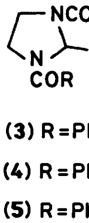
Acyl Derivatives of Cyclic Secondary Amines. Part 1. Dipole Stabilization of Anions: the Cumulative Effect of Two Stabilizing Groups

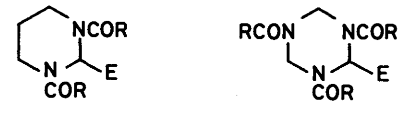
Alan R. Katritzky,* Ramiah Murugan, Hudson Luce, and Michael Zerner
Department of Chemistry, University of Florida, Gainesville, Florida 32611, U.S.A.
George P. Ford
Department of Chemistry, Southern Methodist University, Dallas, Texas 75275, U.S.A.

Lithiation studies with diacylimidazolidines, diacylhexahydropyrimidines, and triacylhexahydro-1,3,5-triazines indicate that no substantial increase in carbanion stability occurs as a result of the introduction of the second stabilizing group. Relative energies are calculated for three conformers of lithiated diformylimidazolidine, six conformers of lithiated diformylhexahydropyrimidine, and eight conformers of lithiated triformylhexahydro-*sym*-triazine. For the six-membered rings, conformers with equatorial lithium are always more stable those those with axial lithium. Although equatorial *syn-syn* conformers (with double O–Li co-ordination) are more stable than equatorial *syn-anti*, the difference is significantly less than that found between the corresponding *syn-anti* and (least stable) *anti-anti* conformers.

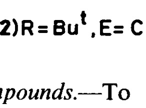
The concept of dipole stabilization of carbanions is well recognized, and dipole-stabilized anions of type $R^1R^2C^- - NR^3 - X{=}Y$ are known for a wide variety of groups $X = Y$.[1] However, little is known about the cumulative effect of such stabilization in derivatives of type $R^1C^-(NR^2 - X{=}Y)_2$. One of us recently demonstrated[2] that lithiation of methylenebispyrazoles to metallated derivatives of type (**1**) is indeed somewhat easier than the formation of the corresponding monocyclic analogues of type (**2**).

We have now examined a series of compounds containing the structural feature $CH_2(NR^1COR^2)_2$ and report both on their lithiation and on calculations of the energy and geometry of the corresponding lithium derivatives, for comparison with the available experimental[1] and theoretical studies[3] of their monofunctional analogues.


(1)


(2a) **(2b)**


(3) R=Ph, E=H
(4) R=Ph, E=CH_3
(5) R=Ph, E=COPh
(6) R=Bu^t, E=H


(7) R=Ph, E=H
(8) R=Ph, E=D
(9) R=Ph, E=COPh
(10) R=Bu^t, E=H
(11) R=Bu^t, E=D
(12) R=Bu^t, E=CH_3


(13) R=Ph, E=H
(14) R=Ph, E=D
(15) R=Bu^t, E=H
(16) R=Bu^t, E=D

Preparation of Compounds.—To reduce the number of possible conformations, we selected cyclic compounds (**3**), (**6**), (**7**), (**10**), (**13**), and (**15**) for study. In each series, only the benzoyl derivatives (**3**), (**7**), and (**13**) have previously been reported: we synthesized (**3**)[4] and (**7**)[5] by a modification of the reported methods and (**13**)[6] without modification. The corresponding pivaloyl derivatives (**6**), (**10**), and (**15**) were prepared similarly.

The structures are fully confirmed by the detailed n.m.r. characteristics described in the following paper.[7]

Lithiation of 1,3-*Diacylimidazolidines*.—Lithiation of (**3**) with lithium di-isopropylamide (LDA) in tetrahydrofuran (THF) at −78 °C gave a dark brown solution of a carbanion. Under most conditions, the very reactive carbanion reacted with more (**3**) acting as an electrophile, to give the self-condensation product (**5**). Formation of (**5**) was confirmed by the appearance of a ketone carbonyl signal in the ^{13}C n.m.r. Inverse addition of LDA to a mixture of (**3**) and electrophile in THF still gave (**5**). Use of benzaldehyde or *p*-tolualdehyde as the electrophile gave the corresponding benzyl alcohol, along with starting material (as shown by ^1H and ^{13}C n.m.r.), and dimers of compound (**3**) (as shown by mass spectroscopy).

Use of system (**6**) in an attempt to avoid self-condensation by the introduction of steric crowding around the carbonyl group by the t-butyl groups failed as (**6**) did not react with LDA, even at 0 °C. Evidently the t-butyl group increased steric crowding not only around the carbonyl but also around the C-2 thus hindering the approach of the base (LDA) to deprotonate 2-H. Similar explanations were given for no reaction of 1,4-dibenzoyl-2,3-dimethylquinoxalines with LDA.[8]

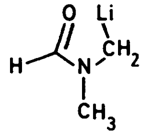
Use of t-butyl-lithium (less nucleophilic) for deprotonation instead of LDA gave mixtures of products after treatment with electrophiles. By this procedure some *C*-methylated compound (**4**) was obtained from compound (**3**) using methyl iodide as electrophile. However, the expected product was not isolated from compound (**6**).

