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O-17 NMR STUDIES ON α-DIAZOKETONES

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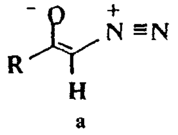
The O-17 NMR spectra of 13 α′-alkyl- and aryl-substituted α-diazoketones were measured. The results obtained show a clear discrimination between them. A good correlation in a series of *para*-substituted α-diazoacetophenones between O-17 chemical shifts and both σ_p^+ and dual substituent parameters indicated a greater contribution of resonance than inductive effects.

INTRODUCTION

In the past 50 years α-diazoketones have received considerable attention owing to their wide synthetic uses[1] and the method of formation of the two principal reactive intermediates available from α-diazoketones, i.e. α-ketocarbenes (carbenoids) and α-diazonium ketones, has been extensively studied. In this regard, EHMO calculations,[2] ^{1}H, ^{13}C and ^{15}N NMR and IR spectra[3] indicate that the oxygen atom is the most negative site in the diazoketone group, suggesting an important contribution of the canonical formula **a**. Nevertheless, the site of complexation of metals or of attack by electrophilic agents to obtain the highly reactive carbenoid and diazonium ketones species, respectively, still appears unclear.[4,5] With the aim of acquiring a better knowledge of the electronic distribution in this complex functionality, we have measured the O-17 NMR spectra of a series of α-diazoketones **1**–**13** (see Table 1). This technique is a valuable tool for the study of structural effects on carbonyl group.[6] O-17 NMR chemical shifts are very sensitive to changes due both to steric and/or electronic factors.



a

RESULTS AND DISCUSSION

The structures of the compounds investigated are shown in Table 1 together with O-17 NMR chemical shifts, molar concentrations and measured line widths. The data show that α-diazoketones are strongly shielded (about 110–140 ppm) compared with 'normal' ketones (e.g. 539 ppm for acetophenone). O-17 NMR chemical shifts depend most on the paramagnetic term of the Karplus–Pople equation.[7] For α-diazoketones, canonical formulae such as **a** influence the charge density bond order matrix with an increased electron density and diminished π-bond order at the oxygen atom; the large value of the observed shielding is a good index of the importance of such resonance structures.

We turn now to the much smaller differences in chemical shifts that can be noted within this class of compounds; α-diazoacetophenones are more shielded (by about 20 ppm) than aliphatic diazoketones, as are acetophenones compared with aliphatic ketones. This similarity helps to rule out the coexistence of *cis* and *trans* conformations in α-diazoketones as a cause of this difference. It is known that all the α-diazoacetophenones exist in solution in the *cis* conformation,[8] as do the aliphatic α-diazoketones with the exception of **2**[8] and, possibly, **4**. Moreover, the *trans* conformation is much less populated than the *cis* conformation[9] and if it relieves steric hindrance at the carbonylic group,[9] this would cause an effect opposite to

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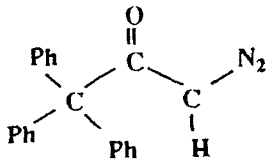
Table 1. Oxygen-17 NMR data for α-diazoketones, $RCOCHN_2$

Compound	R	Concentration (mol dm^{-3})	δ(^{17}O) (ppm)[a]	Others δ (^{17}O) (ppm)	Line width (Hz)
1	Ph_3C	0·30	456·0		870
2	$PhCH_2$	1·00	454·5		350
3	Ph_2CH	0·30	451·0		580
4	*p*-$MeOC_6H_4CD_2$	0·15	450·5	47·5	160
5	9-Fluorenyl	0·60	450·0		785
6	(PhS)(Ph)CH	0·50	445·0		575
7	*p*-$NO_2C_6H_4$	0·60	438·0	577	770
8	*p*-CNC_6H_4	0·50	438·0		640
9	Ph	0·90	430·0		565
10	*p*-ClC_6H_4	0·80	429·5		470
11	*p*-*t*-BuC_6H_4	0·80	429·0		685
12	*p*-MeC_6H_4	0·75	425·5		760
13	*p*-$MeOC_6H_4$	1·00	420·0	59·3	635

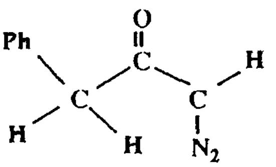
[a] As defined under Experimental.

that observed. All the aliphatic α-diazoketones have very similar chemical shifts, with **1** and **2** most deshielded and **6** most shielded.

