# Indirect Calculations of Relative Rotatory Strengths of Substituted Ketones

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*Summary* The twists $\theta$ $[=\theta(n) - \theta(\pi^*)]$ of the orbitals of the carbonyl group of a series of model substituted ketones reproduce accurately the variation in the c.d. of the $n \rightarrow \pi^*$ transition of chiral substituted ketones even when the substituents are heteroatoms (F, Cl, $SiH_3$).

TABLE 1[a]

| | X | 1 bond | | | | 2 bond | | | | 3 bond | | | | 4 bond | | | | 5 bond | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\theta(n_0)$ | $\theta(\pi^*)$ | $\theta$ | $\Delta\theta$ | $\theta(n_0)$ | $\theta\pi^*)$ | $\theta$ | $\Delta\theta$ | $\theta(n_0)$ | $\theta(\pi^*)$ | $\theta$ | $\Delta\theta$ | $\theta(n_0)$ | $\theta(\pi^*)$ | $\theta$ | $\Delta\theta$ | $\theta(n_0)$ | $\theta(\pi^*)$ | $\theta$ | $\Delta\theta$ |
| Path | H | 0 | 0 | 0 | 0 | −74 | −32 | −42 | 0 | −205 | −46 | −159 | 0 | −309 | −49 | −260 | 0 | −393 | −50 | −343 | 0 |
| Coupling | F | +41 | +13 | +28 | +28 | +63 | −20 | −43 | −1 | −160 | −41 | +119 | +40 | −268 | −44 | −224 | +36 | −341 | −49 | −292 | +51 |
| | Cl | −195 | −33 | −162 | −162 | −290 | −55 | −235 | −192 | −370 | −53 | −317 | −158 | −406 | −49 | −357 | −97 | −455 | −40 | −405 | −62 |
| | $SiH_3$ | −914 | −297 | −617 | −617 | −394 | +9 | −403 | −361 | −798 | −33 | −765 | −606 | −666 | −42 | −624 | −364 | −672 | −47 | −625 | −282 |
| Non Coupling | F | 0 | 0 | 0 | 0 | −117 | −23 | −94 | −52 | −219 | −40 | −179 | −20 | −305 | −47 | −258 | +2 | −378 | −49 | −329 | +14 |
| | Cl | 0 | 0 | 0 | 0 | 0 | −29 | −29 | +71 | −229 | −40 | −189 | −30 | −293 | −47 | −246 | +14 | −378 | −49 | −329 | +14 |

[a] $\theta(n)$, $\theta(\pi^*)$, $\theta$ and $\Delta\theta$ are in minutes of a degree. Positive values represent clockwise twist, negative values (the sign above the number) represent anti-clockwise twist of $n$ [$\theta(n_0)$] and $\pi^*$[$\theta(\pi^*)$] orbitals of the carbonyl group as viewed along the O=C bond. $\theta = \theta(n_0) - \theta(\pi^*)$; $\Delta\theta^x = \theta^x - \theta^H$ (X = substituent).

TABLE 2. Calculated rotatory strength $R$.

| | 1 bond | | 2 bond | | 3 bond | | 4 bond | | 5 bond | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $R$ | $\delta R$ | $R$ | $\delta R$ | $R$ | $\delta R$ | $R$ | $\delta R$ | $R$ | $\delta R$ |
| H | 0 | | +1·0 | | +4·2 | | +6·8 | | +8·6 | |
| Coupling F .. | −2·6 | −2·6 | +1·8 | +0·8 | +3·0 | −1·2 | +5·9 | −0·9 | +7·6 | −1·0 |
| Non-coupling F | 0 | 0 | +3·6 | +2·6 | +4·8 | +0·6 | +7·6 | +0·8 | +8·3 | −0·3 |

DURING the course of our systematic investigation of the optical activity of chiral monosubstituted halogenoketones,[1] we have noted that the substituent increments $\delta\Delta\epsilon$ ($=\Delta\epsilon_{\text{substd. ketone}} - \Delta\epsilon_{\text{unsubstd. ketone}}$) varied with the number of intervening C–C bonds, reaching an unexpected maximum at a separation of 2C–C bonds[1,2]

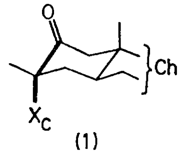
We have shown[3] that the calculated rotatory strength $R$ of a chiral unsubstituted ketone is proportional to the twists of the $n_0[\theta(n_0)]$ and $\pi^*$ [$\theta(\pi)^*$] orbitals of the carbonyl group[3] but opposite in sign (clockwise twist is defined as positive when viewing the ketone in an Octant Rule projection).

