Tetrahedron. Vol. 32, pp 1773 to 1777. Pergamon Press 1976. Printed in Great Britain

AROMATICITY AND TAUTOMERISM—VI[1]

APPLICATION OF PSEUDO BASE EQUILIBRIA IN RESONANCE ENERGY DETERMINATIONS[2]

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(*Received in UK* 10 *February* 1976; *Accepted for publication* 24 *February* 1976)

Abstract—Equilibrium constants for the addition of hydroxide ion to isoquinolinium methiodide and 3,4-dihydroisoquinolinium methiodide, and methoxide ion to 2-phenylisothiazolium, 2-phenylbenzisothiazolium and 2-phenylisothiazolinium methiodides are reported. The results are discussed with reference to the aromatic character of the heteroaromatic systems involved.

The reaction of nucleophiles, particularly hydroxide ion, with quaternary salts of nitrogen heterocycles to form pseudo bases has long been recognised,[3] and aspects of the subject have been reviewed by Beke.[4] Equilibrium constants for pseudo base formation, K_{ROH}, can be defined by eqn (1) where K_w is the ionic product of water.[5] Until recently, however, quantitative data for 6-membered ring heteroaromatic precursors was scanty,[6] but studies on substituted isoquinolinium[7] and quinolinium cations,[5] 2,2'bipyridyl platinium(II) complexes,[8] and particularly the wide ranging investigations, encompassing both kinetic and equilibrium aspects, of Bunting and Meathrel[9,10] have now much improved the situation. Recent research has also centred on locating the site of attack by the incoming nucleophile,[11] and attention has been drawn to the facile covalent amination of heteroaromatic cations in liquid ammonia.[12] Kröhnke *et al.*[13] have correlated half-wave potentials for the transfer of nitromethane anion to various heteroaromatic cations with the cation LUMO energies.

$$R^+ + OH^- \overset{K}{\rightleftharpoons} ROH$$

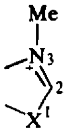
$$K_{ROH} = K \cdot K_w = \frac{[ROH][H^+]}{[R^+]} \qquad (1)$$

Quaternary salts having the structural feature **1** in a 5-membered ring are prone to attack by hydroxide ion and other nucleophiles at the 2-position[14-17] although the presence of a 2-Me group offers an alternative mode of reaction leading to anhydrobases (e.g. **2**→**3**).[15] In aqueous media the pseudo bases, once formed, undergo ring cleavage[14-16] (e.g. **4**→**5**), but this latter pathway is precluded in reactions involving nucleophiles such as alkoxide ions in alcoholic media,[15,17] and examples of stable pseudo bases of type **6** have been isolated.[17]

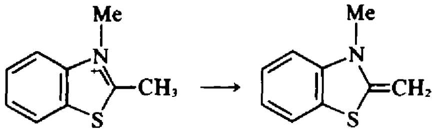
In previous papers in this series we have used tautomeric[18,19] and protonation[1,2] equilibria data for aromatic and non-aromatic models to estimate aromatic resonance energy. Thus the difference between $\Delta G°$ values for 2-pyridone $\rightleftharpoons$ 2-hydroxypyridine and amide $\rightleftharpoons$ iminol equilibria, when converted into $\Delta H°$ values, gave a value of *ca.* 7 kcal mole^{-1} for the greater resonance energy of pyridine over pyridone,[18] and quantitative estimates of the weaker basicity of pyrrole relative to a dienamine afforded a figure of *ca.* 20 kcal mole^{-1} for the resonance energy of the aromatic compound.[1,2] Pseudo base formation by quaternised nitrogen heteroaromatics, like the protonation of pyrrole, involves disruption of the π-electron cloud and the ease of addition of the nucleophile should reflect in part, the aromaticity of the system. In the present study we investigate the measurement of equilibrium constants for pseudo base formation of the 6-membered ring cations **7** and **9** and the 5-membered ring cations **11**, **13**, **15**, **17–22**, the choice of the 2-phenyl derivative ensuring absorption in the UV region of the spectrum.

