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^{13}C NMR Substituent Parameters of Dithioacetal Groups in Benzene Derivatives. The $\sigma_p{}^+$ Values of Cyclic Dithioacetals

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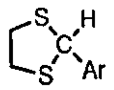
The ^{13}C NMR spectra of forty-six cyclic dithioacetals and their derivatives have been studied. A set of shift parameters was established for each of these heterocycles as substituent. Based on the Hammett type correlation for substituted benzenes, the $\sigma_p{}^+$ values of cyclic dithioacetal groups have been determined.

INTRODUCTION

Although various modern NMR techniques are known to assign unambiguously the ^{13}C chemical shifts of a molecule,[1] the use of substituent increments is still a convenient and powerful tool to predict chemical shifts.[2] The dithioacetal group is a useful protective group for the carbonyl functionality[3] and can serve as a latent methylene group.[4] During the past few years, we have extensively involved in the development of new synthetic applications of dithioacetals.[5] Different kinds of dithioacetals have thus been prepared in our laboratories. In this paper, we have compiled the ^{13}C NMR data of various 2-aryl-substituted 1,3-dithiolanes (**1** and **2**) and 1,3-dithianes (**3** and **4**), monosulfoxides of 1,3-dithiolanes (**5**) and 2-aryl-2-thiomethoxy-1,3-dithianes (**6**) to document the ^{13}C NMR substituent parameters (Z_n) of these moieties in benzene derivatives.



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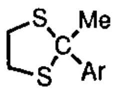

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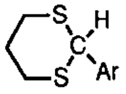

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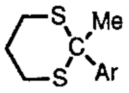

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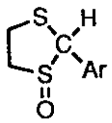

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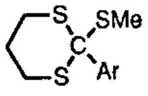

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RESULTS AND DISCUSSION

The ^{13}C NMR spectra of all dithioacetals were obtained in $CDCl_3$ as solvent with shifts listed in δ scale. Tables 1-6 present the spectral data for **1-6**. Since the structures of these compounds are well established, the only problem is to assign of the individual resonance signals to the appropriate carbon atoms. The literature contains several empirical methods for the assignment of carbon resonances.[2] Utilizing the established substituent parameters and, when necessary, either off-resonance or DEPT techniques, we were able to assign all signals. Having assigned the resonance signals to specific carbons, the shift substituent parameters Z_n of various dithioacetal groups **7-12** were established. The Z_n values and their standard deviations are listed in Table 7.

Like many others, the substituents **7-12** affect the chemical shifts most significantly at the position at which the substituent is attached. The Z_1 values increase when the dithioacetal group contains the methyl substituent at the C-2 position (**7** vs **8**, and **9** vs **10**), whereas the sulfoxide group **11** exhibited the smallest Z_1 parameter among those substituents listed in Table 7. These observations are compatible with the literature results; namely, the presence of an additional methyl group causes Z_1 to increase whereas an electron withdrawing group such as carbonyl group normally has a smaller Z_1 value.[2]

Utilizing the substituent parameters (Z_n) summarized in Table 7, we were able to calculate predicted spectra for various aryl-substituted dithioacetals. Tables 1-6 also compile these calculated values. More than 80% of the calculated chemical shifts agree with the experimental value within 1.0 ppm. Of the 222 comparisons, some of the calculated values for ortho-substituted compounds differ from the experimental values by more than 2 ppm.[6] Since the substituent increments depend mainly on the inductive and resonance effects of a substituent, the steric interaction may cause deviations from the predicted values.

As can be seen from Tables 1, 2, 4, and 5, the chemical

Dedicated to Professor Sheng-Lieh Liu (劉盛烈) on the occasion of his eightieth birthday.

