STUDY OF THE KINETIC ENERGY RELEASE IN SOME N-METHYL p-ARYLSULFONAMIDO THIOPHOSPHORORGANIC DERIVATIVES

S. Nicoarã[1], N. Palibroda[2], Z. Moldovan[2], M. Culea[3], O. Cozar[3], I. Fenesan[4]

[1] *Physics Dept., T.U.C-N, C. Daicoviciu str., 15, 3400 Cluj-Napoca,* snicoara@phys.utcluj.ro
[2] *Nat. Inst. R.&D. Isot. Molec. Tech., Donath str., 109, 3400 Cluj-Napoca*
[3] *Physics, "Babeş-Bolyai" Univ., Kogãlniceanu 1, 3400 Cluj-Napoca*
[4] *Chemistry Inst. "Raluca Ripan", Donath str., 103, 3400 Cluj-Napoca*

ABSTRACT: The mass spectra and the metastable ions cleavage processes, detected in the HV and MIKE scanning modes, are interpreted for: p-fluorinebenzenesulfonamide- (**1**), p-chlorinebenzenesulfonamide- (**2**), p-methylbenzenesulfonamide- (**3**), and p-methoxybenzenesulfonamide- (**4**) of the N-methyl N',N' -dimethylamidocyclohexylthiophosphonic acid, some p-X substituted arylsulfonamidic thiophosphonamides. The peak width at 50 % height was used for calculating the kinetic energy release T, and the correlation among the peak shape, the T values, and the fragmentation processes are discussed.

Introduction: The purpose of this paper is to interpret the mass spectral bahaviour of some N-methyl substituted arylsulfonamides of the N'dimethylamidocyclohexyl thiophosphonic acid, synthesized at the Chemistry Institute "Raluca Ripan" Cluj-Napoca, having the structural formula given in figure 1 and Table 1. Aromatic organophosphorus compounds have the potential to induce or to inhibate certain biochemical reactions [1-4], due to their molecular structure and interatomic bonds. Mass spectrometry is intensively used for their qualitative/quantitative analysis [5-7] and serves to the primary structural analysis of organic compounds with biological activity [8-9]. Determining the kinetic energy release T in metastable ions transitions, afford the collection of data on the fragmentation mechanism, as the relative contribution of the excess energy of the activated complex (E^{++}) and of the reverse critical energy (E_o^r) to T, influence the metastable peak shape [10-11].

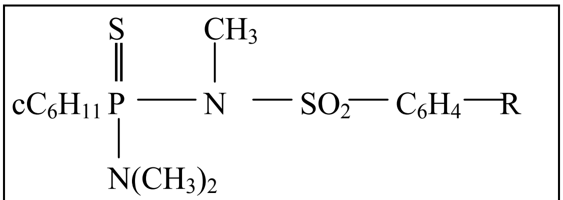

Fig. 1. Structural formula of compounds 1-4.

Experimental

The compounds studied **1-4**, were synthesized at the Chemistry Institute "Raluca Ripan", their purity and chemical structure were tested through IR, NMR and MS analysis [12]. The 70 eV electron impact mass spectra were recorded on a double focusing MAT-311 MS. The electron emission current was 100 µA, the ion source temperature 150 ^oC, and the solid sample inlet system was set at the optimum evaporation temperatures for each compound, as presented in Table 1.

Table 1:

The compounds **1-4**: radicals, molecular ions masses, inlet system temperature.

Compound (mass)	**1** (378)	**2** (394)	**3** (374)	**4** (390)
Inlet temp. T (^oC)	170	200	150	120
R (mass, amu)	F (19)	Cl (35)	CH_3 (15)	OCH_3 (31)

The elemental composition of the fragment ions was checked by HR mass measurements (R= 4000, 10 % valley definition), in the peak matching mode, with PFK masses as reference, for compounds **1** and **2**. Metastable ions cleavages were recorded in the HV scanning (3000 V down to 1000 V), and in the MIKE mode (505 V down to 0, $\Delta U / U_0 = 1000$, U_0= main ion beam voltage) [8,9]. The direct analysis of daughter ions generated in the second field free region, or the DADI spectra, were used to determine the kinetic energy release during the fragmentations recorded.