RESULTS AND DISCUSSION

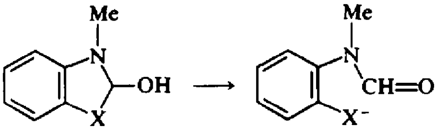
Pseudo base formation. The UV spectrum of isoquinoline methiodide **7** is unchanged on moving from neutral to 2N KOH aqueous but a new band at 312 nm begins to appear in 5N KOH. Full conversion to the new species was achieved using the more basic DMSO-water tetramethylammonium hydroxide (TMAH) system (Table



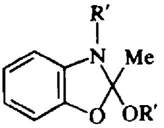
1



2 **3**



4 **5**



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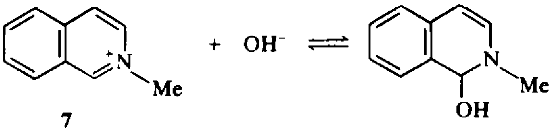
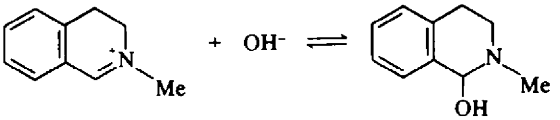


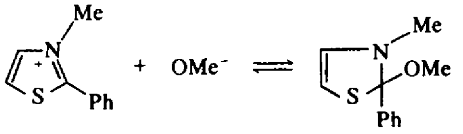
7 **8**

ΔH°_1 (2)



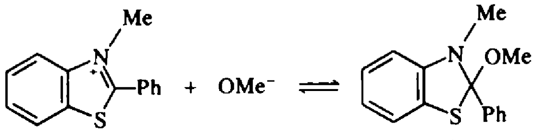
9 **10**

ΔH°_2 (3)



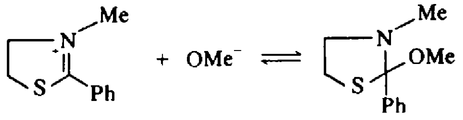
11 **12**

ΔH°_3 (4)



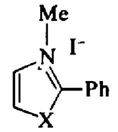
13 **14**

ΔH°_4 (5)

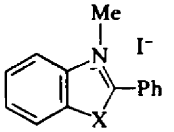


15 **16**

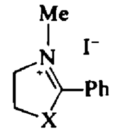
ΔH°_5 (6)



17: X = O
20: X = NMe



18: X = O
21: X = NMe



19: X = O
22: X = NMe

1). Solvents were degassed prior to use and the UV spectrum of the material in the basic solution changed only slightly with time. The 312 nm band seemingly corresponds to the 325 nm band in 1,2-dihydro-2-methylisoquinoline rather than to that of an *o*-enaminobenzaldehyde which should absorb at longer wavelength, and we therefore assign the band to the pseudo base **8** rather than a ring-opened form. Pseudo base formation was demonstrated to be reversible on neutralisation. Ionisation data in media of different basicity were found to follow the $H_{-(q)}$ acidity function[19] (gradient 1.0) and the pK value, 16.29 is in moderate agreement with Bunting and Meathrel's estimate of 15.3.[9]

3,4-Dihydro-2-methylisoquinolinium methiodide **9** reacts with 0.5 N aqueous NaOH to form a new species identified as the pseudo base rather than the ring opened (aminoaldehyde) form from the UV spectrum. Thus values of λ_{max} 264, 271 nm resemble closely those of *o*-methylbenzyl alcohol, λ_{max} *ca.* 260, 271,[20] and differ from those of *o*-methylbenzaldehyde λ_{max} *ca.* 251, 297 nm.[21] The pK_{ROH} for the equilibrium (**9** $\rightleftharpoons$ **10**) was measured as 10.75.

