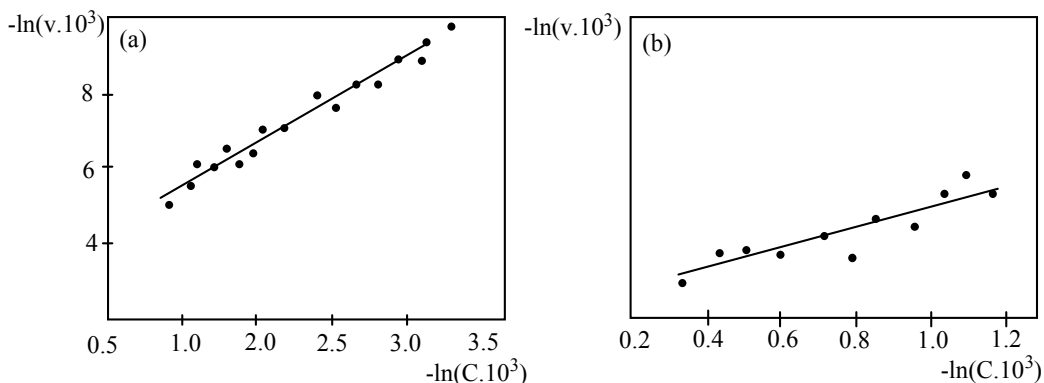


Fig. 4 – The  $\ln v = f(\ln c)$  dependence for the preparation reactions of ylide 3 (a) and ylide 4 (b).

Table 1 lists the reaction orders and rate constants obtained by this method.

Table 1

Reaction orders and rate constants obtained by the differential method for the preparation reactions of ylides 3 and 4, and dimer 5, at 80 degrees

Ylide 3		Ylide 4		Dimer 5	
$n$	$k_1^3 \cdot 10^3$	$n$	$k_1^4 \cdot 10^3$	$n$	$k_2^5 \cdot 10^4$
1.0580	2.3635	0.986	1.4268	1.9003	0.2165

Table 2 gives the correlation coefficients obtained by substitution of the experimental data in the linearized integral kinetic equations corresponding to different reaction orders.

Maximal values of the correlation coefficient show that the ylide preparation reaction in the presence of a base excess is of the first order and the dimerization one is of the second order.

Rate constants were determined with a kinetic equation proper to the order of the reaction, and their values are:

$$k_1^3 = 2,1584 \cdot 10^{-3} s^{-1}; k_1^4 = 1,4736 \cdot 10^{-3} s^{-1}; k_2^5 = 0,1987 \cdot 10^{-4} L/mol \cdot s$$

Table 2

Correlation coefficients for various reaction orders

n	Kinetic equation	R <sup>2</sup> -Ylide 3	R <sup>2</sup> -Ylide 4	R <sup>2</sup> -Dimer 5
0	$c_0 - c = kt$	0.0206	0.0328	0.6453
0.5	$c_0^{1/2} - c^{1/2} = \frac{1}{2}kt$	0.9102	0.7473	0.8455
1	$\ln(c_0 - c) = kt$	0.9948	0.9936	0.9107
1.5	$c^{-1/2} - c_0^{-1/2} = \frac{1}{2}kt$	0.9647	0.8337	0.9855
2	$c^{-1} - c_0^{-1} = kt$	0.8956	0.8978	0.9965
2.5	$c^{-5/2} - c_0^{-5/2} = \frac{3}{2}kt$	0.6839	0.6804	0.9776

Using the half-life time approach, with the equations:  $k_1 = \frac{\ln 2}{t_{1/2}}$  and  $k_2 = \frac{1}{c_0 \cdot t_{1/2}}$ , the resulting values for the rate constants are:

$$k_1^3 = 2,0361 \cdot 10^{-3} s^{-1}; k_1^4 = 1,2918 \cdot 10^{-3} s^{-1}; k_2^5 = 0,1885 \cdot 10^{-4} L/mol \cdot s$$

Validity of the calculation is confirmed by the resembling results gathered by three different methods. Hence, the average values were determined:

$$\bar{k}_1^3 = 2,186 \cdot 10^{-3} s^{-1}; \bar{k}_1^4 = 1,3640 \cdot 10^{-3} s^{-1}; \bar{k}_2^5 = 0,2026 \cdot 10^{-4} L/mol \cdot s$$

The Arrhenius equation was used to assess temperature effect upon the preparation reaction of ylides 3 and 4, and dimer 5:

$$\ln k = \ln A - \frac{E_a}{RT}$$

Table 3 lists the rate constants values at different temperatures.