Lithiation of 1,3-*Diacylhexahydropyrimidines*.—Lithiation of (**7**) with LDA also afforded a dark solution indicating the formation of the carbanion, which again on work-up gave only the self-condensation product (**9**) even after treatment with electrophiles. Where benzaldehyde or *p*-tolualdehyde was used as electrophile, the corresponding benzyl alcohol was formed as shown by ^1H and ^{13}C n.m.r. Use of t-butyl-lithium as the base with compound (**7**) gave the expected carbanion which was trapped with D_2O to give (**8**) along with other products.

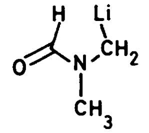
A more stable carbanion was obtained from (**10**) with LDA, and was trapped with D_2O to give (**11**), and with methyl iodide to give (**12**). The ^1H n.m.r. spectrum of (**11**) showed four signals with chemical shifts identical to those of the starting material (**10**). However, the intensity of the signal for 2-H was one-fourth of those for 4- and 6-H.

Lithiation of 1,3,5-*Triacylhexahydro*-sym-*triazines*.—Low solubility of (**13**) in THF and DME below 0 °C prevented the usual procedure with LDA as base. However, LDA addition at 25 °C gave the carbanion which was trapped with D_2O to give (**14**). Metallation under polar conditions was tried, but treatment of (**13**) with dimsyl sodium followed by an electrophile gave on work-up only recovered starting material.

Lithiation of (**15**) with LDA gave the carbanion, which was trapped with D_2O to give (**16**).



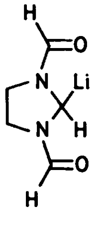
(17a)



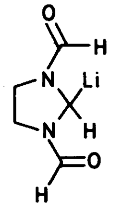
(17b)

Relative Stabilities of Individual Conformers of the Lithium Derivatives.—The relative stability of lithiated esters analogous to (**17a** and **b**) were investigated by Rondan *et al.*[9] at the *ab initio* 4-31G[10] and semiempirical MNDO[11] levels. Using geometries optimized with the smaller STO-3G basis set, the 4-31G procedure predicted the former to be more stable by 13.2 kcal mol^{-1}. A similar result was obtained[9] using MNDO. We have repeated the MNDO calculations[12] for the lithiated amides themselves, and find a difference of 19 kcal mol^{-1} with the *cis* conformer (**17a**) again being more stable.

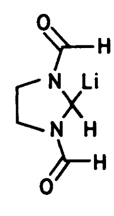
A lithiated diacylimidazolidine (**18**) can exist in three conformations: *syn-syn* (**18a**), *syn-anti* (**18b**), and *anti-anti* (**18c**). For a lithiated diacylhexahydropyrimidine (**19**), there are a total of six conformations because each of the foregoing can exist in two diastereoisomers with the lithium axial (**19d**—**f**) or equatorial (**19a**—**c**). Finally, a lithiated triacylhexahydro-1,3,5-triazine can exist in a total of eight conformations: four with axial Li (**20a**—**d**) and four (diastereoisomeric with the first set) with equatorial Li (**20e**—**i**). We have carried out calculations of the relative stabilities of these conformers. In all cases the acyl groups were taken as formyl (R = H) to simplify the calculations. The MNDO calculations were carried out on a DEC VAX 11/780 using the MOPAC program package.[12] Full geometry optimizations were performed on each molecule. Results are summarized in Table 1—3.



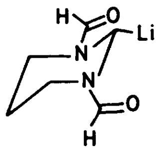
(18a)



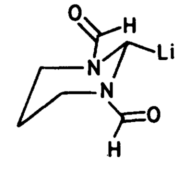
(18b)



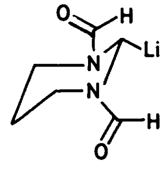
(18c)



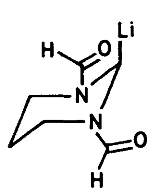
(19a)



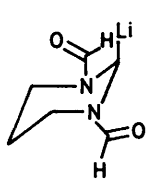
(19b)



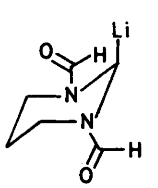
(19c)



(19d)



(19e)



(19f)

Relative Stability of Various Lithiated Diformylhexahydropyrimidine Conformers.—All the Li-equatorial conformers (**19a**—**c**) are more stable than any of the Li-axial conformers (**19d**—**f**). In the former the N–C–Li plane is almost coplanar to that of the N–CHO group, as shown in Table 2, whereas the N–C–Li plane is more nearly perpendicular to this plane for the axial conformers (dihedral angles 114 ± 4°, Table 2). We consider that repulsion between the highly ionic C–Li σ-bonds and the filled N–CHO π-orbitals in the axial conformers is responsible for the deformation of the C–Li bonds from the perpendicular. The lower stability of all the axial conformers than even the least stable (*anti-anti*) Li-equatorial conformer can be attributed to the greater O–Li distances in these conformations (see Table 2).