Pseudo bases of **11**, **13**, **15**, **17–22** were expected to ring-open in aqueous media[14–16] and we therefore investigated the addition of methoxide in methanol. The basicity of methanolic media (H_m) had been well defined for strongly basic media ($H_m > ca.$ 15),[22] but data for less basic media H_m *ca.* 10–15 for which buffers are required, appeared to be limited to a report of the use of phenol/phenolate buffers which would interfere with UV measurements.[23] Prior to the present study we therefore constructed an acidity function using phenol indicators for unbuffered, phosphate buffered, and borate buffered solutions.[24] Insolubility of many phosphate and borate salts in methanol, ease of preparation of reproducible solutions, and optimism that small quantities of hydroxide ion would not disrupt observation of pseudo base equilibria were factors which persuaded us to use the tetramethylammonium hydroxide and methoxide mixture,[24] as the base for the buffered media. Solutions of **11**, **13**, **15**, **17–22** in the basic methanolic medium all showed UV spectral changes with time. Decomposition of **11**, **13** and **15** was slow and extrapolation of log I values to zero time provided data appropriate for pK determinations. **11** Underwent methoxide addition in a region where buffered media were not required (pK_{ROMe} 16.9). In this determination, sodium methoxide was used as base and log I values were plotted

Table 1. UV spectral data and pK_{ROH} data

Compound	UV of quaternary salt		UV of base addition product		pK_{ROH}	Comments
	λ_{max}	log ε	λ_{max}	log ε		
7	282	3.8 (aq.)	312	4.13 (TMAH in H_2O/DMSO)	16.29	HO^- addition; $H_{o(q)}$ function[19] followed
	322	3.5				n = 1.0
9	282	4.1 (aq. pH 7)	264	2.7 (0.5N	10.75	HO^- addition, measured in aq. NaOH
			271	2.6 aq. NaOH)		
11	278	4.22 (MeOH)	a		16.9	MeO^- addition using MeONa in MeOH, H_m = 16.9, slope = 1.0
13	300	4.14 MeOH +0.02M H_3BO_3	a		7.3 ± 0.1	H_m = 10.37, slope = 0.70
15	262	4.05	a		8.2 ± 0.1	H_m = 12.01, slope = 0.68

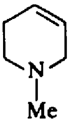
a Slow decomposition precluded accurate determination of λ_{max} for these compounds.

against H_m where $H_m = \log[^-OMe] + pK_{MeOH}$.[24] The slope of the plot is 1.0. For **13** and **15** buffered media were required and log I was plotted vs H_m values reported elsewhere.[24] Good straight lines were obtained but with slopes (m) of about 0.7. H_m values for half pseudo base formation and pK_{ROH} values derived by the Yates equation,[25] are reported in Table 1.

Unlike the decomposition of **11**, **13** and **15** the UV spectra of **17**-**22** in basic methanol changed rapidly with time and extrapolations to zero time were considered unreliable because changes in absorption did not appear to follow a simple pattern. We were therefore unable to obtain pK_{ROR} data for these structures. We assume that traces of hydroxide ions from TMAH interfere with the equilibria although decomposition still occurred even in supposedly anhydrous media using magnesium methoxide as base. Work by Bourson[26] indicates that reversible addition of HX compounds to benzimidazolium anhydro bases does occur, a quantitative estimation of this might overcome the present difficulties.

Aromatic resonance energy of isoquinolinium cation. Additions of hydroxide ion to **7** and **9** are given by eqns (2) and (3) respectively. The less ready formation of **8** compared with that of **10** reflects in part the loss of stability associated with the cyclic π electron system in **7**. However the difference in $\Delta H°$ for the two processes, viz. $\Delta H_1^\circ - \Delta H_2^\circ$ is not a simple measure of the resonance energy of the isoquinolinium salt, ($A_{isoquinolinium}$) which is given by eqn (7) where $A_{benzene}$ is the resonance energy of benzene (36 kcal mole^{-1}),[27] and a and b are the differences in resonance energy between **8** and benzene and **9** and benzene respectively. Fowler[28] has equilibrated **23** ⇌ **24** and obtained a $\Delta G°$ of *ca.* 4 kcal mole^{-1} in favour of the latter which figure we believe provides a reasonable estimate of the resonance energy of an enamine. (The value is of the same order as the resonance energy of ethyl vinyl ether, 3.6 kcal mole^{-1}, obtained from thermochemical data.[29]) The resonance energy of styrene less that of benzene is about 2 kcal mole^{-1}.[29] Using these values we estimate the values of a and b to be 6 ± 2 and 2 ± 1 kcal mole^{-1} respectively, and thus the remaining unknown is ($\Delta H_1^\circ - \Delta H_2^\circ$). p$K_{ROH}$ data give $\Delta G_1^\circ - \Delta G_2^\circ = 7.6$ kcal mole^{-1} and if we assume that the entropy terms in eqns (2) and (3) are the same then $\Delta G_1^\circ - \Delta G_2^\circ = \Delta H_1^\circ - \Delta H_2^\circ$. However studies on base protonation show that even in a simple process such as proton transfer, $\Delta S°$ is not constant in a series, e.g. we have found that the slopes of $\Delta H°$ vs pK_a plots for deprotonation of the conjugate acids of anilines,[30,31] pyridines[30] and pyridine N-oxides[30] are all of the order of 1.1. Unfortunately there appear to be no comparable studies on pseudo base formation: at the present time we take $\Delta H_1^\circ - \Delta H_2^\circ$ as 8 ± 2 kcal mole^{-1} which provides a value for $A_{isoquinolinium}$ of 52 ± 8 kcal mole^{-1}. No previous estimates for this parameter (or the resonance energy of isoquinoline itself) appear to have been made but it is expected to be of the same order as the resonance energy of quinoline which has been reported to be 47.3–69 kcal mole^{-1}.[32]