Table 1. ^{13}C Chemical Shifts of **1**

Substituent		1	2	3	4	5	6	Others
H	Obsd	140.0	127.6	128.1	127.8			55.9, 39.6
	Calcd	140.2	127.8	128.3	127.8			
4-Me	Obsd	137.8	127.8	129.1	137.1			56.1, 40.1, 21.1
	Calcd	137.3	127.7	129.0	136.7			
2-OMe	Obsd	128.1	156.5	110.4	129.2	120.6	128.8	55.6, 49.0, 39.3
	Calcd	125.8	159.2	113.9	128.8	120.6	128.8	
4-OMe	Obsd	131.7	129.0	113.8	159.3			56.0, 55.2, 40.1
	Calcd	132.5	128.8	113.9	159.2			
2-Cl	Obsd	138.5	133.0	128.6	129.2	126.8	128.9	51.9, 39.5
	Calcd	140.6	134.0	128.7	129.1	126.4	129.1	
4-Cl	Obsd	139.2	129.4	128.7	133.8			55.7, 40.3
	Calcd	138.3	129.1	128.7	134.0			
2-Br	Obsd	140.4	124.0	132.8	129.1	127.7	129.5	55.2, 39.8
	Calcd	143.6	122.3	131.7	129.5	126.7	129.5	
4-CF_3	Obsd	144.9	128.2	125.4	130.0[a]			124.0[b], 55.3, 40.2
	Calcd	143.4	128.1	126.1	118.8			
2-OH	Obsd	121.1	155.3	117.6	130.2	120.4	130.1	54.9, 39.9
	Calcd	127.5	154.7	115.6	129.2	121.0	129.2	
2-$CH(SCH_2)_2$	Obsd	137.6	128.9	128.3				52.8, 40.3
	Calcd	139.5	127.6	127.6				
4-$CH(SCH_2)_2$	Obsd	140.6	128.4					56.1, 40.4
	Calcd	139.5	127.6					

[a] J_{CCF} = 33Hz, [b] J_{CF} = 270Hz.

shifts of the carbon atom on the aromatic ring, at which the trifluoromethyl group is attached, deviate significantly from the predicted position. In each of these cases, the resonances occurred at 11.0 ± 0.3 ppm downfield from what has been predicted on the basis of substituent group shift parameters with $Z_1(CF_3)$ = -9.0.[2] Similar difficulty has also been encountered in other trifluoromethyl-substituted systems and the experimental chemical shifts of the carbon atom having this substituent also appear at much lower field than that of the calculated ones.[7] On the other hand, the calculated chemical shifts of other aromatic carbons in **1**, **2**, **4**, and **5** agree well with the experimental data.

Substituents on the aromatic ring in **1** promoted a systematic change in the position of the carbon resonance of C-2 in the heterocyclic substituent by a linear correlation of the chemical shift of C-2 with the σ value of the substituent (slope = -0.94, correlation coefficient = 0.95). However, the presence of a methyl group at the C-2 position as in **2** resulted in relatively random shifts of the C-2 resonance. Whether these variations have their origin in steric interactions due to the presence of the methyl substituent is unclear. Similarly, little correlation existed between the σ

Table 2. ^{13}C Chemical Shifts of **2**

Substituent		1	2	3	4	5	6	Others
H	Obsd	145.7	126.8	127.7	126.5			68.3, 40.0, 33.6
	Calcd	145.9	127.0	127.1	126.9			
4-Me	Obsd	142.7	126.6	128.6	136.6			68.3, 40.2, 33.8, 20.8
	Calcd	143.0	126.9	128.5	135.8			
4-MeO	Obsd	137.6	128.0	113.1	158.5			68.1, 55.2, 40.3, 33.8
	Calcd	138.2	128.0	113.4	158.3			
4-F	Obsd	141.6	128.6[a]	114.5[b]	161.6[c]			67.9, 40.3, 33.8
	Calcd	141.4	128.4	114.9	161.7			
3-MeO	Obsd	147.7	113.1	159.2	112.1	129.0	119.2	68.5, 55.3, 40.2, 33.8
	Calcd	146.9	112.6	158.5	112.5	128.8	119.3	
2-Me	Obsd	142.5	136.6	127.3	126.7	125.5	132.8	69.4, 39.7, 33.3, 22.6
	Calcd	146.6	135.9	128.5	126.8	124.9	126.9	
4-CF_3	Obsd	150.3	127.2	124.9	129.1[d]			124.0[e], 68.0, 40.4, 33.4, 29.6, 22.6
	Calcd	149.1	127.3	125.6	117.9			

[a] $J_{C2\text{-}F}$ = 8 Hz; [b] $J_{C3\text{-}F}$ = 21Hz; [c] $J_{C4\text{-}F}$ = 245Hz; [d] $J_{C4\text{-}F}$ = 33Hz; [e] $J_{C\text{-}F}$ = 269Hz.