Among the Li-equatorial conformers, *syn-syn* (**19a**) is the most stable as expected; however, the increase in stability over the *syn-anti* (**19b**) (13 kcal mol^{-1}) is significantly less than the

Table 1. Calculated relative stabilization energies and geometries of 1,3-diformyl-2-lithioimidazolidine (**18**)

Conformer	$\Delta H°$/kcal mol^{-1} [a]	Relative $\Delta H°$/kcal mol^{-1} [b]	Dihedral angle (°)[c]	C–Li bond length (Å)[d]	O–Li distance (Å)[e]	E_s/kcal mol^{-1} [f]
(**18a**) *syn-syn*	−90.2	0	38.0	1.97	2.18 2.19 (2.18 ± 0.01)	−74
(**18b**) *syn-anti*	−82.0	8	22.9	1.88	2.07 4.86	−55
(**18c**) *anti-anti*	−61.8	28	47.6	1.91	4.47 4.49 (4.48 ± 0.01)	−36

[a] Calculations were carried out using MNDO on a DEC VAX 11/780 computer. [b] All energies are reported relative to the most stable conformer, whose stabilization energy is given as 0 kcal mol^{-1}. [c] Dihedral angles between the N–C–Li plane and the plane of the N–C=O moiety. Angles calculated using $\cos\theta = (A_1A_2 + B_1B_2 + C_1C_2)/(A_1^2 + B_1^2 + C_1^2)^{\frac{1}{2}}(A_2^2 + B_2^2 + C_2^2)^{\frac{1}{2}}$ where A_1, B_1, and C_1 are attitude numbers for the plane N–Li–C defined by the co-ordinates of the Li and lithiated C atoms and where A_2, B_2, C_2 are attitude numbers for the N–C=O plane defined by the co-ordinates of the N atom and carbonyl carbon atom. Attitude numbers are given by $A = -(x_{\rm I} - x_{\rm II})$, $B = -(y_{\rm I} - y_{\rm II})$, $C = -(z_{\rm I} - z_{\rm II})$. [d] C–Li bond lengths in optimized geometries. [e] O–Li distances in optimized geometries. [f] From $E_s = -80[1/R(\text{OLi}) + 1/R(\text{O}'\text{-Li})]$ kcal mol^{-1}, see text.

Table 2. Calculated relative stabilization energies and geometries of 1,3-diformyl-2-lithiohexahydropyrimidine (**19**)

Conformer	$\Delta H°$/kcal mol$^{-1\,a}$	Relative $\Delta H°$/kcal mol$^{-1\,b}$	Dihedral angle (°)^{c}	C–Li bond length (Å)^{d}	O–Li distance (Å)^{e}	E_s/kcal mol$^{-1\,f}$
Li-equatorial						
(**19a**) *syn-syn*	−97.3	0	17.0	2.01	2.15 2.14 (2.14 ± 0.01)	−74
(**19b**) *syn-anti*	−84.5	13	9.0	1.98	4.22 2.07	−58
(**19c**) *anti-anti*	−64.4	33	6.3	1.93	4.09 4.07 (4.08 ± 0.01)	−39
Li-axial						
(**19d**) *syn-syn*	−55.6	42	110	1.94	4.66 4.63 (4.64 ± 0.02)	−34
(**19e**) *syn-anti*	−60.2	37	116	1.94	4.90 4.69	−34
(**19f**) *anti-anti*	−61.7	36	117	1.94	4.93 4.88 (4.91 ± 0.03)	−33

[a–f] See Table 1.

Table 3. Calculated relative stabilization energies and geometries of 1,3,5-triformyl-2-lithiohexahydro-*sym*-triazine (**20**)

Conformer	$\Delta H°$/kcal mol$^{-1\,a}$	Relative $\Delta H°$/kcal mol$^{-1\,b}$	Dihedral angle (°)^{c}	C–Li bond length (Å)^{d}	O–Li distance (Å)^{e}	E_s/kcal mol$^{-1\,f}$
Li-axial						
(**20a**)	−73.8	41	74.7	1.92	4.26 4.76	−36
(**20b**)	−76.8	38	69.8	1.93	4.69 4.77	−34
(**20c**)	−78.6	36	66.6	1.93	4.79 5.24	−32
(**20d**)	−78.3	37	70.4	1.93	4.22 4.72	−36
Li-equatorial						
(**20e**)	−115.2	0	16.3	2.01	2.17 2.15 (2.16 ± 0.01)	−74
(**20f**)	−101.8	13	9.9	1.98	4.23 2.08	−58
(**20g**)	−83.3	32	8.5	1.93	4.05 4.09 (4.07 ± 0.02)	−39
(**20h**)	−104.2	11	9.5	1.98	4.04 2.26	−55

[a–f] See Table 1.

increase in stability of the latter over the *anti-anti* (**19c**) (20 kcal mol^{-1}).