$$A_{isoquinolinium} = A_{benzene} + (\Delta H_1^\circ - \Delta H_2^\circ) + a + b$$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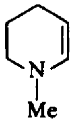
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Aromatic resonance energy of thiazolium and benzothiazolium cations. A similar comparison of equilibria **4** and **6** gives information on the resonance energy of the thiazolium cation, and comparison of **5** and **6** on that for the benzothiazolium cation. As before, however, other increments are involved. Making the simplifying assumption that the conjugation energy of the pendant phenyl group with the rest of the system is the same in **11**, **13** and **15**, eqns (8) and (9) may be written, where e is the difference in resonance energy between **14** and benzene, c is the difference in resonance energy between **12** and ethylene, and d is the resonance energy of interaction of S with the rest of the conjugated system in **15**.

$$A_{thiazolium} = (\Delta H_3^\circ - \Delta H_5^\circ) + c + d \tag{8}$$

$$A_{benzothiazolium} = A_{benzene} + (\Delta H_4^\circ - \Delta H_5^\circ) + e + d \tag{9}$$

Term e will include contributions from the interaction of the nitrogen atom and from the S atom with the benzene ring. The former will be similar to that in dimethylaniline for which 9 ± 1 kcal mole^{-1} can be estimated[33] ($33\,\sigma_R{}^0 = 17.5$, less 8.1 kcal mole^{-1} for strain in the ground state of dimethylaniline). For interaction of the sulphur atom complexation values[34] (for SMe, $\Delta\Delta H$ for complexation with $AlBr_3$ = 4.4 kcal mole^{-1}, with $GaCl_3$ = 5.2 kcal mole^{-1} see discussion in 33) allow an estimate of 5 ± 2 kcal mole^{-1}. Finally there will be a contribution for mutual interaction between the S and N atoms: we estimate this as 2 ± 1 kcal mole^{-1}.[35] (For *para* substituents interaction = $33\,K_{SMe} \cdot \sigma_R{}^0$ (NMe_2) = 1.7 kcal mole^{-1}; for *ortho* substituents should be rather more than this.) This gives for term *e* 16 ± 4 kcal mole^{-1}.

We have stated[35] reasons for belief that interactions of conjugating groups with an ethylenic bond are 75% of the corresponding conjugation energy with a benzene ring. Hence we take term *c* as 12 ± 4 kcal mole^{-1}.

Term *d* can be estimated from the difference in pK_{ROH} of **15** and of **9**. This difference can be estimated from the value of 10.75 for **9** in aqueous solution, and 12.01 for **15** in methanol solution, as being quite small. We take a value of 2 ± 1 kcal mole^{-1}.

To convert the ΔpK values into $\Delta\Delta H°$ values we again assume that entropy terms cancel, and hence obtain $\Delta H^\circ_3 - \Delta H^\circ_5 = 7 \pm 2$ kcal mole^{-1} and $\Delta H^\circ_4 - \Delta H^\circ_5 = -2 \pm 1$ kcal mole^{-1}.