Table 3. ^{13}C Chemical Shifts of 3

Substituent		1	2	3	4	5	6	Others
H	Obsd	139.1	127.7	128.6	128.3			51.4, 32.0, 25.0
	Calcd	139.1	127.7	128.6	128.4			
3-Me	Obsd	139.7	128.8	139.0	129.6	129.0	125.2	51.3, 32.4, 25.3, 21.4
	Calcd	139.0	128.4	137.5	129.1	128.5	124.8	
4-Me	Obsd	136.2	127.6	129.3	138.1			51.2, 32.1, 25.2, 21.1
	Calcd	136.2	127.6	129.3	137.3			
4-OMe	Obsd	131.3	128.9	114.0	159.5			55.3, 50.7, 32.2, 25.0
	Calcd	131.4	128.7	114.2	159.8			
4-Cl	Obsd	137.7	128.9	129.2	134.1			51.2, 32.2, 25.1
	Calcd	137.2	129.0	129.0	134.6			
2-Br	Obsd	138.4	123.0	132.9	129.8	128.1	129.7	50.9, 32.7, 25.6
	Calcd	142.5	122.2	132.0	130.1	127.0	129.4	
2-SiMe$_3$	Obsd	144.6	137.7	133.8	130.0	128.1	127.8	52.4, 32.2, 25.1
	Calcd	143.5	141.1	133.0	127.3	127.5	126.6	

Table 4. ^{13}C Chemical Shifts of 4

Substituent		1	2	3	4	5	6	Others
H	Obsd	143.7	127.6	128.4	126.9			53.8, 32.6, 27.9, 24.5
	Calcd	144.0	128.1	128.4	127.0			
4-Me	Obsd	140.7	127.5	129.1	136.6			53.6, 32.6, 28.0, 24.6, 20.8
	Calcd	141.1	128.0	129.1	135.9			
4-MeO	Obsd	135.7	129.0	113.7	158.5			55.2, 53.4, 32.6, 28.1, 24.7
	Calcd	136.3	129.0	114.0	158.4			
4-F	Obsd	139.5	129.7[a]	115.2[b]	161.7[c]			53.3, 29.6, 28.4, 24.6, 23.5
	Calcd	139.5	129.5	115.5	161.8			
3-MeO	Obsd	145.6	113.8	159.8	112.2	129.4	120.0	55.2, 53.9, 32.7, 28.1, 24.6
	Calcd	145.0	113.7	159.8	112.6	129.4	120.4	
4-Ph	Obsd	143.0	128.8	127.3	139.9			140.6, 128.3, 127.2, 127.1, 53.8, 32.7, 28.2, 24.7
	Calcd	142.8	128.5	127.5	140.1			
4-CF$_3$	Obsd	148.2	128.3	126.8	129.2[d]			124.1[e], 53.5, 32.8, 28.0, 24.4
	Calcd	147.2	128.4	126.2	118.0			
2-Me	Obsd	140.0	137.8	128.4	127.5	125.6	133.7	53.5, 29.6, 28.4, 24.6, 23.5
	Calcd	144.7	137.0	129.1	126.9	125.5	128.0	
3-CF$_3$	Obsd	145.2	124.7	130.8	123.9[f]	128.7	131.3	124.0[g], 53.4, 32.8, 27.9, 24.3
	Calcd	144.3	125.9	119.4	124.8	128.7	131.3	

[a] J_{C2-F} = 8Hz; [b] J_{C3-F} = 21Hz; [c] J_{C4-F} = 245Hz; [d] J_{C4-F} = 33Hz; [e] J_{C-F} = 269Hz; [f] J_{C3-F} = 32Hz; [g] J_{C-F} = 271 Hz.