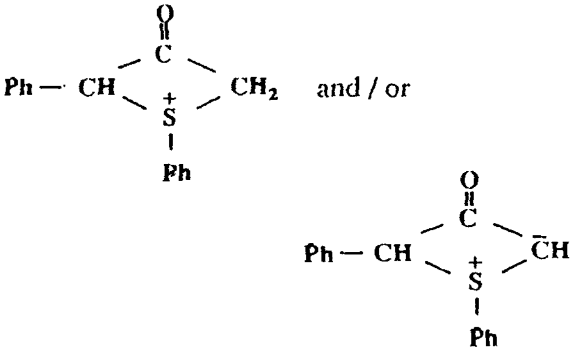
In the structure of **1**, a phenyl group is close to the carbonyl (**b**) and the same situation is likely to occur for **2** in the *trans* conformation (**c**) because of the greater steric requirement of the diazo group compared with hydrogen. Conversely, the chemical shifts of compounds **3**, **4** and **5** are identical within experimental error. This steric deshielding is, however, smaller than that observed in passing from α-diazoacetophenones to aliphatic diazoketones, as already noted. Another difference between aliphatic and aromatic groups is the existence of other canonical formulae for the α-diazoacetophenones, to be discussed later. The special behaviour of **6** in its acetolysis reaction[10] can help us to explain its O-17 NMR shift. Saba *et al.*[10] postulated the intermediacy of **d**.



b

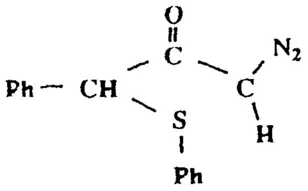


c

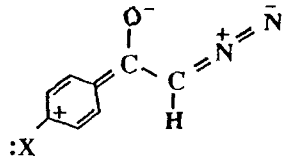


d

It is reasonable to think that for **6**, before the nitrogen leaves, conformations such as **e** are important, where steric effects are slightly relieved so as to justify the observed difference in the shift. Let us now examine, in more detail, the behaviour of α-diazoacetophenones which, as already noted, are more



e



f

shielded than aliphatic diazoketones because of the existence of an additional canonical formula (**f**).

As with **a**, **f** increases the electronic density and diminishes the π-bond order at the oxygen atom, so causing a further shielding. Its weight in determining the overall structure of α-diazoketones must be fairly minor compared with **a**, as reflected by the magnitude (*ca* 20 ppm against *ca* 120 ppm) of the variation in the chemical shift.

It is interesting to compare the effect of *para* substitution in our compounds and in the closely related acetophenones[11,12] and α, α, α-trifluoroacetophenones.[13] We calculated the correlation of our substituent chemical shifts (SCS) both against σ_p and σ_p^+ Hammett constants,[14,15] obtaining correlation coefficients (r^2) of 0·859 and 0·963 respectively. The better correlation obtained with σ_p^+ is indicative of the enhanced interaction of donor substituents showing the relative importance of the resonance and polar terms.

We analysed the data by the dual substituent parameters method (DSP) approach, obtaining

$$\delta_{O-17} = 10{\cdot}25\ \sigma_I + 14{\cdot}39\ \sigma_R^+$$
$$SD = 0{\cdot}6654;\ f = 0{\cdot}077$$

The data are normalized, SD is the standard deviation of the fit and f is the standard deviation divided by the root-mean-square size of the data.[12,16] The DSP procedure is the general method of choice, and only in the special case when $\lambda = (\rho_R/\rho_I)$ is close to unity do single-parameter methods approximate the DSP method.[12]

We can observe that ρ_R is larger than ρ_I, with $\lambda = 1{\cdot}40$, indicating that resonance contribution is more important than inductive effects. This was not the case for acetophenones as reported in Ref. 12 ($\lambda = 1{\cdot}04$), but the authors in that paper computed DSP also for the values in Ref. 11, obtaining $\lambda = 1{\cdot}29$, a value much closer to ours. Brownlee *et al.*[12] attributed this difference to a more precise determination of their data owing to the use of a low uniform concentration and to the fact that nitro and carbonyl group resonances were not resolved in Ref. 11. Whereas the second point is clearly not our case, the first applies to both. We used concentrations only roughly constant (1–1·75 mol dm^{-3}) except, for solubility reasons, for compounds **8** and **11** (see Table 1) and 5–6 times greater than those used by Brownlee *et al.*[12] Nevertheless, as shown in Figure 1, the statistical treatment is reasonable and we think that, as a better correlation was obtained with σ_p^+ than with σ_p, it is possible to deduce that resonance effects are more important than inductive effects.