For a single charged cleavage process: $m_1^+ \rightarrow m_2^+ + m_3^0$, in the second field-free region, the daughter ion mass is: $m_2 = m_1 \cdot U_1 / U_0$, where U_1 is the electric sector voltage corresponding to the daughter ion signal. The amount of kinetic energy T_{50} released during this fragmentation, was calculated using the peak width w at 50 % height, as:

$$T_{50} \cong 5{,}62 \cdot (w_c/U_0)^2 \cdot m_1^2 / m_2 m_3 \text{ (eV)} \quad (1)$$

where w_c is the peak width w at 50 % height corrected with respect to the main ion beam width w_0= 5,83 mm at semiheight, and with respect to the ions masses $w_c = \sqrt{w^2 - \left(w_0 \cdot \frac{m_2}{m_1}\right)^2}$ [8,9]. The coefficient 5,62 results from the experimental conditions used: 2970 V accurately measured accelerating voltage, an average 20,76 V/min electric sector scanning rate, and 20 mm/min paper speed.

Results and Discussion:

Figure 2 presents the fragmentation pattern of compounds (**1-4**), discussed elsewhere [12], and the kinetic energy T_{50} determined for certain metastable ions cleavage in the MIKE mode, for the p-fluorinebenzenesulfonamide of the N',N'-dimethylamidocyclohexylthiophosphonic acid (**1**). Figure 3 shows sample peak shapes for the metastable ions processes analyzed in the MIKE mode for compound (**1**).

The results of the average kinetic energy T_{50} released during the metastable ions fragmentation in compound (**1**) are presented in table 2. The standard deviation σ of average T_{50} was calculated for 3-4 repeated determinations.

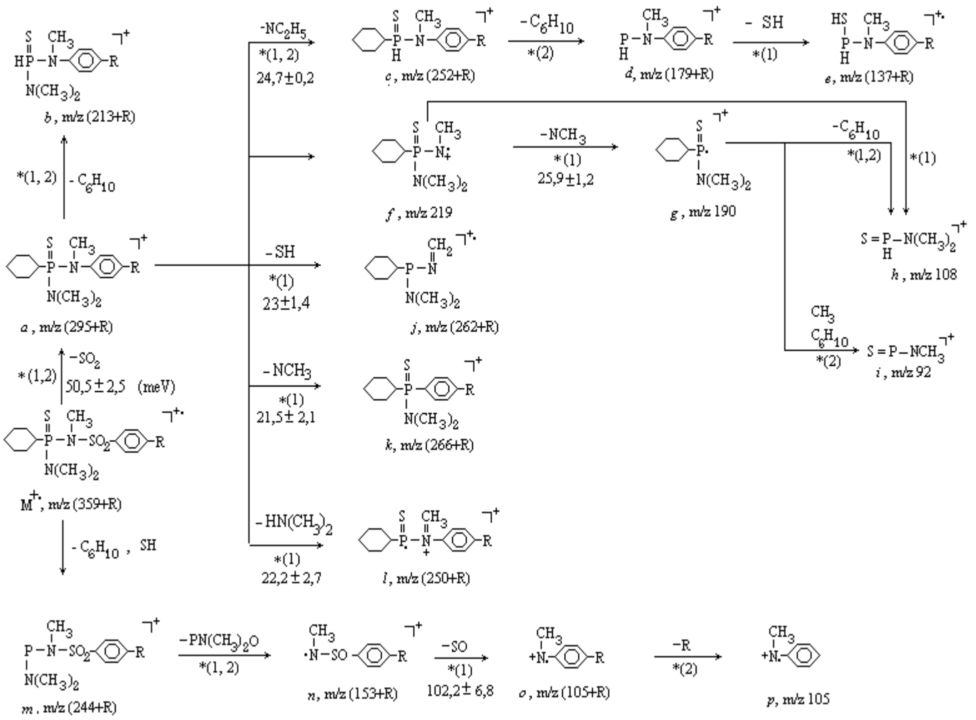

Fig. 2. Fragmentation pathways of the N-methyl derivatives **1-4** (* = metastable ion transition detected in HV or MIKE mode in **1** and **2**). The values of T_{50} are given in meV.

Table 2:

Experimental data, MIKE mode, for the p-fluorinebenzenesulfonamide of the N',N' - dimethylamidocyclohexylthiophosphonic acid (**1**); U_o = 505.0 V main ion beam; m_1 = precursor ion; U_1 = electric sector voltage for the daughter ion signal; m_2 = calculated nominal mass of the daughter ion.