Calculations have also been carried out on the corresponding twist-boat conformations; the same relative order of stability was found for the individual conformers.

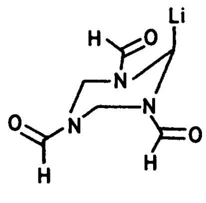
Conformer Stability of Lithiated Diformylimidazolidines.—Because of the almost planar five-membered ring, the N–C–Li plane makes an angle with the N–CHO plane in the range 23—48°: this is intermediate between the angles formed for the axial and the equatorial conformers of (**19**). The double O–Li co-ordination found in the *syn-syn* conformer (**18a**) makes it the most stable one. The *anti-anti* conformer (**18c**) where no O–Li co-ordination is possible is the least stable structure. The *syn-anti* conformer (**18b**) with only one O–Li co-ordination has intermediate stability. Again, the quantitative stabilization of the *syn-syn* conformer (**18b**) compared with the *syn-anti* conformer (**18a**) of 8 kcal mol^{-1} is far less than the stabilization (20 kcal mol^{-1}) of the *syn-anti* (**18c**) relative to the *anti-anti* (**18b**) (see Table 1).

*Conformer Stability of Lithiated Triformylhexahydro-*sym*-triazines.*—This situation is similar to that found above for the diformylhexahydropyrimidines. All the Li-equatorial conformers (**20e**—**h**) are more stable than any of the Li-axial conformers (**20a**—**d**). In the former, the N–C–Li plane is at an angle to the N–CHO plane in the range 9—16°, whereas this angle lies in the range of 67—75° for the axial conformers.

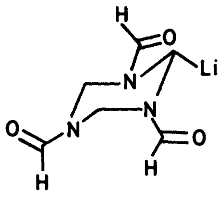
Among the Li-equatorial conformers, (**20e**) is the most stable as expected and again the increase in stability of (**20e**) over (**20f** and **h**) (themselves of almost equal stability) at 12 kcal mol^{-1} is less than the increased stability of (**20f** and **h**), by 20 kcal mol^{-1}, compared with conformer (**20g**), the least stable.

Discussion

It has been suggested that carbanions are stabilized by the proximity of an amine group, –N–R–C=O, and that additional stabilizing groups have additive effects. In general, one speaks of 'dipole stabilization' as shown in Scheme 1 where Z is a group capable of inducing a positive charge on Y, and M is an electropositive metal. In the case of the carbanions of this study Z is C=O and Y is nitrogen (and M = Li), as shown in Scheme 2. The last valence bond structure in Scheme 2 involves *d* orbitals and is unlikely to be important for nitrogen, but might be important for analogous compounds in which sulphur or phosphorus replace the nitrogen atom. Normally the oxygen atom of the CO group would be expected to be negative; the type of resonance above would increase this negative charge, and the CO bond dipole. Carbon atoms adjacent to such a



(20a)



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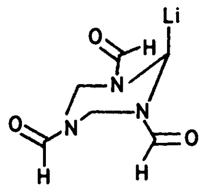

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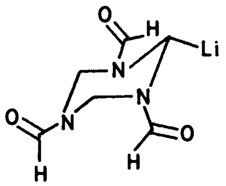
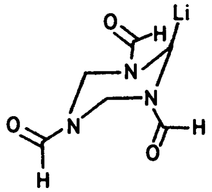
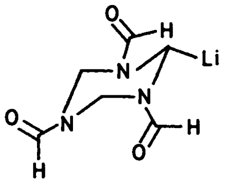


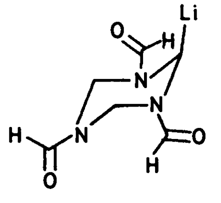
(20f)



(20c)



(20g)



