

## KINETICS AND MECHANISM OF THE 1,3-DIPOLAR CYCLOADDITION OF PHENYL AZIDES TO METHYL 3-PYRROLIDINOACRYLATE

Basil H. Al-Sader<sup>\*a</sup> and Mohamed Kadri<sup>b</sup>

Department of Chemistry, College of Science, University of Baghdad, Jadiriya,  
Baghdad, IRAQ and Department of Chemistry, University of Wahran, Es-Sania,  
Wahran, ALGERIA.

**Summary:** Kinetics of cycloadditions of phenyl azides to methyl 3-pyrrolidinoacrylate (2) produced Hammett  $\rho = 2.2$ . An  $E_a$  of  $13.5 \text{ kcal mole}^{-1}$  and  $\Delta S^\ddagger$  of  $-37.4 \text{ cal.K}^{-1}\text{mole}^{-1}$  were calculated for the cycloaddition of  $p\text{-O}_2\text{NC}_6\text{H}_4\text{N}_3$  to 2. The cycloadditions are concerted, non-synchronous, and are controlled by LUMO (azide) - HOMO (dipolarophile) interactions.

Numerous studies have been carried out on the mechanism of 1,3-dipolar cycloaddition reactions. Based on their systematic studies, Huisgen and coworkers<sup>1</sup> advanced the suggestion that the reaction is a four-center single-step reaction with an activated complex at the rate determining transition state whose structure depends on the extent of bond formation between the reaction centers. On the other hand, Firestone<sup>2</sup> proposed a two-step mechanism involving a diradical intermediate. The regioselectivity of the 1,3-dipolar cycloaddition reactions and the effects of substituents on rates have been rationalized by Houk et al.<sup>3</sup> and Sustmann<sup>4</sup> using the frontier orbital method. Cycloadditions of phenyl azides to olefins with electron-donating or electron-withdrawing substituents<sup>5</sup> led Huisgen<sup>6</sup> to propose a concerted non-synchronous mechanism with partial charges at the transition state which can be stabilized by the substituents. Later, Huisgen<sup>1</sup> adopted the frontier orbital method to explain his results. We here report our kinetic studies<sup>7</sup> on the cycloaddition of phenyl azides (1) to methyl 3-pyrrolidinoacrylate<sup>8</sup> (2) to produce methyl 1-phenyl-1,2,3-triazole-4-carboxylate<sup>9</sup> (4) via triazoline (3).

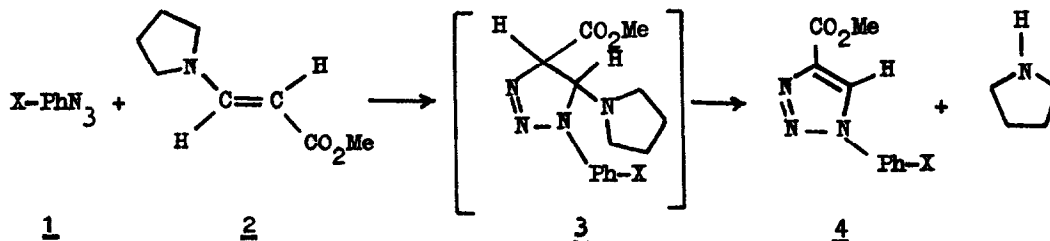


Table I

Rate constants for the cycloadditions of 1 to 2 in benzene at 101.5°.

X	H	p-Me	p-Br	m-Cl	m-NO <sub>2</sub>	p-NO <sub>2</sub>	$\rho = +2.2 \pm 0.1$
$10^6 k M^{-1}S^{-1}$	25	1.5	67	112.7	763	1700	

The kinetic data are reported in Table I. A kinetic study of the cycloaddition of para-nitrophenyl azide (5) to 2 in the temperature range of 75.6 - 101.5° led to five rate constants which gave a reasonable Arrhenius plot, and the following activation parameters were calculated:  $E_a = 13.5$ ,  $\Delta H^\ddagger = 12.8$ ,  $\Delta G^\ddagger = 26.8$  (all in kcal mole<sup>-1</sup>),  $\Delta S^\ddagger = -37.4$  cal mol<sup>-1</sup>K<sup>-1</sup> and  $\log A = 5.15$ . The observation of a positive Hammett reaction constant ( $\rho = 2.2$ ) suggests<sup>11</sup> that the reaction is controlled by the interaction of the HOMO of 2 and LUMO of 1. According to the CNDO/2 calculations<sup>12</sup> the transition state leading to the formation of 3 could be visualized as

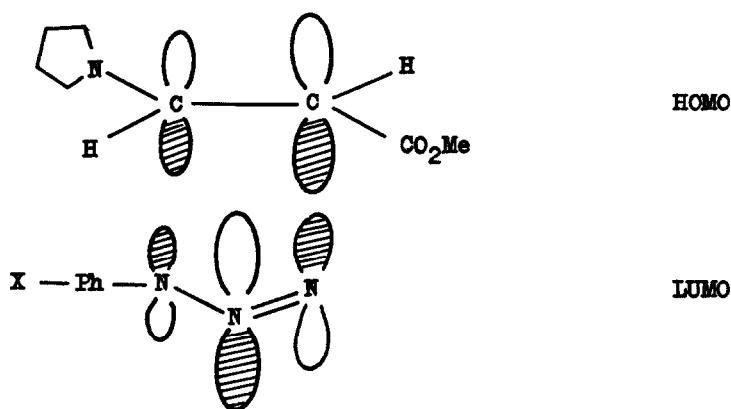


Table II

Rate constants ( $M^{-1}S^{-1}$ ) for the cycloadditions of phenyl azides to certain dipolarophiles at 25°.