Table 3

The rate constants values at different temperatures for the preparation reaction of ylides 3 and 4, and dimer 5

T (K)	313	323	333	343	353
$k_1^3$	$0.2986 \cdot 10^{-3}$	$0.5216 \cdot 10^{-3}$	$0.9462 \cdot 10^{-3}$	$1,2130 \cdot 10^{-3}$	$2,1860 \cdot 10^{-3}$
$k_1^4$	$0.7521 \cdot 10^{-4}$	$0.8631 \cdot 10^{-4}$	$0.3145 \cdot 10^{-3}$	$0.8968 \cdot 10^{-3}$	$1.3640 \cdot 10^{-3}$
$k_2^5$	-	$0.2897 \cdot 10^{-4}$	$0.7860 \cdot 10^{-4}$	$0.2168 \cdot 10^{-3}$	$0.2026 \cdot 10^{-3}$

A  $\ln k = f\left(\frac{1}{T}\right)$  scattered plot was drawn by determining rate constants at 40, 50, 60, 70, and 80 °C (Fig. 5).

Afterwards, the activation energy was calculated from the line slope, with the following results:

$$E_a^3 = 47.835 kJ/mol; E_a^4 = 74.563 kJ/mol \text{ and } E_a^5 = 163.120 kJ/mol$$

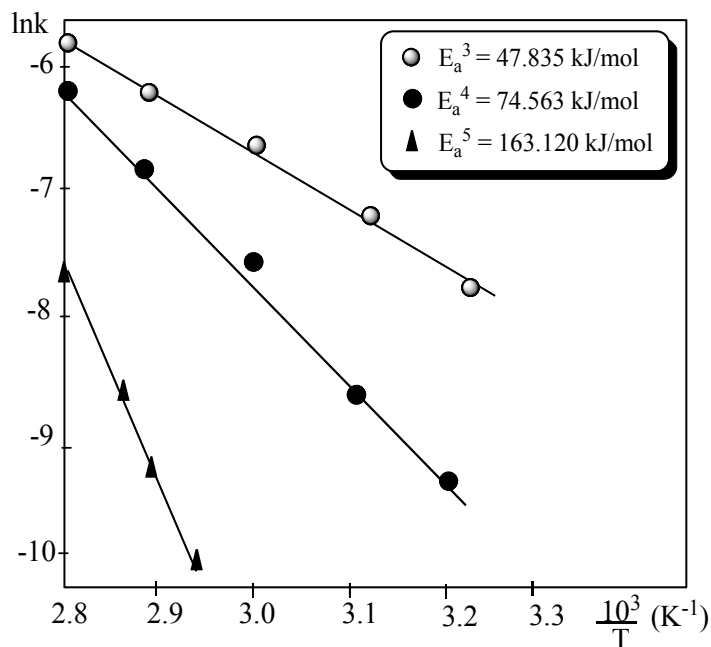


Fig. 5 – Influence of temperature on the rate constants for the preparation reaction of ylides **3** and **4**, and dimer **5**.

Activation energy values reveal a higher reactivity of the **1** cycloimmonium salt compared to **2**. Moreover, a certain stability of the ylide **4** was observed as the activation energy for the dimerization process was higher than the one of the preparation reaction.

Comparing all of the three rate constants, it was observed that the **3** ylide, a stable compound, is obtained with a higher rate than the **4** ylide, which was transformed into a dimer *in situ*. This confirms that the electron attractive group from the benzoyl *para* position ( $-\text{NO}_2$ ) determines an increase in the eliminated proton acidity and ylidic carbanion stability. Contrarily, the electron repulsive group ( $-\text{OCH}_3$ ) is accounted for a decrease in proton acidity and an increase in carbanion nucleophilicity, initializing the ylide dimerization reaction.

## CONCLUSIONS

The kinetic study of the preparation reaction of 1-methylphthalazinium ylides with  $-\text{NO}_2$  and  $-\text{O}-\text{CH}_3$  as substituents in the *para* position of the benzoyl radical bound to the ylidic carbanion permits the following conclusions to be drawn:

- The low solubility of ylides and dimer, experimentally observed, permits a kinetic modeling of the preparation process as a simple unilateral reaction.
- The preparation reaction of the **3** ylide is a simple unilateral process of the first order.
- The obtaining process of the **4** ylide is a simple successive reaction in which the ylide is dimerized using a second order reaction.
- The increased stability of the **3** ylide in comparison with the **4** ylide is confirmed by rate constants values.
- In order to obtain the **4** ylide, an induction period was fixed corresponding both to its maximal concentration and increasing dimerization rate.

## EXPERIMENTAL

A quantity of 0.001 Moles of cycloimmonium salt was treated with 50 mL anhydrous benzene, then 0.05 Moles of triethylamine were added. The mixture was heated on a steam bath at: 40°C, 50°C, 60°C, 70°C and 80°C. Triethylamine bromhydrate was separated by warm filtration. The ylides and the dimer result after cooling. Ylide separation from the dimer was realized using a silica chromatographic method ( $\text{CH}_2\text{Cl}_2/\text{MeOH}$  95:5). Concentrations of salt, ylide and dimer were measured spectrophotometrically with using a Secomam 256 apparatus (Metlo Toledo).

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