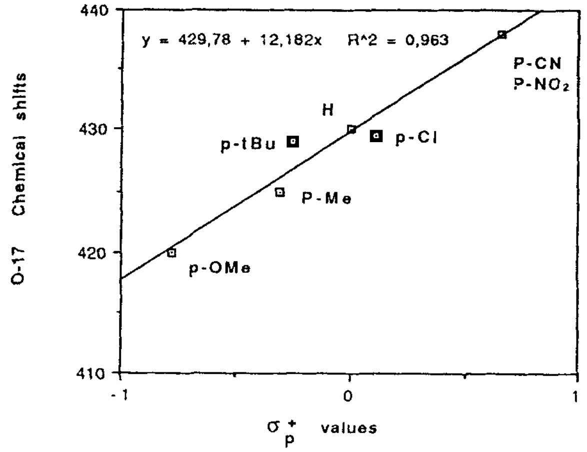


Figure 1. Correlation between O-17 chemical shifts and σ_p^+.

If we compare the effect of the *para* substituent for the three similar classes of compounds, α,α,α-trifluoroacetophenones, acetophenones and α-diazoacetophenones, a difference in their sensitivity can be observed, namely, the effect of the same substituent on the carbonyl shift diminishes on passing from α,α,α-trifluoroacetophenones to α-diazoacetophenones. This result can be compared with those reported by Dahn *et al.*[17] who already noted the difference between α,α,α-trifluoroacetophenones and acetophenones, and our compounds gave a ρ^+ value close to that for methyl benzoate, another cross-conjugated system.

The reason for this behaviour probably lies in the smaller weight of formulae type **f** for our compounds compared with α,α,α-trifluoroacetophenones, in agreement with what was observed by Liu *et al.*[13] for the same type of compounds. The effect of the diazoaceto group on its *para* substituent, i.e. methoxy and nitro groups in **13** and **7**, is evident. These groups have the same shifts as observed for *p*-cyanoanisole[18] and *p*-cyanonitrobenzene,[19] whereas the methoxy group in **4** has a shift very similar to that of the parent anisole.[18]

While a correlation between $E_{n\rightarrow\pi^*}$ and O-17 chemical shifts is theoretically justified,[20] there is no agreement as to whether this correlation is valid for acetophenones.[11,12] In the case of α-diazoacetophenones we obtained a good fit ($r^2 = 0{\cdot}929$) between our O-17 NMR shifts and the literature UV data[21] (Figure 2). We do not assert that this correlation demonstrates that ΔE makes the dominant contribution to the O-17 nuclear screening for the *para*-substituted α-diazoacetophenones, but merely report an experimental observation.

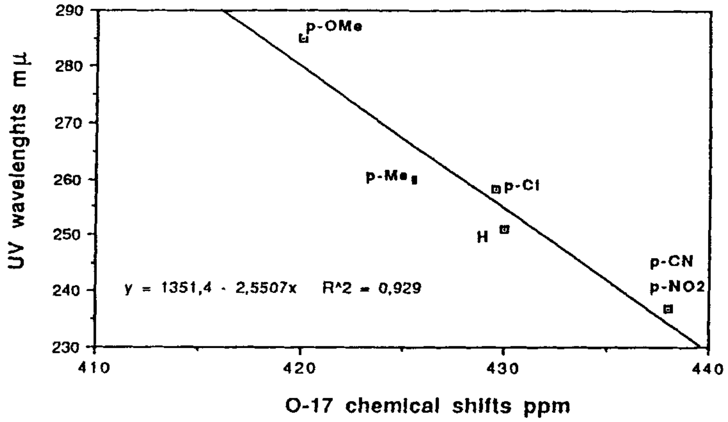


Figure 2. Correlation between UV frequencies and O-17 chemical shifts

On the other hand, St Amour *et al.*[11] did find a good correlation between IR and NMR data, although we do not, for α-diazoacetophenones. This result can be explained by the already mentioned decreased sensitivity to substituent effects of our compounds, which causes the differences in the observed IR frequencies[3] to be smaller than the experimental accuracy.