m_1	m_2	U_1	m_3	average w	w_c	$T_{50} \pm \sigma$	$\bar{r}$
(Da)	(Da)	(V)	(amu, composition)	(mm)	(mm)	(meV)	-
n, 172	*o*, 124	362,5	48 SO	29,5	29,2	102,2±6,8	3,41
a, 314	*c*, 271	435,8	43 NC_2H_5	12,5	11,5	24,7±0,0	3,23
	l, 269	432,6	45 $HN(CH_3)_2$	12,2	10,8	22,2±2,7	3,76
	j, 281	451,0	33 (SH)	11,2	9,5	23,0±1,4	2,60
	k, 285	458,0	29 $HNCH_2$	10,5	8,7	21,5±2,1	2,65
$M^{+\cdot}$, 378	*a*, 314	418,0	64 SO_2	18,5	17,5	50,0±2,5	3,55
f, 219	*g*, 190	437,8	29 NCH_3	12,7	11,2	25,9±1,2	2,98

The kinetic energy release may originate in two different sources: E^{++}, the non-fixed excess energy of the activated complex, and E_o^r, the reverse reaction crytical energy [8,9]. Their contributions T^{++} and T^{r} respectively, to the total translational energy, depend on the precursor ion structure, on the reaction mechanism and products, and influence the metastable peak shape, thus allowing a correlation with the reaction mechanism [13,14]. Simple fission and reactions controlled by the statistical partitioning of the excess energy E^{++} are associated with a Gaussian peak, the squared ratio **r** in Table 2, of the average (22 % height peak width) to the most probable (61 %) energy release, $r=(w_{22}/w_{61})^2$ is equal to 3. If, on the contrary, E_o^r controls the fragmentation, and if the fraction of it appearing as kinetic energy covers only a small range of values, r < 3, the peak is narrower than a Gaussian one. Wider peaks, with r > 3, most likely indicate two or more mechanisms in the fragmentation of the metastable ion.

M→ a (418 V) *a →c, l* (435,8 V; 432,6 V) *n → o* (326,5V)

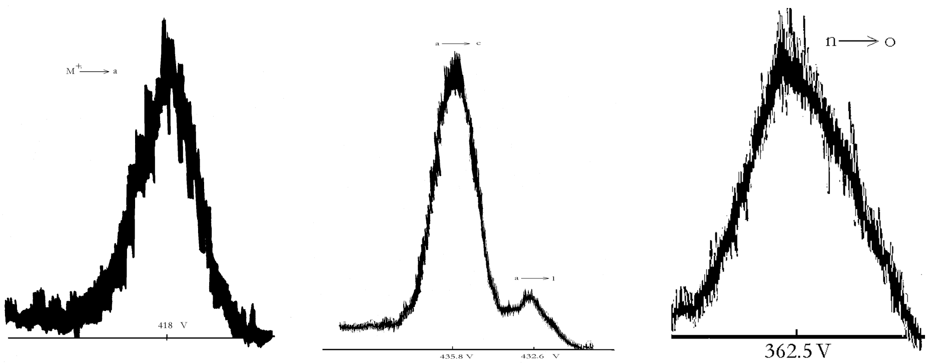

Fig.3. MIKE peaks recorded for the transitions ***M***$^{+\cdot}$ *→a, a → c,l, and n → o, respectively*

The base peaks in all four spectra was at m/z 44, corresponding to the abundant ion $\{N(CH_3)_2\}^+$, confirmed via accurate mass measurements. The molecular ion **M**$^{+\cdot}$**,** m/z (359+R) of low intensity (1-5 %) peaks in all the spectra, undergoes the elimination of a stable neutral molecule SO_2, very typical for such sulfonamidic compounds [15,16]. The process involves a three membered transition state (N,S,C), and the calculated kinetic energy release (fig.3) was 50±2,5 meV, comparable to the values for similar fragmentations [9]. Since r=3,55, the reverse critical energy E_o^r may have an important contribution to T_{50} [8].