Table 5. ^{13}C Chemical Shifts of 5

Substituent		1	2	3	4	5	6	Others
H	Obsd	132.9	128.4	128.7	129.5			77.5, 52.9, 32.2
	Calcd	132.9	128.4	128.7	129.3			
4-Me	Obsd	130.0	128.3	129.6	139.0			77.6, 53.2, 32.3, 21.0
	Calcd	130.0	128.3	129.4	138.2			
4-OMe	Obsd	124.7	129.5	114.2	159.9			77.1, 55.3, 52.9, 32.2
	Calcd	125.2	129.4	114.3	160.7			
4-CF$_3$	Obsd	137.1	128.7	125.7	130.7[a]			123.5[b], 76.9, 53.3, 32.2
	Calcd	136.1	128.7	126.5	120.3			
2-Cl	Obsd	131.4	134.6	129.9	130.2	127.4	130.1	76.4, 52.5, 23.4
	Calcd	133.3	134.6	129.1	130.6	126.8	129.7	
3,4-(OMe)$_2$	Obsd	125.1	111.3	149.1	149.5	111.4	121.0	77.6, 55.9, 55.9, 53.2, 32.1
	Calcd	126.2	115.0	145.7	146.3	115.3	121.7	
2,5-(OMe)$_2$	Obsd	123.0	151.0	114.1	116.0	153.6	111.4	72.4, 56.0, 55.8, 52.6, 33.0
	Calcd	119.5	152.1	115.3	115.9	152.4	115.0	

[a] J_{CCF} = 33Hz, [b] J_{CF} = 270Hz.

Table 6. ^{13}C Chemical Shifts of **6**

Substituent		1	2	3	4	5	6	Others
H	Obsd	140.8	127.8	128.3	128.4			63.9, 28.8, 24.4, 16.2
	Calcd	140.8	127.8	128.3	128.4			
4-Me	Obsd	137.8	127.6	129.1	138.1			63.7, 28.8, 24.3, 21.0, 16.2
	Calcd	137.9	127.7	129.0	137.3			
4-OMe	Obsd	132.8	129.2	113.7	159.4			63.6, 55.3, 28.9, 24.4, 16.3
	Calcd	133.1	128.8	113.9	159.8			
3,4-(OMe)$_2$	Obsd	133.2	110.4	148.7	148.9	112.2	120.4	63.8, 55.9, 55.9, 29.0, 24.4, 16.2
	Calcd	134.1	114.4	145.3	145.4	114.9	121.1	
2,5-(OMe)$_2$	Obsd	130.1	152.5	114.0	115.9	153.1	115.7	62.3, 57.5, 55.7, 28.6, 24.2, 16.4
	Calcd	127.4	151.5	114.9	115.0	152.0	114.4	

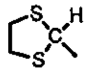
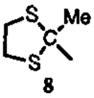
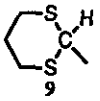
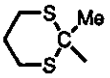
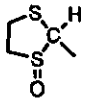
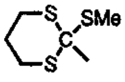
parameters and the position of the C-2 resonance in other substrates **3-6**.

It is known that Z_4 values correlate reasonably well in a Hammett type correlation with σ_p^+ values (Eq. 1).[2,8,9] Based on the results shown in Table 7, the corresponding σ_p^+ values of the dithioacetal groups calculated according to Eq. 1 are also tabulated in Table 7.

$$Z_4 = 7.8\,\sigma_p^+ - 0.93 \qquad (1)$$

As shown in Table 7, the parent 1,3-dithiolane **7** and 1,3-dithiane **9** substituents exhibited small positive σ_p^+ values. The σ_p^+ values for the methyl and acetyl groups are -0.31 and +0.47, respectively.[9] The presence of the two sulfur atoms at the same carbon atom changes significantly the electronic properties of the substituent.