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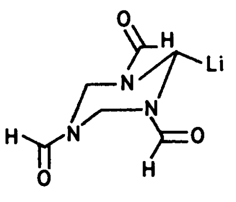
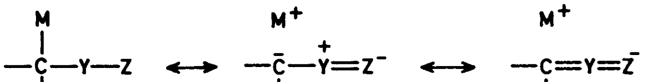
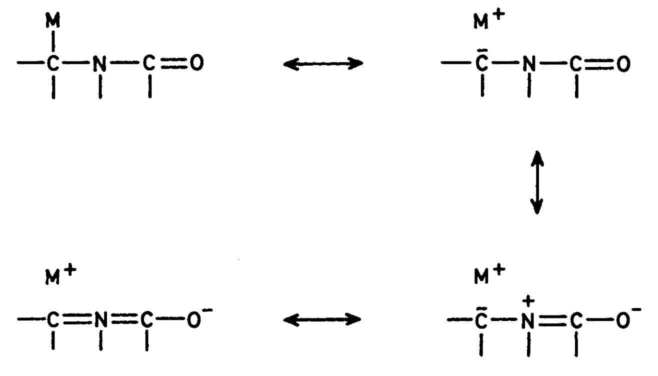


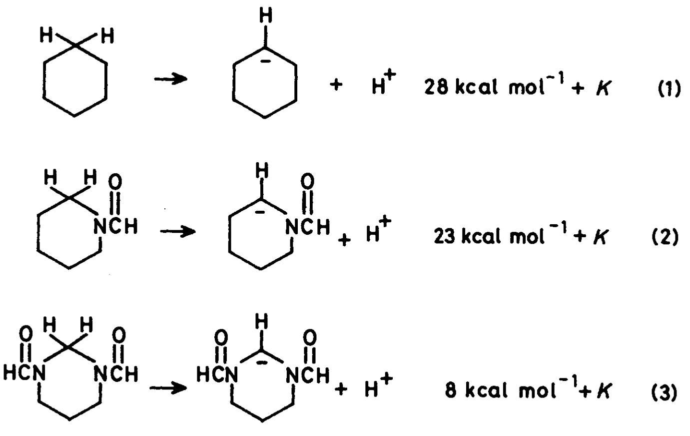
(20h)



Scheme 1. Dipole stabilization



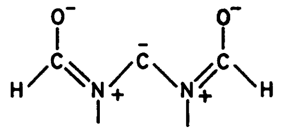
Scheme 2.



Scheme 3.

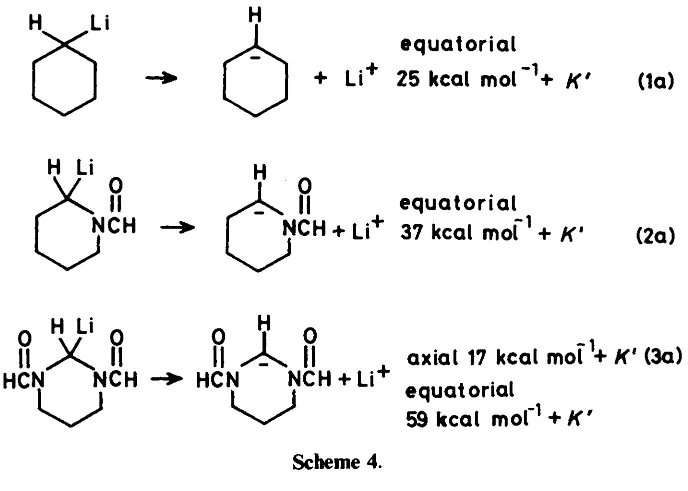
nitrogen atom and bonded to M are expected to tolerate a negative charge more easily, *i.e.* to have more carbanion character.

We attempted to explore this question by first examining the energetics of proton removal in three reactions of Scheme 3 using the MNDO scheme. Although these are somewhat artificial reactions in the gas phase, we are interested only in the relative energies of these three processes. The geometry of each species in the reaction has been optimized: the enthalpies calculated are given to the right of the appropriate equation, where K represents the heat of formation of H^+ and possible media effects. An interesting trend is quite apparent. The loss of a proton from cyclohexane costs 28 kcal mol^{-1} + K. The presence of a single NCHO group has (dipole) stabilized the carbanion by *ca.* 5 kcal mol^{-1}. The presence of a second group has further stabilized the carbanion by a remarkable 15 kcal mol^{-1}. It may be that the possibility of delocalization in such long chains as in (**21**) is an important contributing factor.



(21)

The loss of Li^+ in the three reactions of Scheme 4 in which a lithium atom replaces the proton of Scheme 3 leads to an opposite trend. In Scheme 4, K' represents the heat of formation of Li^+ and again possible media effects. The loss of Li^+ appears



Scheme 4.

to be more difficult in the presence of the NCHO groups. Although this seems inconsistent with the idea that the dipole-stabilizing group stabilizes the carbanion, the loss of the quite ionic O ··· Li ··· O interaction, as we describe later in our explanation of the relative stability of the various conformers, reverses the trend calculated for the loss of H^+.

The above considerations suggest that the NCHO groups stabilize the lithiated species against Li^+ ionization, and it was originally anticipated that this stability might be reflected in the experimental studies. As described in the Experimental section however, these compounds do not show stability to self-condensation.