Placing these terms together in eqns (8) and (9) finally gives estimates for the aromaticity of the thiazolium cation as 21 ± 7 kcal mole^{-1} and for the benzothiazolium cation as 52 ± 6 kcal mole^{-1}. There is no previous work directly on the estimation of resonance energies for these systems although a theoretical study is available for both thiazolium[36] and benzothiazolium.[37] Resonance energy estimates for the neutral thiazole and benzothiazole systems are qualitative and scanty;[38] an early estimate[39] from π-density calculations gave 20 kcal mole^{-1} for thiazole.

EXPERIMENTAL

Materials. The following nitrogen bases, either purchased (isoquinoline, 1 - methyl - 2 - phenylimidazole, 1 - methyl - 2 - phenylbenzimidazole, and 1 - methyl - 2 - phenylimidazoline) or obtained via literature routes (3,4 - dihydroisoquinoline,[40] 2 - phenylthiazole,[41] 2 - phenylbenzothiazole,[42] 2 - phenylthiazoline,[43] 2 - phenyloxazole,[44] 2 - phenylbenzoxazole[45] and 2 - phenyloxazoline[43]) were reacted with excess methyl iodide in ether or neat in a sealed tube at 90–140° for 3–6 hr to afford: **7** m.p. 158°. lit.[46] 159°; **20** m.p. 285–286° (Found: C, 44.1; H, 4.4; N, 8.9. $C_{11}H_{13}IN_2$ requires: C, 44.0; H, 4.4; N, 9.3%); **21** m.p. 264–265° (lit.[47] m.p. 273°); **22** m.p. 190–191° (Found: C, 43.5; H, 4.8; N, 9.6. $C_{11}H_{15}IN_2$ requires: C, 43.7; H, 5.0; N, 9.3%); **9** m.p. 126.5–128.5° (lit.[48] m.p. 124–126°); **11** m.p. 168–169° (Found: C, 39.5; H, 3.4; N, 4.5. $C_{10}H_{10}INS$ requires: C, 39.6; H, 3.3; N, 4.6%); **13** m.p. 210–211° dec (lit.[42] m.p. 218°); **15** m.p. 161–162° (Found: C, 39.7; H, 4.1; N, 4.4. $C_{10}H_{12}INS$ requires: C, 39.4; H, 4.0; N, 4.6%); **17** m.p. 209-210° (Found: C, 41.7; H, 3.5; N, 5.0. $C_{10}H_{10}INO$ requires: C, 41.8; H, 3.5; N, 4.9%); **18** m.p. 205–207° (lit.[49] m.p. 196°); **19** m.p. 112–113° (Found: C, 41.3; H, 4.3; N, 5.0. $C_{10}H_{12}INO$ requires: C, 41.5; H, 4.2; N, 4.8%).

pK_a *measurements* (*Table* 1). The spectroscopic method (UV absorbance) of determining pK values was used[50] using data obtained from a Unicam SP 500 spectrophotometer. The pK_{ROH} value for **7** was determined by a method analogous to that used by Bowden and Cockerill,[51] and subsequently by ourselves,[19] for determining pK_a values of strongly basic compounds ($pK_a > 13$) using 0.047 M-tetramethylammonium hydroxide in Me_2SO–water solutions. Using this medium we earlier set up an H_- scale for the deprotonation of quaternary salts, and denoted the $H_{-(q)}$ scale.[19] The plot of $\log_{10} I$ vs $H_{-(q)}$ where I = [pseudo base]/[quaternary salt] gava a slope of -1.0 indicating that pseudo base formation followed the $H_{-(q)}$ acidity function.

The pK_{ROH} of **9** was measured in aqueous borate–sodium hydroxide buffers. Data for **11** and **15** were obtained in buffered anhydrous methanol using tetramethylammonium hydroxide/methoxide as base prepared and used as described elsewhere.[24] Pseudo base formation of **13** occurred at pK 16.9 in which region no buffering was required. The other salts were investigated in borate and phosphate buffered media.[24] Slopes of $\log I$ vs [pseudo base]/[quaternary salt] were of the order of -0.7 (see text).