It may be concluded that our O-17 NMR results are in agreement with the claimed importance of canonical formula **a** as also for the groups of α-diazoketones examined. Our data show a clear discrimination between aliphatic α-diazoketones and α-diazoacetophenones and a rationalization of the chemical shift differences within the former.

In conclusion, despite the smaller SCS effect observed in the *para*-substituted α-diazoacetophenones compared with acetophenones and to α,α,α-trifluoroacetophenones, a good correlation between O-17 NMR chemical shift and both σ_p^+ and dual substituent parameters has been obtained, further proving the usefulness of O-17 NMR.

Further spectroscopic work on the title compounds is in progress.

EXPERIMENTAL

All the substrates were prepared by treatment of the corresponding acyl chlorides with excess of diazomethane. Analytical and spectroscopic data were in accord with those reported in the literature.[3]

NMR measurements. Oxygen-17 NMR spectra were acquired at 40·662 MHz using a Varian VXR-300 spectrometer, equipped with a 10 mm broad-band probe. All spectra were acquired at natural isotopic abundance at room temperature (probe temperature = 21 °C) in deuteriated chloroform. The signals were referenced to external deionized water. The concentrations varied typically in the range 0·1–1 mol dm^{-3}. In two cases (**2** and **7**) the spectra were run at different concentrations (0·1–1 or 0·9 mol dm^{-3}, respectively) without significant changes in their chemical shifts.

Typical spectroscopic parameters were pulse length 28 μs (*ca* 90°), pre-acquisition delay 100 μs, acquisition time 10 ms, spectral width 36 kHz, 740 data points and 10^5–10^6 scans. The spectra were recorded with sample spinning and without lock and decoupling. The signal-to-noise ratio was improved by applying a 30 Hz exponential broadening factor to the FID prior to Fourier transformation. The data point resolution was improved to 0·08 ppm by zero filling to 16K data points. The reproducibility of the chemical shifts data is estimated to be ± 1·0 ppm. Statistical treatment was performed by the PARVUS[22] program on an IBM PS2 computer.

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REFERENCES

1. F. Weygand and H. J. Bestmann, in *Newer Methods of Preparative Organic Chemistry*, Edited by W. Foerst, Vol. 3, p. 451. Academic Press, New York (1964).
2. I. G. Czimadia, S. A. Houlden, O. Meresz and P. Yates, *Tetrahedron* **25**, 2121 (1969).
3. M. Regitz and G. Waas, *Diazo Compounds. Properties and Synthesis*. Academic Press, London (1986), and references cited therein.

REFERENCES

1. F. Weygand and H. J. Bestmann, in *Newer Methods of Preparative Organic Chemistry*, Edited by W. Foerst, Vol. 3, p. 451. Academic Press, New York (1964).
2. I. G. Czimadia, S. A. Houlden, O. Meresz and P. Yates, *Tetrahedron* **25**, 2121 (1969).
3. M. Regitz and G. Waas, *Diazo Compounds. Properties and Synthesis*. Academic Press, London (1986), and references cited therein.
4. J. Adams and D. M. Spero, *Tetrahedron* **47**, 1765 (1991).
5. A. B. Smith and R. K. Dieter, *Tetrahedron* **37**, 2407 (1981).
6. A. L. Baumstark and D. W. Boykin, in *O-17 NMR Spectroscopy in Organic Chemistry*, Chapter 8, p. 205. Edited by D. W. Boykin. CRC Press, Boca Raton, FL (1991).
7. M. Karplus and J. A. Pople, *J. Chem. Phys.* **38**, 2803 (1963).
8. S. Sorriso, in *The Chemistry of Diazonium and Diazo Groups Part I*, edited by S. Patai, p. 95. Wiley, Chichester (1978).
9. F. Kaplan and G. K. Meloy, *J. Am. Chem. Soc.* **88**, 950 (1966).
10. A. Pusino, V. Rosnati, A. Saba, F. Soccolini and A. Selva, *Gazz. Chim. Ital.* **108**, 557 (1978).
11. T. E. St. Amour, M. I. Burgar, B. Valentine and D. Fiat, *J. Am. Chem. Soc.* **103**, 1128 (1981).
12. R. T. C. Brownlee, M. Sadek and D. J. Craik, *Org. Magn. Reson.* **21**, 616 (1983).
13. K. T. Liu, T. R. Wu and Y. C. Lin, *J. Phys. Org. Chem.* **2**, 363 (1989).