Assuming that the relative energies calculated by the MNDO technique are correct we would like to have a simple model to anticipate our calculated finding on the stabilities of various conformers. The dipole stabilization model as described above cannot be used for this purpose for in all cases it might be expected to increase the negative charge on the carbonyl oxygen atoms by roughly the same amount.

For the moment we ignore the influence of the type of resonance structures that may contribute to the relative stability of all of these systems, and only consider simple electrostatic interactions between the Li atoms and the chelating O atoms of the carbonyl groups. We calculate the relative stabilities as proportional to the sum of the two $1/R$(O–Li) terms. The proportionality constant will include (i) the product of the net charge of the Li atom, which for this analysis we assume the same for all the compounds of this study, (ii) the net charge on the negative oxygen atoms, which we also assume constant for all carbonyl groups, and (iii) the conversion factors into kcal mol^{-1}. Assuming $Q(\mathrm{O}) = -Q(\mathrm{Li}) = -0.5$, this yields: $E_s = -80[1/R(\mathrm{O{-}Li}) + 1/R(\mathrm{O'{-}Li})]$ kcal mol^{-1} with R in Å. This value is also reported in the Tables, and in all cases gives a qualitative understanding of the calculated results.

We conclude that electrostatic interactions between the oxygen atoms of the carbonyl groups and the Li atom are responsible for the relative stabilities of these structures. Indeed, the induced dipoles in the C–N bonds from this type of resonance predicts the incorrect order of relative stabilities in most of these compounds [see, for example, structures (**18a**—**c**)]. We note further that this electrostatic model helps to explain the difficulty in Li^+ loss calculated for the 'dipole-stabilized' compounds.

Experimental

In all the reactions, THF was refluxed over and distilled from sodium benzophenone ketyl. Bu^{n}Li (1.6M in hexane) and Bu^{t}Li (1.7M in pentane) were standardized by titration.[13] Di-isopropylamine was refluxed over and distilled from CaH_2.

M.p.s were recorded on a Bristoline hot-stage microscope and are uncorrected. ^{1}H N.m.r. spectra were recorded on a Varian EM 36OL spectrometer using internal Me_4Si as the reference. I.r. spectra were obtained on a Perkin-Elmer 283 B spectrophotometer.

General Procedure A for Metallation of Substrates.—LDA (1 mmol) was prepared by adding dropwise di-isopropylamine (0.14 ml, 1 mmol) to n-butyl-lithium in hexane (1 mmol) at −20 °C under nitrogen. Stirring was continued until it became cloudy (0.5 h) when dry THF (5 ml) was added. The whole was then cooled to −78 °C and the saturated heterocyclic amide (**3**), (**5**), (**6**), or (**8**) (1 mmol) in dry THF (10 ml) was added. After 40 min at −78 °C the electrophile (1 mmol) was added. Stirring was continued for 1 h at −78 °C and for 10 h more at 20 °C. Water (1 ml) was added, and solvents removed at 40—50 °C and 20 mmHg. The residue in CH_2Cl_2 (50 ml) was washed with saturated aqueous NaCl (10 ml) and water (10 ml) and then dried (Na_2SO_4) and evaporated at 40—50 °C and 20 mmHg. Products were separated by preparative t.l.c.

General Procedure B for Metallation of Substrates.—This was as procedure A except that t-butyl-lithium was used instead of LDA.

1,3-*Dibenzoylimidazolidine* (**3**).—Ethylenediamine (5 g, 0.08M) and formaldehyde (6 g; 37% solution) at 100 °C were stirred for 0.5 h. The viscous colourless liquid was then kept at 55—60 °C, with the pH maintained at 8—10 by adding 10% NaOH solution (75 ml), while benzoyl chloride (20 g, 0.14 mol) was added dropwise over 30 min. The mixture was stirred for 1 h more at 25 °C. 1,3-Dibenzoylimidazolidine separated and was recrystallized from acetone (10 g, 40%) as plates, m.p. 140 °C (lit.,[4] 140—141 °C); $\nu_{max.}$($CHBr_3$) 1 628 cm^{-1}; δ($CDCl_3$) 3.88 (4 H, s), 5.19 (2 H, s), and 7.55 (10 H, s).

1,3-*Dipivaloylimidazolidine* (**6**).—Ethylenediamine (5 g, 0.08 mol), formaldehyde (6 g; 37% solution), and water (50 ml) were stirred at 100 °C for 1 h. To the viscous colourless liquid, aqueous sodium hydroxide (32 g, 0.8 mol in 120 ml water) was added. The mixture was cooled to −10 to −20 °C and trimethylacetyl chloride (19.2 g, 0.16 mol) added dropwise. After further stirring for 1 h, 1,3-*dipivaloylimidazolidine* (9 g, 50%), separated; it was washed with water and recrystallized from chloroform to give prisms, m.p. 141 °C (Found: C, 64.7; H, 10.1; N, 11.4. $C_{13}H_{24}N_2O_2$ requires C, 64.9; H, 10.1; N, 11.6%); $\nu_{max.}$($CHBr_3$) 1 620 cm^{-1}; δ($CDCl_3$) 1.28 (18 H, s), 3.79 (4 H, s), and 5.05 (2 H, s).