Acknowledgement—We would like to thank the S.R.C. for postgraduate studentships (to A.D.P. and R.D.T.).

REFERENCES

[1] Part V see M. J. Carmody, M. J. Cook, N. L. Dassanayake, A. R. Katritzky, P. Linda and R. D. Tack, *Tetrahedron* **32**, 1767 (1976).

[2] Preliminary communication, M. J. Cook, A. R. Katritzky, P. Linda and R. D. Tack, *Tetrahedron Letters* 5019 (1972).

[3] A. Claus and P. Himmelmann, *Ber. Dtsch. Chem. Ges.* **13**, 2045 (1880); H. Decker, *Ibid.* **25**, 443 (1892); A. Hantzsch and M. Kalb, Ibid. **32**, 3109 (1899); H. Decker, *J. Prakt. Chem.* **47**, 28 (1893).

[4] D. Beke, *Adv. Heterocyclic Chem.* **1**, 167 (1963).

[5] C. J. Cooksey and M. D. Johnson, *J. Chem. Soc.* (B) 1191 (1968).

[6] R. J. Goldacre and J. N. Phillips, *Ibid.* 1724 (1949); D. Magrath and J. N. Phillips, *Ibid.* 1940 (1949); J. F. Bunnett, C. F. Hauser and K. V. Nahabedian, *Proc. Chem. Soc.* 305 (1961).

[7] V. Šimánek, V. Preininger, S. Hegerová and F. Šantavý, *Coll. Czech. Chem. Comm.* **37**, 2746 (1972).

[8] R. D. Gillard and J. R. Lyons, *J. Chem. Soc.* Chem. Comm. 585 (1973).

[9] J. W. Bunting and W. G. Meathrel, *Ibid.* **50**, 917 (1972).

[10] J. W. Bunting and W. G. Meathrel, *Ibid.* **51**, 1965 (1973).

[11] D. J. Pokorny and W. W. Paudler, *Ibid.* **51**, 476 (1973); J. E. Dickeson, I. F. Eckhard, R. Fielden and L. A. Summers, *J. Chem. Soc.* Perkin I 2885 (1973); J. W. Bunting and W. G. Meathrel, *Canad. J. Chem.* **52**, 303 (1974).

[12] J. A. Zoltewicz, T. M. Oestreich, J. K. O'Halloran and L. S. Helmick, *J. Org. Chem.* **38**, 1949 (1973).

[13] W. Kiel, F. Kröhnke and G. Schneider, *Liebigs Ann.* **766**, 45 (1972).

[14] G. D. Maier and D. E. Metzler, *J. Am. Chem. Soc.* **79**, 4386 (1957); H. Vorsanger, *Bull. Soc. Chim. Fr.* 551, 2124 (1967); P. F. Jackson, K. J. Morgan and A. M. Turner, *J. Chem. Soc.* Perkin II 1582 (1972); Y. Asahi and M. Nagaoka, *Chem. Pharm. Bull.* **19**, 1017 (1971); E. Felder and D. Pitrè, *Gazz. Chim. Ital.* **89**, 1079 (1959).

[15] J. Metzger, H. Larivé, R. Dennilauler, R. Baralle and C. Gaurat, *Bull. Soc. Chim. Fr.* 2857, 2868 (1964).

[16] A. D. Clark and P. Sykes, *J. Chem. Soc* (C) 103 (1971).

[17] L. Oliveros and H. Wahl, *Bull. Soc. Chim. Fr.* 345 (1970).

[18] M. J. Cook, A. R. Katritzky, P. Linda and R. D. Tack, *J. Chem. Soc.* Perkin II 1295 (1972).

[19] M. J. Cook, A. R. Katritzky, P. Linda and R. D. Tack *Ibid.* Perkin II 1080 (1973).

[20] J. Entel, C. H. Ruof and H. C. Howard, *J. Am. Chem. Soc.* **74**, 441 (1952).

[21] P. Grammaticakis, *Bull. Soc. Chim. Fr.* 821 (1953).