R-N <sub>3</sub>	Cyclopentene <sup>a</sup>	Compound <u>2</u>	1-Pyrrolidinocyclohexene <sup>a</sup>
C <sub>6</sub> H <sub>5</sub> -	$2.4 \times 10^{-7}$	$2.5 \times 10^{-7(b)}$	$9930 \times 10^{-7}$
p-O <sub>2</sub> NC <sub>6</sub> H <sub>4</sub> -	$14.9 \times 10^{-7}$	$158.5 \times 10^{-7(c)}$	$1420000 \times 10^{-7}$

(a) reference 5 ; (b) estimated ; (c) calculated.

It can be seen from Table II, that phenyl azide adds to 2 with a rate comparable with its rate of addition to cyclopentene, which in turn is ten

times faster than its rate of addition to 1-heptene ( $k_2=0.24 \times 10^{-7} \text{ M}^{-1}\text{s}^{-1}$  at  $25^\circ$ )<sup>5</sup>. Further, p-nitrophenylazide (5) cycloadds faster than phenyl azide to the following dipolarophiles (i) cyclopentene six times, (ii) 2 over 50 times (68 times at  $101.5^\circ$ ), (iii) 1-pyrrolidinocyclohexene 143 times. This would suggest that the pyrrolidino group in 2 is involving in raising the energy level of the HOMO, but not to the same extent as in the 1-pyrrolidinocyclohexene, due to the presence of the  $\text{CO}_2\text{Me}$  group whose effect is lowering the energy level of the HOMO. But the increase in the HOMO is more than compensated by its decrease. Furthermore, it appears that the involvement of the pyrrolidino group, in 2, in stabilizing the activated complex is greater when the 1,3-dipole is p-nitrophenylazide than when it is phenylazide. This could be explained by assuming that at the transition state the positive character developed at the carbon alpha to the pyrrolidino group, in the dipolarophile moiety of the activated complex, is more when an electron-withdrawing group, e.g. p- $\text{NO}_2$ , is para to the azido group in the 1,3-dipole moiety of the activated complex. This increase in the positive character at the  $\alpha$ -carbon is the consequence of the decrease in the negative character of the inner nitrogen of the azido group, due to the additional stabilization offered by the p- $\text{NO}_2$  group at the transition state.

Thus our results reveals that (i) cycloaddition of phenylazides to 2 is concerted but non-synchronous, with  $\sigma$ -bond formation between the terminal nitrogen of the azido group and the carbon  $\alpha$  to the  $\text{CO}_2\text{Me}$  group occurring to a greater extent than  $\sigma$ -bond formation between the carbon  $\alpha$  to the pyrrolidino group and the proximal azido nitrogen; and (ii) an electron-withdrawing group para to the azido group has some influence on the degree of bond formation between the reaction centers.

#### References and Notes

- (a) University of Baghdad, (b) University of Wahan.
- (1) R. Huisgen, *J. Org. Chem.*, 41, 403 (1976).
  - (2) R. A. Firestone, *J. Org. Chem.*, 33, 2285 (1968); *idem*, *ibid*, 37, 2181 (1972); *idem*, *J. Chem. Soc., A*, 1570 (1970).
  - (3) K. N. Houk, *J. Am. Chem. Soc.*, 94, 8953 (1972); K. N. Houk, J. Sims, R.E. Duke, Jr., R. W. Strozier and J. K. George, *ibid.* 95, 7287 (1973); K. N. Houk, J. Sims, C. R. Watts and L. J. Iuskus, *ibid.*, 95, 7301 (1973); J. Sims and K. N. Houk, *ibid.*, 95, 5798 (1973).
  - (4) R. Sustmann, *Tet. Letters*, 2717 (1971); R. Sustmann and H. Trill, *Angew. Chem. Internat. Edit.*, 11, 838 (1972).

- (5) R. Huisgen, G. Szeimies and L. Mobius, *Chem. Ber.*, 100, 2494 (1967).
- (6) R. Huisgen, *J. Org. Chem.*, 33, 2291 (1968).
- (7) Kinetic Studies were carried out following the change in the intensity of the ir stretching vibration of the azide group  $\nu_{N_3}$  at  $2150\text{ cm}^{-1}$  as described by Huisgen<sup>5</sup>.
- (8) R. Huisgen, K. Herbig, A. Siegl and H. Huber, *Chem. Ber.*, 99, 2526 (1966).
- (9) Methyl 1-phenyl-1,2,3-triazole-4-carboxylate; m.p.  $121-122^\circ$ , nmr and ir spectral data are the same as those reported<sup>10</sup>. GLC analysis of the reaction mixture, after 80% reaction, using 5% QFI 3 meter column revealed the presence of pyrrolidine, unreacted (2) and phenyl azide, and (4).
- (10) R. Huisgen, R. Knorr, L. Mobius and G. Szeimies, *Chem. Ber.*, 98, 4014 (1965), R. Huisgen, G. Szeimies and L. Mobius, *ibid.*, 99, 475 (1966).
- (11) O. Henri-Rousseau and F. Texier, *J. Chem. Educ.*, 55, 437 (1978).
- (12) J. Bastide, N. El-Ghondour and O. Henri-Rousseau, *Bull. Soc. Chim. Fr.*, 2290 (1973); K. N. Houk, J. Sims, R. E. Duke, R. W. Strozier and J. K. George, *J. Am. Chem. Soc.*, 95, 7287 (1973).

(Received in UK 12 April 1985)