1,3-*Dibenzoylhexahydropyrimidine* (**7**).—Propane-1,3-diamine (15 g, 0.20 mol), water (150 ml), and formalin (37%; 25 ml) were stirred at 100 °C for 2 h. Sodium hydroxide (2.5M; 75 ml) was added at 25 °C and then benzoyl chloride (28 g, 0.20 mol) dropwise. After stirring for another 1 h, 1,3-dibenzoylhexahydropyrimidine (15 g, 25%) separated; it crystallized from ether–chloroform as plates, m.p. 94—95 °C (lit.[5] 92—96 °C) $\nu_{max.}$($CHBr_3$) 1 625 cm^{-1}; δ($CDCl_3$) 1.80 (2 H, p, J 6 Hz), 3.81 (4 H, t, J 6 Hz), 5.17 (2 H, s), and 7.40 (10 H, s).

1,3-*Dipivaloylhexahydropyrimidine* (**10**).—Propane-1,3-diamine (3.7 g, 0.05 mol), formalin (37%; 25 ml), and water (150 ml) were stirred at 100 °C for 2 h. Sodium hydroxide (2.5M; 70 ml) was added at −40 °C, and then pivaloyl chloride (12.1 g, 0.10 mol) dropwise. After stirring the mixture at 0 °C for 1 h, column chromatography (alumina and ether) gave *hexahydro-1,3-dipivaloylpyrimidine* (4 g, 32%) which crystallized as plates (from ether), m.p. 115 °C (Found: C, 65.9; H, 10.0; N, 11.3. $C_{14}H_{26}N_2O_2$ requires C, 66.1; H, 10.3; N, 11.0%); $\nu_{max.}$($CHBr_3$) 1 620 cm^{-1}; δ($CDCl_3$) 1.28 (18 H, s), 1.70 (2 H, m), 3.76 (4 H, t, J 6 Hz), and 5.31 (2 H, s).

1,3,5-*Tribenzoylhexahydro*-sym-*triazine* (**13**).—Compound (**13**) was prepared as has been reported earlier;[6] it formed prisms (from ether–chloroform), m.p. 221 °C (lit.,[6] 220—223 °C); $\nu_{max.}$($CHBr_3$) 1 640 cm^{-1}; δ($CDCl_3$) 5.30 (6 H, s) and 7.40 (15 H, s). 1,3,5-*Tripivaloylhexahydro*-sym-*triazine* (**15**) was prepared by the method[6] for (**13**) in 45% yield as needles (from ether–chloroform), m.p. 134—136 °C (Found: C, 63.8; H, 9.9; N, 12.2. $C_{18}H_{33}N_3O_3$ requires C, 63.7; H, 9.7; N, 12.3%); $\nu_{max.}$($CHBr_3$) 1 630 cm^{-1}; δ($CDCl_3$) 1.35 (27 H, s) and 5.40 (6 H, s).

1,3-*Dibenzoyl-2-methylimidazolidine* (**4**).—1,3-Dibenzoylimidazolidine (**3**) in procedure B with methyl iodide as the electrophile gave 1,3-*dibenzoyl-2-methylimidazolidine* (**4**) (20%) as needles (from $CHCl_3$), m.p. 150 °C (Found: C, 73.3; H, 6.3; N, 9.4. $C_{18}H_{18}N_2O_2$ requires C, 73.5; H, 6.1; N, 9.5%); $\nu_{max.}$($CHBr_3$) 1 625 cm^{-1}; δ($CDCl_3$) 8.30—7.30 (10 H, m), 5.50 (1 H, q, J 5 Hz), 4.35—3.60 (4 H, m), and 1.38 (3 H, d, *J* 5 Hz).

1,2,3-*Tribenzoylimidazolidine* (**5**).—1,3-Dibenzoylimidazolidine (**3**) in procedure A with no electrophile gave 1,2,3-*tribenzoylimidazolidine* (**5**) (90%) as needles from $CHCl_3$, m.p. 228 °C (Found: C, 74.8; H, 5.5; N, 7.4. $C_{24}H_{20}N_2O_3$ requires C, 75.0; H, 5.2; N, 7.3%); $\nu_{max.}$($CHBr_3$) 1 710 and 1 625 cm^{-1}; δ($CDCl_3$) 8.50—7.30 (15 H, m) and 4.00 (4 H, s), 2-H not observed.