[22] R. Schaal and G. Lambert, *J. Chim. Phys.* **59**, 1164 (1962); R. A. More O'Ferrall and J. H. Ridd, *J. Chem. Soc.* 5030 (1963); A. Streitwieser, Jr., C. J. Chang and A. T. Young, *J. Am. Chem. Soc.* **94**, 4888 (1972); C. H. Rochester, *Trans. Faraday Soc.* **62**, 355 (1966); C. H. Rochester, *Acidity Functions.* In *Organic Chemistry, a Series of Monographs* (Edited by A. T. Blomquist) Vol. 17, Chap. 7. Academic Press, London (1970).

[23] C. H. Rochester and B. Rossall, [a]*J. Chem. Soc.* (B), 743 (1967); [b]*Trans. Faraday Soc.* **65**, 1004 (1969).

[24] M. J. Cook, A. R. Katritzky and A. D. Page, *Tetrahedron* **31**, 2707 (1975).

[25] K. Yates and R. A. McClelland, *J. Am. Chem. Soc.* **89**, 2686 (1967).

[26] J. Bourson, *Bull. Soc. Chim. Fr.* 2373 (1973).

[27] M. J. Cook, A. R. Katritzky and P. Linda, *Adv. Heterocyclic Chem.*, **17**, 255 (1974); and refs. therein. See p. 260.

[28] F. W. Fowler, personal communication.

[29] G. W. Wheland, *Resonance in Organic Chemistry*. Wiley, New York (1955).

[30] M. J. Cook, N. L. Dassanayake, C. D. Johnson, A. R. Katritzky and T. W. Toone, *J. Chem. Soc.* Perkin II 1069 (1974).

[31] P. D. Bolton, C. D. Johnson, A. R. Katritzky and S. A. Shapiro, *J. Am. Chem. Soc.* **92**, 1567 (1970).

[32] Ref 27, p. 310.

[33] T. B. Grindley, A. R. Katritzky and R. D. Topsom, *J. Chem. Soc.* Perkin II 289 (1974).

[34] I. P. Romm, E. N. Guryanova and K. A. Kocheshkov, *Tetrahedron* **25**, 2455 (1969).

[35] T. B. Grindley, A. R. Katritzky and R. D. Topsom, *J. Chem. Soc.* Perkin II 443 (1975); N. C. Cutress, T. B. Grindley, A. R. Katritzky and R. D. Topsom *Ibid.* Perkin II 263 (1974).

[36] Y. Ferré, É.-J. Vincent, H-Larivé and J. Metzger, *Bull. Soc. Chim. Fr.* 3862 (1972).

[37] Y. Ferré, É.-J. Vincent, H-Larivé and J. Metzger, *Ibid.* 1003 (1973).

[38] Ref. 27, p. 299.

[39] E. Vincent and J. Metzger, *Bull. Soc. Chim. Fr.* 2039 (1962).

[40] H. R. Snyder and F. X. Werber, *J. Am. Chem. Soc.* **72**, 2962 (1950).

[41] M. Bachstez, *Ber. Dtsch. Chem. Ges.* **47**, 3163 (1914).

[42] L. M. Clark, *J. Chem. Soc.* **127**, 973 (1925).

[43] H. Wenker, *J. Am. Chem. Soc.* **57**, 1079 (1935).

[44] W. E. Cass, *Ibid.* **64**, 785 (1942); J. J. Rosenbaum and W. E. Cass, *Ibid.* **64**, 2444 (1942).

[45] F. F. Stephens and J. D. Bower, *J. Chem. Soc.* 2971 (1949).

[46] *Dictionary of Organic Compounds* (4th Edn.) Vol. 3, p. 1966. Eyre & Spottiswoode, London (1965).

[47] A. V. El'tsov and Kh. L. Muravich-Aleksandr, *Zh. Org. Khim.* **1**, 1307 (1965) [*Chem. Abstr.* **63**, 13238*g* (1965)].

[48] Y. Ban, O. Yonemitsu and M. Terashima, *Chem. Pharm. Bull.* **8**, 194 (1960).

[49] L. M. Clark, *J. Chem. Soc.* 232 (1926).

[50] A. Albert and E. P. Serjeant, *The Determination of Ionisation Constants* p. 49. Chapman and Hall, London (1971).

[51] K. Bowden and A. F. Cockerill, *J. Chem. Soc.* (B) 173 (1970).