In order to establish whether this relationship still holds when the ketone is substituted, we calculated the twists for model ketones (**8**)—(**12**) [$X_N = X_C = H$; $X_C$ = F, Cl and $SiH_3$, $X_N$ = H (coupling path) and $X_N$ = F and Cl, $X_C$ = H (noncoupling path)].† The results are presented in the Tables.

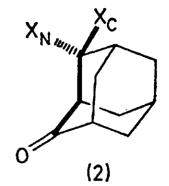
Agreement between experimental $\delta\Delta\epsilon$ and calculated $-\Delta\theta$ values for F and Cl in coupling and noncoupling paths is very good, despite the fact that the coupling path in (**10**) is idealised in comparison with the path in (3). The same is true for (**12**) and (5).‡ It can be seen that the $\Delta\theta$ reproduces all variations of the $\delta\Delta\epsilon$, especially in the 2 bond case (**2**). The agreement can be improved further if adjustments are made for the 2 to 5 bond cases to correct for the remainder of the cyclohexanone unit by placing a methyl group on the methyl carbon of the acetyl group in (**9**)—(**12**). The comparison of $\delta R$ and $\Delta\theta$ ($X_N$ = F and $X_C$ = F) is equally good (Tables 1 and 2).

We have established experimentally that the $SnMe_3$ group has a larger consignate $\delta\Delta\epsilon$ increment in series (**3**)[4] (8·3) than in series (**2**)[5] (6·5), in contrast to I and Br. We have checked this result by calculation on the weaker $\sigma$-donor, $SiH_3$ group.

The limited experimental data agree well. The $\Delta\theta$ values for $SiH_3$ group show that properly oriented $X_C = CH_2SiH_3$



(1)



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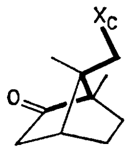

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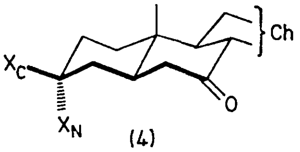
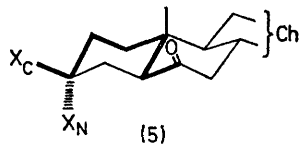


(4)



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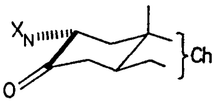
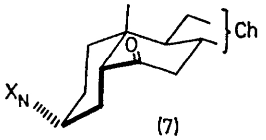
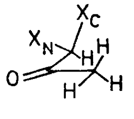


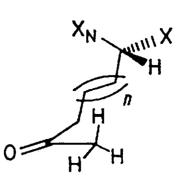
(6)



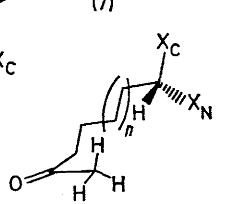
(7)



(8) (1 bond)



(9) (2 bonds; $n$=0)
(11) (4 bonds; $n$=1)



(10) (3 bonds; $n$=0)
(12) (5 bonds; $n$=1)

Ch = cholestane residue

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† The following bond lengths were used: C=O, 1·23; C–H, 1·09; O=C–C, 1·52; C–C, 1·54; C–F, 1·34; C–Cl, 1·78; C-Si, 1·865; and Si–H, 1·48 Å. All angles were tetrahedral except the C–CO–C which was 120°.

‡ The ideal system comparable to (**12**) embodied in a real molecular framework would be steroidal 6α-(coupling) and 6β-(noncoupling) substituted D-homo-17a-ketone.

can simulate the chiroptical behaviour of $X_C$ = Br, I, or $S^-$.[4,5]

This work shows that carbonyl group rotatory strengths, which are proportional to $-\Delta\theta = [\theta(n_0) - \theta(\pi^*)]$, can be easily obtained from ground state MO wave function calculations using CNDO/2[6] with a limited basis set (*d* orbitals were used only for Cl and Si). This greatly simplified method can be used effectively not only for first row perturbers but also, for the first time, for second row perturbers, and no doubt for composite perturbers such as $-C\equiv N$, $-NO_2$, $-SO_2R$, *etc.* as well.

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