Table 7. ^{13}C NMR Substituent Increments and σ^+ of Dithioacetal Groups

Substituent	Z_1	Z_2	Z_3	Z_4	σ_p^+
 **7**	11.7±0.7	-0.7±0.3	-0.2±0.1	-0.7±0.2	+0.03
 **8**	17.4±0.5	-1.5±0.3	-0.7±0.2	-1.6±0.5	-0.08
 **9**	10.6±0.3	-0.8±0.1	0.1±0.1	-0.1±0.5	+0.11
 **10**	15.5±0.5	-0.4±0.3	-0.1±0.2	-1.5±0.4	-0.06
 **11**	4.4±0.3	-0.1±0.1	0.2±0.1	0.8±0.6	+0.22
 **12**	12.3±0.3	-0.7±0.2	-0.2±0.1	-0.1±0.6	+0.11

As expected, the methyl substituent at C-2 changes the electronic properties of the dithioacetal moiety. Thus, the σ_p^+ values of **8** and **10** are negative, but the absolute values are relatively small. That substituents **9** and **12** exhibit the same σ_p^+ values indicates that the presence of the thiomethoxy group at the C-2 position does not change the electronic properties of the dithiane substituent.

In summary, we have established the shift parameters and σ_p^+ values for different kinds of dithioacetal substituents. Our results provide useful information to understand the electronic effects of various dithioacetal moieties.

EXPERIMENTAL SECTION

^{13}C NMR spectra were recorded on a Bruker AC200 spectrometer operating at 50 MHz. Chemical shifts are reported on the δ scale with deuteriochloroform (δ 77.0) as the internal standard. Dithioacetals **1-4**,[10] 1,3-dithiolane-S-oxides **5**,[11] and orthothioesters **6**[12] were prepared according to literature methods. All compounds gave satisfactory spectroscopic properties (^1H and ^{13}C NMR, IR, MS). All new compounds gave satisfactory analytical data (C: ±0.3%, H: ±0.3%) and/or accurate mass.

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Key Words

Substituent parameters; ^{13}C NMR; σ^+ values; Dithioacetals; Sulfoxides.

REFERENCES

1. Derome, A. E. *Modern NMR Techniques for Chemistry Research*; Pergamon: Oxford, **1987**.
2. For general references see: Levy, G. C.; Nelson, G. L. *Carbon-13 Nuclear Magnetic Resonance for Organic Chemists*; Wiley-Interscience: New York, **1972**.
3. Greene, T. W. *Protective Groups in Organic Synthesis, Wiley: New York,* **1981**; p 129.
4. Carey, F. A.; Sundberg, R. J. *Advanced Organic Chemistry*, 3rd ed.; Plenum: New York, **1990**; Part B, p 266.
5. For reviews, see: (a) Luh, T.-Y.; Ni, Z.-J. *Synthesis* **1990**, 89. (b) Luh, T.-Y. *Rev. Heteroatom Chem*. **1991**, *4*, 140. (c) Luh, T.-Y. *Acc. Chem. Res*. **1991**, *24*, 257.
6. Because of the size of these deviations, these experimental values were not incorporated into the statistical analysis used to determine the parameters listed in Table 7.
7. Gassman, P. G.; Cue, B. W., Jr.; Luh, T.-Y. *J. Org. Chem*. **1977**, *42*, 1344.
8. Eq. 1 was obtained on the basis of a plot of Z_4 values of substituents NMe_2, NH_2, MeO, OH, Me, H, Ph, Cl, Br, $COCH_3$, CN against the corresponding $\sigma_p{}^+$ parameters ($r = 0.98$).
9. March, J. *Advanced Organic Chemistry*, 3rd ed, Wiley: New York; **1985**, p 244.
10. Fieser, L. F. *J. Am. Chem. Soc*. **1954**, *76*, 1945.
11. Price, C. C.; Hydock, J. J. *J. Am. Chem. Soc*. **1952**, *74*, 1943.
12. Ellison, R. A.; Woessner, W. D. *J. Org. Chem*. **1972**, *37*, 2757.