The metastable ion *a*, m/z (295+R) undergoes the transfer of a H atom from the dimethylamido group onto P, through a four membered transition state, and a kinetic energy release (fig.3) of 24±0,2 meV (r=3,23), that coresponds to the reaction type described, and to the number of excited atoms in the activated complex. The transition *f→ g*, with the simple P-N bond fission, and the subsequent elimination of a neutral $HN=CH_2$ molecule, involves a kinetic energy release of 25,9±1,2 meV, that corresponds to this type of fragmentation [8,9,13]. The Gaussian peak, r=2,98, suggests that T^{++} may have an important contribution to T. The ion *a* may also undergo the transfer of a H atom from the cyclohexyl group to S, through a five membered transition state (P valence changes from 5 to3), prior to the elimination of neutral SH radical, with a kinetic energy release of 23$\pm$1,4 meV. The relatively small value of T_{50} and r = 2,60 indicate that T^{++} brings its major contribution to T. The ion *a* may also lose the neutral NCH_3 radical and result in ion *k*. The kinetic energy T=21,5$\pm$2,1 meV suggests that this process follows a more complex pathway [9], through a five membered transition state, with the migration of H and the subsequent elimination of an unsaturated amine ($HN=CH_2$) molecule. The peak shape (r=2,65) and the relatively small value of T indicates a random distribution of the kinetic energies, with T^{++} dominant. To produce the structure *l*, the ion *a* may undergo the rearrangement of H from the amidic methyl to N, in a five membered transition state, followed by the loss of a neutral $HN(CH_3)_2$. The relatively low value of the kinetic energy release 22,2$\pm$2,7 meV supports this type of fragmentation [8]. The fragment ion *n* produces (fig 3) the abundant ion *o*, by eliminating a neutral SO, with a high kinetic energy release, 102$\pm$6,8 meV, that may indicate a dominant contribution of T_0^r to the total T. The wider that Gaussian peak (r=3,41) suggests a complex fragmentation mechanism.

Conclusions:

The following values were obtained for the kinetic energy release during metastable ions cleavage:

- simple fission, n > 5: $T_{50} \cong 26$ meV
- fragmentation with rearrangements of atoms (H,S), m = 3, n = 2-3: $T_{50} > 50$ meV.
- fragmentations with rearrangement of atoms, m = 4 or 5, n > 5, or n = 2: T_{50}=20-30 meV, where T = the kinetic energy release calculated based on the half height width of the MIKE peak; m= nr. of active centers in the cyclic transition state of the fragment ion; n= nr. of atoms in the neutral radical or molecule eliminated. A correlation was observed between the kinetic energy release and the type of fragmentation mechanism, the activated complex energy (E^{++}) and the reverse critical energy (E_o^r) contributing in different amounts to the total kinetic energy release, in different fragmentation mechanisms.

References

1. I. Fenesan, I. Chioreanu, A. Hantz, Al. Alexandru, R. Pop, *FARMACIA* **XXXI**, 3 (1988) 143-150
2. L. Almasi: "Les composees thiophosphororganiques", Ed. Masson, Paris (1976).
3. C. Fest, K. J. Schmidt: "The Chemistry of Organophosphorus Pesticides", Springer Verlag, Berlin (1973).
4. I. Fenesan, R. Popescu, A. Scozzafava, V. Crucin, E. Mateiciuc, R. Bauer, M. Ilies, C. Supuran, *J. Enzyme Inhibition*, 15 (2000) 297-302.
5. Q. N. Porter and J. Baldas: "Mass Spectrometry of Heterocyclic Compounds", Wiley- Interscience, New-York (1971).
6. F. W. McLafferty and F. Turecek: "Interpretation of Mass Spectra", University Science Books, Hill Valley, California (1993).

7. I. Fenesan, R. Popescu, C. T. Supuran, S. Nicoarã, N. Palibroda, M. Culea, O. Cozar, *Rapid Commun. Mass Spectrom.*, **15** (2001) 721-729.
8. R. G. Cooks, J. H. Beynon, R. Caprioli and G. Lester: "Metastable Ions", Elsevier, Amsterdam (1973).
9. Z. Moldovan, N. Palibroda, V. Mercea and G. Mihãilescu, *Org. Mass Spectrom.*, **20** (1985) 77-86.
10. R. K. Boyd and J. H. Beynon, *Int. J. mass Soectrom. Ion Phys*., **23** (1977) 163.
11. J. H. Beynon and R. K. Boyd, ,*Adv. Mass Spectrom.*, **78** (1978) 1115.
12. S. Nicoara, M. Culea, N. Palibroda, O. Cozar, I. Fenesan, A. Hantz, *Rapid Commun Mass Spectrom*., 9 (1995) 61-66.
13. Z. Moldovan, Teza: "Studiul proceselor de ciocnire la molecule poliatomice prin spectrometrie de masã" (1982)
14. S. Nicoarã: "Utilizarea spectrometriei de masã cu impact electronic în investigarea structurii moleculelor unor compusi organici biologic activi", teza (1997).
15. Opreanu: "Spectrometria de masã a compusilor organici", Ed. Dacia, Cluj-Napoca (1973).
16. Monica Culea, N. Palibroda, Z. Moldovan, Simona Nicoarã, I. Fenesan, R. Popescu, V. Muresan, E. Postoiu, V. Znamirovschi, *Rapid Commun. Mass Spectrom.*, **12** (1998) 1808-1812.