2-*Deuterio*-1,3-*dibenzoylhexahydropyrimidine* (**8**).—1,3-Dibenzoylhexahydropyrimidine (**7**) by procedure B with D_2O as the electrophile gave 2-*deuterio*-1,3-*dibenzoylhexahydropyrimidine* (**8**) (20%) as needles (from ether), m.p. 95 °C (Found: C, 73.2; H, 5.8; N, 9.1. $C_{18}H_{17}DN_2O_2$ requires C, 73.2; H, 5.8; N, 9.5%); $\nu_{max.}$ ($CHBr_3$) 1 625 cm^{-1}; δ($CDCl_3$) 7.40 (10 H, s), 5.17 (1 H, s), 3.81 (4 H, t, *J* 6 Hz), and 1.80 (2 H, m).

1,2,3-*Tribenzoylhexahydropyrimidine* (**9**).—1,3-Dibenzoylhexahydropyrimidine (**7**) by procedure A with no electrophile gave 1,2,3-*tribenzoylhexahydropyrimidine* (**9**) (80%) as needles (from $CHCl_3$), m.p. 225 °C (Found: C, 75.2; H, 5.7; N, 7.0. $C_{25}H_{22}N_2O_3$ requires C, 75.4; H, 5.5; N, 7.0%); $\nu_{max.}$($CHBr_3$) 1 715 and 1 628 cm^{-1}; δ($CDCl_3$) 8.20—7.25 (15 H, m), 4.05—3.30 (4 H, m), 1.90—1.30 (2 H, m), 2-H not observed.

2-*Deuterio*-1,3-*dipivaloylhexahydropyrimidine* (**11**).—1,3-Dipivaloylhexahydropyrimidine (**10**) by procedure A with D_2O as electrophile gave 2-*deuterio*-1,3-*dipivaloylhexahydropyrimidine* (**11**) (50%) as plates (from CH_2Cl_2), m.p. 115—116 °C (Found: C, 65.8; H, 10.1; N, 10.8. $C_{14}H_{25}DN_2O_2$ requires C, 65.9; H, 9.8; N, 11.0%); $\nu_{max.}$($CHBr_3$) 1 620 cm^{-1}; δ($CDCl_3$) 5.25 (1 H, s), 3.75 (4 H, t, *J* 6 Hz), 1.67 (2 H, m), and 1.26 (18 H, s).

1,3-*Dipivaloyl*-2-*methylhexahydropyrimidine* (**12**).—1,3-Dipivaloylhexahydropyrimidine (**10**) by procedure A with methyl iodide as the electrophile gave 1,3-*dipivaloyl*-2-*methylhexahydropyrimidine* (**12**) (80% based on recovery of starting material) as needles (from $CHCl_3$), m.p. 125 °C (Found: C, 67.5; H, 10.6; N, 10.3. $C_{15}H_{28}N_2O_2$ requires C, 67.2; H, 10.4; N, 10.4%); $\nu_{max.}$($CHBr_3$) 1 630 cm^{-1}; δ($CDCl_3$) 6.90 (1 H, q, *J* 6 Hz), 4.40—3.40 (4 H, m), 2.00—1.40 (2 H, m), 1.29 (18 H, s), and 1.18 (3 H, d, *J* 6 Hz).

2-*Deuterio*-1,3,5-*tribenzoylhexahydro*-sym-*triazine* (**14**).—1,3,5-Tribenzoylhexahydro-*sym*-triazine (**13**) by procedure A, but with addition of LDA to (**13**) in THF at 25 °C, with D_2O as electrophile gave 2-*deuterio*-1,3,5-*tribenzoylhexahydro*-sym-*triazine* (**14**) (65%) as plates (from $CHCl_3$), m.p. 221 °C (Found: C, 72.1; H, 5.3; N, 10.3. $C_{24}H_{20}DN_3O_3$ requires C, 72.0; H, 5.0; N, 10.5%); $\nu_{max.}$($CHBr_3$) 1 640 cm^{-1}; δ($CDCl_3$) 7.54 (15 H, s) and 5.40 (5 H, s).

2-*Deuterio*-1,3,5-*tripivaloylhexahydro*-sym-*triazine* (**16**).—1,3,5-Tripivaloylhexahydro-*sym*-triazine (**15**) by procedure A with D_2O as electrophile gave 2-*deuterio*-1,3,5-*tripivaloylhexahydro*-sym-*triazine* (**16**) (85%) as plates (from $CHCl_3$), m.p. 135 °C (Found: C, 63.4; H, 9.6; N, 12.2. $C_{18}H_{32}DN_3O_3$ requires C, 63.5; H, 9.4; N, 12.3%); $\nu_{max.}$($CHBr_3$) 1 630 cm^{-1}; δ($CDCl_3$) 5.40 (5 H, s) and 1.35 (27 H, s).

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